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New Early Jurassic (Hettangian-Sinemurian) sauropodomorph tracks from the Trento carbonate Platform (Southern Alps, Northern Italy)

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SUMMARY - *New Early Jurassic (Hettangian-Sinemurian) sauropodomorph tracks from the Trento carbonate Platform (Southern Alps, Northern Italy)* - A new Early Jurassic (late Hettangian - early Sinemurian) dinosaur tracksite is reported from the Trento Platform of the Italian Southern Alps. The trace fossils occur in a carbonate layer near the top of the Monte Zugna Fm. (Gruppo dei Calcari Grigi), early Sinemurian in age. The poorly preserved footprints, detected by laser-scanner technique, are referable to medium sized sauropodomorph dinosaurs.

RIASSUNTO - *Tracce di sauropodomorfi del Giurassico inferiore (Hettangiano-Sinemuriano) della Piattaforma carbonatica di Trento (Alpi meridionali, Italia settentrionale)* - In questo lavoro è segnalato un nuovo affioramento con orme di dinosauro riferibile al Giurassico Inferiore (Hettangiano superiore - Sinemuriano inferiore) della Piattaforma di Trento, nelle Alpi meridionali. Le orme fossili sono state rinvenute in un livello carbonatico al tetto della Formazione di Monte Zugna (Gruppo dei Calcari Grigi), ascrivibile al Sinemuriano inferiore. Le impronte, mal preservate, sono state riprodotte mediante laser-scanner e sono attribuili a dinosauri sauropodomorfi di medie dimensioni.

Key words: sauropodomorph tracks, laser scanner, Trento Platform, Southern Alps
Parole chiave: orme di sauropodomorfi, laser scanner, Piattaforma di Trento, Alpi meridionali

1. INTRODUCTION

In the Calcari Grigi Group (Lower Jurassic) that extends through the eastern Southern Alps, up to now four main trampled levels (megatracksites) have been recognized (Leonardi & Mietto 2000; Avanzini *et al*. 2001, 2006, 2007a).

The Calcari Grigi Group is several hundred meters thick and it has been studied by many researchers since the eighteenth century (Bosellini & Broglio Loriga 1971; Avanzini *et al*. 2007b *cum bibl.*). The Monte Zugna Formation represents the lowermost unit of the Group (Avanzini *et al.* 2007b). A further subdivision of the Monte Zugna Formation into three informal units (Masetti *et al.* 1998), shows the occurrence of a lower cyclic, subtidal unit, a middle peritidal unit and an upper subtidal unit. This last unit coarsens upward into the Loppio Oolitic Limestone Fm.

The tracks here described were found on the western flank of the Monte Finonchio, nearby the locality of S. Corrado in the "upper subtidal unit" (*sensu* Masetti *et al*. 1998; Avanzini *et al.* 2006), that represents the uppermost part of the Monte Zugna Fm., connecting the underlying peritidal deposits with the granular body of the Loppio Oolitic Limestone Fm. (Fig. 1). It is characterized by a basal, grainy body overlain by brown and dark grey mudstone-wackestone organized into thin (10-30 cm) nodular beds that contain scattered evidence of tractive sedimentary structures, such as parallel, or low-angle lamination. This muddy, nodular unit contains a small amount of yellowish-grey clay that forms small lenses whose thickness and lateral persistence increase upward until they merge together, building continuous layers about 5 cm thick. Toward the top of the unit, the grainy fraction increases and packstone and grainstone, in which ooids and peloids, predominate.

Footprints are preserved as underprints at the top of a mudstone layer covered by a stromatolitic layers that was exposed subaerially and are superimposed on dark grey wackestone/packstone beds. The same level was recognized in a wide sector of the Trento Platform and was considered a megatracksite (Avanzini *et al*. 2006). The trampled layer is late Hettangian - early Sinemurian in age, according to the biostratigraphic data reported in Avanzini *et al*. (2006, 2007b). It is worth to mention that the Hettangian-Sinemurian boundary is associated with a lowstand/sea le-

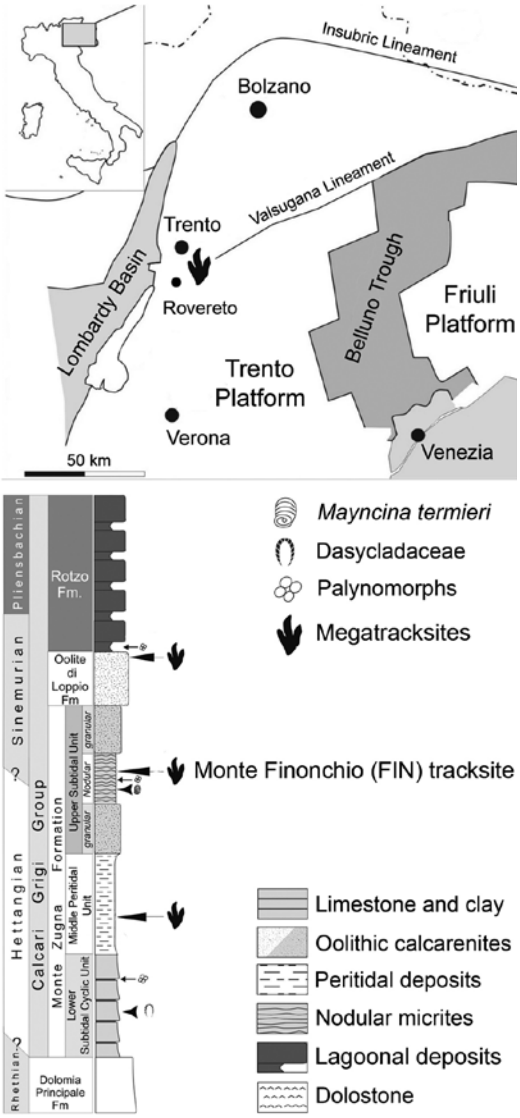

Fig. 1 - Palaeogeographic setting of the Italian Southern Alps in the Early Jurassic and schematic diagram of Lower Jurassic Calcari Grigi Group with the position of the trampled layer.

Fig. 1 - Schema paleogeografico delle Alpi Meridionale nel Giurassico inferiore e stratigrafia semplificata del Gruppo dei Calcari Grigi con indicazione del livello ad orme.

vel fall in the Boreal and Tethys realm (Haq *et al*. 1987; Hesselbo & Jenkyns 1998).

2. LASER SCANNER DOCUMENTATION

The possibilities of a direct study of the footprints are strongly limited because the tracksite is situated on a wall where layers present a very steep dip, in a hardly accessible area (Fig. 2). Time consuming techniques would be necessary to reach the footprints and study them with traditional methods. Laser scanners are instruments capable to realize a "point cloud" that gives an accurate and precise three dimensional representation of a considered target. From the "point cloud is then possible to obtain a 3D model of the scanned object (Remondino 2003; Petti *et al*. 2008). For these reasons terrestrial laser scanner (TLS) has been used in order to obtain a model of the trampled area taking advantage of the fact that TLS allows a highly detailed geometric characterization also on target situated at distances up to tens of meters. The acquisition has been performed with a Leica ScanStation 2 laser scanner from a distance of approximately 90 m, setting a mean point to point spacing of 0,005 m (Fig. 3). The study and the interpretations of the footprints have been then performed directly on the 3D model.

3. FOOTPRINT DESCRIPTION

Five large and poorly preserved manus-pes couples made by a quadruped trackmaker are recognizable on three superimposed carbonate layers (Figs. 4-5). Due the nature of the substrate (a mudstone/wackestone covered by a stromatolite bindstone) and the shallow impression, all the tracks could be considered as undertracks. FIN 1 is the uppermost, while FIN 2, 3, 4 and 5 are preserved in two underlying layers. Bedding plane B is 8 cm below surface A, and surface C is 2 cm deeper than B.

In general, all the prints are surrounded by slightly raised displacement rims. The pedal prints are much larger than the manual ones (marked heteropody). The pedal prints are elliptical in shape, generally associated with sub-circular or sub-elliptical manus impressions. Pes prints and manus prints are sometimes partially overlapped and the manus-pes distance is usually of about 50 cm. Manus prints are rotated outward in respect to the pes-long axis. Outward rotation values in manus prints are variable between 20 and 25°.

Pedal prints are about 8-10 cm deep, the manual ones are only 2-3 cm deep. It is worth nothing that the same impression depth values on the three levels suggest footprints that could be probably the effect of three diachronic trampling phase, even if they could be considered the same as underprints.

The best preserved sample (FIN 1) displays a small manus print that is longer (15.5 cm) than wide (14 cm), without digit traces. The oval-shaped pedal print is longer (64 cm) than broad (57 cm) and shows an asymmetric outline with the proximal portion narrow and deeper. The best-preserved pes impressions reveal two depressed areas separated by a rim perpendicular to the pes length. This rim establishes an anterior area where the feet pressed the ground in the last moment. This morphology is common in all the tracks.

4. DISCUSSION

From the Monte Zugna Fm. many middle to large-size sauropodomorph footprints and associated tracks were reported (Avanzini 1999; Leonardi & Mietto 2000; Avanzini *et al*. 2006). These are quadrupedal, narrow gauge tracks. The pedal prints are usually pyriform and deeper anteriorly. The man-

Fig. 2 - The trampled layer corresponds with a wall where layers present a very steep dip, in a hardly accessible area along the Adige Valley. In the inset A a close up view of the outcrop.
Fig. 2 - Lo strato con orme corrisponde ad una parete quasi verticale che si affaccia sulla Valle dell'Adige, situata in una zona di difficile accesso. Nel riquadro (A) è rappresentato un ingrandimento dell'affioramento.

ual prints, when preserved, are kidney-shaped, crescent-like or nearly horseshoe-like, with a marked notch in the posterior margin. All the tracks show a noticeable heteropody and were attributed to cfr. *Parabrontopodus* Lockley, Farlow and Meyer 1994 and to *Lavinipes* Avanzini, Leonardi and Mietto 2003 ichnogenera. *Lavinipes* has a narrow-gauge trackway. The most evident characteristic of the pedal footprints is their elongated shape with a longer digit III and a marked impression of the digit IV. The pendadactyl manual prints have a U-shaped morphology with apparently clawless digits. This ichnotaxon was classified as a basal Eusauropoda on the basis of the pentadactyl U-shaped manual prints and the quadrupedal narrow-gauged trackway. The here described footprint differs from *Lavinipes* in general outline and wider dimensions.

Gierliński (1997), Gierliński & Sawicki (1998), Gierliński & Pieńkowski (1999) reported a narrow-gauge sauropod trackway left by both adult and juvenile sauropods (?*Parabrontopodus* isp.), from the Early Jurassic (Hettangian) deposits of Central Poland, with crescent shaped manus prints, considerably smaller than the pes prints (with four claw marks), and similar in the general outline to those of the Monte Finonchio. In the tracks described by Gierliński (1997) and Gierliński & Pieńkowski (1999) a deep heel impression close to those of the FIN specimens is also preserved.

Avanzini (1999) and Avanzini *et al*. (2006) reported some large sauropod footprints from the same stratigraphic interval that crops out at Monte Finonchio. The prints are medium sized,

Fig. 3 - Leica ScanStation 2 laser scanner used for the acquisition of the data.
Fig. 3 - Il laser scanner Leica ScanStation 2 utilizzato per l'acquisizione dei dati metrici.

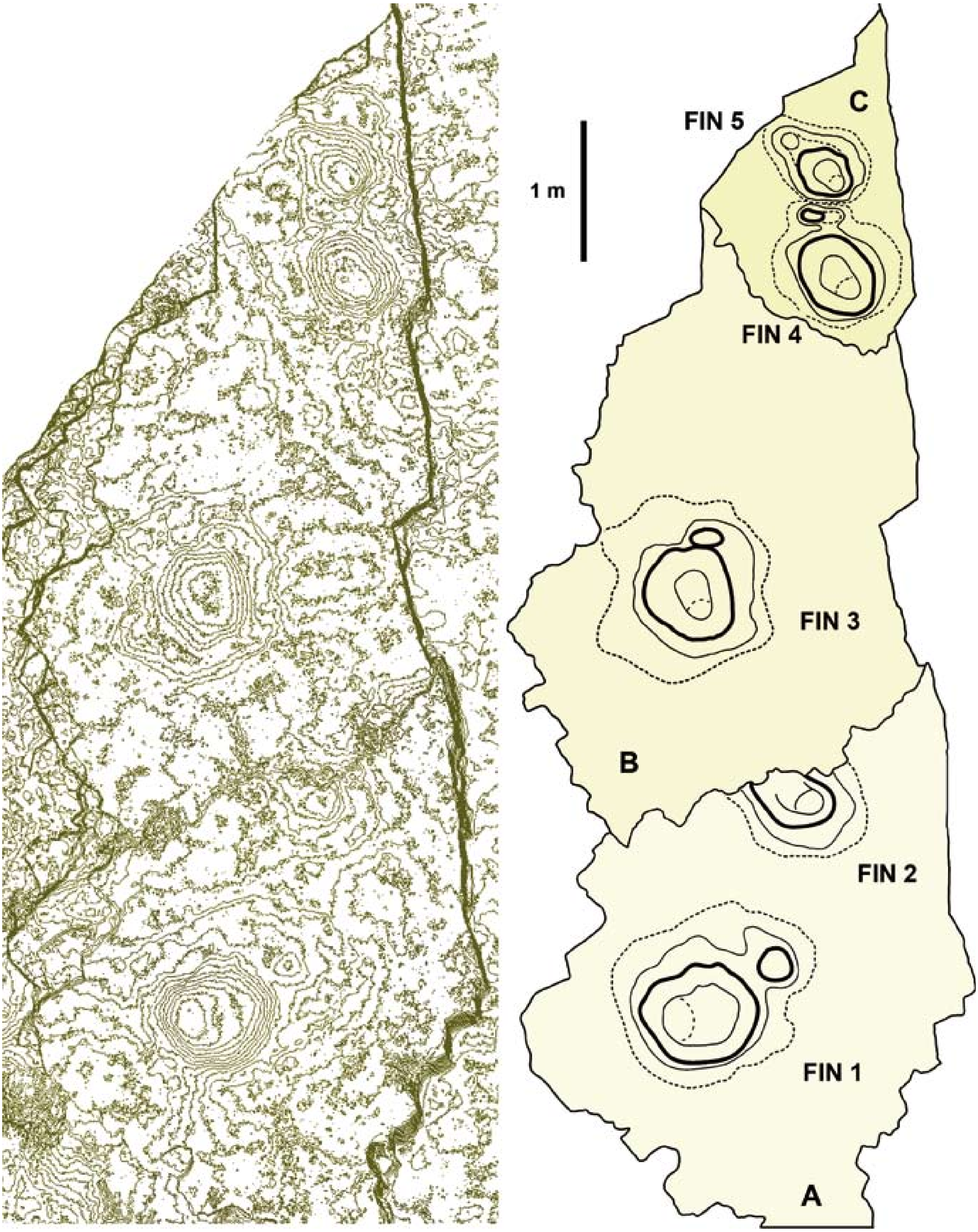

Fig. 4 - 3D contour map model and interpretative drawing of the trampled surface. A, B, C, indicate the tree superimposed layers.
Fig. 4 - Rilievo 3D e schema interpretativo della superficie con orme. A, B, C, indicano tre livelli stratigrafici sovrapposti.

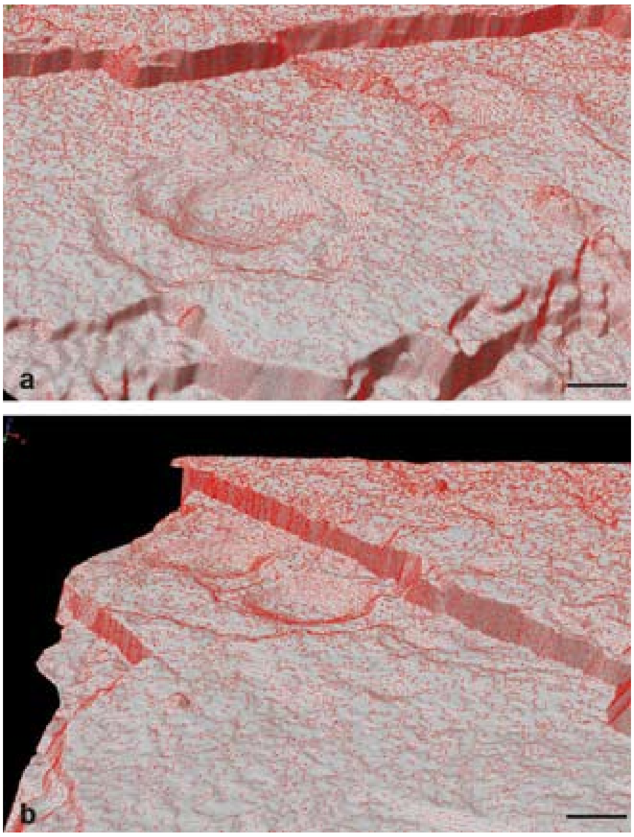

Fig. 5 - 3D contour map models of FIN 2, FIN3 (a) and FIN 4, FIN 5 (b) manus-pes couples. Scale bar 30 cm.
Fig. 5 - Modello 3D delle coppie mano-piede FIN 2, FIN3 (a) e FIN 4, FIN 5 (b). Scala 30 cm.

longer than wide, with a small and slightly impressed manus and were tentatively referred to the *Parabrontopodus* ichnogenus.

5. CONCLUSIONS

The discovered footprints, could be attributed to sauropodomorphs and correspond to the faunal characteristic pointed out for several sites of this tracklevel (Avanzini *et al*. 2006).

All the discovered early Sinemurian ichnosites belonging to the Calcari Grigi Group are dominated by sauropodomorphs and this predominance coincides both with a change in regional floras, as substantiated by palynomorphs, and with sedimentological data indicating an environmental shift from arid to humid conditions on the Trento Platform between the Hettangian and the Sinemurian (Avanzini *et al*. 2006).

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REFERENCES

Avanzini M., 1999 - Impronte di sauropodi nel Giurassico inferiore del Becco di Filadonna (Piattaforma di Trento – Italia settentrionale). *Studi Trent. Sci. Nat.*, *Acta Geol.*, 72 (1995): 193-198.

Avanzini M., Leonardi G., Tomasoni R. & Campolongo M., 2001 - Enigmatic dinosaur trackways from the Lower Jurassic (Pliensbachian) of the Sarca Valley, Northeast Italy. *Ichnos*, 8: 235-242.

Avanzini M., Leonardi G. & Mietto P., 2003 - *Lavinipes Cheminii* Ichnogen., Ichnosp. nov., A Possible Sauropodomorph Track from the Lower Jurassic of the Italian Alps. *Ichnos*, 10/2: 179-193

Avanzini M., Piubelli D., Mietto P., Roghi G., Romano R. & Masetti D., 2006 - Lower Jurassic (Hettangian-Sinemurian) Dinosaur Track Megasites, southern Alps, Northern Italy. In: Harris J.D., Kirkland J.I. & Milner A.R.C. (eds), The Triassic-Jurassic Terrestrial Transition. *New Mexico Mus. Nat. Hist. Sci. Bull.*, 37: 207-216.

Avanzini M., Petti F.M. & Tomasoni R., 2007a - A new Lower Jurassic (Sinemurian-Pliensbachian) dinosaur tracksite in the Central-Eastern Southern Alps (Dro, Trento, Italy): a preliminary report. Geoitalia 2007, VI Forum Italiano di Scienze della Terra. *Epitome*, 2: 304.

Avanzini M., Masetti D., Romano R., Podda F. & Ponton M., 2007b - Calcari Grigi. In: Cita Sironi M.B., Abbate E., Balini M., Conti M.A., Falorni P., Germani D., Groppelli G., Manetti P. & Petti F.M. (a cura di), *Carta Geologica d'Italia – 1:50.000, Catalogo delle Formazioni, Unità tradizionali.* APAT, Dipartimento Difesa del Suolo, Servizio Geologico d'Italia. *Quaderni serie III*, 7/Fascicolo VII: 125-135. *http://www.accordo-carg.it/nomi_tradizionali.html.*

Bosellini A. & Broglio Loriga C., 1971 - I "Calcari Grigi" di Rotzo (Giurassico inferiore, Altopiano di Asiago) e loro inquadramento nella paleo-geografia e nella evoluzione tettonico-sedimentaria delle Prealpi venete. *Annali dell'Università di Ferrara*, (N.S.), ser. 9, 5 (l): 1-61.

Gierliński G., 1997 - Sauropod tracks in the Early Jurassic of Poland. *Acta Palaeont. Pol.*, 42 (4): 533-538.

Gierliński G. & Sawicki G., 1998 - New sauropod tracks from the Lower Jurassic of Poland. *Geol. Quart.*, 42 (4): 477-480.

Gierliński G. & Pieńkowski G., 1999 - Dinosaur track assemblages from the Hettangian of Poland. *Geol. Quart.*, 43 (3): 329-346.

Haq B.U., Hardenbol J. & Vail P.R., 1987 - The chronology of fluctuating sea level since the Triassic. *Science*, 235 (4793): 1156-1167.

Hesselbo S.P. & Jenkyns H.C., 1998 - British Lower Jurassic sequence stratigraphy. In: de Graciansky P.C., Hardenbol J., Jacquin T., Farley M. & Vail P.R. (eds), "Mesozoic-Cenozoic Sequence Stratigraphy of European Basins". *Special Publication of the Society for Sedimentary Geology (SEPM)*, 60: 561-581.

Leonardi G. & Mietto P. (eds), 2000 - *Dinosauri in Italia: le orme giurassiche dei Lavini di Marco (Trentino) e gli altri resti fossili italiani.* Pisa, Accademia editoriale: 494 pp.

Lockley M.G., Farlow J.O. & Meyer C.A., 1994 - *Brontopodus* and *Parabrontopodus* ichnogen. nov. and the significance of wide- and narrow-gauge sauropod trackway. *Gaia*, 10: 135-145.

Masetti D., Claps M., Giacometti A., Lodi P. & Pignatti P., 1998

- I Calcari Grigi della Piattaforma di Trento (Lias inferiore e medio, Prealpi Venete). *Atti Ticin. Sci. Terra*, 40: 139-183.

Petti F.M., Avanzini M., Belvedere M., De Gasperi M., Ferretti P., Girardi S., Remondino F. & Tomasoni R., 2008 - Digital 3-D modelling of dinosaur footprints by photogrammetry and laser scanning techniques: first evaluation of the integrated approach at the Coste dell'Anglone tracksite (Lower Jurassic, Eastern Southern Alps, Northern Italy). This volume.

Remondino F., 2003 - From point cloud to surface: the modelling and visualization problem. In: Gruen A., Murai Sh., Niederoest J. & Remondino F. (eds), Proceedings of ISPRS International Workshop on Visualization and Animation of Reality-based 3D Models, 24-28 February 2003, Tarasp-Vulpera, Switzerland. *IAPRS*, XXXIV-5/W10, (CD-Rom).