

PERMIAN CONODONTS FROM SOUTHEASTERN ARIZONA

by

William Charles Butler

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I hereby recommend that this dissertation prepared under my
direction by William Charles Butler
entitled Permian Conodonts from Southeastern Arizona
be accepted as fulfilling the dissertation requirement of the
degree of Doctor of Philosophy

Ronald L. Bryant
Dissertation Director

7 September 1972
Date

After inspection of the final copy of the dissertation, the
following members of the Final Examination Committee concur in
its approval and recommend its acceptance:*

Ronald L. Bryant

7 September 1972

Dietmar Schumacher

9/7/72

Joseph F. Schreiber, Jr.

September 7, 1972

*This approval and acceptance is contingent on the candidate's
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SIGNED:

William C. Butler

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ABSTRACT

The near-extinction of conodonts in the Early Permian is documented in southeastern Arizona by a marked change from a fauna dominated by adetognathids and spathognathodids to one dominated by neostreptognathodids, anchignathodids, and sweetognathids. The stratigraphic succession of conodonts in the Colina Limestone in the Tombstone Hills was determined by a reconnaissance examination and in the Epitaph, Scherrer, Concha, and Rainvalley formations 40 miles to the northwest in the Empire Mountains by detailed sampling. These five formations were deposited in the Pedregosa Basin, which provided a sanctuary during the conodont phylogenetic crisis.

Sweetognathus is a newly recognized index fossil in Arizona. Its acmic development, which delimits the Wolfcamp-Leonard stage boundary, is found between 440 and 600 feet above the base of the 950-foot-thick Colina Limestone. Spathognathodus whitei, a shallow-water species which defines the upper Wolfcamp Stage, occurs in the upper 180-foot-thick member of the Epitaph Dolomite. Consequently, the lower part of the Colina Limestone of southwestern Cochise County, Arizona, is the shallow-water dolomitized facies of the Epitaph Dolomite in eastern Pima County, Arizona. Delineation of time-stratigraphic boundaries has permitted a facies interpretation for the upper Wolfcamp Stage in southeastern Arizona and extreme southwestern New Mexico.

Reworked conodonts of Virgil through late Wolfcamp age were found in apparently reversed biostratigraphic order from the uppermost Epitaph Dolomite and from the middle member of the Scherrer Formation. Interpretation of these conodonts gives a minimum age of late Wolfcamp for the beginning of the regressive phase that resulted in the deposition of the predominantly clastic Scherrer Formation.

The basal 75 feet of the 500-foot-thick cherty Concha Limestone yielded the only specimens of Neostreptognathodus sulcopicatus. Because the range of N. sulcopicatus is restricted to the Leonard stage, the superjacent strata, up through the basal Rainvalley Formation, are assigned to the Word substage. The Word conodonts are characterized by Neospathodus arcucristatus, Lonchodina festiva, L. muelleri, Xanio-gnathus tortilis, and undefined species of Roundya and Anchignathodus. In addition, the appearances of the Triassic form-species Lonchodina triassica, Ellisonia cf. E. triassica, and Hindeodella nevadensis, and species of Parafusulina are also significant.

The Word-Capitan substage boundary is tentatively placed 120 feet above the Concha-Rainvalley contact at the last occurrence of Lonchodina festiva. Here also is the first appearance of an assemblage containing L. inflata, Neospathodus cf. N. divergens, and Roundya sp. C. The Capitan-equivalent strata in the middle part of the Rainvalley Formation are nearly barren of conodonts.

Consistently high neostreptognathodid-to-anchignathodid ratios during the Middle Permian reflect the nearshore environment of water less than 30 feet deep, whereas low ratios indicate water of about 30 to 60 feet deep. Sweetognathus is a deeper water form, and

the miogeosynclinal-depth gondolellids were not found. Identifiable conodonts were recovered from low-grade metamorphic limestone containing tremolite and wollastonite.

INTRODUCTION

"The establishment during the past decade of conodont biostratigraphic zones for most of the Paleozoic systems make it clear that conodonts now provide the most promising group of fossils for refined correlation in rocks of that age" (Rhodes, 1970, p. 403). However, before the present investigation was undertaken, the feasibility of using conodonts to determine Permian stage boundaries in Arizona was unknown. Because none of the Permian strata in the Pedregosa Basin of southeastern Arizona had ever been systematically sampled for these microfossils, it is appropriate that the objectives of this study are:

(1) to determine which strata in southeastern Arizona are conodont bearing through the systematic collection from the Scherrer carbonate member, the Concha and Rainvalley formations and parts of the Colina and Epitaph formations; (2) to describe these conodonts, depending upon their abundance and preservation, according to the form-genus concept; (3) to document the local succession of conodonts; and (4) to utilize the conodonts as potential local, regional, and worldwide guide fossils by virtue of their rapid evolution, cosmopolitan habitat, and ease of extraction from the rocks.

Other time-sensitive microfossils, such as fusulinids, are rare or even absent in the Lower and Middle Permian rocks of southeastern Arizona. There are one or two fusulinid species, assigned to the genus Parafusulina, in the upper part of the Concha Limestone in the Empire Mountains. Their range of late Leonard or early Word has previously

been uncertain (Sabins and Ross, 1963, p. 364; Ross and Tyrrell, 1965, p. 618), but now, because preliminary work has indicated that many conodont genera are associated with genus Parafusulina, additional time-stratigraphic meaning can be attributed to both groups of animals. This study will hope to show that a whole new battery of commonly occurring conodonts can be used to complement the fusulinid occurrence.

Recent work in conodont biostratigraphy has shown that some elements are not only useful as excellent guide fossils but also as environmental indicators. It is hoped that this work can also provide additional independent information concerning the paleoenvironments of southern Arizona. In particular, specific parts of the Pedregosa Basin may be located by examining the conodont biofacies. Pertinent stratigraphic problems, such as the Colina-Epigraph facies problem (Sabins, 1957, p. 494), can be reevaluated and perhaps clarified if the time-stratigraphic relationships are examined in light of the time-sensitive conodonts recognized herein.

The ultimate goal of a study such as this one would be to establish biozones that could be correlated to biozones on other continents. Although tentative zones have been erected by the present author, it remains for further investigations to refine the zonations. If nothing else is accomplished within the scope of this study, it is expected that the delineations of the conodont-bearing strata will be a significant time-saving contribution for other interested researchers. With this information, others can now collect from beds that are known to contain conodonts. In this way much more sample can be processed and larger populations of species can be retrieved per fossiliferous unit. The use

of larger populations is obviously an advantage for paleontologists who may wish to refine the zonations, to resolve the taxonomic problems, and also to implement eventually the multi-element classification.

The order or phylum (Melton and Scott, 1970, p. 395) to which conodonts have been ascribed is known to have been close to extinction during the Early Permian. Consequently, the surviving elements must be assessed at the family, genus, and species levels as to their relative biostratigraphic value.

If the objectives of this study are achieved, the results should enable geologists to assign isolated Permian outcrops in southern Arizona to their proper time-stratigraphic positions, especially where macrofossils and microfossils other than conodonts are absent. Finally, the determination of time-lines, which are necessary in any paleogeographic interpretation, and the possibility of estimating the rates of marine transgression and regression will be considered through the application of the conodont evidence.

Sample Locations

Most of the samples, about 200, were collected at Total Wreck Ridge in the Empire Mountains of southeastern Pima County, Arizona (fig. 1, location 3). These samples were obtained from the locality and stratigraphic section described by Butler (1969). Forty samples of the Colina Limestone were obtained from J. C. Wilt, who collected them from the southeast ridge of the Tombstone Hills, Cochise County, Arizona (fig. 1, location 6).

Miscellaneous localities from which other rocks were analyzed include the following:

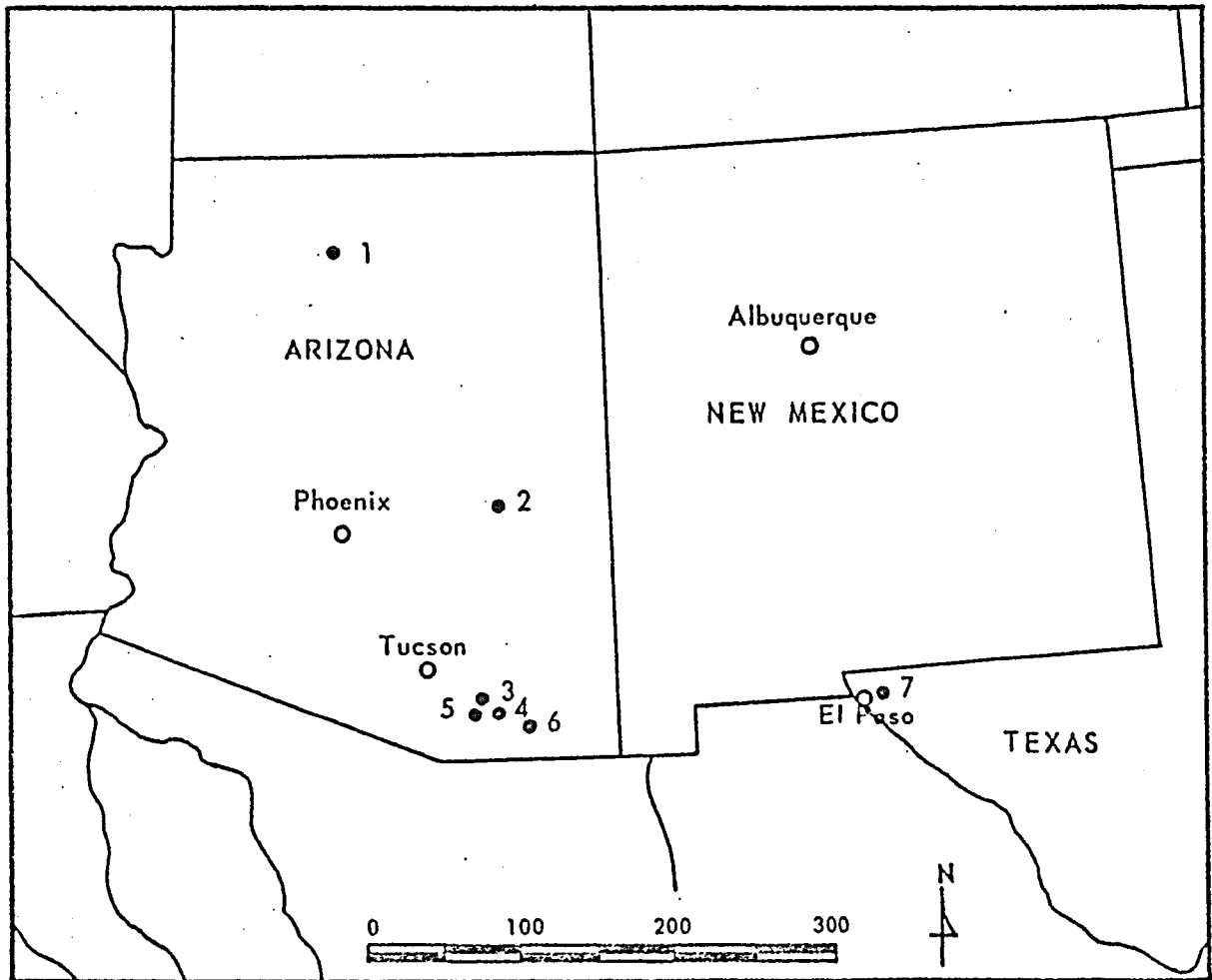


Figure 1. Index Map of Collecting Localities

1. Hermit Trail, Grand Canyon.
2. Cedar Creek, Fort Apache Indian Reservation.
- 3.. Total Wreck Ridge, Empire Mountains.
4. Dry Canyon, Whetstone Mountains.
5. Helmet Peak, San Xavier.
6. Southeast Ridge, Tombstone Hills.
7. Powwow Canyon, Hueco Mountains.

1. Twelve samples from the dolomite beds of the Permian Toroweap and Kaibab Formations exposed in the Grand Canyon, Arizona (fig. 1, location 1). These samples, plus thirteen others, were collected by Dietmar Schumacher, Department of Geosciences, The University of Arizona, along the Hermit Trail. Only a few identifiable scraps of conodonts were found in one of the twelve samples. This sample, taken from the top of the Kaibab Limestone, was a very fossiliferous dolomite containing echinoid spines, Meekella sp., small gastropods, crinoid columnals, and ostracods. The other thirteen samples yielded no conodonts.
2. Twenty samples from 70 feet of the lower part of the Hueco Canyon Formation just above the Powwow conglomerate in Powwow Canyon (fig. 1, location 7). This canyon and outcrop are in the Hueco Mountains about 20 miles east of El Paso, Texas, on Highway 180. No conodonts were found in these samples. Similar results have been reached by others regarding the paucity of conodonts in the standard North American Permian section of West Texas (Ellison, 1962b, p. 266; R. C. Burton, 1969, personal communication; Clark and Behnken, 1970, p. 418).
3. Two samples of very cherty limestone from the upper part of the Naco Formation that crops out on the Fort Apache Indian Reservation in east-central Arizona. The exact location of these samples is discussed in the section on the Naco Formation.
4. Several samples from the Rainvalley Formation exposed at the north end of Helmet Peak about 15 miles south of Tucson near San Xavier, Arizona (fig. 1, location 5). These samples in

general, were not productive because the processing was hampered by a large amount of iron oxide minerals choking the heavy mineral fraction of the insoluble residues.

5. Several samples collected by R. H. Bruns, Department of Geosciences, The University of Arizona, from a bed 2 feet below the red chert-pebble conglomerate within the Earp Formation that crops out in Dry Canyon, Whetstone Mountains, Cochise County, Arizona (fig. 1, location 4). Bruns discovered well-preserved conodonts in this bed, and some have been identified and illustrated in the present study (fig. 2).

An excellent locality near Caborca, Sonora, Mexico, is known to the author that has not been examined for conodonts. This locality, where rocks of Guadalupe age are exposed which contain fusulinids and ammonites (Miller, 1945; Cooper and Arellano, 1946; Cooper and others, 1953), is recommended for future study.

Field Methods and Laboratory Techniques

Because two of the objectives of this study were to determine stage boundaries and to document the local succession of Permian conodonts in southeastern Arizona, it was paramount that the collecting localities be those where previously described and mapped stratigraphic sections are available. Also areas of structural complexity had to be avoided. For these reasons, the author selected the Empire Mountains locality to examine the Epitaph, Scherrer, Concha, and Rainvalley formations described by Alberding (1938), Bryant (1955), Butler (1969), and Finnell (1971). Rocks of the Colina Limestone that Wilt (1969) collected

Figure 2. Miscellaneous Conodonts and Other Microfossils
All magnifications X60

- 1 Hindeodella sp. C. Lateral view, Anaconda Company specimen, Twin Buttes pit, Sahuarita, Arizona.
- 2 Anchignathodus sp. C. Oblique aboral view, sample 73, Concha Limestone, Empire Mountains, Arizona.
- 3 Spathognathodus cristulus Youngquist and Miller. Lateral view, Earp Formation, Whetstone Mountains, Arizona.
- 4-6 Anchignathodus sp. Lateral views, Anaconda Company specimens, Twin Buttes pit, Sahuarita, Arizona.
- 7 ?Adetognathus lautus (Gunnell). Oral view, Earp Formation, Whetstone Mountains, Arizona.
- 8,9 Adetognathus gigantus (Gunnell). 8, Aboral view; 9, oral view of (8); Earp Formation, Whetstone Mountains, Arizona.
- 10,11 Adetognathus lautus (Gunnell). Oral views, both from Earp Formation, Whetstone Mountains, Arizona.
- 12 ?Adetognathus lautus (Gunnell). Oral view, broken specimen, Earp Formation, Whetstone Mountains, Arizona.
- 13 Adetognathus lautus (Gunnell). Lateral view, Earp Formation, Whetstone Mountains, Arizona.
- 14 Adetognathus sp. Lateral view, Earp Formation, Whetstone Mountains, Arizona.
- 15 ?Sweetognathus sp. Oral view, Kaibab Limestone, Grand Canyon, Arizona.
- 16 Adetognathus sp. A of Reid. Lateral view, Earp Formation, Whetstone Mountains, Arizona.
- 17,18 Adetognathus gigantus (Gunnell). 17, Aboral view; 18 oral view of (17).
- 19-22 Adetognathus lautus (Gunnell). 19, Lateral view; 20, oral view; 21, lateral view; 22, oral view of (21); all from Earp Formation, Whetstone Mountains, Arizona.
- 23-26 Indet. genera. Lateral views; all from Earp Formation, Whetstone Mountains, Arizona.
- 27,28 Ligonodina sp. 27, Lateral view; 28, oblique aboral view of (27); Earp Formation, Whetstone Mountains, Arizona.
- 29,30 Fish teeth. 29, Concha Limestone, Empire Mountains, Arizona; 30, Kaibab Limestone, Grand Canyon, Arizona.
- 31,32 ? Sponge spicules. 31, Concha Limestone, Empire Mountains, Arizona; 32, Rainvalley Formation, Empire Mountains, Arizona.

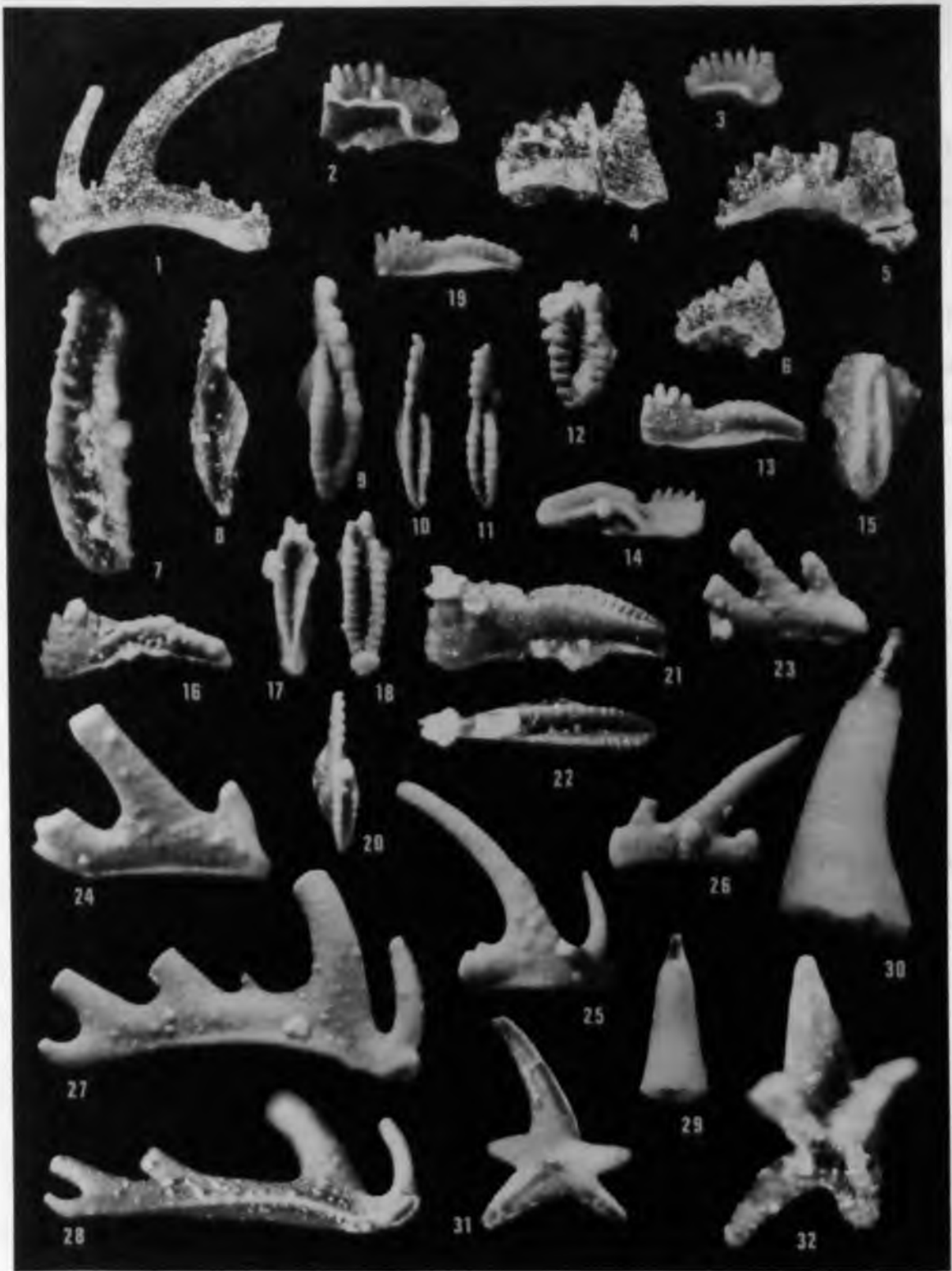


Figure 2. Miscellaneous Conodonts and Other Microfossils

in the Tombstone Hills, described, and provided for the present author allowed a precise matching of description, stratigraphic position, and conodont taxa. This matching is important if detailed studies are to be made correlating the conodont abundance to lithology. A current trend in conodont research is to use these correlations for determining the ecology of the conodont-bearing animal.

Samples were taken at 5- to 6-foot stratigraphic intervals using the Jacob staff. At least two samples were collected per interval, preferably near the top and bottom, which were crushed and mixed in the laboratory to assure good representation from each unit. The outcrop of each unit was marked in order that conodont-bearing ones could be re-collected.

Procedure in the laboratory was essentially that outlined by Collinson (1963). Unless otherwise noted, the amount of each sample dissolved in 10 percent glacial acetic acid was 500 grams. Light and heavy mineral residues from the acid digestion were collected on the Tyler standard screen with 170 meshes to the inch (U.S. series equivalent 170) and separated using tetrabromoethane (sp. gr. 2.96 at 20°C). A few of the Epitaph rocks contained so much fibrous organic matter--which caused separation problems--that dilute hydrogen peroxide was added to them.

To see if the Permian conodonts in southeastern Arizona were adequately preserved for possible ultrastructure study, three conodont specimens were selected for examination with the scanning electron microscope (Cambridge stereoscan 600). According to Barnes, Sass and Moore (1970, p. 375) and Ziegler (1970, p. 410), ultrastructure may be the key

to establishing higher taxonomic relationships in conodonts. Also, the technique of micromorphologic analysis has been successfully used to differentiate conodont species (Rhodes and Williams, 1970, p. 404). Figure 3, numbers 1 and 2, show bundles of fibers that make up the denticles of Neostreptognathodus sp. A from the Rainvalley Formation. This is the same type of columnar structure observed by Pierce and Langenheim (1970, fig. 2, nos. 7, 10) on the anterior denticles of Spathognathodus sp. that is classified with the multi-element genus Lochriea.

Previous and Current Work

Permian conodonts have received very little attention because, as Clark and Behnken (1970, p. 417) have noted, "fewer conodont taxa are known from the Permian than from the Triassic or from any of the Paleozoic systems." The first Permian conodont study in southern Arizona was part of a general survey of conodonts in Mexico, New Mexico, Arizona, Texas, and Wyoming reported by Clark and Ethington in 1962. Samples collected by these authors in southern Arizona yielded only several specimens, and they were able to erect only one new species from Leonard strata. The 1962 study was intended to be preliminary and unfortunately the collection site near Tombstone, Arizona, was inexactly described. Despite the very poor results in Arizona, better collections of Permian conodonts were found in the other states sampled.

The next Arizona study, which was also of a preliminary nature, was completed by Micklin (1969) for his Master of Science thesis at The University of Arizona. Micklin (1969, p. 3) tried ". . . to evaluate the

Figure 3. Scanning Electron Micrographs of Conodont Surface
Texture

1. Neostreptognathodus sp. A. Lateral view of platform conodont. Note that blade denticles are bundles of fibers. Apron of basal cavity is crushed. Specimen from the topmost beds of the Rainvalley Formation at Total Wreck Ridge, Arizona. X150.
2. Same conodont as in (1). Close-up view of second and third denticles from anterior end; vertical fibers comprising denticles are clearly visible. X750.
3. Gnathodus sp. Oral view of three rounded nodes on posterior end of carina. Upper right of micrograph shows the slight longitudinal depression or furrow that is parallel to the axis of the nodes. Surface texture is notably etched. Specimen collected from the basal beds of the upper member of the Epitaph Dolomite at Total Wreck Ridge, Arizona. X750.



Figure 3. Scanning Electron Micrographs of Conodont Surface
Texture

usefulness of conodonts as guide fossils in relation to fusulinids . . ." in a Pennsylvanian-Permian outcrop of the northeastern Dragoon Mountains, Cochise County, Arizona. He concluded that the fusulinids provide the best fossils for determining stage and substage boundaries because the conodont sampling was reconnaissance designed. However, he did predict that his scant numbers of Earp conodonts were potentially useful to provide an accurate age determination for the entire Earp Formation. The 420-foot-thick Earp section in the Dragoon Mountains is divisible into a three-member formation. The middle clastic member was barren, but the upper and lower limy members are conodont bearing. Relying on fusulinid evidence, namely, the Leptotriticites Concurrent-range Zone, Micklin was able to establish the Virgil-Wolfcamp stage boundary about 80 feet above the base of the Horquilla Limestone-Earp formation contact within the lower member.

The prediction of Micklin that an age assignment for the Earp Formation in the Dragoon Mountains might be determined now warrants an interpretation based upon the Wolfcamp, Leonard, and Word collections of the present study. While specimens referred to as genus undescribed sp. A. by Micklin (1969, p. 173, fig. 20, nos. 1, 2, 14) were correctly diagnosed as undefined by him in 1969, the taxonomic assignment can now most certainly be brought to Sweetognathus sp. The acmic development of genus Sweetognathus was during the time represented by upper Wolfcamp rocks (D. L. Clark, personal communication, 1972). It is therefore not fortuitous to find the only occurrence of Sweetognathus sp. (that is, genus undescribed sp. A) at the top of the Earp Formation just a few feet below the Colina Limestone. Biostratigraphically, that is

where this fossil should occur--in the uppermost Earp strata--if the strata are indeed of late Wolfcamp age.

Therefore, the present author suggests that the Earp Formation, as described by Micklin (1969) in the Dragoon, Arizona, area, is a condensed interval representing deposition during early and part of late Wolfcamp time. Because the inferred cyclic nearshore to supratidal environment (Micklin, 1969, p. 59) was not suited for adaptation by Sweetognathus, the seven specimens found by Micklin must have been washed into the shallower water environment. The middle barren member is without mid-Wolfcamp conodonts for two possible reasons: (1) conodonts became nearly extinct during early middle Wolfcamp time, and hence the middle member could reflect this worldwide rare abundance and low diversity of middle Wolfcamp conodonts; or (2) many previously unnoticed bedding-plane disconformities or diastems are within the terrigenous middle member. These numerous disconformities have in effect "condensed" the total thickness of the Earp strata, and much of the middle Wolfcamp is not recorded in the rock. To test these possibilities, one could make a more thorough examination of the middle member to find if the middle to upper Wolfcamp species Spathognathodus whitei did inhabit the shallowest part of the Pedregosa Basin in the Dragoon area.

Three important conclusions can now be extracted from Micklin's previous work. First of all, the evolutionary crisis of conodonts was real and can be documented within the Earp Formation. Streptognathodus elegantulus, strictly a pre-crisis element, was recovered from beds 30 to 100 feet above the base of the Permian in the middle part of the

260-foot lower limestone member. Streptognathodus elegantulus is in rocks of earliest Wolfcamp age, and because extinction of streptognathodids occurred at the end of this time, it is not represented in younger rocks (Ellison, 1941, p. 128; Merrill, 1970b, p. 411; Clark, 1972b, p. 154). As noted previously, the middle 110-foot clastic member is barren, but the younger post-crisis conodonts, represented by the genus Sweetognathus, appear in the upper interbedded member. Secondly, the middle terrigenous member of the Earp Formation does not represent continuous geologic time. These rocks were deposited, as correctly postulated by Micklin (1969), during the maximum regression of the Earp seas. Marine deposition was discontinuous as the strandline migrated basinward. This is supported, in part, by field evidence in the Dragoon Mountains of channeling on a supratidal mud flat. Finally, the occurrence of Sweetognathodus sp. possibly permits an age estimate of late Wolfcamp for the youngest strata of the Earp Formation.

Other Permian conodont studies in the United States, China, Greece, Sicily, Asia, Poland, Greenland, and Germany have been adequately abstracted by Clark and Behnken (1970, p. 417) and Bender and Stoppel (1965, p. 332), beginning with the first reported Permian specimens by Branson (1932b). Clark and Ethington (1962) also cite the few studies prepared between the years 1932 and 1962.

More specifically, Clark and Ethington's paper revealed that the lower Wolfcamp fauna found by Ellison (1941) and the meager upper Leonard fauna described by Youngquist, Hawley, and Miller (1951) were not just isolated provincial occurrences. Furthermore, the Clark and Ethington (1962) study demonstrated that Permian marine strata could

prove productive if the effort were made to examine the rocks. Since these initial surveys in western United States, Rhodes (1963) has described upper-middle Wolfcamp conodonts from the Tensleep Formation of Wyoming. Bender and Stoppel (1965) have published on Middle and Upper Permian conodonts from strata outside the United States. The two most recent articles have also identified conodont remains from outside the United States. These are Szaniawski's (1969) report of Guadalupe conodonts from Poland and Sweet's (1970) very instructive paper based upon extensive collecting in Pakistan at the Permian-Triassic boundary. Sweet's conodonts were so abundant that he was able to employ the multi-element classification. His work is significant because he was the first to apply this concept of classification, which attempts to synthesize a statistical assemblage, to Permian conodonts. No natural assemblages have yet been reported for Permian conodonts. Although Clark and Behnken (1970) stated that their contribution to the Geological Society of America Memoir No. 127 was merely devoted to summarizing the Permian conodont biostratigraphy, they did, for the first time, elaborate on the state-of-the-knowledge of all Permian conodonts in addition to describing three new species.

In summation of previous work, only nine papers have been published on Permian conodonts that have significant biostratigraphic value. Table 1 lists the taxa and their range that have been erected from 1932 to 1971. Nevertheless, several works in progress offer to fill this research void. The "Pander Letter" (Huddle, 1972b), prepared by the informal Pander Society for better communication among conodont workers of the world, lists the following current or planned

Table 1. Distribution of Conodont Taxa in the Upper Paleozoic and Lower Triassic, Compiled from Work Prior to 1972

PENN.	PERMIAN				TRIASSIC		Taxon Name
	Virgil	Wolfcamp	Leonard	Guadalupe Word Capitan	Ochoan	Scythian	
							<i>Ellisonia triassica</i> Müller
							<i>E. teichertii</i> Sweet
							<i>E. pyrata</i> Sweet
							<i>Foundrya</i> A Huckriede
							<i>R. sp. A</i> Bender and Stoppel
							<i>R. sp. B</i> Bender and Stoppel
							<i>Ligonotina typa</i> (Gunnell)
							<i>L. lexingtonensis</i> (Gunnell)
							<i>Synprioniodina microdenta</i> Ellison
							<i>Pfioniodus pultosa</i> Lillison
							<i>P. ? conflexus</i> Lillison
							<i>Pfioniodina ? obtusa</i> Ellison
							<i>P. lindstroemi</i> Szaniawski
							<i>P. sp. of Clark and Behnken</i>
							<i>Gnathodus roundyi</i> Gunnell
							<i>G. sicilianus</i> Bender and Stoppel
							<i>G. bassleri</i> (Harris and Hollingsworth)
							<i>Apatognathodus tribulosus</i> Clark and Ethington
							<i>Xantognathus curvatus</i> Sweet
							<i>Adetognathus gigantus</i> (Gunnell)
							<i>A. laetus</i> (Gunnell)
							<i>A. missouriensis</i> (Gunnell)
							<i>A. flexus</i> (Lillison)
							<i>Spathognathodus divergens</i> Bender and Stoppel
							<i>S. whittei</i> Rhodes
							<i>S. galvatus</i> Bender and Stoppel
							<i>S. miratus</i> (Lillison)
							<i>S. cristatus</i> Youngquist and Miller
							<i>S. isarcicus</i> Huckriede
							<i>Neoprioniodus conjunctus</i> (Gunnell)
							<i>Hindogonella delicatula</i> Stauffer and Plummer
							<i>H. triassica</i> Müller
							<i>H. nevadensis</i> Müller
							<i>Hiltbergella</i> sp. of Clark and Ethington
							<i>H. subcorda</i> (Gunnell)
							<i>H. elliptica</i> Szaniawski
							<i>Sireptognathodus gracilis</i> Stauffer and Plummer
							<i>S. sulcopicatus</i> Youngquist, Hawley and Miller
							<i>S. wabausensis</i> Gunnell
							<i>S. excolius</i> Stauffer and Plummer
							<i>S. elongatus</i> Gunnell
							<i>S. elegantulus</i> Stauffer and Plummer
							<i>S. simulator</i> Lillison
							<i>Lambognathus</i> sp. Clark and Ethington
							<i>Ozarkodina abstracta</i> (Clark and Ethington)
							<i>O. delicatula</i> (Stauffer and Plummer)
							<i>O. campbelli</i> Youngquist and Heezen
							<i>O. tortilis</i> Tatge
							<i>O. turgata</i> Bender
							<i>Neogondolitea</i> sp. of Clark and Behnken
							<i>N. carinata</i> (Clark)
							<i>Lonchodus</i> sp. of Bender and Stoppel
							<i>Lonchodina ponderosa</i> Ellison
							<i>L. inilata</i> Bender and Stoppel
							<i>L. clarki</i> (Gunnell)
							<i>L. mulleri</i> Tatge
							<i>L. vistulensis</i> Szaniawski
							<i>L. festiva</i> Bender and Stoppel
							<i>Anchignathodus typicalis</i> Sweet
							<i>A. isarcicus</i> (Huckriede)
							<i>Neospathodus divergens</i> (Bender and Stoppel)
							<i>N. arcuicristatus</i> Clark and Behnken
							<i>Subtrivantodus abstractus</i> Clark and Ethington
							<i>Inantognathus zirgleri</i> (Diebel)
							<i>Cypridodella muelleri</i> (Tatge)
							<i>Gondolitea rosenkrantzi</i> Bender and Stoppel
							<i>G. elegantula</i> Stauffer and Plummer
							<i>G. denuda</i> Lillison
							<i>G. serrata</i> Clark and Ethington
							<i>G. nankingensis</i> Ching
							<i>G. idahoensis</i> Youngquist, Hawley and Miller
							<i>G. bisselli</i> Clark and Behnken
							<i>G. monerogensis</i> Tatge
							<i>G. bella</i> Stauffer and Plummer
							<i>G. gracilis</i> Clark and Ethington
							<i>G. phosphoriensis</i> Youngquist, Hawley and Miller
							<i>Iptognathodus ellisoni</i> Clark and Behnken
							<i>I. delicatus</i> Gunnell
							<i>I. tersus</i> Lillison

Permian conodont research. Shingo Hayashi is working on Permian-Triassic conodonts in Japan, Hisayoshi Igo is also working on Permian conodonts from strata in Japan, and Toshio Koike is planning to do research on Permian faunas from Japan. Svend Stouge is planning a Late Permian-Early Triassic age study on strata from Greenland. Current research by Dieter Stoppel involves Ordovician through Triassic rocks of Thailand, and Erik Flügel is now working on the Permian System from the Southern Alps and Anatolia. Fred Behnken is currently determining the biostratigraphy of the Leonard and Guadalupe of Nevada and west Texas. David Clark's current research is the paleoecology of Permian and Triassic conodonts in western North America, and Walter Sweet is continuing studies of uppermost Permian and Lower Triassic conodonts from Iran, the Southern Alps, and Greenland.

Because the past published literature is very limited in regards to Permian conodont articles, anyone seriously considering working on Permian faunas should write to J. W. Huddle of the U.S. Geological Survey, Washington, D.C., and request that he be sent future copies of the "Pander Letter." This letter is intended to keep all interested paleontologists informed about current conodont research and is free of charge.

TAXONOMIC PROBLEMS AND THE CONODONT CRISIS

The major taxonomic problem of a dual nomenclature has been recognized since Hinde (1879) pointed out that distinct conodonts could be co-elements in one organism. Thus, he introduced the idea of the conodont assemblage whereby an entire conodont cluster is given one name. This type of classification is termed the multi-element genus concept. However, Pander, the discoverer of conodonts, described the first fauna in 1856 by giving each morphologically different disjunct element a different name. Known as the form-genus concept, this scheme of classification is strictly "utilitarian" in the sense that each form has a unique name, and species names can therefore be used with great success to delimit biostratigraphic zones.

Although some paleontologists have long recognized that many different conodont forms did in fact belong to the same biologic animal, they have continued to view conodonts as a "collection of nuts and bolts." They have adhered to the form-genus school of nomenclature mostly out of necessity because the multi-element concept can only be used where either a "natural" assemblage has been found essentially undisturbed in the living position or where a "statistical" grouping can be synthesized from a large population.

The advantage of the utilitarian scheme is that different conodont elements within the single biologic species evolve at different rates, and thus the nomenclature will reflect this change--hence, an excellent means of determining short-time stratigraphic elements. The advantage

of the other scheme is that any obvious errors in form-species nomenclature are evident if the two schemes are compared. Also, this multi-element classification conforms to the true meaning of the word "species." So the problem initially is do we give each disjunct element a unique trivial name because it is distinguishable from all others by its characteristic features or do we give the whole assemblage one name because all elements either found in place together or reconstructed belong to one true biological species. The latter should be the objective--whether achievable or not--of all conodont workers in at least those parts of the geologic column where the conodonts have been thoroughly studied. Inasmuch as the collection of the present study is limited, multi-element taxonomy cannot be easily applied, and no attempt has been made to determine statistical assemblages.

The problem of naming an assemblage without creating synonyms while at the same time abiding by the rules of the "International Code of Zoölogical Nomenclature" (ICZN) (Schenk and McMasters, 1956) is complex. Three alternative solutions have been suggested. First, the entire apparatus or assemblage could be named after the first applicable name, that is, after the oldest valid genus and species name. Second, a new technical name could be applied to the assemblage. This, however, is unsatisfactory because it violates the rules of the ICZN not to use generic and specific names. Third, each component form-species in the assemblage could keep its original name, but a new separate name would be given to the entire assemblage. This seems to be the best alternative to follow at present. Although it defies the rules of the Code, it nevertheless prevents taxonomic chaos. Because a complete account

of general taxonomic problems is beyond the scope of this paper, the reader wishing further information is referred to Scott (1942), Rhodes (1952), Sweet and Bergström (1970), and Huddle (1972a).

Most of the taxonomic problems in the present study arise from the inadequate attention given Permian conodonts. Although the existence of only meager collections is unmistakably due to the low diversity of upper Paleozoic genera--in addition to the provinciality and environmental control of some groups--some of the Permian elements cannot be easily brought to the existing few form-species and much work remains to be done erecting new form-species.

Generic names, such as Spathognathodus, were used for those species with clearly Early Permian affinities. On the other hand, assignments to the genera Xaniognathus and Anchignathodus were deemed more appropriate for those species of Ozarkodina and Spathognathodus, respectively, with Triassic affinities. The fact that the types of many of the Permian genera are middle Paleozoic species militates against confident assignments for the Permian specimens. Furthermore, what are the limits of variation from the type?

According to Clark (1972b, fig. 5), more form-genera were becoming extinct than were evolving during Mississippian through Triassic time. This trend, which was most pronounced during the earliest Early Permian, is known as the conodont crisis. Of the thirty to thirty-five species represented in rocks of Virgil age, possibly only two or three survived into the late Early Permian. Based on present knowledge, strata of early Leonard age can be identified by one, and only one, species--Neostreptognathodus sulcopicatus (table 1).

The conodont diversity in strata of late Wolfcamp through early Leonard age is markedly low but increases again to its pre-crisis (Virgil through lower Wolfcamp) level in rocks of Guadalupe age. Spathognathodus, which gave rise to the post-crisis genera Anchignathus, Sweetognathodus, and possibly Neostreptognathodus, was one group that persisted in increasing numbers through the Early and Middle Permian. The multi-element genus Ellisonia of Sweet and the form-genus Gondolella account for the remainder of the survivors. Although the Early Permian crisis did effectively trim and simplify the conodont phylogenetic tree, many lineages are still uncertain. The recognition of several indeterminable genera in the Permian samples nourishes the question in the present author's mind of really just how close this phylogenetic tree was pruned.

CONODONT BIOSTRATIGRAPHY AND PALEOECOLOGY

Only the 50 most stratigraphically or environmentally important elements collected from the Colina Limestone near Tombstone and from the Epitaph, Scherrer, Concha, and Rainvalley formations in the Empire Mountains, as discussed in this chapter, have been systematically described in the appendix. The majority of the Naco Formation conodonts are not described, but they are illustrated. The stratigraphic positions of all conodonts found during this investigation are entered on tables included with the discussion of the appropriate formation. In these tables, only those specimens which are identifiable are listed and tabulated under the taxa column.

Naco Formation Conodonts

A seemingly diverse collection of conodonts (fig. 4) was recovered from a single 9-foot-thick cherty limestone bed about 40 feet stratigraphically below the Supai-Naco formational contact in east-central Arizona (fig. 1, location 2). In places, the red-to-orange chert exceeds 50 percent of the total rock content. The resistant bed is a good field marker within the Naco Formation that crops out at several localities on the Fort Apache Indian Reservation at approximately long 110°15' W. and lat 33°50' N. The 1,000-gram sample was obtained from H. W. Peirce of the Arizona Bureau of Mines, Tucson, Arizona, who requested the author to examine it for possible diagnostic conodonts. Although the results were positive, the conodonts proved, within limits, to be time-stratigraphically inconclusive.

Figure 4. Pennsylvanian-Permian Boundary Conodonts from the Uppermost Naco Formation, East-central Arizona

All magnifications X60, except (36) and (40) which are X125.

- 1,2 Spathognathodus minutus (Ellison). Both lateral views.
- 3 ? Spathognathodus minutus (Ellison). Lateral views.
- 4-7 Spathognathodus coloradoensis Murray and Chronic. 4, Lateral view; 5, lateral view; 6, oral view of (5); 7, lateral view.
- 8 Indet. genus.
- 9 Hibbardella sp. Anterior view.
- 10 Indet. genus.
- 11 ? Lonchodus sp. Lateral view.
- 12 Indet. genus. Lateral view.
- 13,14 Prioniodus? conflexus Ellison. Anterior and lateral views, respectively.
- 15,16 Adetognathus sp. Both lateral views.
- 17-19 Adetognathus inflexus Dunn. 17, Lateral view; 18, aboral view, of (17); 19, oral view.
- 20 Hindeodella sp. Inner lateral view of broken specimen.
- 21 Indet. genus.
- 22-25 ? Lonchodina sp. 22, Posterior view; 23, posterolateral view of (22); 24, anterolateral view; 25, posterior view of (24).
- 26 Indet. genus.
- 27 Hindeodella cf. H. multidenticulata Murray and Chronic. Outside lateral view.
- 28,29 ? Hindeodella sp. Posterior and posteroaboral view, respectively, of same specimen.
- 30 Adetognathus sp. Oral view.
- 31 Cratognathodus sp. Lateral view.
- 32 Gondolella sp. Oral view
- 33 Indet. genus.
- 34 Ozarkodina lauta Youngquist and Downs. Lateral view.
- 35 Ozarkodina cf. O. campbelli Youngquist and Heezen. Lateral view.
- 36 Ozarkodina delicatula (Stauffer and Plummer). Lateral view.
- 37,38 Hindeodella sp. Both lateral views.
- 39 ? Hindeodella megadenticulata Murray and Chronic. Lateral view.
- 40 Adetognathus sp. Oral view of (16).
- 41 Indet. genus.



Figure 4. Pennsylvanian Permian Boundary Conodonts from the Uppermost Naco Formation, East-central Arizona

Peirce collected the Naco sample at the first big creek east of Carizzo Creek at the CD1-Ipps contact shown on the "Composite Geologic Map of Arizona Counties" (Wilson, Moore, and O'Haire, 1960). The precise stratigraphic position and lithologic characteristics of the 550-foot-thick Naco and the much thicker superjacent Supai Formations are described by Winters (1963, p. 80). The limestone is virtually free of heavy minerals and clay, and the conodonts are associated with fish teeth and echinoid spines and plates.

According to Winters (1963, p. 15),

The Supai-Naco contact in the Fort Apache area is apparently concordant. On the basis of fusulines (Triticites spp., Section 8) and macrofossils, the upper Naco is considered Upper Pennsylvanian. The overlying deposits suggest a marked environmental change. Unfortunately, they are unfossiliferous near the boundary. In the absence of paleontological data, the Pennsylvanian-Permian (Virgilian-Wolfcampian) boundary in the Fort Apache Indian Reservation is arbitrarily taken as the contact of the Naco and Supai formation as herein described.

As noted above, species of fusulinids, identified as Triticites, afford some independent biostratigraphic control for the conodonts. The fusulinids appear in several units about 185 and 225 feet below Winters' unit 12. Possibly contemporaneous (Virgil) species of Triticites, more recently described by Ross (1969) from what is considered to be lower Earp and upper Horquilla formations in the Gila Mountains (30 miles southeast of Winters' section 7), may help delineate the time-rock boundary on other than arbitrary lithologic criteria. Passmore (1969, p. 7) has also correlated the upper Naco Formation with the Horquilla Limestone in her study of the Supai Formation of southeastern Arizona.

Conodont studies, especially biostratigraphic ones, should not rely on single grab-sample collecting methods. This author believes that conodonts from such single samples are difficult to interpret for age-assignment purposes and the true stratigraphic meaning of the

conodonts and their correlation with other biozones will always be ambiguous. However, it may have some merit in certain studies, such as this one, where the literature is impoverished on similar microfossils of this age. The fact that these conodonts have never been formally noted is significant--in addition to the fact that they are the most diverse youngest Pennsylvanian or earliest Permian conodonts ever recognized in Arizona. And, of course, their recognition provides a potential contribution to the now poorly understood Pennsylvanian-Permian boundary in east-central Arizona.

Several other reasons are apparent for illustrating these conodonts. First, the conodonts are unlike others in several respects. The streptognathodids are absent, and the 1:4 ratio of platforms to blades is more characteristic of post-crisis (earliest Early Permian) conodont assemblages than pre-crisis ones (Clark, 1972b, table 3). The Pennsylvanian conodont-bearing animal that used the streptognathodid functional morphology did not survive this crisis. However, its homeomorph element did reappear in Leonard time and is placed in the new form-genus Neostreptognathodus.

Many of the other elements cannot be identified to species level because there is either nothing or very little to which the conodont can be compared. Those conodonts, in addition to the platforms, spathognathodids, ozarkodinids, and several other unique elements, such as Cratognathodus sp., have been noted because it is not known at this time which elements can become important for correlating and for solving multi-element classification problems. Webster (1970, p. 406) has pointed out that Spathognathodus coloradoensis Murray and Chronic may represent an index for the middle Pennsylvanian in the Great Basin. His zonation will need revision because S. coloradoensis was the most

abundant species in the Naco unit of much younger age. The long-ranging species, Adetognathodus inflexus Dunn was another conodont from Winters' (1963) unit 12. According to Dunn (1970, p. 323), this exclusively right-sided element would be indistinguishable from a right-sided A. lautus--if A. lautus had a right-sided counterpart. Dunn noted the occurrence of A. inflexus as Lower Pennsylvanian from Utah and Nevada, and Totten (1972, p. 37) noted it in strata of Morrowan to Missourian age in the Horquilla Limestone of southeastern Arizona. The other indeterminable species are numerically inadequate to classify properly. (See Ellison, 1941, p. 138.) Inadequate sampling in the Great Basin is hampering a more refined zonation in Upper Pennsylvanian rocks.

Several other reasons militate against assuming a more precise age other than latest Pennsylvanian or earliest Wolfcamp. Micklin (1969, fig. 4) noted only two Virgil species, one of which is a relatively nondiagnostic hindeodellid. Elements found by Reid (1968) in the lower Virgil are either very long ranging or else not represented in Winters' unit 12 collection. Negative evidence, that is, the apparent lack of Gnathodus roundyi, species of Neoprioniodus, and species of Streptognathodus or Adetognathodus lautus, implies an age younger than Virgil (Webster, 1970, fig. 3; Reid, 1968, fig. 9). But the upper Virgil and lower Wolfcamp conodonts are either similar enough or so ill defined that even an early Wolfcamp age assignment is only tentative at best. The value of these conodonts is that they were collected at the best determined stage boundary based on present knowledge. Given proper attention, the excellently preserved conodonts from the uppermost Naco will undoubtedly serve as an excellent biostratigraphic tool (Schumacher, 1972, p. 69).

Colina Limestone Conodonts

Working with strata in central Cochise County, Arizona, Gilluly, Cooper, and Williams (1954) defined the Colina Limestone as one of the formations in the Naco Group of Pennsylvanian-Permian age. Their work dealt primarily with the measurement, description, and correlation of Colina strata and the identification of its macrofossils. Except for the one cephalopod specimen, Perrinites sp., most of the fossils in their collections are more environment sensitive than time significant. Thus, the fossils proved to be inconclusive for providing a means of regional correlation and for the precise recognition of the Wolfcamp-Leonard stage boundary (Gilluly and others, 1954, p. 39). Therefore, these geologists were forced to conclude that the Colina Limestone was of Wolfcamp and Leonard(?) age.

Subsequent work by Wilt (1969) added much to the knowledge about the environment of Colina deposition. The 950-foot stratigraphic section measured and described by Wilt (p. 87) and referred to as Southeast Ridge (fig. 1, location 6) was selected by the present author for a conodont study. This study has determined that some of the best preserved Permian conodonts of the Pedregosa Basin can be collected from the Colina Limestone (figs. 5 and 6). Furthermore, the Colina is the oldest Permian formation in Arizona that has yielded abundant (but low diversity) post-crisis conodonts. For this reason the Colina is important. The near extinction of the Order Conodontophorida during the Early Permian has greatly simplified the late Wolfcamp-early Leonardy phylogeny of this order. The few genera that survived the crisis naturally gave rise to the Middle and Upper Permian and Triassic conodonts. When

Figure 5. Colina Limestone Conodonts from Tombstone Hills
All magnifications X60.

- 1-6 Hindeodellids. All lateral views. 1, UA-2456; 2, UA-2457;
3, UA-2458; 4, UA-2459; 5, UA-2460; 6, UA-2461.
- 7-16 Genus and species indeterminable. 7, Lateral view, UA-2462;
8, lateral view, UA-2463; 9, lateral view, UA-2464; 10,
lateral view of possible hindeodellid, UA-2465; 11, UA-2466;
12, posterior aboral view, UA-2467; 13, anterior? view, UA-
2468; 14, lateral view, UA-2469; 15, lateral view, UA-2470;
16, lateral view, UA-2471.
- 17 Cypridodella sp. A. Lateral view, UA-2472.
- 18, 30 Neospathodus sp. C. 18, lateral view, UA-2473; 30, lateral view,
UA-2484.
- 19, 20 Ozarkodina sp. A. 19, Lateral view, UA-2474; 20, lateral aboral
view of (19).
- 21, 22 ? Gnathodus sp. 21, Oral view, UA-2475; lateral aboral view,
UA-2476.
- 23, 24 Anchignathodus minutus (Ellison). 23, Lateral view of immature
individual, UA-2477; 24, lateral view of mature individual
with anteriormost denticle broken off, UA-2478.
- 25 Lonchodina sp. A. Anterior view, UA-2479.
- 26 Hindeodella sp. B. Lateral view, UA-2480.
- 27-29 Ozarkodina sp. A. 27, Lateral view, UA-2481; 28, lateral view,
UA-2482; 29, lateral view, UA-2483.
- 31-35 Hindeodella sp. A. 31, Interior lateral view, UA-2485; 32,
lateral view, UA-2486; 33, lateral view, UA-2487; 34,
lateral view, UA-2488; 35, lateral view, UA-2489.
- 36-41 Hindeodella sp. of Szaniawski. 36, interior lateral aboral view,
UA-2490; 37, lateral aboral view, UA-2491; lateral view,
UA-2492; 39, aboral view, UA-2493; 40, lateral aboral view,
UA-2494; 41, lateral view of (40).

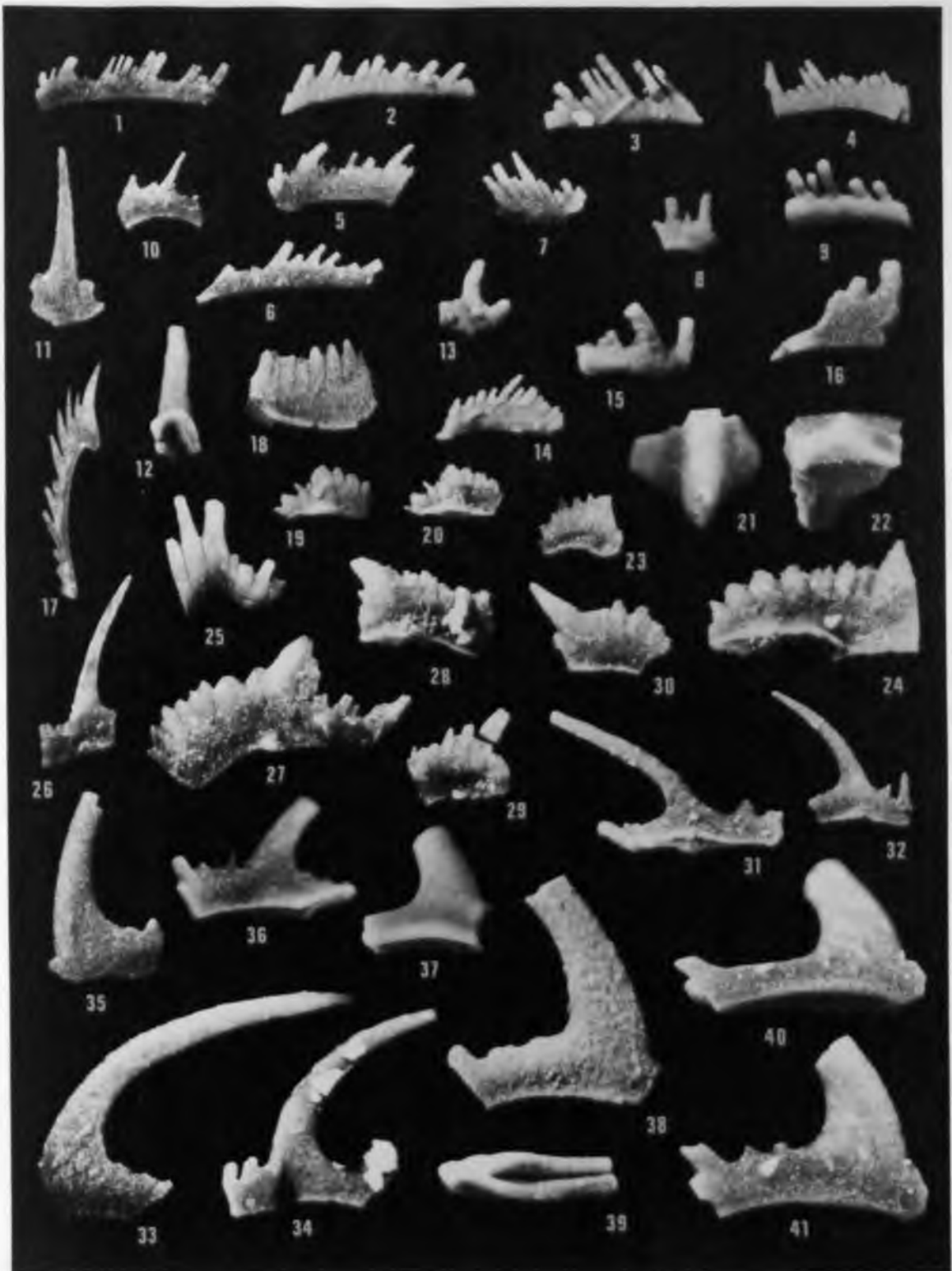


Figure 5. Colina Limestone Conodonts from Tombstone Hills

Figure 6. Genus Sweetognathus of the Colina Limestone
All magnifications X60.

- 1-3 Oral, aboral, and lateral views, respectively, of UA-2430.
- 4,5 Oral and lateral views, respectively, of UA-2431.
- 6 Oral view of juvenile, UA-2432.
- 7 Oral view of juvenile, UA-2433.
- 8 Oral view of juvenile, UA-2434.
- 9 Oral view of broken specimen, UA-3435.
- 10 Oral view of juvenile, UA-2436.
- 11,12 Oral and aboral views, respectively, of juvenile, UA-2437.
- 13,14 Oral and aboral views, respectively, of UA-2438.
- 15 Oral view, UA-2439.
- 16 Oral view, UA-2440.
- 17 Oral view, UA-2441.
- 18 Oral view, UA-2442.
- 19 Oral view, UA-2443.
- 20 Oral view, UA-2444.
- 21,22 Oral and aboral views, respectively, of UA-2445.
- 23 Oral view, UA-2446.
- 24 Oral view, UA-2447.
- 25 Lateral oral view, UA-2448.
- 26,27 Oral and aboral views, respectively, UA-2449.
- 28,29 Oral and aboral views, respectively, of later growth stage,
UA-2450.
- 30-32 Oral, aboral, and lateral views, respectively, of gerontic
individual, UA-2451.
- 33 Oral view of later growth stage, UA-2452.
- 34 Lateral oral view of gerontic individual, UA-2453.
- 35 Oral view of gerontic individual, UA-2454.
- 36,37 Oral view of anterior end and aboral view, respectively, of
gerontic individual, UA-2455.

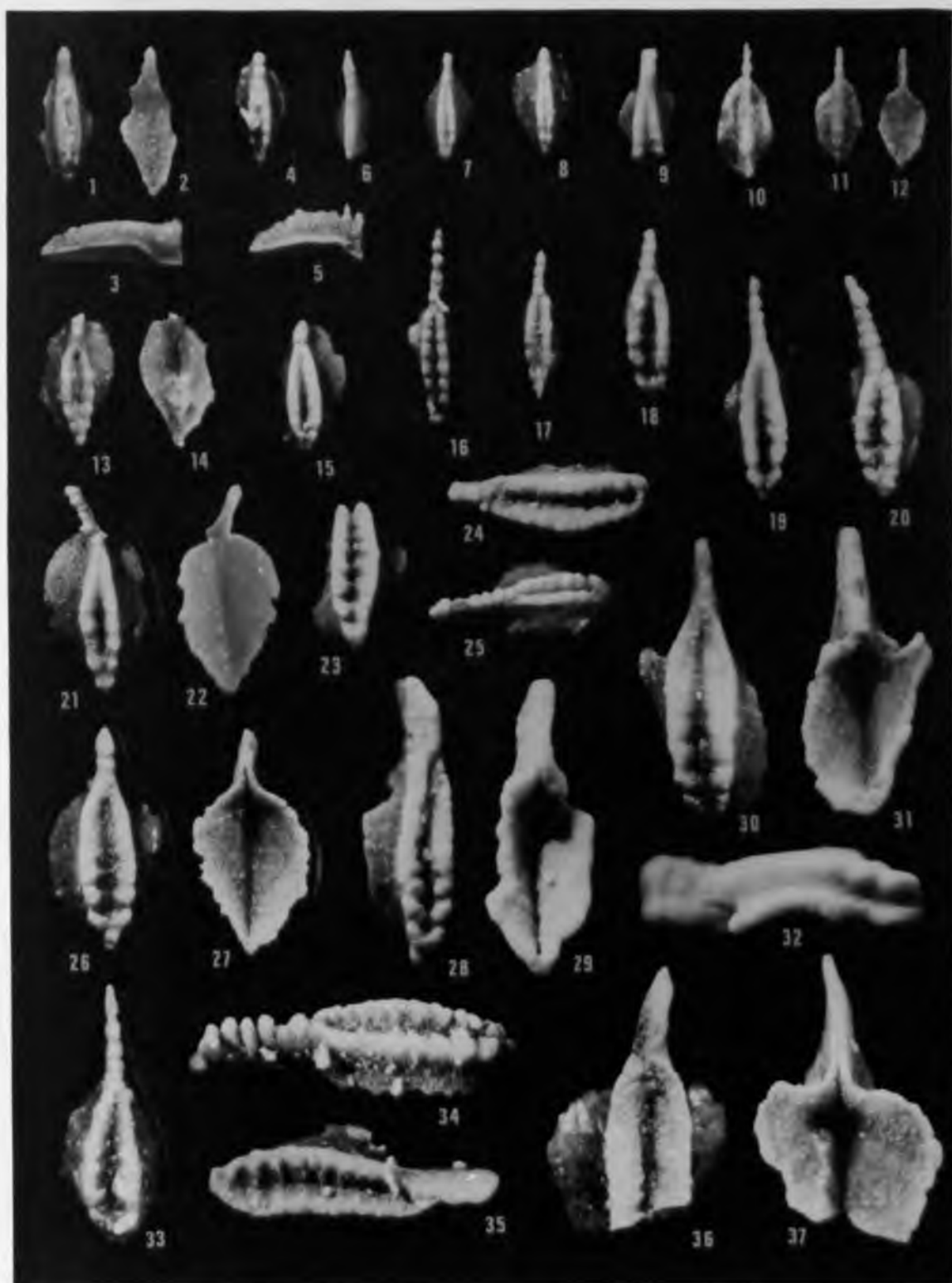


Figure 6. Genus Sweetognathus of the Colina Limestone

adequate conodont work has been done on rocks of Wolfcamp age, it should be easier to establish the relatively few post-crisis multi-element species that presumably existed. The Colina Limestone will provide this opportunity. With the results from the present study, the Colina Limestone of the type area near Tombstone, Arizona, can now be described as consisting of three biostratigraphic zones: two zones with rare conodonts and a thinner middle zone with common conodonts of the genus Sweetognathus.

When the taxonomy is adequately refined, conodonts in general are extremely valuable tools for delineating short increments of geologic time and hence for establishing precise worldwide stage boundaries. Unfortunately, Permian studies dealing with biostratigraphic zonation are still in the pioneer stage of progress and refinement. Thus, based on preliminary conodont evidence, the Wolfcamp-Leonard stage boundary is tentatively placed within unit 27 (Wilt, 1969, p. 91), which is 600 feet above the base of the Colina Limestone. This unit marks the uppermost unit in the Colina where relatively abundant individuals of Sweetognathus sp. have been found (Table 2). Sweetognathus sp. is the most abundant taxon in the formation, and according to D. L. Clark (personal communication, 1972), it is an important genus in recognizing the uppermost Wolfcamp because its biostratigraphic range is above that of Spathognathodus whitei (upper Wolfcamp) but below that of Neostreptognathodus sulcopicatus (lower to upper Leonard). If the presence of Sweetognathus sp. conclusively defines the Wolfcamp-Leonard stage boundary, then the upper 350 feet of the Colina at the Southeast Ridge is definitely of Leonard age. This age agrees with that determined by Sabins (1957, p. 474).

Table 2. Distribution and Abundance of Conodonts in the Colina Limestone of the Tombstone Hills

Stratigraphic Thickness of Biozones (in feet)	Wilt's (1969) Unit Number	Original Field Designation of Sample ^a	Number of Conodonts per 500-g Sample, including Pieces	Genus <u>Sweetognathus</u> Clark	<u>Anchignathodus minutus</u> (Ellison)	? <u>Gnathodus</u> sp.	<u>Ozarkodina</u> sp. A	<u>Cyrtodella</u> sp. A	<u>Neospathodus</u> sp.	<u>Lenchodina</u> sp. A	<u>Hindeodella</u> sp. of Szantawski	<u>Hindeodella</u> sp. A	<u>Hindeodella</u> sp. B	Posterior Bars of <u>Hindeodellids</u>
350	42	152	0											
	39	151e	0											
	33	142b	1	1										
	32	139f	1								?1			
	30	135	2	2	1							1		
	29	133	1											1
	28	129	0											
160	27	127	15	10			2		1			3		9
		126	3	4							1			1
	26	125b	40	11	1	1	1		2	1	3			9
		121	6	4			1							1
	25	117u	0											
		117	8	9			1							5
		115	6	?1							1			4
	24	114b	0											
		112	0											
	23	106c	4	6	?1						1			
		105c	0											
	21	105a	0											
	101b	0												
	100c	20	4			3				1		1	1	
440	20	100	2			2								
	19	99	1											1
		93	0											
	18	91	0											
	16	78	0											
		68	0											
	15	65	0											
	12	52	3	?1										
	10	32	5	4				1			1		1	3
	5	6	0											
1	1-4	0												

a. Two 500-g batches processed for samples 135, 127, 117, 106c, 105c, and 32; three 500-g batches processed for sample 126.

A positive identification of Perrinites hilli (Smith), which ranges from the lower Leonard through the lower Word, was made by A. K. Miller of the State University of Iowa from a single specimen found by Sabins in the upper Colina Limestone of the Dos Cabezas Mountains.

Only one brief preliminary account prior to the present study has been published that may involve conodonts from the Colina Limestone. Clark and Ethington, (1962, p. 103) stated: "Extensive collecting in the Arizona Permian has been largely unsuccessful but several specimens have been obtained from outcrops (Wordian ?) on the west side of U.S. Highway 80, about six miles south of Tombstone, T. 20 S., R. 23 E. (locality 4)." The Colina Limestone and Epitaph Dolomite are the youngest Permian strata that crop out in this general area, but neither formation is as young as Wordian. One new species, Subbryantodus abstractus, was erected by Clark and Ethington from their samples at locality 4. However, because the exact stratigraphic and geographic position of their sample is uncertain, the conodont find is of minor biostratigraphic value. Subbryantodus abstractus was subsequently reassigned to the genus Ozarkodina (Clark and Behnken, 1970, p. 426) and noted to be an important element in middle(?) to upper Leonard assemblages. Ozarkodina abstractus (Clark and Ethington) was not encountered in Colina strata by the present writer. This implies that the upper 350 feet of Colina is no younger than early to middle(?) Leonard.

More recently, Clark and Behnken (1970, p. 419) concluded the following about Wolfcamp conodonts

Because few conodonts have been discovered in the type West Texas or Eurasian Permian our knowledge of Permian conodonts is based on collections from excellent exposures in Nevada,

Utah, Idaho, and Wyoming. However, most of these sections are satisfactory as "type" sections only in the broadest sense. For example, a half-dozen Wolfcampian sections were studied in the western United States, and only the one at the Moorman Ranch locality in east-central Nevada yielded sequences of conodont faunas.

The present author has also tested the Hueco Canyon Limestone of Wolfcamp age (Seewald, 1969) in the Hueco Mountains of West Texas with negative results. Certainly then the significance of the Colina conodonts is emphasized by the apparent lack of good Wolfcamp collections elsewhere in the United States.

The middle 160-foot conodont-bearing zone in the Tombstone Hills is hereby assigned to the uppermost Wolfcamp. The bottom 440-foot zone, nearly devoid of diagnostic conodonts, is middle Wolfcamp. Other elements, in addition to Sweetognathus sp., aid in establishing these biostratigraphic zones. Anchignathodus minutus is found within 40 feet above and below the stage boundary. In addition, Ozarkodina sp. A and Hindeodella sp. of Szaniawski (1969, p. 330) are restricted to the middle 160-foot zone. Neospathodus sp. also seems to be a very diagnostic conodont, particularly in the upper 20 feet of the 160-foot zone. Two significant changes are noted in the prevalent hindeodellids of the middle biozone. Hindeodella sp. A and Hindeodella sp. B occur only at the top and the base of the 160-foot zone, respectively. These latter two, plus H. sp. of Szaniawski, could conceivably all be Hindeodella triassica, but this author prefers to treat them separately until additional work can be done. Regardless of their form-species assignment, each of the three hindeodellids are doubtless one part of the multi-element species Ellisonia triassica Sweet, which has been definitely identified in upper Wolfcamp rocks (Clark, 1972b).

The frequency of occurrence for all conodonts from the Colina Limestone seems to bear little relationship to the lithologies from which they were derived. Eight different rock types were tested, but most of the lithologies processed were (1) sparse to packed biomicrites, (2) fossiliferous micrites, and (3) combinations of the two. Based upon general observations, it is the author's opinion that of the eight types, the combination of packed biomicrites to fossiliferous micrites is usually the most productive. Dolomites, sparse biomicrites, sparse to packed biomicrites, micrites, fossiliferous micrites, and dolomitic intramicrites yielded fewer or no conodonts from the same formation. Based upon a single sample, cherty fossiliferous micrites are also productive. Although the carbonate rocks contain more insoluble clay-size sediment than the other Permian formations tested, the Colina samples were the easiest to process because they contain fewer heavy minerals--but of greater variety--than the other Permian samples.

Evidence is available from this and other studies to show that the conodont-bearing animals may have been depth stratified or otherwise facies controlled (Seddon, 1970a; Merrill, 1970a; Barnett, 1970; Seddon and Sweet, 1971). Although the Epitaph Dolomite in the Empire Mountains is in part time-equivalent to the Colina Limestone in the Tombstone Hills, the two formations record two different environments of deposition and yield two different ecologically controlled conodont assemblages. Streptognathodids and spathognathodids represent the Epitaph biofacies, and sweetognathids and hindeodellids predominated in the relatively deeper water Colina biofacies. Clark (1972a, p. 312) suggested that Streptognathodus, Gnathodus, Idiognathodus, and Adetognathus were

groups of the conodont community that characterized the shallow-water environment and *Sweetognathus* was another group that flourished in water deeper than 30 feet. His hypothesis is further verified by the previously noted difference between conodonts in the Epitaph and Colina. No specimens of *Neostreptognathodus sulcopicatus* were found in the Leonard part of the Colina because it was ecologically impossible for them to occur there. The same might be concluded for the lack of *Spathognathodus whitei* in the lower barren beds of the Colina. If the dolomitic beds of the Epitaph are in fact the shallow-water facies of the Colina beds, as has been regarded in the past from field observations by J. F. Schreiber, Jr. (personal communication, 1972), then the Colina assemblage is consistent with Clark's (1972a) hypothesis.

Overall, the paleoenvironment of the Colina apparently did not change very much. Consequently, one must assume that the appearance and disappearance of different form-genera in this stratigraphic section are due more to evolutionary changes than to ecological changes. Present work reveals that no representatives of *Gondolella* were found in the Colina or, for that matter, in any post-crisis rocks of the Pedregosa Basin. Merrill (1970b, p. 409-410) considered the occurrence of this genus *Gondolella* too provincial for widespread biostratigraphic zonation. A conspicuous lack of these fossils may also have environmental meaning. Because the environments of deposition have been previously determined (Butler, 1971), the conclusion can be drawn that any of three general environments can be inferred when upper Wolfcamp-lower Leonard conodonts are found. These include: (1) shallow-water environment (less than 30 feet) recognized by individuals of *Streptognathodus* or *Gnathodus*;

(2) moderate-depth water (30-60 feet) recognized by individuals of Sweetognathus; and (3) deep water (deep basin to miogeosynclinal depths) recognized by individuals of Gondolella. Because most of the existing work on Permian conodonts has been done on deep-water geosynclinal strata, the problem arises of how to correlate shallow-water shelf assemblages. A solution may be to erect standard biozones for each type of environmental assemblage.

In summary, the author recommends placing the Wolfcamp-Leonard stage boundary at the last abundant occurrence of Sweetognathus sp. and the first occurrence of Hindeodella sp. A, which both occur in sample 27 (table 2). The other elements which help define the transition (samples 20-27, table 2) include Ozarkodina sp. A and Hindeodella sp. of Szaniawski. More precisely, Anchignathodus minutus, Hindeodella sp. A, ?Spathognathodus divergens, Neospathodus sp., and Lonchodina sp. A all range from sample 26 through sample 30. The relatively abundantly occurring, previously unreported fossil genus in the Colina, Sweetognathus, not only provides a means of recognizing the uppermost Wolfcamp strata on a regional scale but also assures the recognition of Colina rocks for correlation at the local level. The platform-to-blade ratio for the Colina conodonts is 5.5:1. This parameter is consistent with others calculated for post-crisis collections (Clark, 1972b, table 3). Certain conodont elements are suspected of being ecologically controlled and not stratigraphically controlled. Colina rocks prove that the Pedregosa Basin was a conodont-inhabited sanctuary during their near extinction in the Early Permian. When environmental conditions arise that threaten to exterminate a group of animals, usually only the most

conservative members of that community survive. The implication is that the Colina assemblage must represent the most conservative of all conodont elements by virtue of its Wolfcamp age (in part). Conservative elements are difficult to use biostratigraphically due to their minor morphological changes with time. Obviously, the processing of only forty samples from the Colina Limestone leaves room for the refinement of the Wolfcamp-Leonard stage boundary. Nevertheless, the initial testing and documentation of the local succession have filled a large gap in the conodont biostratigraphy of southeastern Arizona.

Epitaph Dolomite Conodonts

The uppermost 180-foot member of the Epitaph Dolomite in the Empire Mountains (Butler, 1969, p. 35) was examined for conodonts with some positive and some negative results. This member of the Epitaph (fig. 1, location 3) showed the least effects of local contact metamorphism within the four-member formation. For this reason, it was selected for study. On the negative side, the absence of conodonts at all levels throughout this uppermost member detracts from its biostratigraphic value. Only the lower 30 feet of this 180-foot section proved to bear indigenous conodonts (table 3, fig. 7). Also, the surface of these conodonts shows considerable etching and pitting (fig 3, no. 3), possibly caused by penesaline conditions at the sediment-water interface, or by diagenetic processes, such as dolomitization.

On the other hand, the time-stratigraphic position of the 30-foot section can be confidently assigned a late Wolfcamp age. Although it is not possible to locate precisely the Wolfcamp-Leonard stage

Figure 7. Epitaph Dolomite Conodonts from Empire Mountains
All magnifications X60.

- 1,2 Undefined genus A. 1, Inner lateral aboral view, UA-2495;
2, outer lateral view of (1).
- 3,4 Undefined genus B. 3, Interior lateral view, UA-2496; 4, outer
lateral view of (3).
- 5-8 Species indeterminable. 5, Lateral view of ?prioniodellid frag-
ment, UA-2497; 6, lateral view, UA-2498; 7, lateral view,
UA-2499; 8, lateral view, UA-2500.
- 9 Neospathodus aff. N. divergens (Bender and Stoppel). Lateral
view, UA-2501.
- 10-12 Hindeodellids. 10, Lateral view, UA-2502; 11, lateral view,
UA-2503; 12, oblique oral view, UA-2504.
- 13 Sweetognathus sp. Oral view of anterior half, UA-2505.
- 14,15 Cratognathodus sp. 14, Inner lateral view, UA-2506; 15,
? Cratognathodus sp., UA-2507.
- 16-18 Gnathodus sp. 16, Oral view, UA-2508; 17, oral view, UA-
2509; 18, oral view, UA-2510.
- 19-27 Spathognathodus whitei Rhodes. 19, Anterolateral view, UA-
2511; 20, oblique oral view, UA-2512; 21, oblique aboral
view of (20); 22, oral view of platform, ? posterior end up,
late growth stage, UA-2513; 23, oblique lateral view, UA-
2414; 24, oral view of (23); 25, oblique oral view of plat-
form, UA-2515; 26, lateral view, severely etched, UA-
2516; 27, oblique oral view of platform, UA-2517.
- 28 Neospathodus sp. B. Lateral view, UA-2518.
- 29,30 Ozarkodina sp. A. 29, Lateral view, UA-2519; 30, lateral
view, UA-2520.
- 31-33 Anchignathodus sp. A. 31, Lateral view, UA-2521; 32, lateral
view of gerontic specimen, UA-2522; 33, outer lateral view
of (32).
- 34 Spathognathodus sp. B. Lateral view, UA-2523.
- 35 Anchignathodus minutus (Ellison). Lateral view, UA-2524.
- 36 Anchignathodus sp. B. Lateral view, UA-2525.
- 37 ? Hindeodella sp. A. Lateral aboral view of gerontic individual,
UA-2526.
- 38-41 Idiognathodus sp. A. 38, oral view, UA-2527; 39, aboral view,
UA-2528; 40, oblique oral view, UA-2529; 41, lateral view
of (40).
- 42 Lonchodina sp. B. Inner lateral view, UA-2530.

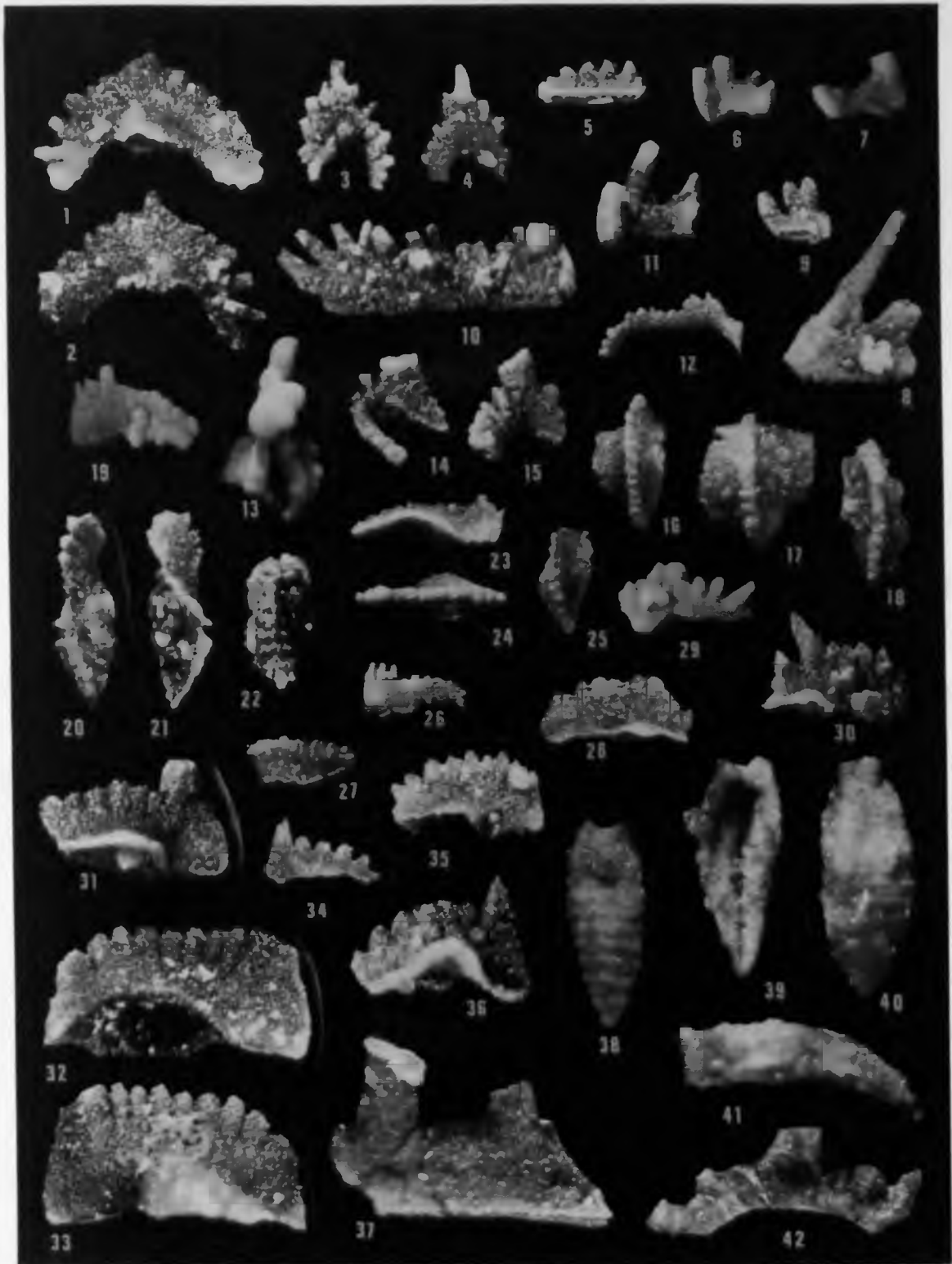


Figure 7. Epitaph Dolomite Conodonts from Empire Mountain

boundary within the Epitaph Dolomite of the Empire Mountains, it is reasonable to assume that the boundary is within the upper member. This is a good approximation because the upper Wolfcamp species Spathognathodus whitei occurs in this 30-foot interval of this uppermost member (fig. 8).

Furthermore, by using the occurrence of S. whitei and the inference of its limited range, one can consider the following positive ramification: if the upper Epitaph Dolomite in the Empire Mountains is of Wolfcamp and ?Leonard age, then at least the upper strata of the Colina and Epitaph are conclusively time-equivalent and hence lateral facies of each other. (See Zeller, 1965, p. 51.)

Although the shallow Colina sea transgressed to the northwest across the Permian continental shelf, the contact between the Colina and Epitaph formations descends stratigraphically and becomes older in a general northwest direction from the Tombstone Hills to the Empire Mountains. Presented here is a model different from the classic model of rock unit contacts becoming progressively younger in the direction of regional transgression. Nonselective penecontemporaneous dolomitization of "Colina lithologies" induced by the downward percolation of magnesium-rich waters in the high intertidal environment is responsible for the highly irregular Colina-Epitaph contact and for the greater thickness of "Epitaph lithologies" in the Empire Mountains. Initially, transgression did little more than provide the environment which allowed the marine limestone to be deposited in southeastern Arizona. It did not control the position of the contact in space in the classic model sense. With this information, the areas of dolomitization, as depicted in figure

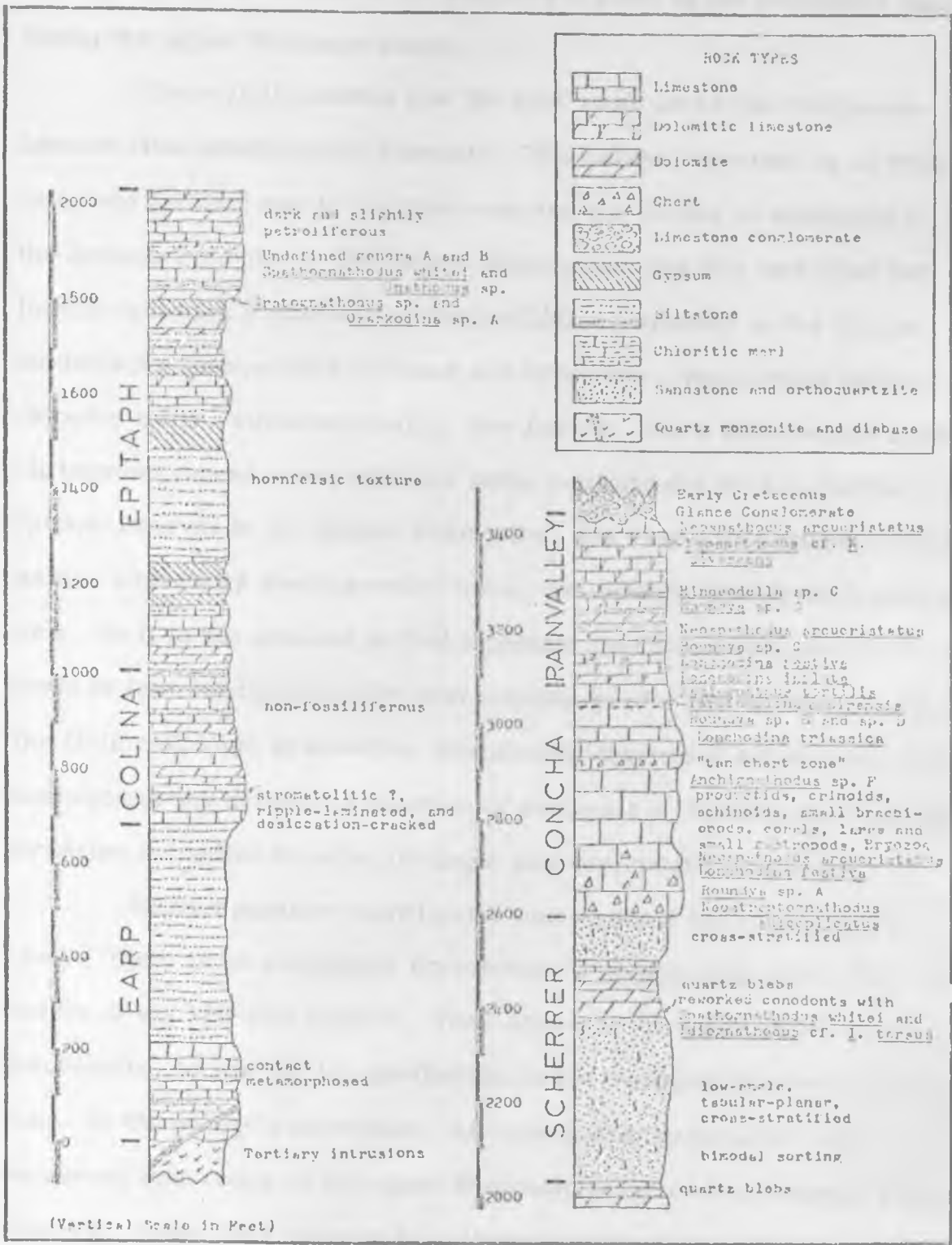


Figure 8. Stratigraphic Occurrences of Diagnostic Permian Conodonts in the Empire Mountains, Pima County, Arizona

9, can be used to delineate the shallowest parts of the Pedregosa Basin during the upper Wolfcamp stage.

Figure 10 illustrates how the rock units cross the Wolfcamp-Leonard time-stratigraphic boundary. The Colina Limestone is of Wolfcamp and Leonard age in the type area and the Colina is subjacent to the Epitaph Dolomite in the Empire Mountains. But this fact does not justify assuming a similar age for the Colina formation in the Empire Mountains. Intercalated gypsums and dolomites, desiccation features, chloritic marls, stromatolites(?), few fossils, and a thin-bedded nature all together record a very shallow water environment for the Colina-Epitaph interval in the Empire Mountains. But even local marine environments, especially shallow-water ones, can change quickly with geologic time. So it is not unusual to find a contact that fluctuates several hundreds of feet stratigraphically over a distance of a few to tens of miles. The Colina-Epitaph space-time relationship discussed above serves to demonstrate the dangerous practice of assuming a "blanket age" for any formation according to only lithologic and superposition criteria.

Another positive contribution has emerged from the Epitaph study. There is an anomalous occurrence of Idiognathodus sp. near the middle of the 180-foot section. They appear to be out of place stratigraphically, as are the idiognathodids in the overlying Scherrer Formation. To the author's knowledge, idiognathodids have never been recovered from rocks of the upper Wolfcamp stage or from younger rocks. However, there does seem to be a logical explanation for their occurrence here.

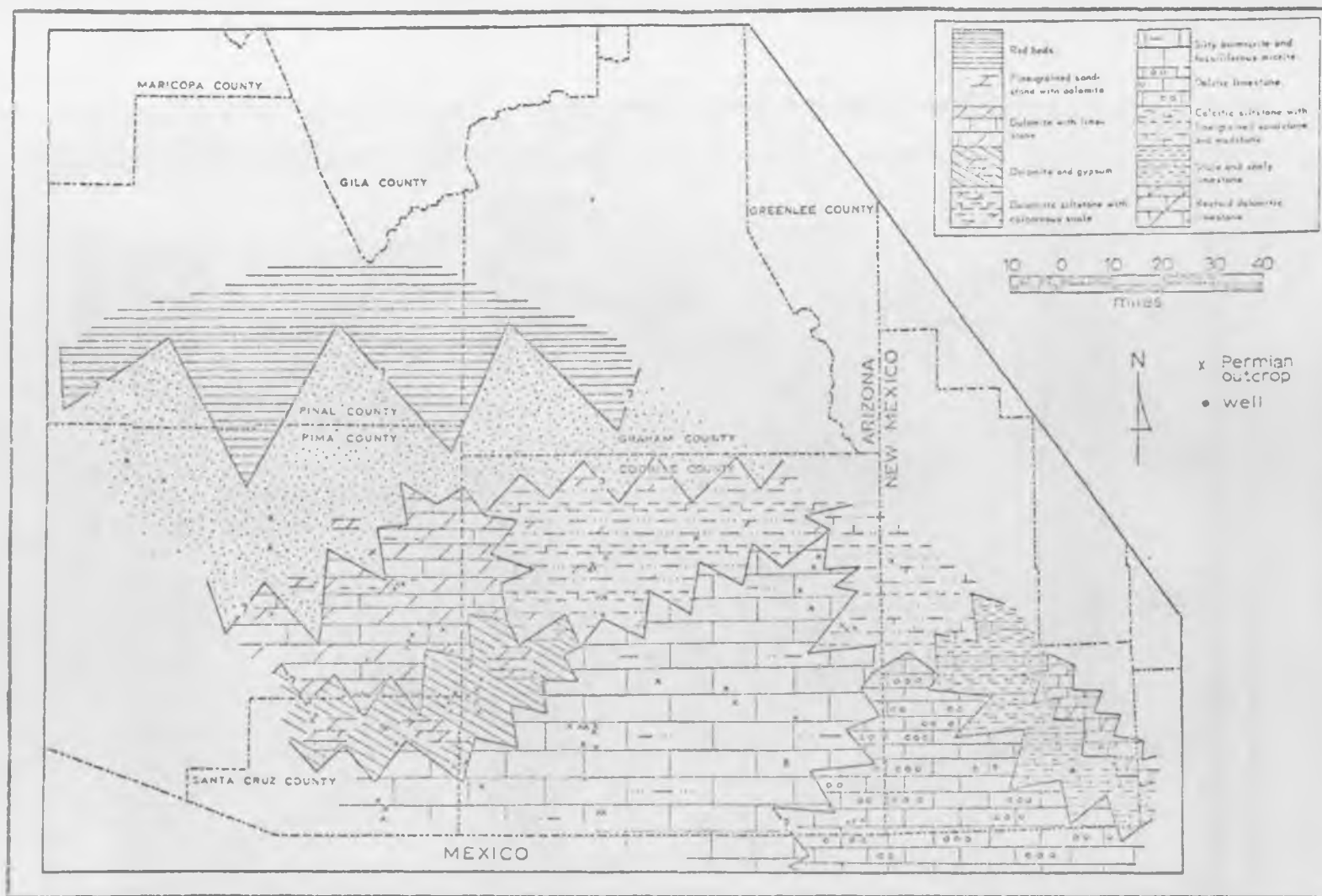


Figure 9. Facies Map of the Pedregosa Basin During the Upper Wolfcamp Stage

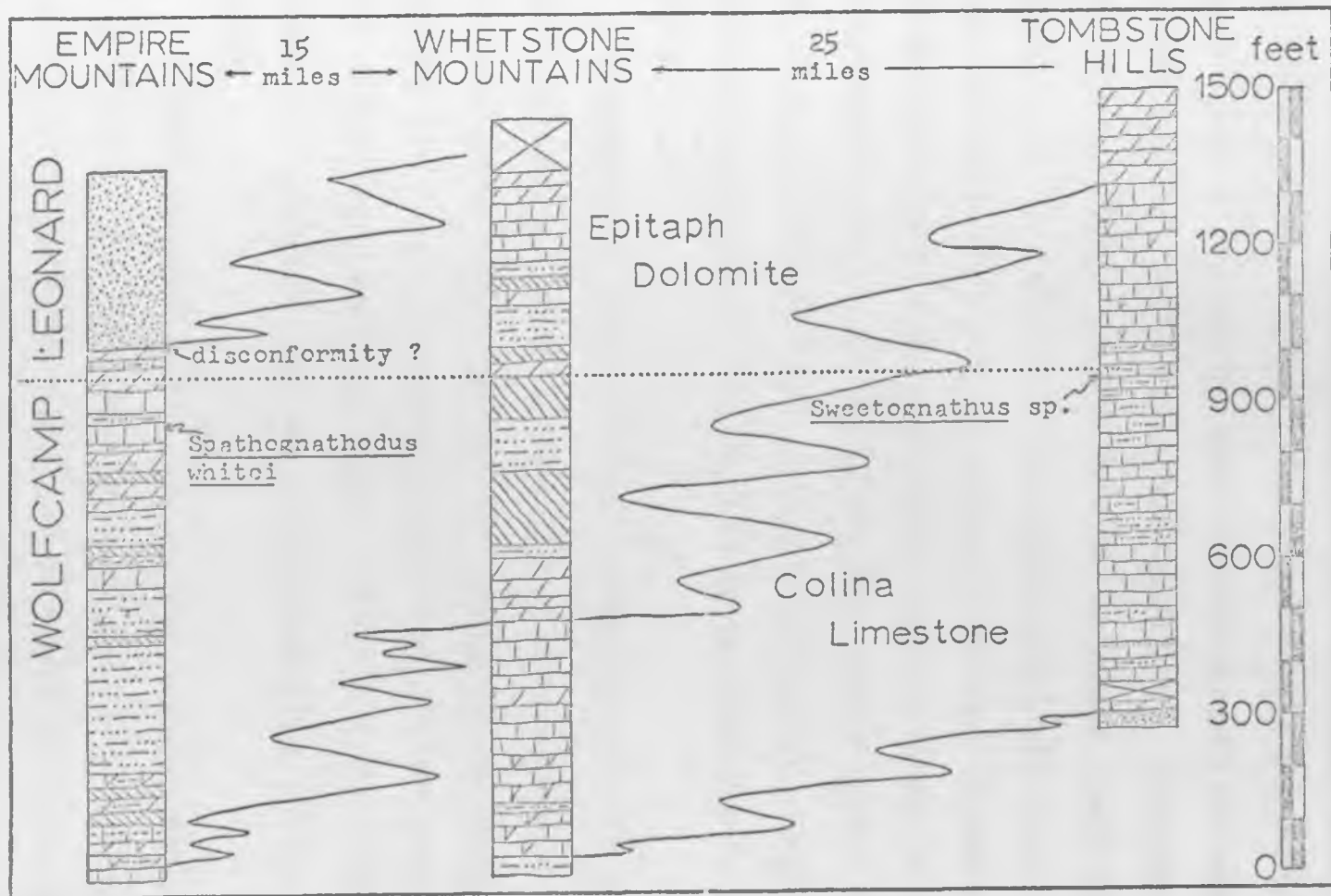


Figure 10. Time-stratigraphic Relationship of the Colina Limestone and Epitaph Dolomite

These species of Idiognathodus in samples 16 and 18 (table 3) mark the beginning of a change in sedimentation. The change is the start of the regressive phase that culminated with the deposition of the mostly clastic Scherrer Formation. The idiognathodids must have been transported into the basin as the result of renewed uplift and erosion of older rocks around the northern perimeter of the basin. Evidence to support this interpretation is twofold: (1) other conodonts, including Idiognathodus sp. A, all indicative of being stratigraphically mixed, have been recovered from the overlying rocks of the Scherrer Formation and (2) a local conglomeratic zone 2 feet thick has been reported at the top of the Epitaph Dolomite in the Empire Mountain section (Butler, 1969, p. 93). One can then predict that at least local regression began at about the same time that the uppermost Wolfcamp rocks were being deposited.

In comparison with the Colina, the Epitaph conodonts have several identical and several new elements. Those elements common to both sections include Sweetognathus sp., Anchignathodus minutus, Ozarkodina sp. A, and ?Hindeodella sp. A. Important new genera and species include Spathognathodus whitei, undefined genera A and B, Gnathodus sp., Cratognathodus sp., and Neospathodus aff. N. divergens.

Undefined genera A and B (fig. 7, nos. 1-4) are noteworthy because they were both found in the same sample. Do they represent part or all of a previously unrecognized apparatus in a short-ranging multi-element species? Or do they represent a symmetry transition within selective parts of the conodont animal? Because the function

Table 3. Distribution and Abundance of Conodonts in the Epitaph Dolomite of the Empire Mountains

Sample Number	Number of Conodonts per 500-g Sample, Including Pieces	Undefined genus A	Undefined genus B	<u>Cratognathodus</u> sp.	<u>Spathognathodus whitei</u> Rhodes	<u>Spathognathodus</u> sp. B	<u>Anchignathodus</u> sp. A	<u>Anchignathodus minutus</u> (Ellison)	Genus <u>Sweetognathus</u> Clark	<u>Lonchodina</u> sp. B	<u>Ozarkodina</u> sp. A	<u>Gnathodus</u> sp.	<u>Idiogonathodus</u> sp. A	<u>Anchignathodus</u> sp. B	<u>Neospathodus</u> aff. <u>N. divergens</u> (Bender and Stoppel)	<u>Neospathodus</u> sp. B	? <u>Hindocodella</u> sp. A	Posterior Bars of <u>Hindeodellids</u>
30	0																	
29	0																	
28	0																	
27	0																	
26	0																	
25	0																	
24	0																	
23	0																	
22	0																	
21	0																	
20	0																	
19	0																	
18	3												3					
17	0																	
16	3												1					2
15	0																	
14	0																	
13	0																	
12	0																	
11	0																	
10	0																	
9	1																	
8	0																	
7	0																	
6	12				1						? 1							
5	0																	
4	30			? 1	4						1	3		1		2		1
3	40	1	1	1	2		2	1	1		3			1			1	4
2	2																	
1	19				3	1				1	2	2						

(position) of each element controls its morphology, then possibly the functions of these two parts of the conodont animal were different from those in better known conodonts. Accordingly then, these elements cannot be brought to any previously established form-genus. The present author prefers the second alternative in which rare specimens that are difficult to fit into natural assemblages are thought to be symmetry transitions between form-genera (Lindström, 1964, chap. 7, 8). Of course, with only one specimen of each, no more than speculation is justified.

In review, a definite boundary between the Wolfcamp and Leonard stages cannot be located in the upper 180-foot member of the Epitaph Dolomite in the Empire Mountains. Nevertheless, this member does contain some conodonts identical to some in the middle 160-foot section (table 2) of the Colina Limestone in the Tombstone Hills. Based on this similarity and because Sweetognathus sp. is a rare contemporary but an abundant immediate descendant of Spathognathodus whitei, the two sections are thought to be nearly correlative in time. The Epitaph conodonts are (1) few in number; (2) a unique collection of undefined genera, including the only positive occurrence of the genus Gnathodus; (3) restricted stratigraphically to the base of the upper member; (4) assignable to a maximum age of late Wolfcamp based on ten specimens of Spathognathodus whitei; and (5) suggestive of sediment reworking in the upper half of the 180-foot member, which in turn reflects the beginning of the ensuing marine regression. The ratio of platform to blade types is 1:1--a variance from the Colina ratio of 5.5:1. This variance could be interpreted in light of the fewer numbers of genus Sweetognathus in the Epitaph. In determining this ratio, all spathognathodids (except

Spathognathodus whitei) and anchignathodids are considered to be blades. The low ratio could imply that Sweetognathus sp. was a mono-element platform species. As shown in the Colina-Epitaph example, time-sensitive fossils, such as conodonts, are indeed useful for a meaningful time-stratigraphic perspective of the rocks that contain them. To be sure, conodonts have helped to resolve a geologic problem.

Scherrer Formation Conodonts

In all the studies performed on Permian conodonts, the Leonard stage has been the most neglected. Some conodont workers are reluctant to start research on strata of Leonard age because of the anticipated scarcity of conodonts. One such worker, J. W. Collinson (personal communication, 1972), stated that because of this belief, he personally has not begun work on Leonard conodonts. Permian conodont biostratigraphy is currently being studied at the University of Wisconsin by two pioneer workers, D. L. Clark and F. H. Behnken. In their authoritative publication (1970, p. 425), they noted that "less is known concerning Leonardian conodonts than about conodonts from any other Permian series."

The Scherrer Formation of Leonard age contains fewer time-diagnostic macrofossils than any other Permian rock unit of formation rank in the Pedregosa Basin. Although the recognition of conodont microfossils (fig. 11) does little to alleviate the biostratigraphic anonymity, it does specify useful stratigraphic information about the conditions of deposition for the Scherrer Formation. In southeastern Arizona, the Scherrer consists of four members in the type area at Scherrer Ridge (Gilluly and others, 1954, p. 248; Luepke, 1971, p. 248) but of only three members in the Empire Mountains (Butler, 1969, p. 39). The middle

Figure 11. Scherrer Formation Conodonts from Empire Mountains
All magnifications X60.

- 1 Hindeodella aff. H. triassica Müller. Lateral view, UA-2401.
- 2-5 Miscellaneous elements. All lateral views; 2, UA-2402; 3, UA-2403; 4, UA-2404; 5, UA-2405.
- 6 Spathognathodus sp. Lateral view, UA-2406.
- 7 Lonchodina sp. Lateral view, UA-2407.
- 8-10 Spathognathodus sp. A. 8, Lateral view, severely worn, UA-2408; 9, lateral view, posterior fragment, UA-2409; 10, lateral view, UA-2410.
- 11,12 Ozarkodina cf. O. delicatula (Stauffer and Plummer). 11, Lateral view, UA-2411; 12, lateral view, UA-2412.
- 13-19 Spathognathodus whitei Rhodes. 13, Oral view, UA-2413; 14, oblique oral view of (13); 15, lateral view of (13); 16, aboral view of juvenile, UA-2414; 17, oral view of (16); 18, aboral view of gerontic individual, UA-2415; 19, oral view of individual in later growth stage, UA-2416.
- 20-24 Spathognathodus cristulus Youngquist and Miller. 20, Lateral view, UA-2417; 21, lateral view, anterior portion, UA-2418; 22, lateral view, worn dextral specimen, UA-2419; 23, interior lateral view, UA-2420; 24, exterior lateral view, UA-2421.
- 25-28 Idiognathodus cf. I. tersus Ellison. 25, Oblique oral view of worn specimen, UA-2422; 26, oral view of broken specimen, UA-2423; 27, oral view, UA-2424; 28, aboral view of (27).
- 29-32 Idiognathodus sp. A. 29, Aboral view, UA-2425; 30, aboral view, UA-2426; 31, oblique oral view of (30); 32, oblique oral view of (30) with lighting from upper right.
- 33 Spathognathodus sp. B. Lateral aboral view of immature individual, UA-2427.
- 34 Adetognathus lautus? (Gunnell). Oral view, UA-2428.
- 35-38 Idiognathodus sp. A. 35, Oblique oral view, UA-2429; 36, aboral view of (35); 37, lateral view of (35); 38, oblique oral view of (35).

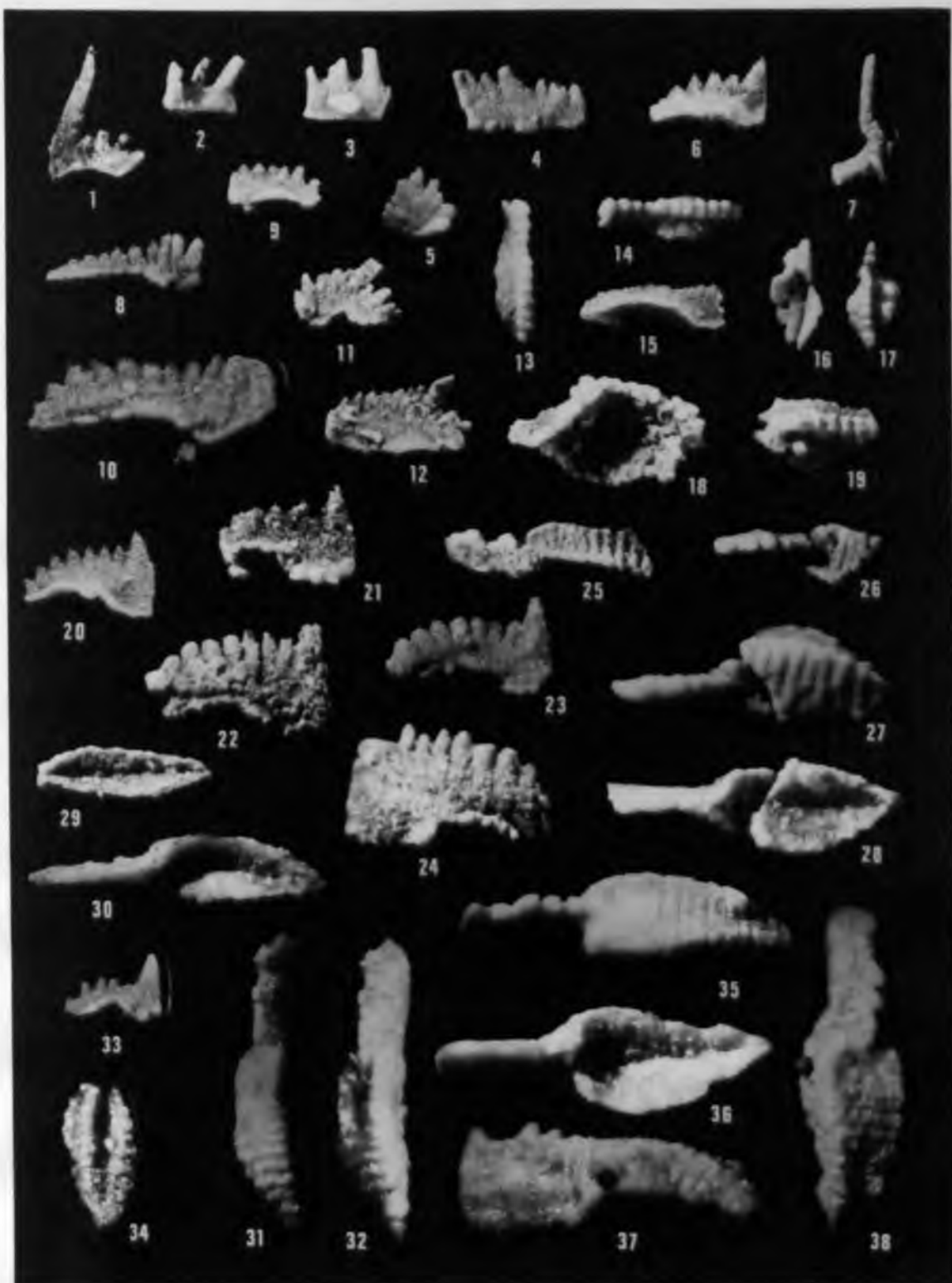


Figure 11. Scherrer Formation Conodonts from Empire Mountains

member is a dolomitic carbonate unit, and it is this member in the Empire Mountains that was examined for conodonts. No attempt was made to recover conodonts from the lower and upper orthoquartzite members of this formation.

Upon first appraisal of the conodont assemblage from the middle unit, the Scherrer appears to be biostratigraphically reversed. The observations that suggest this are occurrences of Virgil conodonts in the upper part of the carbonate unit and Wolfcamp conodonts in the lower part. Several working hypotheses are offered to explain these anomalous observations.

The first hypothesis, and probably the most tenable, proposes that these conodonts in the Scherrer Formation have been reworked from older sediments. (See Lindström, 1964, and Seddon, 1970b, for a discussion on the recognition of reworked conodonts.) This interpretation readily explains why the Scherrer contains conodont elements not previously reported in Leonard rocks elsewhere in the world. Several lines of evidence to favor this hypothesis include the obvious fragmentary condition of the conodonts themselves. There are no well-preserved conodonts in the Scherrer Formation where studied at Total Wreck Ridge (fig. 1, location 3). As can be seen in table 4, sample 1 contains more than a hundred pieces of conodont remains per 500 grams of original sample. Just by this frequency of occurrence, it may be deduced from Lindström's (1964, fig. 24) diagram that the Scherrer represents a submarine rise near the terrigenous source. The rationale is that currents sweeping the rise would concentrate the phosphatic conodonts as they would concentrate any other heavy mineral by removing the fines.

Table 4. Distribution and Abundance of Conodonts in the Middle Member of the Scherrer Formation of the Empire Mountains

Sample Number	Total Number of Conodonts per 500-g Sample, Including Fragments	<u>Spathognathodus whitei</u> Rhodes	<u>Spathognathodus cristulus</u> Youngquist and Miller	<u>Spathognathodus</u> sp. A	<u>Spathognathodus</u> sp. B	<u>Idiognathodus</u> cf. <u>I. tersus</u> Ellison	<u>Idiognathodus</u> sp. A	<u>Adetognathus lautus?</u> (Gunnell)	<u>Ozarkodina</u> cf. <u>O. delicatula</u> (Stauffer and Plummer)	<u>Lonchodina</u> sp.	<u>Hindeodella</u> aff. <u>H. triassica</u> Müller
17	0										
16	2										
15	0										
14	10		1			1			1		1
13	5		1			1			1	1	
12	0										
11	0										
10	0										
9	8	1	1								
8	2										
7	0										
6	0										
5	40	3	2	3			? 1				
4	8					1					
3	0										
2	0										
1	100+	5		2	1			1			

Theoretically, then, more conodonts per unit sample should be recovered from this environment than in a deeper basin receiving a rapid supply of sediment. However, to interpret the Scherrer as a submarine rise rather than as a high intertidal environment is not consistent with the other evidence of geometry and sedimentary structures.

The nature of the Scherrer Formation suggests an accumulation of sediment that has been conspicuously disturbed by tectonism prior to lithification. For example, Butler (1971, p. 99) recognized submarine slumping within the Scherrer at American Peak, Santa Cruz County, Arizona. Influx of clastic material into the Pedregosa Basin down a steep paleoslope may have been triggered by faulting, isostatic adjustments, or other tectonic pulses along the Deming axis. Others have also mentioned that mid-Permian times were those of renewed tectonic and orogenic activity. To the west of the continental shelf, the Cordilleran geosyncline must have been orogenically active (Bissell, 1959, p. 176; 1970, p. 303 and Dott and Batten, 1971, p. 33). In the author's opinion, the parent rocks contributing detritus to the open-ended Pedregosa Basin were eroded along the Deming axis (Butler, 1971; Turner, 1962) from the Burro Uplift to the Naco Highlands or even perhaps south of that line. This idea concurs with that of Reid (1968, p. 14).

In reference to late Paleozoic tectonism in southwestern New Mexico, Turner (1962, p. 67) reported that "all Pennsylvanian strata were removed in the vicinity of the Florida Mountains, and beds of Virgil age are missing over a somewhat broader region." Kottowski (1962, p. 347) prepared an isopach map for the Pennsylvanian System of southeastern Arizona and southwestern New Mexico which illustrates the thinning of strata toward the Florida Islands area. He inconclusively

attributed the thinning and absence of beds of Virgil age to removal by erosion or to nondeposition.

One might speculate that southwestern New Mexico had been an avenue for sediment transport into the Pedregosa Basin. Or did the Scherrer receive its older reworked conodonts through "erosive cannibalism" of the underlying strata? But an erosional disconformity has not been recognized between the Epitaph and Scherrer Formations. In addition, any supposition that the Florida Islands could have been the source for pre-Leonard conodonts seems inconclusive because isopach lines show that sediments become thinner toward these ancient land areas. Furthermore, based on Butler's (1971, p. 87) clastic ratio data, the direction of sediment transport into the Pedregosa Basin is regarded as being from the north and not from the east.

For the first hypothesis, which advocates a mixed conodont assemblage in the Scherrer Formation, to be possible, the conodonts must have been washed completely free of their original embedding matrix. Secondly, the source area must have been uplifted during middle to late Early Permian time.

The high intertidal littoral (probably swash zone of a nonbarred coast) environment of deposition inferred for the Scherrer sediments fits the picture of a deltalike lobe being deposited and shifted basinward by wave action into a very shallow repository. Geometrically, the top-set portion of this lobe, including the area from isopach lines 500' to 700' (Butler, 1971, p. 83), was conjecturally less steep and representative of the planar surface of the effective wave base. Luepke (1971, p. 249) noted wavy laminations within the otherwise structureless middle

carbonate unit which probably represent bedding surfaces where significant movements of sediment have occurred.

It must be noted that the Scherrer conodonts are not entirely randomly mixed. The stratigraphic position of Spathognathodus whitei clearly indicates that the conodonts in samples 1 through 9 (table 4) were derived from a source area where the rocks were of early to late Wolfcamp age. As erosion of the source was continuing, the youngest rocks were stripped away and redeposited, but at the same time older--possibly mid-Virgil rocks--were being elevated and exposed. These older source rocks yielded Idiognathodus cf. I. tersus and Spathognathodus cristulus. Individuals of these species were destined to become entombed in Scherrer samples 4, 5, 9, 13, and 14 (table 4). A pre-crisis element Ozarkodina cf. O. delicatula has also been recovered from samples 13 and 14. Here again the oldest forms have been extracted from the youngest beds of the carbonate member. If the hypothesis is valid, the conclusion can be drawn that the maximum age of the Scherrer Formation in the Empire Mountains is earliest Leonard.

A second hypothesis to support the data seems less plausible. Its thesis is that the Scherrer Formation is not all Leonard but is also in part latest Wolfcamp. If the sediments have not been reworked, the Wolfcamp-Leonard stage boundary would be within the middle carbonate member at the top of the Spathognathodus whitei zone (table 4). To put the stage boundary this high in the stratigraphic section so near the Leonard-Guadalupe stage boundary would imply either (1) the existence of a major erosional disconformity between the upper Scherrer and the superjacent Concha Limestone or (2) a very slow deposition rate.

Although this formational contact is very sharp in the Empire Mountains, there are other localities, such as in the Waterman and Patagonia Mountains and in the type area of the Gunnison Hills, where the contact is gradational. According to Zeller (1965, p. 52), the upper contact of the Scherrer in southwest New Mexico is conformable and the age of the Scherrer is entirely Leonard.

Also required to defend this second hypothesis is the assumption that Idiognathodus cf. I. tersus, Ozarkodina cf. O. delicatula, and Spathognathodus cristulus are not really the taxa as assigned but actually their Leonard-age homeomorphs. Homeomorphy in conodonts is quite common (Rexroad, 1958, p. 1158; Lindström, 1964, p. 94; Austin, 1970, Sweet and Bergström, 1970, p. 171; and Ziegler, 1970, p. 410), but to recognize its presence would necessitate the compilation of much more information on Permian conodonts than is now available. Because as many as four different pre-Leonard species have been found in the Scherrer, it is unlikely that all four would represent pre-Leonard homologous forms in a post-crisis conodont-bearing animal.

A third hypothesis to explain the apparent reversed stratigraphic relationships in the middle carbonate member simply states that (1) all conodonts are indigenous, (2) the taxa ranges as noted in this study are correct and not really reversed, and (3) the ranges are actually extensions of previously known ranges up into the Leonard. The conclusion reached by Clark and Behnken (1970, p. 425) that the upper boundary of the Spathognathodus whitei zone is unknown adds credence to this hypothesis.

A final hypothesis is offered. If one regard the ranges determined by previous workers to be valid, one may conclude that Idiognathodus cf. I. tersus, Ozarkodina cf. O. delicatula, Spathognathodus cristulus, and Spathognathodus whitei are really the post-Wolfcamp homeomorphs that they may be. Of the four hypotheses, this one is the least consistent with the available evidence.

In conclusion, the Scherrer Formation can best be interpreted as being characterized by reworked Wolfcamp and perhaps Virgil conodonts. The ratio of platform-to-blade types is meaningless because the conodonts probably represents a reworked thanatocoenose. The reward of studying the Scherrer conodonts is neither in being able to establish biostratigraphic zones nor in being able to solve a specific geologic problem but rather in the inceptive recognition that a problem does exist.

Concha Limestone Conodonts

The 500-foot-thick Concha Limestone in the Empire Mountains (fig. 1, location 3) is arbitrarily and nearly equally divided into a lower part (samples 1-36, table 5) and an upper part (samples 37-73, table 6) to show the abundance and local ranges of conodont taxa.

Subjacent to the Concha Limestone is the Scherrer Formation, which has yielded conodonts--but probably none are indigenous. If the youngest reworked conodonts in the Scherrer Formation are late Wolfcamp and the oldest conodonts in the Rainvalley Formation overlying the Concha are of late Word age, then, allowing enough time for reworking, the Leonard-Guadalupe stage boundary must logically be in the Concha Limestone. Indeed, Concha conodonts (figs. 12 and 13) show

Table 5. Distribution and Abundance of Conodonts in Samples 1-36 of the Concha Limestone of the Empire Mountains

Sample Number	Total Number of Conodonts per 500-g Sample	Neostreptognathoid-to anchignathoid Ratio	Neostreptognathoid sulcollicatus (Y., H., M.)	Neostreptognathoid sp. A	Anchignathoid sp. C	Xanognathus tortilis (Tatge)	Neospathodus arcuicristatus Clark & Behnken	Neospathodus sp. A	Roundya sp. A	Lonchodina mülleri Tatge	Lonchodina festiva Bender & Stoppel	Lonchodina triassica Müller	Ellisonia cf. E. triassica Müller	Hindodella triassic Müller	Hindodella nevadensis Müller	Indet. genus B	Hindodellid Fragments
36	9				3											1	1
35	9	1:3		1	3									2	1	1	2
34	--	--															
33	2																
32	4				3					1							
31	10	4:4		4	4												
30	10	2:2		2	2		1										
29	11			1						1							1
28	10	7:2		7	2												
27	8			2												1	
26	10	1:3		1	3										1		
25	11	2:3		2	3										1		
24	50	9:18		9	18			2		2				3			7
23	60	10:14		10	14			2		?1				1			8
22	60	15:15		15	15		?1			1	1	1		1		1	7
21	30	3:11		3	11									1		1	3
20	50	8:11		8	11	1	?1								2		8
19	5			2								1					
18	8	1:1		1	1												2
17	8				1						1		1				?2
16	8			1					1	1			1		1		
15	20				4				2	1					2		
14	7	1:3		1	3				?1								
13	100+	15:12		15	17											1	3
12	70	9:15	2	7	15											6	
11	12				2												2
10	10				2												1
9	5				1				1								
8	50	4:1		4	1				1							20	
7	20	5:2		5	2											8	1
6	25			3						1						1	
5	20	9:4		9	2												
4	6			3													
3	1																
2	14		2	1					?1								
1	30	5:1		5	1						1						2

Table 6. Distribution and Abundance of Conodonts in Samples 37-73 of the Concha Limestone of the Empire Mountains

Sample Number	Total Number of Conodonts per 500-g Sample	<i>Neostreptognathoid</i> -to- <i>anchignathoid</i> Ratio	<i>Neostreptognathodus</i> sp. A	<i>Anchignathodus</i> sp. C	<i>Anchignathodus</i> sp. F	<i>Neospathodus arcuicristatus</i> Clark & Behnken	<i>Neospathodus</i> sp. A	<i>Roundya</i> sp. B	<i>Roundya</i> sp. D	<i>Lochodina mülleri</i> Tøtge	<i>Lochodina festiva</i> Bender & Stoppel	<i>Lochodina triassica</i> Müller	<i>Hindcodella triassica</i> Müller	<i>Hindcodella nevadensis</i> Müller	<i>Hindcodella</i> cf. <i>H.</i> sp. C	? <i>Hindcodella baltica</i> Szaniawski	Indet. genus B	Indet. genus C	<i>Ellisonia</i> cf. <i>E. triassica</i> Müller	Hindcodellid fragments
73	5			4																
72	8	1:4	1	4									2							1
71	5			1																1
70	7			2																1
69	20	2:9	2	9						1										2
68	6			1									1							1
67	8	1:5	1	5									1							1
66	9			5			1						1							1
65	30			8					2				1							4
64	20			5							1					1				1
63	11			4													1			1
62	2			1													1			1
61	20	1:12	1	12																1
60	20	1:8	1	8									1							1
59	20	2:9	2	9				1	1								1	1		1
58	14	3:7	3	7			1							1						1
57	10	3:6	3	6																1
56	9			4																1
55	9	1:4	1	4					1	1							1			2
54	40	1:27	1	27						1										1
53	31	8:11	8	11		2				1										1
52	21	1:14	1	13						1							1			1
51	11	1:1	1	1		1		1												2
50	6			1									1							1
49	10			1				1												1
48	25			1				1	1											2
47	11			1				2				1							2	1
46	4	1:1	1	1									?							
45	8	2:2	2	2									?							
44	7	1:1	1	1																
43	5		1											1			3			
42	5			2														1		
41	1			1																
40	1																			1
39	5														1					
38	5			1							1						1			
37	6			2											1		1			

Figure 12. Neospathodus, Hindeodella, Anchignathodus, and Roundya of the Concha Limestone, Empire Mountains

All magnification X60, except (9) which is X150.

- 1-5 Hindeodella nevadensis Müller. All lateral views; 1, UA-2648; 2, UA-2649; 3, UA-2650; 4, UA-2651; 5, UA-2652.
- 6 Neospathodus sp. A. Lateral view, UA-2669.
- 7,8 Indet. genus C. 7, Oral view, UA-2686; 8, lateral view of (7).
- 9 Neospathodus arcucristatus Clark and Behnken. Lateral view, UA-2670.
- 10 Anchignathodus sp. F. Lateral view, UA-2666.
- 11 Roundya sp. A. Lateral view, UA-2680.
- 12-21 Anchignathodus sp. C. All lateral views, excepted as noted; 12, UA-2637; 13, UA-2638; 14, UA-2639; 15, UA-2640; 16, UA-2641; 17, UA-2642; 18, UA-2643; 19, oral view, UA-2644; 20, UA-2645; 21, UA-2667.
- 22,23 Anchignathodus sp. D. Both lateral views; 22, UA-2646; 23, UA-2647.
- 24-26 Roundya sp. D. All lateral views; 24, UA-2681; 25, UA-2682; 26, UA-2683.
- 27-31 Roundya sp. B. 27, Oral anterior view, UA-2673; 28, posterior view, UA-2674; 29, oral anterior view, UA-2675; 30, oblique oral view, UA-2676; 31, aboral posterior view, UA-2677.



Figure 12. Neospathodus, Hindeodella, Anchignathodus, and Roundya of the Concha Limestone, Empire Mountains

Figure 13. Lonchodina, Neostreptognathodus, Hindeodella, Ellisonia, and ?Hibbardella of the Concha Limestone, Empire Mountains

All magnifications X60, except (2) and (14) which are X150.

- 1 Lonchodina muelleri Tatge. Inner lateral view, UA-2631.
- 2,3 Hindeodella triassica Müller. 2, Posterior end of UA-2685;
3, lateral view of same specimen.
- 4,5 Neostreptognathodus sp. A. Both lateral views; 4, UA-2633;
5, UA-2634.
- 6,7 Lonchodina triassica Müller. Both lateral views; 6, UA-2664;
7, UA-2665.
- 8 ?Lonchodina triassica Müller. Lateral view, UA-2672.
- 9 Indet. genus. UA-2660.
- 10-12 Indet. genus B. 10, UA-2653; 11, UA-2654; 12, UA-2655.
- 13-15 Indet. genera. All lateral views; 13, UA-2661; 14, UA-2662;
15, UA-2663.
- 16 Hindeodella cf. H. sp. c. Lateral view, UA-2656.
- 17,18 ?Lonchodina sp. Both lateral views; 17, UA-2658; 18, UA-
2659.
- 19 Lonchodina muelleri Tatge. Inner lateral view, UA-2632.
- 20 Neostreptognathodus sulcopicatus (Youngquist, Hawley, and
Miller). Oblique oral view, UA-2628.
- 21 Neostreptognathodus sp. A. Oral view, UA-2635.
- 22,23 Lonchodina festiva Bender and Stoppel. Both interior lateral
views; 22, UA-2629; 23, UA-2630.
- 24 ?Hibbardella baltica Szaniawski. Lateral view, UA-2678.
- 25 Ellisonia cf. E. triassica Müller. Posterior view, UA-2679.



Figure 13. Lonchodina, Neostreptognathodus, Hindeodella, Ellisonia, and ?Hibbardella of the Concha Limestone, Empire Mountains

that this boundary is in the Concha Limestone and is in the lower part between samples 13 and 19 (table 5).

Sample 12 is the highest stratigraphic occurrence of Neostreptognathodus sulcopicatus, which, according to Clark and Behnken (1970, fig. 4), marks the Leonard-Guadalupe time-stratigraphic boundary. Roundya sp. A, and less importantly Lonchodina muelleri, also characterize the upper Leonard. But about 45 feet above the highest occurrence of Neostreptognathodus sulcopicatus are conodonts that are only found in rocks of Guadalupe or younger age. These diagnostic post-Leonard conodonts include Lonchodina festiva, Xaniognathodus tortilis, and Neospathodus arcucristatus. Amid several longer ranging conodonts, seven other taxa found in association with the three diagnostic ones are Neospathodus sp. A, Hindeodella nevadensis, Lonchodina triassica, ?Hibbardella baltica, Roundya sp. A, Roundya sp. D, and Anchignathodus sp. F. Thus, the present author suggests that the best approximation of the Leonard-Guadalupe boundary in the Concha Limestone of the Empire Mountains is between 80 and 125 feet above the base of the formation. This transition interval in the Empire Mountains is represented by conspicuously cherty (15 to 25 percent) biomicrite that topographically forms the sharp bench at the top of Total Wreck Ridge.

The most numerically abundant group of conodonts, the anchignathodid group, which comprises 46 percent of the total assemblage, occurs in over 80 percent of all Concha samples and is equally represented in both the lower and upper parts. However, only 18 percent of the second most abundant group of conodonts, the neostreptognathodids, which comprises 25 percent of the total assemblage, occurs in the upper

part. The lower part contains the remaining 82 percent of the neostreptognathodids. Conclusively, the stratigraphic distribution of the neostreptognathodids in the Middle Permian must be a reflection of environmental conditions and not entirely of evolutionary changes. The above relationship strongly implies that both form-genera groups, the anchignathodids and the neostreptognathodids, were not part of the same biological genus. Fifteen percent of the Concha assemblage is made up of hindeodellids, and all other conodonts make up 14 percent. It is this 14 percent that is the most useful for biostratigraphic purposes. Such forms as neospathodids, lonchodinids, and species of Roundya (or hindeodellids to some paleontologists) are the most important components of the concurrent range zone in the Concha Limestone. The anchignathodids are the least important forms based upon their present refinement.

In 1961, Bryant and McClymonds (p. 1330) tentatively assigned the reference section of the Concha Limestone in the Mustang Mountains of northeastern Santa Cruz County, Arizona, to a Leonard and Guadalupe (?) age. Ross and Tyrrell (1965, p. 621) have noted that the same formation in the Whetstone Mountains about 8 miles north-northeast of the Mustang Mountains contains Parafusulina boesei and P. sullivanensis about 450 feet above its base. They further noted that the same fusulinids occur in the lower and middle parts of the Word Formation of West Texas. But other than conodonts, P. empirensis Sabins and Ross (1963, p. 326) is the only identifiable time-sensitive fossil known to exist in the Concha Limestone in the Empire Mountains. P. empirensis is considered to be of early Word age, according to Sabins and Ross (1963, p. 364), because the gigantism which these Concha specimens display

in the microspheric form is most common in strata younger than Leonard. In the Empire Mountains *P. empirensis* occurs about 40 to 45 feet below the Concha-Rainvalley contact (Butler, 1969, p. 115). Time-stratigraphically, it occurs not in beds of early Word age but in beds of early late Word age. This age is based on the time correlation of local range zones of the Concha conodonts to concurrent range zones depicted in table 1.

Intuitive reasoning dictates that the Concha Limestone in the Empire Mountains would be younger than in the Whetstone Mountains because the Concha sea was time-transgressive and its sediments would become younger to the north-northwest. Thus, Ross and Tyrrell (1965) are probably correct in their early-to-middle Word interpretation for the age of the Concha Limestone in the Whetstone Mountains. Six fusulinid horizons, all of the genus *Parafusulina*, were found in the Concha Limestone by Zeller (1965, p. 54) in the Big Hatchet Mountains of southeastern Hidalgo County, New Mexico. Although none of the fusulinids were identifiable to species level, the collection was judged to be from strata of middle to late(?) Leonard age. If this interpretation is correct, it definitely establishes the time-transgressive nature of the Concha Limestone--the fusulinids at least being of middle to late(?) Leonard age in Hidalgo County, early to middle Word age in west-central Cochise County, and early late Word age in southeastern Pima County. A line in cross section, representing a distance of 145 miles from the Big Hatchet Mountains to the Empire Mountains, that connects the stratigraphic position of these fusulinid horizons, would probably mark the maximum inland invasion by the Concha sea.

In conclusion, 650 conodonts, including fragments, were extracted from 73 of the 500-gram samples taken from the Concha Limestone. Every successive 6-foot interval of the 500-foot-thick formation yielded some conodont material. Other microfossils most commonly found with these conodonts were very small gastropods, tetraxon sponge spicules, fish teeth, echinoid spines and plates, and crinoid columnals. In addition to the previously mentioned diagnostic conodonts, the conodont assemblage from the Concha differs from those of the older Permian formations in consisting of proportionately more numerous bar types of large and laterally compressed shape. For the lower part of the Concha, the overall ratio of platform-to-blade types is almost 1:1 (131:151 or 65:75), which is identical to that of the Rainvalley Formation. For the upper part, this ratio is 1:5 (29:146) and is much smaller than for the lower part. Finally, the age of the Concha strata at Total Wreck Ridge is late Leonard to early late Word.

Rainvalley Formation Conodonts

Based on conodont evidence (figs. 14-16), the lower and upper parts of the Rainvalley Formation in the Empire Mountains of Pima County, Arizona (fig. 1, location 3), is of Word and early Capitan age, respectively. The time-stratigraphic boundary between samples 94 and 95 (table 7) is somewhat arbitrary, but because there are at least three diagnostic Capitan species in the upper two-thirds of the formation, this upper portion is here considered to be equivalent to the lower Capitan strata of West Texas.

Important elements included in these Capitan species are Roundya sp. C, Neospathodus arcucristatus and Neospathodus cf. N.

Figure 14. Bar-type Conodonts from the Rainvalley Formation,
Empire Mountains

All magnifications X60

- 1-4 Indet. genus A. All lateral views of possible hindeodellid anterior limbs; 1, UA-2603; 2, UA-2604; 3, UA-2605; 4, UA-2606.
- 5 Xaniognathus tortilis (Tatge). Lateral view of twisted anterior limb in late growth stage, UA-2607. Insufficient material to describe adequately.
- 6-10 Indet. genera. All lateral views; 6, UA-2608; 7, UA-2609; UA-2610; 9, UA-2611; 10, UA-2612.
- 11,12 Hindeodella triassica Müller. Both lateral views; 11, UA-2613; 12, UA-2614.
- 13 Hindeodella sp. Lateral view, UA-2615.
- 14 ?Hindeodella sp. Lateral view, UA-2616.
- 15 Hindeodella nevadensis Müller. Interior lateral aboral view, UA-2617.
- 16 Indet. genus. Lateral view, UA-2618.
- 17 ?Lonchodina sp. Lateral view, UA-2619.
- 18 ?Hindeodella sp. C. Lateral view, UA-2620.
- 19,20 Hindeodella nevadensis Müller. Both lateral views; 19, UA-2621; 20, UA-2622.
- 21 Lonchodina inflata Bender and Stoppel. Outer lateral view of juvenile, UA-2623.
- 22 Prioniodina sp. of Clark and Behnken. Anterior aboral view, UA-2624.
- 23 Lonchodina festiva Bender and Stoppel. Lateral view (note regenerated apex of cusp), UA-2625.
- 24 Lonchodina inflata Bender and Stoppel. Inner lateral view, UA-2626.
- 25 ?Lonchodina sp. Lateral view, UA-2627.



Figure 14. Bar-type Conodonts from the Rainvalley Formation, Empire Mountains

Figure 15. Blade and Platform Conodonts from the Rainvalley Formation, Empire Mountains

All magnifications X60, except (15), which is X150.

- 1-5 Neospathodus arcucristatus Clark and Behnken. All lateral views; 1, UA-2565; 2, UA-2566; 3, UA-2567; 4, UA-2568; 5, UA-2627.
- 6 Neospathodus cf. N. divergens (Bender and Stoppel). Lateral view of uncoated specimen, UA-2569.
- 7,8 Neospathodus sp. A. 7, Inner lateral view, UA-2570; 8, outer lateral view, UA-2571.
- 9-11 Anchignathodus sp. D. All lateral views; 9, UA-2572; 10, UA-2573; 11, UA-2574.
- 12-14 ?Anchignathodus sp. A. All lateral views of broken specimens; 12, UA-2575; 13, UA-2576; 14, UA-2577.
- 15 Xaniognathus tortilis (Tatge). Lateral view of juvenile, UA-2578.
- 16 Cratognathodus sp. Lateral view, UA-2579.
- 17-20 Anchignathodus sp. C. All lateral views; 17, UA-2580; 18, UA-2581; 19, UA-2582; 20, UA-2583.
- 21,22 Anchignathodus sp. A. 21, Inner lateral view, UA-2584; 22, oral view of (21).
- 23-29 Anchignathodus sp. C. All lateral views; 23, UA-2585; 24, UA-2586; 25, UA-2587; 26, UA-2588; 27, UA-2589; 28, UA-2590; 29, UA-2591.
- 30 Anchignathodus sp. E. Lateral view, UA-2592.
- 31-42 Neostreptognathodus sp. A. 31, Oral view, UA-2593; 32, oblique aboral view of (31); 33, oral view, late growth stage, UA-2594; 34, lateral view, UA-2595; 35, oblique aboral view, UA-2596; 36, lateral view, UA-2597; 37, oral view, UA-2598; 38, aboral view of (37); 39, oral view, UA-2599; 40, oral view, UA-2600; 41, oral view, UA-2601; 42, oblique oral view, UA-2602.



Figure 15. Blade and Platform Conodonts from the Rainvalley Formation, Empire Mountains

Figure 16. Conodonts from the Rainvalley Formation, Empire Mountains

All magnifications X60, except (36), (39), and (40) which are X150.

- 1,2 Diplododella sp. 1, Oral view, UA-2531; 3, lateral view of (1).
- 3 ?Apatognathus sp. Lateral view, UA-2532.
- 4-13 Neostreptognathodus sp. A. 4, Lateral view, UA-2533; 5, aboral view of mature individual, UA-2534; 6, oral view of (5); 7, oral view, UA-2535; 8, oral view, UA-2536; 9, lateral view of (8); 10, oral view, UA-2537; 11, oral view of juvenile, UA-2538; 12, oral view, UA-2539; 13, oral view, UA-2540.
- 14 ?Neostreptognathodus sp. A. Lateral view, UA-2541.
- 15 Anchignathodus aff. A. minutus (Ellison). Lateral view, UA-2542.
- 16,17 Anchignathodus cf. A. isarcicus (Huckriede). 16, Oral view, UA-2543; 17, lateral view of (16).
- 18 Anchignathodus aff. A. isarcicus (Huckriede). Lateral view, UA-2544.
- 19,20 Roundya sp. C. 19, Lateral view, UA-2545; 20, oblique aboral view, UA-2546.
- 21-32 Neostreptognathodus sp. A. 21, Oral view, UA-2547; 22, lateral view, UA-2548; 23, oral view, UA-2549; 24, oblique aboral view of (23); 25, oral view, UA-2550; 26, oral view, UA-2551; 27, oral view of juvenile, UA-2552; 28, oral view of juvenile, UA-2553; 29, oblique oral view, UA-2554; 30, lateral view of (29); 31, oblique aboral view, UA-2555; 32, lateral view, UA-2556.
- 33 Hindeodella sp. C. Inner lateral view, UA-2557.
- 34 Ellisonia cf. E. triassica Müller. Lateral aboral view of anterior processes, UA-2558.
- 35 Neospathodus sp. B. Lateral view, UA-2559.
- 36 Hindeodella triassica Müller. Posterior lateral view, UA-2560.
- 37 Hindeodella nevadensis Müller. Interior lateral view (note regenerated apex of cusp), UA-2561.
- 38 Indet. genus. Lateral view, UA-2562.
- 39 ?Neospathodus sp. Lateral view, UA-2563.
- 40 Anchignathodus sp. Lateral posterior view of broken specimen, UA-2564.

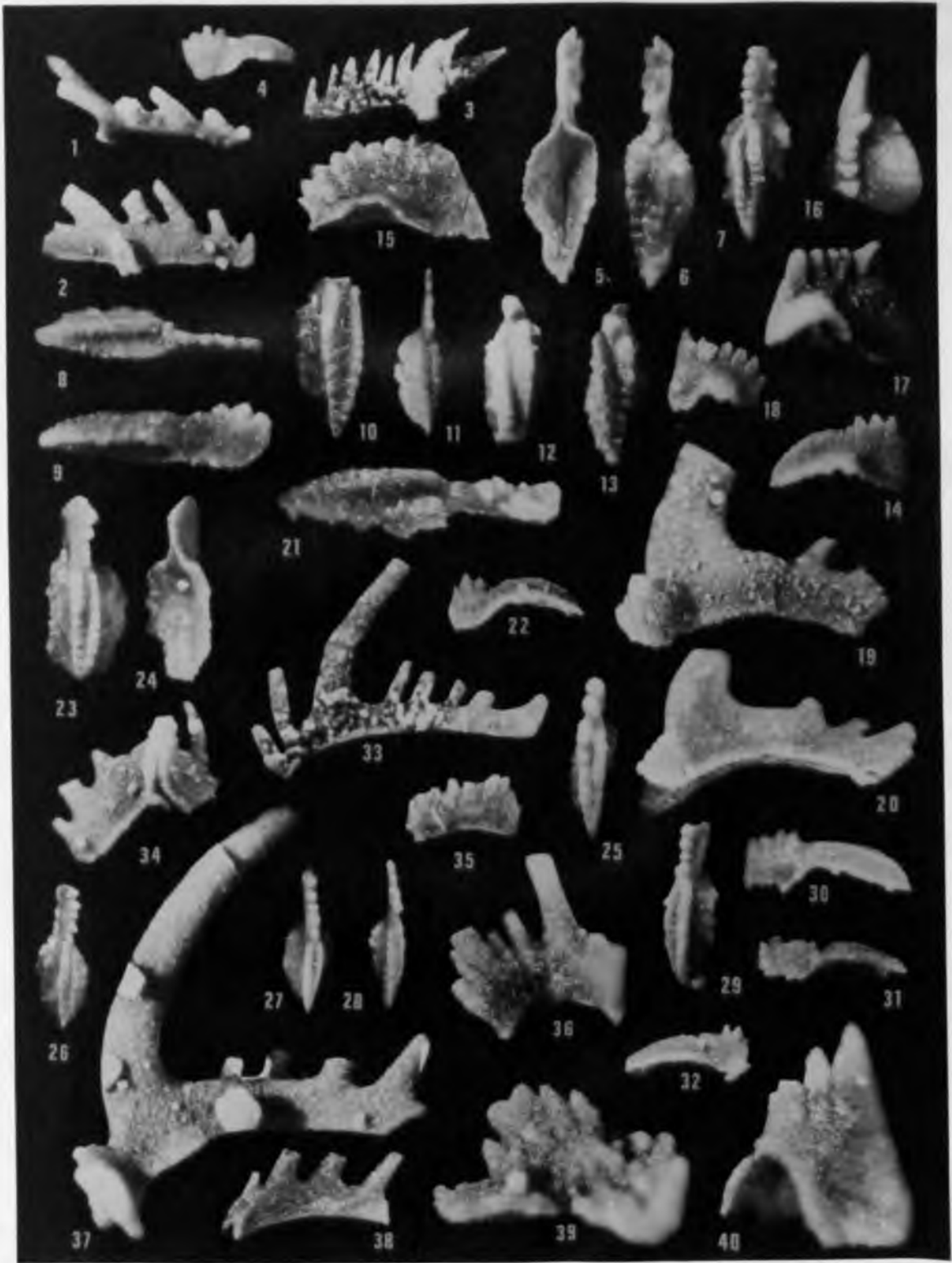


Figure 16. Conodonts from the Rainvalley Formation, Empire Mountains

Table 7. Distribution and Abundance of Conodonts in the Rainvalley Formation of the Empire Mountains--Continued

Sample Number	Total Number of Conodonts per 500-g Sample	Neostreptognathodus-to-anchignathodus Ratio	?Apatognathus sp.	Diploiodella sp.	Roundy3 sp. C	Anchignathodus cf. A. isarcicus (Huckriede)	Anchignathodus aff. A. minutus (Ellison)	Anchignathodus sp. A	Anchignathodus sp. C	Anchignathodus sp. D	Anchignathodus sp. E	Neospathodus eucristatus Clark & Behnken	Neospathodus cf. N. divergens (Bender & Stoppel)	Neospathodus sp. A	Neospathodus sp. B	?Neospathodus sp.	Neostreptognathodus sp. A	Xanognathus fortillis (Fratge)	Lochodina festiva Bender & Stoppel	Lochodina inflata Bender & Stoppel	?Lochodina sp.	Cratognathodus sp.	Ellisonia cf. E. triassica Müller	Hindodella triassica Müller	Hindodella nevadensis Müller	Hindodella sp. C	Prionofina sp. of Clark and Behnken	Indet. genus A	Hindodellid Fragments	
100	1																1													
99	14	3:4				?1		2				1					3							?1	1			1	3	
98	10	5:1															2				1								4	
97	10	3:1						1				1					3					1		1	1				2	
96	20	8:2						2				1					6													
95	7	2:1			1			1									2													
94	30	6:6				1		5				?1					6	?1						1	1				5	
93	20	6:2						2								1	6						1					2		
92	12							1														1							6	
91	13							1	1					1				1						?1					7	
90	5							2																					2	
89	6						1	3											1										1	
88	10							1													1			1	3		1		3	
87	0																													
86	0																													
85	0																													
84	0																													
83	6							1																					4	
82	6																										1		3	
81	3																													
80	0																													
79	12	5:2						2									5	1											2	
78	20	8:5						3									8								2				4	
77	5							1						1															1	
76	5	2:1								1																				
75	4																2							1	?1					
74	5					1		1		1											1		1						2	

divergens. Clark and Behnken (1970, fig. 4) have used N. arcucristatus and N. divergens to establish biostratigraphic zones for the Guadalupe Stage. The highest occurrence of the former and the lowest occurrence of the latter define the lower beds of the Capitan strata in the absence of the species Gondolella rosenkrantzi. Previous to this study, the only reported species of Roundya in the Permian System have come from the Zechstein I rocks of Poland and Germany, which have been equated to Capitan rocks of the United States.

In the field, the faunal boundary between the Word and Capitan is about 100 to 120 feet stratigraphically above the top of the Concha Limestone or about 35 to 40 feet stratigraphically below the lowest clastic bed that crops out near the middle of the Rainvalley Formation.

The age of the Rainvalley Formation has been a difficult problem to resolve because no fusulinids have ever been reported in the formation. Except for the nautiloid cephalopods of indeterminate generic assignment, the macrofauna of the Rainvalley Formation (Bryant and McClymonds, 1961, p. 1333) is a benthonic assemblage that consists of mostly long-ranging species and genera. McKee (1967, p. 215, 221, and table 1) and Tyrrell (1957, p. 91) judged that there was not sufficient evidence to assign the Rainvalley Formation to the Guadalupe Stage. However, Bryant (1955, p. 8, 9; 1968, p. 42), Bryant and McClymonds (1961, p. 1333), and Ross and Tyrrell (1965, p. 619) have all believed that because of the stratigraphic position of these strata, the beds were possibly younger than late Leonard. The conodonts from the Rainvalley beds validate the Guadalupe interpretation and dismiss the late Leonard age preferred by McKee.

Lonchodina festiva, present in the lowest third of the Rainvalley Formation and in part of the subjacent Concha Limestone, delimits these rocks as being of Word equivalent. Anchignathodus sp. E, Prioniodina sp. of Clark and Behnken, Xaniognathus tortilis, Cratognathodus sp., and Anchignathodus sp. D are also confined to the upper Word substage in the lower part of the Rainvalley Formation (samples 74-94, table 7).

In the lower Capitan faunal assemblage (samples 95-133, table 7), Hindeodella sp. C and Neospathodus cf. N. isarcicus were found associated with the three important Capitan species. Other species noted in table 7, such as Lonchodina inflata and Hindeodella nevadensis, further substantiate the idea that the Rainvalley rocks are indeed of Guadalupe age. The latter two species, both present in the middle part of the Rainvalley Formation, were identified by Clark and Behnken (1970, p. 428, 432) as accessory constituents in the Gondolella rosenkrantzi Assemblage Zone of early Capitan age from miogeosynclinal rocks of Nevada.

An interesting relationship of paleoecological significance has emerged from the Rainvalley study. First, while the genus Neostreptognathodus is the second most numerically abundant group of conodonts in the Guadalupe collection of this study, in the several published reports of Guadalupe faunas, this fossil group has not been noted. Clark and Behnken (1970, p. 427) concluded that Leonard and younger pre-Guadalupe strata in the western United States are characterized by Streptognathodus sulcopicatus Youngquist, Hawley, and Miller. This is now brought to Neostreptognathodus sulcopicatus (Youngquist,

Hawley, and Miller) because post-crisis streptognathodids are known to be homeomorphic with the pre-crisis streptognathodids (Clark, 1972b, p. 155, table 1 and fig. 10).

Second, because neostreptognathodids commonly occur in the Rainvalley Formation of Guadalupe age, the Pedregosa Basin apparently remained a shallow-water sanctuary for conodonts from Early through early Middle Permian time. A previous conclusion of this study, drawn from an examination of the Colina Limestone conodonts, has intended to demonstrate that some conodonts were depth stratified and flourished only in shallow water. The following test was devised to determine if the hypothesis is really tenable that neostreptognathodids inhabited shallow waters in preference to relatively deeper water. The ratio of genus Neostreptognathodus individuals to genus Anchignathodus individuals was calculated for most of the conodont-bearing units. If the upper Rainvalley beds do reflect a shoaling environment (Butler, 1971, p. 85), the ratio should become larger higher in the Rainvalley Formation. Because the anchignathodids show a ubiquitous distribution in the Permian, they were used as a control group. As can be seen in tables 5-7, of the 31 ratios calculated for the deeper water Concha Limestone (samples 12 through 72), 30 have values of 1:1 or smaller. However, in the overlying beds that represent the shoaling environment of the Rainvalley Formation, 10 of the 11 ratios are 1:1 or larger. This relationship supports the proposed paleoecological hypothesis for neostreptognathodids.

Medium-dark-gray to grayish-black recrystallized limestones in a low-grade metamorphic environment would not normally be selected

by conodont workers as good rock to process with the expectation of its yielding conodonts. Near the completion of this study, the author had the opportunity to examine a core containing this type of limestone from a hole drilled by The Anaconda Company near their Twin Buttes pit south of Tucson, Arizona. In addition to the large amount of tremolite, wolastonite and diopside(?) in all four core samples processed, surprisingly well-preserved conodonts (fig. 2, in part) were found in three of the 400- to 600-gram samples. The conodonts were in abundances of 3 to 12 per sample. The four recrystallized limestones were picked as showing the least alteration within a 100-foot stratigraphic section that contained no ghosts of macrofossils. The conservative anchignathodids were not diagnostic, but one specimen of Hindeodella sp. C enabled the author to assign tentatively one core sample to lower Capitan strata based upon the faunal assemblage recognized in the Rainvalley Formation of the Empire Mountains.

In summary, 38 percent of the Rainvalley assemblage consists of hindeodellids, 29 percent of the assemblage is neostreptognathodids, 17 percent is anchignathodids, and 6 percent is neospathodids. Gondolellids, a deep-water or mid-continent provincial group was not encountered in the Rainvalley sediments. The overall ratio of platform-to-blade elements is slightly less than 1:1 (65:75). More of the conodonts collected for this study show an affinity to Triassic conodonts than to Pennsylvanian conodonts. In the Empire Mountains samples, conodonts are rare or absent between the lowest and highest clastic beds and from the 30-foot interval just above the highest clastic bed. The relative abundance of the genus Neostreptognathodus is greatest in sediments

deposited in shallow water; thus, this nearshore genus was environmentally controlled. In the past, most geologists working in southern Arizona have presumed that the Rainvalley Formation is of Guadalupe(?) age by its stratigraphic position. Now it can be assigned with certainty to the Guadalupe Stage on the basis of the conodont assemblage which it contains. Lastly, the recognition that conodonts can survive low-grade metamorphism, where macrofossils cannot, could be a new tool for exploration geologists.

APPENDIX

SYSTEMATIC PALEONTOLOGY OF PERMIAN CONODONTS OF SOUTHEASTERN ARIZONA

The morphological terminology after Lindström (1964) was used in the systematic descriptions. In this terminology, the cusp always projects posteriorly and the blade of a platform conodont is always the anterior end. A few terms--but no orientation conventions--were borrowed from Fay (1952) and Hass (1962). All figured hypotypes (UA-2401 to UA-2685), including all conodonts described, are in the repository of the Department of Geosciences, The University of Arizona, Tucson, Arizona.

Order Conodontophorida
Genus Adetognathus Lane, 1967
Adetognathus lautus? (Gunnell, 1933)
 Figure 11, no. 34

Cavusgnathus lautus Gunnell, 1933, p. 286, pl. 31, figs. 67, 68.
Adetognathus lauta (Gunnell). Lane, 1967, p. 933, pl. 121, figs. 1-5,
 10, 11, 14, 15, 17, 18; Reid, 1968, p. 118, fig. 20, nos. 9-16;
 Micklin, 1969, fig. 17, nos. 2, 3, 12, 13; Dunn, 1970, p. 327,
 pl. 61, figs. 1, 4.

Remarks.--Distinct aboral crease between inner and outer platform "plates"; aboral surface broad and nearly flat; a left-sided specimen with the free blade missing from the left anterior margin; deep median sulcus; parapet on inner side with about 9 ribs; poor preservation prohibits a confident assignment to A. lautus. This species is known from strata of Morrow through early Wolfcamp age; it occurs in the basal bed of the middle member of the Scherrer Formation in the Empire Mountains.

Material Studied and Repository.--1 specimen; figured hypotype UA-2428.

Genus Anchignathodus Sweet, 1970
Anchignathodus minutus (Ellison, 1941)
 Figure 5, nos. 23, 24; Figure 7, no. 35

Spathodus minutus Ellison, 1941, p. 120, pl. 20, figs. 50-52.
Spathognathodus minutus (Ellison). Ellison and Graves, 1941, p. 3;
 Reid, 1968, p. 167, fig. 25, nos. 22-24; Micklin, 1969, p. 190,
 fig. 21, nos. 4, 5.
Anchignathodus minutus (Ellison). Sweet, 1970, p. 221.

Description.--Juvenile, very small, height of unit equals length of basal cavity; mature individual more elongate; a small diagnostic denticle anterior of cusp; 5-6 denticles posterior of cusp in juvenile forms and 7-8 denticles in mature forms; ontogenetically, denticles may become larger posteriorly as in some older form; in the mature specimen

the posteriormost denticles become inclined posteriorly; leaf-shaped basal cavity in aboral view only moderately deep but extending to both ends; anterior end of cavity narrowly tapers to a point under anterior denticle; greatest depth and flaring of cavity near mid length; denticles three-quarters of height of unit and either vertical or gently inclined posteriorly; except for apices, denticles fused downward to top of basal cavity; cusp only slightly larger than largest of other denticles.

Discussion.--Not confused with others if anterior portion of specimen intact; this species is a spathognathodid that survived the conodont crisis. The reader is referred to Clark (1972b) or Sweet (1970) for a discussion of taxonomy presently being considered for post-crisis elements. The specimen from the Rainvalley Formation is undoubtedly a transition form between the Wolfcamp occurrences and Anchignathodus typicalis Sweet of the Permian-Triassic boundary.

Occurrence.--A long-ranging species previously reported from Chester strata through middle Wolfcamp strata; occurs in the upper half of the Colina Limestone in the type area, in sample 3 of the Epitaph Dolomite in the Empire Mountains, and possibly in the basal bed of the Rainvalley Formation.

Material Studied and Repository.--5 specimens; figured hypotypes UA-2477, UA-2478, UA-2542.

Anchignathodus cf. A. isarcicus (Huckriede, 1958)
Figure 16, nos. 16, 17

Spathognathodus isarcica Huckriede, 1958, p. 162, 167, pl. 10,
figs. 6, 7.

Anchignathodus isarcicus (Huckriede). Sweet, 1970, p. 223, pl. 1,
figs. 18, 19.

Remarks.--This specimen undoubtedly belongs to the anchignathodid group and it has been referred to A. cf. A. isarcicus strictly because it exhibits an exceptionally capacious, cuplike, and broadly flaring basal cavity; the unit is left-sided and the apron is better developed on the inner side; the basal cavity is more tightly up arched than in other anchignathodids. Sweet (1970, p. 224) suggested that this species is the Triassic descendant of the upper Permian-lower Triassic species A. typicalis.

Occurrence, Material Studied, and Repository.--One specimen from sample 95 and one possible occurrence from sample 99, both of the Rainvalley Formation in the Empire Mountains; figured hypotype UA-2543.

Anchignathodus sp. A
Figure 7, nos. 31-33; Figure 15, nos. 21, 22

Description.--Ambidextrous element evenly bowed but not significantly arched; basal cavity subtriangular in aboral outline, very diagnostic; cavity extends only from posterior tip of unit to one-half to one-third of the distance to anterior end; cavity is also deep and anterior end descends at nearly a 90-degree angle; posterior end descent is less steep; outer apron of basal cavity widely flared at midlength; aboral-anterior part of blade very thin and extends anteriorly without showing germ denticles; strong anterior cusp; unit with about 7-9 stubby

denticles with rounded apices; posteriormost denticles noticeably larger but not higher; denticles of midsection are equal in height.

Discussion.--Unit is possibly a post-crisis homeomorph of Spathognathodus cristulus. This species is similar to S. cristulus but it has a deeper basal cavity and a more rounded apex of the cusp.

Occurrence.--Upper Wolfcamp strata from the basal beds of the upper member of the Epitaph Dolomite and lower Guadalupe strata from the basal bed of the Rainvalley Formation; both occurrences from the Empire Mountains.

Material Studied and Repository.--3 whole conodonts and 3 fragments; figured specimens UA-2521, UA-2522, UA-2584.

Anchignathodus sp. B
Figure 7, no. 36

Description.--Basal cavity extends the entire length of unit; in lateral view, apron of basal cavity descends aborally by equal amounts both in an anterior and a posterior direction; maximum flaring and arching of unit is slightly anterior of midlength where the upflaring of the apron is also most conspicuous; cusp strong; about 6 denticles nearly fused to apices.

Discussion.--The shorter and more arched blade separates this species from A. sp. A; denticles on A. sp. B descend gradually posteriorly, and the denticle tops are not of equal height, as in A. sp. A; this species is possibly an homeomorph of the pre-crisis Spathognathodus cristulus.

Occurrence.--Upper Wolfcamp strata from the basal beds of the Epitaph Dolomite, Empire Mountains.

Material Studied and Repository.--1 specimen; figured specimen UA-2525.

Anchignathodus sp. C
Figure 2, no. 2; Figure 12, nos. 12-21;
Figure 15, nos. 17-20, 23-29

Remarks.--A collection of highly variable ambidextrous forms that have all been assembled into Achignathodus sp. C primarily on the basis of their stratigraphic distribution from the Concha and Rainvalley formations. Thus, they have little time-stratigraphic value at present. Nearly every specimen would represent a different species if the same criteria that is used in the differentiation of other groups were applied to these anchignathodids. With the collection at hand, there seems to be no consistent scheme for their morphological classification. The basal cavity of this group varies from that of being nearly circular in aboral outline and symmetrical in transverse section and extending under the cusp to that of being asymmetrically subtriangular and not extending to the anterior end; the number of denticles varies from 5 to 10. Anchignathodus sp. D differs in having a subsquare shape to the basal cavity in aboral view and in being a slightly smaller form in general.

Occurrence.--Ubiquitous in the writer's collection of the Concha and Rainvalley formations of late Leonard to early and middle Guadalupe age.

Material Studied and Repository.--338 specimens; figured specimens UA-2580 to UA-2583, UA-2585 to UA-2591, UA-2637 to UA-2645, UA-2667.

Anchignathodus sp. D
Figure 12, nos. 22, 23; Figure 15, nos. 9-11

Remarks.--(See remarks under Anchignathodus sp. C.) Based on 5 specimens, this is a small-to-moderate size unit, not unlike other Permian anchignathodids; it has a subsquare (4-point diamond to irregular ellipsoid shape) basal cavity outline in aboral view which distinguishes it; the depth of the basal cavity is reduced by equal amounts in both a posterior and anterior direction from the deepest part which is in the center; the cavity does not reach the anterior end but terminates one-third the unit distance from that end; 5-7 denticles excluding the cusp.

Occurrence.--Samples 74, 76, and 91 of the Rainvalley Formation and samples 35 and 37 of the Concha Limestone in the Empire Mountains.

Material Studied and Repository.--5 specimens; figures specimens UA-2572 to UA-2574, UA-2646, UA-2647.

Anchignathodus sp. E
Figure 15, no. 30

Remarks.--Unit with 10 denticles, all nearly vertical and spade-shaped outline in oral view; cusp either absent or subtle groove in cusp may make cusp appear to be two fused denticles; basal cavity deep and asymmetrical in lateral view because the anterior end descends more abruptly in an anterior direction at midlength of blade than the posterior end descends posteriorly; basal cavity extends to both ends of unit but only as a short groove under the anterior end; apron of the cavity is broad and slopes gently posteriorly; the apparent lack of a cusp, the

extensive apron, and the shape of the basal cavity in longitudinal section distinguishes this species.

Occurrence.--Sample 74 of the basal bed of the Rainvalley Formation, Empire Mountains.

Material Studied and Repository.--1 specimen; figured specimen UA-2892.

Anchignathodus sp. F
Figure 12, no. 10

Remarks.--Right-sided blade element with 8 denticles and 1 anterior cusp that points anteriorly; 4 posteriormost denticles reclined posteriorly, others are nearly vertical; cusp has elliptical outline in cross section; unique, prominent, and thin aboral-anterior extension of blade; basal cavity moderately deep; deepest and widest flaring part of nearly symmetrical basal cavity posterior of midlength; denticles of equal height and size, except posteriormost one or two are shorter; cusp 1.5 times the diameter of denticles; cusp of this species different from all other anchignathodids in that it points anteriorly as in the neospathodid group; apron extends horizontally to both sides and has a slightly raised lip around its perimeter. This species could be a progenitor of the neospathodids.

Occurrence.--Upper part of the Concha Limestone in beds of Word age from the Empire Mountains.

Material Studied and Repository.--2 specimens; figured specimen UA-2666.

Genus Cratognathodus Mosher, 1968

Cratognathodus sp.

Figure 4, no. 31; Figure 7, no. 14;

Figure 15, no. 16

Description.--Unit with a large, spike-shaped, laterally compressed main denticle and a diagnostic laterally curved posterior bar; posterior bar laterally compressed near cusp and it may be curved slightly to strongly downward as well as laterally; anterior process very short, directed downward, and composed of 2-4 posteriorly pointing fused denticles; in plan, the curved posterior bar makes an angle of 60° - 90° with the anterior bar; aboral margin of anterior bar widens toward main denticle and becomes the brim of the small basal cavity; aboral edge of unit sharp and not grooved; denticles on posterior bar gradually become rounded in a lateral direction; main denticle thickened at base but basal cavity not widely flaring.

Discussion.--Most similar to Cratognathodus sp. B (Mosher, 1968, p. 919, pl. 113, fig. 12) in that the posterior bar is twisted laterally and the anterior bar is short. In following the convention that the cusp points toward the posterior, the orientations anterior and posterior are reversed from those used by Mosher (1968). This species most closely resembles the prioniodinids from which the genus Cratognathodus was erected. However, the specimens assigned to Cratognathodus sp. cannot be brought to genus Prioniodina which has straight processes.

Occurrence.--Previously found in the middle Triassic strata of Europe. The specimens described herein are from the Naco Formation at locality number 2, the basal beds of the Epitaph Dolomite of late Wolfcamp age, and from the lower part of the Rainvalley Formation of late Word age. The latter two occurrences are from the Empire Mountains.

Material Studied and Repository.--5 specimens; figured specimens UA-2506, UA-2579.

Genus Cypridodella Mosher, 1968
Cypridodella sp. A
 Figure 5, no. 17

Description.--A small and delicate, slightly bowed bar that arches gracefully in a downward direction; cusp situated at greatest curvature of bar which is also the posterior end; cusp is perpendicular to bar and projects posteriorly and somewhat laterally; specimen has discrete and sharply pointed denticles of nearly equal size that are recurved upward making an angle of 30 degrees to the bar; all denticles are on the anterior bar; posterior bar nearly absent; cusp projects parallel to axis of anterior bar; no basal cavity and aboral margin bevelled.

Discussion.--Although in his definition of Cypridodella, Mosher (1968, p. 920) noted that the curvature of the cusp is such as to make the long bar posterior, several of his illustrations show the long bar may be anterior in some species such as the specimen described herein as Cypridodella sp. A. The genus was erected by Mosher to encompass several similar Triassic forms, including genera of Lonchodina and Pri-
oniodina. Lonchodina vistulensis was erected by Szaniawski in 1969 (p. 331, pl 1, figs. 1-4) but is probably conspecific with some of the cypridodellids. Cypridodella sp. A is also similar to some of the taxa included under the multi-element genus Ellisonia. (See Sweet, 1970, p. 224 for a discussion.)

Occurrence.--Mosher considered Cypridodella to range from the Permian throughout the Triassic. This specimen is from sample 10 of Wolfcamp age from the Colina Limestone.

Material Studied and Repository.--1 specimen; figured specimen UA-2472.

Genus Diplododella Bassler, 1925

Diplododella sp.

Figure 16, nos. 1, 2

Description.--A nearly bilaterally symmetrical bar unit; unit not arched and anterior end only slightly bowed; the laterally compressed bar bifurcates posteriorly; denticles become smaller and shorter anteriorly and are inclined posteriorly; cusp at juncture of two posterior limbs; anterior limb with 5 denticles; the one Empire Mountains specimen is broken which prohibits counting the number of denticles on the posterior limbs; basal surface with narrow groove under all processes.

Discussion.--The location of the largest denticle (cusp) and the posteriorly forked bar distinguishes this specimen from all others. The upper Paleozoic and Triassic forms seem to differ considerably from the middle Paleozoic forms. This Permian specimen is not arched, and the denticles are not closely set as in its older and younger counterparts. The inclination of the denticles may not be consistent with other diplododellids, but nonetheless this specimen closely resembles Diplododella sp. A of Mosher (1968, p. 924, pl. 113, figs. 28, 29). Lindström (1964, p. 147, 176) believed that genus Diplododella is synonymous with the genus Roundya.

Occurrence.--Sample 128 of the uppermost Rainvalley Formation. According to Hass (1962, p. W50), the genus Diplododella occurs in the late Devonian. However, it has been found in rocks as young as late Triassic (Mosher, 1968, p. 923-925).

Material Studied and Repository.--1 specimen; figured specimen UA-2531.

Genus Ellisonia Müller, 1956
Ellisonia cf. E. triassica Müller, 1956
 Figure 13, no. 25; Figure 16, no. 34

Ellisonia triassica Müller, 1956a, p. 822, pl. 96, figs. 12-14.

Remarks.--Although Lindström (1964, p. 147) has considered Ellisonia to be conspecific with Roundya Hass, 1953, enough distinction exists to warrant separation. Only the anterior portion of specimens of this species are intact; nevertheless, these specimens compare favorably with Müller's descriptions because both have large, bilaterally symmetrical, denticulated, anterolateral processes that intersect at an angle of 130 degrees; the difference between the Permian and Triassic forms is that the Permian forms have a narrow but deep basal cavity that extends under both anterolateral processes and the posterior process. The development of an inverted basal cavity by early Triassic time must have been a significant phylogenetic trend in many Permian bar-type conodonts, such as genus Ellisonia. In one specimen the two anterior processes form an S-shape in oral view--the end of one being curved posteriorly and the end of the other curved anteriorly; pit at intersection of the three processes is small, round, and deep; bilaterally symmetrical limbs with 6 denticles, the outer 2 being very small; the 6 denticles are curved inward and the outer 3 are reclined nearly to horizontality. Roundya sp. C and sp. D have much smaller anterolateral processes and Roundya sp. B is not bilaterally symmetrical. The anterolateral processes of Roundya sp. A intersect at a 30-degree angle--a much smaller

angle than in this species. Sweet (1970, p. 235) has erected a multi-element species by the same name, E. triassica, which includes the form-genus E. triassica.

Occurrence.--This species has been only found from rocks of Word age from parts of the Concha and Rainvalley formations in the Empire Mountains. Elsewhere, Clark and Behnken (1970, p. 428) noted E. triassica in the Gerster Formation of Nevada which they judged to be of Capitan age. Müller's collection of E. triassica was from the lower Triassic beds of Nevada.

Material Studied and Repository.--7 specimens; figured hypotypes UA-2558, UA-2679.

Genus Gnathodus Pander, 1856

Gnathodus sp.

Figure 7, nos. 16-18

Description.--Platform typically arched, particularly at posterior end; long axis straight or slightly bowed; basal cavity broad, flaring, shallow, and elongate; a prominent medial carina, somewhat narrow, with about 13 nodes; apron of cavity slightly depressed aborally near carina; in lateral view, posterior apron of basal cavity descends, while in oral view it tapers toward platform axis at a 30-degree angle; posteriormost nodes may be larger than anterior ones; blade broken from all specimens examined.

Discussion.--Young individuals of Gnathodus sp. easily confused with Spathognathodus whitei; however, nodes on G. sp. are smaller, not laterally enlarged, and more numerous; also, apron of G. sp. is much wider and nodes of carina are not connected by median longitudinal

ridge; this species differs from all spathognathodids in being more elongate, and the short numerous nodes gives Gnathodus sp. the appearance of a platform rather than a blade; sweetognathids have a characteristic split carina, even in the juveniles, and have fewer nodes on the carina. Gnathodus is not a good utilitarian generic assignment for the specimens described here, but neither is Spathognathodus. The described taxon and the spathognathodids probably occupied equivalent positions in the apparatus; however, enough difference is evident between them to remove Gnathodus sp. from the spathognathodids. Clark (1972b, table 1) considered the genus Gnathodus to be included in the genus Anchignathodus.

Occurrence.--Basal beds of the upper member of the Epitaph Dolomite in the Empire Mountains.

Material Studied and Repository.--5 specimens; figure specimens UA-2508 to UA-2510.

Genus Hindeodella Bassler, 1925

Hindeodella nevadensis Müller, 1956

Figure 12, nos. 1-5; Figure 14, nos. 15, 19, 20;
Figure 16, no. 37

Hindeodella nevadensis Müller, 1956a, p. 826, pl. 96, figs. 2, 3.

[?] Hindeodella triassica Müller. Bender and Stoppel, 1965, p. 343, pl. 14, fig. 12, pl. 15, figs. 1-5.

Hindeodella nevadensis Müller. Mosher, 1968, p. 925, pl. 114, fig. 24; Sweet, 1970, p. 237, pl. 5, figs. 9, 21, 22; Clark and Behnken, 1970, p. 432, pl. 2, fig. 13.

Remarks.--Several of the Empire Mountains specimens conform remarkably to the description of the early Triassic type species, except for the presence of the basal cavity on the Permian specimens. This basal cavity extends from end to end; it is slightly flared and is deepest

under the cusp. The larger size of the primary denticles and of the anterior bar, in addition to the fewer number of denticles on the anterior bar, distinguish this species from H. triassica. The latter is more laterally compressed, and it does not have the deep basal cavity that Permian species of H. nevadensis exhibit. The anterior bar of H. nevadensis is quite variable, and this species, as described here, encompasses all those hindeodellids with strong and sparsely denticulated limbs directed in an anterior, anterolateral, or anteroaboral direction. The posterior bar of H. triassica is long relative to the size of the small and closely spaced denticles on it.

Occurrence.--Mosher (1968, p. 928) reported the range of this species to be from Scythic to lower Anisic in both Europe and North America. Sweet (1970) identified it from the upper Permian of Pakistan, and Clark and Behnken (1970) identified it in rocks of early Capitan age in Nevada. The Empire Mountains specimens are from strata of early Word through early Capitan age from parts of the Concha and Rainvalley formations.

Material Studied and Repository.--17 specimens; figured hypotypes UA-2617, UA-2621, UA-2622, UA-2561, UA-2648 to UA-2652.

Hindeodella triassica Müller, 1956
Figure 13, nos. 2, 3; Figure 14, nos. 11, 12;
Figure 16, no. 36

Hindeodella triassica Müller, 1956a, p. 826, pl. 96, figs. 4, 5; Hirschmann, 1959, p. 56, pl. 4, figs 13-16; [?] Bender and Stoppel, 1965, p. 343, pl. 14, fig. 12, pl 15, figs. 1-5; Mosher, 1968, p. 929, pl. 114, fig. 22; Szaniawski, 1969, p. 329, pl. 1, figs. 9-11; [non] Sweet, 1970, p. 237, pl. 5, figs. 9, 21, 22.

Remarks.--The posterior bar of this species is smaller but proportionately longer than in H. nevadensis and not arched as much.

the posterior bar of H. triassica contains more denticles which are partially fused, but distinct to base of bar; and is more laterally compressed than in either H. nevadensis or H. sp. c: the anterolateral process may be incurved posteriorly if long enough; cusp only slightly larger than largest of other denticles and cannot be confused with the stout cusp of H. nevadensis; H. sp. of Szaniawski and H. sp. A both have a better developed basal cavity than the younger Empire Mountains forms; denticles on posterior bar become more inclined posteriorly in a posterior direction.

Occurrence.--From strata of Word age from parts of the Concha and Rainvalley formations in the Empire Mountains; also in upper Permian through lower Triassic strata from Europe, Pakistan, and Nevada.

Material Studied and Repository.--23 specimens, many of which are incomplete; figured specimens UA-2560, UA-2613, UA-2614, UA-2685.

Hindeodella sp. of Szaniawski
Figure 5, nos. 36-41

Indet. genus Bender and Stoppel, 1965, p. 353, pl. 16, fig. 10
Hindeodella sp. Szaniawski, 1969, p. 330, pl. 1, fig. 8

Description.--V-shaped aboral groove under entire bar unit and wider under cusp than rest of bar; arcuate cusp inclined posteriorly; cusp is proportionately large and oval in cross section which differentiates this species from H. triassica; posterior bar diagnostically bell-shaped in transverse section; first two denticles posterior of cusp are small, but third is enlarged; anterior process is gently curved but not

downward as in some specimens of H. nevadensis; bar slightly arched and bowed; sharp aboral margins.

Discussion.--Nearly identical to description of Szaniawski's (1969), except basal cavity of Colina specimens not flared laterally quite as much. This species also resembles H. nevadensis (and probably evolved into the latter), but not enough Colina specimens were collected to warrant the assignment. H. triassica is more laterally compressed than this species and does not have the characteristic basal groove.

Occurrence.--Szaniawski collected his specimens from the Zechstein 1 of Poland. Collected from the Colina Limestone of late Wolfcamp and early Leonard age in the Tombstone Hills.

Material Studied and Repository.--9 specimens; figured specimens UA-2490 to UA-2494.

Hindeodella sp. A
Figure 5, nos. 31-35

Description.--A thinly compressed bar that is laterally bowed; cusp is flattened oval in cross section near base but becomes more oval toward apex; cusp gracefully curved toward the posterior; degree of cusp curvature varies and in some specimens the oral end of cusp may nearly parallel the posterior bar; aboral side with very narrow deep slit that widens slightly to a shallow V-shaped groove under the cusp; slit extends under anterior process; scanning electron micrographs show that the slit extends nearly a third of the distance up to the oral margin of bar; anterior process more bladelike than barlike; aboral margins sharp; denticles small and closely spaced on posterior bar.

Discussion.--The curvature and size of the cusp are diagnostic. This species differs from H. sp. of Szaniawski in that the posterior bar is more flattened as seen in transverse section and not bell-shaped. The basal slit of this species cannot be confused with the expanded shallow trough under the cusp of H. sp. of Szaniawski. The multi-element species that might include this taxon is Ellisonia triassica Sweet, 1970.

Occurrence.--Occurs in the upper third of the Colina Limestone of early Leonard age in the Tombstone Hills.

Material Studied and Repository.--5 specimens; figured specimens UA-2485 to UA-2589.

Hindeodella sp. B
Figure 5, no. 26

Remarks.--A very thin denticulated bar probably not significantly arched; germ denticles on both anterior and posterior bars; anterior process slightly curved laterally; cusp moderately curved posteriorly; posterior bar broken on the only specimen collected; aboral edge sharp under anterior process; unit similar to H. triassica because in both species the bar and denticles are strongly laterally compressed; H. sp. B has a very small basal cavity beneath the cusp and not beyond, whereas H. triassica has no aboral opening in the Triassic forms; cusp is less curved than in H. sp. A and is more delicate and smaller in diameter than in H. sp. of Szaniawski; H. sp. A has a long narrow aboral slit, whereas H. sp. B does not.

Occurrence.--Base of the middle 160-foot zone in the Colina Limestone of the Tombstone Hills; strata are considered to be upper Wolfcamp.

Material Studied and Repository.--1 specimen; figured specimen UA-2480.

Hindeodella sp. C
Figure 2, no. 1; Figure 16, no. 33

Description.--A right-sided denticulated and laterally compressed bar with an incurved anterolateral denticulated process; main cusp moderately curved posteriorly; at least 5 primary denticles on arched posterior bar; cusp becomes more rounded in cross section toward apex; distinct aboral groove under entire unit is slightly wider beneath cusp; very slight lateral flaring of aboral margins; noncoalescing denticles on anterolateral process that project posteriorly and may be inclined anteriorly; 2 or 3 primary denticles on anterolateral process but secondary denticles may be present also.

Discussion.--Although obviously related to H. nevadensis, the denticles and cusp of H. nevadensis are stronger, and the anterior limb of the latter may be less inwardly and more downwardly curved; also, the denticles on the anterior limb of N. nevadensis may be fused to nearly their midheight. This species differs from H. triassica in that it has fewer primary and secondary denticles and the posterior bar is much shorter; H. sp. C is larger than H. triassica but smaller than H. nevadensis; H. sp. B is more compressed and H. sp. A has more posterior bar denticles than H. sp. C.

Occurrence.--Recovered from the upper half of the Rainvalley Formation of early Capitan age from the Empire Mountains and from a core sample near The Anaconda Company's Twin Buttes pit.

Material Studied and Repository.--5 specimens; figured specimens UA-2557 and figure 2, no. 1.

Genus Idiognathodus Gunnell, 1931
Idiognathodus cf. I. tersus Ellison, 1941
 Figure 11, nos. 25-28

Idiognathodus tersus Ellison, 1941, p. 134, pl. 23, figs. 5, 6.

Description.--Platform lanceolate in oral outline and distinctly thickened orally as seen in cross section; slight curvature of platform axis; basal cavity not deeply excavated and interior and exterior aprons only moderately flared; anterior end of basal cavity much less sharply pointed than posterior end; platform not ornamented except for about 9 transverse ridges and intervening narrow transverse depressions; a suggestion of nodes at interior margins of anteriormost ridges in one specimen; blade either flexed or straight with about 6 denticles that become larger and higher toward anterior end; key recognition features are the "corrugated" appearance to the platform and the abrupt medial attachment of the blade to the platform; carina is very short; aboral surface with crease at junction of inner and outer platform "plates".

Discussion.--The high blade and the lack of a deep sulcus on both sides of the carina differ from I. tersus; however, the other platform characteristics justify the close assignment to I. tersus. Disregarding the free blade, the platform superficially resembles that of Idiognathoides corrugatus (Harris and Hollingsworth) and Polygnathodella

sp. Harlton. I. tersus can be compared to I. ellisoni Clark and Behnken, except the former is wider and lacks lateral lobes.

Occurrence.--I. tersus is known from the middle Missouri to middle Virgil. This species was collected from the middle member of the Scherrer Formation in the Empire Mountains. Because the Scherrer Formation is of Leonard age, these specimens probably have been reworked.

Material Studied and Repository.--3 specimens; figured hypotypes UA-2422 to UA-2424.

Idiognathodus sp. A

Figure 7, nos. 38-41; Figure 11, nos. 29-32, 35-38

Description.--An aborally arched and ambidextrous platform; narrow lanceolate in oral outline; posterior end sharply pointed; platform axis straight to slightly bowed; 12-15 transverse ridges on platform extending from inner to outer margin; in mature individuals, anterior part of oral surface slightly depressed into a shallow sulcus at the point of junction with the fixed blade; adcarinal grooves not well developed; basal cavity of moderate depth and widest at midlength of unit; carina absent; 5-7 denticles on blade not higher than platform but do increase in height anteriorly; blade is median to platform; longitudinal crease on aboral surface where inner and outer platform plates join; upper platform margins enlarged so that they overhang the apron of the basal cavity.

Discussion.--The platform of this species differs from that of I. cf. I. tersus in being narrower, longer, more arched, more pointed, and having more transverse ridges. It differs from I. ellisoni in not possessing accessory lobes and in having a squared-off appearance at the "shoulders" (anterior margin) of the platform.

Occurrence.--From the upper member of the Epitaph Dolomite and the middle member of the Scherrer Formation, both in the Empire Mountains. These specimens have probably been reworked from rocks of Virgil or early Wolfcamp age.

Material Studied and Repository.--6 specimens; figured specimens UA-2425, UA-2426, UA-2429, UA-2526 to UA-2529.

Genus Lonchodina Bassler, 1925
Lonchodina festiva Bender and Stoppel, 1965
 Figure 13, nos. 22, 23; Figure 14, no. 23

Lonchodina festiva Bender and Stoppel, 1965, p. 345, pl. 15, figs. 9, 10; Clark and Behnken, 1970, p. 432, pl. 2, fig. 9.

Description.--An ambidextrous unit named for its graceful form; rounded cusp at apex of 90-degree up-arch is very large and directed posteriorly; posterior process, with 3-4 large denticles, is longer than anterior process with 3 small denticles; posterior denticles twice as high and twice the diameter of the anterior ones; denticles on the posterior process are reclined posteriorly and recurved toward the interior and anterior; the posteriormost denticle is nearly horizontal; posterior and anterior processes are pointed 45 degrees downward, but the posterior process is recurved upward at the end; triangular-shaped basal surface in aboral view is bipartite, each section separated by a deep narrow groove extending to each end of unit; the most diagnostic feature is the bulging flared lip of the inner basal margin; the aboral surface is open to the interior but not visible from the exterior lateral view.

Discussion.--This species was found on only two specimens which may be earlier growth stages than the excellent specimens recovered from the Concha and Rainvalley formations. In addition to its

limbs being short relative to cusp size, L. festiva is much larger than either L. inflata or L. muelleri (or Cypridodella muelleri Mosher). L. inflata and L. muelleri are more sharply arched and their anterior and posterior denticles are of nearly equal size.

Occurrence.--Throughout the Concha Limestone and in the lower third of the Rainvalley Formation, Empire Mountains; its stratigraphic range is restricted to the Guadalupe Stage but is most common in the Word substage which helps to define the Word equivalent strata in the Empire Mountains.

Material Studied and Repository.--6 specimens; figured hypotypes UA-2625, UA-2629, UA-2630.

Lonchodina inflata Bender and Stoppel, 1965
Figure 14, nos. 21, 24

Lonchodina inflata Bender and Stoppel, 1965, p. 346, pl. 15, figs. 8, 11, pl. 16, figs. 18, 24; Clark and Behnken, 1970, p. 432, pl. 2, fig. 3.

Remarks.--The specimen in figure 13, no. 24 somewhat resembles Cypridodella muelleri (Tatge, 1956), but it has been assembled into L. inflata because the inner prominent bulge at the base of the large central cusp and the tightly arched unit suggests an affinity closer to genus Lonchodina. (See Mosher, 1968, p. 921, pl. 113, figs. 15 non 16.) This species is like L. muelleri, but the latter has fewer denticles and the cusp is less curved posteriorly; L. inflata possesses more denticles on its two processes than does L. festiva and is totally much smaller; each limb has 6 fused but discrete denticles of varying size that are curved toward the cusp and also slightly to the interior; basal groove indistinct, if present.

Occurrence.--Rainvally Formation in the Empire Mountains, previously found by Bender and Stoppel in the Zechstein I strata of Germany and by Clark and Behnken in the lower part of the Gerster Formation in Nevada of middle Guadalupe age.

Material Studied and Repository.--4 specimens; figured hypotypes UA-2623, UA-2626.

Lonchodina muelleri Tatge, 1956
Figure 13, nos. 1, 19

Lonchodina mülleri Tatge, 1956, p. 133, pl. 5, fig. 15. [fide Huckreide, 1958, p. 151-152, pl 10, figs. 9, 16, 17, pl. 11, figs. 8, 9, pl. 12, figs. 28, 29, pl. 14, figs. 9, 33, 36]; [?] Hirschmann, 1959, p. 61-62, pl. 5, figs. 18, 19; Clark and Ethington, 1962, p. 110, pl. 1, fig. 4; Bender and Stoppel, 1965, p. 347, pl. 15, fig. 12 (non 13, 14).

Cypridodella muelleri (Tatge), Mosher, 1968, p. 921, pl. 113, fig. 15 (non 16).

Remarks.--Small unit with characteristic lateral extension of inner basal margin under large cusp; cusp reclining to the interior and posterior; narrow aboral groove extends from anterior to posterior ends; fewer or less well-developed denticles than Lonchodina inflata and entire unit much smaller than L. festiva; centrally located cusp, recurved less than in L. inflata; narrow anterior-to-posterior groove under laterally expanded basal surface, which may not be present in L. inflata; angle of intersection of anterior and posterior limbs 90 degrees or less, whereas same angle in lateral view may be obtuse in L. festiva; a clear distinction between Permian specimens of L. muelleri and L. inflata may be more apparent than real.

Occurrence.--Concha Limestone of late Leonard to late Word age in the Empire Mountains; others have reported it from upper Leonard to Upper Triassic strata.

Material Studied and Repository.--11 specimens; figured hypotypes UA-2631, UA-2632.

Lonchodina triassica Müller, 1956
Figure 13, nos. 6, 7

Lonchodina triassica Müller, 1956a, p. 828, pl. 96, fig. 10; Sweet, 1970, p. 237, pl. 5, fig. 1.

Remarks.--Stout bar with 8 large noncoalescing denticles reclined and curved to the posterior; bar compressed and flexed laterally into a subtle S-shape in oral view; unit only very slightly arched; denticles of nearly equal size but may be larger posteriorly; basal groove narrow, deep, and extending to each end; unit may have a lateral enlargement perpendicular to bar near the posterior end; bar compressed laterally less than most Permian hindeodellids; cannot be confused with hindeodellids or other lonchodinids because it lacks well-defined anterior and posterior processes separated by a main denticle; other Permian lonchodinids are also tightly arched; phylogenetically, this species loses its basal groove by the Triassic to develop an inverted one.

Occurrence.--Beds of early and middle Word age in the Concha Limestone of the Empire Mountains.

Material Studied and Repository.--4 specimens; figured hypotypes UA-2664, UA-2665.

Lonchodina sp. A
Figure 5, no. 25

Remarks.--An asymmetrical unit with 2 denticulated, down-curved, anterolateral processes; cusp gently incurvate posteriorly; processes meet at 90 degrees; very small but distinct basal cavity

stretching from end of one process to the other; end of interior process curved posteriorly. The similarity is close to elements of the multi-element species Ellisonia gradata Sweet (1970, p. 229, pl. 4, figs. 1-8). Clark (1972b, p. 156) has stated that although E. gradata is present in the upper Wolfcamp rocks, it has never been definitely documented. In addition to a reduced posterior bar, the Traissic prioniodinids (Mosher, 1968, p. 934-935) have smaller basal cavities (if any) than the several lonchodinids which Mosher has considered synonymous with the prioniodinids. Within limits, the Colina specimen compares to specimens described by Hirschmann (1959, p. 61, pl. 5, figs. 18-21) as L. muelleri Tatge. However, although L. muelleri has been reported from strata of Leonard age in the present study and in others, the basal surface is smaller than in L. muelleri.

Occurrence.--Sample 26 of the Colina Limestone from the Tombstone Hills.

Material Studied and Repository.--1 specimen; figured specimen UA-2479.

Lonchodina sp. B
Figure 7, no. 42

Remarks.--A moderately arched, laterally compressed, and slightly bowed denticulated bar of stout character; central cusp equally as wide as bar is high and about 1 1/2 to 2 times the width of the other denticles; denticles large and noncoalescing; posterior bar denticles possibly recurved toward the posterior-projecting cusp; V-shaped basal cavity of consistent width extends entire length of unit; cavity

moderately deep but deeper under cusp; aboral margins sharp; according to the multi-element classification, this species would be included in the genus Ellisonia.

Occurrence.--Upper member of the Epitaph Dolomite, Empire Mountains.

Material Studied and Repository.--1 specimen; figured specimen UA-2530.

Genus Neospathodus Mosher, 1968
Neospathodus arcucristatus Clark and Behnken, 1970
 Figure 12, no. 9; Figure 15, nos. 1-5

Neospathodus arcucristatus Clark and Behnken, 1970, p. 436, pl. 2, figs. 1, 2, 5.

Description.--A small, usually straight, arched, and compressed blade characterized by 12 posteriorly inclined denticles; anteriormost denticles may be curved but posteriormost ones are straight; 2 large denticles located over the posterior third of unit; one specimen has 2 denticles posterior of the 2 main denticles and 8 denticles anterior to them, whereas three specimens have 4 posterior and 6 anterior denticles (excluding the 2 main ones); all other specimens have 3 posterior and 7 anterior denticles; unlike the holotype, the Empire Mountains specimens show a nearly complete fusion of the 2 main denticles which may be mistaken for only one large denticle; the smaller denticles are discrete from a third to a half of their height; basal cavity is most cuplike under binary cusps or slightly posterior to them. It extends from one extremity to the other and is very narrow except where cuplike.

Discussion.--According to Clark and Behnken, N. arcucristatus gave rise to N. divergens in the late Guadalupe by a reduction in the

number of denticles from 12 or more to 5 or 6, and by the modification of 2 cusps to 1 in N. divergens.

Occurrence.--This species rarely occurs in the upper two-thirds of the Concha Limestone of Word age; its more abundant occurrence in the middle and upper part of the Rainvalley Formation helps to define the latter strata as lower Capitan equivalent. Clark and Behnken (1970, p. 436) noted that it defined the fauna of the lower Guadalupe Plympton Formation in Nevada.

Material Studied and Repository.--11 specimens; figured hypotypes UA-2565 to UA-2568, UA-2627, UA-2670.

Neospathodus cf. N. divergens (Bender and Stoppel, 1965)
Figure 15, no. 6

Spathognathodus divergens Bender and Stoppel, 1965, pl. 16, figs. 1-3, 21; Szaniawski, 1969, p. 333, pl. 2, figs. 1-5.

Neospathodus divergens (Bender and Stoppel), Clark and Behnken, 1970, p. 436, pl. 2, fig. 6.

Description.--Basal cavity wide, nonflaring, relatively shallow (except for a deep pit directly under cusp), and under entire unit; proportional to the size of unit, the cavity is large; cavity is canoe-shaped in aboral outline except both ends slightly rounded; white matter restricted to upper half of unit where denticles become discrete; one stubby large main denticle, twice the size of the others, is projected posteriorly; 3 distinct denticles of equal height on posterior limb; in an anterior direction from the cusp there are 2 broad denticles followed by 3 to 4 small ones; unit is up-arched at a 120-degree angle.

Discussion.--This specimen, according to Clark (personal communication, 1972), is a transition species between N. arcucristatus and N. divergens. It possesses more denticles than the latter and less

denticles than the 12 of the former. Unit is wider than N. arcucristatus from the Empire Mountains.

Occurrence.--Sample 128 of the Rainvalley Formation; it defines the beds of early Capitan age in the Empire Mountains. The closest related species to the Rainvalley specimen is N. divergens which is stratigraphically restricted to beds of Capitan age, namely, the Zechstein 1 of Germany and Poland, the Gerster Formation of Nevada, and the Park City Formation of Wyoming.

Material Studied and Repository.--1 specimen; figured hypotype UA-2569.

Neospathodus sp. A

Figure 12, no. 6; Figure 15, nos. 7, 8

Remarks.--Although the anteriorly located cusp may not conform to criteria established for genus Neospathodus, the resemblance to other Permian neospathodids is positive. Unit is ambidextrous with about 10 denticles, including the cusp situated on the anterior half of the blade; unit very much like N. arcucristatus, except that in N. sp. A the anterior-posterior denticle relationship is reversed from that of the former; also, the cusp is singular and not double as in N. arcucristatus; the 2' or 3 anterior denticles are curved posteriorly as are the 6 or 7 posterior ones; basal cavity is posterior to cusp near midlength.

Occurrence.--Ranges throughout the strata of the Guadalupe age in the Concha and Rainvalley formations of the Empire Mountains.

Material Studied and Repository.--9 specimens; figured specimens UA-2570, UA-2571, UA-2669.

Neospathodus sp. B
Figure 7, no. 28; Figure 16, no. 35

Description.--A nearly straight blade with about 10 fused denticles of variable size; anterior process well developed; posterior process short; denticles may be discrete nearly to aboral edge; subtle but diagnostic flaring brim on basal edge; small basal cavity or minute groove beneath 3 posteriormost denticles; basal cavity, if present, rounded anteriorly but tapering posteriorly to a point; aboral-anterior end rounded and extended in an anterior direction.

Discussion.--Might be confused with the genus Ozarkodina, but posterior limb of the latter is better developed and neither limb of N. sp. B is deflected downward as much; also, the greater height-to-length ratio of this unit differs from that of Ozarkodina; furthermore, there is no conspicuous main denticle in N. sp. B; the basal cavity is too small to be that of a spathognathodid. The one Rainvalley specimen vaguely resembles N. microdus Mosher (1968, p. 31, pl. 115, figs. 3, 4, 8) because both have the two adjacent slightly enlarged denticles, a distinctive gentle arch, and a short anterior process.

Occurrence.--From sample 4 of the Epitaph Dolomite and from sample 78 of the Rainvalley Formation, Empire Mountains.

Material Studied and Repository.--3 specimens; figured specimens UA-2518, UA-2559.

Neospathodus sp. C
Figure 5, nos. 18, 30

Remarks.--An up-arched to straight blade with 6-8 or more variable denticles; denticles discrete and fused nearly to apices; denticles vertical to curved and inclined either anteriorly or posteriorly;

one specimen with enlarged posteriorly directed denticle; posterior process reduced, nonexistent, or broken off; unit characterized by lateral brim along aboral edge; the general morphology of this taxon is also similar to species of Ozarkodina described herein. These specimens do not have the distinctive limb of the ozarkodinids and do not have the characteristic canoe-shaped basal cavity of the Colina and Epitaph ozarkodinids. Because the amount of interspecific variation of Permian neospathodids is unclear, Neospathodus sp. may actually represent two species.

Occurrence.--Samples 26 and 27 of earliest Leonard age from the Colina Limestone in the Tombstone Hills. Stratigraphically, this is the lowest recognized occurrence for neospathodids (Sweet, 1970, p. 244).

Material Studied and Repository.--3 specimens; figured specimens UA-2473, UA-2484.

Genus Neostreptognathodus Clark, 1972
Neostreptognathodus sulcopicatus (Youngquist,
 Hawley, and Miller, 1951)
 Figure 13, no. 20

Streptognathodus sulcopicatus Youngquist, Hawley, and Miller, 1951, p. 363, pl. 54, figs. 7-9, 16, 17, 22-24; Clark and Ethington, 1962, p. 111, pl. 1, figs. 8, 9, 18; pl. 2, figs. 3, 4, 7; Bender and Stoppel, 1965, p. 352, pl. 16, figs. 5-7, 22; Clark and Behnken, 1970, p. 431, pl. 1, figs. 22, 23.

Neostreptognathodus sulcopicatus (Youngquist, Hawley, and Miller), Clark, 1972b, p. 155.

Description.--Straight to bowed ambidextrous platform unit slightly arched so that posterior tip is curved down about 30 degrees from long axis; platform lanceolate in oral outline; well-developed blade with at least 5 denticles that become higher anteriorly; blade

meets platform medially; split carina with 15-20 nodes in the mature individual; split carina forms a deep medial "V" anteriorly; posterior-most nodes on carina nearly coalescing to form transverse ridges; moderately deep basal cavity extends three-fifths of total unit length under the carinae but extends under blade as a narrow groove; widest flaring near midlength.

Discussion.--The high, well-developed, anterior ends of the inner and outer carinae are diagnostic. This species differs from Neostreptognathodus sp. A in being about twice the mature specimen size, in having a longer platform relative to the entire unit, and in having a better developed interior carina at the posterior end. Sweetognathodus is also similar to this species, but N. sulcopicatus does not have a bifurcating carina nor a blade that joins the platform without a break with the carinae. (See discussion under N. sp. A for taxonomic information.)

Occurrence.--Lowermost 60-70 feet of the Concha Limestone in the Empire Mountains and has been most commonly found in strata of early through late Leonard age in Greece, China, Idaho, Utah, Wyoming, New Mexico, and Nevada. This species is one of the few reliable indices to strata of Leonard age.

Material Studied and Repository.--4 specimens; figured hypotype UA-2628.

Neostreptognathodus sp. A
Figure 13, nos. 4, 5, 21; Figure 15, nos. 31-42;
Figure 16, nos. 4-13, 21-32

Description. An ambidextrous, slightly to moderately arched platform conodont with a deep lanceolate basal cavity; unit recognized

by the 4-to-7-denticle blade that joins the platform medially but is not joined to the double carina; split carina, consisting of usually 9-12 nodes, is better developed posteriorly with larger nodes; outer carina is diagnostically higher and better developed posteriorly than inner carina; both carinae may converge posteriorly at one large bulbous node; widest flaring of apron and strongest arching near midlength; second and third anteriormost denticles on blade are highest and largest, fused nearly to apices, and may be slightly curvate posteriorly; blade usually straight but is flexed at a 90-degree angle to long axis in rare specimens, the anterior end of basal cavity curves sharply at midlength of unit toward the long axis, then continues anteriorly as a narrow slit for about a third of the blade length.

Discussion.--This species represents a group that probably descended from species of Sweetognathodus and therefore the two may be confused. However, N. sp. A has a narrower carina with more nodes and the carina is not laterally expanded in mature specimens; the anterior ends of the carinae are distinct from the blade, whereas they are not distinct but rather continuous with the blade in species of Sweetognathodus; furthermore, the inner carina at the posterior end of N. sp. A may be more poorly developed than the outer one, and the basal cavity is more deeply excavated. Clark (1972b, p. 155) did not systematically describe genus Neostreptognathodus which he erected. However, he noted that because genus Streptognathodus did not survive the conodont crisis, the generic name Streptognathodus cannot apply to post-crisis conodonts. Previous to the present study, genus Neostreptognathodus was known only from a single species. Although Clark's rationale

deviates from the utilitarian classification, which categorizes on morphology and not on biological affinities--or lack thereof--the present author accepts Clark's taxonomic procedure.

Occurrence.--Throughout the Concha and Rainvalley formations of late Leonard through early Capitan age in the Empire Mountains.

Material Studied and Repository.--227 specimens; figured specimens UA-2533 to UA-2541, UA-2547 to UA-2556, UA-2593 to UA-2602, UA-2633 to UA-2635.

Genus Ozarkodina Branson and Mehl, 1933
Ozarkodina cf. O. delicatula (Stauffer and Plummer, 1932)
 Figure 11, nos. 11, 12

Bryantodus delicatulus Stauffer and Plummer, 1932, p. 29, pl. 2, fig. 27.
Ozarkodina delicatula (Stauffer and Plummer), Ellison, 1941, p. 120,
 pl. 20, figs. 40-42, 47.

Ozarkodina cf. O. delicatula (Stauffer and Plummer), Rhodes, 1963, p.
 408, pl. 47, figs. 12, 15.

Ozarkodina sp. A of Reid, 1968, p. 162, fig. 25, no. 13.

? Ozarkodina spatula Dunn, 1970, p. 338, pl. 62, figs. 27, 28
 (non 31).

Remarks.--Considering the poor-to-fair quality of preservation of only two specimens, this species compares favorably to the description of Ellison (1941) and the illustrations by Rhodes (1963).

Occurrence.--Samples 13 and 14 of the middle member of the Scherrer Formation, Empire Mountains. Webster (1970) reported its stratigraphic range in Nevada to be no younger than of late Desmoines age, and from late Morrow through the Pennsylvanian in the mid-continent region.

Material Studied and Repository.--2 specimens; figured hypotypes UA-2411, UA-2412.

Ozarkodina sp. A
Figure 5, nos. 19, 20, 27-29;
Figure 7, nos. 29, 30

Description.--Slightly bowed blade unit with 5 posterior and 7 anterior denticles; denticles laterally compressed; posterior limb shorter than anterior; basal cavity nearly symmetrical, canoe-shaped, deep, and typically expanded under apical denticle; ends of cavity extend nearly to ends of unit as very narrow, tapering slits; apical denticle gently curved posteriorly and is about 1 1/2 times the size of anterior denticles; denticles on posterior limb vary in height and thickness; in some specimens, the first denticle posterior to apical denticle is two-thirds as high of apical denticle and fused to it; in other specimens, the first denticle anterior to apical denticle is fused to apical denticle; several small coalescing denticles on anterior limb appear as a single large denticle; base of denticles more or less perpendicular to their respective blade axes.

Discussion.--Only two post-crisis but pre-Guadalupe species of Ozarkodina have been reported: O. abstractus (Clark and Ethington) and O. delicatulus (Stauffer and Plummer). The limbs of O. abstractus are more barlike than bladelike as in O. sp. A. Genus Ozarkodina is characterized by its sharp aboral edge; the Colina and Epitaph specimens possess a basal cavity that is more characteristic of the genus Subbryantodus Branson and Mehl, 1934.

Occurrence.--Upper Wolfcamp strata of both the Colina Limestone, Tombstone Hills, and the Epitaph Dolomite, Empire Mountains.

Material Studied and Repository.--14 specimens; figured specimens UA-2474, UA-2481-UA-2483, UA-2519, UA-2520.

Genus Roundya Hass, 1953Roundya sp. A

Figure 12, no. 11

Remarks.--Bilaterally symmetrical unit with large cusp directed posteriorly; posterior bar denticulated but broken in all specimens; two diagnostic anterolateral processes deflected downward; the latter processes intersect at about 30 degrees in oral view--an angle significantly different than in other species of Roundya described here; anterolateral processes consist of fused denticles, at least for most of their height, and are inclined outward about 30 degrees; narrow basal groove under all three processes.

Occurrence.--Collected from the basal 100 feet of the Concha Limestone in the Empire Mountains; strata are of late Leonard and (?) earliest Word age.

Material Studied and Repository.--7 specimens; figured specimen UA-2680.

Roundya sp. B

Figure 12, nos. 27-31

Remarks.--This species is distinguished by its long S-shaped anterolateral processes as viewed orally; S-shape may be slight to strong; each of two anterolateral processes has as many as 7 denticles and is slightly down-flexed; these denticles are almost circular in cross section and closely spaced but not touching; the two anterolateral processes vary in degree and direction of curvature from nearly straight lateral to recurved parallel to the posterior bar; one anterolateral process recurved anteriorly, the other recurved posteriorly; very deep and very narrow slit under all three processes and only slightly expanded

under cusp; cusp is vertical, centrally positioned between anterolateral processes, and not much larger than other denticles; this species cannot be confused with Roundya sp. A, C, or D, which do not have the long, asymmetrical, S-shaped processes; neither do they have the numerous and differentiated denticles on the anterolateral processes nor the tubular shaped denticles; the posterior process is either incomplete or it is noticeably short; basal groove narrower than in Roundya sp. A, C, or D.

Occurrence.--Upper half of the Concha Limestone in beds of middle Word age, Empire Mountains.

Material Studied and Repository.--6 specimens; figured specimens UA-2673 to UA-2677.

Roundya sp. C
Figure 16, nos. 19, 20

Description.--Unit with a large posteriorly curved cusp adjacent to two small denticulated anterolateral limbs; anterolateral limbs make an angle of 110 degrees with each other; denticles on these limbs, about 4, are fused but are discrete and become smaller outward; posterior bar, laterally compressed and arched, with at least 4 posteriorly inclined primary denticles; secondary denticles not observed; a broad U-shaped cavity under posterior bar that extends as a narrow slit under both laterally compressed, anterolateral limbs; basal cavity deepest and widest under anterior part of cusp.

Discussion.--Lindström (1964, p. 147) considered the following to be synonymous with genus Roundya: Ellisonia Müller, 1956; ? Diplododella Bassler, 1925; and ? Hibbardella Bassler, 1925. The Permian species of Roundya have a distinctively and longitudinally

persistent basal cavity and a large denticulated posterior bar to distinguish them from species of Hibbardella. Both specimens of Roundya sp. C have a posterior bar similar to that of Ellisonia triassica, but the anterior limbs of the latter are much larger. The Empire Mountains specimens most closely resemble the Permian species Roundya sp. A and Roundya sp. B, both of Bender and Stoppel (1965, p. 350, pl. 15, figs. 19, 20). Szaniawski (1969, p. 332) erected the species Hibbardella baltica and considered the two Roundya species to be conspecific with H. baltica. The posterior bar of Roundya sp. C is proportionately larger than that in the other species of Roundya described here.

Occurrence.--In samples 95 and 115 of the Rainvalley Formation in the Empire Mountains. In the Permian, species of Roundya have previously been reported only from the upper Guadalupe Stage in the Zechstein 1 of Germany. If Hibbardella baltica be conspecific with Roundya sp. A and Roundya sp. B of Bender and Stoppel, which it probably is not, then the genus Roundya is also known from the Zechstein 1 of Poland.

Material Studied and Repository.--2 specimens; figure specimens UA-2545, UA-2546.

Roundya sp. D
Figure 12, nos. 24-26

Remarks.--In general, a unit smaller than Roundya sp. A and C; posterior bar similar to that of Roundya sp. A, but the two anterolateral processes are smaller in the latter species and are directed more laterally than anteriorly; main posterior bar longer than in Roundya sp. B, and the anterolateral processes are much shorter and more symmetrical;

this species most closely resembles Roundya sp. C, but the cusp in Roundya sp. D is proportionately smaller in comparison to the size of the anterolateral processes; innermost denticle on each anteriolateral process is farther from the cusp than in Roundya sp. C.

Occurrence.--In the upper half of the Concha Limestone of middle Word age in the Empire Mountains.

Material Studied and Repository.--5 specimens; figured specimens UA-2681 to UA-2683.

Genus Spathognathodus Branson and Mehl, 1941
Spathognathodus cristulus Youngquist and Miller, 1949
 Figure 2, no. 3; Figure 11, nos. 20-24

Spathognathodus cristulus Youngquist and Miller, 1949, p. 621, pl. 101, figs. 1-3.

Spathognathodus cf. S. minutus (Ellison), Rhodes, 1963, p. 408, pl. 47, fig. 3.

Spathognathodus cristulus Youngquist and Miller, Reid, 1968, p. 166, fig. 25, nos. 20, 21; Micklin, 1969, p. 189, fig. 21, no. 11; Dunn, 1970, p. 339, pl. 64, fig. 30.

Description.--Ambidextrous blade moderately to strongly bowed with about 7-9 coalescing denticles that keep their originality well down into unit in specimens of late growth stage; blade slightly arched; denticle apices round; cusp pointed and from 1 1/2 to 2 1/2 times the width of other denticles; posterior denticles become slightly enlarged but not higher than anterior ones; basal cavity centrally located and descends anteriorly at about 45 degrees terminating under denticle next to cusp.

Discussion.--Because S. cristulus has no denticles anterior to the cusp, it cannot be confused with S. minutus.

Occurrence.--Previously noted from beds of late Mississippian through early Virgil age; occurs in samples 5 through 14 of the probably

reworked carbonate member of the Scherrer Formation in the Empire Mountains.

Material Studied and Repository.--5 specimens; figured hypotypes UA-2417 to UA-2421.

Spathognathodus whitei Rhodes, 1963
Figure 7, nos. 19-27; Figure 11, nos. 13-19

Spathognathodus whitei Rhodes, 1963, p. 404, pl. 47, figs. 4, 9, 10, 25, 26.

Description.--Asymmetric outline of the "platform"; basal cavity in the mature specimen is narrow lanceolate in oral outline; gerontic and juvenile forms may exhibit a more widely flared basal cavity than mature forms; apron laterally flared two-thirds of the platform distance from posterior end; relative to platform height, cavity is deeply excavated and pointed at each end; unit slightly arched and bowed; "denticles" on the platform are short; the massive blunted "carina" composed of discrete nodelike denticles that grow laterally into separate transverse ridges is diagnostic of this species; the latter growth leaves a characteristic narrow, low, longitudinal ridge where separation takes place; this longitudinal ridge connects the transverse ridges; transverse ridges with narrow intervening furrows; blade denticles on juveniles are not noticeably separate; apron may be smooth to somewhat bulbous or hummocky on oral interior side; carina, with 8-10 nodes in mature individual, becomes narrower anteriorly; free-blade denticles, about 3-5, rise higher than carina and are laterally enlarged as are the extreme posterior nodes; gerontic individuals show complete lateral separation of the entire carina and the transverse ridges all become separate nodes.

Discussion.--Young specimens of S. whitei may be confused Anchignathodus typicalis Sweet and S. cristulus because the denticles of S. whitei are relatively large and high relative to the overall platform size in the youthful ontogenetic stage; S. cristulus is shorter and more arched than S. whitei, and mature individuals of the former show no free blade; A. typicalis has prominent anterior cusp and no free blade and the denticles are higher and less stubby; the 2-to-3 fixed-blade denticles of S. whitei are narrower than denticles on the posterior end of the carina, whereas the denticles of A. typicalis do not show this relationship. D. L. Clark (personal communication, 1972) recommended that the genus Spathognathodus should only apply for pre-crisis conodonts. He preferred the newly erected genera Sweetognathus and Anchignathodus for post-crisis spathognathodids. Some specimens of S. whitei exhibit a symmetry transition with the Permian gnathodids.

Occurrence.--Clark and Behnken (1970, p. 424) reported this species from upper Wolfcamp beds in Nevada, and Rhodes (1963) collected it from the basal Tensleep Sandstone of Wyoming. Indigenous specimens occur in the upper carbonate member of the Epitaph Dolomite, and possibly reworked specimens were found at the base of the middle carbonate member in the Scherrer Formation; both latter formations crop out in the Empire Mountains.

Material Studied and Repository.--19 specimens; figured hypotypes UA-2413 to UA-2416; UA-2511 to UA-2517.

Spathognathodus sp. A
Figure 11, nos. 8-11

Description.--Unit bears 9-10 denticles that are fused but discrete, nearly equal in diameter, vertical, and progressively shorter posteriorly; cusp is anterior and 1 1/2 times the size of other denticles; maximum flaring and arching slightly anterior to midlength; basal cavity pointed at both ends--posterior end very narrow and anterior end deep and terminates just posterior to cusp; height-to-length ratio about 1:3.

Discussion.--Differs from S. spiculus Youngquist and Miller in that the latter has one tiny denticle anterior to cusp, a widely flaring and symmetrical basal cavity, and maximum flaring at midlength of the blade. S. cristulus does not have the denticle anterior to the cusp, and the blade of S. minutus consists of 12-15 small straight denticles with several small denticles anterior to cusp. Triassic species of Anchignathodus have a narrow aboral groove which extends nearly to anterior extremity of element, and the basal cavity of S. sp. A is more lanceolate in plan than the lachrymiform outline of Anchignathodus typicalis. The basal cavity of this species is similar to that of A. sp. A, except the latter has enlarged posteriormost denticles.

Occurrence.--Possibly reworked specimens from the basal 30 feet of the Scherrer carbonate member, Empire Mountains.

Material Studied and Repository.--5 specimens; figured specimens UA-2408 to UA-2410.

Spathognathodus sp. B
Figure 7, no. 34; Figure 11, no. 33

Remarks.--A small blade unit of which nearly one-fourth to one-third of the total length is cusp; cusp is anterior and stout; unit

arched with basal cavity lachrymiform in plan and which does not extend to posterior end; cavity small and deep; posterior end of cavity descends at 30 degrees and anterior end descends at 60 degrees; denticles compressed and discrete; posteriormost denticle inclined posteriorly. These specimens are significantly different from mature specimens of S. cristulus to warrant separation; however, they could be immature specimens of S. cristulus. Specimens differ from most other Permian spathognathodids in that the basal cavity does not extend to posterior end.

Occurrence.--From sample 1 of the Scherrer Formation and from sample 1 of the Epitaph Dolomite.

Material Studied and Repository.--2 specimens; figured specimens UA-2427, UA-2523.

Genus Sweetognathus Clark, 1972

Sweetognathus sp.

Figure 6, nos. 1-37; Figure 7, no. 13

Description.--A slightly arched ambidextrous platform unit that is lanceolate in plan; long axis bowed or straight, but more commonly bowed; asymmetrical basal cavity is widely flaring and shallow posteriorly but moderately deep anteriorly; longitudinally concentric growth rings on aboral surface around pit; curved or straight free blade bearing 5-7 erect denticles; denticles are higher than platform and differentiated almost to base of blade; denticles also laterally compressed, may be pointed, and discrete in upper third of height; apron of anterior end of basal cavity converges to form a tapering V-shaped groove under fixed blade and a narrow slit under free blade; the central longitudinal trough on the oral side is diagnostic on all specimens; bifurcating blade always

joins platform medially; ontogenetic changes are pronounced; in juveniles, the carina is very narrow, high, and with a barely perceptible medial trough and the top margins are sharp after separation occurs; nodes develop on split carina in mature individuals, and the carina becomes rounded--posteriorly first and anteriorly last--thus, mature individuals have greatest lateral separation of carina near posterior end; as a rule, the later the growth stage, the farther toward the anterior end the carina is split; average specimen bears 9 nodes; nodes become larger posteriorly; inner and outer carinae of gerontic individual become so widely separated and massive that they become inclined laterally.

Discussion.--May be confused with neostreptognathodids; the blade of Sweetognathus sp. splits into double carina upon joining the platform but the blade of the other group joins its platform as a short median carina and does not bifurcate.

Occurrence.--Abundant near the Wolfcamp-Leonard stage boundary in the Colina Limestone, Tombstone Hills; one rare occurrence in the upper Wolfcamp strata of the Epitaph Dolomite, Empire Mountains.

Material Studied and Repository.--58 specimens; figured hypotypes UA-2505, UA-2430 to UA-2455.

Genus Undefined A
Figure 7, nos. 1, 2

Description.--Asymmetrical palmatelike blade unit with main denticle centrally located and rising higher than other denticles; blade laterally bowed with anterior and posterior processes strongly down-curved and of equal length; 7 denticles on anterior process are nearly horizontal; posterior process bears 8-10 fused denticles; deep

subrectangular to rounded basal cavity beneath main denticle; cavity tapers to acute angle under posterior limb; posterior limb more compressed than anterior one.

Discussion.--Both anterior and posterior downcurved limbs distinguish this genus from Ozarkodina; basal cavity is much smaller than upper Paleozoic and Triassic species of Anchignathodus.

Occurrence.--Upper Wolfcamp stratum from the Epitaph Dolomite of the Empire Mountains.

Material Studied and Repository.--1 specimen; figured specimen UA-2495.

Genus Undefined B
Figure 7, nos. 3, 4

Description.--A strongly arched denticulated bar; all denticles and central cusp are gently curved posteriorly and are subcircular in cross section; rounded basal cavity in aboral view directly under cusp; unit gently bowed; about 8 denticles on posterior limb and about 5 on the anterior limb.

Discussion.--Main denticle slightly curves to the interior because the entire unit is bowed laterally; however, the limb orientation is considered as anteroposterior and not lateral. This specimen cannot be assigned to genus Synprioniodina because the cusp is central. The circular basal cavity and arching are unlike that of any other genus with Permian affinities.

Occurrence.--From sample 3 of the Epitaph Dolomite, Empire Mountains; this sample is interpreted to be of late Wolfcamp age.

Material Studied and Repository.--1 specimen; figured specimen UA-2496.

Genus Xaniognathus Sweet, 1970
Xaniognathus tortilis (Tatge, 1956)
 Figure 14, no. 5; Figure 15, no. 15

Ozarkodina tortilis Tatge, 1956, p. 138, pl. 5, figs. 9-11; Bender and Stoppel, 1965, p. 348, pl. 15, figs. 16, 17.

? Ozarkodina tortilis Tatge. Mosher and Clark, 1965, p. 563, pl. 66, fig. 11.

Ozarkodina tortilis Tatge. Mosher, 1968, p. 932, pl. 115, fig. 23; Clark and Behnken, 1970, p. 432, pl. 2, fig. 18.

[?] Xaniognathus elongatus Sweet, 1970, p. 266, pl. 3, fig. 19.
Xaniognathus tortilis (Tatge). Clark, 1972b, p. 155-156.

Remarks.--Only three specimens of this blade species have been recovered from the Concha and Rainvalley formations in the Empire Mountains. Although only fair in preservation and a great degree of variance ontogenetically in the size of the unit and the closeness of the denticles, it is the only ozarkodinid-like blade recovered from the Guadalupe strata of the Empire Mountains. The processes of this unit may be characteristically twisted. The preservation and number of specimens does not permit an in-depth description. This species ranges from the middle Permian through the Triassic.

Repository.--Figured hypotypes, UA-2607, UA-2578.

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