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William I. AUSICH & M. Cemal GÖNCÜOĞLU

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Juvenile eucladid crinoid from the Middle Devonian of Turkey

William I. AUSICH
School of Earth Sciences, 155 South Oval Mall,
The Ohio State University, Columbus, OH 43210 (United States)
ausich.1@osu.edu

M. Cemal GÖNCÜOĞLU
Department of Geological Engineering,
Middle East Technical University, Ankara (Turkey)
mcgoncu@metu.edu.tr

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ABSTRACT
A microcrinoid-sized eucladid crinoid (Eucladida Wright, 2017) is described from the Yığınlı Formation (Devonian, Famennian) in the Büyük Zap Anticline in the Hakkari region of SE Turkey. Compared to other eucladids of similar size, the Yığınlı Formation specimen is at a quite advanced morphological stage with arms present through at least the secundibrachials. Early post-larval development is a key for understanding homologies among crinoid clades; however Paleozoic crinoids in the microcrinoid range (≤ 2.0 mm) are very rare. This specimen is either at a very advanced developmental stage for its size, or typical microcrinoids are neotenic.

KEY WORDS
Crinoid,
Devonian,
Famennian,
Hakkari,
southeastern Turkey.

RÉSUMÉ
Crinoïdes eucladides juvéniles du Dévonien moyen de Turquie.
Une micro-crinoïde eucladide (Eucladida Wright, 2017) est décrite de la Formation Yığınlı (Dévonien, Famennien, anticlinal Büyük Zap, région d'Hakkari, sud-est de la Turquie). Comparé à d'autres eucladides de même taille, ce spécimen est à un stade morphologique un peu plus avancé, avec des bras présents au moins jusqu'aux secundibrachiales. Le développement post-larvaire est une clé pour la compréhension des homologies au sein des clades de crinoïdes. Cependant, les crinoïdes paléozoïques de la taille de celles des micro-crinoïdes (≤ 2.0 mm) sont très rares. Ce spécimen est soit à un stage de développement très avancé pour sa taille ou bien les micro-crinoïdes typiques sont néoténiques.

MOTS CLÉS
Crinoïdes,
Dévonien,
Famennien,
Hakkari,
Turquie du Sud-Est.

INTRODUCTION

Confident homology statements are required for robust phylogenetic analyses, but this may be difficult due to disparate adult morphologies. This is especially true among echinoderm clades (Sumrall & Waters 2012), as well as among major clades of the Crinoidea. Study of early post-larval development provides important data for understanding homologies (e.g., Lane & Sevastopulo 1982a, b; Sevastopulo & Lane 1988; Ausich 1996; Wright 2015; Ausich *et al.* 2020). The early post-larval developmental stages are known for only a very few Paleozoic crinoids, which makes the specimen described here an important discovery despite the fact that it cannot be assigned to a genus or species with certainty.

The first Paleozoic crinoidal remains described from Turkey were based on isolated columnals (Arthaber 1900). *Arachnocrinus sarizensis* Webster, Yılmaz & Kozluc, 2008 was the first Paleozoic crinoid described from Turkey based on crown material, but it was based largely on disarticulated material, including isolated brachial plates, a juvenile aboral cup, holdfast, and columnals. *Arachnocrinus sarizensis* is Middle Devonian in age. In this report, we describe the first nearly complete crinoid known from Paleozoic strata of Turkey. This new specimen is from the uppermost part of the Yığınlı Formation in the Büyük Zap Anticline in the Hakkari region of SE Turkey. It is a eucladid crinoid. Despite being nearly complete, this new specimen is a juvenile individual for which adult characters cannot be determined with certainty, which precludes confident assignment to a genus or species.

GEOLOGICAL FRAMEWORK

In Anatolia, thick Paleozoic sedimentary successions of northeastern Gondwana-origin crop out in the Istanbul-Zonguldak, Tauride-Anatolide, and the SE Anatolian terranes (Fig. 1A) (Göncüoğlu 1997; Yalçın & Yılmaz 2010). In the Hakkari province of SE Turkey in the northern promontory of the Arabian microcontinent, more or less complete Paleozoic successions occur in a number of E-W trending anticlines. Between the towns of Hakkari and Cukurca close to the Iraq border, Upper Devonian and lower Carboniferous rocks were reported (Janvier *et al.* 1984) in the cores of two east-west-trending anticlines, the Büyük Zap Anticline to the north and the smaller Cukurca Anticline to the south (Fig. 1B). The best exposures are along the Zap and Cevizlik rivers cutting through these structures. In the former one, the succession comprises the Cambrian Sadan, Zabuk and Koruk formations and the Ordovician Seydişehir and Bedinan formations, respectively (Bozdoğan & Ertuğ 1997; Dean 2006).

The unconformably overlying Middle Devonian-early Carboniferous Zap Group is divided into the Yığınlı (Middle-Late Devonian) and Köprülü (early Carboniferous) formations (e.g. Gourvennec & Hoşgör 2012). The Group is unconformably overlain by the Late Permian Gomaniibrik Formation (Yılmaz & Duran 1997).

The new fossil crinoid specimen is from the Yığınlı Formation, which was named by Açıkbaş (1978). In the northern and southern flanks of the Büyük Zap Anticline, the thickness of this formation varies between 200 and 270 metres, respectively. Overall the formation is brick-red colored arenites, dolomites, and grey to greenish mud- and siltstones (Yalçın & Yılmaz 2010). In the southerly located Çukurca anticline, five informal members were recognised (e.g. Higgs *et al.* 2002). From bottom to the top these members are: 1) brown dolomites alternating with red shales representing carbonate intertidal flats and a muddy coastal plain; 2) pink quartz-sandstones and grey shales of fluvial-wave influenced deltaic environment; 3) red sandstones and siltstones with upward thinning sequences, which represent continental fluvial deposits; 4) Tidal-wave influenced grey sandstones and grey siltstones/shales including echinoderms; and 5) alternation of grey mudstones with thin dolomites and limestones characterizing a carbonate-dominated complex of intertidal, shoreline, and marine shelf environments (Higgs *et al.* 2002). This new juvenile crinoid reported here is from the lower part of Member 5 of the Yığınlı Formation (Fig. 2). The small slab containing this new juvenile also contains brachiopods, bryozoans, and other crinoid columnals.

The overlying Köprülü Formation consists mainly of shallow marine carbonates and includes three informal members (Hoşgör *et al.* 2014). The lower member, representing a transgressive phase above the Yığınlı Formation, is dark grey and light pink silty and sandy limestones. The lower part of this member includes a fish fauna (Janvier *et al.* 1984) and corals (Denayer & Hoşgör 2014). Stratigraphically above is an alternation of thinly laminated, dark gray, calcareous shales and siltstones with gray limestone interbeds of the middle member with bivalves and cephalopod remains (Hoşgör *et al.* 2014). The upper part of this member characteristically includes carbonate concretions. The upper member of the Köprülü Formation is a sequence of massive grey limestones with dolomitic interbeds.

In previous studies, the upper part of the Yığınlı Formation was dated by the aid of fish remains indicating a latest Devonian (Strunian) age (Janvier *et al.* 1984). More recently, miospore taxa suggesting a Famennian age have been reported from the same strata in the upper part of the Yığınlı Formation in the southern Çukurca anticline (Higgs *et al.* 2002). The Middle Devonian (upper Givetian) brachiopods reported by Gourvennec & Hoşgör (2012) from the upper middle part (Member 4 of Higgs *et al.* 2002) provided evidence for an even earlier deposition age for the formation.

Just above the boundary-dolomite in the Middle Member of the Köprülü Formation, Hoşgör *et al.* (2014) reported bivalves of Tournaisian age and more recently rugose corals (Denayer & Hoşgör 2014) of Tournaisian age. Thus, the D-C boundary was put within the boundary-dolomite (e.g. Hoşgör *et al.* 2014).

On the basis of the lithostratigraphic correlation and new biostratigraphic data, the location of the juvenile crinoid bearing sample is from the lower part of Member 5 (Higgs *et al.* 2002) and is constrained to the Famennian.

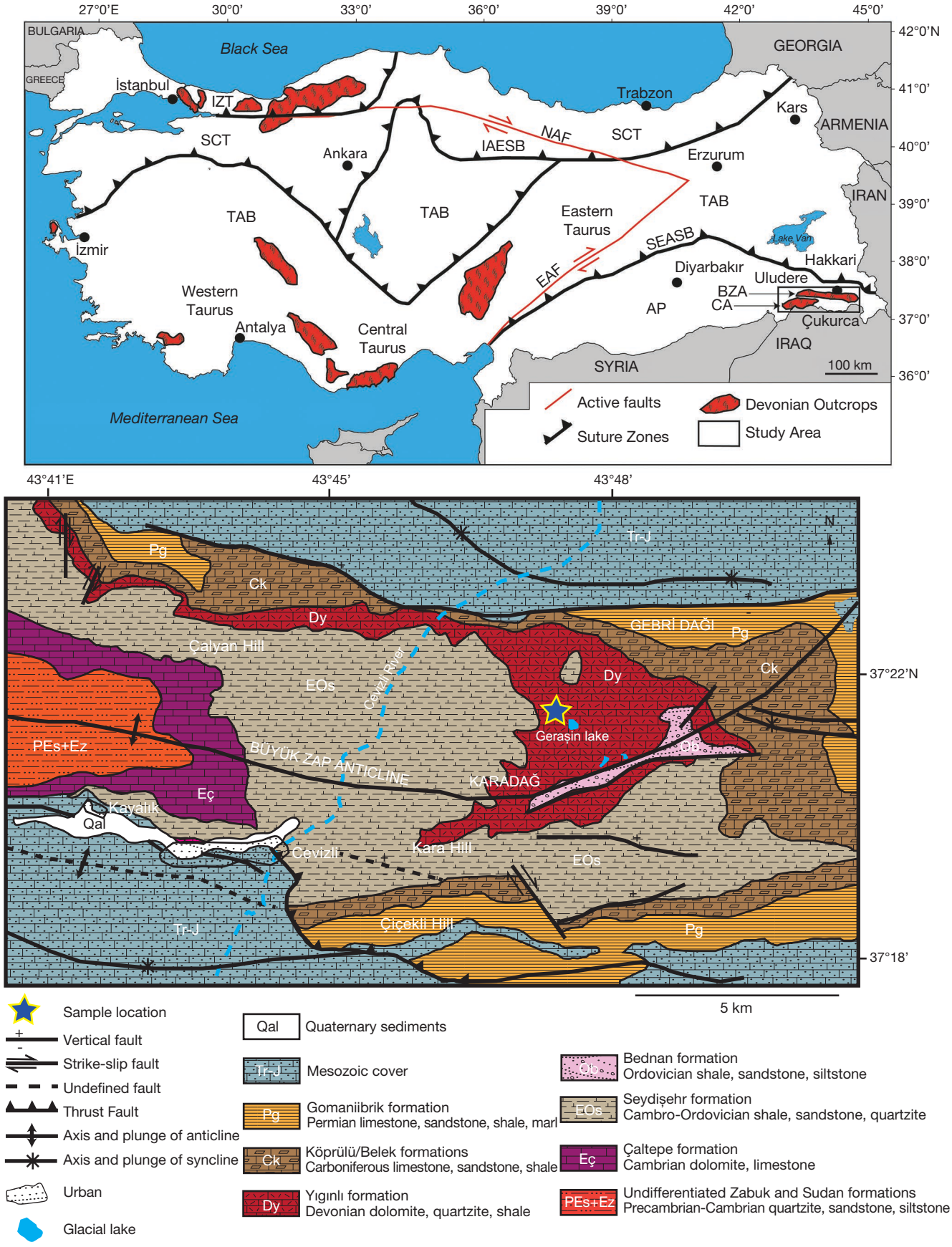

FIG. 1. — Distribution of Devonian units in Turkey (after Göncüoğlu 1997): **A**, tectonic map of Turkey with Devonian outcrops indicated; **B**, geological map (after Şenel 2002) of the Büyük Zap Anticline with the location of the crinoid bearing sample. Abbreviations: **AP**, Arabian Platform; **BZA**, Büyük Zap Anticline; **CA**, Çukurca Anticline; **IAESZ**, İzmir-Ankara-Erzincan Suture Zone; **IZZ**, Istanbul-Zonguldak Terrane; **NAF**, North Anatolian Fault; **SEASB**, Southeast Anatolian Suture Belt; **SCT**, Sakarya Composite Terrane; **TAB**, Tauride-Anatolide Belt.

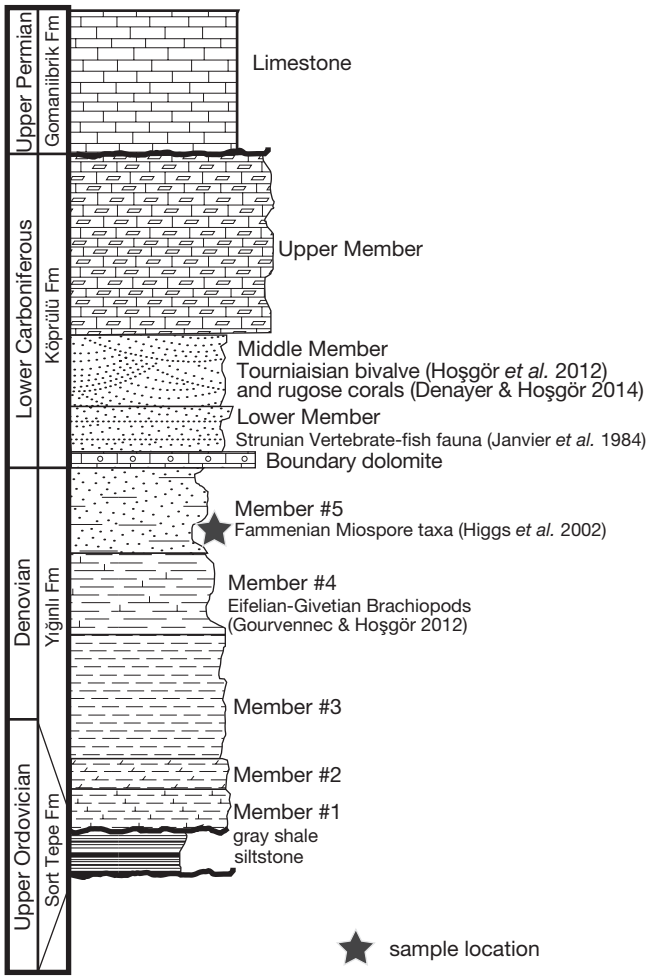

FIG. 2. — Generalized columnar section of Devonian-Lower Carboniferous units in the study area (modified after Higgins *et al.* 2002; Hoşgör *et al.* 2014). For lithological details see text.

MATERIAL AND METHODS

ANATOMICAL TERMINOLOGY

Morphological terminology follows Ubaghs (1978) and Ausich *et al.* (1999), with modifications from Ausich (1998) and Ausich *et al.* (2015). All measurements are in mm. Specimens are photographed after whitened with NH4Cl.

Measurement abbreviations

ACH	aboral cup height;
ACdW	aboral cup distal width;
ACpW	aboral cup proximal width;
AH	arm height;
ASH	anal sac height;
BH	basal plate height;
BW	basal plate width;
CoH	column height;
CrH	crown height;
IH	infrabasal circlet height;
RH	radial plate height;
RW	radial plate width.

Institutional abbreviations

METU	Geology Museum, Department Geological Engineering, Middle East Technical University, Ankara.

PHYLOGENETIC POSITION

The classification used here follows the phylogeny-based revision of crinoid higher taxa by Wright *et al.* (2017). Recent phylogenetic analyses have Camerata sister to the Cladida, with hybocrinids nested within the Cladida and sister to the porocrinids (Ausich *et al.* 2015; Wright 2017). Disparids and hybocrinids belong to the infraclass Inadunata, within the subclass Pentacrinoidea (Wright *et al.* 2017).

SYSTEMATIC PALEONTOLOGY

Class CRINOIDEA Miller, 1821
Parvclass CLADIDA Moore & Laudon, 1943
Magnorder EUCLADIDA Wright, 2017
Family DENDROCRINIDAE Wachsmuth & Springer, 1886

Genus and species indet.

MATERIAL. — METU-Geol Mus 2018-P1.

LOCALITY. — South of Geraşin glacial lake, Karadağ Mountain to the NE of Cevizli Village, Çukurca, Hakkari, southeastern Turkey (37°21'56.64"N, 43°47'45.14"E).

HORIZON AND AGE. — Yığınlı Formation, lower part of Member 5; Late Devonian (Famennian).

MEASUREMENTS (in mm; *, indicates an incomplete measurement or a crushed specimen). — CrH, 10.7; ACH, 2.14; ACpW, 0.3; ACdW, 2.9*; ICH, 0.42; BH, 0.64; BW, 0.57; RH, 0.79; RW, 0.86; AH, 9.7; ASH, 8.4; CoH, 7.1.

DESCRIPTION AND COMPARISON

Very small crown, conical (Fig. 3). Aboral cup medium cone shaped, width to height ratio approximately 1.3 (with cup compacted), plates gently convex, surface texture of plates not preserved.

Infrabasal circlet approximately 23% of aboral cup height, base truncate; individual infrabasal plates not defined. Basal circlet approximately 35% of aboral cup height; non-CD interray basal plates, hexagonal, approximately as high as wide, smaller than radials. Radial circlet approximately 42% of aboral cup height; as known radial plates pentagonal, approximately 1.1 times wider than as high (Fig. 4). Radial facets probably peneplenary, planate.

Anal plates unknown. Central portion of preserved crown characterized by many, poorly defined, irregularly shaped small polygons that may represent the anal sac. This structure is nearly as high as the arms, tapers distally to a rounded shape.

Arms branch once, as known, in what appears to be an isotomous division. All brachials higher than wide or much higher than wide, 4 or more primibrachials. All brachials rectangular uniserial, aborally convex (Fig. 4).

Column circular, heteromorphic, holomeric; proxistele columnals wider than high; latus convex; mesistele columnals more equidimensional with straight latus (Fig. 3); other details of column unknown.

Fig. 3. — Photograph of Dendrocrinidae? gen., sp. indeterminate. Specimen coated with ammonium chloride. Scale bar: 1.0 mm.

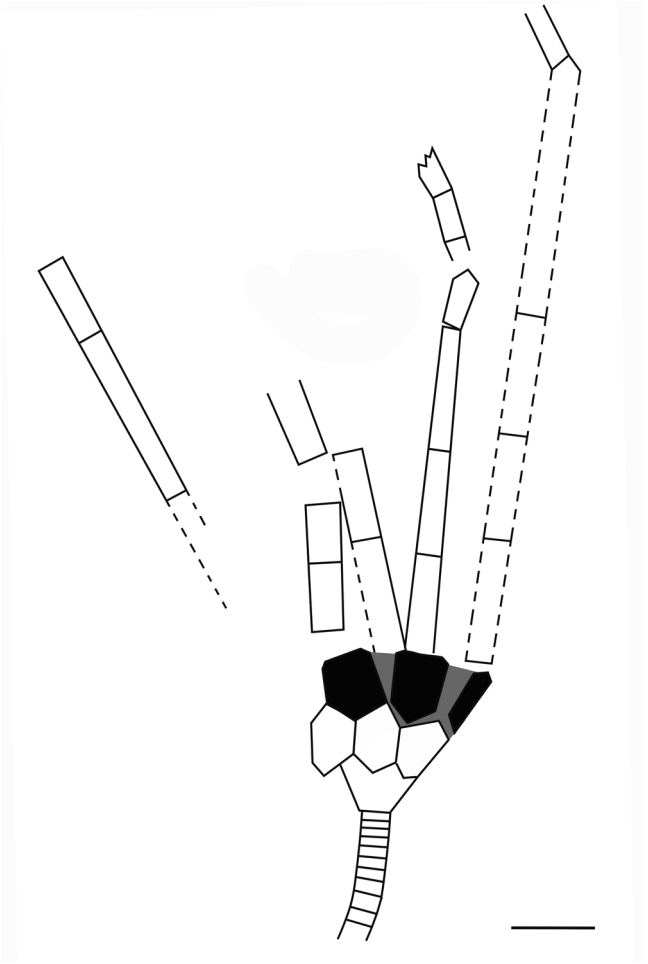

Fig. 4. — Plate diagram of Dendrocrinidae? gen., sp. indet. **Black**, radial plates; **grey**, matrix; Scale bar: 1.0 mm.

DISCUSSION

Key morphological features needed to diagnose this crinoid, such as the posterior interray plating and complete arm branching pattern, are not known in this new juvenile specimen. Further, the shape of the brachials, shape of the aboral cup, and relative heights of aboral cup plates would be expected to change through growth. It is possible that this new specimen belongs to the Dendrocrinidae. However, without a clear understanding of all diagnostic characters, the taxonomic affinities of this specimen cannot be determined with precision.

Both the very small size and brachial plates that are much higher than wide indicated that this new specimen is a juvenile. Juvenile crinoids are relatively rare, undoubtedly due to the small size, thin plates, and typically poorly sutured calyx plates. Most juvenile crinoid specimens known are microcrinoids, which are specimens with an aboral cup height less than or equal to 2.0 mm (Lane & Sevastopulo 1982a, b; Sevastopulo & Lane 1988). Growth series are known in many examples with the 2 mm height reached at a stage immediately after the radial facets form.

In striking contrast to typical microcrinoids, this new specimen is at a much more advanced growth stage. With the aboral cup *c.* 2.0 mm in height, arms are present through at least the secundibrachials, and the column is at least 3.0 mm in height. Although relatively few examples are known, juveniles of Paleozoic eucladids at approximately the comparable growth stage are much larger. Ausich & Wood (2012) described a juvenile *Hypselocrinus hoveyi* (Worthen, 1875) (Mississippian eucladid). This juvenile had a higher aboral cup (*c.* 4.0 mm), and pinnules had begun to develop. Compared to the specimen form Turkey, the *H. hoveyi* juvenile had a lower height:width ratio of the brachial plates. Although different in many ways, both the Mississippian and Devonian juveniles have a gradient of columnal heights from very short proximally to higher distally. The smallest Pennsylvanian juvenile eucladids reported by Peters & Lane (1990) also had an aboral cup height of *c.* 4.0 mm

and arm bifurcations above the first primibrachial. Again, this crinoid had a lower height:width ratio of the brachial plates than the Turkish specimen reported here. Amemiya *et al.* (2014: fig. 7E) illustrated a juvenile of the extant crinoid *Metacrinus rotundus* with an aboral cup height of *c.* 1.5 mm. This extant juvenile has a broader aboral cup, pinnules present on the second primibrachial, and more robust columnals.

In summary, this new juvenile from Turkey adds to our understanding of development in fossil crinoids but confirms that our understanding of the full spectrum of eucladid post-larval growth remains poorly understood.

CONCLUSIONS

A key to understanding homologies in echinoderms is study of early post-larval development (Lane & Sevastopulo 1982a, b; Sevastopulo & Lane 1988; Ausich 1996; Wright 2015). However, very few Paleozoic crinoids are known from this early developmental stage. The new specimen reported herein from the Devonian (Famennian) of Turkey is at an advanced morphology for its size, which is in the microcrinoid size range. If the morphology of this Devonian crinoid is typical for eucladid crinoids, it is possible that the typical microcrinoids are neotenic. More very small juveniles are needed to confirm this hypothesis.

Crinoids have multi-element mesodermal skeletons in which the individual plates are held together during life with ligamentary tissue, muscular tissue, or both. These connective tissues decay rapidly after death (Meyer 1971; Liddell 1975), so a complete crinoid must have been permanently buried when alive (Donovan 1991; Taylor & Brett 1996; Ausich 2001, 2016). The nearly complete preservation of the very small and delicate specimen described here indicates that depositional conditions existed favoring crinoid preservation during the Devonian of Turkey. Thus, a targeted search for additional fossils should yield more complete or nearly complete fossil crinoid specimens in the Devonian of Turkey.

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