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FIRST RECORD OF *SIMOSAURUS* (SAUROPTERYGIA, NOTHOSAUROIDEA) FROM THE CARNIAN (LATE TRIASSIC) OF ITALY

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Abstract. The nothosauroid sauropterygian *Simosaurus* is reported for the first time both from Italy and from the lower Carnian (lowermost Upper Triassic). Diagnostic dorsal neural arches and clavicles as well as dorsal ribs have been collected in the Rio dal Lago Formation near Dogna (Friuli). Purported *Simosaurus* remains from the Ladinian of Austria cannot be attributed to this genus with certainty and the presence of additional articular structures in the dorsal neural arch (“infraprezygapophyses” and infrapostzygapophyses) cannot distinguish *Simosaurus* from *Bobosaurus* if the craniocaudal polarity or other vertebral features are unknown.

Riassunto. Il saurotterigio notosauroide *Simosaurus* è segnalato per la prima volta in Italia e nel Carnico basale (Triassico superiore). Archi neurali dorsali e clavicole diagnostici del genere, nonché costole dorsali, sono stati rinvenuti nella Formazione di Rio del Lago presso Dogna (Friuli). Resti attribuiti a *Simosaurus* trovati nel Ladinico austriaco non possono essere riferiti con certezza a questo genere e la presenza di strutture articolari supplementari negli archi neurali (“infraprezigapopfisi” e infrapostzigapofisi) non consentono di distinguere *Simosaurus* da *Bobosaurus* se la polarità cranio-caudale o altri caratteri vertebrali non sono noti.

Introduction

The nothosauroid sauropterygian *Simosaurus* is one of the most characteristic and well-known marine reptiles that inhabited the shallow sea covering Central Europe during the Middle Triassic. It has been described in several papers between 1842 and 2000 (e.g., H. v. Meyer 1842; Huene 1921, 1948, 1952, 1959; Rieppel 1994, 2000).

Recently Mr. Roberto Rigo found about 150 scattered fossil bone remains in the debris of a small landslide occurring in the lower Carnian rocks of the upper part of the Lavaz Creek in the western Julian Alps of north-eastern Italy (Fig. 1). Most of those bones are referable to *Simosaurus*. This is the first record of the genus in Italy and, together with other recent discoveries, allows a reconsideration of its stratigraphic and geographic distribution.

Terminology

The neural spine is here considered as a part of the neural arch (Goodrich 1930; Romer 1956). The neural arch height is measured from the top of the centrum, or from the neurocentral sutural surface, to the apex of the neural spine as a line normal to the dorsal surface of the centrum. The neural spine height in the dorsal vertebrae is measured as in Rieppel (2001) from the dorsal surface of the transverse process up to the dorsal margin of the spine. The centrum height is measured from the top of the neural canal to the bottom edge of the centrum.

Infraprezygapophysis, infrapostzygapophysis, zygosphene and zygantrum are articular structures described in the dorsal vertebrae of *Simosaurus* (Huene 1952; Rieppel 1994, 2000). The zygosphene is an anterior (cranial) articular device made of a median lamina that bifurcates ventrally, whereas the zygantrum is a posterior (caudal) depression crossed in the middle by a thin, vertical lamina (this can be observed in the isolated *Simosaurus* vertebrae at the GPTI and in SMNS 14733; pers. obs.). The infraprezygapophysis in the meaning of Rieppel (1994, 2000; the term was taken from Huene 1952, p. 167), is an additional, ventral articular surface of the prezygapophysis. The term “infraprezygapophysis” is used here in brackets because actually it is not a true apophysis (i.e., a process) distinct from the prezygapophysis. Instead, the prezygapophysis is crossed mediolaterally by a more or less shallow groove that separates a dorsal prezygapophyseal facet from a ventral prezygapophyseal facet. A true infraprezygapophysis would be a separate, additional articular process ventral to the prezygapophysis.

The work used as a reference for the systematics of the stem-group Sauropterygia is Rieppel (2000).

Specimens are deposited at the Museo Friulano di Storia Naturale (MFSN), Udine, Italy. Other institutional abbreviations: GPTI =

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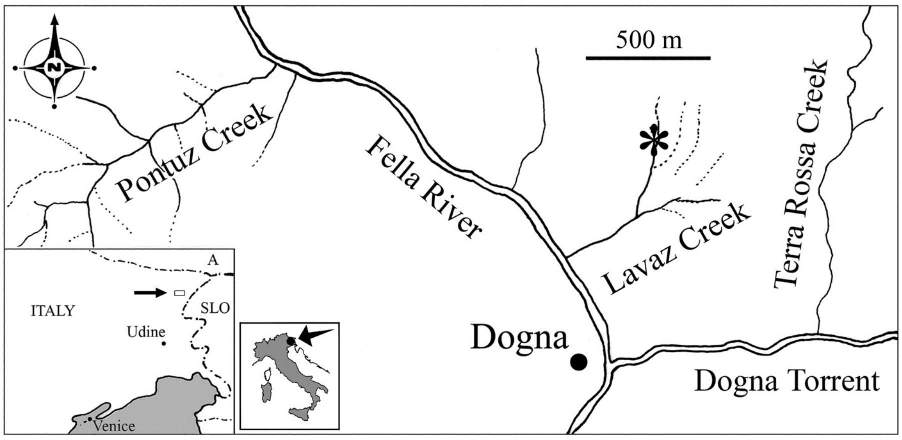

Fig. 1 - Location of the field site (asterisk) close to the Dogna village in northern Friuli, Udine Province, NE Italy.

Geologisch-Paläontologisches Institut der Universität, Tübingen, Germany; MNHN = Muséum national d'Histoire naturelle, Paris, France; SMNS = Staatliches Museum für Naturkunde, Stuttgart, Germany.

The *Simosaurus* record

The taxonomic and systematic history of the genus *Simosaurus* is convoluted.

According to Rieppel (1994, 2000) *Simosaurus* is a monotypic genus represented by the species *S. gaillardoti* H. v. Meyer, 1842 based on skulls and lower jaws (both the lost holotype and the neotype MNHN AC.9028 chosen by Rieppel 2000) from quarries opened in the upper part of the Upper Muschelkalk (uppermost Anisian to basal Ladinian according to Hagdorn & Rieppel 1999; *semipartitus* Ammonoid Zone, lower Ladinian according to Rieppel 2000) of Réhainvillers near Lunéville (France). It shows peculiar features such as a broad, flat and brevirostrine skull with unconstricted snout and "tooth crowns broad and blunt, distinctly set off from tooth base" and with "enamel distinctly striated" (Rieppel 1994, p. 4; 2000, p. 61). Three of such skulls from the Upper Muschelkalk of Lunéville are at the Muséum National d'Histoire Naturelle, Paris (Rieppel 2000). Fourteen skulls and two lower jaws have been reported from different horizons in the Upper Muschelkalk near Crailsheim (Baden-Württemberg, Germany) according to Rieppel (1994). Most are from the upper part of the Upper Muschelkalk (Discoceratitenschichten; *nodosus* through *semipartitus* Ammonoid Zone, lower Ladinian according to Hagdorn & Rieppel 1999, p. 663). A skull was collected in the upper part of the Upper Muschelkalk (Lower Ladinian) of Rüblingen near Kupferzell (Baden-Württemberg) (Rieppel 1994).

A skull from the Lettenkeuper (Ladinian, Hagdorn & Rieppel 1999; early to middle Ladinian, Hagdorn & Rieppel 1999; upper Ladinian, Rieppel 2000) of Hoheneck near Ludwisburg (Baden-Württemberg) was considered as a separate species (*S. guilielmi*) by H. v. Meyer (1847-55) but was later synonymized with *S. gaillardoti* by Rieppel (1994).

A skull from the lowermost Gipskeuper (uppermost Ladinian according to Hagdorn & Rieppel 1999) of Obersontheim (Baden-Württemberg) was described as *S. guilielmi* var. *angusticeps* by Huene (1959) and considered as *S. gaillardoti* by Rieppel (1994). Mounted with this skull in a slab exhibited at GPTI is a partial, articulated skeleton (GPTI, uncatalogued) (Huene 1959) from the same locality and horizon. The neck in the slab is artificial and the skull and postcranium were found separated, although associated and close to each other. Tetrapod remains are exceedingly rare in that facies of Gipskeuper ("Alabastergips") and the association of the skull and postcranium makes it highly likely that they are from the same individual. The postcranium is in such a poor state of preservation that Rieppel (1994) did not take it into account in his redescription of *Simosaurus*. However, this is the only case of a *Simosaurus* skull associated with postcranial material and the youngest reported occurrence of the genus.

The only other partial, associated skeleton without skull (SMNS 14733) was collected in the uppermost Muschelkalk (lower Ladinian according to Hagdorn & Rieppel 1999, p. 663) of Tiefenbach near Crailsheim (Huene 1952). SMNS 14733 preserves most of the postcranial skeleton excluding the pectoral girdle, in particular six centra and three neural arches from the cervical region, 26 centra and 28 neural arches from the dorsal region, five sacral vertebrae according to Huene (1952), three according to Rieppel (1994), and two proximal and one distal caudal vertebrae. The skeleton was fully disarticulated and the bones were completely removed from the matrix before the study by Huene (1952). A cast was made before preparation but was later lost during World War II. Thus Huene (1952) did not know about the original position of the bones in the slab. Its attribution to *Simosaurus* is based on the association of some teeth with a broad crown distinctly set off from the base, typical of this genus, with the postcranial bones.

Based on comparisons with the elements of the two postcranial skeletons (apparently only on SMNS 14733, according to Rieppel 1994) a vertebra, isolated pectoral girdle elements, humeri, femora and a tibia from some sites of the Upper Muschelkalk near Crailsheim were attributed to *Simosaurus gaillardoti* (Rieppel 1994). An interclavicle from Hegnabrunn near Kulmbach (Bavaria, Germany), humeri from Wahlheim (Rheinland-Pfalz, Germany), Schwenningen (Baden-Württemberg) and Ludwisburg (Baden-Württemberg), a femur from Wolfsbuch near Creglingen (Baden-Württemberg), all found in the Upper Muschelkalk, were also attributed to this species.

It is unclear from Rieppel (1994) how the isolated shoulder girdle bones could be attributed to *Simosaurus*, as the shoulder girdle is not preserved in SMNS14733 (Rieppel 1994, p. 16), and only the coracoid is complete in GPTI, uncatalogued. I will consider this attribution as valid *fide* Rieppel (1994).

According to the German and French material, Rieppel (1994, p. 4; unmodified in Rieppel 2000) diagnosed the genus on the base of both cranial and postcranial characters. The diagnosis of the species *S. gaillardoti* is the same as for genus because of monotypy (Rieppel 1994, p. 5). The diagnostic characters of interest for the scope of this work are: tooth crowns broad and blunt, distinctly set off from tooth base, enamel distinctly striated; vertebrae platycoelous and non-notochordal with "infraprezygapophysis" and infrapostzygapophysis in addition to zygosphene and zygantrum; clavicle with short anterolateral process. Rieppel (1996, 2000) also seems to consider as diagnostic of *Simosaurus* the distally broadened dorsal ribs, a feature not included in that diagnosis (but see the discussion section for more details).

Remains belonging to a single skeleton from the Partnachschichten (possibly its upper part, late Ladinian) of Braz, Vorarlberg, Northern Calcareous Alps (Austria) consist of a string of 15 articulated dorsal vertebrae, two incomplete and one complete disarticulated dorsal vertebrae, a left scapula with a fragment of the clavicle, a fragmentary coracoid, several complete and fragmentary, distally broadened, dorsal ribs. They were originally the type material of *Partanosaurus zitteli* Skuphos, 1893a (Skuphos 1893a, b), but later were identified as *Simosaurus* cf. *gaillardoti* by Rieppel (1996), because of features of the neural arch (shape of the zygapophyses, neural canal, transverse processes and neural spine) and ribs. This attribution is questioned below in the discussion section. *Simosaurus* is reported on the base of a fragmentary, distally broadened rib also from the Arlbergschichten (middle Ladinian) of Tyrol, Austria (Rieppel 2000).

A skull fragment, half of a pectoral girdle, an interclavicle and a sacral rib from Makhesh Ramon, Negev, Israel were attributed to *Simosaurus* sp. (Rieppel et al. 1999). They come from the lower member of the Saharonim Formation, Anisian-Ladinian boundary.

Finally, a dorsal neural arch from the Middle Triassic Jilh Formation of Saudi Arabia is referred to *Simosaurus* because of the presence of "infraprezygapophyses" and "infrapostzygapophyses" (Vickers-Rich et al. 1999).

It is worth to note that vertebrae from Austria and Saudi Arabia and the clavicle from Israel have features diagnostic of *Simosaurus gaillardoti* as the diagnosis of the genus coincides with that of the species, but Rieppel (2000, p. 64) considers them "not diagnostic at species level".

Summarizing, the remains to date attributed to *Simosaurus* span the whole Ladinian (Fig. 2A1) and the genus occurred from the Central European Basin to the Gondwanian margin of Tethys (Fig. 2B).

Locality, age, geology and associated sauropterygians

The new specimens come from the upper Lavaz Creek, 600 m above sea level, near the Prerit and Balador localities of the Dogna village, Udine Province, northern part of the Friuli-Venezia Giulia Autonomous Region, NE Italy (Fig. 1), lat. 46° 27′ 16″ N; long. 13° 19′ 02″ E.

They were collected from a small landslide accumulation that originated from the collapse of a 1.5 metre-thick stratigraphic section consisting of well-bedded, nodular limestone and thin intercalations of blackish to dark greenish, clayey marl. The limestone is dark grey to blackish, heavily bioturbated and often rich in bivalves and crinoid remains. The bones occur in the limestone. A dorsal neural arch of *Simosaurus* and a placodont palatine tooth were collected *in situ* in the lowermost limestone bed of the section; the other specimens were preserved inside scattered limestone blocks found in the debris.

The section is in the lower part of the Rio del Lago Formation which is dated to the early Carnian (Julian; *aonoides* Ammonoid Subzone) according to its palynomorph and ammonoid content (Preto et al. 2005; Dalla Vecchia 2006) and the conodonts occurring in the lithostratigraphic unit ("dolomie del Rio di Terra Rossa") immediately below (Jadoul & Nicora 2000; Preto et al. 2005) (Fig. 2A2).

The Rio del Lago Formation in the Dogna area, as well as the nearby Cave del Predil area (formerly Raibl) where the historical stratotype of the Carnian stage is located, is rich in shallow water marine invertebrates (molluscs, corals, echinoderms) and has also yielded vertebrate macrofossils (Sirna et al. 1994; Rieppel & Dalla Vecchia 2001; Dalla Vecchia & Avanzini 2002; Dalla Vecchia 2006). The lower-middle part of the unit

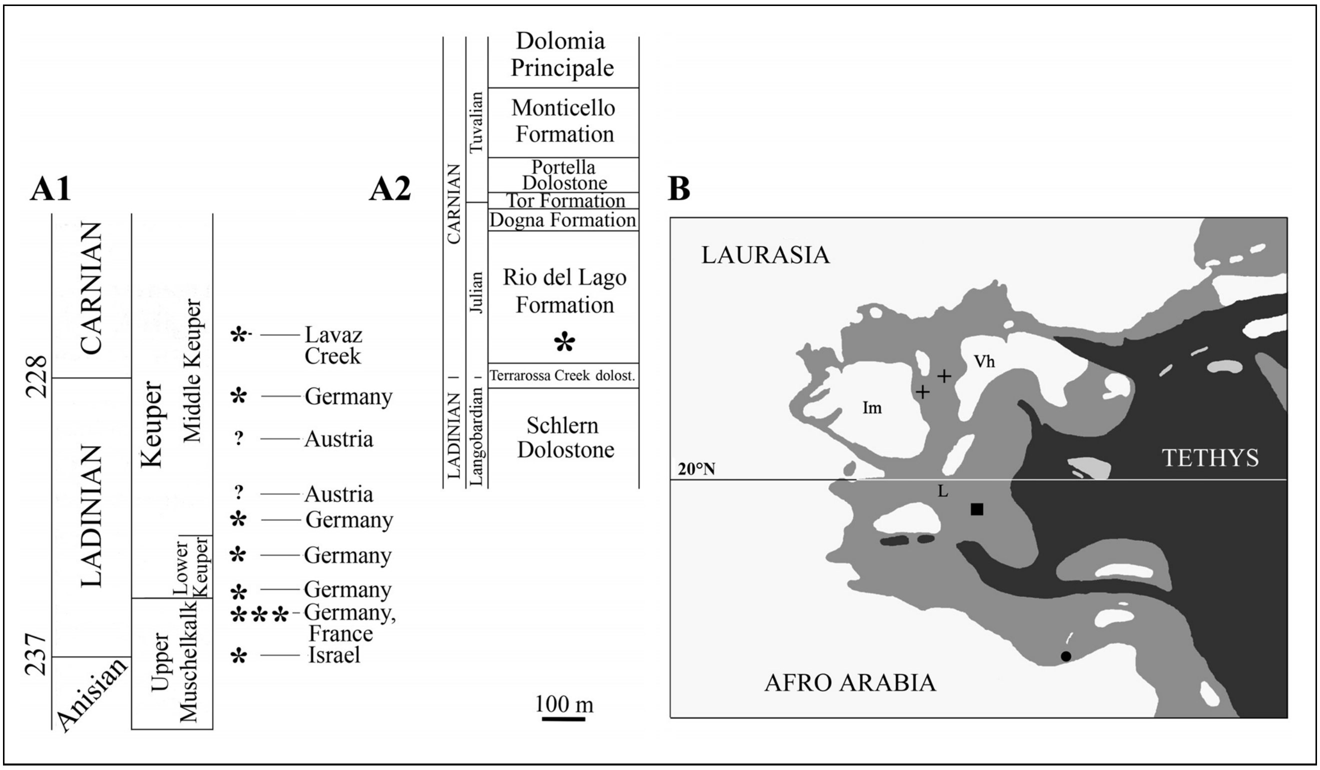

Fig. 2 - A1) Stratigraphic distribution of specimens attributed in literature to *Simosaurus* (asterisks; question mark for questionable attributions); the peak of abundance is in the uppermost Muschelkalk. A2) The stratigraphic column of the Dogna zone (based on Preto et al. 2005); the asterisk marks the stratigraphic position of the *Simosaurus* specimens from Lavaz Creek. B) The early Ladinian palaeogeographic map of western Tethys (based on Gaetani et al. (2000); symbols mark the position of *Simosaurus* occurrences: Cross = French and German sites; square = Rio Lavaz site, Italy; point = Negev site, Israel. Dark grey = oceans and deep marine basins; grey = epicontinental sea; white = land. Abbreviations: L = Lombardy (northern Italy); Im = Iberian Meseta (Spain); Vh = Vindelician High.

is made of well-bedded alternances of nodular limestone and marl, with a thick oolitic bank at the base; the depositional environment is considered a subtidal carbonate-clastic ramp (Preto et al. 2005).

Sauropterygians, all coming from the lower part of the formation, are represented by the cyamodontoid placodont *Protenodontosaurus italicus* Pinna, 1990, the nothosauroid *Nothosaurus* (Rieppel & Dalla Vecchia 2001), the possible pistosaurid *Bobosaurus forojuliensis* Dalla Vecchia, 2006 and possibly pachypleurosaurians (pers. obs.). Vertebrate remains are relatively rare and are found occasionally as single scattered bones and teeth, or complete but isolated skulls for placodonts; only the holotype of *Bobosaurus forojuliensis* is a nearly complete and slightly disarticulated skeleton (Dalla Vecchia 2006).

Systematic Palaeontology

Amniota

Sauropterygia Owen, 1860
Eosauropterygia Rieppel, 1994
Eusauropterygia Tschanz, 1989
Nothosauroidea Baur, 1887-90
Simosauria Rieppel, 2000
Simosauridae F.v. Huene, 1948
Simosaurus v. Meyer, 1842

Simosaurus aff. **gaillardoti** v. Meyer, 1842

Figs 3-7

Description of the material unquestionably belonging to *Simosaurus*. The sample includes a complete dorsal vertebra (MFSN 31870, Fig. 3A), four complete and isolated dorsal neural arches (MFSN 34884-34887; Fig. 3B-D), a partial centrum with the basal part of its neural arch (MFSN 34996), three incomplete dorsal neural arches (MFSN 34888-34890; all with the articular apophyses at least partly preserved), four apical parts of neural spines (MFSN 34892, 34903, 34907, 34908), seven isolated dorsal centra (MFSN 34891, 34893, 34894, 34896, 34898, 34900, 34902) and four partial transverse processes (MFSN 34895, 34897, 34899, 34901).

Two arches (MFSN 31870, MFSN 34884; Fig. 3A-B) were closely associated with their centra, although they are not fused to them but separated by sutures (as

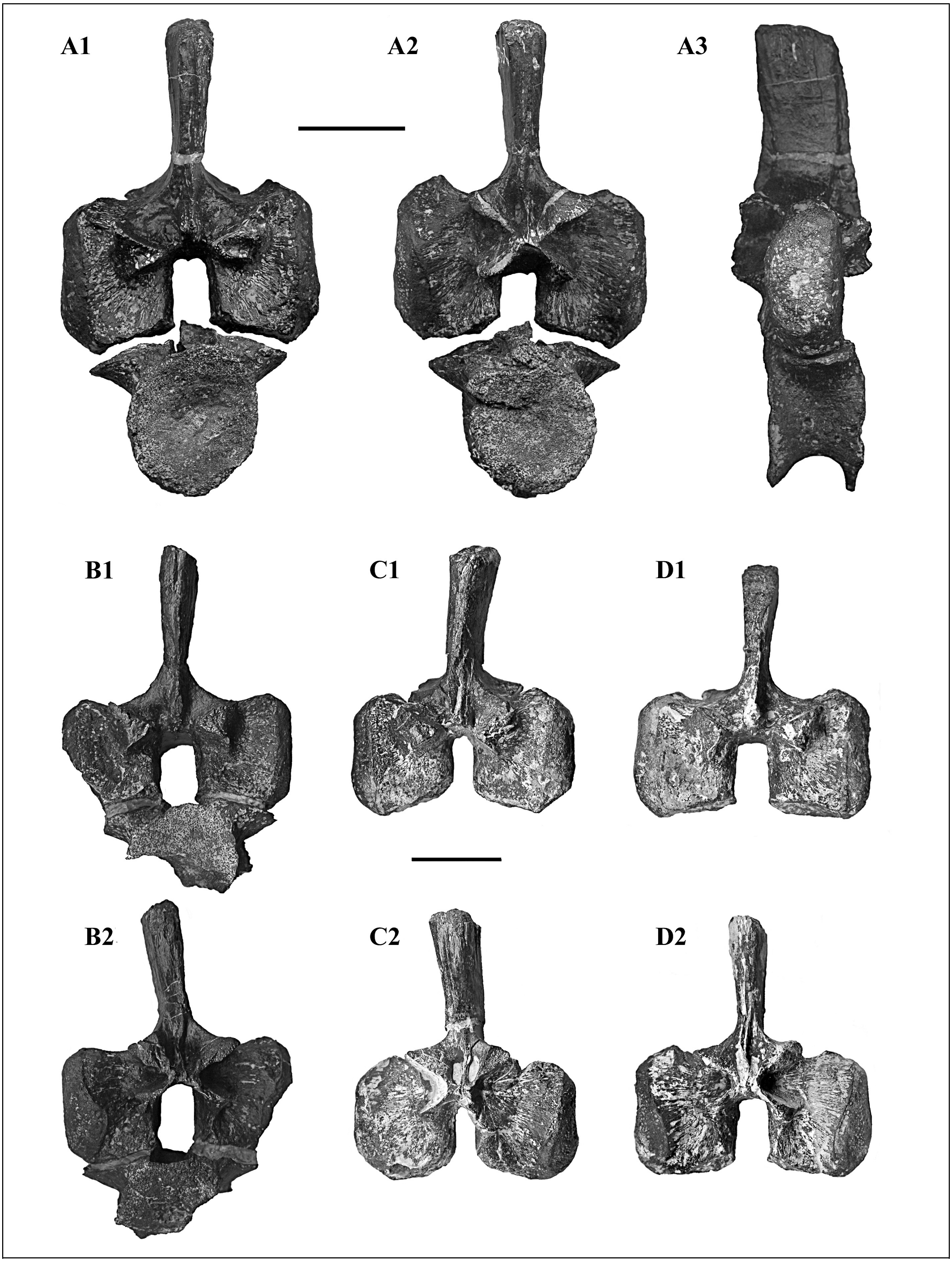

Fig. 3 - Dorsal vertebrae. A) Dorsal vertebra (MFSN 31870) in A1) cranial; A2) caudal; A3) right lateral view. B-D) Neural arches (from left to right: MFSN 34884, 34886 and 34885) in B1-D1) cranial; B2-D2) caudal views. Scale bar equals 2 cm.

usual in stem-group sauropterygians). Neural arch height ranges from 64.5-58 mm (it ranges from 77-72 mm in SMNS 14733), maximum width across the transverse processes ranges from 52.5-50 mm (it ranges from 59-55 mm in SMNS 14733), the height of the neural spine ranges from 36-32 mm. Neural arches show the "infraprezygapophysis" and infrapostzygapophysis. The prezygapophysis is wedge-shaped with the "infraprezygapophysis" as the ventral facet, whereas the infrapostzygapophyses and postzygapophyses form an X-shaped articular structure in the caudal part of the arch that receives the wedge-shaped prezygapophysis (Figs. 4-5). The zygosphene is a thin, bifid, vertical blade that receives a thinner, median, vertical blade of the deep zygantrum. The transverse processes are massive, with a rectangular outline in caudocranial view, occupying the whole subspinal part of the neural arch, extending far down along the neural arch pedicels. The neural canal is rectangular, high and mediolaterally narrow. The neural spine slightly flares apically both in lateral (maximum anteroposterior width 20-17 mm, mode 17 mm) and in craniocaudal (maximum width 9.5-6 mm, mode 9.5 mm) views. The apical part of the neural spine is dorsoventrally grooved, with 5-7 grooves that fade at the base of the upper third of the spine (Fig. 4A-B). The grooves are slightly curved cranially in some specimens (Fig. 4B). The apical margin of the spine is not horizontal, but inclined caudocranially; i.e. the caudal margin of the spine is higher than the cranial one. The apical surface of the spine is rough and crossed craniocaudally by one or two grooves (Fig. 4C-E). The internal, finely spongy (i.e., not hollow) part is visible in the broken neural spines. The more or less complete, isolated dorsal centra have the same shape as those of vertebrae MFSN 31870 and MFSN 34884, and a comparable size. They are constricted and have expanded, subcircular (higher than wider) articular facets (i.e., they are very unlike the cylindrical centra with parallel lateral edges of Nothosauridae; Rieppel 2000). They are amphicoelous, with a deep neural canal groove and large platforms for the neural arch projecting laterally. Centra are small compared to the massive neural arches. The maximum dorsoventral height ranges from 29-22 mm, width from 24-23 mm (not considering the projecting platforms) and length from 20.5-17 mm.

There are at least 17 distal portions of dorsal ribs (MFSN 34909-34912, 34920-34932; Fig. 5 left) that unquestionably show a marked distal broadening. They are striated longitudinally, flattened caudocranially, recurved medially and slightly caudally (i.e., with concavity facing medially and caudally). MFSM 34909 (Fig. 5 left) shows an extreme broadening as the midshaft breadth is only 7.5 mm whereas the distal breadth is 22.5 mm. The distal termination of the ribs has two spongy facets, one facing ventromedially, the other ventrolaterally. The distal width ranges from 28.3-22.2 mm, mean 25.2 mm (it ranges from 25-23 mm in SMNS 14733).

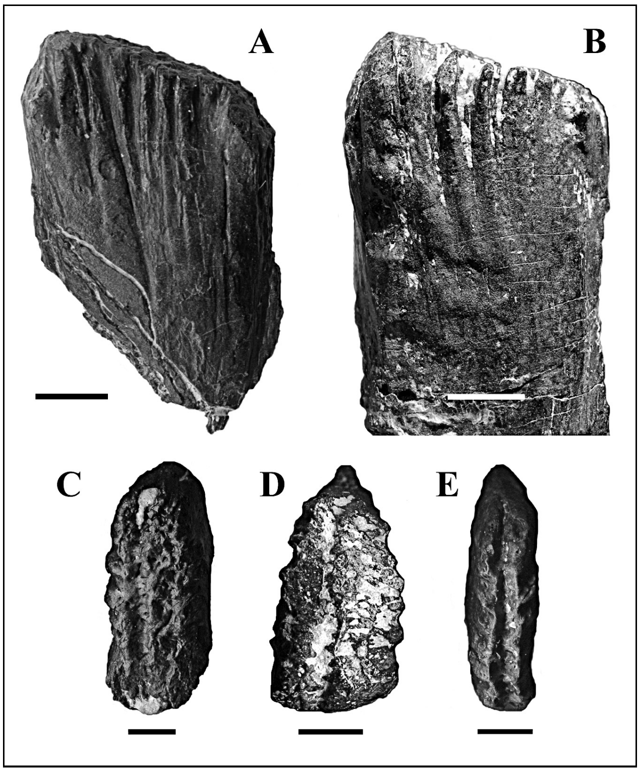

Fig. 4 - Neural spines. A) Right lateral view of MFSN 34907; B) right lateral view of MFSN 34886; C-E) apical view of, from left to right, MFSN 34888, 34886 and 34889. Scale bar equals 0.5 cm.

The other 35 more fragmentary specimens (MFSN 38855, 38869, 38871-38879, 34934-34941, 34943-34950) represent distal portions of dorsal ribs with the same morphology.

Sixteen more or less complete proximal rib portions (MFSN 34880-34883, 34960-34962, 34964-34972; Fig. 5 right), all of a similar size, have a wide, fan-like holocephalous articular part that tapers to a rod-like, recurved shaft. Most likely they are the proximal part of the distally broadened dorsal ribs, although most of them are not sickle-like as the *Simosaurus* dorsal ribs (see SMNS 14733) and the articular facet is always small compared to the size of the transverse processes of the vertebrae collected in the site. In fact, as shown in the distal segment MFSN 34909 (Fig. 5 left), the middle part of the shaft in the dorsal ribs is extremely thin, as it is in the proximal segments.

Twelve fragmentary, holocephalous articular parts (MFSN 34973-34984) and ten curved shaft fragments (MFSN 34858-34861, 34863-65, 34867-34868, 34870) also plausibly belong to dorsal ribs.

Two partial clavicles of similar size (MFSN 34904-34905; Fig. 6), a right and a left one, are 58 and 60 mm long, respectively. Only the zone of the medial

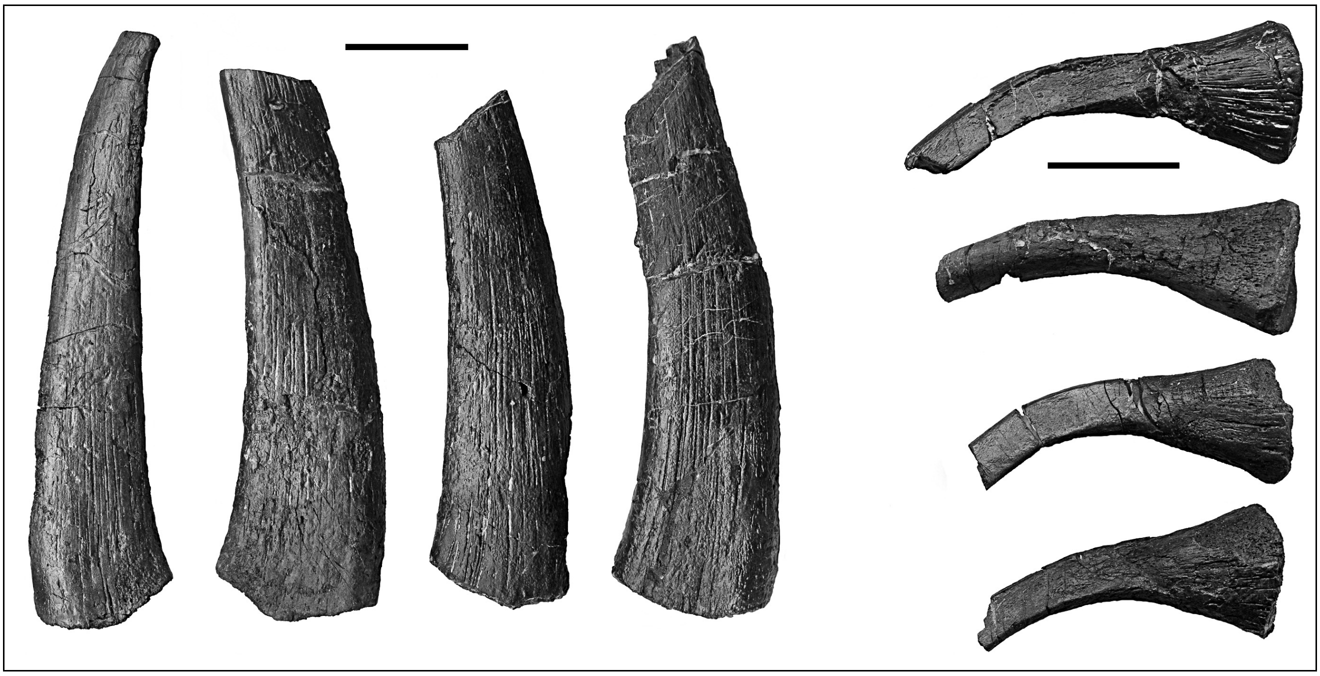

Fig. 5 - Dorsal ribs. Left, distal segments (from left to right: MFSN 34909, 34911, 34910 and 34912). Right, proximal segments (from top to bottom: MFSN 34882, 34883, 34880 and 34881). Scale bar equals 2 cm.

bending, showing the expanded "clavicular corner" described by Storrs (1991), is preserved. Ventrally the clavicle is slightly convex, whereas dorsally it is flat with a deeply excavated medial margin. In the more complete MFSN 34904 the "clavicular corner" has a wide, thin blade that is broken in MFSN 34905. The cranial segment of the clavicle is tubular and hollow inside. Both specimens show a distinct process, which is short but robust and points craniodorsally and only slightly laterally.

Description of the material tentatively attributed to *Simosaurus*. The following specimens were found associated to the vertebrae, ribs and clavicles but their attribution to *Simosaurus* is uncertain.

An isolated, incomplete tooth crown is 12 mm long apicobasally, conical and basally recurved, with a regularly striated surface (MFSN 34915; Fig. 7A). It is unlike the characteristic mid-jaw teeth of *Simosaurus gaillardoti*, but could be a more mesial tooth. Mesial lower jaw teeth of *S. gaillardoti* are relatively elongated, recurved and apicobasally striated (cf. SMNS 7861). It differs from *Nothosaurus* crowns which are slightly sigmoidal, with more spaced apicobasal ridges (see Dalla Vecchia & Avanzini 2002, fig. 7) and is similar to other isolated teeth found in the Rio del Lago Formation of the Dogna zone (see Dalla Vecchia & Avanzini 2002, fig. 6).

A rib, which is 55 mm long, has a fan-like, asymmetrical proximal part and an expanded, paddle-like and thickened distal one (Fig. 7B). It resembles some of the sacral ribs of SMNS 14733 in craniocaudal view (according to Huene 1952, fig. 31-32; Rieppel 1994, fig. 20B, wrongly reported them as in lateral view). It is strongly flattened caudocranially (polarity according Huene 1952). It does not belong to Nothosauridae, which have apomorphic sacral ribs that lack a distinct expansion of the distal end (Rieppel 2000).

A right scapula (MFSN 34913; Fig. 7C) has a typical sauropterygians morphology, with a large (66.5 mm long craniocaudally, 37 mm high and 28 mm of maximum lateromedial width) and massive body (the "glenoid portion" of Rieppel 2000) and a strap-like, narrow, short and posterodorsally directed blade (the "dorsal wing" of Rieppel 1994 and "ascending process" of Rieppel 2000). The scapular body is flat laterally and convex medially. A notch, visible in medial view, corresponds to part of the coracoidal foramen and separates the cranial part from the slightly offset caudal part. The caudal part bears a wide, triangular articular surface divided into two elongated facets. One is the scapular contribution to the glenoid, facing caudoventrolaterally; the other is the coracoidal facet, facing caudoventrally. Only a very shallow triangular depression without a rough surface can be observed in the region where there should be the clavicular facet according to Rieppel (1994). The scapular blade is incomplete (broken distally), flattened lateromedially and slightly recurved laterally. This scapula differs from that of *Simosaurus gaillardoti* figured by Rieppel (1994, fig. 26A) in the deeper body, the shallower coracoidal foramen and the smaller blade. MFSN 34913 differs also from *Nothosaurus* sca-

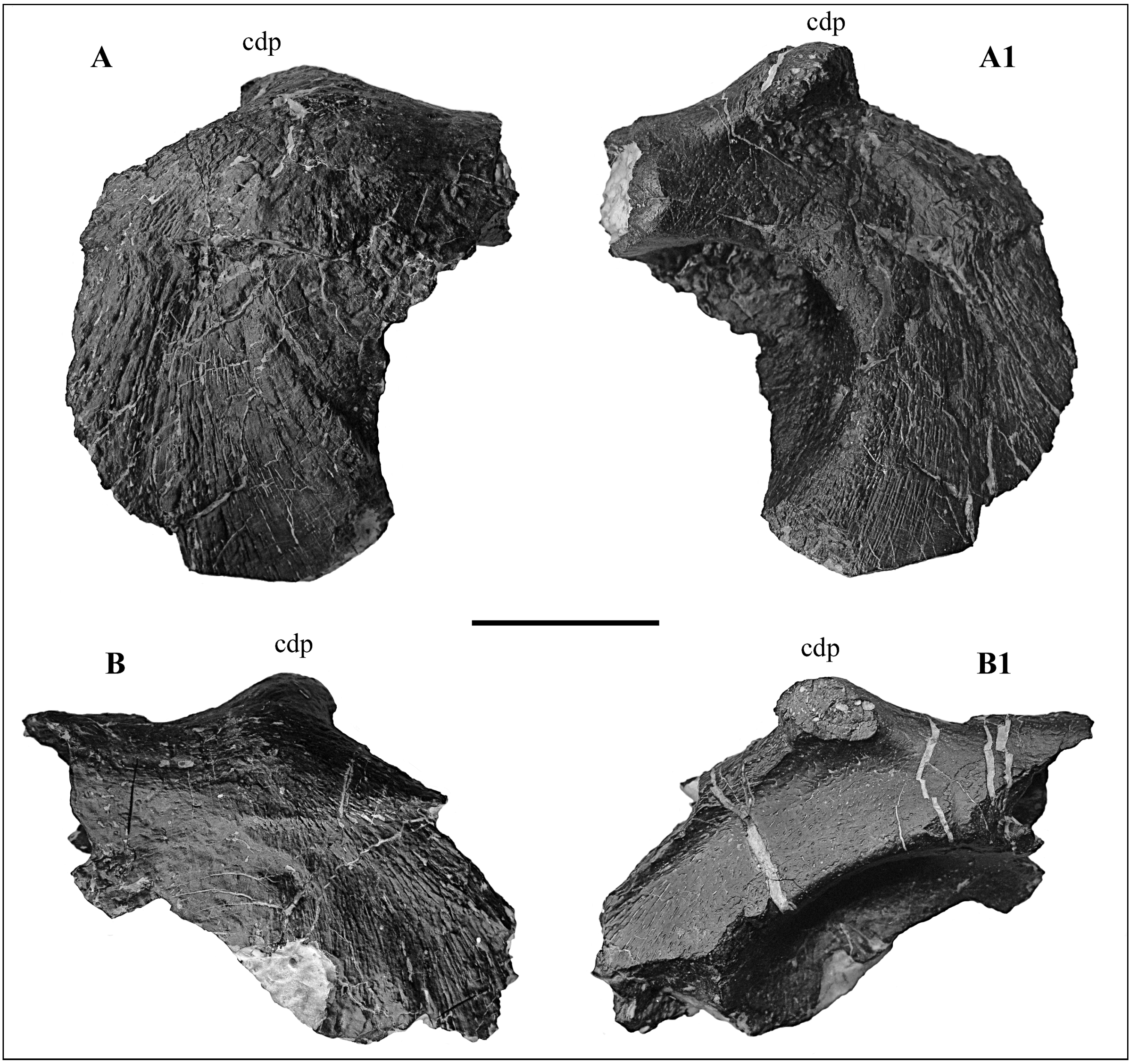

Fig. 6 - Clavicles. A-A1) Ventral and dorsal views of MFSN 34904, right clavicle; B-B1) ventral and dorsal views of MFSN 34905, left clavicle. Abbreviations: cdp = craniodorsal process. Scale bar equals 2 cm.

pulae figured in Rieppel (1994, fig. 54) and Rieppel et al. (1999, fig. 47), and even more from the scapula of *Nothosaurus jagisteus* Rieppel, 2001 (Rieppel 2001, fig. 7-8C) and that of *N.* cf. *giganteus* Münster, 1834 (Rieppel 2000, fig. 8). It resembles the scapula of *Partanosaurus zitteli* (Skuphos 1893b; Rieppel 1996, fig. 5), considering that the area of the apparently missing coracoid foramen was reconstructed in plaster in the latter.

The upper portion of a sauropterygian ilium (MFSN 34914, Fig. 7D) is 31.5 mm high and the incomplete blade is 28 mm long. Only the dorsal end of the much expanded acetabular portion is preserved as there is no trace of the facets for the sacral ribs. This prevents recognizing whether it is a right or left element; as one side is more convex than the other, and supposing it is the lateral side, MFSN 34914 could be a left ilium. The iliac blade is separated from the acetabular portion by a relatively narrow neck. The caudally broken postacetabular process is much larger than the medially bent preacetabular process. This ilium is rather unlike that of *Simosaurus* (Rieppel 1994, fig. 28A-B), as well as those of *Nothosaurus* (Rieppel 1994, fig. 50; Rieppel et al. 1999, fig. 49). It resembles the ilium of *Bobosaurus forojuliensis* (Dalla Vecchia 2006, fig. 13), although it is much smaller.

Discussion. Although we cannot be sure about the exact stratigraphic provenance of each specimen (i.e., the single bed), all the fossils come from a restricted area and a very narrow stratigraphic section of

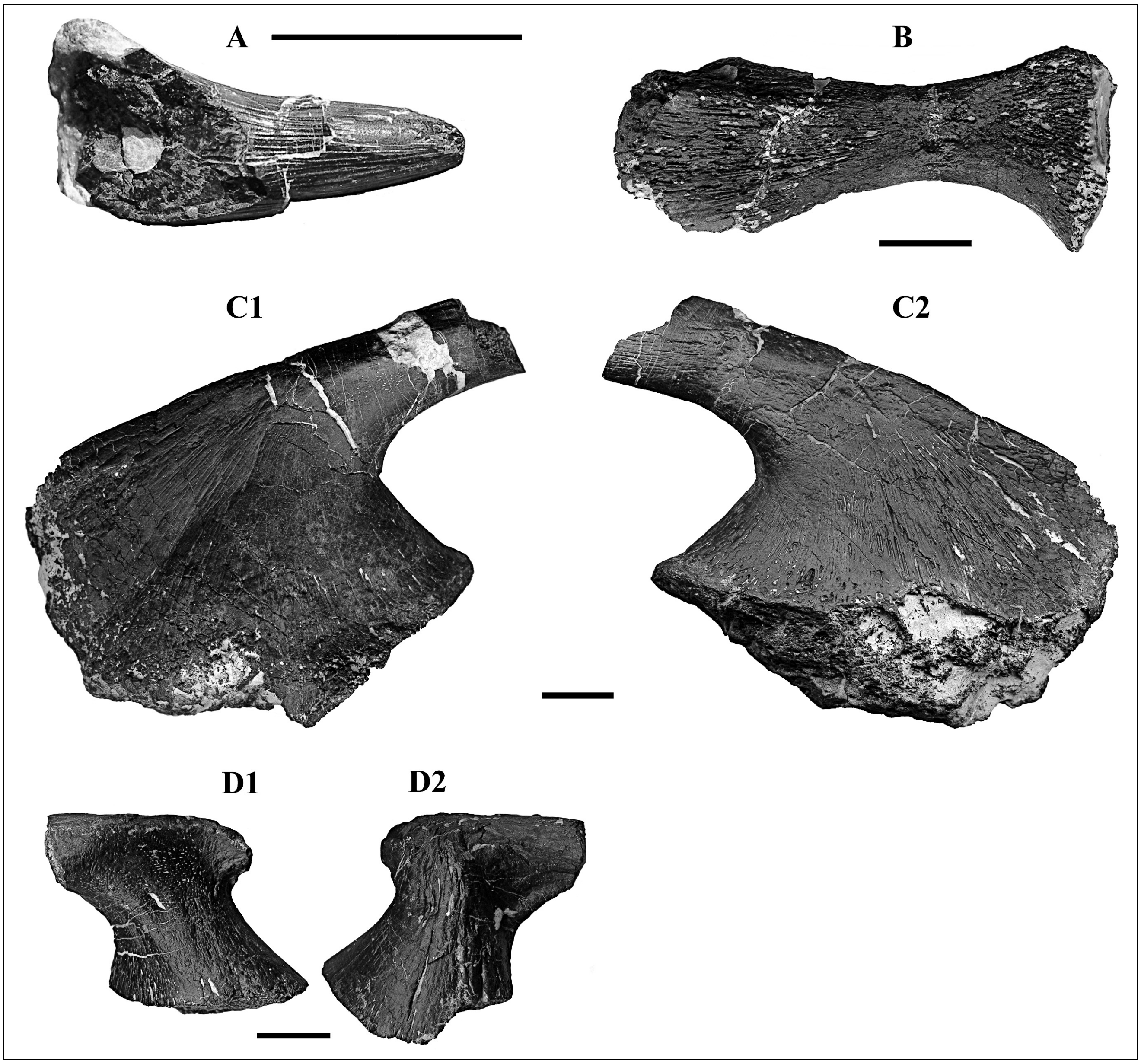

Fig. 7 - Other skeletal elements possibly belonging to *Simosaurus.* A) Tooth (MFSN 34915); B) probable sacral rib (MFSN 34906); C) right scapula (MFSN 34913) in medial view (C1) and lateral view (C2); D) ?left ilium (MFSN 34914) in ?medial view (D1) and ?lateral view (D2). Scale bar equals 1 cm.

a thick unit where vertebrate remains are not very common. Some specimens (MFSN 28917 and MFSN 34886) were collected *in situ* in a limestone bed at the base of the section that apparently was the only vertebrate-bearing bed. Most of the other specimens were preserved inside limestone fragments of similar aspect; more remains, disarticulated but close to each other, were often present on a single limestone block. Possibly most of the specimens of the sample, if not all, originate from a single, fossiliferous bed, probably the basal one. All the vertebral remains found in the site have roughly similar sizes (excluding two very small eosauropterygian centra) and could come from a single individual. They are the only vertebral remains in the sample: no cervical, pectoral, sacral or caudal vertebrae, and also no other dorsal vertebrae with a different morphology were found in the site (excluding the two small eosauropterygian centra). Apparently only a trunk portion (or trunk portions of individuals of the same size) was involved in the small landslide.

The dorsal neural arches still associated to their respective, unfused centra and the close association of dorsal vertebrae and ribs in some limestone fragments suggests that the trunk portion/s was/were not totally disarticulated. Probably the partial disarticulation was enhanced by the invertebrate bioturbation visible in the original blocks.

Neural arches show the "infraprezygapophysis" and infrapostzygapophysis considered diagnostic of *Simosaurus gaillardoti* by Rieppel (1994, 2000) (but see

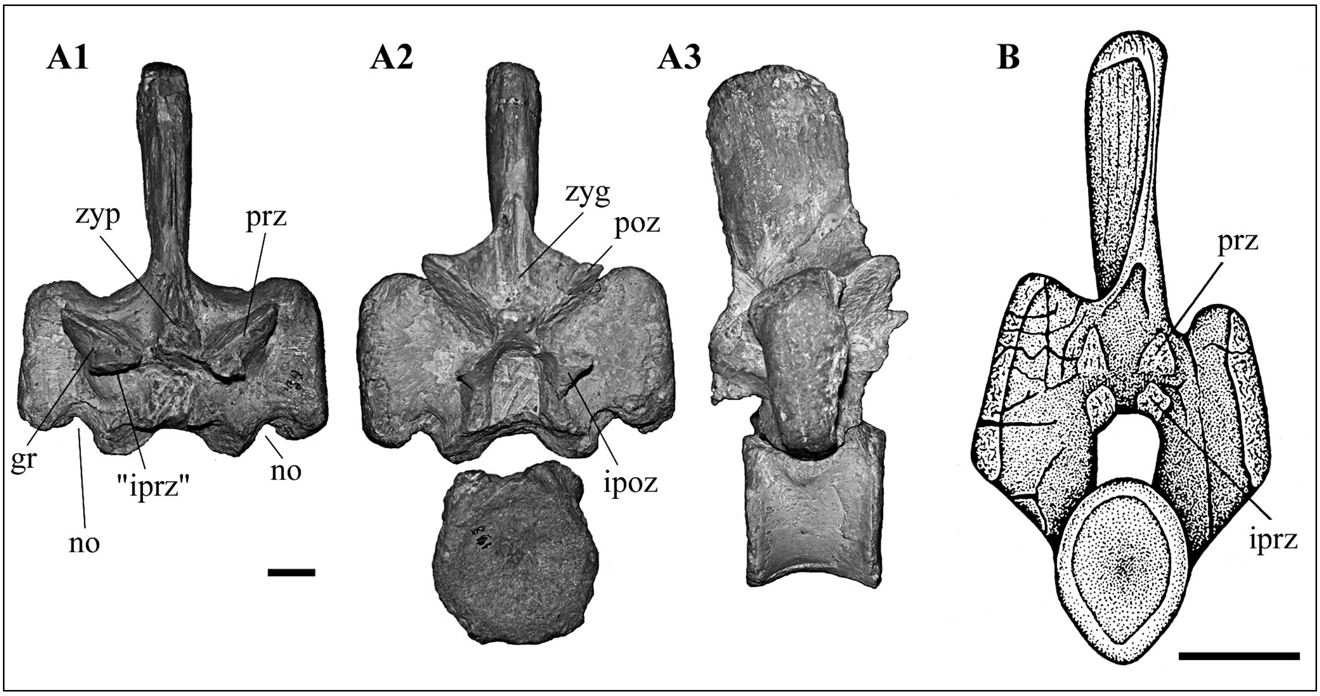

Fig. 8 - Dorsal vertebrae of *Simosaurus gaillardoti* (A, SMNS 14733; A1, cranial view; A2, caudal view; A3, left lateral view) and *Partanosaurus zitteli* (B, complete, disarticulated dorsal vertebra, cranial view, from Rieppel 1996). Abbreviations: gr = mediolateral groove or depression that separates the dorsal zygapophyseal facet from a ventral zygapophyseal facet ("infraprezygapophysis") in the prezygapophysis; ipoz = infrapostzygapohysis; "iprz" = "infraprezygapohysis"; iprz = true infraprezygapohysis; no = notch; poz = postzygapohysis; prz = prezygapophysis; zyg = zygantrum; zyp = zygosphene. Scale bar equals 2 cm.

below for a discussion on this character). Not only the "infraprezygapophysis" and infrapostzygapophysis, but also the overall morphology of the neural arch and centrum, and their relative proportions with a centrum comparatively small with respect to the neural arch, the high and rectangular neural canal, the large, dorsoventrally high and massive transverse processes, the neural spine not very short nor very tall and with an apicobasally striated apical part are similar to those in the dorsal vertebrae of SMNS 14733 (Rieppel 1994; pers. obs.).

The clavicles undoubtedly show a diagnostic feature of *Simosaurus gaillardoti* (presence of a short craniolateral process; Rieppel 1994, 2000). The distal dorsal rib portions are expanded as those of *Simosaurus* and associated with *Simosaurus* dorsal vertebrae. Dorsal ribs distally expanded, not sickle-shaped, very thin at midshaft and with a proximal head smaller than the corresponding transverse process occur in *Partanosaurus zitteli* (*Simosaurus* for Rieppel 1996, as seen above, but see below for an argumentation against this attribution) (Skuphos 1893b; Rieppel 1996).

The sacral rib does not belong to Nothosauridae and could plausibly be simosaurian. However, the presence in the sample of the placodont tooth (MFSN 28917), two small hexagonal osteoderms of a cyamodontoid placodont (MFSN 34918) and two very small eosauropterygian centra (MFSN 34916-34917) shows that the assemblage is not monospecific. Also, as seen above, other sauropterygians are reported from the same basal interval of the Rio dal Lago Formation of the Dogna environs. Thus some of the specimens here described (mainly the small ilium, but possibly also the scapula and the tooth) can only tentatively be attributed to the same taxon as the dorsal vertebrae and ribs, hence to *Simosaurus*.

The main diagnostic feature in the axial skeleton of *Simosaurus* is the peculiar articulation between dorsal neural arches, with wedge-like apophyses fitting inside socket-like structures. However, this kind of articulation occurs also in the pectoral to the proximal caudal vertebrae of *Bobosaurus forojuliensis* (Dalla Vecchia 2006). Thus, the simple morphology of the articular structures does not allow a distinction between *Simosaurus* and *Bobosaurus*. Some other features distinguish between the two:

1) the wedge-like zygapophyses are located on the caudal surface of the neural arch in *Bobosaurus* (its vertebral column is preserved articulated), whereas in *Simosaurus* they are cranial (this cannot be ascertained in SMNS 14733 now, but can be observed in GPTI, uncatalogued), i.e. on the side with the zygosphene. The polarity is therefore reversed in the two;

2) the neural spines are comparatively much taller in *Bobosaurus* and are hollow inside;

3) pre- and postspinal laminae are wide in *Bobosaurus* dorsal vertebrae, but less developed in *Simosaurus*;

4) the transverse processes of the dorsal vertebrae are ventrodorsally narrower, caudocranially thicker and project further laterally in *Bobosaurus* than in *Simosaurus*.

Features 2-4 allow the definitive attribution of the disarticulated vertebrae from the Lavaz Creek to *Simosaurus*. Furthermore, dorsal ribs of *Bobosaurus* are not as broadened distally as those of *Simosaurus* and apomorphically bear distinct uncinate processes (Dalla Vecchia 2006).

The presence of similar zygapophyses in *Bobosaurus* means that all attributions to *Simosaurus* based solely on the articular structures of the dorsal neural arch must be reconsidered.

According to Rieppel (1996) the dorsal vertebrae of *Partanosaurus zitteli* have postzygapophyses and infrapostzygapophyses on the caudal side of the arch, thus they belong to *Simosaurus*. However the incompletely preserved structures, apparently four paired apophyses, occur in the cranial side, as the presence of the bifid zygosphene testifies (Fig. 8B), so they are prezygapophyses and infraprezygapophyses. That is different from the condition described above for *Simosaurus* and also from that of *Bobosaurus* (which unlike the Austrian taxon has dorsoventrally narrower transverse processes in the dorsal vertebrae and very tall neural spine), suggesting that those vertebrae belong to a different taxon (i.e., *Partanosaurus zitteli* could be a valid species). Distally broadened dorsal ribs would therefore not be a diagnostic feature of *Simosaurus* as they occur also in *Partanosaurus*. Consequently also the Arlbergschichten specimen cannot be unambiguously referred to *Simosaurus*. The sharing of distally broadened dorsal ribs by different nothosauroid species was noted by Rieppel (1996, fig. 6), who reports two of such ribs from the upper Gipskeuper (lower Carnian) of Baden-Württemberg as "Sauropterygia indet." In fact, Rieppel (2000) does not list "distally broadened dorsal ribs" as a diagnostic feature of *Simosaurus gaillardoti*. The apicobasally grooved apical part of the dorsal neural spine is not a feature unique to *Simosaurus* and *Partanosaurus*, but also occurs in *Nothosaurus jagisteus* Rieppel, 2001, *N. tchernovi* Haas, 1980, *Augustasaurus hagdorni* Sander, Rieppel & Bucher, 1997 (although with apomorphic "double facets of unfinished bone near the posterior end of neural spine" in middle dorsal vertebrae; Rieppel et al. 2002), and incipiently also in *Bobosaurus forojuliensis*.

The dorsal neural arch from Saudi Arabia is isolated and its actual caudocranial polarity is unknown. The transverse processes are massive, with a rectangular outline in caudocranial view, extending far down along the neural arch pedicels (Vickers-Rich et al. 1999, fig. 5D). The neural arch is figured only in caudal view and, according to Vickers-Rich et al. (1999), the pre- and infraprezygapophysis are broken. Therefore, its attribution to *Simosaurus*, although possible, cannot be confirmed.

Although very similar to those of *S. gaillardoti*, the dorsal vertebrae from Lavaz Creek differ in some details. They are smaller than those of specimen SMNS 14733. The transverse process lacks a ventral notch (see Fig. 8A1-2) and is confluent with the laterally projecting neural pedicel of the centrum. The neural spine is comparatively much shorter craniocaudally (cf. Figs 3A3 and 8A3). Centra are amphicoelous (as in *Partanosaurus*; Rieppel 1996) instead of platycoelous, comparatively smaller and more constricted. Also, the extreme upper-midshaft thinning of the dorsal rib does not occur in SMNS 14733. If the neural arches and the dorsal ribs from Lavaz Creek belong to the same individual, as it seems probable, or to more individuals of the same size, the width of the distal end of dorsal ribs compared to neural arch height is comparatively higher than in SMNS 14733. Thus the Friulian *Simosaurus* had ribs proportionally more expanded distally. Furthermore, the short cranial process of the clavicle is turned dorsocranially instead of projecting straight cranially.

This, united to the younger age and the different palaeogeographic provenance, would suggest the belonging to a separate species. However, I am not confident in instituting a new taxon on such a few osteological differences and a limited sample without skull elements. Thus, I prefer to consider the Friulian material as belonging to a *Simosaurus* species close to *S. gaillardoti*, pending the discovery of more complete skeletons for its formal definition.

With the addiction of *Simosaurus*, the sauropterygian association from the basal part of Rio del Lago Formation of Dogna area can be considered one of the richest and most diverse such Carnian faunas in the world.

Sauropterygians are common also in the vertebrate association from the Fusea site (Tolmezzo, Udine), about 25 km south-west the Dogna area, occurring just above the top of the Dolomia dello Schlern Formation and therefore possibly slightly younger in age (latest Ladinian-earliest Carnian) than those of Dogna area (cf. Fig. 2A2). They include a cyamodontoid placodont unlike *Protenodontosaurus* and closer to *Cyamodus* (Rieppel & Dalla Vecchia 2001; Rieppel & Nosotti 2002) and a large *Nothosaurus* species (*N.* cf. *giganteus*) (Rieppel & Dalla Vecchia 2001); also the prolacertiform *Tanystropheus* (lacking in the Rio del Lago Formation of Dogna zone) occurs (Dalla Vecchia 2000). They are found at the base of a thick sequence of black limestone ("formazione della Val Degano"), with some evidence of brackish or fresh water influence (coal levels) and poorly differentiated invertebrate faunas (no corals, no echinoderms, few bivalves, some gastropods) (Dalla Vecchia 2000). This means that *Simosaurus* reached the Alpine region later, or that it was very sensitive to the environmental conditions.

Conclusions

Simosaurus, a eusauropterygian found mainly in the Ladinian of Central Europe is reported for the first time in Italy and for the first time unambiguously in the Upper Triassic. This is the further evidence of the connection of the Central European Basin and the Alpine region based on marine tetrapod record (e.g., Rieppel 2000; Rieppel & Dalla Vecchia 2001, for *Nothosaurus giganteus*; Rieppel & Dalla Vecchia 2001, for *Placodus*; Dalla Vecchia 2004, for *Tholodus*). It is the youngest record of *Simosaurus* to date. The genus was relatively common in the uppermost Muschelkalk (earliest Ladinian) of the Central European Muschelkalk basin; it became rarer there during the middle and late Ladinian (Lettenkeuper and lower Gipskeuper) and apparently did not reach the Carnian. During the early Carnian it survived in or migrated to the Alpine region (Julian Alps) where the environmental conditions existing in Central Europe during the deposition of the uppermost Muschelkalk (shallow marine carbonate ramp with local oolite shoals; Hagdorn & Rieppel 1999, p. 663) and disappearing in the Gipskeuper time, still existed.

The identification of *Simosaurus* based only on the presence of "infraprezygapophysis" and infrapostzygapophysis is no longer possible, as this feature is shared with *Bobosaurus*.

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