

A REVIEW OF THE PALEOZOIC FISH OF ARIZONA

by

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ABSTRACT

Arizona has many deposits containing Paleozoic fish remains. The fossil fish localities have been described and recorded. Collections of the Museum of Northern Arizona and the University of Arizona were supplemented in this study with the recollecting at the majority of the localities. Extensive collecting was undertaken at the Devonian East Verde River locality (Martin Limestone), Mississippian Dos Cabezas locality (Escabrosa Limestone) and Permian Bottomless Pit locality (Kaibab Limestone, Alpha Member). Material representing thirty-three genera is presented from the Arizona Paleozoic sequence of rocks. New species of fish described are: Janassa hussakofi, Dipterus bradyi, Petalodus milleri, Campodus arizonensis, Cladodus earli, and Diplodus reidi. One new genus and species is proposed, Papalstanus arizonensis.

INTRODUCTION

The Paleozoic stratigraphic sequences of Arizona contain an abundant and varied assemblage of fossil fish. In many localities fossil fish are the only fossils that may be used to determine the age of the strata in which they occur. The Paleozoic fossil fish are a very neglected group of vertebrates.

In 1962 H. W. Miller and W. Breed suggested that the available fish material collected by L. F. Brady, A. A. Stoyanow and R. R. Reid be consolidated and described in order to present a more complete record of Arizona's vertebrate paleontology.

The author soon discovered that the recording of localities as well as the describing of the fish material was in need of extensive treatment. Of the twenty-three localities described in this paper, only eight have been previously mentioned in any scientific publications. The Devonian, Mississippian and Permian are the only periods represented by the localities. Of the specimens described in this paper thirty-three genera and seven new species were added to the faunal list of Arizona. Extensive collecting and laboratory preparation was conducted at the Devonian East Verde locality, Mississippian Dos Cabezas locality and

Permian Bottomless Pit locality. The author feels that each of these three localities should receive more extensive study.

REVIEW OF PERTINENT LITERATURE

Fossil fish were first discovered in Arizona by W. D. Walcott in 1880 at Chuar Creek Valley in the Grand Canyon. The fragmental remains from the Devonian Temple Butte Limestone were described as plates of placogonoid fish and later identified by Gidley (Schuchert, 1918) as Bothriolepis and Holoptychius.

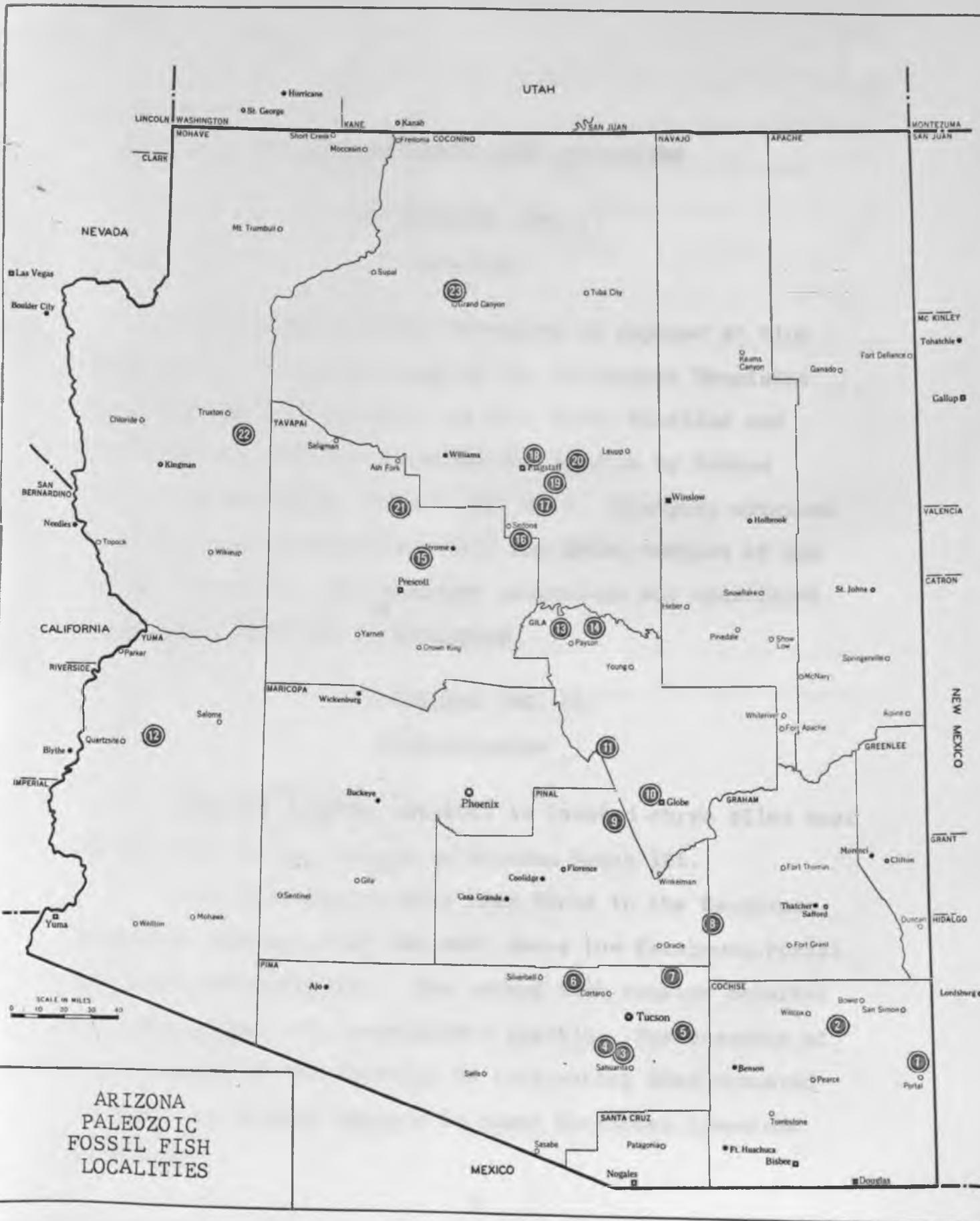
Reid (1928) in an unpublished Master of Science thesis correlated southern Arizona Devonian localities by means of fossil fish remains.

Stoyanow (1936), working with additional material that he had collected, used fish remains as a basis for state-wide correlation of Devonian rocks. He makes no use of the equally useful Mississippian and Permian fish fauna.

More recently Hussakof (1942) published a paper on some fish material collected by L. F. Brady at Mt. Elden. Hussakof mentions four genera and names two new species. Hussakof (1943) published an abstract concerning Permian fish from Arizona listing four genera.

David (1944) published a paper about a single Permian elasmobranch tooth. From this one very large and different tooth she named a new genus and species.

Ethington (1962) published the results of Arizona's Devonian conodont studies, which he had conducted while teaching at Arizona State University at Tempe.



ARIZONA
PALEOZOIC
FOSSIL FISH
LOCALITIES

ARIZONA PALEOZOIC FISH LOCALITIES

BLUE MOUNTAIN (NO. 1)

Devonian

The Devonian Portal Formation is exposed at Blue Mountain on the eastern side of the Chiricahua Mountains (Sec. 20, T26S, R31E, Gila and Salt River Baseline and Meridian) and has been examined for fossils by Sabins (1957) and Ethington (1962). Dr. R. L. Ethington obtained a large conodont assemblage from the lower members of the Portal Formation. The conodont assemblage was considered early Upper Devonian by Ethington.

DOS CABEZAS (NO. 2)

Mississippian

The Dos Cabezas locality is located three miles west of the town of Dos Cabezas on Arizona Route 186.

The fish remains have been found in the Escabrosa Limestone approximately 350 feet above the Escabrosa-Portal Formation disconformity. The varied fish remains occurred in conjunction with invertebrate fossils. The presence of fish remains at the locality is interesting when compared to the lack of fish remains in other Escabrosa Limestone outcrops.

The Paleozoic section crops out north of the highway and dips to the southwest. This outcrop was reconnoitered. The bed indicated (Plate 2, fig. 2) contained the most varied fauna with the beds above and below containing a reduced number of species and specimens. Collection of specimens was difficult because of the surface silicification of the fossils. Some slabs of limestone were dissolved in a twenty per cent acetic acid solution in order to obtain fish scales and teeth.

BEELZEBUB BUTTE (NO. 3)

Permian

Beelzebub Butte, named by E. D. McKee, is a Permian Concha Limestone outlier between Helmet Peak and Sahuarita. Only one fragmentary fossil fish specimen has been recorded from here.

HELMET PEAK (NO. 4)

Permian

Helmet Peak, located some seven miles south of San Xavier Mission of the Twin Buttes road, has been used by the University of Arizona Geology Department as an area for instruction in field mapping techniques for many years. According to Dr. J. F. Lance, students in the past have found ganoid fish teeth in the Concha Limestone.

COLOSSAL CAVE (NO. 5)

Devonian?

Dr. D. L. Bryant reported (personal communication) that during the time he taught a geologic field course in an area of Paleozoic rocks located south of Colossal Cave, Pima County Park, his students found some fish teeth. Specimens were not retained by the University of Arizona. Bryant recalled that these teeth resembled sharks' teeth.

PICACHO DE CALERA (NO. 6)

Devonian

The Picacho de Calera Hills are located northwest of Tucson between the Tucson and Silverbell Mountains. They consist of two closely spaced isolated hills composed of eastward dipping strata. The westernmost hill is composed of Precambrian Pinal Schist, Cambrian Bolsa Quartzite and Cambrian Abrigo Limestone. The saddle between the two hills is also composed of Abrigo Limestone. The easternmost hill is composed of Devonian, Mississippian and Pennsylvanian rocks. The Arizona Portland Cement Company is presently (1963) quarrying the Cambrian Limestone.

The western slope of the easternmost hill contains basal Devonian strata that Stoyanow (1936) referred to as the Picacho de Calera Formation. This has more recently been referred to as a faunal zone within the Martin Formation

(Le Mone, 1958). The uppermost unit of the Picacho de Calera Member is a brown calcareous sandstone with well preserved fish teeth (Reid, 1928; Bryant, 1955).

PEPPERSAUCE CANYON (NO. 7)

Devonian

Peppersauce Canyon is located on the northeast side of the Santa Catalina Mountains, and crosses the Oracle-Mt. Lemon road about nine miles south of Oracle. The zone containing fish remains is located within the upper part of the Martin Formation and was referred to by Stoyanow (1936) as the Lower Ouray Formation. Cladodus teeth are locally abundant within red to brown sandy lenses located approximately sixty feet below the top of the Martin Formation.

The topography of the region is one of steep-sided ridges and valleys. Titled Paleozoic rocks rest upon the Precambrian Apache Group. Cambrian, Devonian, Mississippian and Pennsylvanian? rocks are all well exposed on both sides of the canyon.

GALIURO MOUNTAINS (NO. 8)

Mississippian

The single specimen from this locality was found on the north flank of Little Table Mountain in the North Galiuro Mountains (SE 1/4, Sec. 15, T7S, R18E, Gila and Salt River

Baseline and Meridian). The specimen was located in the Escabrosa Limestone 55 to 63 feet above the lower contact with the Devonian Martin Limestone (Thomssen and Barber, 1958).

SUPERIOR (NO. 9)

Devonian

Devonian rocks at Superior crop out on the first ridge east of the city. The fossil locality consists of a basal bone breccia in a light, coarse-grained, quartzitic sandstone located above the base of the Martin Formation. The bone breccia has a maximum thickness of five feet. Anthrodire plates, with well-defined ornamentation, and scattered teeth comprise approximately twenty per cent of the lithologic material of the breccia. The plates average four millimeters in thickness, lie horizontally and represent two distinct kinds of arthrodires. Fossil fish teeth were also found in the marine limestone (180 feet thick) between the fossil breccia, quartzitic sandstone strata and the next higher quartzitic member. Ethington (1962) reports a varied conodont assemblage throughout the Martin Formation here.

PINAL CREEK (NO. 10)

Devonian

The Martin Formation crops out on the south side of Pinal Creek, three miles northwest of Globe, and contains a

zone with fish teeth in its upper twenty feet. Reid (1928) found two species of Orodus and one fragment of Ptyctodus. Only one Orodus specimen was located in the University of Arizona collection. The area was recollected and only more Ptyctodus fragments were found. Conodonts are associated with the invertebrate fauna beginning at the base of Stauffer's Unit 11 (1928) to the base of the yellow shale (Ethington, 1962).

WINDY HILL (NO. 11)

Devonian

Windy Hill is located about four miles east of Roosevelt Dam on the shore of Roosevelt Lake. Only the upper portion of the Martin Formation is exposed (1936) above the water level. Fish remains are most abundant (Stoyanow, 1936) in the arenaceous limestone unit 206 feet below the top of the Martin Formation.

NEW WATER MOUNTAINS (NO. 12)

Permian

A few fragmentary fish teeth have been collected from the Permian section here and are in the Museum of Northern Arizona collection. No other information is available.

EAST VERDE RIVER (NO. 13)

Devonian

The East Verde locality is located in a roadcut one mile north of the East Verde bridge on Arizona Route 87 between Payson and Pine.

Arthrodire plates are abundant in the sandstones, dolomites and interbedded shales. This locality was discovered by Stoyanow in 1925 and he suggested the name, Sycamore Creek Formation, for the sandstone member. In 1936 he suggested that the sandstone may be more appropriately called the Sycamore Sandstone Member of the Jerome Formation. Huddle and Dobrovolney (1952) suggested the use of the Martin Formation for all the central Arizona Devonian rocks. Other names extended to this locality are: Sycamore Creek, Sycamore Hill No. 26 and Cedar Creek beds.

KOHLS RANCH (NO. 14)

Devonian

The floor of Tonto Creek, at Kohls Ranch nineteen miles northeast of Payson on the Heber-Young road, contains arthrodire plates in rocks of the same lithologies as that of the East Verde locality. Many roadcuts and hill slopes in this and the East Verde area contain arthrodire plate fragments.

MINGUS MOUNTAIN (NO. 15)

Devonian

The Devonian section at Mingus Mountain is quite varied and is best seen in a large quarried roadcut (Plate 2, fig. 3) 9.6 miles west of Jerome along U. S. alternate 89. Many of the roadcuts on both sides of the mountain contain arthrodire plate fragments. The plates are in both a red shaley limestone and a massive gray limestone. The quarried roadcut and the talus slope below the road grade are the major collecting areas. Cross sections of arthrodire plates that measure 1-1/2 inches thick and 15 inches long are abundant.

SEDONA (NO. 16)

Permian

Isolated boulders of Kaibab Limestone, Alpha Member, on the pediment slopes in the Sedona area have provided some of the most spectacular specimens of Arizona fish. The Kaibab Limestone boulders are porous, weathered and reddish. The locality is reached by turning south from Sedona on Arizona Route 179 for 1.4 miles, then turning to the east through the Broken Arrow subdivision for another half mile. The vertebrate material is very scattered and rare. Bone scraps and scales occur with a prolific invertebrate fauna (Clifford Earl, personal communication).

LAKE MARY (NO. 17)

Permian

Lake Mary is located five miles southeast of Flagstaff. L. F. Brady collected ganoid fish teeth and spines from the Alpha and Beta Members of the Kaibab Limestone on the northwest side of the lake. The Museum of Northern Arizona has obtained a few specimens from the Alpha Member of the Kaibab Limestone southwest of Turkey Butte and from the Beta Member in the Thompson Canyon and Clover Spring's area.

MOUNT ELDEN (NO. 18)

Devonian

Mt. Elden, located approximately one mile northeast of Flagstaff, is a laccolith connected to the San Francisco Mountain volcanic group. L. F. Brady and W. L. Thomas located Devonian strata approximately midway up the east side of the mountain. The section was measured and first reported by Stoyanow (1936). The fish fossils are most prolific in a gray thin-bedded limestone about thirty feet above the dacite detritus covered base. Arthrodire plates and fish teeth of various genera are abundant at this locality.

BOTTOMLESS PIT (NO. 19)

Permian

The Alpha Member of the Kaibab Formation is well exposed in the Bottomless Pit area, one mile east of the Flagstaff Country Club on the road to Walnut Canyon National Monument. Isolated ganoid and elasmobranch teeth are abundant in buff-colored, porous limestone.

RIMMY JIM TANK (NO. 20)

Permian

Rimmy Jim Tank is located some thirty-five miles east of Flagstaff in NW 1/4, Sec. 17, T27N, R9S, Gila and Salt River Baseline and Meridian (Chronic, 1952). The fish fauna is associated with a silicified invertebrate assemblage in the Alpha Member of the Kaibab Formation. Ganoid teeth were collected by disintegrating the limestone in a ten per cent solution of monochloroacetic acid.

BLACK MESA (NO. 21)

Devonian

Isolated Devonian arthrodire plates have been found in the road quarry south of U. S. Route 89 approximately nineteen miles south of Ash Fork.

PEACH SPRINGS (NO. 22)

Devonian

Stoyanow (1936) reports fragmental fish plates in a mottled purplish, argillaceous limestone, 167 feet above the Devonian-Cambrian contact. The same general Devonian section is found in the Grand Wash Cliffs and the Music Mountains.

GRAND CANYON (NO. 23)

Devonian and Permian

W. D. Walcott collected Bothriolepis and Holoptychius plate fragments from the Devonian Temple Butte Formation in 1880. Collections were made in Chuar Creek Valley by Walcott (1883), in Sapphire Canyon by Noble (1922) and along the Yak Trail by Stoyanow (1936).

Permian fish remains from the Kaibab Formation have been collected within the campground area and in float gravels on the South Rim of the Grand Canyon. The type specimen for Megactenopetalus kaibabanus was found in the Beta Member of the Kaibab Formation on the North Rim near Point Sublime (David, 1944).

TABLE 1.--Arizona: Stratigraphic Relationships to Orders of Fish.

| Age of Fossil Fish Localities | Orders | | | | | | | | | |
|-------------------------------|------------|------------|---------------------------|---------------|----------|-------------|-----------------|---------------|-----------------|--------|
| | Acanthodii | Arthrodira | Macropetal- ichthyidae | Cladoselachii | Selachii | Bradyodonti | Palaeoniscoidea | Semionotoidea | Acanthopterygii | Dipnoi |
| Lower Permian | | | | | | | | | | |
| Lower Mississippian | | | | | | | | | | |
| Upper Devonian | | | | | | | | | | |

FAUNAL LIST

BLUE MOUNTAIN (NO. 1)

Varied conodont fauna listed by Ethington (1962)
containing sixteen genera and nineteen species.

DOS CABEZAS (NO. 2)

Psammodus sp.
Petalorhynchus sp.
Cladodus costatus Newberry and Worthen, 1866
Cladodus cf. C. praenuntius St. John and Worthen, 1875
Cladodus cf. C. intercostatus St. John and Worthen, 1875
Petrodus occidentalis Newberry and Worthen, 1866
Petalodus milleri Gass, n. sp.
Campodus arizonensis Gass, n. sp.
Venustodus argutus St. John and Worthen, 1875
Venustodus sp.
Acanthodian? scales
Varied poorly preserved conodont fauna
Undeterminable genus A
Poorly preserved micro-teeth, undescribed
Papalstanus arizonensis Gass, n. gen. and n. sp.

BEELZEBUB BUTTE (NO. 3)

Sphaerolepis arctata (Cope) 1877

HELMET PEAK (NO. 4)

Ganoid, isolated teeth

COLOSSAL CAVE (NO. 5)

Cladodus? sp.

PICACHO DE CALERA (NO. 6)

Ptyctodus calceolus Newberry and Worthen, 1866

Diplodus reidi Gass, n. sp.

Lambdodus sp.

PEPPERSAUCE CANYON (NO. 7)

Cladodus sp.

GALIURO MOUNTAINS (NO. 8)

Psephodus sp. B

SUPERIOR (NO. 9)

Ptyctodus sp.

Arthrodire plates - two styles of ornamentation

Conodont faunal list by Ethington (1962) ten genera, fourteen species

Unidentifiable teeth - undescribed, but illustrated

PINAL CREEK (NO. 10)

Ptyctodus sp.

Orodus variocostatus St. John and Worthen, 1875

Conodont faunal list by Ethington (1962) sixteen genera, twenty-seven species

WINDY HILL (NO. 11)

Fish remains, Stoyanow (1936)

NEW WATER MOUNTAINS (NO. 12)

Three isolated teeth - unidentifiable but illustrated

EAST VERDE RIVER (NO. 13)

Oestophorus sp.
Dinichthys spp.
Coccosteus ? sp.
Macropetalichthys ? sp.

KOHLS RANCH (NO. 14)

Arthrodire plates

MINGUS MOUNTAIN (NO. 15)

Coccosteus sp.
Dinichthys spp.
Onychodus sigmoides Newberry, 1857
Ptyctodus cf. P. bradyi Hussakof, 1942

SEDONA (NO. 16)

Megactenopetalus kaibabanus David, 1944
Cladodus earli Gass, n. sp.
 Isolated scales, bones, and a tooth which was given to a collector, "Cladodus" like

LAKE MARY (NO. 17)

Ctenacanthus sp.
Macrodontacanthus sp.
 Undeterminable genus C
 Undeterminable genus B - Clover Spring locality
Psephodus sp. C. - Jones Crossing locality
Helodus sp. - Turkey Butte locality

MOUNT ELDEN (NO. 18)

Coccosteus arizonensis Hussakof, 1942
Dinichthys spp.
Ptyctodus bradyi Hussakof, 1942

Onychodus sigmoides Newberry, 1857
Dipterus cf. D. nelsoni Newberry, 1889
Dipterus bradyi Gass, n. sp.
Climatias ? spine

BOTTOMLESS PIT (NO. 19)

Cladodus sp. - undescribed and not illustrated
Janassa hussakofi Gass, n. sp.
 Undeterminable genus C
 Semionotid scales

RIMMY JIM TANK (NO. 20)

Ganoid teeth

BLACK MESA (NO. 21)

Arthrodire plates

PEACH SPRINGS (NO. 22)

Fragmentary fish plates, Stoyanow (1936)

GRAND CANYON (NO. 23)

Hybodus sp.
Holoptychius sp.
Bothriolepis sp.
Megactenopetalus kaibabanus David, 1944
Psephodus sp. A.
Deltodus mercurii Newberry, 1876

SYSTEMATIC PALEONTOLOGY

The synonymies are abbreviated in that only original descriptions, pertinent changes in taxonomy and previous references to specimens from Arizona are included. The taxonomy is based upon Romer (1945). Some of the generic and specific designations are based upon form genera.

Class Placodermi

Order Acanthodii

Family Diplacanthidae

Genus Climatius Agassiz, 1845

Climatius? spine

A short broad spine from the Devonian rocks at Mt. Elden has been referred to the genus Climatius by the Museum of Northern Arizona personnel. The specimen is 16 mm in length by 6 mm wide at the proximal end. The spine is flat with details observable on both sides. Lineal trending pits are parallel to the length on both sides and the lines converge near the apex. The spine is curved so that the apex is offset (4 mm) from the medial vertical line. Other spines are present in the collection of the Museum of Northern Arizona and are tentatively placed in this genus. The specimen (G-243) is not illustrated.

Family Acanthodidae

Genus Undetermined

Acanthodian scales

Pl. 14, fig. 4

Material.--Isolated acanthodian scales were collected by examining insoluble residues of Mississippian rocks from the Dos Cabezas locality. The scales are on deposit at the Museum of Northern Arizona (DC-424).

Description.--Small abraded acanthodian scales are abundant at the Dos Cabezas locality. The scales are square to rhombohedral in shape. A restricted neck is found on some of the specimens. Neither ridges nor prominent posterior corners were observed on any of the specimens. The color of the specimens varied from white to gray.

Discussion.--Because of the abrasion of the important morphologic features, the specimens can not be accurately placed in a genus. The scales were obtained by dissolving limestone specimens in a ten per cent solution of monochloroacetic acid.

Family Onychodontidae

Genus Onychodus Newberry, 1857Onychodus sigmoides Newberry, 1857

Onychodus sigmoides Newberry, 1857, Proc. Nat. Institute,
n. ser. 1, 124, p. 5.

Onychodus sigmoides Hussakof and Bryant, 1918, Catalog of the fossil fishes in the Museum of the Buffalo Society of Natural Sciences, v. 12, p. 178.

Material.--The Museum of Northern Arizona collection contains specimens from Mingus Mountain (G2-3304, G2-7721) and from Mt. Elden (G2-55).

Description.--The specimens are large presymphysial teeth, sigmoidally curved with large central cavities. The teeth have one large basal sulcus. The teeth are completely covered with a thin coat of enamel. The length of the specimens varies from 13 mm to 34 mm.

Discussion.--Isolated specimens of O. sigmoides presymphysial or lanian teeth are abundant in the Mingus Mountain and Mt. Elden localities. They are easily seen and identified at the outcrop because of their distinctive shape and form.

Order Arthrodira

Suborder Euarthrodira

Infraorder Brachythoraci

Family Coccosteidae

Genus Coccosteus Agassiz, 1844

Coccosteus arizonensis Hussakof, 1942

Pl. 9, fig. 3; Pl. 10, figs. 1-4

Coccosteus arizonensis Hussakof, 1942, Amer. Mus. Novitates, no. 1186, p. 2.

Material.--Coccosteus arizonensis co-type specimens on deposit at the Museum of Northern Arizona are a dorso-median (G2-531), a median ventral plate (G2-663), a left anterior ventro-lateral (G2-3155) and a right posterior ventro-lateral (G2-667). Numerous other specimens at the Museum are referred to this species. They were all collected from the Mt. Elden Devonian section by L. F. Brady.

Description.--C. arizonensis is a small species about two-thirds the size of C. decipiens. The ornamentation consists of small tubercles. The tubercles trend toward a linear arrangement of some of the plates. Complete descriptions of the plates chosen as the co-type specimens are given in Hussakof's paper (1942).

Discussion.--The Mt. Elden locality has provided many isolated well-preserved arthrodire plates. Tor Orvig (1963) has suggested that perhaps the description of the type material is in need of revision. The author believes that Hussakof's descriptions are appropriate and valid. The arthrodire material from the Mingus Mountain and East Verde localities needs further work with respect to collecting and comparative specimen analysis.

Coccosteus?

Pl. 5, fig. 5 and Pl. 8, figs. 1-2

Material.--A large dorso-median and an unidentified plate in close stratigraphic association were collected in a

dolomite from the East Verde locality. The specimens are on deposit at the Museum of Northern Arizona (EV-415, EV-416).

Description.--The dorso-median is covered with large tubercles. The width of the specimen is 19.1 cm. The angle that the sides of the dorso-median makes with the center keeled portion is 135 degrees. A short spine with an articulation process projects beyond the posterior face. A keel follows the median line and increases in size from the posterior to the anterior. There are many other pieces of dermal armor associated with the dorso-median. One of these is an unidentified petal-shaped plate which is strongly crenulated around the margin. The plate was found in contact with other plates along a straight articulation process.

Discussion.--The specimen is similar to one found at Mt. Elden (borrowed from the Museum of Northern Arizona). The dorso-median is referred to the genus Coccosteus because it possesses the same morphologic characteristics. However, there are no described species of Coccosteus that attained such huge proportions. The dorso-median plate alone is almost as large as some entire coccostids. The specimens may well belong to an undescribed genus.

Genus Dinichthys Newberry, 1873

Dinichthys spp.

Pl. 9, figs. 1, 4-5; Pl. 4, figs. 1-2; and Pl. 5, fig. 1

Material.--Dinichthys is one of the most abundant genera in the Devonian rocks at the East Verde, Mingus Mountain,

and Mt. Elden localities. The Mingus Mountain locality has provided very large head shield plates. The illustrated and thin sectioned specimens are on deposit at the Museum of Northern Arizona.

Description.--Casts of large plates have been made from natural molds at the Mingus Mountain locality. Plate 9, figure 1 is a plaster mold which duplicates the underside of a moderately large Dinichthys. A larger unillustrated specimen (G2-7725) is 28 cm long by 20 cm wide at the center. The articulation process extends 15 mm above the plane of the plate. Views of plate ornamentation are illustrated on Plate 9, figure 5 and Plate 4, figures 1 and 2. The stellate pattern of the base of the tubercles are among the rarer specimens.

A nearly complete plate (Pl. 9, fig. 5) was collected from the East Verde locality. The ventral side is illustrated showing the articulation process. This plate is a diminutive form of the larger Mingus Mountain specimen. The dorsal side of the East Verde plate has an ornamentation similar to Plate 4, figure 2. Thin sections of some of the different styles of plates show the tubercle growth through successive layers. A non-ornamented plate (Pl. 5, fig. 4) consists of two layers. The thicker portion of the plate shows the regular arthrodire plate structure, while the bottom of the plate is a more laminar layer which exposes the blood vessels as grooves showing wear. The largest thin section (Pl. 5, fig. 1)

is of a plate 14 mm thick. The plate was tuberculated and a sensory canal crossed the surface (indicated by a red circle). The plate had numerous internal voids filled with matrix material.

Discussion.--None of the material can be speciated. The lack of an assemblage also hinders possible interpretations. The finding of dentary bones will help further interpretation. A partial dental element (G2-921) was collected from the Mt. Elden locality. It was illustrated and discussed by Hussakof (1942). The specimen did not give any clues as to a specific identity.

Suborder Ptyctodontida

Family Ptyctodontidae

Genus Ptyctodus Pander, 1858

Ptyctodus bradyi Hussakof, 1942

Pl. 10, fig. 6

Ptyctodus bradyi Hussakof, 1942, Amer. Mus. Novitates, no. 1186, p. 8.

Material.--Dental elements and tritors referable to the species have been discovered at the Mt. Elden locality. The type specimen is on deposit at the Museum of Northern Arizona (G2-851). Other specimens at the Museum are: G2-70, G2-68, G2-67, G2-65 and G2-58. Fragments have been found at the Mingus Mountain locality.

Description.--The small dental elements are approximately 20 mm long and 9 mm wide. The posterior part of the

oral margin has a narrow tritor. The punctae are visible only under 10x or greater magnification. A more complete description is in Hussakof (1942).

Discussion.--See Hussakof's paper (1942).

Ptyctodus calceolus Newberry and Worthen, 1866

Pl. 15, fig. 3

Ptyctodus calceolus Newberry and Worthen, 1866, Rept. Geol. Surv. Ill., v. 2, p. 106.

Ptyctodus calceolus Eastman, 1908, Iowa Geol. Surv. Annual Rept., v. 18, p. 133.

Ptyctodus calceolus Hussakof and Bryant, 1918, Catalog of the fossil fishes in the Museum of the Buffalo Society of Natural Sciences, v. 12, p. 108.

Material.--Specimens have been collected from the Devonian rocks exposed at the Picacho de Calera, Superior and Pinal Creek localities. The specimens from Picacho de Calera are the only ones that may be referred to a species. The specimens are on deposit at the Museum of Northern Arizona (Picacho de Calera specimens - PC-421, PC-422 and PC-423; Superior specimen - S-424; and Pinal Creek specimens - G-425).

Description.--Detached fragmental tritors are abundant and are the only material available for study. The laminar structure of the tritors is well developed by fine punctae arranged in parallel rows trending obliquely across the tritorating surface. The punctae are small polygonal pits formed by the termini of the medullary canals. The

tritons vary in size up to 2-1/2 cm. No complete tritons were found.

Discussion.--Detached tritons are most abundant at the Picacho de Calera locality. Most of the specimens show signs of wear and abrasion. All of the specimens are broken and most of the larger pieces are badly fractured. The first mention of the occurrence of Ptyoctodus at the Picacho de Calera locality was made by Reid (1928). Stoyanow (1936, p. 488) suggests close affinities with the species P. calceolus.

Order Macropetalichthyidae

Family Macropetalidthyidae

Genus Macropetalichthys Norwood and Owen, 1846

Macropetalichthys? sp.

Material.--Some arthrodire plates collected from the East Verde locality have been referred to this genus. The specimens are on deposit at the Museum of Northern Arizona (G-214, 215, 217 and 219).

Description.--Some of the arthrodire plates from East Verde locality were assigned to this genus by Stoyanow (1936). The plates are thin (2 mm) in comparison to the other plates at the locality. The tubercle arrangement is similar to that described by Dinichthys; however, near the margins the tubercles become elongated normal to the margins.

Discussion.--The ventral plate structures in these specimens are not comparable in that they do not present any of the radiating ridges which are characteristic of the genus. The tubercle ornamentation is, however, rather indicative of the genus. Pending the collection of more diagnostic material, the author will tentatively place the plates in this genus.

Class Chondrichthyes

Subclass Elasmobranchii

Order Cladoselachii

Family Cladoselachidae

Genus Cladodus Agassiz, 1843

Cladodus earli Gass, n. sp.

Pl. 14, fig. 6

Material.--The specimen consists of one tooth in matrix showing in outline form some of the broken accessory cusps. This specimen was obtained from a Permian Kaibab Limestone, Alpha Member, boulder from the Sedona locality. It is currently on loan to the Museum of Northern Arizona (FA-684) by the collector, C. Earl. Earl (1963) is presently making plans to donate the specimen to the Museum.

Description.--The tooth is large and robust in size. The base is irregularly elliptical. The median cone is very robust, rapidly tapering toward the apex, laterally deflected and gently arched in front. It has compressed cutting edges. The medial cone has a vertical cutting face on the posterior

right side while the left side curves toward the apex. There are no costae on the specimen. There are three accessory cusps on each side, the second of which is the largest. The second accessory cusps curve toward the lateral margins of the crown. The longest dimension of the crown is 31 mm, the median cone is 27 mm high and the length of the larger accessory cusps are 12 mm.

Discussion.--Because of the large size of the specimen and distinctive nature of the median cone, a new species is proposed. The closest allied species is C. vanhornei St. John and Worthen. The Sedona specimen has a greater curvature to the posterior left side of the median cone, no curvature on the right side and a greater number of accessory cusps than C. vanhornei. C. vanhornei and the proposed species C. earli are both unusual in their large size and compressed cutting edges. They may represent a subgenera.

Cladodus costatus Newberry and Worthen, 1866

Pl. 15, Fig. 1

Cladodus costatus Newberry and Worthen, 1866, Geol. Surv. Ill., v. 2, p. 27.

Material.--Fragmentary tooth specimens have been found in the Mississippian rocks at the Dos Cabezas locality. The illustrated specimen is on deposit with the Museum of Northern Arizona (DC-411).

Description.--The base of the tooth is flat with a straight anterior border. The principal medial cone is elliptical in outline near the base of the tooth. There are two to three costae on either side of the cone. The two lateral cusps are conical with the larger of the two next to the medial cone.

Discussion.--The specimen, even though fragmentary, fits well in the species C. costatus. Other fragments showed the same general form as the one described. This species is the most common at the Dos Cabezas locality.

Cladodus cf. C. praenuntius
St. John and Worthen, 1875

Pl. 15, fig. 7

Cladodus praenuntius St. John and Worthen, 1875, Geol. Surv. Ill., v. 6, p. 270.

Material.--Fragmentary teeth have been collected from the Mississippian limestones at the Dos Cabezas locality. The illustrated specimen is on deposit at the Museum of Northern Arizona (DC-410).

Description.--The fragmentary tooth is moderately large in size and appears to have only one accessory cusp on either side of the medial cone. The medial cone and accessory cusp have rugose costae. The accessory cusp is narrow and recurved toward the posterior margin of the

tooth. The length of the preserved portion is 13 mm and the total height of the accessory cusp with the base is 8 mm.

Discussion.--Until more complete dentition assemblages are found the validity of the species is somewhat in doubt. The species description fits well in the fragmentary tooth and is, therefore, referred to C. praenuntius.

Cladodus cf. C. intercostatus
St. John and Worthen, 1875

Pl. 15, fig. 2

Material.--Fragmentary teeth from the Mississippian Dos Cabezas locality are referred to this species. The illustrated specimen is on deposit at the Museum of Northern Arizona (DC-409).

Description.--An anterior face of this specimen is exposed. The tooth is of moderate size. The fragment measures 9 mm for the length from the edge of the crown to the opposite base of the medial cone. The medial cone is symmetrical and rapidly tapers toward the point. Both faces have strong costae. The anterior face is deeply sulcated. Two lateral denticles are present on the left side. The outermost denticle is slightly larger in cross section than the second denticle. They are also strongly costate. The right side is broken away.

Discussion.--The specimen can only be referred to this species because not enough is known of the nature of the base of the tooth. This tooth and other similar fragments resemble the species C. intercostatus.

Genus Lambdodus St. John and Worthen, 1875

Lambdodus sp.

Material.--One specimen embedded in a quartzitic sandstone was collected by Reid (1928) at the Picacho de Calera locality. The specimen is on deposit at the University of Arizona (U. of A. 483). The specimen is not illustrated.

Description.--The tooth has only one cone. The specimen measures about 9 mm in lateral length. The cone is subovate in cross section with no sulcus on the posterior face. Rugose costae radiating on the sides of the cone stop at the cone-base margin.

Family Ctenacanthidae

Genus Ctenacanthus Agassiz, 1837

Ctenacanthus sp.

Pl. 9, fig. 2

Casts from a natural mold have been identified by the Museum of Northern Arizona as a spine fragment with part of the base showing a portion of the line of insertion of the spine into the head shield. The specimen is 15 mm long

and 9 mm wide. It is on deposit at the Museum of Northern Arizona (G-1121) and was collected from the Permian rocks at the Lake Mary locality.

Order Selachii

Suborder Hybodontaoidea

Family Hybodontidae

Genus Orodus Agassiz, 1838

Orodus varicostatus St. John and Worthen, 1875

Orodus varicostatus St. John and Worthen, 1875, Geol. Surv. Ill., v. 6, p. 304.

Material.--This species is represented by a single tooth fragment collected in 1927 by R. Reid from the Pinal Creek locality. The specimen is on deposit at the University of Arizona (PC-606). The limestone matrix was dissolved from around the specimen with a ten per cent solution of monochloroacetic acid. The specimen is not illustrated.

Description.--The fragment consists of a median cone and one lateral projection. The crown is contoured from the basal margin to the longitudinal medial crest. The surface is somewhat obscured by the eroding of the enameled portion exposing the termini of the medullary canals. The length of the fragment is 8 mm and the width at the medial cusp area 5.8 mm. The medial cusp is very flat with the folds or plicae becoming obscured before reaching the center.

Discussion.--The genus Orodus is quite varied in the ornamentation represented by the different species. The species O. variocostatus is the only one in which the medial ridge and costae at the medial cusp is obscured.

Genus Petrodus McCoy, 1848

Petrodus occidentalis Newberry and Worthen, 1866

Pl. 13, figs 2,4

Petrodus occidentalis, Newberry and Worthen, 1866, Geol. Surv. of Ill., v. 2, p. 70.

Petrodus occidentalis Woodward, 1889, Catalogue of fossil fishes in the British Museum, pt. I, p. 246.

Material.--One specimen was collected from the Escabrosa Limestone at the Dos Cabezas locality. It is on deposit at the Museum of Northern Arizona (G2-4808).

Description.--The tooth is characterized by a sub-circular base and is terminated by a crenulated edge broader than the crown. The crown is broadly rounded at the summit. It is marked with a number of well-developed, divergent ridges, many of which fork near the base. The ridges are smooth. The face of the specimen is non-punctate. The length of the specimen is 8 mm and the width 6.7 mm.

Discussion.--Agassiz suggested that the species included within this genus are not teeth, but are dermal tubercles of some shark. Regardless of their true nature, specimens can be, nevertheless, validly referred to this

genus and species. Other species of Petrodus are much more rugose, smaller in size and more acutely pointed or smoothed. This author contends that at least this species probably consists of teeth because of large size and rarity. If more than the one specimen had been found, a histologic thin section would have been prepared, and perhaps some idea of the real nature of the specimen could have been determined, whether tooth or scale.

Genus Hybodus Agassiz, 1837

Hybodus sp.

A dorsal spine referred to as Hybodus, is on display at the Grand Canyon Museum. The specimen was collected from the Permian Kaibab Formation at the Grand Canyon. No other information was available.

Family Edestidae

Genus Campodus L. G. deKoninck, 1844

Campodus arizonensis Gass, n. sp.

Pl. 13, fig. 1

Material.--One complete, but fractured tooth, was collected at the Mississippian Dos Cabezas locality. The tooth is on deposit at the Museum of Northern Arizona (DC2-481).

Description.--The tooth has a well-defined medial crest throughout its length. The medial large cusp has two subsidiary cusps on one side and three on the other side. Each cusp has a lateral protruding ridge with a serrated crest on each side that extends to the basal portion. One of the lateral sides has additional folds or serrations along the basal margin throughout the length of the tooth. The enameled portion of the tooth is highly polished and is non-punctate.

Discussion.--Smaller, less regularly formed teeth similar to the described specimen are assigned to the genus Lophodus Newberry and Worthen (1879). They remarked that their specimen bore a close affinity to the genus Orodus. Woodward (1889) placed Lophodus in the genus Campodus. C. arizonensis has better symmetry and more cusps than the closely related species C. scitulus St. John and Worthen (1875). C. scitulus has transverse ridges on one lateral side of the crown; whereas C. arizonensis is bilaterally symmetrical with the transverse ridges continuing across the medial keel. No other described species has the same detailed features of C. arizonensis and C. scitulus

Order Bradyodonti

Family Cochlidontidae

Genus Helodus Agassiz, 1838Helodus sp.

Material.--A tooth plate of a hybodontid shark was collected from the Kaibab Formation southwest of Turkey Butte near the Lake Mary locality. The specimen is on deposit at the Museum of Northern Arizona (G2-2317).

Description.--The specimen is an elongated tooth. The cusp forms a blunt symmetrical knob with radiating costae. The centrally located cusp has on both sides featureless, enamel covered lateral projections. One of the lateral projections is broken. These projections approach the central cusp at an angle of about 150 degrees.

Discussion.--The specimen is not illustrated because it is so relatively featureless. The generic designation is difficult because of the lack of an assemblage of teeth.

Family Cochliodontidae

Genus Deltodus Agassiz, 1859Deltodus spp.

Pl. 12, figs. 5, 8-9

Material.--Three specimens were selected from among several to be representative of the genus Deltodus from the Mississippian rocks at the Dos Cabezas locality. Because

of the poor preservation the specimens are all fragmental. The specimens are on deposit at the Museum of Northern Arizona (DC-414, 415, 416).

Description.--The specimens have a black enamel covered crown which is densely punctate. The specimens have a convex crown which is modified by either gentle or rugose folding. Specimen DC-414 has a flat fold with a slightly modifying sulcus. Specimen DC-415 has a deep sulcus with high narrow lateral folds on both sides. Specimen DC-416 shows a marginal area of enamel wrinkling.

Discussion.--Probably many species are represented by the genus Deltodus at the Dos Cabezas locality. Because of the lack of similar specimens or whole specimens, specific designations are difficult to assign. Deltodus mercurii Newberry has been reported by Hussakof (1943) and David (1944) from the Grand Canyon Permian rocks. The specimen is not at the Museum of Northern Arizona or the Grand Canyon Natural History Museum. The author could not locate or find any other references to the specimen.

Genus Psephodus Agassiz, 1862

Psephodus sp. A

Pl. 17, figs. 1-2

Material.--One large dental element has been found on the North Rim of the Grand Canyon near Point Sublime in

the surface gravels. The specimen is on deposit at the Museum of Northern Arizona (G2-7262).

Description.--The tooth measures 77 mm in length by 30 mm in width. The coronal surface is convexly arched and covered with punctae. The tooth is elongate instead of rectangular and is, therefore, considered an upper dental element. The antero-lateral border is gently curved outward and is marked with strong crenulations on one side. The postero-lateral border is nearly straight and shows less wear than the other side.

Discussion.--Because of the varied characteristics of the individual teeth within one jaw the species is difficult to determine without a full dentition. The large size of this specimen may indicate that it represents a new species.

Psephodus sp. B

Pl. 12, fig. 3

Material.--One tooth was collected from the Galiuro Mountains Mississippian section. The specimen is on deposit at the University of Arizona (TM-1).

Description.--The specimen is a convex elliptical tooth measuring 20.5 mm long by 13.9 mm wide. The black enameled surface of the crown is strongly punctate. The tooth was coated with magnesium oxide in order to obtain a better photograph. The margins of the tooth are embedded

in the quartzite matrix. The rectangular shape of the tooth indicates a lower dental plate.

Discussion.--The specimen appears similar to the species P. dubius. A specific determination is not certain without characteristic morphologic detail around the margins of the tooth.

Psephodus sp. C

Pl. 17, fig. 3

Material.--A dental element and part of its natural mold in the matrix was collected at Jones Crossing near the Lake Mary locality. The specimen is on deposit at the Museum of Northern Arizona (G2-6849).

Description.--A highly convex lower dental element 55 mm long by 20 mm wide. The coronal surface is strongly punctate. A cingulum or shelf extends as a flat area at the basal margin on the antero-lateral side.

Discussion.--This specimen may belong to the same species as Psephodus sp. A. Because of the lack of a complete dental element the true relationship between the two specimens is undeterminable.

Family Petalodontidae

Genus Petalorhynchus Newberry
and Worthen (ex Agassiz MS), 1866

Petalorhynchus sp.

Pl. 12, fig. 4

Material.--A well-shaped portion of the crown was collected from the Mississippian Dos Cabezas locality. The tooth is on deposit at the Museum of Northern Arizona (DC-48).

Description.--The crown is petal-shaped, thin, relatively high, and narrow with a distinct medial apex. The upper edge is marked with very coarse radiating costae. The anterior face is convex and the posterior face is concave. The lower portion is unworn and presents the typically unworn enamel surface of interrupted rows of prismatically indented hachures. The height of the preserved portion of the crown is 6.8 mm and the greatest preserved width is 7.0 mm.

Discussion.--The specimen closely follows the generic description. To place this specimen into a species, the rest of the lower portion and some knowledge of the structure of the root portion is necessary.

Genus Petalodus Owen, 1840

Petalodus milleri Gass, n. sp.

Pl. 12, figs. 1-2

Material.--A nearly complete crown of a tooth with the root broken away was collected at the Mississippian Dos

Cabezas locality. Many fragmental portions of teeth which are referable to Petalodus have been found at this locality. The specimens illustrated are on deposit at the Museum of Northern Arizona (DC-485, DC-486).

Description.--The tooth is transversely elongated, much compressed and elliptical in form. The crown is petal-shaped with a slightly crenulated margin. The root portion is short and extends anteriorly. The apex of the tooth is rounded and is indistinguishable from the rest of the crown. The tooth is concavo-convex vertically. The crenulated margin is roughened by the termini of the calcigerous tubes. The posterior concave face contains six enamel folds which are broad and stand out in bold relief. The enamel folds on the anterior convex face extend higher toward the margin and are much less rugosely imbricated.

Discussion.--Because of the slight curvature of the crown margin this specimen does not fit into any known species from North America. In Great Britain the species P. acuminatus is similar in size and enamel crenulations, but still retains an arched apex. All other species also have an arched apex. The apex could have been removed by wear, but because the medial region has the same degree of curvature as the rest of the tooth it is felt that excessive wear has not taken place. Also the crenulation of the margin as observed on this specimen is obsolete in highly worn teeth. The species

here proposed, P. milleri, is named for H. W. Miller, the author's thesis director.

Genus Janassa Munster, 1832

Janassa hussakofi Gass, n. sp.

Material.--The specimen (G2-91) was collected by L. F. Brady of the Museum of Northern Arizona in 1934. The tooth is from the Permian Kaibab Formation, Alpha Member, at the Bottomless Pit locality.

Description.--A well-preserved palatal tooth with twelve plicae, nine of which cross the breadth of the crown. The sixth and seventh plicae merge near the middle and are interrupted by angulation of the eighth plica. The twelfth plica is weak and discontinuous beyond the middle of the crown. The tooth is S-shaped from the lateral aspect. The proximally reflexed portion of the tooth is the root. The plicated surface is convex and terminates at the root. The cutting laminae surface is concave and recurved. Between the twelfth plica and the distal cutting surface the tooth is spoon-shaped. The cutting surface shows no indication of wear and is distinctly striated. Dimensions of the tooth are: length, 11.8 mm; maximum width, 8 mm; and maximum thickness, 3 mm.

Discussion.--This is by far the largest of the described species of Janassa from North America. The species

J. stringilina does not compare to this specimen because J. stringilina has a sharp fold between the last plica and laminary cutting edge. The other described species are rectangular rather than oval in shape or do not have the spoon-shaped depression between the plica and the cutting laminae surface. Louis Hussakof (1943) published an abstract stating that a new species of Janassa has been found in the Permian of Northern Arizona. He then labeled the specimen as the holotype and returned it to its depository at the Museum of Northern Arizona with the label "Janassa kaibabensis." To date (1963) he has not formally published the proposed scientific name. Therefore, the species J. kaibabensis is invalid and the author names the specimen in honor of Hussakof, the outstanding authority of Paleozoic fossil fish in North America.

Genus Megactenopetalus
David, 1944 (nov. emend.)

Megactenopetalus kaibabanus
David, 1944 (nov. emend.)

Material.--The type specimen is on deposit at the Museum of Northern Arizona (G2-2280). Clifford Earl of Sedona, Arizona has loaned a more complete specimen to the Museum and has permitted the author to describe it in this thesis. Earl's specimen came from an isolated Kaibab Formation, Alpha Member, boulder in the terrace gravels near Sedona.

Description.--The description is confined to the Sedona specimen and reference is made to the type specimen. Greatest depth of crown 7.9 cm, greatest width of crown 10.5 cm and semi-circle diameter of crown 20.2 cm. The Sedona specimen is a nearly complete upper dentition with the root portions missing. The cartilage and bones of the upper dentary, however, have been accurately molded in the porous limestone matrix. There are twelve teeth present in the series but a mold of another tooth is present, making the total count of thirteen. The posterior and anterior faces of the teeth are marked with fine radiating lines on their upper edges. The central tooth has about forty lines with a reduced number proportionately toward the end of the tooth series. The teeth are punctate over the entire surface. Eight of the teeth are defaced on the anterior side by worm borings. The teeth are convex on the anterior face and plane on the posterior face, thinning toward the rims. An enamel covering about 1 mm thick surrounds the teeth and is present on the posterior welt portion. The teeth are worn and present an odd style of wear which would prove difficult to interpret if the jaw was not intact.

Discussion.--This specimen is the most spectacular of the fish studied. Even though the specimen does not accurately fit the generic description, one must note that the generic and specific descriptions were based upon a

single specimen. The author believes that revision of the species should be made to include the variation now known to be present. The teeth of the Sedona specimen, as do the teeth of the type specimen, form a groove with the basal undivided portion, referred to as the crown. However, the Sedona specimen shows no overlap of the teeth. Because of the definite layer of enamel on the posterior welt as well as the teeth, it may be concluded that David's interpretation (1944), that these are not single teeth but a dental plate with denticles, is verified. This is further substantiated in that the next most closely allied fish, Ctenopetalus semicircularis, also has an odd number of denticles (9). The incomplete type specimen was interpreted to have only ten denticles; whereas the Sedona specimen has thirteen.

Family Psammodontidae

Genus Psammodus Agassiz, 1843

Psammodus sp.

Pl. 12, fig. 6

Material.--A single tooth fragment was collected from the Dos Cabezas locality. It is on deposit at the Museum of Northern Arizona (DC-417).

Description.--The enamel crown of the tooth has a series of prismatic pits. This feature in contrast to the

usual circular pitting is the result of elongated vertical columns enclosing medullary tubes.

Discussion.--The shape of the specimen is too modified by breakage to attempt a specific designation. One should note that the specimen referred to as Petalorhynchus sp. has a similar prismatic pitting on the lower part of the tooth. Since these are form genera, a true relationship between them can not be established.

Ichthyodorulites

Genus Oestophorus (Newberry), 1889

Oestophorus sp.

Pl. 6, figs. 1-2

Material.--Three specimens were recovered in the course of extensive collecting at the Devonian East Verde River locality. The smallest specimen was histologically thin sectioned. The best preserved specimen is illustrated. A third and much larger specimen is poorly preserved. It measures eight inches by three inches. The specimens are on deposit at the Museum of Northern Arizona (G4-8088, 8088).

Description.--This is by far the best preserved specimen and shows the arrowhead tuberculation that characterizes the genus. The tubercles measure 1 mm in length by 2 mm in width. They overlap each other in parallel rows pointing anteriorly. The specimen is only a fragment of a

plate, and seems to be a part of the antero-medial lamina of the shoulder girdle of an arthrodire.

Discussion.--The genus is based upon a clavicle six inches in maximum length and 1-1/2 inches in maximum width. Only fragmentary remains have been found of this arthrodire, and there is just the one described species, O. lillyii. So very little is known about the genus that it is not advisable to propose new species. However, the species does not seem to be cosmopolitan or common enough to apply the specific name O. lillyii to the Arizona specimens. One smaller specimen was thin sectioned but showed only the tuberculated structure of a typical arthrodire plate. The author refers the reader to the following references made about the genus in order to present a complete discussion about this specimen. (Newberry, 1889, p. 92; Miller, 1892, p. 716; Eastman, 1908, p. 207; Hussakof and Bryant, 1918, p. 105; and Orvig, 1957, p. 336).

Genus Venustodus St. John and Worthen, 1875

Venustodus argutus
St. John and Worthen, 1875

Pl. 13, figs. 3, 5

Venustodus argutus St. John and Worthen, 1875, Geol. Surv. Ill., v. 6, p. 352.

Material.--A fragmental dental element with many denticles was collected at the Mississippian Dos Cabezas

locality. The specimen is on deposit at the Museum of Northern Arizona (DC-407).

Description.--The dental element is of moderate size. The right extremity is rounded; the left portion is missing. The length of the specimen is 10.6 mm by 2.0 mm in width. The crown of the tooth is centrally transversed by a low row of eight denticles which increase in size toward a large median cone. The median cone is curved toward the right side of the element. The crown has from one to three enamel crenulations surrounding the lateral row of denticles. The denticles are punctate.

Discussion.--This dental element appears to be the same as the type specimen. The descriptions of the two are identical. The proper classification of this genus is somewhat in doubt. The genus does, however, have close affinities with the Hybodontidae.

Venustodus sp.

Pl. 14, fig. 3

Material.--A tooth with one large denticle was collected from the Dos Cabezas locality. The specimen is on deposit at the Museum of Northern Arizona (DC-412).

Description.--A tooth has a dark gray coating of enamel and a non-punctate surface. The tooth has but one denticle which forms the apex of two sides which intersect

each other at an angle of sixty degrees. The root portions of the tooth have been broken away.

Discussion.--The one to three crenulations of the enamel along the crown suggests the affinities to the genus. Without a better preserved specimen, a specific designation can not be made; however, it may be noted that the definition of no described species of Venustodus includes the Dos Caberas specimen.

Macrodontacanthus sp.

Pl. 15, fig. 9

Material.--A mold of a spine in quartzite was collected in the Permian rocks of the Kaibab Limestone Formation at the Lake Mary locality. The specimen is on deposit at the Museum of Northern Arizona (G2-1133).

Description.--The natural mold is in two pieces, 123 mm long and 30 mm long. The shorter piece is the one illustrated. It is 8.3 mm wide at the distal end and 10.5 mm wide at the proximal end. There are fifteen costae parallel with the length of the spine. Ten vertically compressed denticles, which are spaced by about their own diameter, flank one side of the smaller spine.

Discussion.--The spine resembles Ctenocanthus gracillimus Newberry and Worthen except that the Ctenocanthus is distinctly curved while this specimen is straight

and longer. The generic reference may be revised, later, pending the finding of more specimens.

Genus Papolstanus Gass, n gen.

Papolstanus arizonensis Gass, n sp.

Pl. 16, fig. 4

Material.--A small dental plate with many pebbly teeth was collected at the Dos Cabezas locality in the Mississippian Escabrosa Limestone. The genotype specimen (DC-420) is on deposit at the Museum of Northern Arizona.

Description.--The description of the genotype is applicable for both the propose generic and specific names. The specimen is a small dental crushing plate with many pebbly teeth. The largest tooth is 0.5 mm in diameter and the smallest about 0.1 mm. The plate contains about 150 pebbly rounded teeth. The teeth trend in a linear arrangement. The enameled crown is quite thick and smooth. The rest of the tooth is dentine. There are no central pulp cavities. The crown of the plate is flat except for a slight upcurve on one end. This upcurved surface has smaller teeth than the rest of the crown.

Discussion.--The tooth plate is very diagnostic and is a crushing dentition. It is an unusual form not previously found in Mississippian or other Paleozoic rocks. No isolated teeth were found in the insoluble residues obtained from the

Dos Cabezas locality. The author feels that genera belonging to orders of more advance fish characteristic of the Mesozoic should not be applied to the Mississippian. Also since the teeth have no pulp cavities, they belong to a more primitive genus of fish. Mesozoic and Cenozoic genera of fish with the same type of crushing dentition all have the central pulp cavities. With these considerations in mind the author proposes that a new genus be erected to include this specimen. The generic name, Papolstanus, is proposed because of the specimen's pebbly teeth.

Papolstanus? sp.

Pl. 16, fig. 7

A wax squeeze of a tooth plate referable to this genus was made by L. F. Brady from the natural mold of the specimen preserved at the Grand Canyon. The cast is on deposit at the Museum of Northern Arizona (G2-2268). The specimen measures 49 mm in length by 22 mm in width. The pebbly teeth have the same appearance as those of the type specimen. The largest tooth measures 3.5 mm in diameter with the smaller teeth about 1.5 mm in diameter.

Class Osteichthyes

Subclass Actinopterygii

Order Palaeoniscoidea

Genus Sphaerolepis Fritsch, 1877

Sphaerolepis cf. S. arctata

Pl. 16, figs. 1-3

Peplorhina arctata Cope, 1877, Proc. Amer. Philos. Soc.,
p. 54.

Sphaerolepis arctata (Cope), 1911, Carnegie Inst. of Wash.,
No. 146, p. 170.

Material.--The specimen has been etched by means of an acid bath from limestone collected from the Beelzebub locality. The specimen is on deposit at the Museum of Northern Arizona (G2-6458).

Description.--The specimen is a dental element thickly studded with teeth which are not in contact with each other. The teeth are poorly preserved and a later section view shows only a few low conical teeth. The ventral side of the plate is pitted with cone-shaped depressions which represent the extension of the teeth through the dental plate. The teeth average 2 mm in diameter.

Discussion.--Because portions of the specimen were dissolved when it was being prepared, the true relationship to the species S. arctata can not be accurately determined.

Superorder Holostei

Semionotid scales

Pl. 10, fig. 7

Isolated scales were collected from the insoluble residues obtained from the Kaibab Limestone at the Bottomless

Pit locality. These scales are about 0.5 mm in diameter and rhombohedral in shape. They are clear to white in color and have a shiny enameled surface. Lines of growth are represented by faint ghost images within the scale. The ventral side has an attachment process located along the median length.

Superorder Teleostei

Order Acanthopterygii

Genus Diplodus Agassiz, 1838

Diplodus reidi Gass, n. sp.

Pl. 15, figs. 4-5

Material.--Two teeth with complete basal portions were collected from the Devonian rocks at the Picacho de Calera locality by Reid (1928). The specimens are on deposit at the University of Arizona (S-18, S-19).

Description.--The teeth are very small in size. The bases of the teeth are elliptical with an average diameter (laterally) of 3 mm and average width of 2.4 mm. The crown consists of three small cusps with the medial cone smaller than the flanking, equal-sized accessory cones.

Discussion.--The teeth have a base similar to that of the genus Phoebodus, but the cusps of Phoebodus are more equal in size; whereas the cusps on the described specimen are not. The new species is distinguished by the elliptical base which is not present in any of the previously described species of

Diplodus. The specimen is placed in the genus Diplodus because of the characteristic small medial cusp.

Subclass Choanichthyes

Order Dipnoi

Family Dipteridae

Genus Dipterus Sedgwick and Murchison, 1828

Dipterus cf. D. nelsoni Newberry, 1889

Pl. 10, fig. 8

Dipterus nelsoni Newberry, 1889, U. S. Geol. Surv., Monograph no. 16, p. 89.

Material.--The single specimen is from the Mt. Elden locality (early Upper Devonian) and is deposited at the Museum of Northern Arizona (G2-81).

Description.--The dental plate is poorly preserved. A matrix of limestone fills the depressions such that many features are obscured. The outline of the tooth is that of an elongate triangle. The maximum length is 10 mm by maximum width 6 mm. The plate has eight ridges; each ridge is a sharp cutting edge along which are a few faint crenulations.

Discussion.--The specimen resembles D. nelsoni, but because of poor preservation and small size, the specific identification is not positive.

Dipterus bradyi Gass, n. sp.

Pl. 10, fig. 5

Material.--The specimen is from the Devonian Mt. Elden locality. The specimen was named for L. F. Brady who collected

the specimen for the Museum of Northern Arizona. The Museum is the repository for the specimen (G2-1835).

Description.--This upper dental element is from a very small species of Dipterus. The plate consists of five coarse, radiating tuberculated ridges extending to the postero-internal angle in a fan-shape. The dental plate is moderately convex. There is an average of five tubercles on each of the straight ridges. The plate measures 3 mm in maximum length and 3 mm in maximum width. The specimen is covered with very small punctae.

Discussion.--Because of the extreme smallness of the dental plate (three times as small as the closest related species), its straight line symmetry which is rare in dipterine teeth and coarse tuberculation that is a diagnostic morphologic feature observable on only a few species; this specimen would not fit into the definition of any previously described species. D. pectinatus Eastman (1907) is the morphologically closest species; but even it does not have the straight ridges and the characteristic small size of D. bradyi. Microscopic examination proves the specimen to be a tooth rather than a scale because of the presence of the punctae that characterize teeth.

Undeterminable genus A

Pl. 14, fig. 1

Material.--A tooth with the complete root and a fragmented crown was collected from the Dos Cabezas locality.

The specimen is on deposit at the Museum of Northern Arizona (DC-413).

Description.--The tooth has a well-defined root that tapers toward a point. The posterior portion of the root is plane, and the anterior portion is convex. The enameled portion of the crown is non-punctate, shiny, and has vertical cracks. The crown is very thin (0.4 mm) with a convex anterior face and concave posterior face. The width of the tooth is 12.8 mm at the base of the enameled crown. The root portion is 7.4 mm long.

Discussion.--The tooth is petaloid in form. Without more of the upper area of the crown a definite generic assignment is not possible.

Undeterminable genus B

Pl. 14, fig. 5

A tooth fragment was collected from the New Water Mountain locality. The specimen is similar in shape and size as undeterminable genus A; but differs in that genus B is thicker at the base of the crown and tapers toward the top of the crown.

Undeterminable genus C

Pl. 16, fig. 8

A single tooth plate from Clover Spring near the Lake Mary locality has been identified by the Museum of

Northern Arizona as a plate from a bradyodont or hybodont shark. The teeth are very crowded and were distorted during growth to a polyhedral-shape. The teeth are in low relief and have a central pointed apex. A histologic thin section was cut through the specimen to gain information regarding the nature of the supporting base. The section showed only the enamel capping of the teeth. The taxonomic affinities of this specimen are unknown.

Undeterminable genus D

Pl. 16, figs. 5-6

Isolated short cone ganoid teeth with a covering of enamel have been collected from the Lake Mary, Bottomless Pit and Rimmy Jim Tank localities. These teeth have been referred to as Lepidotus? sp. by Hussakof (1943) and as Mesodus by David (1944). Two forms are known. The first form (Pl. 16, fig. 5) is characterized by a short cone 1-2 mm high by 1-2 mm in diameter which may be modified by wear. The illustrated view is a large specimen (6 mm) which shows the attachment area to the plate. A second form (Pl. 16, fig. 6) is smaller, the teeth averaging 0.8 mm in diameter. This second form has a central pit at the apex.

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PLATE 2

- Fig. 1. - East Verde River locality looking NW.
- Fig. 2. - Dos Cabezas locality looking north with the main collecting area marked.
- Fig. 3. - Mingus Mountain locality looking east, main quarried roadcut.



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PLATE 3

Restorations of Four Fossil Fish Common in Arizona

Courtesy Wards Biological Supply

Fig. 1. - Cladodus

Fig. 2. - Cocosteus

Fig. 3. - Hybodont shark

Fig. 4. - Dipterus



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PLATE 4

Fig. 1. - Detail view of Dinichthys plate tuberculation, 5x. p. 25.

Fig. 2. - Dinichthys plate tuberculation, 2x. p. 25.

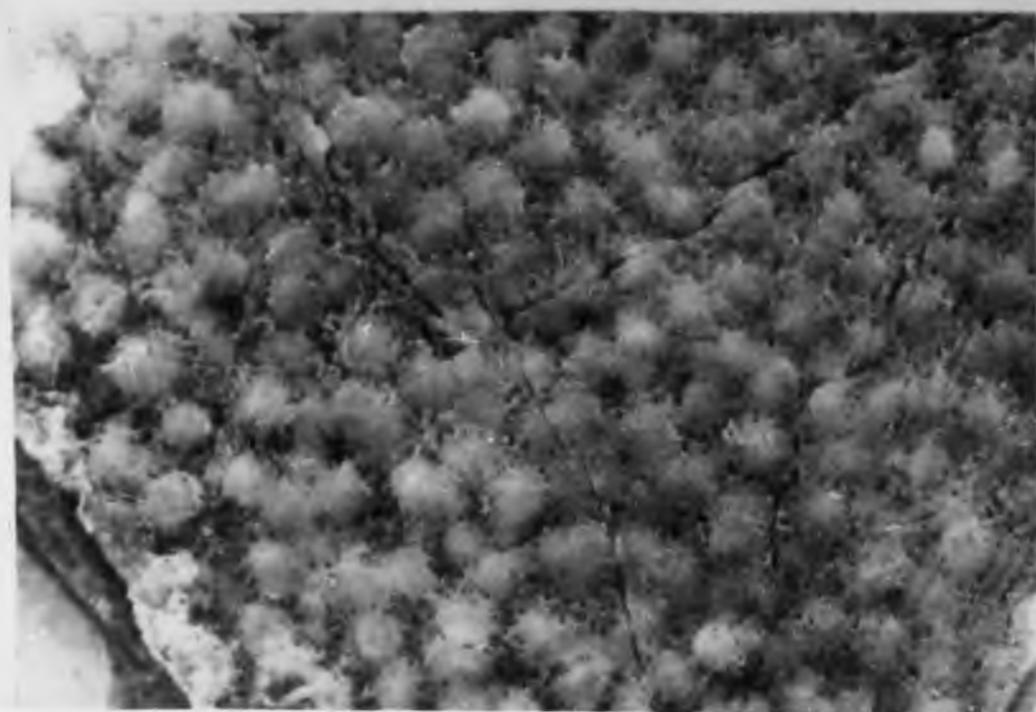


PLATE 5

Figs. 1-4. - Dinichthys thin sections of plates, 3-1/2x, p. 25 .

Fig. 5. - Cocosteus? unidentified plate in association with other plates, 3/4x. p. 24.



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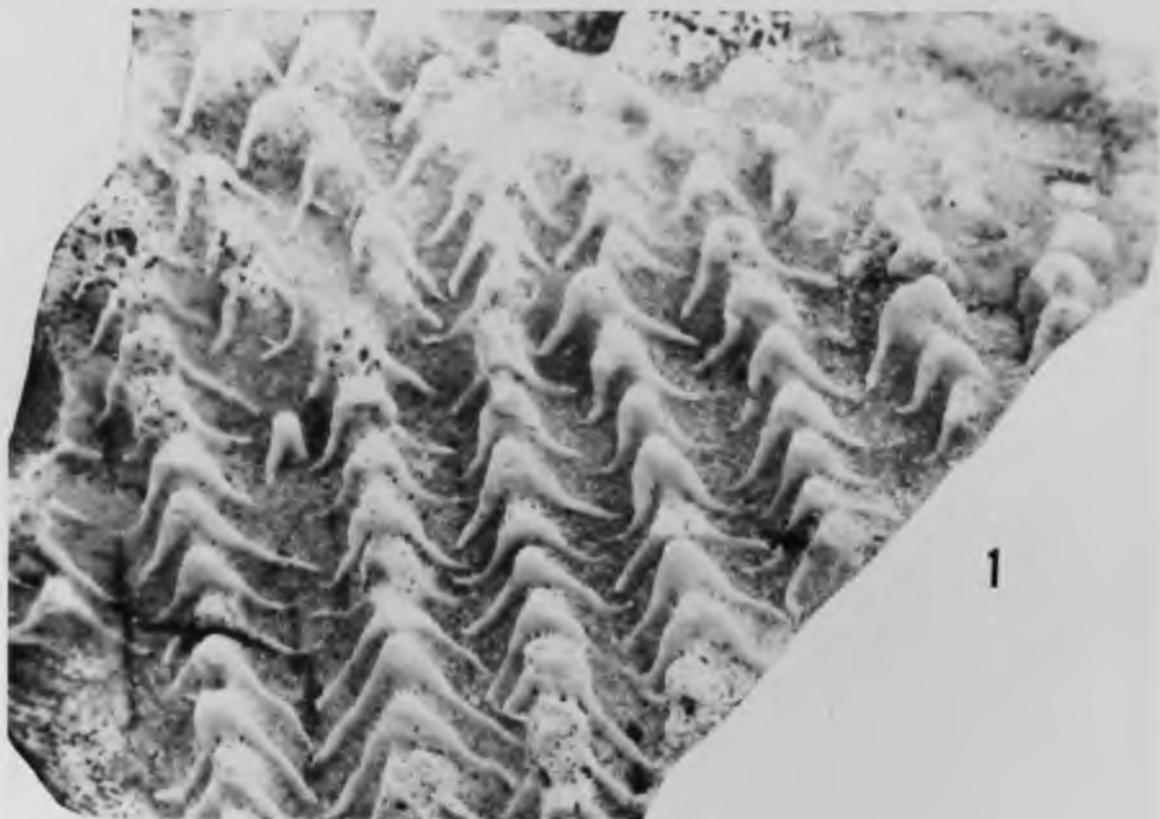
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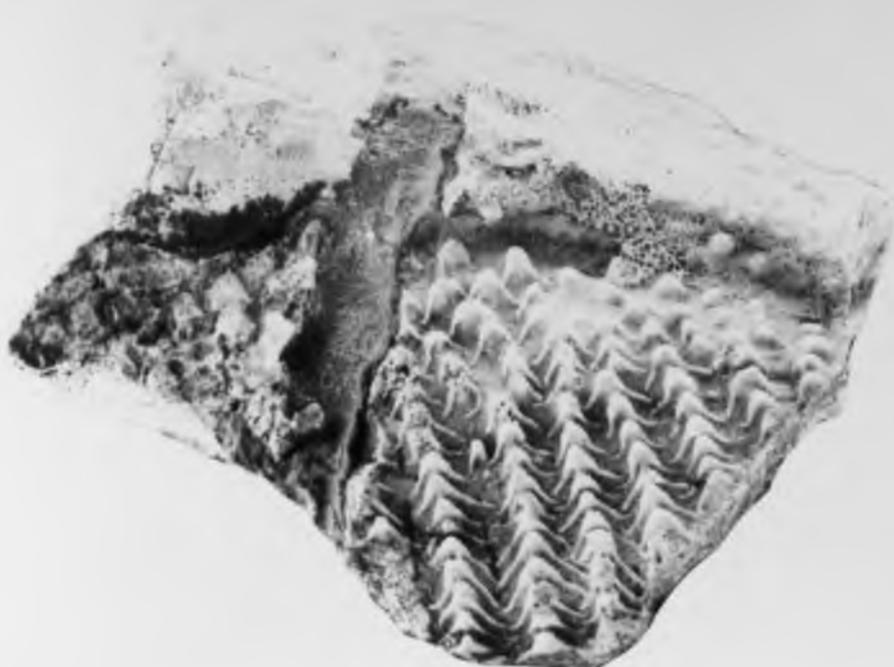
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PLATE 6

- Fig. 1. - Oestophorus sp. tuberculation pattern detail, 6x.
p. 49.
- Fig. 2. - Oestophorus sp. well-preserved plate fragment, 3x.
p. 49.



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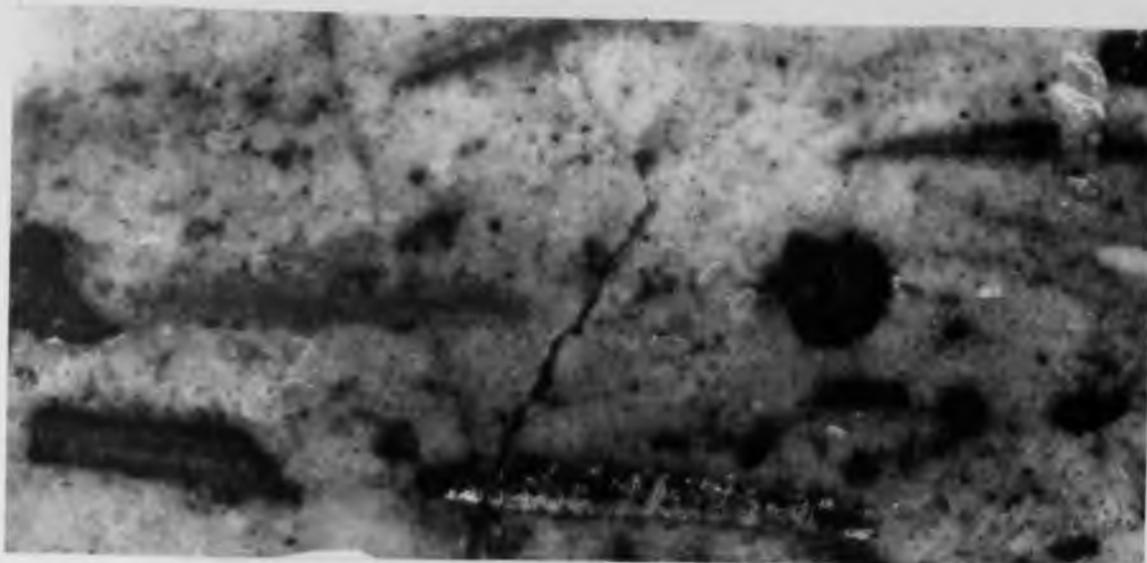


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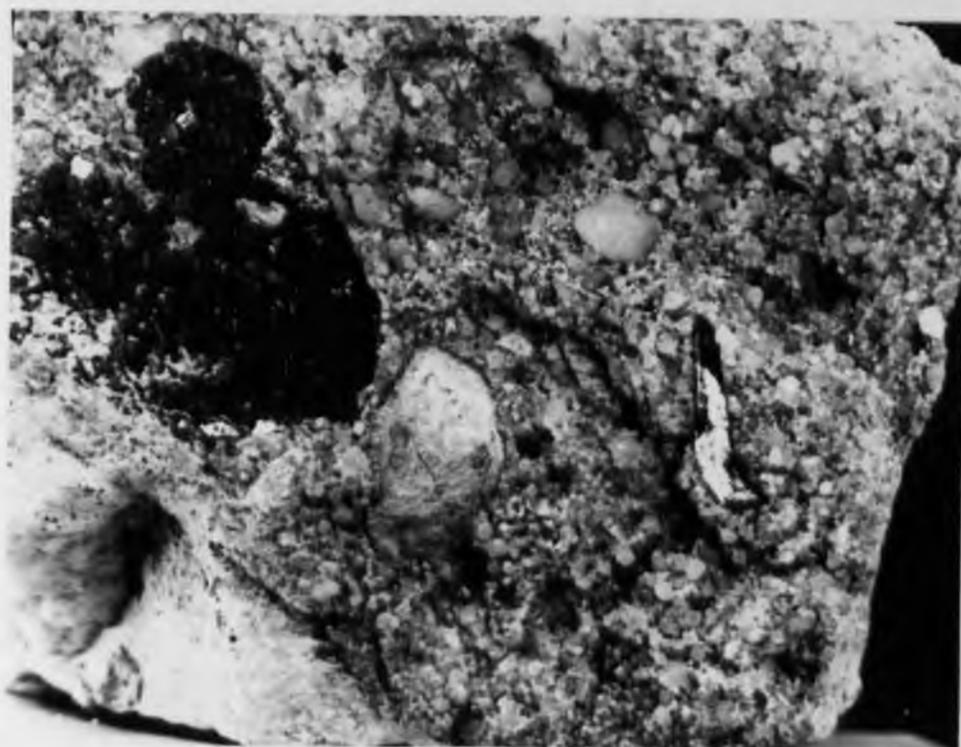
PLATE 7

Fig. 1. - Superior locality bone breccia quartzite section,
2x. p. 9.

Fig. 2. - Superior locality breccia with plates and unidenti-
fiable tooth, p. 9.



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PLATE 8

- Fig. 1. - Cocosteus? view of large dorso-median showing short posterior spine and degree of curvature, 1/2x. p. 24 .
- Fig. 2. - Cocosteus? dorsal view of dorso-median plate with spine and keel well shown, 1/2x. p. 24 .

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PLATE 9

- Fig. 1. - Dinichthys spp. Mingus Mountain locality postero-dorso lateral plate, 1/2x. p. 25.
- Fig. 2. - Ctenacanthus head spine fragment, 2x. p. 34.
- Fig. 3. - Coccosteus sp. Antero-ventro median plate, Mt. Elden locality, 3x. p. 24.
- Fig. 4. - Dinichthys spp. plate ornamentation, 5x. p. 25.
- Fig. 5. - Dinichthys spp. East Verde locality, antero-dorso lateral plate, 1/2x. p. 25.
- Fig. 6. - Plate ornamentation from Superior locality bone breccia, 2x. p. 9.

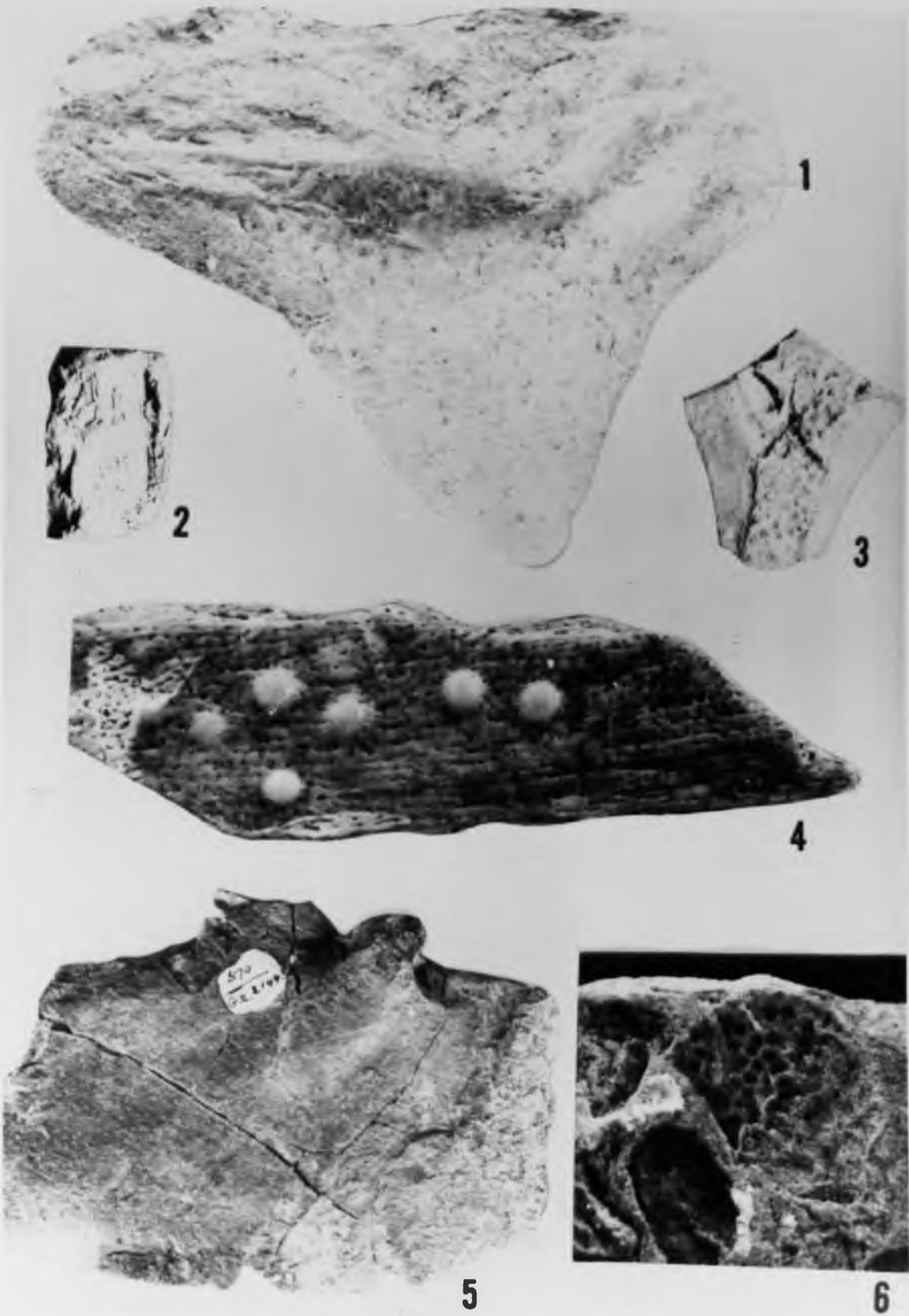


PLATE 10

- Fig. 1. - Arthrodire head shield plate of unknown form, Mt. Elden, 1-1/2x.
- Fig. 2. - Coccosteus arizonensis Hussakof, 1942. Left anterior ventro-lateral, 1-1/2x. p. 23.
- Fig. 3. - Coccosteus arizonensis Hussakof, 1942. Dorso-median, outer view, 1-1/2x. p. 23.
- Fig. 4. - Coccosteus arizonensis Hussakof, 1942. Median ventral plate, 1-1/2x. p. 23.
- Fig. 5. - Dipterus bradyi Gass, n. sp. small tooth, 3x. p. 57.
- Fig. 6. - Ptyctodus bradyi Hussakof, 1942. Lateral view of a small dental element, 1-1/2x. p. 27.
- Fig. 7. - Semionotoid scale, Dos Cabezas locality, 55x. p. 55.
- Fig. 8. - Dipterus cf. D. nelsoni, Mt. Elden locality. 3x. p. 57.



PLATE 11

- Fig. 1-2. - Janassa hussakofi Gass, n. sp.
fig. 1 - crown view, 5x. p. 45.
fig. 2 - lateral view, 5x. p. 45.
- Fig. 3-5. - Onychodus sigmoides Newberry, 1857
fig. 3.- natural mold, Mt. Elden locality, 2x. p. 22.
fig. 4 - Mingus Mountain locality, 2x. p. 22.
fig. 5 - basal cross section, 2x. p. 22.
The pulp cavity is hachured; the thin exterior
enamel surrounding the dentine is not represented.

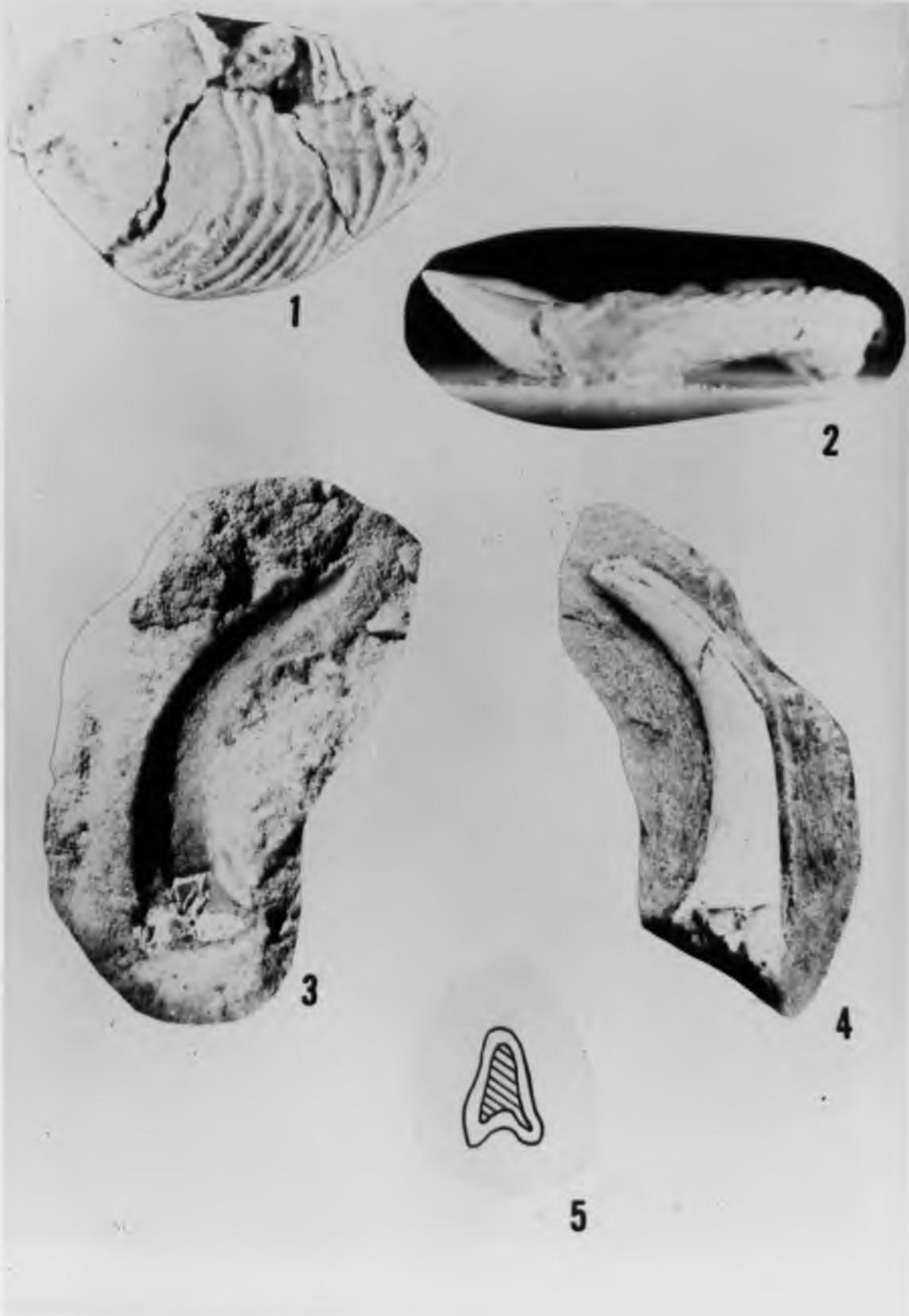


PLATE 12

- Fig. 1-2. - Petalodus milleri Gass, n. sp. p. 43.
fig. 1 - posterior face view. 2x.
fig. 2 - cross section. 2x.
- Fig. 3. - Psephodus sp. B, Galiuro Mountains locality, 3x. p. 41.
- Fig. 4. - Petalorhynchus sp. Dos Cabezas locality, 3x. p. 43.
- Fig. 5. - Deltodus spp. Dos Cabezas locality, the apparent root portion is part of the matrix, 3x. p. 39.
- Fig. 6. - Psammodus sp. Dos Cabezas locality, 3x. p. 48.
- Fig. 7. - Petalodus milleri Gass, n. sp., detail of the wrinkled enamel area, 5x. p. 43.
- Fig. 8-9.- Deltodus spp. Dos Cabezas locality, 3x. p. 39.

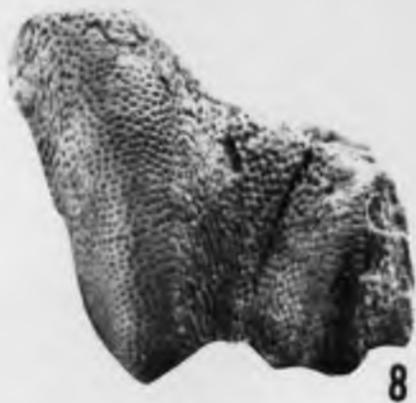
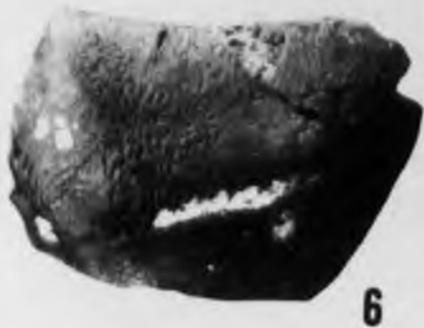


PLATE 13

- Fig. 1. - Campodus arizonensis Gass, n. sp., crown view,
4x. p. 37.
- Fig. 2, 4. - Petrodus occidentalis Newberry and Worthen, 1866
p. 36.
fig. 2 - crown view - 5x
fig. 4 - lateral view - 2x
- Fig. 3, 5. - Venustodus argutus St. John and Worthen, 1875.
p. 50.
fig. 3 - lateral view - 5x
fig. 5 - cross section - 5x
- Fig. 6 - Unidentified tooth, Dos Cabezas locality. Shows
peculiar punctate surface, 5x.



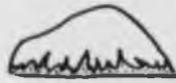
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PLATE 14

- Fig. 1. - Unidentifiable genus A, Dos Cabezas locality, 4x.
p. 58.
- Fig. 2. - Dinichthys spp. plate ornamentation, 5x. p. 25.
- Fig. 3. - Venustodus sp., ventral view, 3x. p. 51.
- Fig. 4. - Acanthodian scales - Dos Cabezas locality, 25x. p. 22.
- Fig. 5. - Unidentifiable genus B, New Water Mountain locality,
4x. p. 59.
- Fig. 6. - Cladodus earli Gass, n. sp., tooth in matrix, 1-1/2x.
p. 30.

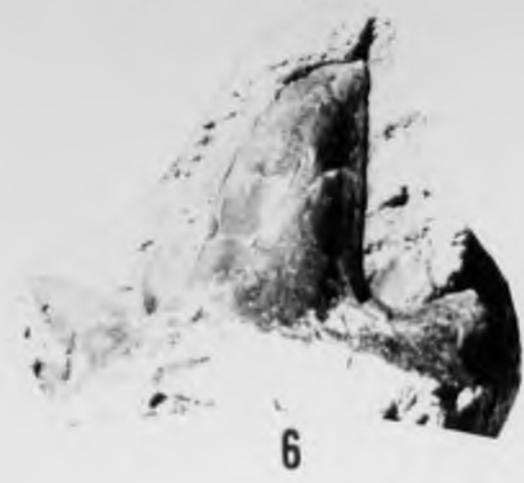
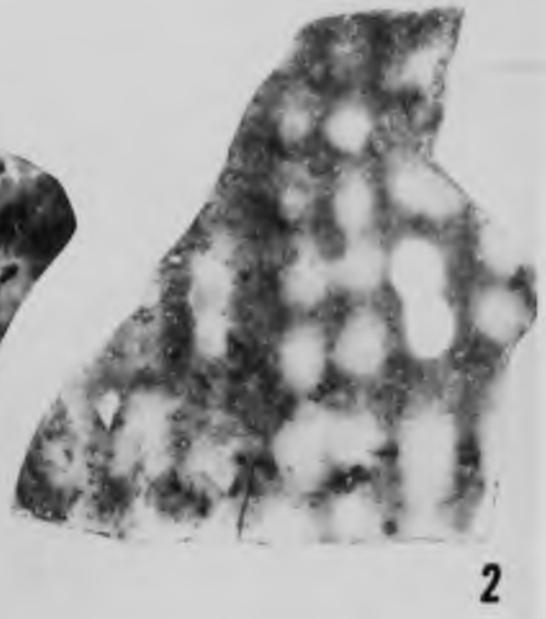
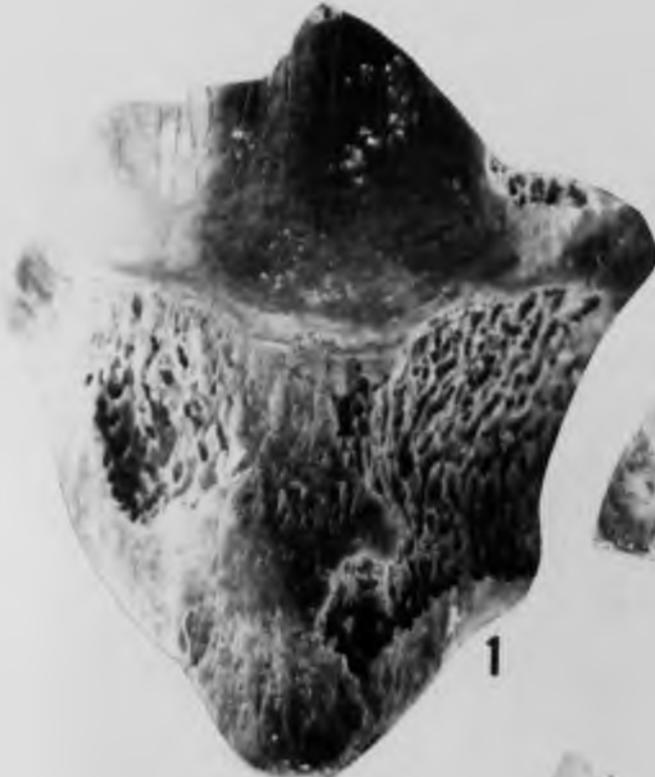


PLATE 15

- Fig. 1. - Cladodus costatus Newberry and Worthen, 1866, a posterior view of a tooth fragment, Dos Cabezas locality, 6x. p. 31.
- Fig. 2. - Cladodus cf. C. intercostatus St. John and Worthen, 1875. Dos Cabezas locality, 6x. p. 33.
- Fig. 3. - Ptyctodus calceolus Newberry and Worthen, 1866, oral surface of an isolated titor, Picacho de Calera locality, 6x. p. 28.
- Fig. 4-5. - Diplodus reidi Gass, n. sp., Picacho de Calera locality, p. 56.
fig. 3 - crown view of a tooth fragment. 6x
fig. 4 - crown view of a slightly larger tooth. 6x
- Fig. 6. - Ptyctodus calceolus Newberry and Worthen, 1866, oral surface of a very small tritator tooth, Picacho de Calera locality, 6x. p. 28.
- Fig. 7. - Cladodus cf. C. praenuntius St. John and Worthen, 1875, a large fragmental tooth posterior view, Dos Cabezas locality, 6x. p. 32.
- Fig. 8. - Ptyctodus sp., Superior locality, 6x. p. 28.
- Fig. 9. - Macrodontacanthus sp., Lake Mary locality, 1-1/2x. p. 52.
- Fig. 10. - Ptyctodus sp., Pinal Creek locality, 6x. p. 28.



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PLATE 16

- Fig. 1-3. - Sphaerolepis cf. S. arctata, Beelzebub Butte locality.
p. 55.
fig. 1 - ventral view. 1-1/2x.
fig. 2 - dorsal view. 1-1/2x.
fig. 3 - lateral view. 1-1/2x.
- Fig. 4. - Papalstanus arizonensis Gass, n. sp., Dos Cabezas
locality, crown view, 4x. p. 53.
- Fig. 5-6. - Unidentifiable genus D, Bottomless Pit locality.
p. 60.
fig. 5 - ventral view of tooth. 20x.
fig. 6 - crown view of five small teeth. 20x
- Fig. 7. - Papalstanus sp., Grand Canyon locality, 1x. p. 54.
- Fig. 8. - Unidentifiable genus C, Lake Mary locality, 2x.
p. 59.

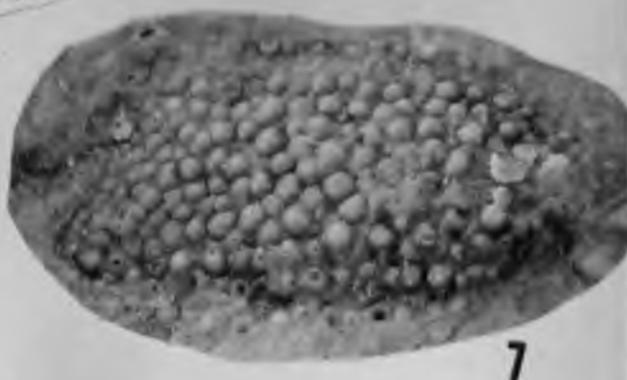
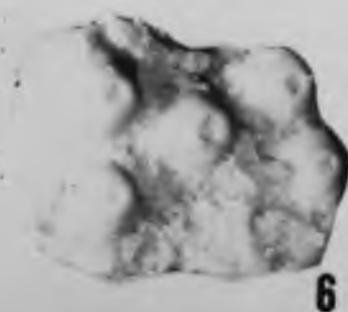
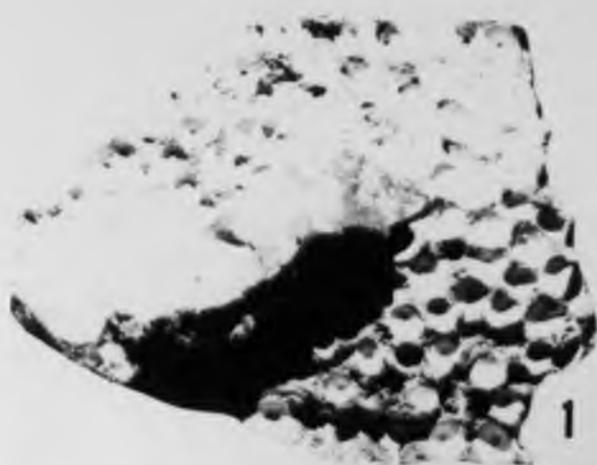


PLATE 17

Fig. 1-2. - Psephodus sp. A, Grand Canyon locality, p. 40.
fig. 1. - crown view. 1-1/2x.
fig. 2. - antero-lateral view. 1-1/2x.

Fig. 3. - Psephodus sp. C, Lake Mary locality. 1-1/2x. p. 41.

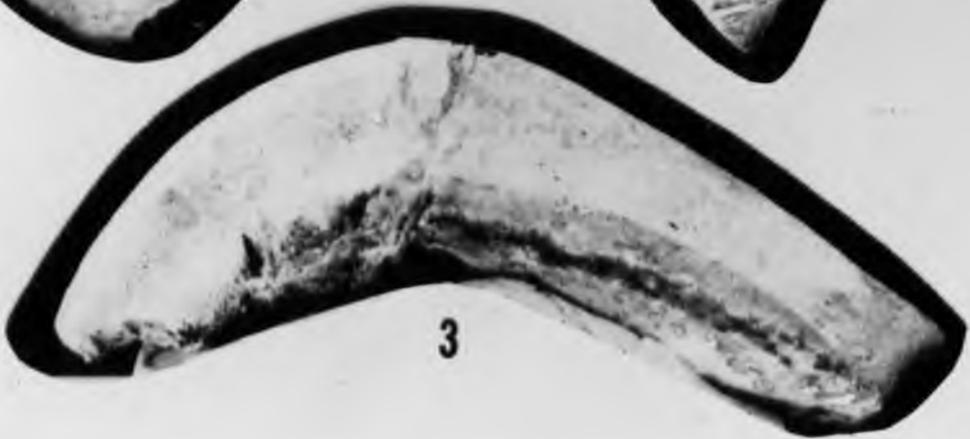


PLATE 18

- Fig. 1-4. - Megactenopetalus kaibabensis David, 1944, Sedona specimen. p. 46.
- fig. 1 - upper left dentition. 1/2x
 - fig. 2 - upper right dentition. 1/2x
 - fig. 3 - upper dentition anterior view. 1/2x
 - fig. 4 - detail of petaloid teeth. 1-1/2x

