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A goniasterid starfish (Echinodermata, Asteroidea) preserved in a mid-Miocene rhyolitic ignimbrite, northwest Romania

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ABSTRACT:

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A well-preserved, near-complete goniasterid asteroid, provisionally referred to the genus *Ceramaster*, is recorded from a rhyolitic ignimbrite assigned to the Dej Tuff Formation, exposed near Ciceu Giurgeşti (northwest Romania). The main interest of this specimen lies in the fact that it constitutes a rare example of preservation of (shallow-) marine biota, and echinoderms in particular, in volcanic strata. Superficially, overall disc shape and size, as well as ornament of marginal and abactinal ossicles, resemble to some extent that of coeval and slightly younger material from the Paratethys (south-central Poland, Austria) and the North Sea Basin (northwest Belgium), previously assigned to *Ceramaster*. So far, only the Polish and Austrian material has been formally named; however, this might actually represent but a single species. The record from Belgium refers to a form which is either conspecific with *C. muelleri* from the Paratethys, or represents a closely related taxon. These, and associated asteroids (e.g., Astropectinidae, Luidiidae), are in need of a modern taxonomic revision and a reappraisal of their palaeoecology is called for as well.

Key words: Miocene; Romania; Echinoderms; Asteroids; Comparisons; Volcanic strata; Preservation.

INTRODUCTION

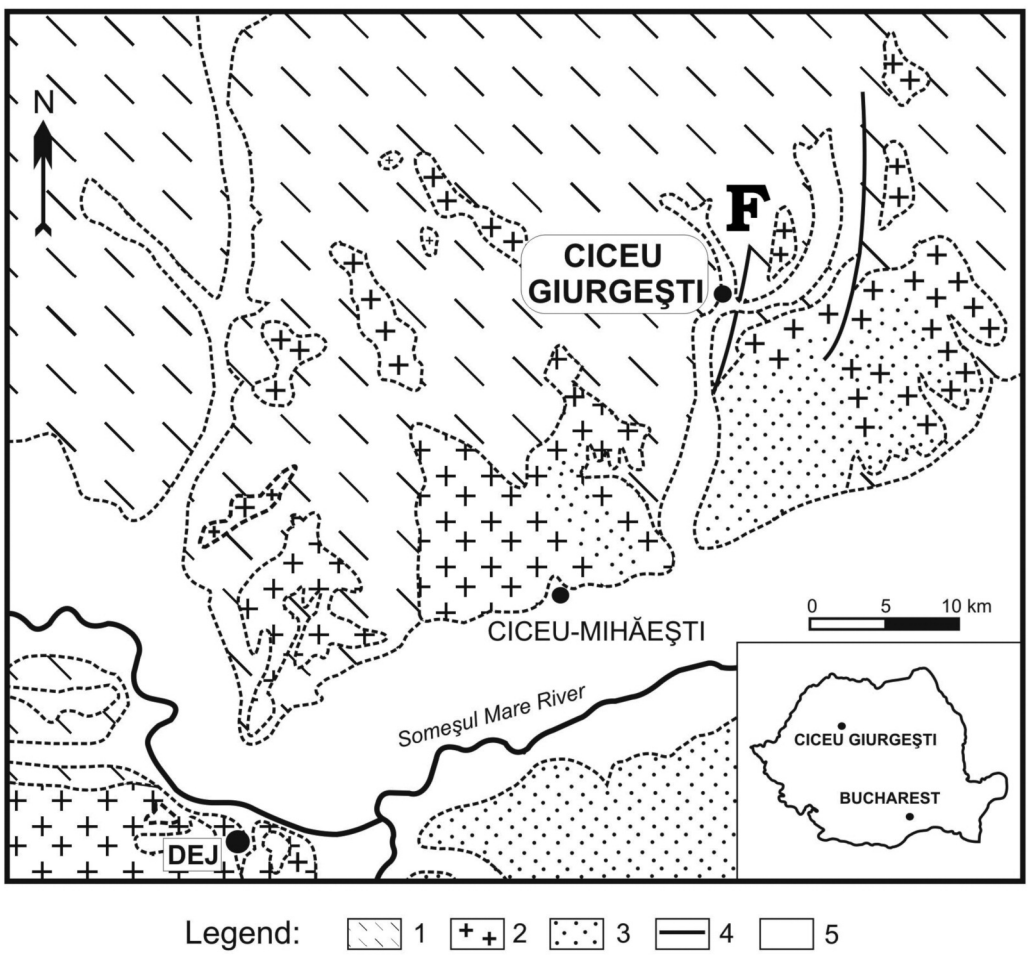
Preservation of fossils, both marine and terrestrial, in volcanic sediments (ash falls etc.) is highly exceptional and echinoderms in particular have only rarely been recorded from such deposits (Wienberg Rasmussen 1972; Lockley 1990; Bonde *et al*. 2008; Webster *et al*. 2009; see also Behrensmeyer 2003). Here we record a near-complete goniasterid starfish from rhyolitic ignimbrites of the mid-Miocene (Langhian, "early Badenian") Dej Tuff Formation, as exposed in a small, opencast pit at Ciceu Giurgeşti, Transylvanian Depression (northwest Romania). A comparison with coeval material from south-central Poland and Austria, as well as with younger (late Miocene) populations in the Kallo area (province of Antwerpen, northwest Belgium), suggests that it cannot be accommodated with these. The Polish, Austrian and Belgian records would seem to refer either to a single species, or to closely related taxa, for which the names *Ceramaster muelleri* and *C. polonicus*, provided that they are in fact distinct, are available.

In general, asteroid material of Neogene age, both from the North Sea Basin and the Paratethys, is com-

paratively poorly known, although a number of more or less well-preserved specimens have been recorded in the literature. Complicating matters even more is the fact that previous authors have at times proposed new taxa on the basis of dissociated ossicles only, mostly marginals. It appears that sturdier-plated forms such as Goniasteridae and Astropectinidae (e.g., Janssen 1972; Nosowska 1997; Radwański and Wysocka 2001, 2004) are over-represented in such assemblages, and that other forms such as Asteriidae and Luidiidae are much rarer (see also Blake 1973, 1986; Jagt 1991; Binder 2002; Kroh 2003, 2007). Thus, Neogene asteroids are in dire need of a modern revision and a proper assessment of their palaeoecology, along the lines proposed by Blake (1989, 1990) and Kroh (2007). Such a detailed account is beyond the scope of the present paper, as is an in-depth comparison with asteroid material from elsewhere in the Paratethys. The main interest of the Romanian find lies in the fact that it illustrates preservation of shallow-water marine biota in a volcanic rock, which is very rare, although there is another Paratethys locality, Salgótarján (Hungary), from where such preservation has been recorded. However, echinoderms appear to be missing from those assemblages (but see Rakusz 1927).

GEOLOGICAL SETTING

The present outline of the Transylvanian Depression in central Romania reflects that of a sedimentary basin which had evolved in this area since the Langhian (middle Miocene; "early Badenian", "Moravian"), as part of the Central Paratethys realm (Rögl 1999; Harzhauser *et al*. 2002, 2003; Kroh 2007; Rögl *et al*. 2008). This intra-mountainous basin was surrounded by the Carpathians and its subsidence history is related to the Old Styrian tectogenesis, which activated crustal peri- and intra-basin fractures (Sănd-



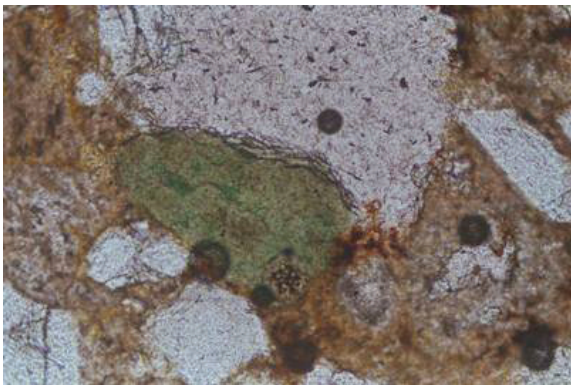
Text-fig. 1. Geological map of the Ciceu-Giurgeşti area in northwest Romania (modified after Seghedi and Szakács 1991). Legend: 1 – lower Miocene; 2 – mid-Miocene ("Badenian") volcanic rocks; 3 – mid-Miocene ("Badenian") sediments; 4 – faults; 5 – Pleistocene/Holocene. "F" denotes the locality from where the asteroid stems

ulescu 1984; Ciulavu *et al*. 2000; Săndulescu and Dimitrescu 2004). During the Langhian ("Badenian"), and extending into the late Serravallian ("Sarmatian"), this basin had connections to the large Pannonian and Dacian depocentres, as well as to several other, smaller intra-mountainous basins (e.g., at Strei, Petroşani and Roşia Montană). Starting during the late Serravallian ("Sarmatian"), the subdivision of the Central Paratethys into several smaller basins was initiated (Rögl and Steininger 1984). The sedimentary infill of the basin occurred during the late Miocene.

The "early Badenian" sedimentary sequence starts with a brief conglomeratic episode, during which masses of clastic rock accumulated in several parts of the basin (e.g., at Tălmaciu, Ciceu-Giurgeşti and elsewhere), followed by the volcano-sedimentary Dej Tuff Formation (Moisescu and Popescu 1967). Rhyolitic tuff predominates within this unit, interbedded with tuffaceous marl rich in foraminifera. Locally, the lithology is very peculiar, referring to rhyolitic ignimbrite forming local massifs, crossed by phyllosilicate-rich mylonite. According to Mărza and Mirea (1991), such rocks came into existence in relation to the main European G9 fracture. The Dej Tuff Formation is not restricted to the Transylvanian Basin; it has also been recorded from several adjacent basins, such as at Şimleu, Baia Mare and Maramureş, from the Carpathian Foredeep, Transcarpathia (Ukraine) and western Slovakia (Mărza and Mészáros 1991).

Apart from microfossils, other biota are rather rare in the Dej Tuff. Some plant remains have been recorded from a number of localities (Givulescu 1991; Codrea *et al*. 2007) and several molluscs have been recovered as well (Chira 1991a, b).

At Ciceu Giurgeşti (Text-fig. 1), where the starfish was discovered several decades ago by a local man by the name of Vasile Poghirc, volcanic rocks (rhyolitic ignimbrite) are extracted in a small, opencast pit named Corobani. This open pit is famous for handmade millstones made from this "Badenian"-aged ignimbrite. At this locality, a sequence of ignimbrite, a few metres thick, is exposed (V. Codrea, pers. obs.); the exact position of the starfish within this sequence is unknown, its discoverer having since died. Of the asteroid, the abactinal (aboral) side is exposed, but all calcite is dissolved leaving only an external mould. However, details of plating are quite well preserved. There is no contortion of the arms or disc, which indicates that the asteroid was killed instantaneously, thus preventing degradation and dispersal into isolated ossicles which is so typical of echinoderms in natural settings (Donovan 1991). In fact, it is comparable to Late Cretaceous (late Maastrichtian) astropectinids described from platy flints in northeast Belgium (Blake and Jagt 2005).



Text-fig. 2. Glauconite grain (just left off centre) in rhyolitic ignimbrite from Ciceu-Giurgeşti (1N, × 40)

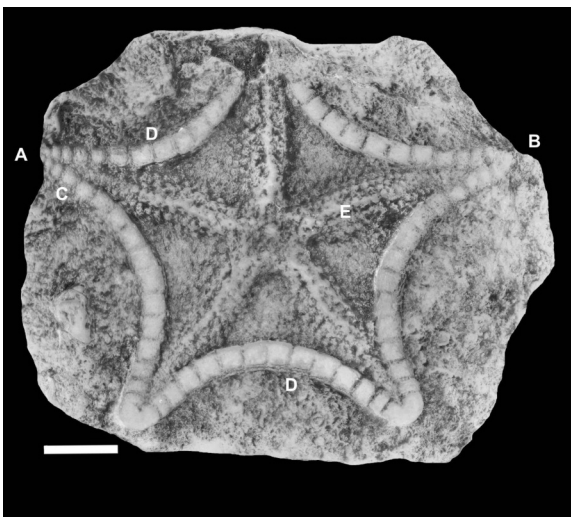
The rock shows a porphyry-clastic structure and a fluidal, oriented texture. In thin section (Text-fig. 2), its composition reveals angular or even idiomorphic mineral clasts, embedded in a hyaline groundmass. The mineral clasts comprise quartz, plagioclase feldspars, biotite and pyroxene; the hyaline groundmass being impregnated with iron hydroxides and showing clear signs of anisotropy due to devitrifying. The rock contains also a few rounded, greenish glauconitic grains (Text-fig. 2), demonstrating deposition of the pyroclastic material in immersion, under a shallow body of marine water. This peculiar structure and texture, as well as its mineralogical composition, are diagnostic of a rhyolitic tuff formed in an ignimbrite facies.

SYSTEMATIC DESCRIPTION

The specimen is contained in the collections of the "Andrei Mureşanu" College, Dej, Romania (AMCD), under registration number 76; an Exaflex cast of the specimen is in the Natuurhistorisch Museum Maastricht collections, NHMM 2009 011. Other material referred to below is housed at the Statens Naturhistorisk Museum (Geologisk Museum), Copenhagen (MGUH); Naturhistorisches Museum Wien (NHMW), and the Faculty of Geology, University of Warsaw (GW). Terminology used follows Gale (1986), Blake (1989), Breton (1992) and Blake and Aronson (1998).

Order Valvatida Perrier, 1884
Family Goniasteridae Forbes, 1841
?Genus *Ceramaster* Verrill, 1899
?*Ceramaster* sp.
(Text-figs 3–4)

Text-fig. 3. ?*Ceramaster* sp. (collections of "Andrei Mureşanu" College Dej, no. AMCD 76), external mould in rhyolitic ignimbrite (Dej Tuff Formation, mid-Miocene) at Ciceu Giurgeşti, northwest Romania. Scale in centimetres



Text-fig. 4. ?*Ceramaster* sp. (NHMM 2009 011), Exaflex cast of AMCD 76 (see Text-fig. 3), showing various details of marginal and abactinal plating (letters A–E; see text). The cast was first blackened with dye, but subsequent oil release prevented the use of ammonium chloride for coating. Alternatively, white powder was used for coating, and in Photoshop a negative of the picture taken was then processed. Scale bar equals 10 mm

MATERIAL: A single specimen (AMCD 76), preserved as an external mould, all calcite having been dissolved, exposing the abactinal (aboral) side.

DESCRIPTION: Medium-sized (major radius [R] *c*. 39 mm; minor radius [r] *c*. 21 mm), five-armed goniasterid; flattened abactinal surface, arms moderately long, pointed; arm tips slightly raised (Text-fig. 4; letter A); interbrachial angles broadly rounded; marginals moderately large, numerous (at least eighteen superomarginals on each side between arm tips), median ones with flat to slightly raised central abactinal surface, apparently with few scattered granules, but otherwise smooth; narrow border covered with rows of closely spaced granules (Text-fig. 4; letter D); median marginals slightly longer than broad, faintly cuneate; ossicles of two series paired, but towards arm tip, where facing superomarginals abut, there is a tendency to alternate (Text-fig 4; letter C); distal marginals longer than broad, with more raised abactinal surface; terminals apparently small, triangular (Text-fig. 4; letter B); abactinal ossicles flattened interbrachially, polygonal and covered by close-set granules; radial rows (one central row of larger-sized, rounded to slightly elongate ossicles, and at least two on either side of slightly smaller, but comparable, ossicles, all covered by granules; Text-fig. 4; letter E) prominent, apparently continuing into arm tip; jumble of ossicles in disc centre difficult to interpret; actinal (oral) side not exposed, precluding observation of inferomarginal, actinal, oral, ambulacral and adambulacral ossicular structure.

DISCUSSION: Overall outline with a flattened abactinal surface, closely spaced adactinal ossicles and robust, block-like marginals allow this form to be assigned to the Goniasteridae without reservation (see also Blake and Portell 2009). Although it is difficult to assess details of marginal ornament, there would seem to be a close resemblance to Paleogene and Neogene species which, more or less routinely, have been assigned to the extant genus *Ceramaster* Verrill, 1899 (type species: *Asterias granularis* Retzius, 1783). As shown by Gale (1986, text-fig. 8), the type species has larger marginal ossicles and less conspicuous radial series, with shorter arms in which superomarginals abut only at arm tip.

In the literature, there are several records of comparable asteroids of Paleogene and Neogene age, the most important ones of which are here listed and briefly discussed. A detailed comparison and revision of these taxa is beyond the scope of the present note. From the "post-Pliocene" of Sicily (Italy), De Gregorio (1895) described a new subgenus and species under the name of *Astrogonium* (*Petalastrum*) *propegeometricum*. From the illustration (pl. 1, figs 1–2), this form would appear to have smaller marginals and a more closely set marginal granulation.

Wienberg Rasmussen (1950, pp. 53–55, pl. 5, figs 17–19) referred, albeit with a query, three late Danian (Paleocene) species from Denmark to this genus, namely *Ceramaster dividuus* (Wienberg Rasmussen,

1945), *C. granulatus* (Wienberg Rasmussen, 1945) and *C.* cf. *granulatus*. Too little is known of these forms to allow a detailed comparison with the present specimen. A year later, Wienberg Rasmussen (1951, fig. 1) added *C. brandenensis* (holotype: MGUH 7639) from the late Oligocene Branden Clay (see Schnetler and Palm 2008) of Denmark, described on the basis of some 30 dissociated marginal ossicles which might have belonged to a single individual. This form displays much shorter arms, more or less straight, or only slightly concave, interbrachial sides and marginals which are much longer than broad. In addition, the abactinal central area shows more numerous granule pits and the border is wider and more irregular. Subsequently, Wienberg Rasmussen (1972, p. 54; pl. 5, figs 11–13) added another new species, *Ceramaster obtusus*, based on dissociated marginals (holotype: MGUH 12794) from the late Danian Sonja Member (Agatdal Formation) of Nugssuaq, West Greenland. This species differs in having marginals that are broader than long and have more regularly distributed granule pits, lacking a smooth abactinal area.

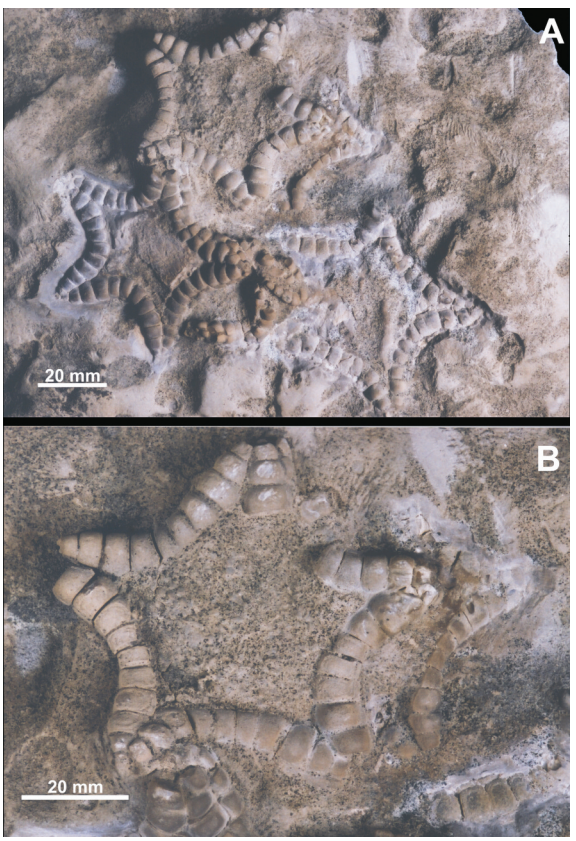
Wienberg Rasmussen (1972, pp. 14, 40, 56) also commented on earlier records, e.g. of *Astropecten* (?*Pentaceros*) *beyrichi* and *Goniaster* (*Goniodiscus*) *raabii*, both introduced by von Linstow (1912), for material from the "middle" Oligocene (i.e., Rupelian) of Mark (Westfalen, Germany). The fragmentary arm which is the holotype of *A. beyrichi* shows marginals that lack a ridge and cannot thus be accommodated in the Astropectinidae; alternatively, it might better be assigned to the Goniasteridae. The lectotype, designated by Wienberg Rasmussen (1972, p. 56), of *G. raabii* is reassigned to *Ceramaster* on account of the structure of the marginal series. It is stated to differ from *C. brandenensis* in having shorter marginals with larger central granule pits, a more restricted marginal ornament which is similar both in supero- and inferomarginals. Wienberg Rasmussen (1972) also noted that this form had been recorded by Hucke and Voigt (1930) from the Rupelian of Steutz, Anhalt (eastern Germany).

Later, Kutscher (1980, p. 226, pl. 3, fig. 3) recorded *C.* cf. *brandenensis* from the upper Oligocene of Sternberg, northeast Germany, on the basis of dissociated marginals. The same author (Kutscher 1985, p. 8, pl. 3, figs 2–4) subsequently recorded disssociated marginals under the same name from the "middle" Oligocene of Magdeburg, eastern Germany.

Breton (1992, p. 195) referred a Late Jurassic (Kimmeridgian) form from Cerin, Ain (France), *Pentagonaster chantrei* de Loriol, 1895, to the genus *Ceramaster*, albeit with a query, and noted that this might represent the rootstock of younger forms.

Borghi (1995, pp. 1, 7) recorded the extant *Peltaster placenta* (Müller and Troschel, 1842) from the Pliocene and Pleistocene of Emiliani, but failed to illustrate this material, so that it cannot be compared with the present specimen.

Kroh (2007, table 2) presented an overview of asteroid taxa then known from Neogene ("Eggenburgian" = upper Aquitanian–lower Burdigalian; "Ottnangian" and "Karpatian" = upper Burdigalian; "Badenian" = Langhian–lower Serravallian) strata in the Central Paratethys, plus pertinent literature sources. That author listed indeterminate asteriids, *Ceramaster polonicus* Nosowska, 1997, '*Goniaster*' *muelleri* Heller, 1858, '*Goniaster*' *scrobiculatus* Heller, 1858, indeterminate goniasterids, *Astropecten anglicus* Nosowska, 1997 (= *A. granulatus* Wienberg Rasmussen, 1972, *non* Müller and Troschel, 1842), *A. forbesi* Heller, 1858, *A. navodicensis* Nosowska, 1997, '*Astropecten*' *verrucosus* Heller, 1858, *Astropecten* sp., *Luidia ciliaris* (Philippi, 1837), *L. alternata* sensu Kaczmarska, 1987, *L. hungarica* Rakusz,



Text-fig. 5A, B – *Ceramaster* aff. *muelleri* (Heller, 1858) from the upper Miocene Deurganckdock Sandstone Level (Kiel Member, Berchem Formation) at Doel-Deurganckdok (Antwerpen area, Belgium; E. Wille Collection). A, assemblage of several specimens; B, detail of one of these specimens. Reference is made to Herman and Marquet (2007, p. 17, pls 25–27) for details

1927 and *Luidia*? sp. Of special note, for the present discussion, is a specimen (NHMW 1877.XXV.57) of *'Goniaster' muelleri*, illustrated by Kroh (2007, fig. 4g). From what is visible, this appears to be so close to the holotype (GW unregistered) of *Ceramaster polonicus* (see Nosowska 1997, pls 8, 9), that they can be considered to be either very closely related or even identical. Naturally, in the latter case the name *muelleri* would have precedence.

Additionally, there are specimens from the upper Miocene of the North Sea Basin (Marquet and Herman 2009). Kallo populations (Text-fig. 5), for the time being here referred to as *C*. aff. *muelleri*, appear closely related to that Paratethyan species, and could even turn out to be conspecific. This form shows much sturdier marginal ossicles than the Romanian goniasterid described here, with shorter arms and superomarginals abutting regularly; unfortunately, actinal and abactinal plating in *C*. aff. *muelleri* is either badly disarticulated and dispersed or not preserved at all (compare Herman and Marquet 2007).

The present specimen also shows a superficial similarity to other goniasterid genera such as *Peltaster* Verrill, 1899 and *Tesselaster* H.L. Clark, 1941. Blake and Aronson (1998, p. 343, figs 4.1–4.5) referred a species from the upper Eocene La Meseta Formation of Seymour Island, Antarctic Peninsula, to the latter genus. However, since the actinal (oral) surface of the Romanian find cannot be studied, the use of open nomenclature is preferred. For a meaningful revision of Neogene asteroids from the North Sea Basin and the Paratethys to be carried out, all material preserved in the various museums and in selected private collections should be considered. Such a revision, and a detailed comparison with extant faunas from the Atlantic (see Koehler 1924; Clark and Downey 1992), is planned for the near future.

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