

NEW EVIDENCE OF ARMoured TITANOSAURIDS IN THE LATE CRETACEOUS - *MAGYAROSAURUS DACUS* FROM THE HATEG BASIN (ROMANIA)

Zoltán CSIKI

Faculty of Geology and Geophysics, Bucharest University, Bd. Bălcescu, 1, 70111 Bucharest, Romania.

Abstract : A peculiar osteoderm discovered in the Late Maastrichtian of the «La Cărare» locality near Sînpetru village (Hateg Basin, Romania) is described and referred to the titanosaurid sauropod *Magyarosaurus dacus*. This represents the third report on the presence of osteoderms in European titanosaurids, besides those from South America and Madagascar, showing that possession of a dermal armour had a wide distribution in these Late Cretaceous sauropods.

Key words : Hateg Basin, *Magyarosaurus*, titanosaurid osteoderms.

Nouvelle preuve de la présence de titanosauridés cuirassés dans le Crétacé terminal - *Magyarosaurus dacus* du Bassin de Hateg (Roumanie)

Résumé : Une plaque osseuse provenant du gisement de «La Cărare» près du village de Sînpetru (Bassin de Hateg, Roumanie) est décrite et attribuée au sauropode titanosauridé *Magyarosaurus dacus*. Il s'agit du troisième titanosauridé européen possédant des ostéodermes ; après les découvertes de titanosaures cuirassés en Amérique du Sud et à Madagascar, les découvertes européennes prouvent que la présence d'ossifications dermiques était très largement distribuée dans ce groupe de sauropodes au Crétacé supérieur.

Mots clés : Bassin de Hateg, *Magyarosaurus*, ostéodermes des titanosauridés.

INTRODUCTION

The Uppermost Cretaceous (of Middle-Late Maastrichtian age; Antonescu *et al.*, 1983; Grigorescu, 1992) deposits of the Hateg Basin (Hunedoara County, Romania) yielded a rich fossil vertebrate (mostly reptile) assemblage, studied by F. Nopcsa beginning with the end of the 19th century; he published his results in several papers between 1900-1934 (Weishampel & Reif, 1984). The researches were restarted in the late seventies by teams of the Faculty of Geology and Geophysics of the University of Bucharest (under the heading of Prof. D. Grigorescu) including Mr. I. Groza from the Hunedoara County Museum, Deva. This work led to a partial taxonomic and systematic reassessment of the Hateg dinosaur fauna (Weishampel *et al.*, 1993) and of its paleoecologic and paleobiogeographic implications (Grigorescu, 1983, 1992; Weishampel *et al.*, 1991). New taxa were also reported, besides abundant remains of the already known ones (Grigorescu, 1984; Weishampel & Jianu, 1996), as well as the discovery of a dinosaur nesting site

(Grigorescu *et al.*, 1994).

The fossils come mostly from the detritic, fluvial deposits of the Sînpetru Formation, outcropping in the Sibisel Valley near Sînpetru village (Grigorescu, 1992), although several important fossil localities were recently identified in the chronostratic equivalent Densus-Ciula Formation as well (Grigorescu *et al.*, 1994). During the 1995 field season, the deposits of the Sînpetru Formation cropping out in the Sibisel valley had yielded a well-preserved, virtually complete osteoderm, found in one of the richest fossil localities (the «La Cărare» = «The Path» site, Csiki, 1995), quarried over a span of several years. The lithology at this site is represented by lens-shaped channel deposits (greenish microconglomerates and sandstones) intercalated in finer-grained floodplain deposits (brownish and variegated mudstones). The osteoderm is of a very peculiar morphology, deserving special attention, being the first non-crocodylian dermal armour element recovered from the Upper Maastrichtian deposits of the Hateg Basin.

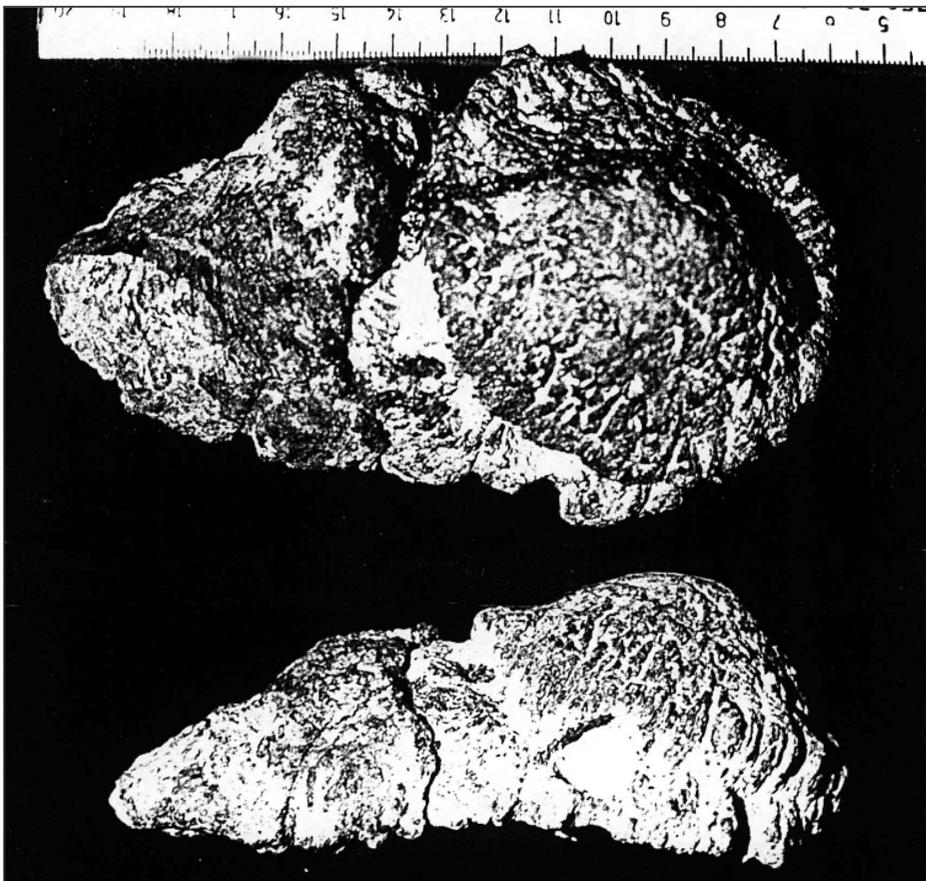
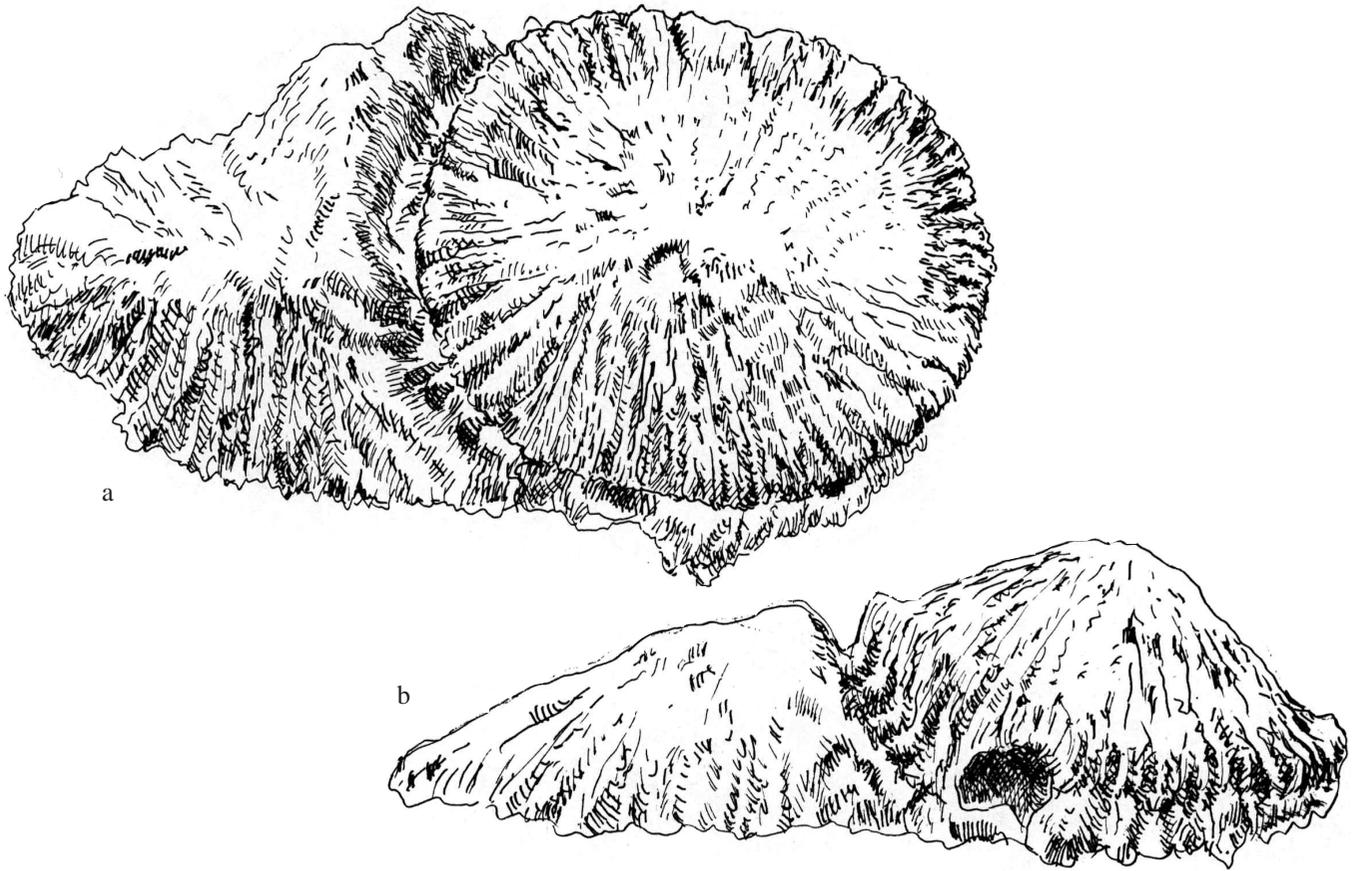


Figure 1. *Magyarosaurus dacus* osteoderm (FGGUB R.1410) from the Late Maastrichtian of the Hateg Basin (Romania) in: a. - external view; b. - side view. Drawings in natural size.

DESCRIPTION

The osteoderm found at the «La Cărare» site (FGGUB R.1410; Fig.1) has an elongated, roughly elliptical outline, with two distinct regions: a «scute» (or «bulb», see Le Loeuff *et al.*, 1994) and a «root» region.

The scute has an almost circular outline (Fig. 1a), measuring 80 mm in length and 68 mm in width, and it presents a low, largely rounded central cone (of 42 mm height) surrounded by a subhorizontal shelf that is partially broken off (it may correspond to the «cingulum» of Sanz & Buscalioni, 1987; Sanz, written comm., 1995). Owing to this breakage, there is a possibility that the complete scute might had an outline close to circular. Around the central cone, there is a slight variation in the development and degree of inclination of the shelf; this latter has a width that ranges from 5-6 mm to 1 cm. The shelf is entirely missing in one side; although a small shelf (now broken and/or eroded) might have been present here, the width of the shelf decrease and its slope increase toward this region, suggesting that the actual slightly asymmetric vertical cross-section of the scute is real rather than taphonomical. Be that as it may, then the cone is subcentral in position, displaced toward the margin with no shelf. The external surface of the central cone is made of tubercles, fibers, holes and grooves of a roughly radial pattern; this pattern is much less evident on the cingulum.

The root has a more irregular shape, elliptical to triangular (Fig. 1a) and it underlies the scute, which is asymmetrically placed on the top of it, at one end of the root (Fig. 1b). Its outline is largely rounded at one end, below the scute, and it narrows to a triangular, pointed opposite end; the long axis of the root seems to be divergent from that of the scute by an angle of 30°. The root is thin below the scute, very thick (up to 4 cm) immediately behind the scute and then thins again. A well-marked groove placed below the cingulum separates the scute from the root region; it becomes shallower at the rounded end of the root (although this feature may be due to erosion). The surface pattern of the root is also very irregular, both in external and in internal view. The flat internal surface shows a roughly irregular, nodular-fibrous pattern. Three foramina can be seen on the internal face. The largest one (4 mm diameter) is placed below the

centre of the scute, and enters the body of the root obliquely; the two other foramina are twinned and placed on the distal quarter of the root. The cross-section on the broken surface at the middle of the root shows the presence of some internal ducts (*sensu* Sanz & Buscalioni, 1987), the larger ones being mostly sub-horizontal and the smaller ones having an ascending trajectory. The most conspicuous feature of the root is a large (1.3 mm wide) foramen that pierces the root below the area of reduced scute shelf. It is roughly circular in outline externally, where it opens into the basal groove, and excavates the base of the scute as well, but expands significantly in antero-posterior direction on the internal side, so that it has an ellipsoidal opening and an anteriorly obliquely ascending tract. It is unclear if this represents a structure of the osteoderm or is taphonomically produced.

COMPARISONS AND DISCUSSIONS

Two groups of reptiles from the Hateg Basin were known to have possessed dermal armor: crocodylians and nodosaurid dinosaurs. From these two groups, remains of the first one, including osteoderms, are common in the «La Cărare» site (Csiki, 1995). Their dermal armor elements, with a characteristic «pits and ridges» external ornamentation cannot be misidentified and FGGUB R.1410 shows clear-cut differences when compared with crocodylian remains.

As Sanz & Buscalioni (1987) have already noted, the only confusion of the presumed titanosaurid osteoscutes can be made with those of the ankylosaurians. This group of mostly Cretaceous armoured ornithischians is represented in the Maastrichtian Hateg fauna by the basal nodosaurid *Struthiosaurus transilvanicus* (Nopcsa, 1929) for which, however, no elements of the dermal armour are known. However hand, Pereda-Suberbiola & Galton (1994) stated that there is no unambiguous character to support a specific distinction between *Struthiosaurus transylvanicus* and *S. austriacus* from the Gosau Beds of Austria, for which, in turn, fine armour plates are known (see Nopcsa, 1929, plate IV) consisting of longitudinally sharply keeled oval plates and high spines. Both morphotypes are distinctly different from FGGUB R.1410.

In Europe, other Late Cretaceous nodosaurid armour plates came from Spain (Sanz, 1986) and respectively, France, from where they were described under the binomial *Rhodanosaurus ludgunensis* (Nopcsa, 1929, plate V) or as *Struthiosaurus lugdunensis* (Lapparent, 1947, plate V, figs.6-26). Both of these taxa are regarded as either nomina dubia or junior synonyms of *S. transylvanicus* (Pereda-Suberbiola, 1992). Strong spines and keeled scutes are both known for these Franco-Iberian nodosaurids, again distinctly different from FGGUB R.1410. The Lower Cretaceous *Hylaeosaurus* and *Polacanthus* (Pereda-Suberbiola, 1993), closely related to *Struthiosaurus* (Coombs & Maryanska, 1990), had oval, flat scutes, keeled plates or conical spines. The North American nodosaurid genera (*Sauropelta*, Ostrom, 1970; *Panoplosaurus* and *Edmontonia*, Carpenter, 1990; *Hierosaurus* and *Niobrarasaurus*, Carpenter *et al.*, 1994) have elongated, usually highly or sharply keeled scutes, triangular spine-like plates, spines or spikes. In conclusion, generally speaking, nodosaurids have «... body covered dorsally by armour plates of three or four shapes including flat, oval to rectangular plates that bears a keel ridge or short spine externally ... (and) ... may have tall conical spikes or spines» (Coombs & Maryanska, 1990, p. 457, 473). All these conditions differ from that seen in FGGUB R.1410, with a small and blunt cone and a surrounding cingulum, let alone the massive «root».

For the assignment of FGGUB R.1410 it is thus necessary to consider a third, potentially armour-bearing reptile group, that of the titanosaurid sauropods, represented in Hateg by *Magyarosaurus dacus*. The genus *Magyarosaurus* was erected by Huene (see Le Loeuff, 1993) for the sauropod remains of titanosaurid affinities referred by Nopcsa (1915) to *Titanosaurus dacus*. On the basis of that material, Huene also erected two new species: *Magyarosaurus hungaricus* and *M. transylvanicus*, species retained as valid (through pending on further revision, in the general context of the family Titanosauridae) by McIntosh (1990). Le Loeuff (1993) proposed the referral of all the Hateg titanosaurid material to *Magyarosaurus dacus*, proposal followed in this paper. (It should be noted, however, that a general revision of Romanian titanosaurid material is necessary to clarify the systematic problems raised by the

Hateg sauropods.)

In consequence, all the sauropod material from the Hateg Basin is attributed to *M. dacus*. It comprises mostly disarticulated limb bones and vertebrae; in the last years a small, incomplete braincase had also been discovered (Weishampel *et al.*, 1991). However, although the presence of dermal armor in certain titanosaurids has been reported on by some authors (Depéret, 1896; Bonaparte & Powell, 1980; Powell, 1992; Sanz & Buscalioni, 1987; Le Loeuff, 1995; Le Loeuff *et al.*, 1994, Jacobs *et al.*, 1993; Dodson *et al.*, 1998), no evidence of such an armour in *Magyarosaurus dacus* existed until now. The osteoderm recovered in 1995 (FGGUB R.1410) may represents a first such evidence.

It must be emphasised as well that the remains of the nodosaurids are extremely rare in the Sinpetru Formation, with only a single well-established occurrence from where the type specimen of *Struthiosaurus transylvanicus* came (Grigorescu, 1983; Csiki, 1995). Their remains are unknown from the «La Cărare» site, where, in turn, *Magyarosaurus* is represented by scattered limb bones and vertebrae. Even if these skeletal remains were not found in close association with FGGUB R.1410, they might provide further support to the idea that the osteoderm is of titanosaurid rather than nodosaurid affinity.

Although it has been long ago suggested (Depéret, 1896) that titanosaurids may had possessed dermal armour (Depéret made his statement based on a scute found in association with caudal vertebrae of the sauropod *Titanosaurus madagascariensis*; see Le Loeuff *et al.*, 1994), the claim for armoured sauropods did not got general acceptance until clear evidence of such osteoderms associated with titanosaurid remains has been reported from the Late Cretaceous of Argentina (Bonaparte & Powell, 1980). Bonaparte & Powell (1980) named and Powell (1992) gave a detailed description of *Saltasaurus loricatus*, a new titanosaurid taxon whose skeletal remains were found associated with two types of osteoderms : dermal scutes up to 12 cm diameter and sheets of small dermal ossicles (the later ones recovered in their presumed natural position, attached to the postero-dorsal region of the ilia, cf. Bonaparte & Powell, 1980). They also suggested the referral of the osteoderms described by Huene (1929) as pertaining to the new South American

nodosaurid taxon *Loricosaurus scutatus*, to one of the three titanosaurid taxa coming from the same locality. The osteoderms were referred to either *Laplatasaurus araukanicus* (Bonaparte & Powell, 1980), or *Saltasaurus australis* (McIntosh, 1990).

Another report on titanosaurid osteoderms came from Spain where the Late Cretaceous (Campanian-Maastrichtian) Armuña site yielded two osteoderms associated with a titanosaurid caudal vertebra (Sanz & Buscalioni, 1987). Osteoderms of variable morphology (spines, scutes, bulbs) were reported from Early Maastrichtian fluvial deposits of Southern France (Le Loeuff *et al.*, 1994), referred to the titanosaurid *Ampelosaurus atacis* by Le Loeuff (1995).

In Africa, two Cretaceous titanosaurs were recently suggested to have had dermal armor. In southern Africa, Jacobs (1993) referred some small, ossicle-shaped calcite pseudomorphs to the newly erected Early Cretaceous *Malawisaurus dixeyi*. Finally, Dodson *et al.* (1998) further substantiated evidences supporting the presence of osteoderms in titanosaurids from Madagascar, renewing Depéret's one century old claim for armoured sauropods.

The above mentioned osteoderms share the following characters: oval to slightly circular in outline; presence of a cingulum at the margins of the scute; cone-shaped external surface with rugosities of a roughly radiated «groove and ridge» pattern; conspicuous woven bone on the internal face and presence of the internal ducts. FGGUB R.1410 exhibits the same character complex, that was shown to distinguish titanosaurid dermal armor from that of the nodosaurid ankylosaurs (Sanz & Buscalioni, 1987). When compared to the other inferred titanosaur osteoderms, it can be noted that it is very reminiscent in the morphology of the scute region to AR/86-102 described from Spain (Sanz & Buscalioni, 1987; Sanz, written comm., 1995), which in turn lacks the root region (Le Loeuff *et al.*, 1994 also noted the occurrence of such rootless scutes - called «spines» by them). Moreover, the general morphology of FGGUB R. 1410 is almost similar to that of MDE-C3-192 (see Le Loeuff *et al.*, 1994, fig.1) from the French material referred by Le Loeuff (1995) to the new titanosaurid taxon *Ampelosaurus atacis*. From the same sample, MDE -C3- 325 has a bulbous shape very similar to FGGUB R.1410, the French specimen having a higher and more pointed «spine». Regardless minor

morphological differences, the external face of FGGUB R.1410 is also reminiscent of the Malagasy osteoderm FMNH PR 2021 (Dodson *et al.*, 1998), an isolated scute.

The above noted similarities, together with the already mentioned co-occurrence with some scattered titanosaurid bones, allows the referral of FGGUB R.1410 to *Magyarosaurus dacus*; it represents the fifth published case in the row of the mounting evidences that all titanosaurids possessed dermal armor (McIntosh, 1990).

On the base of the available data, McIntosh (1990) concluded that possession of dermal armor may represent a titanosaurid synapomorphy. He separated at least three morphotypes of osteoderms among those referred to titanosaurids. However, it should be noted that the arguments for the presence of morphological differences between the scutes referred to *Saltasaurus loricatus* and those coming from Madagascar, Spain, respectively those of the Patagonian '*Loricosaurus scutatus*' are rather weak (as already noted by Bonaparte & Powell, 1980, p.22, the *Saltasaurus loricatus* plates «... show the same general morphology as those figured by Huene, 1929, and referred to an Ankylosaur from Patagonia»).

The small size of FGGUB R.1410, when compared to all the above mentioned specimens, is noteworthy. It has a diameter of only 8 cm as compared to 12 cm in AR/86-102, 17 cm in FMNH PR 2021 or as much as 25 cm in FSL 92827 for the scute or a length of 15 cm vs. 25 cm in MDE-C3-192 for the complete osteoderm, including the root. This obvious size difference might be accounted for by the phenomenon of dwarfism of the Hateg dinosaurs in general, and those of the titanosaurids in particular (Weishampel *et al.*, 1991).

A few final comments can be made regarding the pattern of the dermal armour on the body. Two cases of titanosaurid osteoderms being associated with nothing else than caudal vertebrae were reported (*Titanosaurus madagascariensis*, Armuña titanosaur), situation that allows a making a case for the hypothesis that titanosaurids possessed armor in the tail region. However, it should also be emphasised that in both instances the remains were found in fluvial deposits, so the co-occurrence is of lesser significance and currently there is a general agreement among the specialists that titanosaurids possessed

dorsal armor. Sanz & Buscalioni (1987) considered the armor as being restricted to the dorso-lateral areas of the sacro-pelvic region, with positive evidence existing for the dermal ossicle sheets of *Saltasaurus loricatus* (Bonaparte & Powell, 1980). Le Loeuff *et al.* (1994) suggested another arrangement, with the spinous osteoderms displaced in the shoulder region (homologous with the condition found in some nodosaurids and stegosaurids) and the flat scutes covering the back of the animal.

These different points of view in the tentative dermal armour reconstruction are coherent with two different functional roles inferred. Sanz & Buscalioni (1987) suggested that the armor strengthened the sacral region and helped using the tail as whip-like weapon (way of defence already suggested for some sauropods; Dodson, 1990). Le Loeuff *et al.* (1994) considered that the armor had a defensive role (filled in by the spinous osteoderms in the shoulder region) combined with a role in tightening the dorsal vertebral column. A similar role was inferred for the osteoderms represented by small isolated discs disposed above the neural spines of some primitive pareiasaurs by Lee (1996) who states that these osteoderms had a postural rather than protective role, providing areas of insertion for the axial musculature as they increased their body sizes. However, in titanosaurids the presence of such a supporting system cannot be correlated with increasing size, since at least the European representatives of the group were relatively small-sized sauropods and this being especially true for *Magyarosaurus*, regarded as an island dwarf (Weishampel *et al.*, 1991). It has also been suggested that it could stand for and replace the hyposphenepantrum articulation found in the vertebral column of most sauropods, but missing in titanosaurids (Le Loeuff *et al.*, 1994). Finally, Dodson *et al.*'s (1998) reconstruction proposed a sparse armour differentiated within the different parts of the body, including large, thick, closely appressed scutes with vertical margins, isolated conical ones that taper toward their peripheries and small ossicles interspersed between the larger ones.

The newly described specimen may be seen as embedded in the dermis isolated, following the line of reasoning of Dodson *et al.* (1998). Moreover, FGGUB R.1410 being asymmetric, it was probably displaced from the midline of the body, as part of a

longitudinal scute row. It is most reminiscent of AR/86-102 for which a sacral position has been proposed by Sanz & Buscalioni (1987) and it also seems less suitable for shoulder defence being lower and more rounded than MDE-C3-192. Consequently, a sacro-dorsal position can be very tentatively suggested for FGGUB R.1410 (however, for a more prudent analysis it would be better to wait for the discovery of a more or less complete, articulated dermal armour).

Another aspect worth mentioning is the rarity of these osteoderms in the Hateg Basin, despite of their general robustness that would favour a bias toward their preservation and an over-representation of them in the fossil record. In the Sînpetru Formation, titanosaurid remains, although abundant (along with the euornithopod *Rhabdodon priscus*, *Magyarosaurus dacus* is the most common taxon in Hateg; Csiki, 1995), are represented mostly by isolated limb bones and vertebrae, with a bias, still difficult to explain, against the preservation of the girdle bones (especially those of the pelvic girdle) even in the almost monospecific (i.e. *Magyarosaurus* - dominated) «fossil pockets». If FGGUB R.1410 will be shown to come indeed from the sacro-dorsal region of the back, its position can explain the scarcity of osteoderms, as preferential destruction or removal of the elements of the pelvic girdle (either via scavengers or physical taphonomical agents) might had implied the preferential destruction or removal of the osteoderms as well. Alternatively, Dodson *et al.* (1998) suggested that the general scarcity of titanosaurid osteoderms in the Late Cretaceous of Madagascar, despite of the abundance of other titanosaurid skeletal remains, may be a direct consequence of their arrangement pattern into a sparsely spaced armor; another explanation may come from their hydraulic behaviour, presumably different from those of the vertebrae or long bones.

ACKNOWLEDGMENTS

The fieldwork in the Hateg Basin was supported by funds from the National Science Foundation (IBN 9318747, SRB 9514784), the National Geographic Society, and the Dinosaur Society, through grants to David B. Weishampel (Johns Hopkins University). Dave Weishampel was also the first to suggest in the field that FGGUB R.1410 might belong to a titanosaurid. José Luis Sanz and Jean Le Loeuff are thanked for helping with references; Dan Grigorescu and Jean

Le Lœuff for discussions and help during the preparation of this paper. The figures are drawn by Radu Dumitrescu from the FGGUB.

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