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FIRST RECORD OF ICHTHYOSAURS IN SICILY (UPPER TRIASSIC OF MONTE SCALPELLO, CATANIA PROVINCE)

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Abstract. Here we report for the first time on the presence of ichthyosaurs in Sicily, southern Italy. The deposit of origin (Mufara Formation) can be dated to the upper Carnian (Tuvalian substage) based on a typical association of ammonites, one of which (*Shastites* sp.) is embedded in the sediment still encrusting one of the bone specimens recently found. The latter consist of two isolated vertebral centra that are referred to the Ichthyosauria thanks to their disk-like shape (i.e. they are much taller than long) combined with the amphicelous condition, lack of transverse processes, and presence of rib articulations on the central sides. The largest specimen is more precisely an anterior dorsal vertebra from an adult individual, ascribed to Shastasauridae indet. by the presence of elongated reniform diapophyseal facets, cranially not truncated, and absence of parapophyses. The smaller specimen represents an anterior cervical element from an immature individual of a likely smaller-sized, indeterminate taxon. These finds indicate that the biodiversity of the Monte Scalpello Triassic fauna is higher than previously known, but above all represent the southernmost occurrence of Triassic ichthyosaurs in the western Tethys basin.

Introduction

Triassic reptiles from the central-eastern hills of Sicily (Fig. 1) are known since the XIX century, but with a limited number of poorly studied taxa. The Monte Scalpello area, that geologically belongs to the Monte Iudica group (Lentini et al. 1993), has been the subject of numerous paleontological observations (Calcara 1840, 1845; Nelli 1899a, 1899b; Gemmellaro 1860, 1904; Scalia 1907, 1908, 1909a, 1909b, 1910-1914; Maugeri Patanè 1934; Lentini 1974). Scalia (1907) reported many unidentified "saurian remains" inside the limestone unit from the Acquanova and Paraspora districts of Monte Scalpello. Scalia (1908) mentioned also some "very interesting [...] undeterminable remains that I

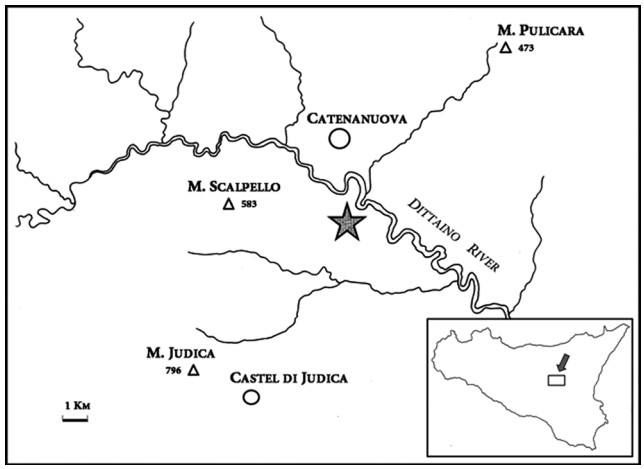

Fig. 1 - Map of Sicily, and close-up of the Monte Scalpello area. The star indicates the place where the specimens here described were found.

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Fig. 2 - The exact position where the outcropping fossiliferous layers yielded the two ichthyosaur vertebrae. GPS coordinates indicate a latitude of 37° 55' 15.69"N, a longitude of 14° 66' 49.63"E, and an altitude of 160 meters above sea level. Monte Scalpello is in the background.

doubtfully ascribe to the genus "*Nothosaurus*", later referring this material to the Monte Iudica group, and more precisely to the localities of Acquanova and Serro Sello, and identifying it as "*Nothosaurus* (?) sp." (Scalia 1909b).

Unfortunately, all the fossil vertebrate material from the Scalia collection, at the time deposited at the IPOP (Istituto Policattedra di Oceanologia e Paleoecologia) of the Università degli Studi di Catania (now "Dipartimento di Scienze Biologiche, Geologiche e Ambientali, Sezione di Scienze della Terra"), has been lost, and no photographic documentation on these specimens is available.

In October 2011, two of us (DDF & AR), while prospecting in the surroundings of Monte Scalpello (Fig. 2), collected some isolated fossil bones outcropping from the ground surface, including a couple of disk-like vertebrae. Based on the anatomical characters described below these new specimens, now housed at the Museo Civico di Storia Naturale di Comiso (MSNC), certainly belong to the Ichthyosauria, a taxon that was not recorded previously by any author in Sicily.

Geological framework

The specimens described herein come from the Mufara Formation (Schmidt di Friedberg & Trovò 1962; Lentini 1974; Lentini et al. 1993; Carbone et al. 2010), a Triassic (Carnian) unit outcropping extensively southward and eastward of Monte Scalpello (Castel di Iudica, Catania Province). The Mufara Formation consists of an alternating sequence of calcareous marlstone, limestones and sandstones (Fig. 3), cropping out in the nearby area of Paraspora and Acquanova.

Based on the information reported by Scalia (1907, 1908, 1909, 1910-1914), Lentini (1974), and on the ammonoid fauna sampled by four of us (AR, DDF, GI & AAC), we are confident in attributing the bone-bearing section to the Carnian, and in particular to the Tuvalian substage. As a matter of fact, in addition to the Tropitaceae (*Discotropites, Pleurotropites)* found in the surrounding sediment, the matrix still encrusting one of the specimens described herein (MSNC 4463) embeds a tiny ammonite, 0.8 mm in diameter (Fig. 4), which is referable to the genus *Shastites* for the presence of "falcoid branching ribs with spiral organised tubercles" (Tozer 1994). This genus has a Tuvalian distribution, just like the formerly mentioned taxa, and this association is typical of the *Tropites dilleri* biozone (Krystyn 1973; Tozer 1994).

Systematic Palaeontology

Ichthyosauria De Blainville, 1835

Remarks. According to Laurin & Reisz (1995) and Maisch (2010), the vertebral centra lack apparent ventral keels in all ichthyosaurs. This is true also for specimens MSNC 4463 and 4464. Ventrolateral keels are known only in *Phantomosaurus neubigi* from the Middle Triassic (Sander 1997; Maisch & Matzke 2000) as an autapomorphy. Ichthyosaurs have completely reduced the dorsal processus transversi, so that the ribs articulate exclusively with the centra. This state is unique among amniotes (Maisch & Matzke 2000). According to recent phylogenetic analyses (e.g. Maisch & Matzke 2000; McGowan & Motani 2003), several shastasaurian-grade taxa are based on undiagnostic or inade-

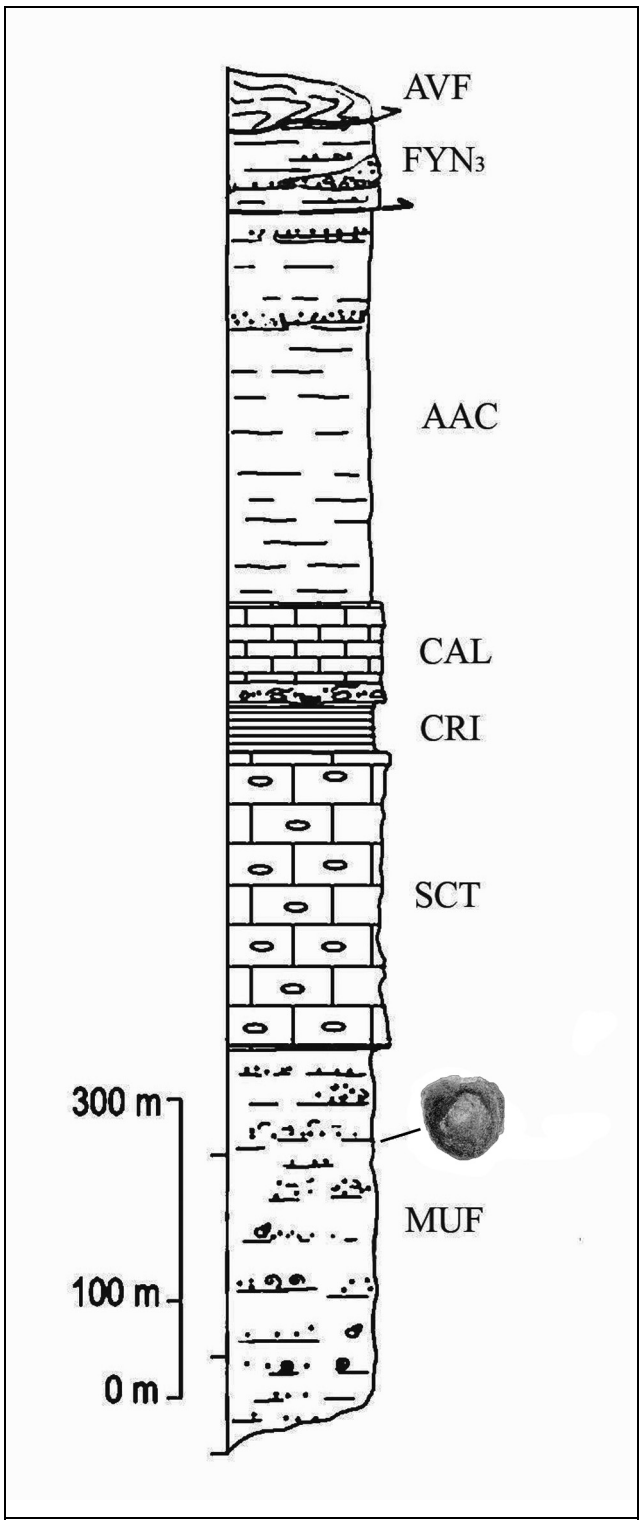

Fig. 3 - Stratigraphic section of the Upper Triassic sediments in the Monte Scalpello Area. The ichthyosaur vertebrae come from the Mufara Formation. (Modified from Carbone et al. 2010). Abbreviations (top to bottom): AVF, Argille Varicolori inferiori (Paleocene-Eocene); FYN3, Flysch Numidico membro di Monti Salici (Upper Oligocene-Burdigalian); AAC, Argille e Arenarie glauconitiche di Catenanuova (Oligocene- Lower Tortonian); CAL, Formazione Caltavuro (Eocene-Oligocene); CRI, Formazione Crisanti (Jurassic- Cretaceous); SCT, Formazione Scillato (Carnian-Norian-?Rhaetian); MUF, Formazione Mufara (Carnian).

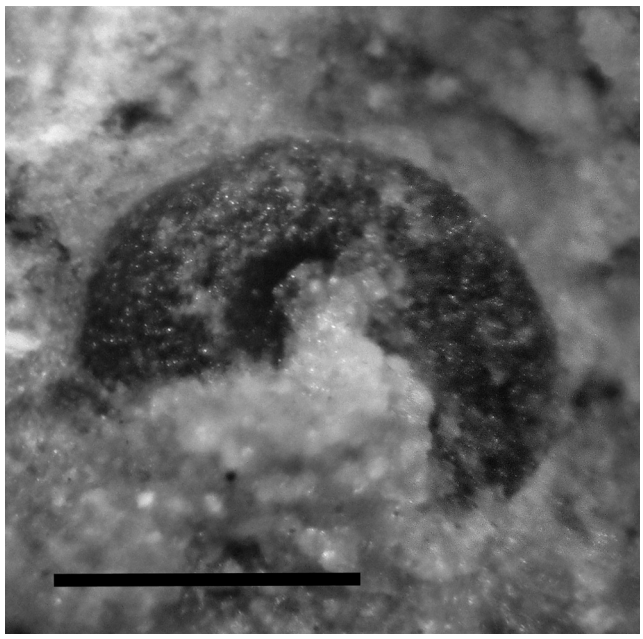

Fig. 4 - Close-up of the tiny ammonite (*Shastites* sp.) embedded in the residual sediment close to the cranial center of specimen MSNC 4463. Scale bar equals 0.5 mm.

quately known material, and must therefore be rejected as nomina dubia. Given this, and given the non-perfect preservation of our specimens, we maintain caution and avoid to refer the material to any genus-level taxon (see Conclusion).

Merriamosauria Motani, 1999

Shastasauridae Merriam, 1902

Referred specimen: An isolated vertebral centrum, housed at the Museo Civico di Storia Naturale di Comiso, Ragusa Province, with inventory number MSNC 4463.

Diagnosis: MSNC 4463 is referable to the Ichthyosauria based on the following combination of characters: vertebral centra notochordal and deeply amphicoelous (character 58.1 in Sander 2000), height/length of dorsal vertebrae >1 (character 59.2 in Sander 2000), transverse processes completely absent, rib articulations directly on the centra (Maisch & Matzke 2000). In addition, MSNC 4463 is assigned to the Shastasauridae by the following characters: costal articular surfaces (diapophyses) cranially not truncated, presence of elongated reniform diapophyseal facets and absence of parapophyses (Callaway & Brinkman 1989).

Age and stratigraphic horizon: Upper Triassic, upper Carnian, Tuvalian substage.

Locality: Monte Scalpello, Castel di Iudica, Catania Province, Sicily, southern Italy. Latitude: 37° 55' 15.69"N. Longitude: 14° 66' 49.63"E.

Description. Isolated vertebral centrum, dark brown to ochre-yellowish in color, nearly discoidal and hour-glass shaped (amphicoelous), with deeply concave articular faces. The bone is pierced at its center by a tiny foramen – the probable remnant of the notochordal

Selected measurements of vertebral centra (mm) Estimated measurements among brackets		
	MSNC 4463	**MSNC 4464**
maximum dorsal length	27.9	14.5
minimum ventral length	22.8	13.0
minimum length at the center of the faces	0.4	0.2
height of cranial face	(41.4)	18.5
width of cranial face	(45.7)	20.0
height of caudal face	(42.1)	17.0
width of caudal face	(42.5)	19.0
minimum height at the ventral concavity	35.0	18.0
maximum width across diapophyses	53.6	(25)

Tab. 1

foramen – still covered by a thin film of matrix, in which a tiny ammonite of the genus *Shastites* is embedded (see Introduction).

The peripheral areas of the articular faces have been exposed to intense weathering and all sides of the bone lack in part the outermost cortical layer, so that the real shape of the centrum is not immediately evident and some measurements can be taken only by estimation (Tab. 1). However, the cranial face appears to be slightly wider than high, and the caudal face as wide as high. The latter is better preserved and shows a flat peripheral surface, almost 1 cm wide, clearly offset from the lateral walls of the centrum. The height/length ratio is around 1.6. The dorsal surface of specimen MSNC 4463 shows a longitudinal furrow, representing the neural canal, flanked on either side by two facets for articulation with the pedicels of the neural arch. In spite of their partial erosion, these facets are enough marked to indicate that the base of the neural arch was much larger in transverse diameter than in craniocaudal diameter. The dorsally depressed area gives the centrum a vaguely cardioid shape.

The ventral surface is concave in lateral view, bounded caudally by the ventral margin of the caudal articular face, and cranially by the remains of a probably similar rim, now lost because of serious weathering. Nevertheless, the ventral face does not have any sagittal keel. Each of the lateral surfaces bears remains of a dorsoventrally elongate and oblique knob, emerging from the main body of the centrum at roughly mid height, and set apart from both the anterior and posterior faces. We interpret these structures as the base of the diapophyses, the dorsal rib articular processes. If this is the case, this would add weight to the interpretation of the centrum position and provide further support to the systematic identification discussed below.

The correct orientation of the vertebra can be inferred by comparison with a number of examples in literature. Following Merriam (1902, pl.7 fig. 2, pl. 8 figs. 3-5, pl.15 fig. 1), Kuhn-Schnyder (1980, figs. 2-4), Callaway & Brinkman (1989, fig. 2), Sander (1989, fig. 5; 1992, figs. 3, 5; 1997, fig. 5), Nicholls & Manabe (2001, figs. 3, 7, 8), and McGowan & Motani (2003, figs. 10, 11A, 18C), at least three characters render craniocaudally asymmetrical the vertebral centra in the presacral series of shastasaurian-grade ichthyosaurs:

1) the facets for the neural arch face slightly dorsocaudally;

2) the caudal face extends more ventrally than the cranial face, so that in lateral view the ventral concavity (or side) of the centrum faces cranioventrally;

3) the long axis of each rib articulation is oblique, with the lateroventral portion more cranially placed than the laterodorsal portion. The latter is usually placed at mid-length of the centrum.

Ichthyosauria indet.

Referred specimen: An isolated vertebral centrum, housed at the Museo Civico di Storia Naturale di Comiso, Ragusa Province, with inventory number MSNC 4464.

Diagnosis: MSNC 4464 is referable to the Ichthyosauria based on the following combination of characters: vertebral centra notochordal and deeply amphicoelous (character 58.1 in Sander 2000), height/length of dorsal vertebrae >1 (character 59.2 in Sander 2000), transverse processes completely absent, rib articulations directly on the centra (Maisch & Matzke 2000).

Age and stratigraphic horizon: As for MSNC 4463 Upper Triassic, upper Carnian, Tuvalian substage

Locality: As for MSNC 4463 (see above).

Description. This second isolated centrum, found in the proximity of MSNC 4463, is similar to it not only in colour and preservation, but also in shape. In fact, it is subcircular, taller and wider than long and markedly hourglass shaped, with the central constriction pierced by an evident notochordal foramen. The main differences from MSNC 4463 are the smaller size and the proportionally larger notochordal foramen, which indicates a younger ontogenetic stage.

MSNC 4464 was eroded all along its margins and to the right side, it lacks part of the ventrolateral portion, but the cranial and caudal articular faces are less weathered than those of MSNC 4463 are. This allows seeing that, contrary to specimen MSNC 4463, a flat peripheral surface is clearly absent. The height/length

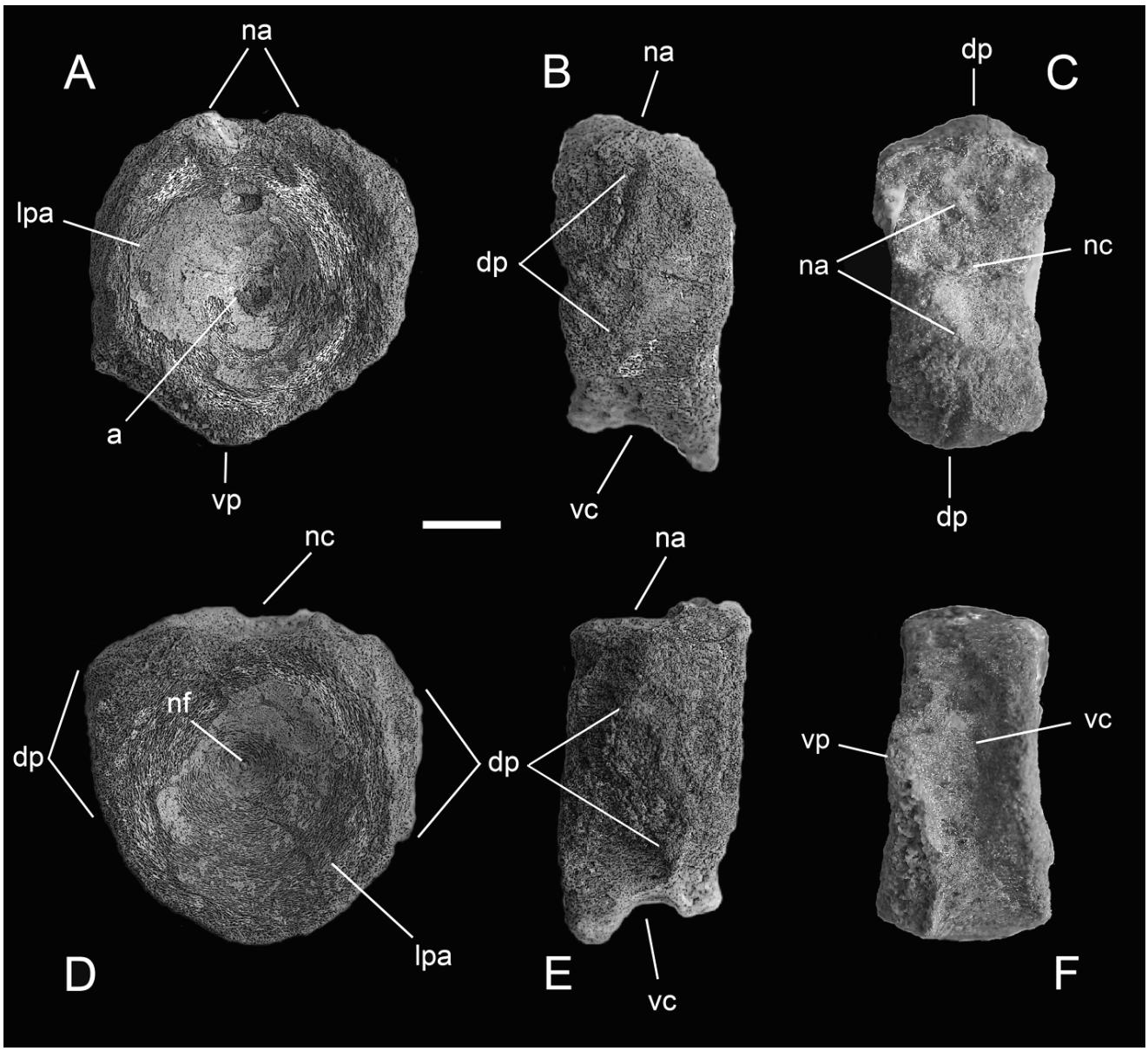

Fig. 5 - Specimen MSNC 4463 in cranial (A), left lateral (B), dorsal (C), caudal (D), right lateral (E) and ventral (F) view. Scale bar equals 10 mm. Abbreviations: a, ammonite; dp, diapophysis; lpa, limit of peripheral flat area; na, facet for neural arch; nc, floor of neural canal; nf, notochordal foramen; vc, ventral concavity; vp, ventral peak.

ratio of specimen MSNC 4464 is 1.3. As in specimen MSNC 4463, on the dorsal side the two articular facets for the pedicels of the neural arch show a shorter-than-wide neural arch, and on the ventral surface a concavity is present, and any keel is absent. In lateral view, a drop-shaped rib articulation is preserved only to the left side, whereas to right side a marked and irregularly concave erosion occupies the same position.

The orientation of this vertebra can be inferred mainly from the only preserved rib articulation, that is asymmetrically positioned close to the cranial face (e.g., McGowan & Motani 2003, figs. 2; 18A, C) and oblique, laterodorsally directed, with the lateral portion almost touching the cranial face rim.

Discussion

Since the taxonomic identity of ichthyosaurian isolated centra is often in doubt (e.g., McGowan 1994; McGowan & Motani 2003), and since their relative position in the vertebral column can only be estimated, isolated vertebrae are usually of limited value. On the other hand, this material is the first finding of its kind in the Upper Triassic of Sicily, and then its scientific value is out of question.

As written above, specimens MSNC 4463 and MSNC 4464 preserve a combination of characters that is diagnostic for Ichthyosauria: both vertebral centra are circular in craniocaudal view, strongly amphicoelous,

nothochordal, with a typical discoidal "ashtray-like" morphology (i.e. higher than long), as usually described in literature (e.g., McGowan & Motani 2003; Rieppel 1994). Here we discuss further on the anatomical position of the centrum MSNC 4463, and on the characters supporting its taxonomic attribution. As for centrum MSNC 4464, we cannot discuss its anatomy with equal detail, but we can infer its position in a vertebral series.

Anatomical position

The vaguely cardioid shape, slightly wider than high, with a flat dorsal surface bounded laterally by pedicels for the articulation with the neural arch, and the presence of diapophyses, support the identification of specimen MSNC 4463 as an element of the presacral column. At first sight, the cranial face of this centrum appears subpentagonal, or "heart-shaped", with a ventral "peak". This is worth of examination, as it is considered a cervical feature since several time (e.g., Merriam 1902). Actually, at closer view this shape reveals to be an artifact of preservation, as the cranioventral margins of the centrum have been straightened by erosion both on the left and on right sides, thus exposing their inner spongy bone and leaving untouched the ventralmost surface, which became protruded as a "peak". Actually, the texture of the untouched portion of the cranial face is circular all along its perimeter. Therefore this centrum was originally almost perfectly circular both in cranial and caudal view. According to McGowan & Motani (2003), this would indicate a dorsal position. The better preserved ventralmost portion of the centrum allows to investigate another key-character (Maisch 2010): the presence/absence of intercentral facets. Cervical intercentra are known in most ichthyosaurs. Particularly the Triassic genera, as shown for *Shastasaurus* and *Cymbospondylus* by Merriam (1908), have them well developed. In contrast to the cervical vertebrae, intercentra of the dorsal vertebral column are not known in any ichthyosaur (Rieppel 1994). In our specimen there is no sign of intercentral facets, which means that the centrum MSNC 4463 belongs to a post-cervical series.

The single rib facets, in form of elongated diapophyses on the lateral surfaces of the centrum, indicate that parapophyses are absent. This is usual in the dorsal vertebrae of all non-thunnosaurian neoichthyosaurs (sensu Sander 2000). The position of the diapophyses, dorsally approaching the facets of the neural arch and extending to about the middle of the lateral face of the centrum, at equal distance from the cranial and caudal borders of the central faces, supports the interpretation of specimen MSNC 4463 as an anterior dorsal element. In facts, dorsally placed diapophyses, confluent with the neural pedicels, are typically found in cervical vertebrae, whereas more ventrally set diapophyses are usually seen in more caudally positioned elements (McGowan & Motani 2003). According to Sander (1997), "in shastasaurids in general, the single articular facet separates from the neural arch before the middle dorsal region (Sander 1989, 1992; Camp 1980; Merriam 1908)".

Direct comparison of a cast of the Monte Scalpello specimen MSNC 4463 with the holotype of *Besanosaurus leptorhychus* (Dal Sasso & Pinna 1996) housed at the Museo di Storia Naturale di Milano, confirms it is consistent with anterior dorsal centra, both in shape or in size (Dal Sasso pers. obs. 2012). In particular, the two share the following characters: notochordal centra with height/lenght ratio >1; articular facets for the neural spines with transverse diameters >50% of craniocaudal widths; parapophyses absent; diapophyses elongated and located laterally but not far from the dorsal flank of the centrum; intercentra absent.

In basal ichthyopterygians, the shape of the amphicoelous concavities changes within a single individual depending on the position of a vertebra in the vertebral column: the more posterior the position, the more restricted the amphicoelous concavity to the middle, and the more extensive the peripheral flat area (McGowan & Motani 2003). In specimen MSNC 4463 this area is almost 1 cm wide, i.e. occupies at least one third of the concavity. On the other hand, our vertebra is not laterally compressed to the extent seen in the caudal vertebrae and does not show a higher, laterally compressed and shorter appearance as for the vertebrae of the pelvic region. In *Cymbospondylus petrinus*, the peripheral flat area becomes conspicuous as far anteriorly as the mid or anterior dorsal area, but at least the cervical and anteriormost dorsal vertebrae are devoid of such flat areas (Merriam 1902, 1908; McGowan & Motani 2003). In the end, on a comparative basis, identification as an anterior dorsal vertebra is highly reliable for specimen MSNC 4463.

Specimen MSNC 4464, on the other hand, in spite of the lack of its right ventrolateral portion preserves an evident pentagonal appearance, especially in cranial view (Fig. 6A), and several other features characterize the anterior cervical centra (McGowan & Motani 2003, figs. 2A; 18A-D):

i) rib articulation placed more dorsally than in specimen MSNC 4463, and definitely confluent with the facet for neural arch;

ii) ventral concavity of the centrum in lateral view facing caudoventrally, rather than cranioventrally (opposite to centrum MSNC 4463);

iii) articular facets for the neural arch markedly shorter-than-wide;

iv) length/height ratio higher than centrum MSNC 4463;

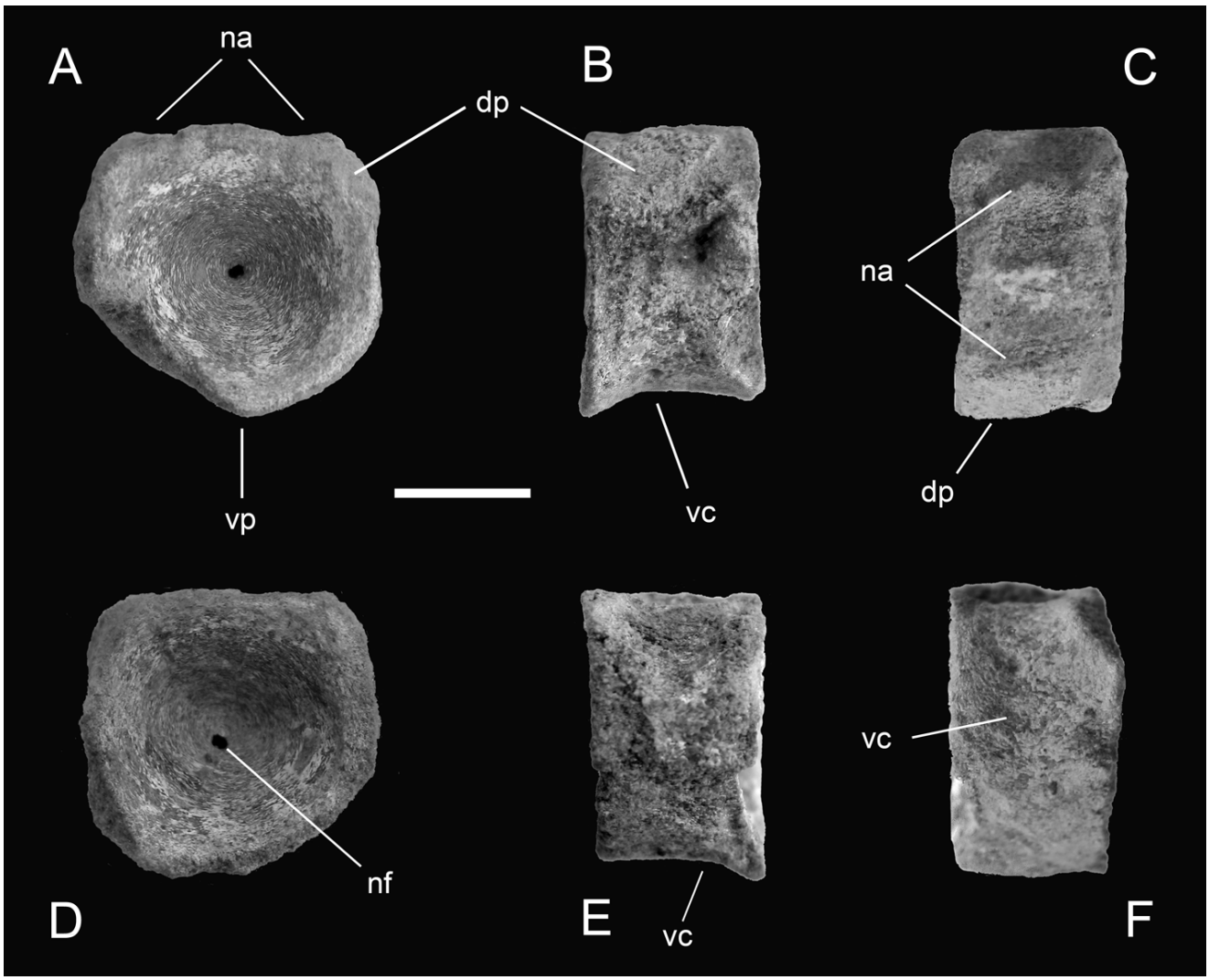

Fig. 6 - Specimen MSNC 4464 in cranial (A), left lateral (B), dorsal (C), caudal (D), right lateral (E) and ventral (F) view. Scale bar equals 10 mm. For abbreviations, see captions to fig. 5.

v) absence of flat peripheral area bordering the cranial and caudal faces.

The only contrasting character is the absence of intercentral facets, but this might be an artifact of preservation.

Taxonomic attribution

The absolute size of centrum MSNC 4463 is well within the range of adult large-sized ichthyosaurs, like shastasaurids (with the exclusion of giant species such as *Shonisaurus popularis*), parvipelvians (sensu Motani 1999) but not mixosaurids, the latter being relatively smaller. The length/height ratio of centrum MSNC 4463 is also within the proportional range of medium-large Middle to Upper Triassic ichthyosaurs *Besanosaurus*, *Cymbospondylus* and *Shastasaurus*, and unlike the one of contemporary much smaller forms, such as *Merriamia* (junior synonym of *Toretocnemus* [Motani 1999]), *Mixosaurus*, *Pessosaurus* (regarded as *nomen dubium* by Maisch & Matzke [2000]), and *Qianichthyosaurus* (Li 1999).

Both absolute size and length/height ratio of MSNC 4463 are much like the ones of the holotype of *Besanosaurus leptorhynchus*, which means an individual 5/6 meters-long. Apart from that, attribution to the Besanosauridae (sensu McGowan & Motani 2003) is unlikely. The characters shared above (see Anatomical position, this paper) are more likely related to homology of anatomical position, and are much likely symplesiomorpies of shastasaurian-grade ichthyosaurs. Apart the different geological context and age (Mufara Formation, late Carnian vs Besano Formation, Anisian-Ladinian boundary), really different from *Besanosaurus* in anatomical terms is the concavity of the ventral margin of the centrum, which occurs in craniocaudal aspect in the Besano specimen (Dal Sasso & Pinna 1996: fig. 13C), and in lateral aspect in the Monte Scalpello specimen MSNC 4463 (Fig. 5B, D).

On the other hand, it must be noted that like *Besanosaurus*, specimen MSNC 4463 does not have the "anterior diapophyseal truncations" considered diagnostic of the anterior dorsal vertebrae of the genus *Cymbospondylus* (Huene 1916; Sander 1989, 1992), although McGowan (1994) had questioned the reliability of this character for the identification of isolated ichthyosaur vertebrae. The presence of diapophyses set at mid-height and far from the anterior margin excludes the Cymbospondylidae in any case and is consistent with the Shastasauridae (Sander 1997). In facts, in *Shastasaurus* the cranioventral extension of the diapophysis remains well separated from the cranial margin of the centrum.

Maisch & Matzke (2000) report the Merriamosauria "except *Besanosaurus leptorhynchus*" to be united by six synapomorphies, among which is the "anterior dorsal rib facets not confluent with anterior central facets". This is another way to describe the absence of anterior diapophyseal truncations, a status that – as told just above – is actually found in *Besanosaurus* (Dal Sasso & Pinna 1996; Dal Sasso pers. obs. 2012). Therefore, Maisch & Matzke (2000) should probably recode the character for this taxon. What is more important herein is that the Monte Scalpello specimen MSNC 4463 shows a basal merriamosaurian-like condition in the single elongated rib facets. In shastasaurian-grade ichthyosaurs the rib articulations of the presacral series are largely unicipital, due to the loss of the ventral (parapophyseal) rib facets: parapophyses are present in the cervicalmost vertebrae, but while going caudally, they gradually diminishes in size and disappear along the cervical-dorsal transition (Merriam 1902, 1908; Camp 1980; Sander 1987, 1989; Dal Sasso & Pinna 1996; Maisch & Matzke 2000). The lack of parapophyses in the dorsal vertebrae has been well documented for *Cymbospondylus* (Sander 1989: fig. 5), *Shastasaurus* (Merriam 1902: pl. 7), *Californosaurus* (Merriam 1908: fig. 27), *Shonisaurus* (Camp 1980: figs. 28-30), and *Pessosaurus* (Callaway & Brinkman 1989: fig. 2).

Another character of shastasaurian-grade ichthyosaurs that might be examined in specimen MSNC 4463 is the presence/absence of a flattened rim bordering the concave articular faces. In our specimen the amphicoelous concavity is limited to the mid-center of the articular surface, as is the case in basal ichthyopterygians, and differently from derived ichthyosaurs in which the concavity occupies most of the articular surface. A flat peripheral area can be seen in both Shastasauridae (e.g., Callaway & Massare 1989a: fig. 5.4) and Cymbospondylidae (e.g., Merriam 1902: pl. 16 figs. 3, 5), with *Cymbospondylus* seemingly distinguished by an increased deepening of the amphicoelous excavation of vertebral centra near center (Sander 1992). The Monte Scalpello vertebra MSNC 4463 shows a similar trend, but is slightly different in having a peripheral rim not as flat as in *Cymbospondylus*, and a more gradual deepening towards center. However, following McGowan & Motani (2003), we are conscious that this difference may not be as diagnostic as it seems, because -as told above- in basal ichthyopterygians the shape of amphicoelous concavities changes within a single individual depending on the position of a vertebra in the vertebral column.

Among other basal Euichthyosauria [sensu McGowan & Motani (2003); Longipinnati sensu Maisch & Matzke (2000)], Toretocnemidae (i.e. *Qianichthyosaurus* and *Toretocnemus*) must be excluded because of their double-headed dorsal ribs and peripheral rim concavity continuous with the concavity of the faces (Maisch & Matzke 2000). Also the Californosauridae can be ruled out, based on their dorsal neural spines with transverse diameters <50% of craniocaudal widths (e.g., Callaway 1989; Merriam 1902), and anterior dorsal (= "thoracal") vertebral centra rather elongate, more than two thirds as long as high (Maisch & Matzke 2000).

In the end, the merriamosaurian Shastasaurinae [sensu McGowan & Motani (2003)] remain the most probable candidates. Maisch & Matzke (2000) diagnose the most representative taxon of this clade, the North American Upper Triassic *Shastasaurus*, as having thoracal ribs unicipital, which is consistent with the single elongated rib articulations seen in the Monte Scalpello specimen MSNC 4463. In addition, MSNC 4463 is characterized by a length/height ratio of 0.6, which is a value inside the range of 0.28-0.6 indicated as diagnostic for *Shastasaurus* (Callaway & Massare 1989a). The fact that this value approaches the highest term (0.61) is another element in favor of the anatomical interpretation herein suggested, i.e., that this specimen is an anterior dorsal vertebra, because a value close to 0.6 characterizes the longest centra, which are usually the anteriormost dorsals. Even though a height/length ratio of over 2 is common in dorsal vertebrae assigned to *Shastasaurus*, specimens with unusually longer dorsals (height/length ratio around 1.6) are described (Sander 1997: figs. 3,5). There is great variability in this ratio, as it appears to be size-related, with the small species – such as *S. neoscapularis* – having relatively long vertebrae, and the large species – such as *S. careyi* - having relatively short vertebrae (Sander 1997).

Two European shastasaur-like ichthyosaurs, *Mikadocephalus* (Maisch & Matzke 1997) and *Wimanius* (Maisch & Matzke 1998), from the Anisian-Ladinian of Monte San Giorgio, cannot be checked due to the lack of homologous anatomical elements (the holotype and only known specimen consists of cranial material). Nevertheless, some authors regard these taxa as possible junior synonyms of *Besanosaurus* (Sander 2000) or *Pes-*

sosaurus (McGowan & Motani 2003). Concerning the latter, some similarity can be seen in the reniform shape of the diapophysis of specimen MSNC 4463, as described by Callaway & Brinkman (1989). Anyway, even this character is probably homoplastic for shastasaurian-grade ichthyosaurs, so that most material described as *Pessosaurus* is not diagnostic beyond the family-level Shastasauridae (McGowan & Motani 2003).

At least two Chinese shastasaurids are known from the Carnian Xiaowa Formation: *Guanlingsaurus liangae* and *Guizhouichthyosaurus tangae* (Yin et al. 2000). Both taxa cannot be easily compared with our material, in spite of the existence of fairly complete and articulated fossils, as the vertebrae are not described in detail. We know that *Guanlingsaurus liangae* (assigned to *Shastasaurus* by Sander et al. [2011] but more recently maintained as a different genus by Ji et al. [2013]) presents the highest number of vertebrae of any ichthyosaur (approximately 86 presacrals and over 100 caudals). We also know that, "compared to other Merriamosauria, the loss of contact of the diapophysis with the neural arch occurs very far back, on the 69th presacral" (Sander et al. 2011). More precise information comes from a recently described new specimen (Ji et al. 2013), in which "the dorsal vertebrae are remarkably discoidal and the height/length ratio at the 20th vertebra is 2.6": a value definitely higher than the one we measured in the Monte Scalpello specimens. *Guizhouichthyosaurus* (Yin et al. 2000) was also assigned to the genus *Shastasaurus* by Shang & Li (2009), that describe it as having "both the centra and the neural spines...similar in proportional sizes to that of *Shastasaurus osmonti* (Merriam 1902)", and dorsal vertebrae 18 to 30 "with a height/length ratio of approximately 2.3".

Given this, and considering all available data, we cannot but follow a cautious approach, and refer the Monte Scalpello specimen MSNC 4463 to Shastasauridae indet. In fact, only two other *Shastasaurus*-like taxa remain, but can be easily ruled out. *Phantomosaurus (= Shastasaurus neubigi),* known from the Late Anisian of Germany, can be excluded because of its strong lateroventral keels on the thoracal vertebral centra, that are not found in any other ichthyosaur (Maisch & Matzke 2000). According to McGowan & Motani (2003), this taxon must be considered *incertae sedis*. Lastly, the giant North-American form *Shonisaurus* can be excluded as well, as it is characterized by thoracal vertebral centra very high, more than three times as high as long.

The craniocaudally, other than dorsoventrally, oriented rib articulation of specimen MSNC 4464, coupled with its close proximity to the base of the neural arch, is reminiscent to that of *Mixosaurus cornalianus* (Dal Sasso pers. obs. 2013 on Besano material housed at the Museo di Storia Naturale di Milano). In addition, differently from the cervical centra of *Besanosaurus*, *Cymbospondylus* and *Shastasaurus* (Merriam 1902, 1908; Sander 1989), there is no evidence of double rib-articulation. However, the latter feature must be taken with caution: taking into account the highly weathered sides of this centrum, it is highly possible that the parapophyses got lost on both sides together with part of the bone wall. In facts, Callaway (1997) is the only modern author indicating Mixosaurids as having holocephalous cervical ribs. Maisch & Matzke (2000) report that mixosaurids, as well as *Utatsusaurus*, *Grippia* and *Chaohusaurus*, do possess largely unicipital rib articulations in the presacral series, just except for the cervicals and the region around the sacrum. In the end, McGowan & Motani (2003) recognized that the most distinct vertebral character of the Mixosauria (i.e., the one that they differ from other ichthyosaurs) is having narrow, high neural spines that are almost perpendicular to the vertebral column – a feature that we cannot check.

Morphometric data can be more helpful in our case. The absolute size, coupled with an unambiguous immaturity-related character (relatively large, open notochordal foramen) indicate that the centrum MSNC 4464 belongs at minimum to a subadult specimen from a medium-sized ichthyosaur. At its stage of development, this individual might have measured 2-3 meters in length, a size that is too large for any known adult mixosaurid. Also the height/length ratio (1.3) and the length/height ratio (0.7) of centrum MSNC 4464 are far from those indicated for the Mixosauria by McGowan & Motani (2003), and approach the range of shastasaurian-grade ichthyosaurs. In conclusion, the somewhat unusual diapophysis, more craniocaudally than dorsoventrally directed, and the impossibility to examine any parapophyseal remains, does not allow placing specimen MSNC 4464 below the taxonomic level of Ichthyosauria indet.

Paleobiogeographic significance of the Monte Scalpello ichthyosaurs

Triassic ichthyosaurs are well known in the Tethydean area mainly from the Muschelkalk Basin (central and western Europe), from Carinthia (Austria), from Besano-Monte San Giorgio (Italian-Swiss border), and from other localities in northern Italy (Callaway & Massare 1989b). Mixosaurian remains aside, Italy has yielded very few and fragmentary fossils of Triassic ichthyosaurs. Notable the exception of *Besanosaurus leptorhynchus:* a complete skeleton of a pregnant female with embryonic remains, unearthed in the Besano Formation (=Grenzbitumenzone, Anisian-Ladinian bound-

ary), which was formerly referred to shastasaurids (Dal Sasso & Pinna 1996, but see Motani 1999, McGowan & Motani 2003, and see Taxonomic attribution, this paper). Fragmentary specimens possibly belonging to *Cymbospondylus buchseri* (Sander, 1989) and to a *Pessosaurus*-like ichthyosaur are very rare in northern Italy but relatively frequent within the Besano Formation in Lombardy (Tintori et al. 2005a; Dal Sasso pers. obs. 2013). A partial skeleton referred to *Cymbospondylus* sp. has been reported in the Livinallongo Formation (Ladinian) of Monte Seceda, Alto Adige (Kuhn-Schnyder 1980). Isolated vertebrae attributed to *Cymbospondylus* sp. come from the Anisian of Bergamo province (Rieppel & Dalla Vecchia 2001), and isolated vertebrae attributed to *Shonisaurus* sp. are known from the upper Carnian (Durrenstein Formation) of Dolomites (Dalla Vecchia & Avanzini 2002). Furthermore, Dalla Vecchia (2009) referred to "Genus indet." an isolated centrum from the Middle Triassic of northern Friuli, which bears some resemblance with typical shastasaurian centra.

South of the Alps, in the whole central and southern Italy there is no record of ichthyosaurs even in Jurassic and Cretaceous deposits, with the single exception of a semi-articulated skeleton (still under study, but possibly belonging to Thunnosauria) found in the Kimmeridgian of Camponocecchio, near Genga, Marche (Tintori et al. 2005b). In this context, the specimens herein described from Monte Scalpello, Sicily, are a remarkable novelty: these finds represent the southernmost occurrence of ichthyosaurs from Late Triassic times in the western Tethys basin, and in particular, MSNC 4463 is the first shastasaurid from the southern Italian territory.

Conclusion

The vertebral centra MSNC 4463 and 4464 from Monte Scalpello, Sicily, despite their isolated and fragmentary condition, are remarkable because they represent the first ichthyosaurian remains ever found in southern Italy. Based on proportional and morphological key characters, specimen MSNC 4463 can be ascribed to a fully adult Shastasauridae indet. Uncertainty remains about lower level attribution, as the type genus of the clade has a North American distribution, whereas in recent years some European "*Shastasaurus*" taxa have been subjected to review, becoming ascribed to other Merriamosauria, and new taxa have been unearthed in China. Specimen MSNC 4464 is referred with more caution to Ichthyosauria indet., but it certainly belongs to a second and immature individual.

Paleoecological conclusions are presently hard to be made. Medium-large shastasaurs are considered pelagic animals, well adapted to open waters since Middle Triassic times, but it cannot be excluded that some species inhabited or frequented coastal environments. The malacofauna studied by Scalia (1910-1914) shows a mixture of pelagic and littoral forms, which seems to indicate some post-mortem mixing. Similarly, it is possible that the ichthyosaur vertebrae suffered remarkable transportation, after disarticulation of the carcasses. Nevertheless, the new specimens indicate that the paleobiodiversity of the Monte Scalpello Triassic fauna is higher than previously known, and probably mostly unknown.

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