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The occurrence of the vertebrate ichnogenus *Synaptichnium* in the Anisian (Middle Triassic) of Southern Alps

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SUMMARY - *The occurrence of the vertebrate ichnogenus* Synaptichnium *in the Anisian (Middle Triassic) of Southern Alps* - The specimens pertaining to the ichnogenus *Synaptichnium* found in the Anisian of Southern Italian Alps are described and compared. All the recovered specimens were discovered in Pelsonian marine marginal sediments. The reported morphotypes are sufficiently diversified for excluding "track preservation variations". So some consideration could be proposed due to different stratigraphical occurrence of the morphotypes. It seems that *S. pseudosuchoides* is characteristic of the lower part of the sedimentary succession (early Pelsonian), while *S.* cf. *cameronense* appears only in the upper layers (middle to late Pelsonian). The trackmakers lived closer to the water and in the lower to upper intertidal. During the time interval considered, the environmental conditions shifted to a coastal delta mouth bars to a silicoclastic tidal flats with a more marked marine influence. This environmental variation could be considered as possible responsible for the apparent change in the ichnofauna.

RIASSUNTO - *La distribuzione dell'icnogenere* Synaptichnium *nell'Anisico (Triassico Medio) delle Alpi Meridionali* - Vengono descritti e confrontati gli esemplari riferiti all'icnogenere *Synaptichnium* rinvenuti nei terreni anisici delle Alpi Meridionali. Tutti gli esemplari fino ad oggi documentati sono riferibili a sedimenti marino marginali di età Pelsonica. I morfotipi individuati sono sufficientemente caratterizzati da escludere "varianti preservazionali". Per questo possono essere fatte alcune considerazioni in base alla loro distribuzione stratigrafica. Sembrerebbe che *S. pseudosuchoides* sia caratteristico della parte bassa della successione stratigrafica (Pelsonico inferiore), mentre *S.* cf. *cameronense* appare nei livelli superiori (Pelsonico medio-superiore). Gli autori delle orme vivevano prossimi all'acqua in condizioni intertidali. Durante l'intervallo di tempo considerato, le condizioni ambientali passano da barre fangose costiere a una piana tidale silicoclastica piu vicina al mare. Questa variazione ambientale potrebbe essere responsabile dell'apparente cambio nella composizione delle icnofaune.

Key words: vertebrate footprints, Synaptichnium, Middle Triassic, Southern Alps
Parole chiave: orme di vertebrati, Synaptichnium, Triassico Medio, Alpi Meridionali

1. INTRODUCTION

The occurrence of the ichnogenus *Synaptichnium* in the Middle Triassic sedimentary units (De Zanche *et al*. 1993) of the Southern Italian Alps was reported for the first time by Avanzini (1999) based on findings from Pelsonian sediments of the Non Valley (Trento and Bolzano Province) (Conti *et al*. 2000; Avanzini *et al.* 2001; Nicosia *et al.* 2005).

Recent research records the presence of the ichnogenus, in a short stratigraphical interval, from several ichnosites of the eastern area of the Italian Southern Alps (Fig. 1) (Avanzini & Mietto, in press).

The aim of this paper is to provide a description of the specimens referable to this ichnogenus recorded in northern Italy. This description is based on the author's examination and measurement of all the specimens held in the Museo Tridentino di Scienze Naturali, Trento (MTSN) and Naturmuseum Sudtirol, Bolzano/Bozen (NMS).

2. GEOLOGY AND AGE

All the specimens described come from Anisian continental to marine marginal sediments referred to the Voltago Conglomerate and to the Recoaro Limestone (Delfrati *et al*. 2000).

The Voltago Conglomerate is made up of conglomerates, sandstones, siltstones and claystones mostly red in colour. The lower part of the unit consists of grey silty-micaceous, locally nodular, bioturbated wackestones and red, green and grey quartzy micaceous fine grained sandstones. Sandstones and siltstones are commonly cross-laminated. Conglomerate beds consist of rounded centimetre-sized pebbles in a white and yellow sandy matrix.

In the upper part of the unit, grey centimetre/decimetre-thick strongly wavy to nodular grainstone beds are interbedded with grey and red grained sandstones and biolaminated silty limestones. Plant debris is abundant throughout the unit. Owing the presence of the Binodosus Subzone ammonites in

Fig. 1 - Sketch map showing the location of the areas where *Synaptichnium* footprints were recovered. 1. Rio Urban (Northern Non Valley), 2. Gampenpass (Northern Non Valley), 3. Bad Gfrill - Tisens (Northern Adige Valley).
Fig. 1 - Mappa schematica con l'indicazione delle località dove sono state rinvenute orme attribuibili a Synaptichnium*. 1. Rio Urban (Valle di Non settentrionale), 2. Gampenpass (Valle di Non settentrionale), 3. Bad Gfrill - Tisens (Valle dell'Adige settentrionale).*

the overlaying Recoaro Limestone and a comparison with marine etheropic sediments in Dolomites and Carnia, this unit is early Pelsonian in age (Cuccense Subzone).

This unit reflects a transitional continental to marine environment characterised by coastal delta mouth bars deposited under relatively arid conditions.

The ichnofauna comes from the middle (final lowstand) and upper portion (trasgressive system tract) of the succession.

The uppermost Recoaro Limestone predominantly consists of nodular, bioturbated, fossil-rich packstones and packstones/grainstones arranged in decimetre-thick layers alternating with thin calcisiltite beds containing angular fine grained quartz.

The fauna is locally abundant and mainly made up of brachiopods (*Coenothyris vulgaris* (Schloteim), *Tetractinella trigonella* (Schlotheim), *Decurtella decurtata* (Girard), bivalves, gastropods (*Undularia scalata* (Schlotheim), crinoids (*Encrinus liliiformis* Lamark), echinoids, celenterata. Ammonoids of the Binodosus Subzone (*Bulogites zoldianus* Mojsisovich) (Pelsonian) are also documented (De Zanche & Mietto 1981).

The depositional environment is referable to a carbonate ramp slightly contamined by terrigenous input.

The vertebrate ichnofauna is preserved in the basal layers of the formation that correspond to the trasgressive system tract.

3. SISTEMATIC ICHNOLOGY

As observed by Klein & Haubold (2007) the ichnotaxonomic situation in *Synaptichnium* Nopcsa, 1923 is complicated by several circumstances: no type has been clearly fixed thus far in the Early and Middle Triassic it can possibly synonimized with other ichnotaxa (i.e. *Protochirotherium* and "*Megarynchosauroides*") (Diedrich & Fichter 2003; Fichter & Kunz 2004) and footprint named as *Synaptichnium* show a transition to "*Brachychirotherium*" in different extramorphologial variations (Klein & Haubold 2004).

A revision of the ichnotaxon seems necessary (Klein & Haubold 2004; Demathieu & Demathieu 2004), but this is not the purpose of this paper.

In the following chapters we will only provide a description of the specimens referable to this ichnogenus recorded in the Southern Alps following the diagnosis by Haubold (1971) emended by King *et al*. (2005)

Ichnogenus *Synaptichnium* Nopcsa, 1923

General diagnosis of the ichnogenus from Haubold (1971) emended by King et al. *(2005)*

Manus. Pentadactyl and relatively large (manus/pes ratio > 0.53) with a mesaxonic structure. Manual digit III is the longest and digits II and IV are approximately in the same length. Digit V is straight and situated proximally at an angle of about 40° to the long axis through digit III. The manus narrows posteriorly and terminates in a metatarsal-phalangeal pad to the rear of digit V. All terminal phalanges show distinct sharp claw casts. Digit prints exhibit prominent phalangeal nodes that indicate that digits I-III probably contained 2, 3 and 4 phalanges respectively.

Pes. Pentadactyl, ectaxonic, larger and more elongated than the manus, generally only about 10 cm long. Digits, nearly parallel, increase in length from I to IV. Digit V is straight and situated proximally at an angle of about 40° to the long axis through digit III. The pes terminates posteriorly in a large oval metatarsal-phalangeal pad to the rear of digit V. All digits show sharp claw casts at the tips. Casts of digits exhibit prominent phalangeal nodes. This indicates that digits I-III probably contained 2, 3 and 4 phalanges respectively.

Trackway. Pattern not yet well established (see King *et al.* 2005, for a complete discussion). Traditionally, the *Synaptichnium* trackway is described as relatively wider than that of other chirotheriids. The pace angulation observed by Peabody (1948) varies from 140° to 160°, but in the *Synaptichnium priscum* trackway depicted by Demathieu (1970) the pace angulation is only about 120°.

Type ichnospecies: *Synaptichnium pseudosuchoides* Nopcsa, 1923. Middle Triassic England.

3.1. Southern Alps ichnospecies and morphotypes

Synaptichnium pseudosuchoides (Nopcsa, 1923) (Fig. 2a)

Description

Manus. Pentadactyl and relatively large with a mesaxonic structure. Manual digit III is the longest, and digits II and IV are approximately of the same length. Digit V is straight and placed proximally at an angle of about 40° to the long axis through digit III. All terminal phalanges show distinct sharp claw casts.

The total length of the manus is 4.5 cm with a maximum width of 3.5 cm.

Pes. Pentadactyl, ectaxonic, larger and more elongated than the manus. Digits nearly parallel, increase in length from I to IV. Digit V is straight and situated proximally at an angle of about 40° to the long axis through digit III. The pes terminates posteriorly in a large oval metatarsal-phalangeal pad to the rear of digit V. All digits show sharp claw casts at the tips.

The total length is 10 cm and the maximum width is 4.9 cm.

Trackway. No trackways are known.

Referred material

(MTSN - RU 2a/b) Non Valley (Rio Urban - TN) early Pelsonian (Voltago Conglomerate), (MTSN - RU 5) Non Valley (Rio Urban - TN) early Pelsonian (Voltago Conglomerate), (MTSN - RU 5a) Non Valley (Rio Urban - TN) early Pelsonian (Voltago Conglomerate), (MTSN - RU 1a) Non Valley (Rio Urban - TN) early Pelsonian (Voltago Conglomerate), (MTSN - RU 1b) Non Valley (Rio Urban - TN) early Pelsonian (Voltago Conglomerate), (MTSN - BG1997-1) Bad Gfrill (Tisens - BZ) early Pelsonian (Voltago Conglomerate).

Discussion

The characteristics of the recovered tracks are typical of this ichnospecies. The presence of distinct phalangeal pads, long claws and slightly convergent digits III and IV is clearly recognisable in all the discovered tracks. *S. pseudosuchoides* is relatively common in the Lower and Middle Triassic of Europe (Haubold 1984; King *et al.* 2005).

Synaptichnium isp. 1 (Fig. 2b)

Description

Manus. 4.8 cm long and 2.3 cm wide. Digits I-IV diverge within a 60° angle. Digit I is very small, II and IV subequal, III the longest. Small sharp claws are present. Manus V is thumb-like, but straighter than the pes.

Pes. 9 cm long and 4.8 cm wide. Digit IV is at least as long as III and appears to be even longer because of the marked slant of the metatarsal/phalangeal axis. Digit I is about half the length of II, the latter slightly over half the length of III. Thus the progressive increase in length from I to III is marked. The cross axis with the long axis of the foot makes an angle of 55°. Pes digit V is long and slender. Digits I-IV tend to be parallel with each other. Narrow claws are present on digits I-IV. The phalangeal formula is 2-3-4-5. The pes is impressed more strongly on the median side.

Trackway. The trackway pattern is relatively wide, with a pace angle of about 140°. The manus and pes are turned outward.

Referred material

(MTSN - ULF 22) Km. 44 S.S. 243 Palade (Valle di Non - BZ) early Pelsonian (Voltago Conglomerate).

Discussion

The footprints are well defined.

The feet of the track makers crossed the surface of firm or stiff mud leaving distinct and sharply defined footprints. Marginal ridges were weakly developed in some cases, and were limited to only one side of the shaft. The footprints preserve fine anatomical details and the impression of the skin can be recognised (Avanzini 2000). The footprint is very close to *S. pseudosuchoides* from which it differs in that digits III and IV are more parallel and in that the morphology of digit V is stouter and shorter. In a pedal print, the distal part of digit V shows a slender phalangeal impression that bends slightly outward. However, the tracks are very slightly impressed with a partial impression of digit V and could represent only a "track preservation variation" of *S. pseudosuchoides*

Synaptichnium cf. *S. cameronense* Peabody, 1948 (Fig. 2c)

Description

Manus. Relatively wide (2.5 cm) and 3.5 cm long. Digit I is only faintly impressed in contrast to digit group II-IV. The digits present short narrow claws. Digits III and IV are separated slightly more than the others. Digit V is relatively short and slender distally.

Pes. Long digits with rounded, marked digital pads. Digit IV is slightly longer than III and the metatarsal-pha-

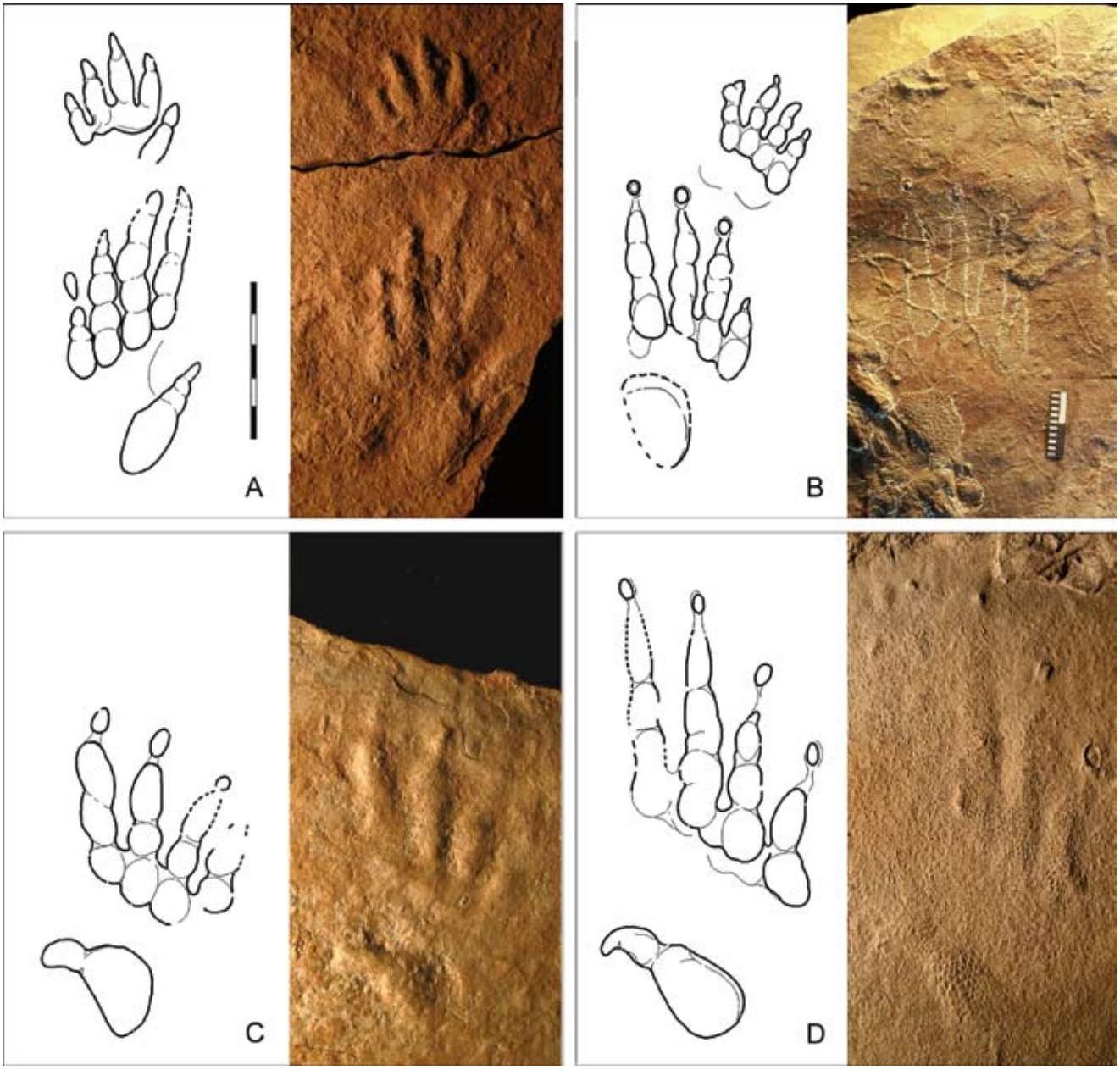

Fig. 2 - Some specimens of *Synaptichnium* footprints from the Southern Alps. A. *S. pseudosuchoides* from Rio Urban (TN), B. *Synaptichnium* isp. 1 from Gampenpass (BZ), C. *S.* cf. *S. cameronense* from Bad Gfrill (BZ), D. *S.* isp. 2 from Bad Gfrill. (Scale: 5 cm).
Fig. 2 - Alcuni esemplari di orme di Synaptichnium *dalle Alpi Meridionali. A.* S. pseudosuchoides *da Rio Urban (TN), B.* Synaptichnium *isp. 1 da Gampenpass (BZ), C.* S. *cf.* S. cameronense *da Bad Gfrill (BZ), D.* S. *isp. 2 da Bad Gfrill. (Scala: 5 cm).*

langeal axis is about 55°. The divergence of digits I-IV varies about 40°. Digits II and III are curved and outward rotated. Digit V is relatively small, curved, and set well back in respect to digit group I-IV. The length of the pes is about 50 mm.
Trackway. No trackways are known.

Referred material

(MTSN - BzBG1) Bad Gfrill (Tisens - BZ), Pelsonian (Recoaro Limestone).

Discussion

The track, attributed to *S. cameronense* using open nomenclature, is clearly distinct from the other specimens from the Southern Alps attributed to *Synaptichnium*. The strong digits, with marked pads that strengthen in the distal phalanges and their inward rotation, appear peculiar. Digit V with its well marked pad and the curved extremity also appears peculiar. The landmark analysis suggests a short, wide morphology of the pedal print, making it clearly diffe-

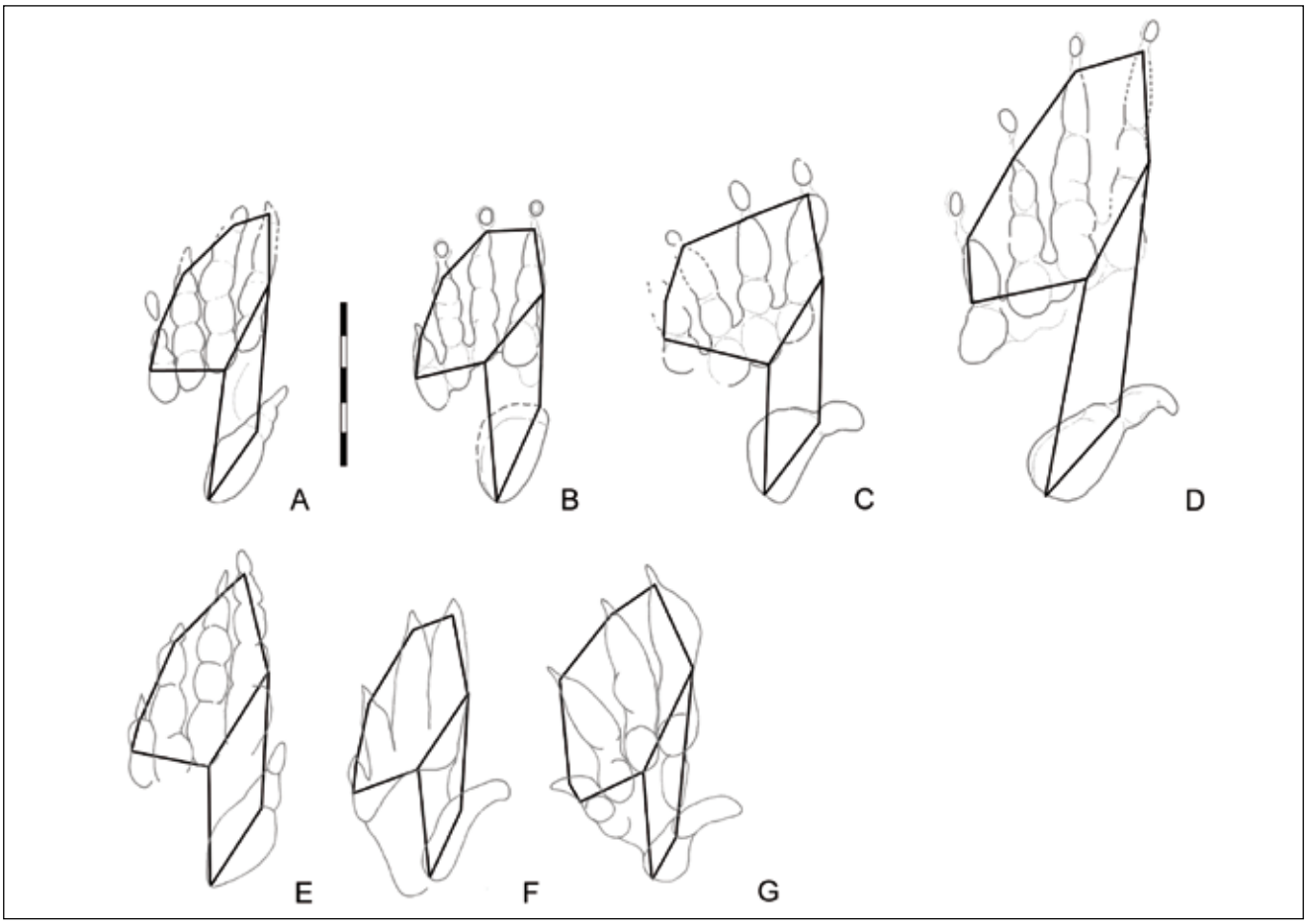

Fig. 3 - Landmark analysis (Klein & Haubold 2003) of some *Synaptichnium* specimens from the Southern Alps and comparison with some type specimens. A. *S. pseudosuchoides* from Rio Urban (TN), B. *S.* isp. 1 from Gampenpass (BZ), C. *S.* cf. *S. cameronense* from Bad Gfrill (BZ), D. *S.* isp. 2 from Bad Gfrill, E. *S. pseudosuchoides* Nopcsa, 1923, F. *S. diabloense* (Peabody, 1948) Haubold 1971, G. *S. cameronense* (Peabody, 1948) Haubold 1971 (Scale: 5 cm).

Fig. 3 - Landmark analysis (Klein & Haubold 2003) di alcuni esemplari di Synaptichnium *delle Alpi Meridionali e confronto con le specie tipo. A.* S. pseudosuchoides *da Rio Urban (TN), B.* S. *isp. 1 da Gampenpass (BZ), C.* S. *cf.* S. cameronense *da Bad Gfrill (BZ), D.* S. *isp. 2 da Bad Gfrill, E.* S. pseudosuchoides *Nopcsa, 1923, F.* S. diabloense *(Peabody, 1948) Haubold 1971, G.* S. cameronense *(Peabody, 1948) Haubold 1971 (Scala: 5 cm).*

rent from the other *Synaptichnium* footprints (Klein & Haubold 2003) (Fig. 3).

S. cameronense is a typical ichnospecies of the Anisian Moenkopy Fm. in Northern America (Peabody 1948), but is also reported in the French Muschelkalk (Demathieu & Haubold 1972, 1974; Demathieu &Gand 1981).

Synaptichnium isp. 2 (Fig. 2d)

Description

Manus. 4 cm long and 3 cm wide. Digits I-IV diverge within a 60° angle. Digit I is very small, II and IV subequal, III the longest. Small sharp claws are present. Manus V is thumb-like, but straighter than the pes.

Pes. 13 cm long and 6 cm wide. Digit IV is at least as long as III and appears to be even longer because of the marked slant of the metatarsal/phalangeal axis. Digit I is about half the length of II, the latter slightly over half the length of III. The cross axis with the long axis of the foot makes an angle of 55°. Pes digit V is long and slender, distally curved. Digits I-IV are nearly parallel to each other. Narrow, inward claws are present on digits I-IV.

Trackway. No trackways are known.

Referred material

(MTSN - BzBG15a) Bad Gfrill (Tisens - Bz) Pelsonian (Recoaro Limestone).

Discussion

The dimensions are the greatest of all the specimens recovered. These peculiar *Synaptichnium* footprints have long, straight, parallel digits. In general, it is similar to *S. diabloense* (Peabody, 1948), but it seems to differ in the lon-

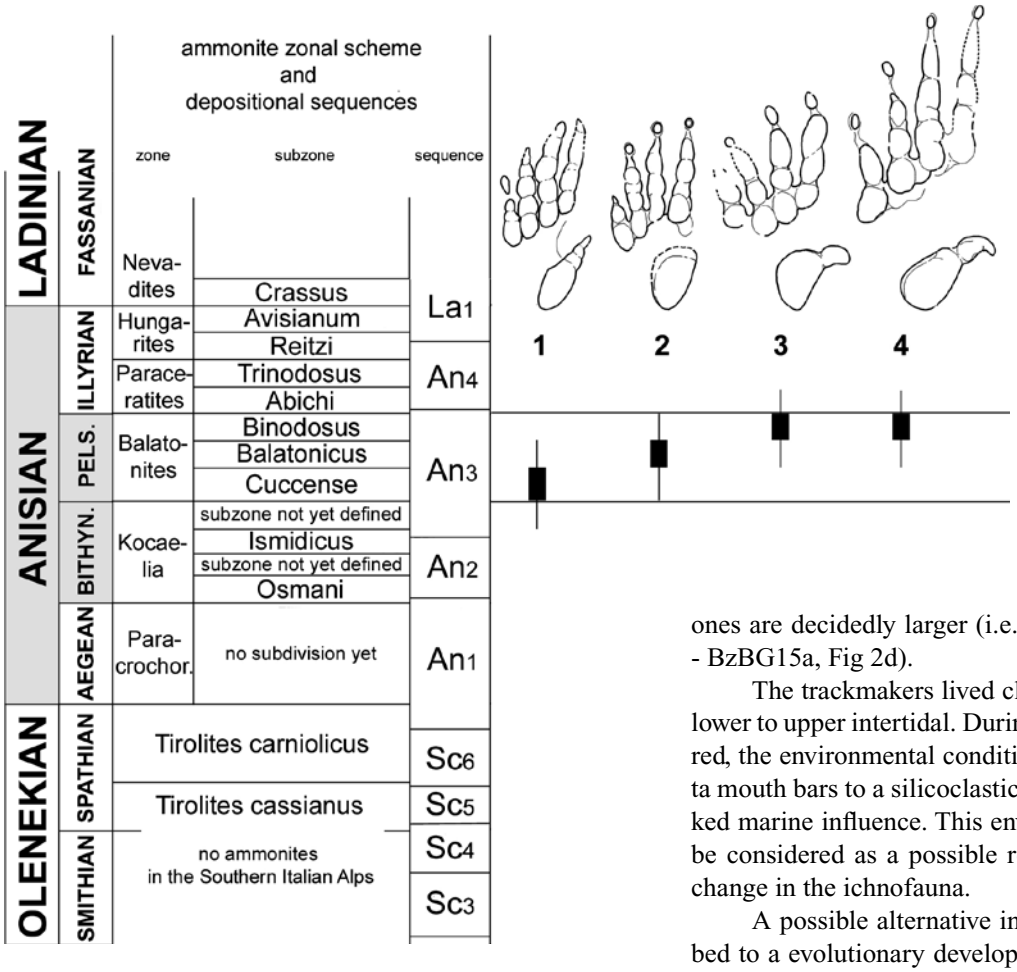

Fig. 4 - Stratigraphic distribution of *S. pseudosuchoides.* 1. *S.* isp. 1, 2. *S.* cf. *S. cameronense*, 3. *S.* isp. 2, 4. in the Anisian of Southern Alps.
Fig. 4 - Distribuzione stratigrafica di S. pseudosuchoides. *1.* S. *isp. 1, 2.* S. *cf.* S. cameronense, *3.* S. *isp. 2, 4. in the Anisian of Southern Alps.*

ger digit V and the central position of the proximal margin of pad V. The landmark analysis underlines some similarity with *S. pseudosuchoides* from which it nevertheless differs in the morphology of digit V.

4. CONCLUSIONS

In the Southern Alps ichnofauna, the ichnogenus *Synaptichnium* seems confined to the Pelsonian.

The here reported morphotypes and ichnospecies are sufficiently diversified for excluding that of some authors (i.e. Diedrich 2005, 2008) consider "track preservation variations" related to extramorphological (substrate-controlled) phenomena. So, some consideration could be proposed due to different stratigrapical occurrence of the form groups.

In the sites with a multiple trampled layer (i.e. the Gampenpass - Bad Gfrill area), it seems that *S. pseudosuchoides* is characteristic of the lower part of the sedimentary succession (Early Pelsonian) while *S.* cf. *cameronense* appear only in the upper layers (Middle to Late Pelsonian) (Fig. 4).

It is also interesting to note an apparent progressive dimensional trend of *Synaptichnium* footprints. The early Pelsonian forms are small and slender, the late Pelsonian ones are decidedly larger (i.e. *Synaptichnium* isp. MTSN - BzBG15a, Fig 2d).

The trackmakers lived closer to the water and in the lower to upper intertidal. During the time interval considered, the environmental conditions shifted to a coastal delta mouth bars to a silicoclastic tidal flats with a more marked marine influence. This environmental variation could be considered as a possible responsible for the apparent change in the ichnofauna.

A possible alternative interpretation could be ascribed to a evolutionary developments of the locomotor apparatus of the *Synaptichnium* trackmaker (Klein and Haubold, 2007) with the apparent replacement by small to large specialised forms in a relatively short time interval (about 2 million years).

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