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# PENNSYLVANIAN FISHES FROM THE SANDIA FORMATION, SOCORRO COUNTY, NEW MEXICO

ALEXANDER IVANOV<sup>1</sup>, SPENCER G. LUCAS<sup>2</sup> AND KARL KRAINER<sup>3</sup>

<sup>1</sup>Department of Paleontology, St. Petersburg University, 16 Liniya 29, St. Petersburg 199178, Russia

<sup>2</sup>New Mexico Museum of Natural History, 1801 Mountain Road N. W., Albuquerque, New Mexico 87104

<sup>3</sup>Institute for Geology & Paleontology, University of Innsbruck, Innrain 52, Innsbruck A-6020 AUSTRIA

**ABSTRACT**—We document an assemblage of fishes from the Middle Pennsylvanian (Atokan) Sandia Formation at the Arroyo de la Presilla in Socorro County, New Mexico that consists of the following taxa: *Stethacanthus* sp., *Bythiacanthus* sp., *Petalodus* cf. *P. acuminatus*, *Peripristis* cf. *P. semicircularis*, a bradyodont and Palaeonisciformes. The fish assemblage of the Sandia Formation is not taxonomically diverse but includes typical marine chondrichthyans: predators and durophagous fishes. The fish remains occur in coarse, fossiliferous limestones that form the tops of transgressive cycles and were deposited during relative sea-level highstands in a shallow, high-energy, open marine environment. The Atokan Sandia Formation localities yield a characteristic Middle Pennsylvanian chondrichthyan assemblage.

## INTRODUCTION

Fossil fishes are known from a variety of Carboniferous localities in New Mexico, most notably the Upper Pennsylvanian Kinney Quarry in the Manzanita Mountains near Albuquerque (Zidek, 1992). However, only one fish fossil has been previously reported from the Middle Pennsylvanian (Atokan) Sandia Formation—a pectoral fin spine of *Acanthodes* sp. from Socorro County (Zidek and Kietzke, 1993). Here, we document an assemblage of chondrichthyan and actinopterygian fishes from the Sandia Formation in the Arroyo de la Presilla area east of Socorro (Fig. 1). In this article, NMMNH refers to the New Mexico Museum of Natural History and Science, Albuquerque.

## GEOLOGICAL CONTEXT

At the Arroyo de la Presilla, a complete section of the Sandia Formation (~ 162 m thick) is exposed and yields conodonts of Atokan age (Lucas et al., this guidebook). We collected fossil fish (chondrichthyan and P. actinopterygian) remains from four localities in the middle to upper part of the Sandia Formation in this section: NMMNH localities 5311, 5607, 5609 and 5610 (Fig. 1).

The Sandia Formation at the Arroyo de la Presilla is composed of several mixed siliciclastic-carbonate cycles that commonly begin with crossbedded conglomerate and sandstone, grading into shale and finally into coarse, fossiliferous limestone. The transgressive cycles are composed of fluvial channel-fill sediments that grade upward into siltstone and shale and finally into coarse, fossiliferous limestone of a shallow, high-energy, open marine environment.

The lower 46 m of the Sandia Formation are almost entirely composed of siliciclastic sediments with only one thin intercalated limestone bed. The next 46 m are mostly composed of siliciclastic sediments with several intercalated fossiliferous limestone horizons containing fish remains (units 27, 29 and 39; Fig. 1). The uppermost 70 m are dominantly siliciclastic with thin limestone intervals in the upper part.

In the lower part of the section there is only one poorly exposed, thin, fossiliferous limestone bed (10-20 cm thick). In the middle and upper part limestone intervals are 0.3-2.2 m thick, commonly brownish weathered, gray to dark gray and bedded, with bed thicknesses of 5-30 cm. Typically the limestones are coarse-grained, sandy and fossiliferous, containing abundant fragments of crinoids, brachiopods, bryozoans and subordinate solitary corals. Rarely, the limestones display cross-bedding (unit 27) or appear massive.

Two microfacies types are observed: bioclastic wackestone to packstone and crinoidal wackestone to packstone. Bioclastic wackestone to packstone is coarse-grained, poorly sorted, indistinctly laminated and contains a few bioclasts (shell fragments) up to several cm in diameter. Abundant bioclasts (strongly fragmented) are bryozoans, crinoids and brachiopod shell fragments; subordinate are trilobite fragments, ostracods and brachiopod spines.

Crinoidal packstone is coarse-grained, moderately to poorly sorted, non-laminated to indistinctly laminated with grain size mostly 0.5-2 mm, rarely up to 1 cm. This microfacies contains abundant crinoid stem fragments, and detrital, angular to subangular quartz grains. Subordinate are bryozoans, brachiopod shell fragments and spines and rare trilobite fragments and ostracods. This type is well washed and calcite cemented. Quartz is present in various amounts, mostly < 5%; individual thin layers contain 20-70% quartz.

A large fragment of a *Bythiacanthus* fin spine and the fragment of petalodontid tooth were found at locality 5311. The fish-bearing deposits of locality 5607 contain the teeth of *Stethacanthus* sp., fragments of undetermined cladodont teeth, a tooth of *Peripristis* cf. *P. semicircularis* (Newberry & Worthen), fragments of petalodontid teeth, an incomplete bradyodont tooth plate, and a fulcral scale of Palaeonisciformes (Fig. 2A). Fragments of petalodontid teeth were recovered at locality 5609, and a tooth of *Petalodus* cf. *P. acuminatus* Agassiz and a spine fragment of an undetermined shark were collected at locality 5610. The best-preserved chondrichthyan remains are described in this paper.

## SYSTEMATIC PALEONTOLOGY

**Class Chondrichthyes Huxley, 1880**  
**Subclass Elasmobranchii Bonaparte, 1838**  
**Order Symmoriida Zangerl, 1981**  
**Family Stethacanthidae Lund, 1974**  
**Genus *Stethacanthus* Newberry, 1889**  
*Stethacanthus* sp.

Fig. 2B-D

**Description:** The isolated teeth (NMMNH P-42310, P-42312) found at locality 5607 are moderately well preserved, with partially abraded surfaces. They are of moderate size: basal length of well-preserved tooth (NMMNH P-42310) = 26.1 mm, tooth height with central cusp = 14.6 mm. The teeth have a cladodont crown with five cusps and a flat base. The cusps are rounded in cross section. The large median cusp is slightly inclined lingually above the base. It bears distinct straight or slightly curved cristae on all cusp surfaces. The lateral cusp is higher than the intermediate ones. The base has a trapezoidal lingual torus, a button on the occlusal side and a labio-basal projection on the basal side.

**Discussion:** *Stethacanthus* has been recorded from strata of Late Devonian to Middle Permian age in different regions of the world. Such descriptions are usually based on isolated teeth, but only the Late Famennian-Early Carboniferous species *Stethacanthus altonensis* (St. John & Worthen) is known from articulated skeletons (e.g., Williams, 1985). Most teeth defined as *Stethacanthus* need to be reviewed to determine their generic and specific affinities. However, most of the Late Devonian teeth referred to the genus actually belong to *Cladodoides*, a primitive cladodont shark probably related to ctenacanthid chondrichthyans (Ginter and Maisey, 2007). On the other hand, some taxa described as separate genera based on teeth should be referred to the genus *Stethacanthus*. Thus, the genus *Pinegocaptus* (= *Pinegia*), from the Permian of northern European Russia (Minikh, 2004, 2006), is a junior synonym of *Stethacanthus*.

**Order Ctenacanthiformes Glikman, 1964**  
**Ctenacanthiformes incertae sedis**  
**Genus *Bythiacanthus* St. John & Worthen, 1875**  
*Bythiacanthus* sp.

Fig. 3

**Description:** The median part of a fin spine (NMMNH P-42303) from locality 5311 has broken distal and proximal parts but possesses an ornamentation region with well preserved tubercles. The fin spine is large, thick and considerably compressed laterally. Maximum preserved length = 135 mm, maximum widths of the broken ends are 69 mm and 53 mm. The anterior edge of the spine is rounded, and the posterior face is strongly concave. The deep posterior depression can be traced along the entire posterior face of the spine fragment. The transverse sections in the broken edges exhibit a very massive anterior portion of the spine. The lateral walls separated by the depression are thick and have rounded edges. The ornamentation includes rounded or slightly

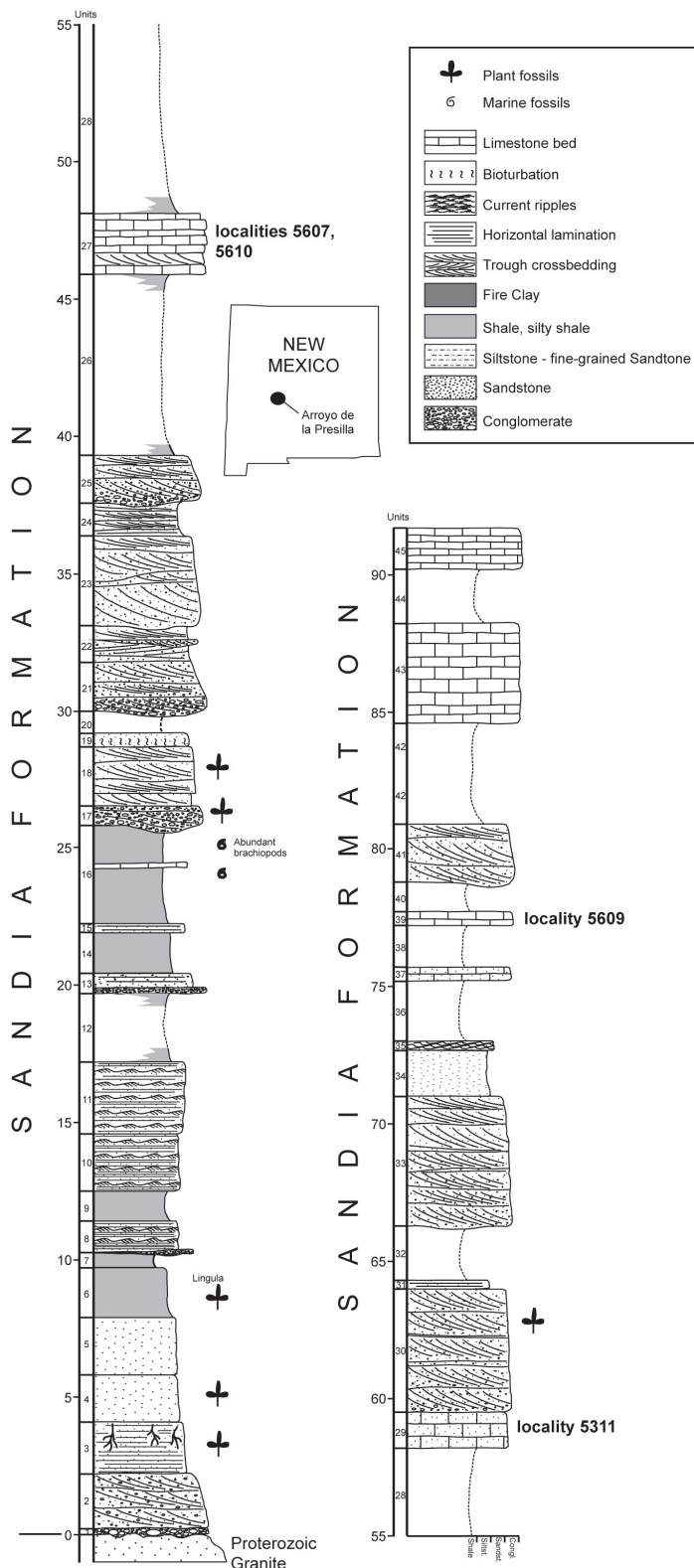


FIGURE 1. Measured section of the lower-middle part of the Sandia Formation at the Arroyo de la Presilla. Section measured in the NE  $\frac{1}{4}$  NE  $\frac{1}{4}$  sec. 11. The fossil fish localities are indicated in beds 27, 29 and 39.



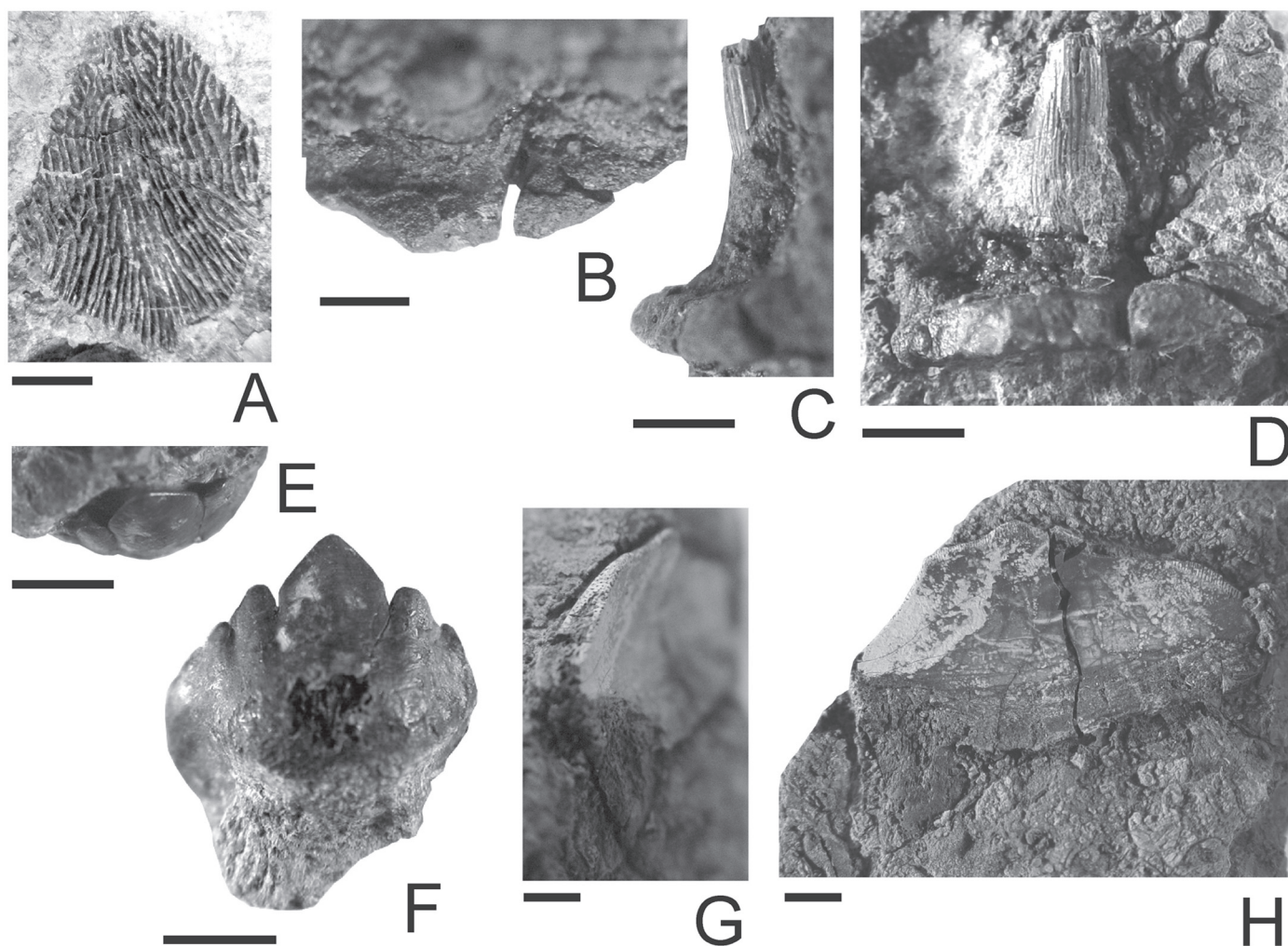


FIGURE 2. Fish remains of the Sandia Formation. A, Palaeonisciformes, NMMNH P-58202, fulcral scale, external view, locality 5607. B-D, *Stethacanthus* sp., NMMNH P-42310, tooth in B – occlusal, C – lateral and D – lingual views, locality 5607. E-F, *Peripristis* cf. *P. semicircularis* (Newberry & Worthen, 1866), NMMNH P-42314, tooth in E – occlusal and F – labial views, locality 5607. G-H, *Petalodus* cf. *P. acuminatus* (Agassiz, 1838), NMMNH P-423050, tooth in G – lateral and H – lingual views, locality 5610. Scale bars equal 5 mm.

oval tubercles with radiating ridges, which are arranged in closely-spaced rows. The tubercles on the distal part of the fragments have a flattened top and are placed more compactly in the rows than the conical tubercles from the proximal part. The tubercle rows are straight in the distal part but slightly curved and sometimes bifurcate near the proximal margin of the ornamentation region.

**Discussion:** The preservation of the fin spine does not allow us to determine the species, but it closely resembles the spines of *Bythiacanthus brevis* (Agassiz) known from the Lower Carboniferous of the Bristol region, England (Agassiz, 1837) and *B. peregrinus* (Khabakov) found in the Lower Carboniferous of the Kuznetsk Basin, Siberia, Russia (Khabakov, 1928).

**Subclass Euchondrocephali Lund & Grogan, 1997**

**Order Petalodontiformes Zangerl, 1981**

**Family Petalodontidae Newberry & Worthen, 1866**

**Genus *Petalodus* Owen, 1840**

***Petalodus* cf. *P. acuminatus* (Agassiz, 1838)**

**Fig. 2G-H**

**Description:** The lateral tooth (NMMNH P-42305) from locality 5610 possesses a crown with a broken lateral edge and a poorly preserved, incomplete base. The tooth is symmetrical and slightly sigmoid in profile. The crown (16.2 mm tall) has a moderately curved and broad rhomboid shape. It has a convex labial side and a concave lingual side, a few basal ridges on the lingual side and a slightly prominent tip. The base is flattened and narrower than the crown.

**Discussion:** *Petalodus* is common in the marine Carboniferous and Lower Permian deposits of many regions. Petalodontids are known mainly from isolated teeth, except for *Janassa*, *Belantsea*, *Netsepoye* and *Siksika*, which were described from articulated specimens (Lund, 1989). Besides the latter four genera, petalodontid taxa were established in papers published during the nineteenth century, and many of them were not redescribed after that. Thus, the genus *Petalodus* is a taxon that definitely requires a taxonomic revision of all known species.

*Petalodus ohioensis* Safford is frequently mentioned in the late Palaeozoic chondrichthyan assemblages of North America.

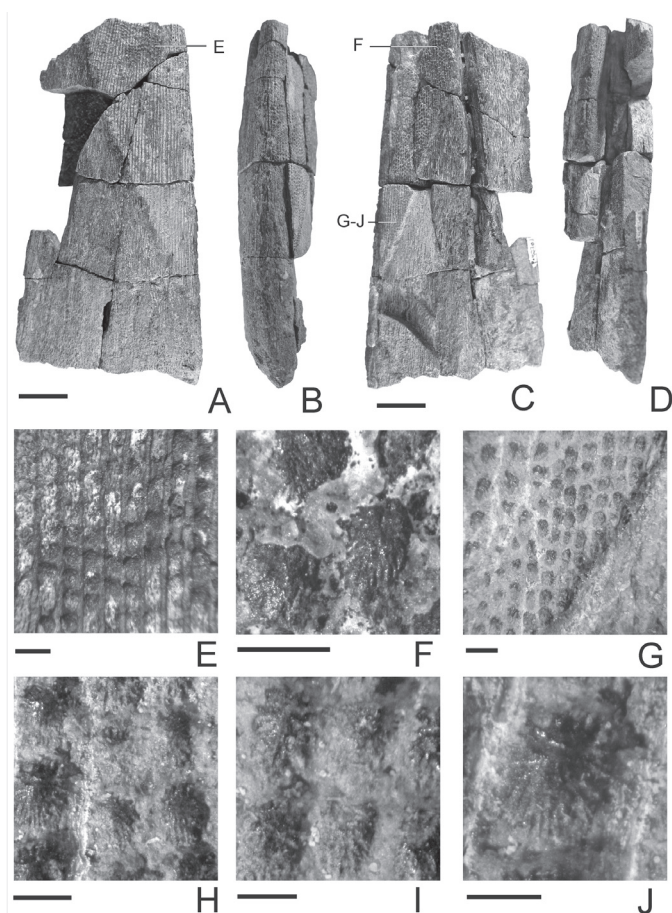


FIGURE 3. Fin spine of *Bythiacanthus* sp. from the Sandia Formation, locality 5311, NMMNH P-42303; A, right side, B, anterior, C, left side, D, posterior views, E-J, ornament details, position of details shown on A and C. Scale bars for A-D = 20 mm, E, G = 1 mm, F, H, I = 0.5 mm, J = 0.25 mm.

The teeth of *P. acuminatus* Agassiz differ from those of *P. ohioensis* in the wide, lingually-ridged band according to Hansen (1997), and in their smaller tooth size and equally short crown and base according to Zidek and Kietzke (1993). However, the lingual band of *P. ohioensis* teeth described by various authors from different localities displays a large variation in width. Such differences could be explained by the position of the teeth in the heterodontous dentition of one *Petalodus* species. Probably, a detailed redescription of Safford and Agassiz's type collections will allow recognition of, or synonymy of those species. Indeed, such a redescription may demonstrate that the tooth referred by us to *P. cf. P. acuminatus* should be assigned to *P. ohioensis*.

#### Family Pristodontidae Woodward, 1889

##### Genus *Peripristis* St. John, 1870

##### *Peripristis* cf. *P. semicircularis* (Newberry & Worthen, 1866)

##### Fig. 2E-F

**Description:** The upper(?) tooth (NMMNH P-42314) from locality 5607 has a well-preserved crown and incomplete base. The crown is smooth, curved labiolingually, is triangular in the

cuspidate part, and has a well developed cutting edge but lacks basal ridges on the labial face. The tooth is very small: crown width = 12.5 mm, crown height = 8.2 mm. The cross section of the crown is u-shaped: the labial surface is convex, the lingual is concave. The five cusps are angular. The large, triangular median cusp is separated from the medium-sized intermediate cusps by narrow notches. The intermediate and smaller lateral cusps are more elongate and narrow. All cusps are distinguished by distinct radial grooves on the labial side. The tooth base is short, narrower than the crown and more flattened, especially on the lingual side. The base is separated from the crown by a shallow depression.

**Discussion:** The complete dentition is unknown in *Peripristis*, but in another pristodontid, *Siksika ottae* Lund, there is considerable heterodonty in the jaws (Lund, 1989). *Peripristis* is a monospecific genus--*Peripristis semicircularis* (Newberry & Worthen) occurs in the Lower Carboniferous-Lower Permian of the USA. The teeth described from the different localities as *P. semicircularis* exhibit a wide variation in tooth morphology. Probably, they should be assigned to more than one species of the genus. The tooth described here most resembles the tooth illustrated by Zidek (1992, fig. 9A) from the Virgilian of Kansas.

#### DISCUSSION

The fish assemblage of the Sandia Formation is not taxonomically diverse but includes typical marine chondrichthyans: predators and durophagous fishes. The fish remains occur in coarse, fossiliferous limestones that form the tops of transgressive cycles in the middle of the Sandia Formation. The limestones were deposited during relative sea-level highstands in a shallow, high-energy open marine environment.

The late Paleozoic genus *Stethacanthus* is a widely distributed taxon. *Petalodus acuminatus* Agassiz and *P. ohioensis* Safford are common in the Carboniferous and Lower Permian of the USA, England, Italy, Slovenia and Russia (Lebedev, 2001; Elliott et al., 2004). In New Mexico, *Petalodus* determined as *P. ohioensis* is found in the Middle Pennsylvanian (Gray Mesa Formation, Desmoinesian) of the Cerros de Amado, Socorro County (Lucas and Estep, 2000); *P. acuminatus* has been mentioned from the Middle Pennsylvanian (Flechado Formation, Atokan-Desmoinesian), near Talpa, Taos County (Zidek and Kietzke, 1993); and *Petalodus* belonging to the group of those species is reported from the Upper Pennsylvanian (Missourian) and Lower Permian (Wolfcampian) strata of the Horquilla Formation in the Big Hatchet Mountains, Hidalgo County (Ivanov et al., 2007).

*Peripristis* and *Bythiacanthus* are not common in Carboniferous chondrichthyan assemblages. *Peripristis semicircularis* (Newberry & Worthen) occurs in the Upper Mississippian (Cheslerian)-Lower Permian (Wolfcampian) of the North American midcontinent (Hansen, 1984) but is most abundant in the Pennsylvanian of Indiana, Kansas and Nebraska. This species in New Mexico is reported from the Upper Pennsylvanian Kinney Quarry in the Manzanita Mountains (Zidek, 1992). *Bythiacanthus* is known from the Early Carboniferous of England, Russia (Kuznetsk Basin) and from Illinois, Kentucky and Tennessee in the USA (Maisey, 1982); from the Middle Pennsylvanian



(Minturn Formation, Desmoinesian) of Colorado (Itano et al., 2003) and the Upper Pennsylvanian (Stanton Formation, Missourian) of Nebraska (Maisey, 1983).

The Minturn Formation locality in Colorado yields *Bythiacanthus*, *Peripristis semicircularis*, *Petalodus ohioensis* and some cladodont sharks similar to the fish localities of the Sandia Formation. Such a taxonomic composition of the fish assemblage is characteristic of the Middle-Late Pennsylvanian, so the Atokan Sandia Formation localities yield a characteristic Middle Pennsylvanian chondrichthyan assemblage.

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### REFERENCES

- Agassiz, J. L. R., 1833-1843, Recherches sur les Poissons Fossiles. 5 vols., Neuchâtel (Nicolet), Imprimerie de Petitpierre, 1420 p. + supplement.
- Bonaparte, C. L. J. L., 1838, Selachorum tabula analytica. Nuovi Annali delle Scienze Naturali, v. 1, p. 195-214.
- Elliott, D.K., Irmis, R. B., Hansen, M.C., and Olson, T., 2004, Chondrichthyans from the Pennsylvanian (Desmoinesian) Naco Formation of Arizona: Journal of Vertebrate Paleontology, v. 24, p. 268-280.
- Ginter, M. and Maisey, J. G., 2007, The braincase and jaws of *Cladodus* from the Lower Carboniferous of Scotland: Palaeontology, v. 50, p. 305-322.
- Glikman, L. S., 1964, Akuly Paleogena i ih stratigraficheskoe znachenie [Paleogene Sharks and their stratigraphic significance]. Nauka, Moskva, 228 pp. [in Russian].
- Hansen, M. C., 1984, Systematic relationships of petalodontiform chondrichthyans; in Duto, J. T., Jr. and Pfefferkorn, H. W., eds., Compte Rendu, vol. 5, Paleontology, Paleogeology, Paleogeography, Neuvième Congrès International de Stratigraphie et de Géologie du Carbonifère. Southern Illinois University Press, Carbondale and Edwardsville, p. 523-541.
- Hansen, M.C., 1997, Phylum Chordata—vertebrate fossils; in Feldman, R.M. and Hackathorn, M., eds., Fossils of Ohio. Ohio Division of Geological Survey, Bulletin 70, p. 288-369.
- Huxley, T. H., 1880, On the application of the laws of evolution to the arrangement of the Vertebrata and more particularly of the Mammalia: Proceedings of the Zoological Society of London, 1880, p. 649-662.
- Itano, W. M., Houk K. J. and Lockley M. J., 2003, *Ctenacanthus* and other chondrichthyan spines and denticles from the Minturn Formation (Pennsylvanian) of Colorado: Journal of Paleontology, v. 77, p. 524-535.
- Ivanov, A.O., Lucas, S.G., Rinehart, L.F., and Spielmann, J.A., 2007, Pennsylvanian-Permian petalodont chondrichthyan from the Big Hatchet Mountains, southern New Mexico: New Mexico Geology, v. 29, p. 62.
- Khabakov, A.V., 1928, Description of new species of ichthyodolites of the genus *Ctenacanthus* Ag. from the Carboniferous deposits of USSR: Izvestiya Geologicheskogo Komiteta, v. 47, p. 23-31 [in Russian with English summary].
- Lebedev, O.A. 2001, Vertebrates; in Makhlina, M. K., Alekseev, A. S., Goreva, N.V., Gorjunova, R.V., Isakova, T. N., Kossovaya, O. L., Lazarev, S. S., Lebedev, O. A. and Shkolin, A. A., eds., Srednij Karbon Moskovskoy sineklizy (yuzhnaya chast') [Middle Carboniferous of the Moscow syncline (southern part)]. Volume 2. Paleontologicheskaya kharakteristika [Paleontological characteristics]: Nauchnyj Mir, Moscow, p. 196-201 [in Russian].
- Lucas, S.G. and Estep, J.W., 2000, Pennsylvanian selachians from the Cerros de Amado, central New Mexico: New Mexico Museum of Natural History and Science, Bulletin 16, p. 21-28.
- Lucas, S. G., Krainer, K. and Barrick, J. E., 2009, Pennsylvanian stratigraphy and conodont biostratigraphy in the Cerros de Amado, Socorro County, New Mexico: New Mexico Geological Society, 60<sup>th</sup> Fall Field Conference Guidebook, p. 183-212.
- Lund, R., 1974, *Stethacanthus altonensis* (Elasmobranchii) from the Bear Gulch limestone of Montana: Annals of the Carnegie Museum, v. 45, p. 161-178.
- Lund, R., 1989, New petalodonts (Chondrichthyes) from the Upper Mississippian Bear Gulch Limestone (Namurian E2b) of Montana. Journal of Vertebrate Paleontology, v. 9, p. 350-368.
- Lund, R. and Grogan, E. D., 1997, Relationships of the Chimaeriformes and the basal radiation of the Chondrichthyes: Reviews of Fish Biology and Fisheries, v. 7, p. 65-123.
- Maisey, J. G., 1982, Studies on the Paleozoic selachian genus *Ctenacanthus* Agassiz: No. 2. *Bythiacanthus* St. John and Worthen, *Amelacanthus*, new genus, *Eunemacanthus* St. John and Worthen, *Sphenacanthus* Agassiz, and *Wodnika* Münster: American Museum Novitates, no. 2722, p. 1-24.
- Maisey, J., 1983, Some Pennsylvanian chondrichthyan spines from Nebraska: Transactions of the Nebraska Academy of Sciences, v. 11, p. 81-84.
- Minikh, A.V., 2004, New sharks from the Permian Ufimian and Kazanian stages of northern regions of European Russia; in Ivanov A.V., ed., Voprosy paleontologii i stratigrafii verkhnego Paleozoya i Mezozoya: Saratov, p.128-132 [in Russian].
- Minikh, A.V., 2006, Class Chondrichthyes; in Grunt T.A., ed., Perm' Poluostrova Kanin: "Nauka," Moscow, p. 180-183 [in Russian].
- Newberry, J. S., 1889, The Paleozoic fishes of North America: U.S. Geological Survey, Monograph 16, 340 p.
- Newberry, J. S. and Worthen, A. H., 1866, Descriptions of vertebrates: Geological Survey of Illinois, v. 2, p. 11-141.
- Owen, R., 1840-45, Odontography; or treatise on the comparative anatomy of the teeth; their physiological relations, mode of development, and microscopic structure in the vertebrate animal. 2 vols., Hippolyte Bailliere, London, 655 p.
- St. John, O. H., 1870, Descriptions of fossil fishes from the upper Coal Measures of Nebraska: Proceedings of the American Philosophical Society, v. 11, p. 431-437.
- St. John, O. H. and Worthen, A. H., 1875, Descriptions of fossil fishes: Geological Survey of Illinois, v. 6, p. 245-488.
- Williams, M. E., 1985, The "cladodont level" sharks of the Pennsylvanian black shales of central North America: Palaeontographica A, v. 190, p. 83-158.
- Woodward, A. S., 1889, Catalogue of the fossil fishes in the British Museum, Part I. Trustees, British Museum of Natural History, London, 474 p.
- Zangerl, R., 1981, Chondrichthyes 1. Paleozoic Elasmobranchii, Gustav Fischer Verlag, Stuttgart, 115 p.
- Zidek, J., 1992, Late Pennsylvanian Chondrichthyes, Acanthodii, and deep-bodied Actinopterygii from the Kinney Quarry, Manzanita Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 138, p. 145-182.
- Zidek, J. and Kietzke, K. K., 1993, Pre-Permian vertebrates of New Mexico, with remarks on some Early Permian specimens: New Mexico Museum of Natural History and Science, Bulletin 2, p. 1-10.