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The geologically youngest remains of *Trachyaspis lardyi* Meyer, 1843 (Testudines, Cheloniidae): a new specimen from the late Pliocene of the Stirone River (Northern Italy)

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ABSTRACT - A new specimen of the marine turtle Trachyaspis lardyi *Meyer, 1843 collected from Piacenzian sediments cropping out in the bed of the Stirone River (Northern Italy) is herein described. The identification of the remains is based mainly on the vermicular ornamentation visible on the dorsal surface of the carapace plates, a diagnostic feature of the genus. Marine turtles assigned to* Trachyaspis *have also been found in other Italian localities as well as in France, Switzerland, Egypt, the United States and Japan, but all these remains come from Miocene sediments. The specimen from the Stirone River sediments is therefore the youngest known occurrence of the genus.*

Remains found in Egypt, the United States and Japan have been assigned to the genus Syllomus *in the past, but other authors consider the two genera to be synonyms and* Trachyaspis *to be the valid one. The specimen found along the Stirone River bed is morphologically similar to other specimens that have been assigned to either* Trachyaspis *or* Syllomus.

RIASSUNTO - [I resti più recenti di *Trachyaspis lardyi* Meyer, 1843 (Testudines, Cheloniidae): un nuovo esemplare dal Pliocene superiore del Torrente Stirone (Italia settentrionale)] - *In ambito paleontologico, il Torrente Stirone è conosciuto soprattutto per le tracce fossili e i resti di invertebrati e mammiferi, ma dai sedimenti esposti lungo il suo alveo sono stati estratti anche resti di piante, pesci e di un singolo rettile: una tartaruga marina ritrovata in diatomiti piacenziane vicino alla località La Farfanara. In questo lavoro vengono descritti i resti di tale tartaruga, assegnabili alla specie* Trachyaspis lardyi *per via dell'ornamentazione vermicolare presente sulla superficie dorsale degli elementi ossei del carapace. Si tratta dei resti più recenti attribuiti al genere* Trachyaspis *e dell'unico suo ritrovamento in rocce non mioceniche.*

Resti attribuibili a Trachyaspis *provengono anche da altre località italiane, dalla Svizzera, dalla Francia, dall'Egitto, dagli Stati Uniti e dal Giappone, ma il materiale proveniente dagli ultimi tre paesi è stato in passato assegnato a un genere differente:* Syllomus. *In assenza di una completa revisione di tutto il materiale attribuito ai due generi, la controversia è ancora aperta, ma l'esemplare proveniente dallo Stirone condivide caratteri morfologici sia con esemplari attribuiti a* Trachyaspis *provenienti dalla località italiana della Pietra Leccese, sia con esemplari attribuiti a* Syllomus *provenienti dalla Calvert Formation (Stati Uniti) e dal Giappone.*

INTRODUCTION

Starting from the second half of the XIX century, the riverbed of the Stirone River (Emilia-Romagna, Northern Italy) has undergone a process of erosion in its course between the built-up area of Scipione Ponte and Laurano (Cigala Fulgosi, 1976; Regione Emilia-Romagna, 1997). This erosion has exposed a succession of sediments covering the last ten millions of years, which have yielded a large variety of fossil remains of plants (Gregor, 1986; Mai, 1994), invertebrates (Papani & Pelosio, 1962; Marasti, 1973; Raffi, 1975; Pelosio & Raffi, 1977; Regione Emilia-Romagna, 1997; Borghi & Vecchi, 1998, 1999, 2001, 2003, 2006; Janssen, 2000; Borghi, 2001; Monegatti et al., 2001; Dominici, 2004; Garassino & De Angeli, 2004; Bertolaso et al., 2009) and vertebrates (Marasti, 1973; Cigala Fulgosi, 1976; Regione Emilia-Romagna, 1997; Landini et al., 2005; Bisconti, 2010), as well as fossil traces (Uchman & Pervesler, 2007; Pervesler & Uchman, 2009; Pervesler et al., 2011). As for the vertebrates, the findings consist mostly of marine fish remains (Marasti, 1973; Regione Emilia-Romagna, 1997), but fossils of tetrapods have been collected too. The Tortonian sandy marls exposed near the locality of La Bocca have yielded the remains of three balaenopterid whales (Landini et al., 2005; Bisconti, 2010), including the holotype of *Plesiobalaenoptera quarantellii* Bisconti, 2010, whereas from the fluvio-lacustrine Pleistocene deposits located near the confluence with the Ghiara River come the fossils of two rhinoceroses referred to *Dicerorhinus hemitoechus* (Falconer, 1868) by Cigala Fulgosi (1976), but later assigned to *Stephanorhinus hundsheimensis* (Toula, 1902) by Pandolfi et al. (2013). Here we report on the remains of the only fossil reptile coming from the Stirone River: a marine turtle found near the locality of La Farfanara.

GEOLOGICAL SETTING

The outcrop of the Stirone River is located near Salsomaggiore Terme (Parma, Italy), at the foothills of the Northern Apennines. The Stirone section is a coarsening upward succession of growth strata exposed in the easternmost distal sector of the Castell'Arquato wedge-top basin (Artoni et al., 2004); the latter is filled by

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a succession of foreland-dipping marine and continental synorogenic growth strata deposited between the late Miocene and the early Pleistocene.

In particular, between the localities Scipione Ponte and Laurano, the Post-evaporitic succession of the Padano-Adriatic edge emerges. This is a transgressive-regressive sedimentary cycle, closely related to the East-Northeast migration of foredeep depocenters and composed by fossiliferous sediments, in which the palaeoenvironmental, palaeoclimatic and palaeobiological evolution characterizing this territory from the late Messinian to the Middle Pleistocene is recorded. The thickness of this sequence, still controversial, was measured as at least 900 meters by Mary et al. (1993).

The bottom part of the sequence appears near the locality Scipione Ponte, where late Messinian siltstones and sandstones (Colombacci Formation) containing fossils of paralic environments, e.g., gastropods of the genera *Melanoides*, *Melanopsis* and *Theodoxus*, are overlain by blue-gray claystone and mudstone (Argille Azzurre Formation) embedding fossils of deep marine environments, e.g., *Astraea fimbriata* (Borson, 1821), *Clinura calliope* (Brocchi, 1814) and *Xenophora testigera* (Bronn, 1831) (Mary et al., 1993; Channel et al., 1994; Regione Emilia-Romagna, 1997; Amorosi et al., 1998).

In the following part of the sequence, a progressive marine regression, whose sedimentary expression is characterized, along the section from upstream (south) to downstream (north), by a succession of palaeoenvironments gradually closer to the coastline (Sintema del Torrente Stirone), can be recognized. At the top of the section there is a lacustrine and fluvio-deltaic depositional system known as Sintema di Costamezzana (Di Dio, 2005).

Two separate palaeomagnetic studies (Mary et al., 1993; Gunderson et al., 2013), conducted in the Argille Azzurre Formation exposed at the outcrop of the Stirone River, document several magnetic reversals spanning from the early Pliocene to the early Pleistocene.

The fossil turtle comes from diatomaceous layers located near La Farfanara (Fig. 1). These layers cover a chemoherm bed that, according to the study by Mary et al. (1993), marks the boundary between the Zanclean and Piacenzian stages.

MATERIALS AND METHODS

The fossil remains here described have been collected by the late Raffaele Quarantelli in November 1994 and are now stored in the Museo Paleontologico "Il Mare Antico" in Salsomaggiore Terme (Parma, Italy). Terminology follows Zangerl (1969), as updated by Hutchison & Bramble (1981), for the shell and Hirayama (1998) for the humerus.

SYSTEMATIC PALAEONTOLOGY

Order Testudines Batsch, 1788
Suborder Cryptodira Cope, 1868
Superfamily Chelonioidea Baur, 1893
Family Cheloniidae Bonaparte, 1832

Genus *Trachyaspis* Meyer, 1843
Type species *Trachyaspis lardyi* Meyer, 1843

1843 *Trachyaspis* Meyer, p. 699.
1896 *Syllomus* Cope, p. 139.
1956 *Kurobechelys* Shikama, p. 35-62.

Trachyaspis lardyi Meyer, 1843
(Figs 2-3)

1843 *Trachyaspis lardyi* Meyer, p. 699.
1851 *Testudo varicosa* Costa, p. 4.
1864 *Chelonia varicosa* (Costa) - Costa, p. 12, Pl. 1.

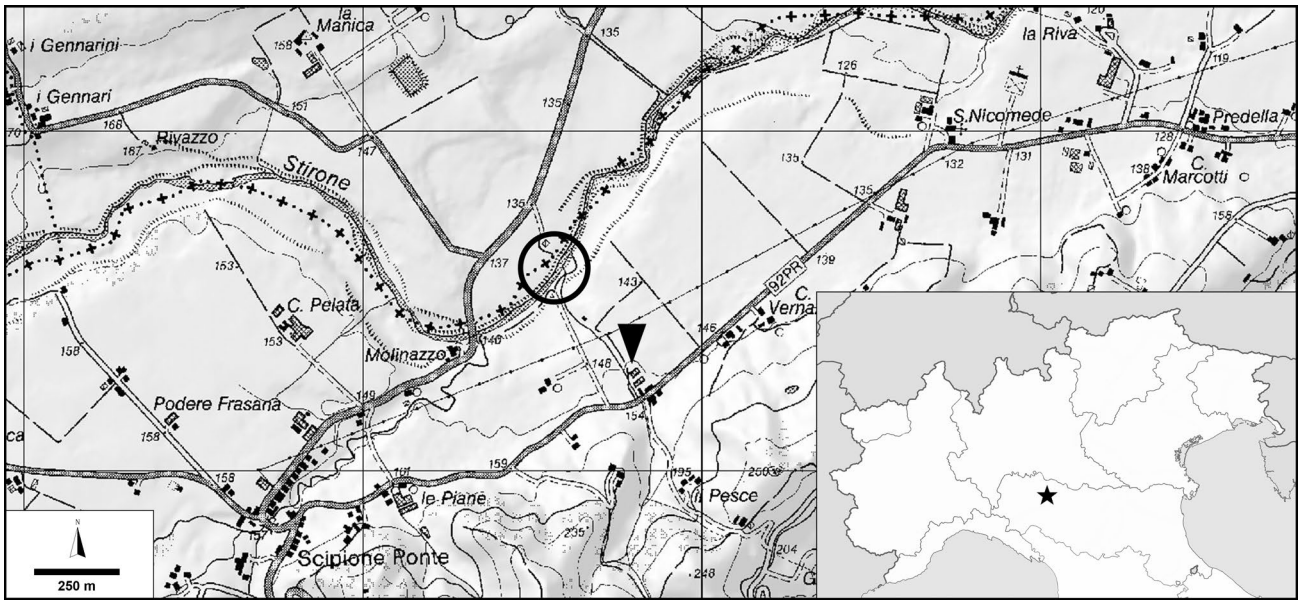

Fig. 1 - Location of the outcrop (encircled) where PR004104 has been found. The arrow marks the near built-up area of La Farfanara.

	Carapace	Neurals					Left costals					Right costals	
		2	3	4	5	6	2	3	4	5	6	4	5
Maximum length	38.2	5.2	4.6	5.6	5.5	/	6.4	6.3	6.1	6	5.8	5.8	5.8
Maximum width	37.5	3.3	3	3	3	2.8	14	14.8	13.4	13.2	11.3	/	13.1

Tab. 1 - Measurements of the partially articulated portion of the carapace of PR004104 and of the best preserved plates (in cm). Maximum length of neural 6 and maximum width of right costal 4 have not been measured because they are too fragmentary.

1869 *Trachyaspis miocoenus* Delfortrie, p. 419-420, Pl. 28, figs 24-26.
1889 *Trachyaspis aegyptiaca* Lydekker, p. 53-54.
1896 *Syllomus crispatus* Cope, p. 139.
1911 *Trionyx bellunensis* Misuri, p. 1, 8, Pls 1-2.
1932 *Trachyaspis bellunensis* (Misuri) - Hummel, p. 102.
1936 *Chelonia marylandica* Collins & Lynn, p. 151, 155, 162, Pl. 2.
1936 *Peritresius virginianus* Berry & Lynn, p. 176, Pls 1-4.
1956 *Kurobechelys tricarinata* Shikama, p. 37, 54, Pl. 7, figs 1-2, Pl. 8, figs 1-3.
1958 *Syllomus marylandica* (Collins & Lynn) - Zangerl, p. 40-41.
1958 *Syllomus virginianus* (Berry & Lynn) - Zangerl, p. 40-41, 52.
1974 *Syllomus aegyptiacus* (Lydekker) - Weems, p. 284-292, Tabs 1-4, Figs 1-10, Pls 1-4.
1980 *Syllomus aegyptiacus* Weems - Weems, p. 621-624, Figs 1-3.
2000 *Trachyaspis aegyptiaca* Lydekker - Lapparent de Broin, p. 59.
2001 *Trachyaspis lardyi* Meyer - Lapparent de Broin, p. 182.
2005 *Syllomus aegyptiacus* Weems - Hasegawa, Hirayama, Kimura, Takakuwa, Nakajima & Gunma Koseibutsu Kenkyukai, p. 32.
2007 *Trachyaspis lardyi* Meyer - Chesi, Delfino, Varola & Rook, p. 328-331, Figs 1A, 4-5.
2013 *Trachyaspis lardyi* Meyer - Moody, Walker & Chapman, p. 455.
2013 *Trachyaspis lardyi* Meyer - Weems & George, p. 570.

Material - PR004104 (Fig. 2): incomplete shell, left humerus and various indeterminate fragments.

Locality - La Farfanara, Salsomaggiore Terme (PR), Italy.

Age - Late Pliocene (Piacenzian).

Description - The specimen is exposed in dorsal view and consists of an incomplete carapace, an incomplete plastron, the left humerus and a number of fragments of indeterminate skeletal elements (in some case no longer included in the matrix). Measurements of the specimen are given in Tab. 1.

The carapace covers most of the other visible preserved bones. Anteriorly, below the preserved neurals, some

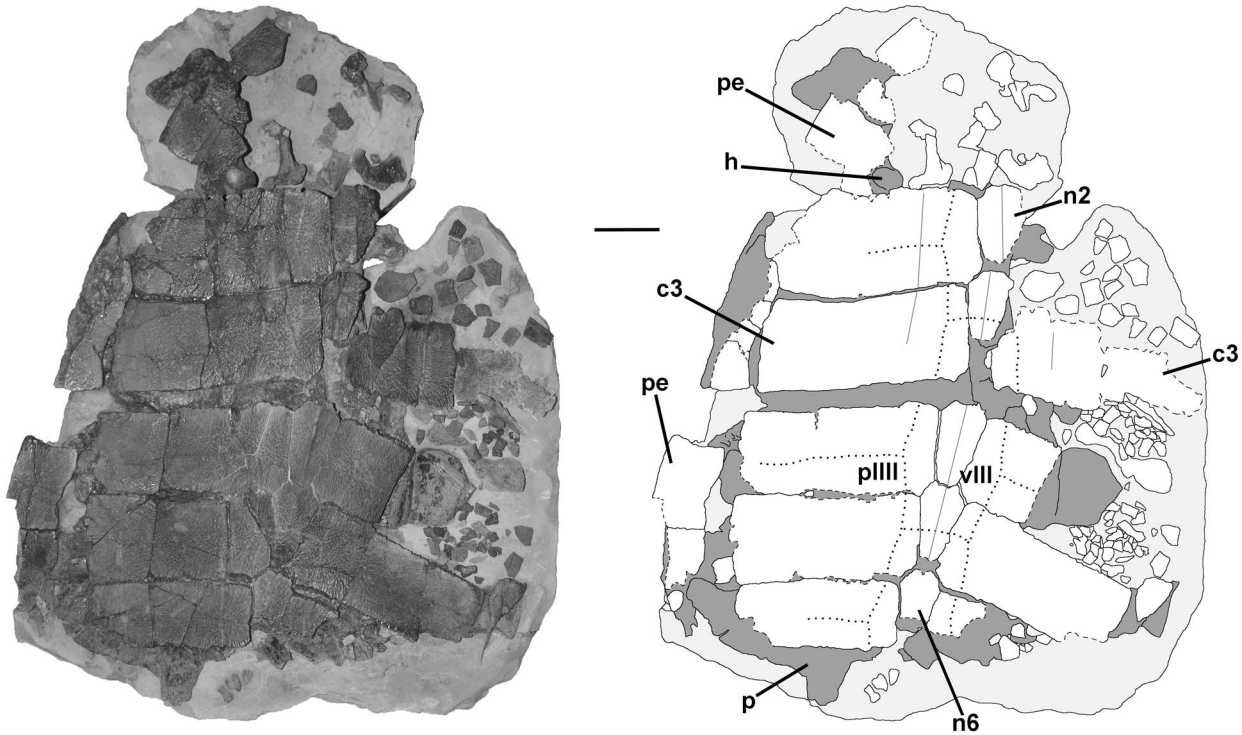

Fig. 2 - *Trachyaspis lardyi* Meyer, 1843 (PR004104) from the Stirone River and its interpretative drawing. In the drawing, the matrix is colored in light grey, bones overlaid with other bones are colored in dark grey, ridges on the carapace are depicted with grey lines and sulci left by the scutes are depicted with dotted lines. Outline of the carapace plates is continuous if natural and depicted with a dashed line if it is the result of breakage. Abbreviations: c3, costal 3; h, humerus; n2, neural 2; n6, neural 6; pe, peripheral; p, plastron; plIII, pleural III; vIII, vertebral III. Scale bar = 5 cm.

elements still included in the matrix are visible. These elements could be interpreted as vertebrae because of their position, but their morphology is not observable with precision. The specimen is fragmented and deformed, but the preserved elements of the shell are still partially articulated. Five neurals, five left costals, four right costals and at least five left peripherals can be recognized in the carapace. Based on the position of the sulci left by the scutes, we can hypothesize that the preserved plates are neurals 2 - 6, left costals 2 - 6 and right costals 3 - 6. The peripherals are too damaged to hypothesize their original position. Neurals 4 and 5 are complete and well preserved, whereas the other three are incomplete; neurals 4 - 6 are articulated and contact left costals 4 - 6 and right costals 4 - 6, whereas neurals 2 and 3 are in contact with left costals 2 and 3 only. Neurals have a 6A shape (sensu Pritchard, 1988): they are hexagonal and antero-posteriorly elongated, with postero-lateral margins about three times longer than the antero-lateral ones and maximum width measuring about 1/2 of the maximum length (in the best preserved ones). With the exception of neural 6, all of them show clearly a low ridge developed in medial position along the entire bone. Left costals are deformed and fragmented, but partially articulated: costals 2 and 3 contact each other and neurals 2 and 3, whereas costals 4 - 6 contact each other and neural 4 - 6. Costals and peripherals seem not to be in direct contact in the posterior half of the specimen, but this could also be a preservation artifact due to deformation. With the exception of costal 5, the right costals are very poorly preserved: costal 3 is very fragmentary and deformed, whereas only the proximal portion of costal 4 is preserved and costal 6 is represented only by a small fragment contacting neural 6. Right costals 4 - 6 are articulated with neurals 4 - 6. The best preserved costals are sub-rectangular in shape; their width is about twice their length. A very low ridge running antero-posteriorly is visible on the dorsal surface of left costals 2 and 3 and right costal 3, located at about one third of their length from the medial margin; no ridge can be recognized on the other costals. Left peripherals are very fragmentary and deformed, therefore it is not possible to identify their original shape. The dorsal surface of every preserved carapace plate shows a dense vermicular ornamentation made of low and narrow ridges and small tubercles (Fig. 3). The ornamentation is more dense in the medial portion of the carapace.

Sulci left by the scutes can be seen on the same surface: we can recognize the sulci between vertebrals II and III (on neural 3 and left costal 3), vertebrals III and IV (on neural 5, left costal 5 and right costal 5), vertebral II and left pleural I (on left costal 2), vertebral II and left pleural II (on left costals 2 and 3), vertebral III and left pleural II (on left costals 3 and 4), vertebral III and left pleural III (on left costals 4 and 5), vertebral IV and left pleural III (on left costals 5 and 6), vertebral IV and left pleural IV (on left costal 6), vertebral III and right pleural II (on right costals 3 and 4), vertebral III and right pleural III (on right costals 4 and 5), vertebral IV and right pleural III (on right costals 5 and 6), left pleurals I and II (on left costal 3), left pleurals II and III (on left costal 4), left pleurals III and IV (on left costal 6) and right pleurals II and III (on right costal 4). Despite the deformation, the outline of vertebral scute III is clearly visible and permits to define its shape: the scute was hexagonal, antero-posteriorly elongated and it had a maximum length about twice as long as the maximum width; it covered neural 4 entirely, part of neurals 3 and 5, the proximal ends of left costal 4 and right costal 4, the proximal posterior angle of left costal 3 and right costal 3 and the proximal anterior angle of left costal 5 and right costal 5. The visible portion of the outline of left pleural scute III also permits to hypothesize its shape, even though it is strongly conditioned by the strong deformation of the costals: the scute was sub-rectangular, with the major axis medio-laterally-developed; it covered costal 5, the posterior half of costal 4 and the anterior half of costal 6 (where they were not covered by vertebral scutes).

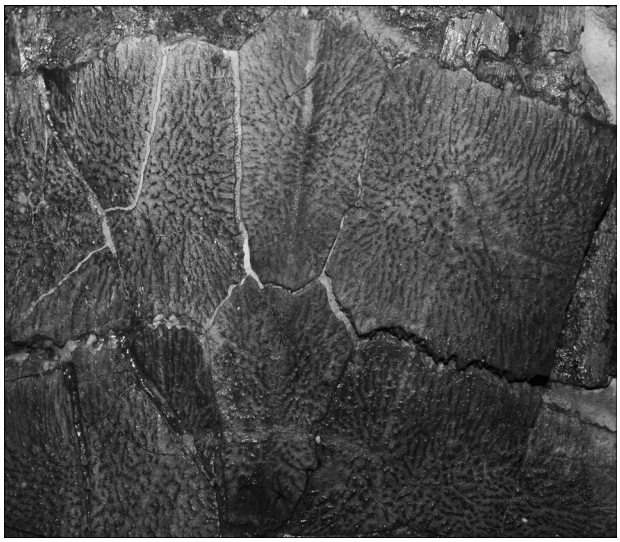

Fig. 3 - Close-up of neurals 4 and 5 and of the medial portions of left and right costals 4 and 5 of *Trachyaspis lardyi* Meyer, 1843 (PR004104). Note the dense vermicular ornamentation.

In the posterior portion of the specimen, ventrally to the preserved parts of the carapace, part of the plastron can be seen in dorsal view: the visible bones are probably the xiphiplastron and the hypoplastron. On the left side, the contact between hypoplastron and some of the preserved peripherals is visible. Other portions of the plastron are preserved, but the carapace covers the majority of them.

The humerus is almost entirely covered by the carapace too: only the proximal epiphysis and part of the lateral and medial surfaces can be seen. The epiphysis is partially broken: its medial portion is lacking, but laterally the caput humeri is recognizable. The latter is medio-laterally compressed and higher than the diaphysis in lateral view. Distally to the caput humeri, on the lateral surface there is the short and stocky lateral process, which is pyramidal in shape. Between the caput humeri and the lateral process, another smaller process projects in a ventro-distal direction.

Remarks - Hirayama (1994, 1998) considers a distally-located lateral process in respect to the caput humeri as a feature of Chelonioidea, even though it is not listed as an unambiguous synapomorphy of the taxon in his list of osteological characters (Hirayama, 1998). Hexagonal neurals with antero-lateral margins shorter than the postero-lateral ones, the carapace constituted by plates

and not by small ossicles and the presence of scute sulci on the carapace allow us to assign PR004104 to the family Cheloniidae, preventing the attribution to Protostegidae and Dermochelyidae (Hirayama, 1994, 1997, 1998, 2006; Chesi et al., 2007). Among cheloniid marine turtles, the ornamented dorsal surface of the carapace plates is a feature of the genus *Trachyaspis* (Lapparent de Broin, 2001; Chesi et al., 2007), which includes only one valid species, *T. lardyi* (Lapparent de Broin, 2001; Chesi et al., 2007). PR004104 strongly resembles the remains of *T. lardyi* from the Miocene of Pietra Leccese figured in Chesi et al. (2007) in having the medial ridge on the neurals and in the shape of bony plates and scutes, but differs from them in the ridges on the costals that do not continue on the posterior ones.

DISCUSSION AND CONCLUSIONS

The genus *Trachyaspis* has been originally established by Meyer (1843) on the basis of a single ornamented bony plate coming from the lower Miocene of Switzerland. In addition to the type species, *Trachyaspis lardyi*, two other European species, both from the lower Miocene, have been later attributed to the genus: *Trachyaspis miocoenus* Delfortrie, 1869 from France and *Trachyaspis bellunensis* Misuri, 1911 from Italy (Lapparent de Broin, 2001; Chesi & Delfino, 2007; Chesi et al., 2007). Lapparent de Broin (2001), however, stated that both species are identical to *T. lardyi* and therefore they should be considered junior synonyms. Three other species, *Trachyaspis sanctae crucis* Pictet, 1858-1860 (in Pictet & Campiche, 1858-1860) from the Lower Cretaceous of Switzerland, *Trachyaspis turbulensis* Bergounioux, 1957 from the Aptian of Spain and *Trachyaspis hantoniensis* Lydekker, 1889 from the Upper Eocene of England, are not considered anymore to be part of *Trachyaspis*: the two Cretaceous taxa are now assigned to Solemydidae, whereas the other is still considered a Cheloniidae, but belongs to an indeterminate genus (Lapparent de Broin, 2001; Pérez-García et al., 2012). Lydekker (1889) established also the Miocene species *Trachyaspis aegyptiaca* from Egypt, but Weems (1974) referred it to the genus *Syllomus*, together with other ornamented chelonian material coming from the Calvert Formation (Middle Miocene, United States) and with *Kurobechelys tricarinata* Shikama, 1956 from the Miocene of Japan. Following an unpublished observation of Zangerl (Weems, 1974), he considered the genus *Trachyaspis* to be part of Dermatemydidae instead of Cheloniidae and therefore he separated American, Egyptian and Japanese forms (referred to *Syllomus aegyptiacus*) from European ones (referred to *T. lardyi*). Lapparent de Broin (2001) rejected the conclusions of Zangerl, pointing out that dermatemydids are continental turtles whereas *Trachyaspis* remains are always found in marine sediments (and the specimen coming from the Stirone River is no exception). Anyway, she confirmed the possibility that American, Egyptian and European species could be generically identical, stating that, in that case, *Trachyaspis* would be the senior synonym. Chesi et al. (2007) mentioned an unpublished analysis of *Syllomus* and *Trachyaspis* made by Hirayama, which recalls the separation between the two genera and suggests a non-marine nature and trionychid affinities for *Trachyaspis*.

Since no complete revisions of the two taxa have been published up to the present, here we follow Lapparent de Broin (2001) and Chesi et al. (2007) in considering *Trachyaspis* as a cheloniid and *Syllomus* as a junior synonym of the former taxon, with *Trachyaspis lardyi* as the only valid species. Remains attributed to *Syllomus aegyptiacus* figured by Weems (1974) and Hasegawa et al. (2005) are very similar to PR004104 in ornamentation, shape of neurals and costals, outline of vertebral scutes and morphology of the humerus. These affinities could support the assignment of all the material to a single taxon, which should be *T. lardyi* following the laws of priority. Longitudinal ridges on the dorsal surface of the carapace are a very variable feature in North American specimens (Weems, 1974), whereas all specimens figured by Hasegawa et al. (2005) show three prominent ridges running along the carapace. Weems (1974) considered the differences in development of the ridges to be the result of individual variation not linked to growth patterns. If this is true, similarities and differences between the ridges on the carapace of PR004104 and those of other specimens should not be used to distinguish different taxa.

It has to be noted that all remains attributed in previous works to *Trachyaspis lardyi* (specimens from Switzerland, France and Italy) or to *Syllomus aegyptiacus* (specimens from Egypt, United States and Japan) have been found in deposits dated back to the Miocene. The specimen coming from the Stirone is remarkable in this sense because it is the only fossil remain of *Trachyaspis* (including also the possible junior synonym *Syllomus*) coming from late Pliocene (Piacenzian) deposits, and as such represents the youngest occurrence of the genus known so far.

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