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TANYSTROPHEUS (ARCHOSAUROMORPHA, PROLACERTIFORMES) REMAINS FROM THE TRIASSIC OF THE NORTHERN FRIULI (NE ITALY)

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Riassunto. Vengono descritti i primi resti ossei rinvenuti nell'Italia nordorientale senza dubbio appartenenti al grande rettile prolacertiforme *Tanystropheus*. Si tratta di una vertebra caudale prossimale del Triassico medio della Val Aupa (Udine, Friuli) e di una vertebra cervicale del Carnico di Fusea (Udine). La vertebra cervicale rappresenta la prima segnalazione del genere nel Carnico e la sua testimonianza più recente, se si esclude *T. fossai* del Norico. Durante il Triassico Superiore *Tanystropheus* viveva lungo le coste della Tetide nordoccidentale mentre era scomparso nell'Europa Centrale, dominata da ambienti continentali.

Abstract. The first diagnostic remains of the large prolacertiform *Tanystropheus* are reported from northeastern Italy. They include a proximal caudal vertebra from the Middle Triassic of Aupa valley (Udine, Friuli) and a cervical vertebra from the Carnian of Fusea (Udine). The cervical vertebra represents the first record of *Tanystropheus* in the Carnian and is the geologically youngest occurrence other than the Norian *T. fossai*. *Tanystropheus* lived along the coasts of the northwestern Tethys during the Late Triassic while it disappeared in Central Europe where continental environments were prevailing.

Introduction.

During the last ten years the amount of reptile remains found in the Mesozoic formations of northeastern Italy increased dramatically (Sirna et al., 1994; Dalla Vecchia, in press; Rieppel & Dalla Vecchia, in press, and references therein; Marco Avanzini, pers. comm.) with the discovery of most of the main reptilian clades, such as Chelonia, Placodontia, Sauropterygia, Ichthyopterygia, Prolacertiformes, Crocodylia, Pterosauria, and Dinosauria.

Some remains of coastal reptiles from the Middle to Upper Triassic of northern Friuli were described by Dalla Vecchia (1994) and most of the sauropterygians, the placodonts and the truly marine reptiles (ichthyopterygians) from the Middle-Upper Triassic of NE Italy are described by Rieppel & Dalla Vecchia (in press).

New specimens were found in two different localities and Triassic horizons of the northern part of the Friuli region (Fig. 1). They belong to the prolacertiform *Tanystropheus* v. Meyer, 1852, and enrich the list of the Mesozoic reptiles found in this eastern area of Southern Alps.

Abbreviations: MFSN, Museo Friulano di Storia Naturale, Udine.

Systematic Palaeontology

Class **Reptilia** Laurenti, 1768
Subclass Diapsida Osborn, 1903
Superdivision Neodiapsida Benton, 1985
Division Archosauromorpha von Huene, 1946
Order Prolacertiformes Camp, 1945
Genus *Tanystropheus* H.v. Meyer, 1852

Type species: *T. conspicuus* H.v. Meyer, 1852

Tanystropheus sp.

Specimen MFSN25761

Description of the specimen and comparisons. The specimen was completely freed from the matrix. It is a complete, isolated proximal caudal vertebra 37 mm long and 52 mm tall of a prolacertiform reptile (Fig. 2). Its size and morphology closely corresponds to that of the proximal caudal vertebrae of *Tanystropheus* figured by Wild (1973, figs. 57-61, pls. 7-9; 1980, pl. 5). The specimen is slightly deformed due to compression. The right prezygapophysis, right postzygapophysis and right pleurapophysis are clearly more developed that the left ones. This cannot have been caused by compression

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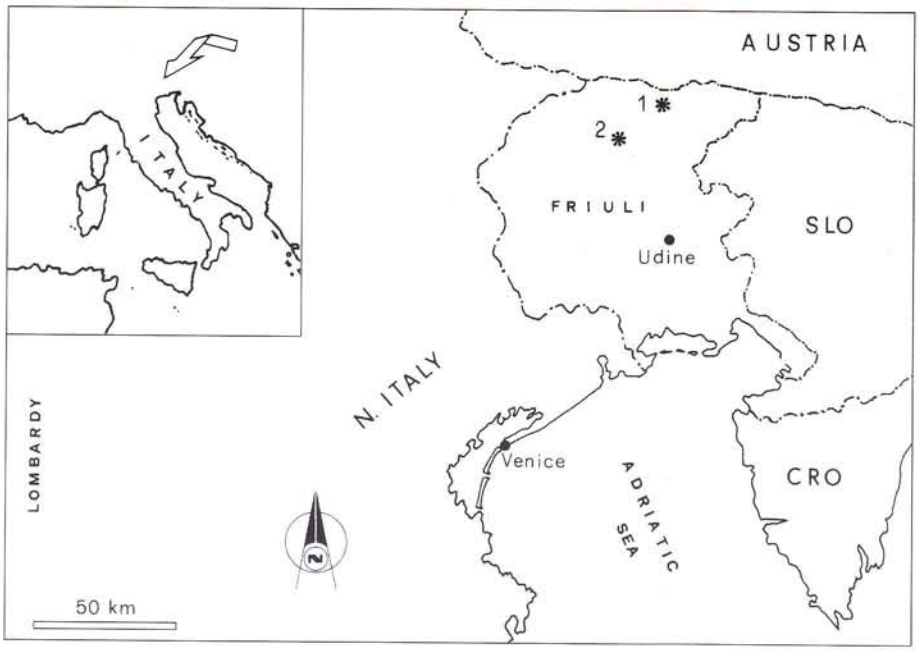

Fig. 1 - Location of the fossiliferous localities in Friuli, NE Italy. 1) Dell'Andri Creek, Aupa Valley; 2) Fusea.

because compression can deform a body but cannot reduce its size. The skeletal element was probably originally misshapen because of a trauma which affected the base of the tail, a part of the body subject to the highest stresses. Despite the fact that the specimen is preserved within a conglomerate, representing a relatively high-energy environment of deposition, it did not suffered a prolonged transport. For example, it does not show any damage to the long and thin pleurapophyses. Only the tip of the left pleurapophysis was posteriorly crushed by a clast and appears spoon-like. The amphicoelous centrum (24 mm long) is laterally constricted just below the pleurapophysis. The ventral profile is also concave (arched) in lateral view and the centrum is spool-shaped. The articular surfaces are elliptical because of a slight deformation. There is a narrow longitudinal groove along the ventral side, like in the caudal 6 or 7 of *T. conspicuus* figured by Wild (1973, fig. 60e). The elongated and narrow pleurapophyses (the right one is 37 mm long) are directed laterally, posteriorly and slightly downward. They attach to the centrum between the basis of the pedicel of the neural arch and the dorsal margin of the centrum. The pleurapophyses are flattened dorsoventrally but the distal tip was probably swollen and rounded. The neural arch is fused to the centrum but a suture is possibly present at the base of the right pedicel. The prezygapophyses are very short and do not project beyond the centrum. Their articular surface is elliptical and faces forward, dorsally and only slightly outward. They are connected to the anterior neural spine by short supraprezygapophysial laminae. Another channel-like structure is developed between the prezygapophyses and just above the small neural channel. Its floor is a short intraprezygapophysial lamina. The postzygapophyses project posterolaterally beyond the centrum and are larger than the prezygapophyses. They have elliptical elongated articular surfaces, facing downward and slightly posteriorly and laterally; however, the orientation is somewhat distorted by deformation. Suprapostzygapophysial and intrapostzygapophysial laminae are present. The intrapostzygapophysial laminae converge medially and ventrally inside the neural arch, just above the neural channel. There is a deep infra-postzygapophysial cavity. The neural spine is quadrangular, wide and slightly inclined backward. Its cross-section in anteroposterior view is a tall, upside-down triangle, and its top is thickened and flat. The surface of the neural spine is rugose, the anteroventral part just above the prezygapophyses is blade-like and becomes a prespinal lamina.

The centrum is comparatively less elongated than the centra of the caudal vertebrae of *T. longobardicus* (Bassani, 1886) and *T. conspicuus*. The shape of the pleurapophyses is similar to that of the pleurapophyses of the anterior caudal vertebrae of *T. longobardicus* (Wild, 1973, pls. 7-9; 1980, pl. 5). The shape of the pleurapophyses differs from that of the anterior caudal vertebrae of *T. conspicuus* which are much broader (Wild, 1973, figs. 57-61). There are other characters of MFSN25761 which differ from those of the caudal vertebrae of *T. conspicuus*: the posterior inclination of the neural spine of MFSN25761 is higher, the prezygapophyses are shorter and have articular facet facing more forward (i.e. the facet is subvertical), the intraprezygapophysial laminae are shorter and thinner, the neural channel is smaller, and the lateral sides of the centrum are probably more excavated.

The size indicates that the vertebra belongs to a rather large individual which, however, was smaller than *T. conspicuus*.

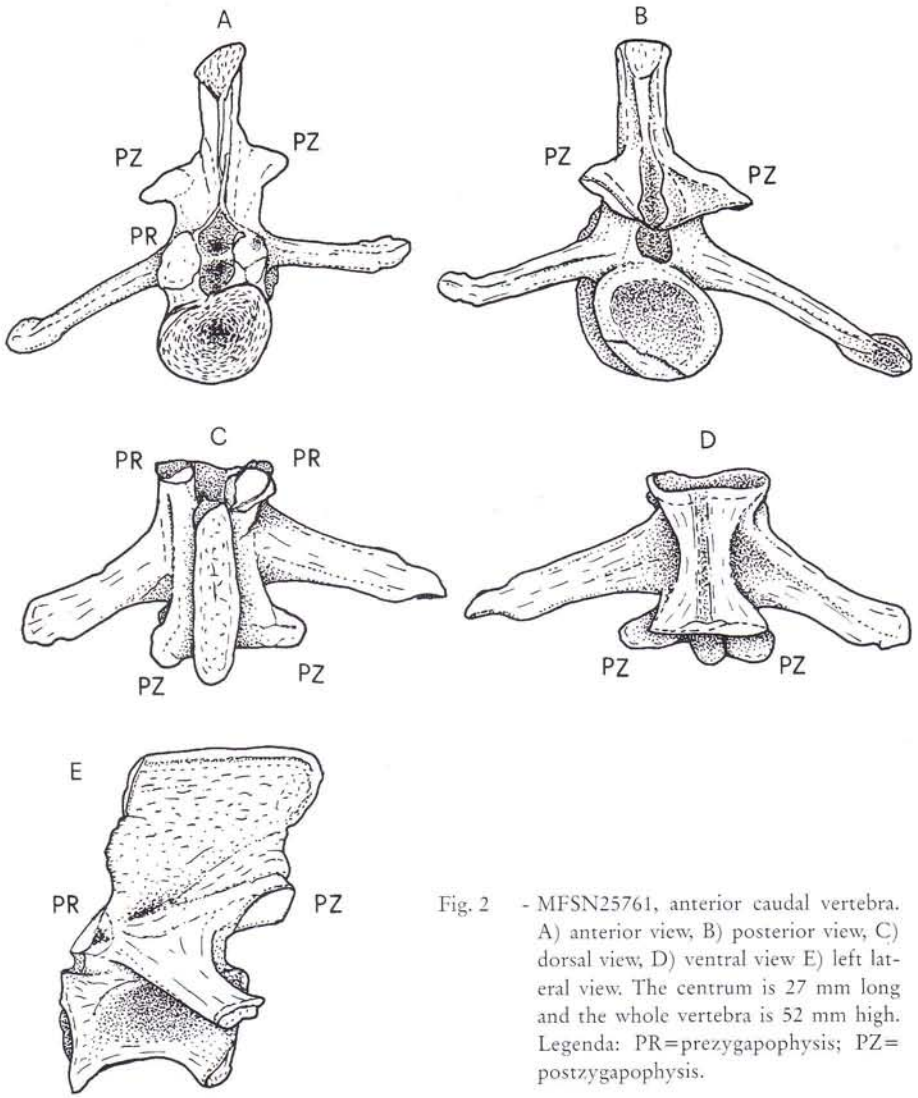

Fig. 2 - MFSN25761, anterior caudal vertebra. A) anterior view, B) posterior view, C) dorsal view, D) ventral view E) left lateral view. The centrum is 27 mm long and the whole vertebra is 52 mm high. Legenda: PR=prezygapophysis; PZ= postzygapophysis.

The proximal half of a thoracic rib, without the articular head (MFSN 25762; Fig. 3), was found in the same block with MFSN25761. The proximal portion of MFSN 25762 is anteroposteriorly flattened with an elliptical cross-section and presents an anterodorsal and a posterodorsal longitudinal ridge. The distal portion is elliptical in cross-section, it is less flattened than the proximal portion and it enlarges fan-wise distally. Although this bone is not actually diagnostic, it closely resembles the posterior thoracic ribs of *T. longobardicus* (Wild, 1973, fig. 35 left). Since it was found in the same block with the caudal vertebra and it belongs to a large reptile of comparable size, it could plausibly belong to the same taxon of the caudal vertebra and possibly to the same individual.

Other very fragmentary bones (MFSN25763, MFSN 25764, MFSN25765, MFSN 25766) found in the same block are not completely freed from the rock matrix and cannot be identified with certainty.

Geological setting. The specimens were found by dr. Corrado Rosenfeld in a single isolated block near the confluence of the Dell'Andri creek with the Aupa torrent, just near the bridge of the road Bevorchians-Studena alta (Aupa Valley, Moggio Udinese, Udine province; Fig. 1). The rock containing the specimens is conglomerate with a silty-carbonate matrix and with dark gray, millimetric carbonate clasts, bivalves, and echinoderm elements. Only the carbonate Upper Serla Formation (late Anisian) and the terrigenous "Torbiditi d'Aupa" (late Anisian-early Ladinian) outcrop in the catchment basin of the creek (Jadoul & Nicora, 1979). The limestones and dolomitic limestones of the Upper Serla Formation are decidedly different from the lithology of the

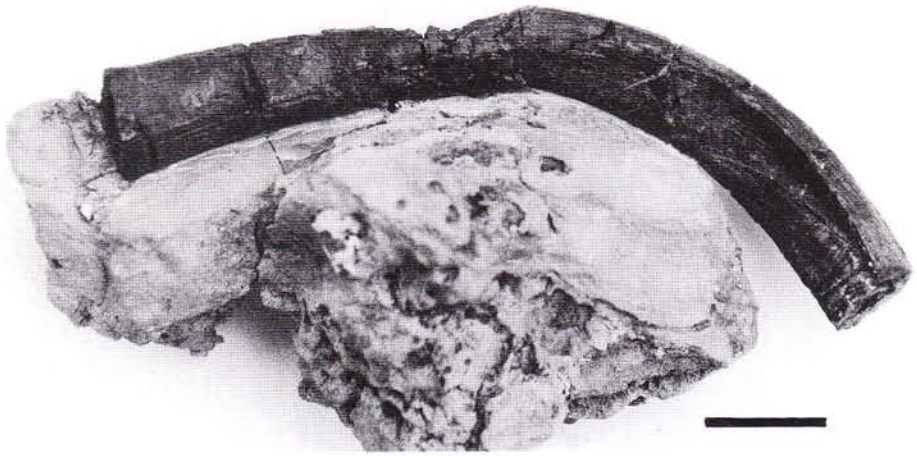

Fig. 3 - MFSN25762, partial posterior thoracic rib. Scale bar = 1 cm.

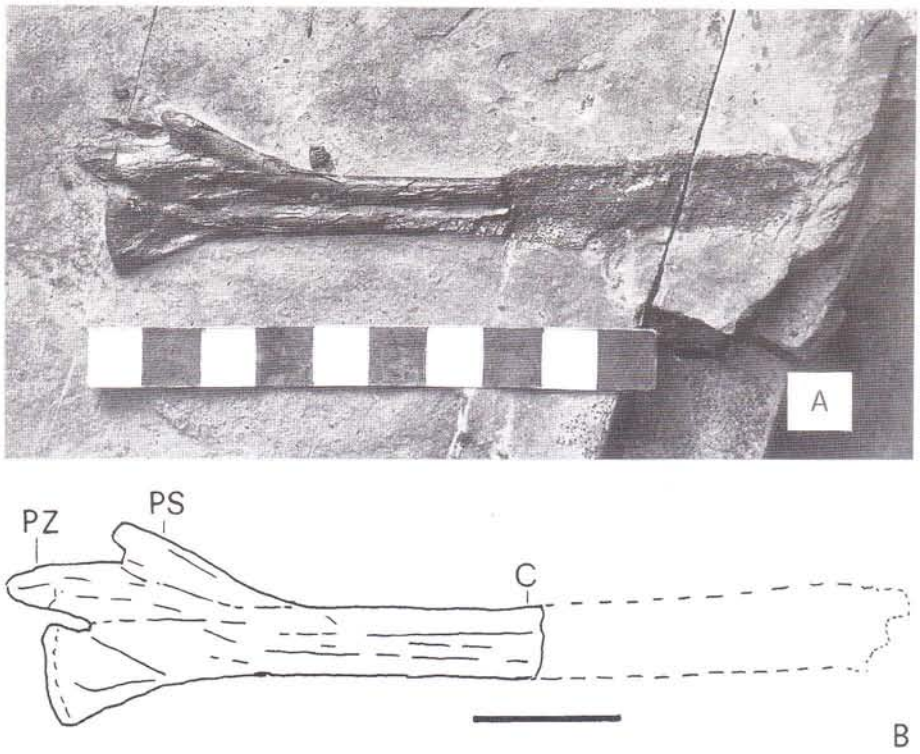

Fig. 4 - MFSN25760, cervical vertebra, right lateral view. A) photograph, B) drawing. The scale bar is centimetric in A and 2 cm in B. Legenda: C = centrum; PS = processus spinosus; PZ = postzygapophysis.

bone-bearing block, which shows a significative terrigenous content. The "Torbiditi d'Aupa" is a marl-sandstone basinal, deep-water unit. However, many other lithostratigraphic units ranging from basal Triassic to Norian outcrop along the valley and, for example, similar conglomerates with carbonate-terrigenous components could be present in other Middle Triassic units (e.g. the "Terrigeno Ladinico"; Jadoul & Nicora, 1979). The block could come from the morainal deposits all around the creek and could have been transported from nearby valleys by glaciers during Pleistocene times. Anyway, a stratigraphic framework similar to that of the Aupa valley is found along these valleys.

Specimen MFSN25760

Description of the specimen and comparisons. The specimen is the posterior half of a single isolated cervical vertebra, the anterior half of which was weathered away (Fig. 4). The preserved part of the vertebra, bone and natural mold, is 128 mm long, and the preserved portion of the centrum is 123 mm long. The part of the centrum preserved as bone is 68 mm long. The middle to anterior part of the centrum, lacking the anterior end carrying the prezygapophyses, is preserved only as natural mold. The tube-shaped centrum is very low, about 10 mm in the middle, and collapsed because it is hollow inside. The posterior articular end of the centrum, 14 mm high, is enlarged and slightly deflected ventrally. The *processus spinosus* of the neural arch projects shortly above the postzygapophyses, is triangular and similar to the fin of an airplane tail, ending cranially against the dorsal margin of the centrum. It is similar to the *processus spinosus* of the cervical vertebra 7 and 4 (Wild, 1973, pl. 9), 7-8 (Wild, 1973, pl. 11) or 5-7 (Wild, 1973, pl. 16) of *T. longobardicus*. The neural arch is extremely low, a feature of the cervical vertebrae of *Tanystropheus*. In fact, according to Peyer & Kuhn-Schnyder (1955, p. 594, translated from French) in the cervical vertebrae of *Tanystropheus* "..the neural arch is not rised above the vertebral centrum, and the neural channel seems to pass inside the latter". This character can be observed in the cervicals of *T. conspicuus* figured in Wild (1973, see the vertebral cross sections in figs. 43, 44, 51). The right postzygapophysis is relatively strong and long, projecting well beyond the posterior end of the centrum. The specimen MFSN25760, with its elongated tubular aspect, and very low neural arch, resembles most closely the middle to posterior cervical vertebrae of *Tanystropheus longobardicus* (Wild, 1973, pls. 9, 11, 13, 16).

Geological setting. The specimen was found in the Fusea site (Tolmezzo, Udine; Fig. 1).

I collected the bone at the top surface of the layer E (Fig. 5) of this site which is particularly rich in fossil vertebrates. Abundant disarticulated elements of *Nothosaurus* sp. , *N.* cf. *giganteus* Münster, 1834 and of a cyamodontoid placodont (Dalla Vecchia, 1994; Rieppel & Dalla Vecchia, in press), together with *Acrodus*-like teeth and other fish teeth, and plants were found on the exposed upper part of layer E. Scattered bones and armour elements of cyamodontid placodonts, bones and teeth of *Nothosaurus* sp. and fish teeth are also found in the middle part of the layer and in the layers A, D and F. In layer D, skull roof bones of a dipnoan fish were also found.

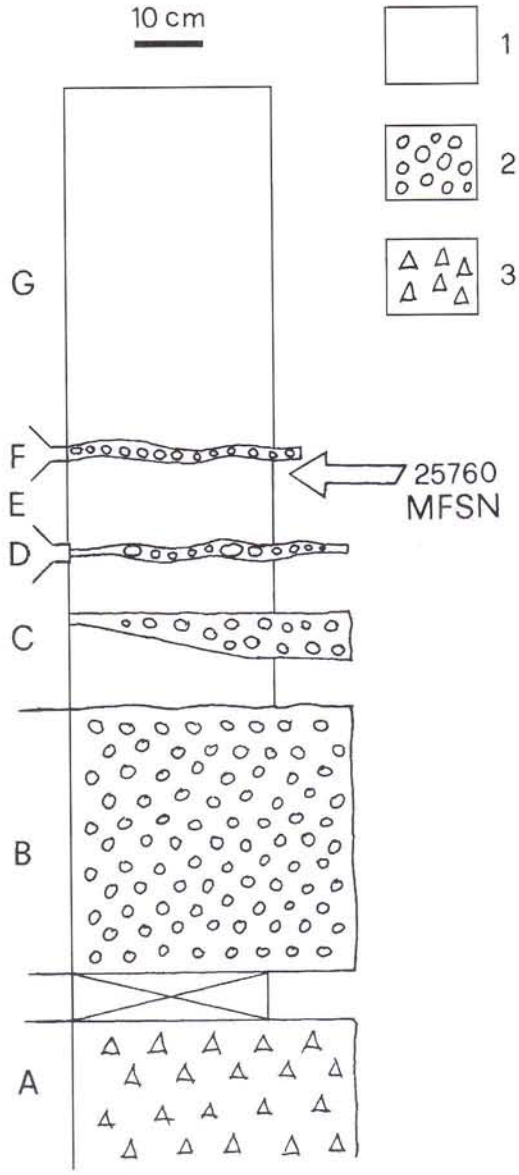

Fig. 5 - Stratigraphic column of the Fusea site, lower Carnian. Legenda: 1) black limestone (wackestones-packstones), 2) conglomerate with prevailing carbonate clasts, 3) white to light-gray dolomitic limestone, poorly bedded and with lenses of intraformational breccia. The arrow point to the position of the vertebra MFSN25760.

The stratigraphic section containing the bone-bearing layers is just at the transition between the top of a thick carbonate platform sequence and well-bedded black limestones hundreds of metres thick.

The carbonate platform sequence is referred to as Dolomia Cassiana by Carulli *et al.* (1995, p. 76) and as Dolomia dello Schlern by Pisa (in Braga *et al.*, 1971), and dated as late Ladinian-middle Carnian in both papers. It is the last carbonate platform before the deposition of the Dolomia Principale. The thick sequence of "black limestones" is the basal portion of the so called "Raibl Group" (Pisa in Braga *et al.*, 1971). This basal part is considered middle Carnian in age by Pisa (in Braga *et al.*, 1971) because of the presence of *Myophoria kefersteini* (Münster, 1845) and *Clypeina besici* (Pantic, 1966). The layer where MFSN25760 was found is at the very base of these "black limestones". For references on the geology of the surroundings of Fusea, see Dalla Vecchia (1994). The comparison with the well-studied stratigraphy of Dolomites suggests that the stratigraphic position of the section is most probably in the upper part of the lower Carnian, between Car2 and Car3 depositional sequence (De Zanche *et al.*, 1993). This dating is also supported by Carulli *et al.* (1995, p. 76). The tentative of biostratigraphical correlation of the fossiliferous section by palynomorphs was not successful (Guido Roghi, pers. comm.), and the rare foraminifers indicate only a possibly late Ladinian to early Carnian age (presence of *Trocholina* cf. *cordevolica*, Sandro Venturini, pers. comm.).

Conclusions.

Most of the fossil record of *Tanystropheus* comes from the Muschelkalk of Europe (southern Spain, France, Germany, Slesia,Transylvania) (i.e. *T. antiquus* v. Huene, 1908, *T. conspicuus* and *T.* sp.), the Muschelkalk of Israel (Peyer, 1955), the upper Anisian-Anisian/Ladinian *Grenzbitumenzone* (= Besano Formation) of Tessin (Southern Switzerland) and Lombardy (NW Italy) (*T. longobardicus*), and the lower Ladinian Lower Meride Limestone of Tessin (*T. meridensis* Wild, 1980). A fragmentary cervical vertebra is reported from the Middle Triassic of Saudi Arabia (Vickers-Rich et al., 1999). A partial, single tooth attributed to *T.* cf. *meridensis* (Wild, 1980) was also found in the lowermost Keuper (upper Ladinian) of SW Germany. A partial dorsal centrum tentatively identified as *Tanystropheus* by Wild (1980, p. 14, fig. 10) comes from the "Tufi a Pachicardie", upper Ladinian of Alto Adige/Süd Tirol (N Italy). The youngest record of *Tanystropheus* is from the upper Norian Argilliti di Riva di Solto of Lombardy with the small *T. fossai* Wild, 1980 (Wild, 1980; Benton, 1994). *T. fossai* is represented only by a segment of four vertebrae from the cervical vertebral column. The specimen belongs to a very small individual, the vertebrae are not longer than 35 mm. It is very similar to a segment of the middle tail of a basal pterosaur, and pterosaurs have been found in the same formation. However, some structures (e.g. the rised facets for the articulation of the cervical ribs) support the identification as cervical vertebrae of *Tanystropheus*.

The specimens MFSN25760 and MFSN25761 here described are the first remains unambiguously attributable to *Tanystropheus* from northeastern Italy. The caudal vertebra from Aupa valley partly differs from the proximal caudal vertebrae of *Tanystropheus* described in literature but the material is too incomplete to war-

rant the erection of a new species. The specimen from Fusea is the first Carnian evidence of *Tanystropheus* and, other than the Norian *T. fossai*, is the geologically youngest occurrence of the genus. The absence of *Tanystropheus* in the Central Europe during the Late Triassic (Keuper) is most probably related to the reduction of coastal environments and the predominance of continental environments not suited for the way of life of this reptile. The genus survived during the Carnian and the Norian along the coasts of the western Tethys.

The tubular vertebra MFSN25760 confirms the phylogenetic trend of the cervical vertebrae of *Tanystropheus* toward a more and more elongation, hypothesized by Wild (1980, p. 25-26, fig. 14).

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