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Early-Middle Triassic echinoderm remains from the Istranca Massif, Turkey

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With 5 figures

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Abstract: In the northwestern part of the Istranca Massif close to the Turkish-Bulgarian border, recrystallized limestones above germanotype fluvial clastics (Buntsandstein-equivalents) yielded remains of echinoderms and bivalves. The limestones are lensoidal, flaser-bedded and bioturbated, like the *Holocrinus* lagerstätten, which are common in the germanotype Muschelkalk. The sufficiently preserved crinoid ossicles can be assigned to genus *Holocrinus,* a crinoid clade that occurs worldwide in Early and Middle Triassic sediments. This is so far the first Triassic fossil data from the Istranca Massif and provides evidence for the correlation with similar Triassic successions in the Balkans to the West and the Istanbul Terrane to the East.

Key words: Early to Middle Triassic, Turkey, Istranca-Massif, crinoids, palaeoecology.

1. Introduction

Alpine collisional tectonics and post-Alpine strike-slip displacements in the southeastern Balkan have resulted in a complex network of tectonic units or terranes in Bulgaria (YANEV et al. 2006) and Turkey (GÖNCÜOGLU et al. 1997). They are the Moesian, Balkan, and Thracian terranes in East Bulgaria, and Istranca, Istanbul and Zonguldak terranes in Northwest Turkey (Fig. 1). Istranca (Strandzha in Bulgarian) Composite Terrane as one of them covers almost 1200 km^2 across the Turkish-Bulgarian border. The structural setting and geology of the Istranca Terrane has been recently reviewed in some detail in the Bulgarian (GERDJIKOV 2005) and Turkish (OKAY et al. 2001) parts.

During a joint-project on the stratigraphic correlation of the Turkish and Bulgarian terranes, the second author and co-workers discovered crinoid and bivalve remains in the recrystallized limestones in the Northeast of Kofcaz (Fig. 2) close to the Turkish-Bulgarian boundary. Until now, this is the only documented Triassic fossil finding from the meta-sediments of the Istranca Terrane in the Turkish part.

Crinoidal limestones in the late Early and early Middle Triassic sediments of the Balkanide-type (mainly germanotype) Triassic were reported by CHATALOV (1980, 1991) in Southeast Bulgaria. However, MALIAKOV & PROKOP (1997) stated that these crinoidal limestones in the Malko Tırnovo area just across the Turkish-Bulgarian boundary were assigned to Devonian. In the Turkish Istranca, on the other hand, crinoidal calc-schists and carbonates were reported by CAGLAYAN & YURTSEVER (1998) from another locality to the North of Kofcaz (Tastepe Village, Fig. 2). The crinoids were determined by E.

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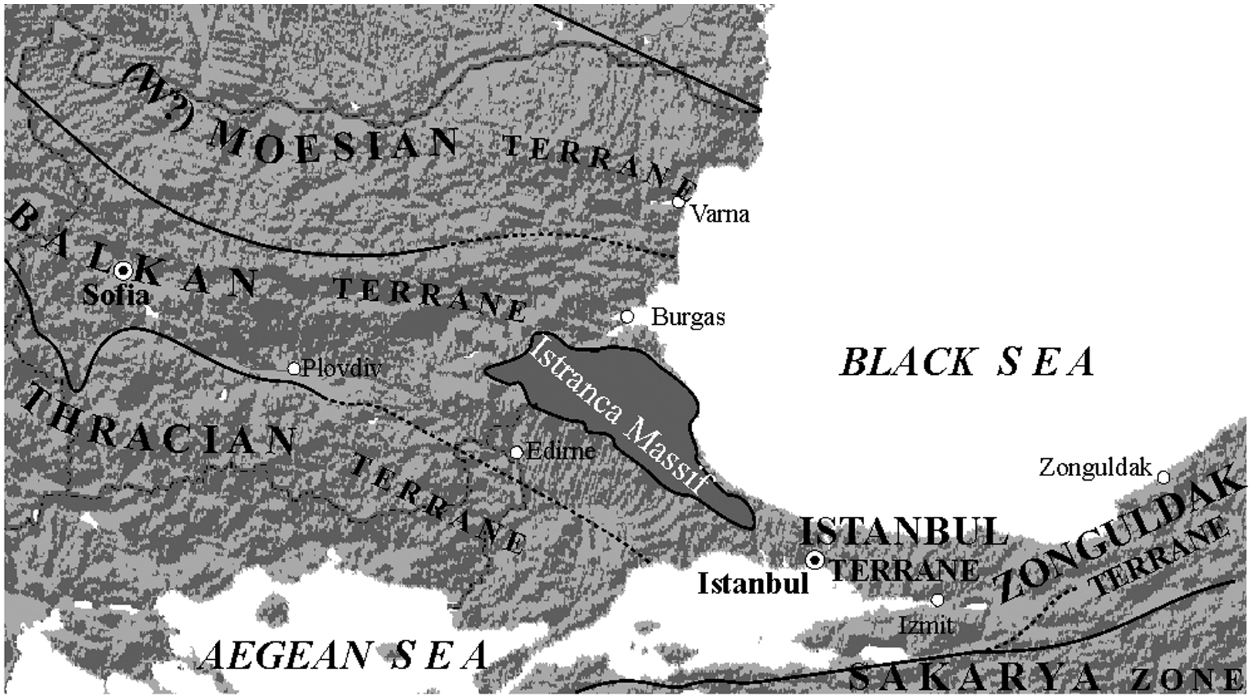

Fig. 1. Distribution of the Palaeozoic terranes in Southeast Balkans and Northwest Turkey (after Yanev et al. 2006).

Sezginman in unpublished internal reports (MTA Geology Department, internal reports Nr. 199 and 200, 1984) as *Pentacrinus* cf. *laevisutus* Pompecki and assigned to Late Liassic (Domerian in the original report).

Crinoids may serve as useful index fossils in sediments that yield no cephalopods or conodonts for facies or diagenetic reasons, because of their rapid radiation since the beginning of the Middle Triassic. Consequently, for the Anisian and Ladinian stages, a crinoid biostratigraphic scheme for the western Palaeotethys and its marginal seas based on crinoids has been established (Hagdorn & Gluchowski 1993; Hagdorn et al. 1997) that could be expanded both for the Early Triassic and the Late Triassic.

In this study, the authors will describe the echinoderm remains from the Istranca Massif and discuss the stratigraphic correlation as well as the geologic and palaeogeographic implications of this finding.

2. Geological setting

The metamorphic rock-units in Central Thrace covering vast areas between Bulgaria and Turkey were classically known as the Istranca Massif (Pamir & Baykal 1947). Later work on the stratigraphy and metamorphism of the Triassic rocks (e.g. Chatalov 1991) or structural relations (e.g. Gocev 1991) helped to distinguish several nappes, which can be grouped in three main packages (e.g. Dabovski & Savov 1988) in the Bulgarian part of the Istranca Massif. From top to bottom they are the Veleka, Strandja, and Sakar units (Gerdjikov 2005). The Veleka unit includes several tectonic slices with Grammaticovo and Zabernovo formations of Palaeozoic age (e.g. Boncheva & Chatalov 1998). The Palaeozoic and Early Mesozoic rock-units of the Strandja and Sakar units only differ in the grade of metamorphism, the latter being highly metamorphosed.

In the Turkish part of the Istranca Massif Caglayan & Yurtsever (1998) and Okay et al. (2001) recognized two main north-verging tectonic units. The upper one consists of a pre-Triassic crystalline basement (Kırklareli Group of Caglayan & Yurtsever 1998) with metamorphic rocks and metagranites intruding them. Recently, Okay et al. (2001) published U/Pb single zircon evaporation ages of about 271 Ma (Early Permian) from the granites. The intrusion age of the orthogneisses in the basement, on the other hand, was dated as Carboniferous (Sunal

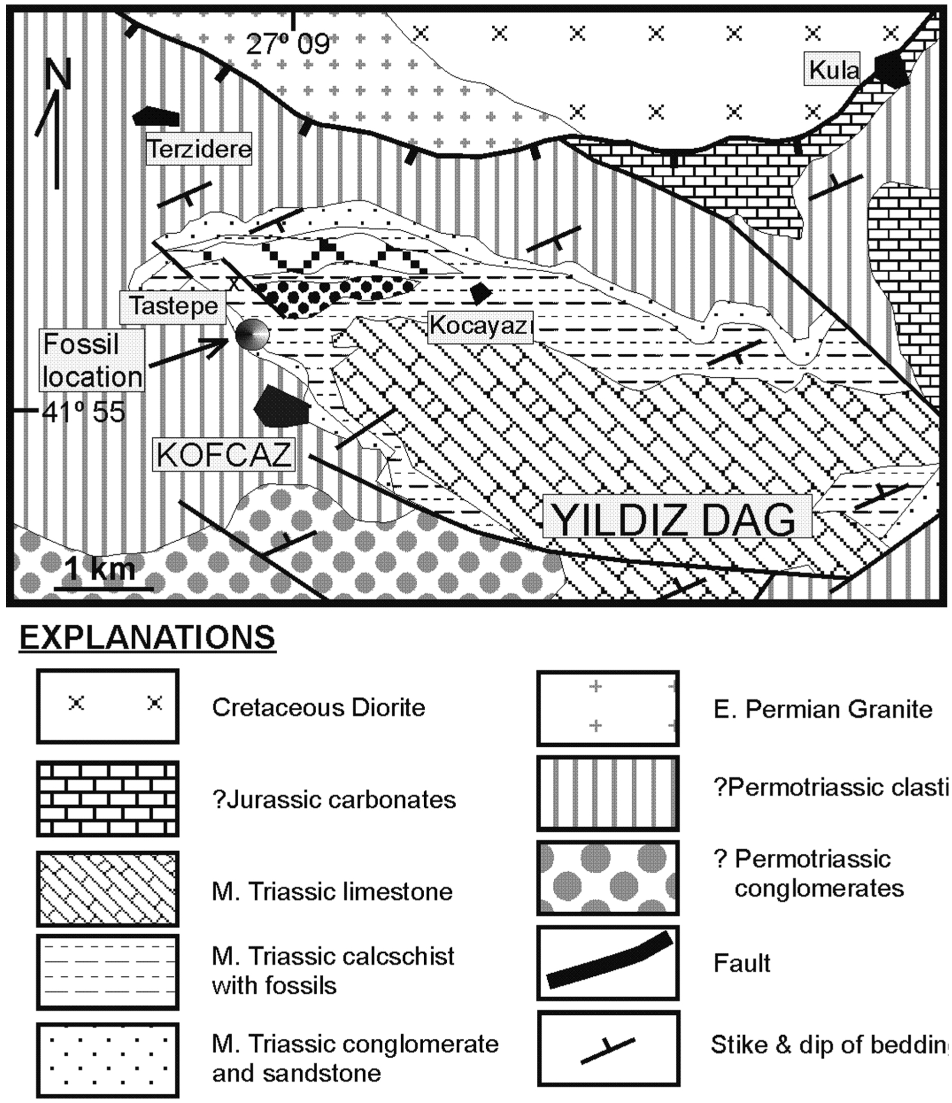

Fig. 2. Geological map of the area around Kofcaz and the fossil location (modified after CAGLAYAN & YURTSEVER 1998).

et al. 2006). The structurally underlying unit mainly comprises metasediments (Istranca Group of CAGLAYAN & YURTSEVER 1998) and will be described in more detail, as it includes the only macrofossils found until now from the Turkish part.

The lower part of the Istranca Group includes metaconglomerates and metasandstones. The contact to the crystalline rocks of the Kırklareli Group is generally faulted (Fig. 2). However, previous studies (e.g. AYDIN 1982; CAGLAYAN & YURTSEVER 1998) report locations where the metagranitoids are disconformably overlain by quartzo-feldspatic sandstones with local and discontinuous pockets of basal conglomerates.

The fossiliferous succession is situated within the Istranca Group of CAGLAYAN & YURTSEVER (1998) that represents the lower tectono-stratigraphic unit in the area. It comprises the lower part of the "Mesozoic metasedimentary cover" of OKAY et al. (2001).

The studied section is located within a NW-SE trending zone between Kofcaz and Yıldız Dagı (Fig. 2), where the succession is relatively well-exposed along the southern limb of the Yıldızdag syncline. The lower part of the clastic succession (Kocabayır metaclastics, CAGLAYAN & YURTSEVER 1998) is more than 2 km thick and consists mainly of gray, green and pink fluvial conglomerates, conglomeratic sandstones, and sandstones. The conglomerates are polygenic and dominated by quartz and K-feldspars. Towards top, a fining upward series of variegated siltstones and mudstones, and channel-type conglomerates are dominating. The uppermost part of the Kocabayır

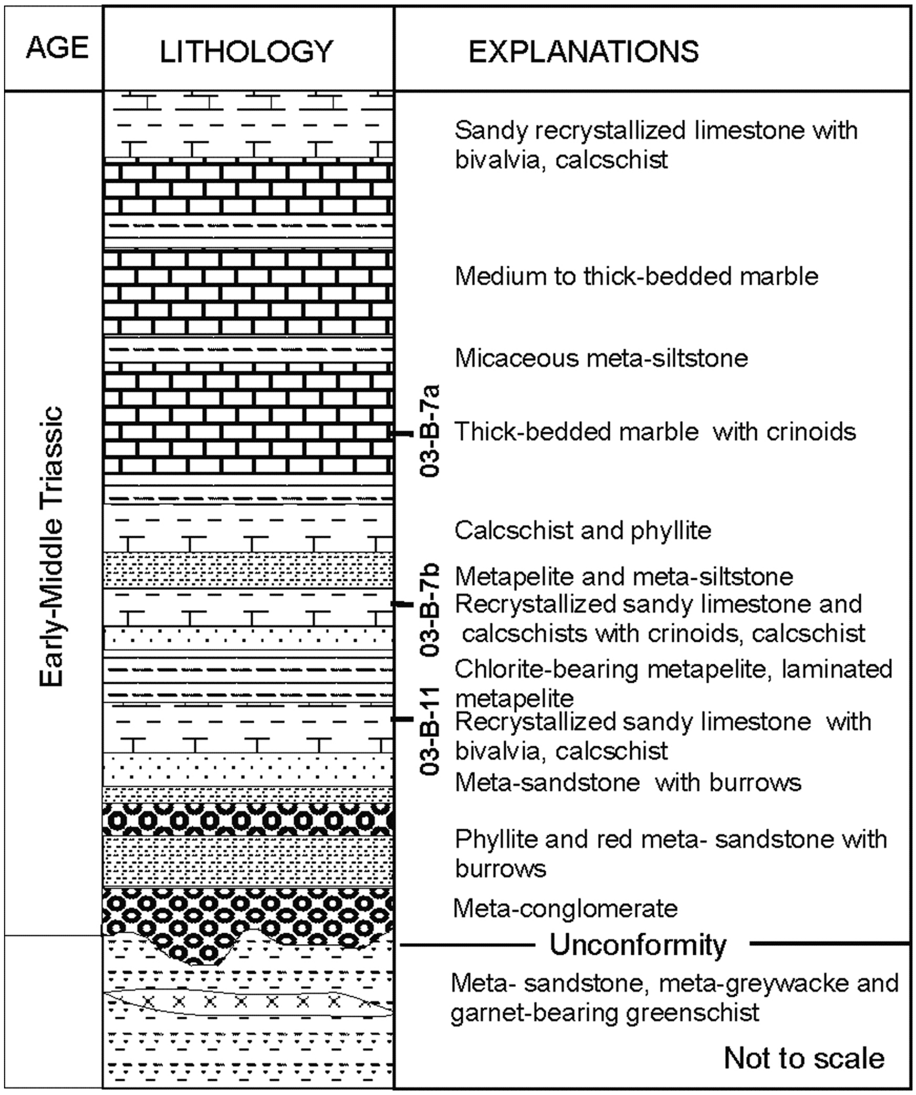

Fig. 3. Columnar section of the studied Lower – Middle Triassic succession in the Kofcaz area, Istranca Massif.

Metaclastics is made up of greenish greywackes, volcanogenic greenschists, and garnet-bearing metapelites.

On the road-cuttings to the Northeast of Kofcaz (Fig. 2), the Kocabayır Metaclastics are overlain by another metasedimentary succession that starts with a discontinouos conglomeratic horizon (Fig. 3), which very probably represents an unconformity. In contrast to the well-rounded conglomerates of the underlying Kocabayır metaclastics, these include flattened pebbles of white and gray recrystallized limestone, basic metavolcanic rocks and lydites. The conglomerates alternate with phyllites and red meta-sandstones, very rich in burrows. Upward, a 15 m-thick section of laminated metasiltstones-metapelites, chlorite-bearing metapelites and recrystallized sandy limestones are following. The sandy limestones include bivalve ghosts. With increasing carbonate content, first mica-rich calcschists, then thin-bedded limestones, and finally medium-bedded limestones with crinoid-bearing levels are following. Although the upper part of the succession is not observed in the studied section, it is represented by thick-bedded dolomitic marbles or dolomites (Kapaklı dolomite member of Caglayan & Yurtsever 1998) to the Northeast of Yıldız Dağı in Dereköy area. However, the stratigraphy in this area considerably differs from the studied one and may belong to a different tectonic slice. No fossils were obtained from these carbonates yet and their age is unknown. The radiometric age data (83 Ma; Aydin 1982) from the diorites intruding the recrystallized carbonates indicate that they are pre-Santonian in age.

The post-tectonic Late Cretaceous cover of the Istranca "Massif" outcrops along the Black Sea coast and is not in contact with the recrystallized carbonates in the studied succession.

3. Material

Three samples from the Kofcaz section (Kırklareli – Kofcaz-Taştepe road; GPS locality: UTM Zone 35, 512.978 Easting, 6445.411 Northing) containing echinoderm remains have been studied by H. H. Their stratigraphic positions are indicated in Fig. 3. The samples were deposited in the Muschelkalkmuseum Ingelfingen (MHI).

Sample 1 (03-B-11; MHI 1187): A slab of limestone measuring ca. 7 x 9 x 4 x 8 cm. The light grey, microsparitic limestone is interstratified with cm-thick lensoid flasers of light brownish to ochre-coloured dedolomite containing mica flakes. The strongly leached surface shows two questionable remains of poorly preserved, recrystallized, convex-up, indeterminable bivalves and some echinoderm ossicles most of which are also unidentified. Due to the solution process, their crystalline structure with the cleavage faces is clearly visible. Size and outline of some of the ossicles, which may show a central canal, are indicative for crinoid origin (columnals of a small crinoid). The section at one edge of the slab shows that the ossicles are better preserved inside the sample. Assignment to any crinoid group is not possible.

Sample 2 (03-B-7a; MHI 1188; Fig. 4a): A slab of limestone measuring 8 x 6 x 9 x 4 cm. The surface of the grey, sparitic, crinoidal limestone (biospararenite) with small glauconite grains, is densely covered with echinoderm ossicles, most of which are abraded and leached. Their poor preservation hampers determination. The following types of ossicles could be identified: (1) Numerous subcircular to basaltiform crinoid columnals with a circular central canal, some of them, due to strong leaching, showing radial canals. A few columnals show an indistinct pattern of marginal crenulae that are adradially arranged to simple petals (Fig. 5a, b). Despite of leaching, most of these columnals are relatively high. (2) A few very small, low, pentagonal to stellate columnals with no articulation pattern preserved, because of strong leaching. (3) Some basaltiform to subpentagonal columnals showing oval cirrus scars with a transverse ridge (Fig. 5a). (4) Numerous small echinoderm ossicles, among which are a few long, cylindrical cirrals with oblique articulation facets, and some questionable brachials. Most of these small ossicles are more likely to be ophiuroid sclerites. (5) An interambulacral plate of an echinoid with a crenulated and perforate tubercle, and a few very poorly preserved fragments of echinoid spines (Fig. 5e).

Sample 3 (03-B-7b; MHI 1189; Fig. 4b): A slab of limestone measuring 7 x 6 x 6 cm. The brownish, microsparitic limestone with mica scales shows an up to 1.5 cm thick lens of grey, sparitic, crinoidal limestone (biospararenite). At the surface, numerous echinoderm ossicles are weathered out, most of which are poorly preserved. The following types of ossicles could be identified: (1) A pluricolumnal of a crinoid comprising 6 columnals, the surface of which is strongly leached almost down to the central canal. Its diametre of ca. 2.3 mm equals the largest isolated columnals among samples 2 and 3. The articular facets are not to be seen, and, due to leaching, the sutures are enlarged and do not show traces of the original crenulation. (2) A few columnals with subcircular to subbasaltiform outline, measuring 0.7 to 1.5 mm. Two of these columnals show articular facets with short marginal crenulae forming a simple petaloid pattern in radial position (Fig. 5c, d). Their central canal is circular and more or less wide, depending on the degree of leaching. One columnal showing radial canals is likely to be a nodal, although no cirrus scars are to be seen. (3) Numerous echinoderm ossicles smaller than 1 mm, among which are semi-lunar shaped ophiuroid laterals. Due to abrasion and leaching, most of these small ossicles cannot be determined.

4. Assignment of the echinoderm remains

Crinoids: The sufficiently preserved crinoid ossicles can be assigned to genus *Holocrinus* (Articulata, Holocrinidae), a crinoid clade that occurs worldwide in Early to Middle Triassic sediments. The small size of the ossicles gives further evidence for relation with the small species of this genus that have been recovered worldwide in late Early Triassic (Olenekian) sediments (Klikushin 1987). Because of their fragmentary preservation – so far only isolated columnals, pluricolumnals, and cirrals have been found – they are poorly known. Assignment of the

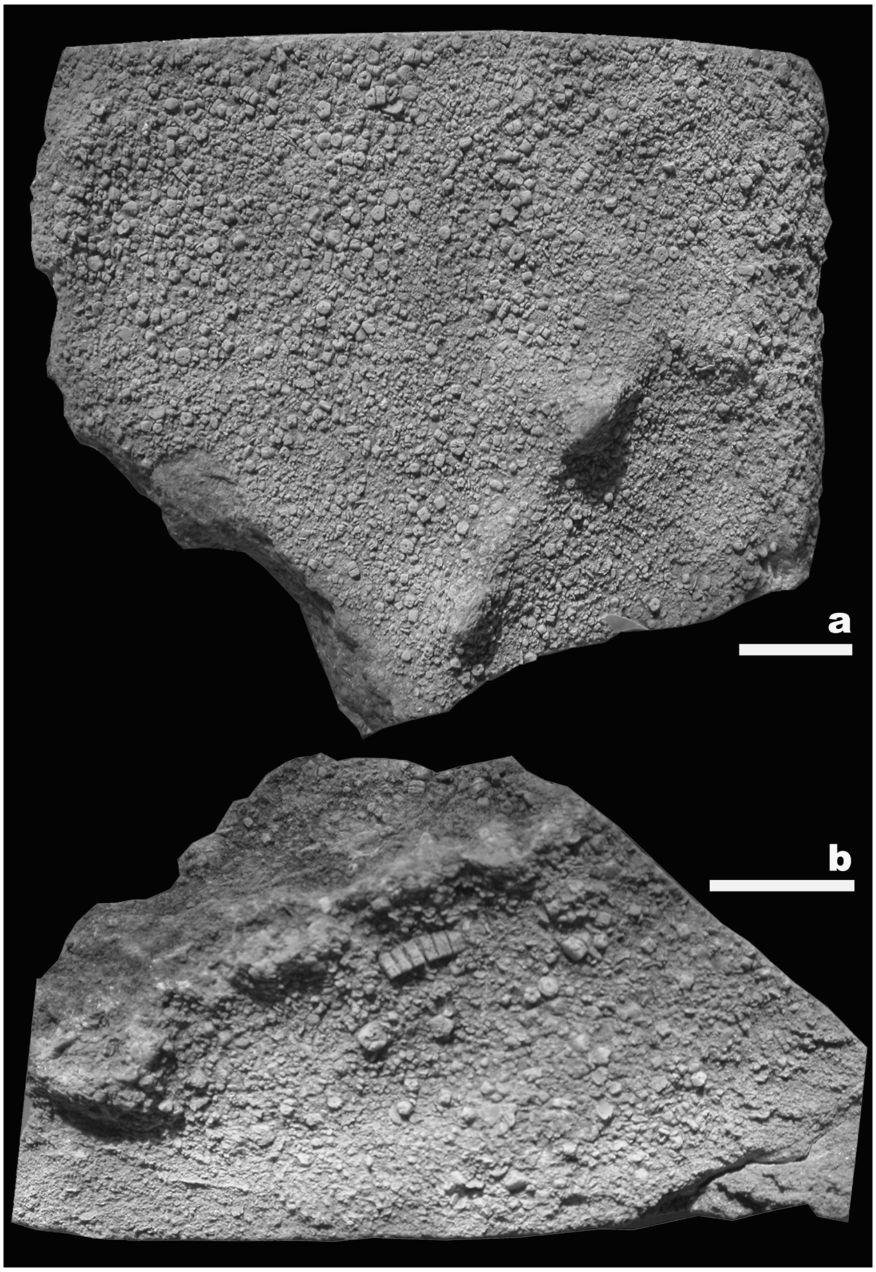

Fig. 4. Samples with echinoderm remains. Lower – Middle Triassic section at Kırklareli – Kofcaz-Taştepe road.
a – Sample 2 with columnals of *Holocrinus* sp., MHI 1188.
b – Sample 3 with strongly leached pluricolumnal and isolated columnals of *Holocrinus* sp., MHI 1189. Scale 1 cm

Istranca material to any of the established species is impossible.

A relatively close relation may exist with an undetermined *Holocrinus,* the remains of which are commonly found in the late Olenekian Cencenighe Member (Werfen Formation) of the Dolomites (Italy; LEONARDI 1968; BROGLIO-LORIGA et al. 1988; own collections) and the Northern Calcareous Alps (Austria; MOSTLER & ROSSNER 1984). Isolated material of this crinoid have also been found in the Csopak Formation of Lake Balaton (Hungary; own collections). *Holocrinus smithi* (CLARK & TWITCHELL) from the coaeval Virgin Limestone (Moenkopi Formation; Nevada, Arizona; USA) and the Thaynes Formation (Idaho; HAGDORN 1986; SCHUBERT et al. 1992) is larger and has articulation facets with a more distinct petaloid pattern. The early Anisian (Bithynian) *Holocrinus acutangulus* (MEYER) from the Lower Germanic Muschelkalk (HAGDORN et al. 1996) and the Lapis Formation of Southern Hungary (Mecsek Mountains; HAGDORN et al. 1997) is also larger than the material under description.

Due to the very small size, the Istranca columnals also resemble *Holocrinus cisnerosi* SCHMID from the Muschelkalk Superior (lower crinoid horizon) of Alicante (Spain; SCHMIDT 1936).

Echinoids: The echinoid material is also insufficient for unquestionable assignment to one of the known taxa. With its crenulate and perforate tubercle, the interambulacral plate resembles *Lenticidaris utahensis* KIER from the Olenekian Virgin Limestone and the slightly older Sinbad Limestone (Moenkopi Formation; Utah, USA; KIER 1968; NÜTZEL & SCHULBERT 2005). A "*Miocidaris*" from the earliest Triassic (Induan) Tesero Horizon (Werfen Formation; Dolomites) figured by BROGLIO-LORIGA et al. (1988: pl. 2, fig. 10) additionally shares a non-confluent scrobicle with the specimen from the Istranca Massif. *Triadotiaris grandaeva* (ALBERTI) from the Anisian Germanic Muschelkalk, which has been reported from the entire western Palaeotethys, is larger than the Istranca specimen and has confluent scrobicles (HAGDORN 1995a).

Ophiuroids: Due to incomplete and poor preservation, assignment of the ophiuroid ossicles was not possible. The laterals could belong to *Aspiduriella,* a common Middle Triassic brittle star.

5. Stratigraphic correlation of the samples

The few nodals among the crinoid columnals have cirrus sockets showing a transverse ridge. As this character is diagnostic for post-Palaeozoic Holocrinida and Isocrinida, the samples cannot be older than Early Triassic. Moreover, columnal size and crenulation pattern of the articular facets give evidence for assignment to *Holocrinus,* a common genus that occurs worldwide in Early to Middle Triassic strata. Probably, the present Istranca *Holocrinus* has Early Triassic age because most of the Anisian and Ladinian *Holocrinus* are larger. Only the Spanish *Holocrinus cisnerosi* of Ladinian age equals the Istranca *Holocrinus* in size. The echinoid material is too poor for a stratigraphical indication. However, it is not contradictive for a correlation of the samples with Early or Middle Triassic.

For these reasons, an age determination of the samples more precise than Early Triassic or Middle Triassic cannot be given.

6. Palaeoecology and taphonomy of the fossil lagerstätte

Early Triassic crinoid faunas are worldwide characterized by monotypy of genus *Holocrinus.* However, among undetermined Lower Triassic crinoid remains from different continents, other crinoid clades may be represented that have either survived the end-Palaeozoic extinction, or originated soon after this event (KLIKUSHIN 1987; TWITCHETT & OJI 2005). Like its extant descendants, the Isocrinidae, living *Holocrinus* was attached to the sea floor with its cirri. Differently from the Encrinida with permanent attachment by means of a holdfast, *Holocrinus* was able to re-attach itself after disruption from its substrate. For this purpose, the Holocrinidae developed a preformed rupture point in their stems at the lower nodal facet that automatically positioned a nodal with a cirrus whorl at the very end of the stem (HAGDORN 1983; BAUMILLER & HAGDORN 1995).

Lenses of cm-thick crinoidal limestone in flaser-bedded, bioturbated limestones, like the samples under discussion, represent a type of *Holocrinus* lagerstätten that is common in the Germanic Muschelkalk. The dominance of isolated distal columnals and cirrals is explained by a behaviour observed among the living descendants of the Holocrinidae, the Isocrinidae. Below their infrabasal circles they produce permanently new columnals while older stem parts gradually move towards the end of the stem and are eventually shed off at the rupture points below the nodals (OJI & SHONAN 1992; SHONAN & OJI 1998). The taphonomic data of *Holocrinus* lagerstätten in the Muschelkalk give evidence for the same behaviour in *Holocrinus.* Permanent shedding of distal stem parts explains why distal columnals and cirrals are over-represented and proximal columnals or brachials and cups are extremely rare in *Holocrinus* concentration lagerstätten. However, the Germanic Muschelkalk also yielded conservation lagerstätten with complete, articulated *Holocrinus* individuals that were smothered by mud (HAGDORN & BAUMILLER 1998). The samples from Istranca-Massif represent the much more common concentration lagerstätten that are dominated by completely disarticulated, distal columnals (HAGDORN & BAUMILLER 1998). Typical for this type of lagerstätten are mechanical abrasion, probably after prefossilisation, and glauconite grains.

Comparably with the Cencenighe Member of the Werfen Formation, or with the Germanic Muschelkalk, in the Istranca samples *Holocrinus* is associated with brittle stars.

Holocrinus is the oldest Mesozoic crinoid hitherto known that descended from unknown Palaeozoic Ampelocrinidae somewhere in the Palaeotethys, or in Panthalassa. *Holocrinus* is generally regarded the ancestor of all Mesozoic and extant crinoids (Schubert et al. 1992; Hagdorn 1995b). Since their Late Permian/Early Triassic almost-extinction, the Crinoidea commenced a new radiation that enabled them to occupy different ecological niches by the end of the Triassic. In Turkey, Holocrinidae has been recorded before only from Ladinian/Carnian Hallstatt-type limestones of the Taurus Mountains (Genus *Tollmannicrinus;* Kristan-Tollmann & Krystyn 1975).

7. Correlation with similar Early–Middle Triassic successions in the East Balkans and Northwest Turkey

The Early and Middle Triassic germanotype fluvial sediments were already recognized in the southeastern Balkans and in the Istanbul Terrane in Northwest Anatolia (Arthaber 1914). Hence, the new finding in Istranca forms a link between these areas.

Within the Balkanide facial type of Triassic in the southeastern Balkans, the dominantly red terrigenous clastics (Buntsandstein) occur in the lower part of the Early Triassic. They include channel bars and sheets of braided river sediments with subordinate amounts of andesites. Upwards, a series of variegated terrigenous-carbonate follows. The carbonates include bivalves, crinoids, gastropods and less frequently ammonites and foraminifera (Chatalov 1991). Based on the occurrence of *Meandrospira iulia* the carbonate deposition commences in "Spathian" (original nomenclature of Chatalov 1991) and continues in Anisian. The carbonate successions were attributed to the Muschelkalk in Europe, whereas the underlying terrigenous sediments were correlated to Middle and Upper Buntsandstein (Mader & Chatalov 1988).

The Sakar-type Triassic, on the other hand, is similar to the Balkanide-type but is metamorphic, as it is the case in the Turkish Istranca. The lower part of the succession is again represented by fluvial conglomerates, metasandstones and metaquartzarenites. The upper part, however, contains an alternation of quartzites, marbles and amphibolites. The marbles include bivalves and gastropods (*Costatoria costata* Zenker, *Gervilleia* (*Bakevellia*) cf. *modiola* Frech, and *Myalina* sp.) indicating late Early Triassic (Chatalov 1991). The overlying marbles contain Anisian and Ladinian conodonts.

Almost 300 km to the Southeast of our new Early-Middle Triassic finding in the Istranca, the Buntsandstein rocks were recognized in the 1900's (Kessler 1909) in the Kocaeli Peninsula (Bythnian). In this area red and violet fluvial conglomerates unconformably overlie the Palaeozoic successions and grade into an alternation of conglomerates, sandstones and subordinate andesitic volcanics (Kapaklı Formation of Altınlı, 1971). The first limestones in the succession were recognized by Arthaber (1914) who used the name "Obere Werfener Schichten" for these *Naticella*-bearing limestones. Yurttaş-Özdemir (1971) determined *Naticella acutecostata* Klipstein in these limestones and also found crinoids in the lower part of the overlying dolomitic limestones.

Both the Southeast Bulgarian and Istanbul-Zonguldak successions of the Early-Middle Triassic (Buntsandstein-Muschelkalk) successions are very similar to the recently found Kofcaz (Istranca) succession.

By this, the new location reported in this study clearly indicates that the Southeast Balkan, Istranca and Istanbul areas were on the same geological and palaeogeographical setting and on the eastern continuation of the Central European continental rift system.

8. Conclusions

The *Holocrinus* material described in this study is so far the first documented fossil data from the metasedimentary rocks of the Istranca "Massif". The discovery of Early to Middle Triassic fluvial and marine sediments facilitated the correlation of the germanotype Triassic formations between the terranes in the Eastern Balkans, Northwest Turkey, hence their palaeogeographic association during the Early Mesozoic. With the *Holocrinus* bearing samples from the Istranca-Massif, another occurrence of this Early to Middle Triassic crinoid clade has been added to the fossil record.

9. Systematic palaeontology

Phylum Echinodermata
Subphylum Crinozoa Matsumoto, 1929 [= Pelmatozoa Leuckart, 1848]
Class Crinoidea Miller, 1821
Subclass Articulata Miller, 1821

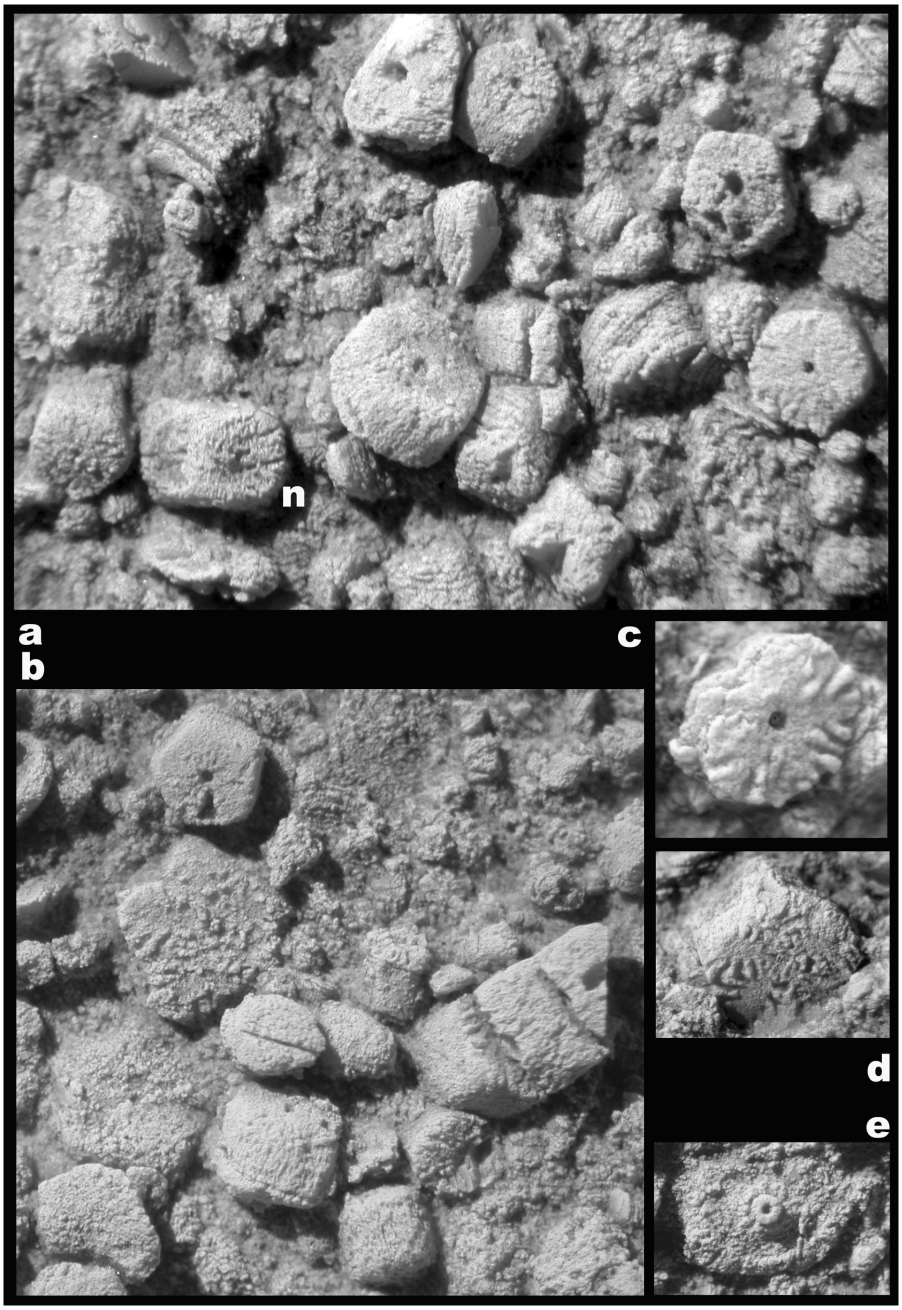

Fig. 5. Echinoderm remains from samples 2 and 3. Lower – Middle Triassic section at Kırklareli – Kofcaz-Taştepe road. **a-d** – *Holocrinus* sp. **a:** subcircular to subpentagonal internodals; nodal with large cirrus scars in lateral view (n); MHI 1188; width of figure 7.5 mm. **b:** subpentagonal internodal with pyriform petal; oval cirral; pluricolumnal; MHI 1188; width of figure 7.5 mm. **c:** immature internodal; MHI 1189; width of columnal 1.3 mm. **d:** internodal with pyriform petal; MHI 1189; width of columnal 1.7 mm. **e:** Echinoidea indet., interambulacral plate with perforate mamelon and crenutated platform; MHI 1188; width of interambulacral 2.3 mm.

Order Holocrinida JAEKEL, 1918 [nom. transl. ex Holocrinidae]
Family Holocrinidae JAEKEL, 1918
Genus *Holocrinus* WACHSMUTH & SPRINGER, 1888

Holocrinus sp. indet.
Figs. 4, 5a-d

Material: Numerous columnals, cirrals, a few pluricolumnals, and a few brachials covering the bedding plane of two slabs of limestone (03-B-7a, MHI 1188; 03-B-7b, MHI 1189).

Description: Columnals small (diameter 0.7–2.3 mm) with subcircular to subpentagonal and substellate outline. Articular facets with pyriform petals and short adradial and marginal crenulae (Fig. 5b, d). The smallest columnals with a few short crenulae that do not surround a distinct petal (Fig. 5c). Axial canal circular. Nodals high with high oval cirrus sockets and a transverse ridge (Fig. 5a). Lower nodal facet not observed. Brachials with oblique muscular articulation.

Occurrence: Kırklareli – Kofcaz-Taştepe road (GPS locality: UTM Zone 35, 512.978 Easting, 4645.411 Northing).

Subphylum Echinozoa HAECKEL in ZITTEL, 1895
Class Echinoidea LESKE, 1778
Subclass Euechinoidea BRONN, 1860
Order and family indet.

Euechinoidea indet.
Fig. 5e

Material: One incomplete interambulacral plate on sample 2 and a few spine fragments (03-B-7a, MHI 1188.

Description: Interambulacral plate of 2.3 mm width. Tubercle with perforate mamelon; platform crenulated; scrobicule non-confluent. Scrobicular tubercles not enlarged. Spines not ornamented.

Occurrence: Kırklareli – Kofcaz-Taştepe road (GPS locality: UTM Zone 35, 512.978 Easting, 4645.410 Northing).

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