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PRELIMINARY REPORT ON A NEW VERTEBRATE TRACK AND FLORA SITE FROM PIZ DA PERES (ANISIAN–ILLYRIAN): OLANG DOLOMITES, NORTHERN ITALY

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With 2 figures and 4 plates

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Abstract

This paper deals with the description of a large late Anisian (Illyrian) ichnosite with lens-shaped layers rich in fossil plants located between Olang (Valdaora) and San Vigilio di Marebbe (Pustertal – Val Badia) in the Northern Dolomites denominated Piz da Peres/Furklpass (Passo Furcia). A relatively large ichnoassociation, in which various ichnogenera can be recognized, comes from the siliciclastic Richthofen Conglomerate of Illyrian (Upper Anisian) age. Most of the footprints and trackways are, according to the preliminary studies, referable to *Rhynchosauroides* and probably pertain to lizard-like reptiles. Subordinately footprints of archosaurs are preserved. In particular, the ichnogenera *Isochirotherium* and various chirotheroid footprints have been recognized. Many tracks are at present unidentified. The site also yielded numerous fossil plant horizons and some scattered invertebrate tracks and remains. The richest and best preserved plants occur in the lower part of the Richthofen Conglomerate, although isolated plant-fragments can be found everywhere in the Morbiac Dark Limestone. A preliminary analysis allows the identification of a flora with representatives belonging to Sphenophyta, Pteridophyta, Pteridospermae and Cycadophyta. The conifer *Voltzia recubariensis* is largely dominant.

Zusammenfassung

Beschrieben werden neue Vorkommen von Tetrapodenfährten und Landpflanzen aus dem späten Anisium (Illyrium) vom Piz da Peres, in den nordöstlichen Dolomiten, zwischen Olang im Pustertal und dem Gadertaler Ort St. Vigil. Sie liegen im Niveau des Richthofen-Konglomerats und in der Morbiac-Formation. Die meisten Fährten und Eindruckformen lassen sich als *Rhynchosauroides* bestimmen. Die Erzeuger waren vermutlich eidechsenähnliche Tetrapoden. Ferner wurden vereinzelt Fuß- und Handeindrücke von Archosauriern gefunden, die möglicherweise zu Chirotherien gehören. Die Vorkommen von Landpflanzen sind meist an größere Linsen gebunden. Entsprechende Schichten sind selten mächtiger als 50 cm. Die fossilen Pflanzenreste können den Schachtelhalmen, Farnen, Samenfarnen, Cycadeen und Koniferen zugeordnet werden. Dabei dominieren die Koniferen, insbesondere die Art *Voltzia recubarensis* (De Zigno) Schenk 1868. Vereinzelt fanden sich Spuren von Invertebraten.

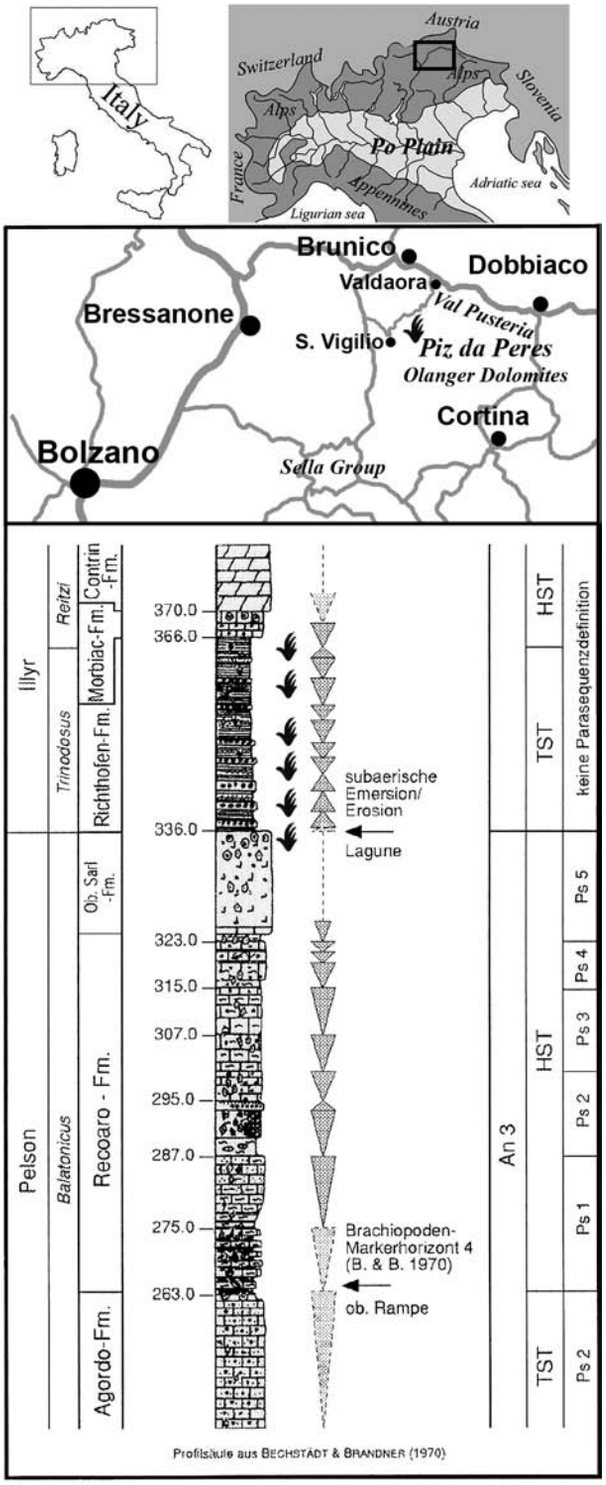

Fig. 1: Locality map showing the outcrop of Late Anisian sediments investigated and stratigraphic position of the fauna and flora described (from Zühlke, 2000, mod.).

1. Introduction

After the discovery of a new and rich plant and vertebrate deposit located on the northern slope of Kühwiesenkopf in 1999, the biodiversity of Anisian ecosystems of the Prags Dolomites and Piz da Peres sedimentary units has been studied by Tintori *et al.* (2001), Broglio Loriga *et al.* (2002), Renesto & Posenato (2003), Posenato *et al.* (2004), Kustatscher (2004), Kustatscher & Roghi (2006), Kustatscher *et al.* (2006), Lombardo *et al.* (2006), Van Konijnenburg–van Cittert *et al.* (2006) and Kustatscher *et al.* (2007).

In 2007, one of the authors (M.W.) discovered a new fossil site over the Furkl-Pass in the direction of Piz da Peres containing an interesting nearshore paleoecosystem with numerous tetrapod tracks, marine biota (jellyfish, bivalves etc.) and a rich flora. The strata belong to the Richthofen Conglomerate and Morbiac Dark Limestone (both Illyrian in age) *sensu* De Zanche *et. al.* (1992).

The discovery of vertebrate footprints in the Piz da Peres area is not a novelty. In the first decades of the 1900s, mostly during the First World War, the Austrian geologist Julius Pia discovered the first Triassic tetrapod footprints from the south-eastern Alps in the Olang Dolomites in upper Anisian sedimentary levels. The material was studied by Abel (1926), who established the new ichnospecies *Rhynchosauroides tirolicus* Abel 1926. Later Rainer Brandner described tracks from the same area and from the same levels (Bechstädt & Brandner 1970; Brandner, 1973). He identified several prints that were attributed to *Rhynchosauroides tirolicus* Abel 1926, *Chirotherium* cf. *C. rex* Peabody 1948 and *Brachychirotherium* aff. *B. parvum* Hitchcock 1858. The presence of footprints in the Anisian of the Prags Dolomites was also pointed out by De Zanche *et al.* (1992; 1993), but lacked an extensive survey as was made for the first time by the present authors in the summer of 2007.

In this paper we give a brief and preliminary description of a diverse and polymorphic ichnofauna coming from a sector of Piz da Peres very close to those of the first finds of Pia and Brandner (Fig. 1).

2. Geological Setting

The geology of the Prags Dolomites is well known since the work of Pia edited in 1937 (Stratigraphie und Tektonik der Pragser Dolomiten in Südtirol). The Anisian succession cropping out along the Prags and Olang Dolomites shows a mixed carbonate and terrigenous succession that

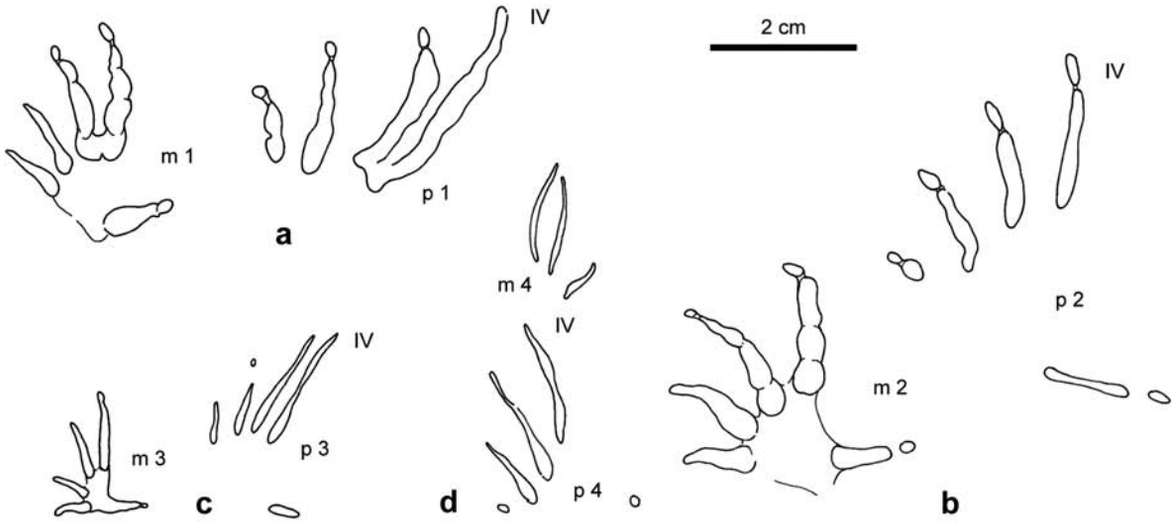

Fig. 2: *Rhynchosauroides* footprints types from Piz da Peres ichnosite (m: manus, p: pes).
a) *Rhynchosauroides tirolicus* Abel 1926; b) *Rhynchosauroides* sp. Morph. A (Valdiserri and Avanzini 2006); c) *Rhynchosauroides* sp. Morph. B; d) *Rhynchosauroides* sp. Morph. C.

overlies the top of the Early Anisian (Aegean) carbonates (Lower Serla Dolomite) and is overlain by the lower beds of the Late Anisian (Illyrian) carbonates (Contrin Formation) (see also Bechstädt & Brandner, 1970; De Zanche *et al.*, 1992).

The trampled layers are attributed to the Obere Peresschichten *sensu* Pia (1937) and Bechstadt & Brandner (1970) that are now called Richthofen Conglomerate (Avanzini *et al.*, 2007a) and Morbiac Dark Limestone (Delfrati & Farabegoli, 2000) in the official Italian stratigraphical nomenclature (both Illyrian in age) (Fig. 1).

The Richthofen Conglomerate is dominated by red sandstones and siltstones and subordinate conglomerate beds. This unit has been interpreted as having been deposited in a relatively arid fluvial or in a transitional continental to marine environment (De Zanche *et al.*, 1992; 1993; Avanzini *et al.*, 2007a). The Morbiac Dark Limestone prevalently consists of silty, decimetre-thick grey or light brown lime wackestones and packstones with foraminifers and ostracods. Stromatolitic bindstones and thin grey or green siltstone layers are interbedded. Plant debris is common. The depositional environment is referable to a marine marginal setting with lagoons and swamps contaminated by terrigenous input (Delfrati & Farabegoli, 2000).

3. Systematic ichnology

Due to outcrop situations, only isolated slabs were recovered during the preliminary work on the ichnosite. Most slabs show isolated footprints only. Trackways occur infrequently and are never longer than two or three manus-pes sets. Some slabs show footprints attributable to different ichnogenera. Footprints are generally well preserved, occasionally showing skin traces.

The described specimens are temporarily stored at the Museo Tridentino di Scienze Naturali at Trento (Italy) and will be housed at the Museum of Nature of South Tyrol at Bozen (Italy) after the studies will be finished.

The terminolgy concerning vertebrate palaeoichnology mainly follows Leonardi (1987). To avoid repetition in the systematics, authors and years of publication of the ichnotaxa will only be listed at the first mention.

Five main layers with trampled surfaces are documented from the Richthofen Conglomerate. Besides *Rhynchosauroides* footprints, the lowermost layer yielded at least some archosaur footprints (chirotheroid and *Isochirotherium* isp.) with different degrees of preservation. In the uppermost layers *Rhynchosauroides* isp. is largely repre-

sented, along with *Rhynchosauroides tirolicus* Abel 1926.

At the base of the Morbiac Dark Limestone a sixth layer containing abundant *Rhynchosauroides* isp. has been observed.

3.1. Ichnogenus *Rhynchosauroides* Maidwell 1911

A lizard-like trackway. Pace angulation of the pes varying from 70° to 125° depending on the speed of quadrupedal locomotion. Pes plantigrade to digitigrade, pentadactyl. Digits slender, increasing in length from I to IV, with the distal phalanges curved towards the midline. Digit V short. Manus similar to the pes, but smaller and plantigrade, partly overstepped by the pes. Most specimens have a distinct tail drag (diagnosis of the ichnogenus from Haubold, 1971b).

The ichnogenus *Rhynchosauroides* is the most abundant in the ichnofauna (Fig. 2, Plate 1, Figs 1–5). The presence of extramorphological variants related to the influence of different substrate and walking gait and the co-presence on the same surface of print and underprints was considered. However, the high preservation degree of the recovered material, permits to separate the whole footprints in at least four morphotypes that, pending further analysis, we describe as possible distinct ichnotaxa (Fig. 2).

Rhynchosauroides tirolicus Abel 1926 seems to be the predominant ichnotaxon (Fig. 2a; Plate 1, Figs 1, 3, 5). The pes (L 45-60 mm) is digitigrade with characteristic digit proportions IV>III>II>I. Digit I and V are rarely impressed. The manus (L 25–40 mm) is ectaxonic and semiplantigrade (L/W=1.25) about half the length of that of the foot. The divergence of the manus digit group I-IV varies from 34° at 90° with an average of about 60°. Digit proportions are IV≅III>II>I>V. Trackways show overstep of the manus by the pes. The pace angulation of the pes is 85°, of the manus 125° respectively. The pes is outwardly rotated with respect to the midline by 12°.

R. tirolicus is well known from several ichnosites of the Southern Alps (Brandner, 1973; Avanzini, 1999; Avanzini *et al*., 2001; Avanzini & Renesto, 2002) and other parts of Europe (Diedrich, 1998a, 1998b, 2001, 2002; Diedrich & Oosterink, 2000). The stratigraphic distribution is confined to the Anisian with dominance in the Illyrian.

Associated with *Rhynchosauroides tirolicus* is a form called *Rhynchosauroides* sp. Morph A by Valdiserri & Avanzini (2006), which is also common (Fig. 2b; Plate 1, Figs. 3, 4). In this footprint type, the pes is pentadactyl with digits I-IV slightly curved inwards at the distal edges. Digit V is rotated outwards and has an angle close to 90° with the digit IV. The length-to-width of the pes ratio is 1.25. The manus is pentadactyl and semiplantigrade, and occasionally (mostly on wet substrate) plantigrade. Digits are thin and strongly arcuate inward. The length-to-width ratio of the manus is equal to 1. The angle between digits I-IV is 70°, between I-V is 131°. Some footprints are well preserved and show skin impressions with rectangular scales outlined in two parallel lines on the digits and a mosaic of rounded scales close to each other on the palm. No trackways were recognised.

Similar footprints are reported by Valdiserri and Avanzini (2006) from another Anisian site of the Southern Alps. Valdiserri & Avanzini (2006) suggest that these footprints could either represent a new *Rhynchosauroides* ichnospecies or an intraspecific variation of *R. tirolicus* (i.e. sexual dimorphism).

A third Piz da Peres form (*Rhynchosauroides* sp. Morph B) shows a pentadactyl pes with long and thin digits. Digits III and IV are parallel with their base anteriorly located while the bases of digits I and II are posterior and proximally shifted.

The manus is semiplantigrade, similar to the pes and with slender and straight digits (Fig. 2c; Plate 1, Fig. 3). The manual digit IV shows the base lined up to digit III but is straight and definitely longer. The length-to-width ratio is 1.46. The angle between digits I-IV is 90°, between I-V is 180°.

The overall morphology of these footprints with digit IV longest confirms the attribution of these footprints to the ichnogenus *Rhynchosauroides*. Nevertheless, among the Triassic *Rhynchosauroides* ichnospecies none has similar manus and pes morphology. Further studies are in progress to point out more diagnostic patterns and to attribute this footprint to a new ichnospecies if necessary.

A fourth morphotype (*Rhynchosauroides* sp. Morph C) shows pes generally poorly preserved, mostly just as an incomplete impression of digits very similar to those of the manual prints. Digit V is represented only by a claw cast. Digits are long and thin, without ungual traces. The manus is penta-

dactyl (?) and digitigrade (Fig. 2d; Plate 1, Fig. 2). Digits are thin and elongate. Digits III and IV are slightly convergent, one toward the other. The prints are generally incomplete and lack one or more digits. The manus/pes set is apparently not overstepping.

The general pattern of footprints seems to suggest the attribution to the ichnogenus *Rhynchosauroides*, nevertheless at present the thin and slightly impressed footprints makes a correct classification difficult.

3. 2. Chirotheroid footprints

Among the ichnological material there are some incomplete, medium-sized footprints that can be attributed to the chirotheroid group (Haubold 1971a).

The scattered manual imprints are pentadactyl and digitigrade (Plate 1, Figs. 1, 2). Digits II, III and IV are better impressed than I and V; the last ones are also placed backward. The length of the manus imprints varies between 50 mm and 120 mm, and the width between 65 mm and 130 mm.

Two partially preserved pes imprints have been recovered on two different slabs. One contains just the short and stout digits II, III and IV. The second is part of an apparent manus pes set (Plate 2, Fig. 1). The pedal imprint is represented by two elongate digits (?II and III) with rounded claw impressions. The related manus shows three digits (II, III, IV) similar in shape to those of the pes. Although incomplete, this manus-pes imprints show well preserved skin impressions but an ichnologic classification is impossible.

3. 3. Ichnogenus *Isochirotherium* Haubold 1971b

Narrow, quadrupedal trackways. A small pentadactyl manus impression occurs regularly in front of a much larger pentadactyl pes which resembles a reversed human hand. Manus and pes are digitigrade.

Digit III is longest. Digit IV is shorter than I and often close to III. The phalangeal pad of digit V is aligned with the phalangeal-metatarsal pads of digits I-IV. The pace angulation is about 165°. Reptiles represented by these tracks are considered to be archosaurs (diagnosis from Haubold, 1971b).

Some of the well preserved archosaurian tracks of the ichnocoenosis are assigned to *Isochirotherium delicatum* Courel and Demathieu 1976 (Plate 2, Figs 2, 3).

The footprints are longer than wide, with an average length to width ratio (L/W) of about 2.4. Digit impressions II and III are almost equal in length, and definitely the longest (Plate 2, Fig. 3). The digit I impression is very small and thin, and parallel to digit II, from which it is almost indistinguishable. The impression of digit IV is shorter than I and separate from III. Digit V is characterised by the presence of a large metatarsal-phalangeal pad impression. The claw impressions of digits II and III are robust and triangular, those of fingers I and IV are thinner and arched. The manus imprints are very small (about 1/5 of the length of the footprints) with short, small and variable digit traces.

This form was identified for the first time at the Anisian-Ladinian boundary (Courel & Demathieu, 1976). *Isochirotherium delicatum* is also well documented in the Anisian beds of the Southern Alps. A relatively well preserved ichnoassociation of Pelsonian age was recognised some years ago along the Adige Valley (Avanzini & Lockley, 2002) and scattered footprints of Illyrian age have been recently discovered in the Eastern Dolomites (Avanzini *et al.*, 2007b).

4. The macroflora

The lower part of the Richthofen Conglomerate, a few centimetres above the lower boundary with the Upper Serla Dolomite, is rich in plant fossils. The plants are concentrated in some centimetre-thick lenses of grey to yellow fine siltstone, marly and carbonate siltstone. Marine biota are present, especially swamp-adapted bivalves and some rare gastropods. The plant horizon can be traced over several hundred metres and is dominated by the conifer *Voltzia recubariensis* (De Zigno 1862) Schenk 1868 and associated with ferns, cycads, seed ferns and horsetails. Above this plant horizon a root horizon has been found, followed by typical strata containing *Rhynchosauroides* and ripple-marks.

After a first analysis, the fossil plants belong to the following divisions: Sphenophyta, Pteridophyta, Pteridospermae, Cycadophyta and Coniferophyta.

The Sphenophytes are documented by some *Equisetites*-stems (Plate 3, Fig.1) with typical nodes and microphylls. These stems could belong to *Equisetites mougeotii* (Brongniart) Wills 1910, already described from the nearby fossiliferous locality Kühwiesenkopf (Kustatscher *et. al*., 2007).

The Pteridophytes contain at least five different genera: *Anomopteris* Brongniart 1828, *Neuropteridium* Schimper 1879, *Scolopendrites* Goeppert 1836, *Cladophlebis* Brongniart 1849 *and Gordonopteris* Van Konijnenburg-Van Cittert *et al.* 2006. The genus *Neuropteridium* is present with two species: *Neuropteridium elegans* (Brongniart 1828) Schimper 1879 and *Neuropteridium voltzii* (Brongniart) Schimper 1879 (Plate 3, Fig. 2). These ferns, characterised by a neuropterid venation with a clear midrib and secondary veins forking up to three times, are typical of the Anisian macroflora of the Dolomites (Kustatscher, 2004; Kustatscher *et al*., 2003; Van Konijnenburg-Van Cittert *et al.,* 2006) and the German Basin (e.g. Grauvogel-Stamm, 1978), just like their fertile fronds attributed to the genus *Scolopendrites* (Plate 3, Fig. 2). *Anomopteris mougeotii* Brogniart 1828 is composed of bipinnate fronds with a broad rachis and long linear pinnae. The pinnules are perpendicularly attached to the pinna rachis. Also typical is the presence of an aphlebia at the base of each pinna (Plate 3, Fig. 4). The fragments of *Cladophlebis leuthardtii* show small, falcate pinnules (2–3 mm), however the venation is invisible (Plate 3 fig. 3). Frond fragments of *Gordonopteris lorigae* Van Konijnenburg-Van Cittert *et al.* 2006 show small, rounded pinnules with a short midrib and forking secondary veins, attached with their whole base to the axis. This genus is typical of the Anisian of the Dolomites (Van Konijnenburg-Van Cittert *et al.,* 2006).

Various ovuliferous organs of *Peltaspermum bornemannii* Kustatscher *et al.* 2007 belong to the Pteridospermae, consisting of umbrella-shaped discs. They are surprisingly well preserved (Plate 4, Fig. 1). Also, some of the foliage belonging to those ovuliferous organs is present: *Scytophyllum bergeri* Bornemann 1856.

Cycadophyta are common in the Dolomites from the Anisian to the Ladinian (Kustatscher, 2004), and also in the studied locality. Various leaf fragments belong perhaps to *Bjuvia dolomitica* Wachtler and Van Konijnenburg-Van Cittert 2000 (Plate 3, Fig. 5) and to *Taeniopteris* sp. Important were the findings of both upper sterile and basal fertile fragments of some megasporophylls belonging to the genus *Dioonitocarpidum* Rühle von Lilienstern 1828 (Plate 4, Figs 2-3). Till now we cannot assign these macrosporophylls to any cycad leaf genus.

The Coniferophyta, especially *Voltzia recubariensis* (De Zigno 1862) Schenk 1868, are the most common taxa in these strata. *Voltzia recubariensis* consists of characteristic branches with spirally arranged falcate leaves with a more or less acute apex. (Plate 4, Figs 4-6).

5. Conclusions

The footprints recovered at Piz da Peres represent a typical Middle Triassic ichnofauna (Demathieu & Haubold, 1972, 1974; Haubold, 1984) characterized by an Archosauria-Lepidosauria association, which lived on a tidal flat influenced by continental sedimentation.

The flora is interesting as well as it is slightly younger than the one described from Kühwiesenkopf (for references see introduction) but is also still older than the Ladinian floras from the Dolomites. Therefore it fills a gap in the record of the distribution of the floras in time and space.

The greatest importance of this site is, however, the outstanding association of plants and well preserved tracks of a number of primitive tetrapods and other animals such as worms, and jellyfishes, essential to study the biological explosion after the big Permo-Triassic crisis.

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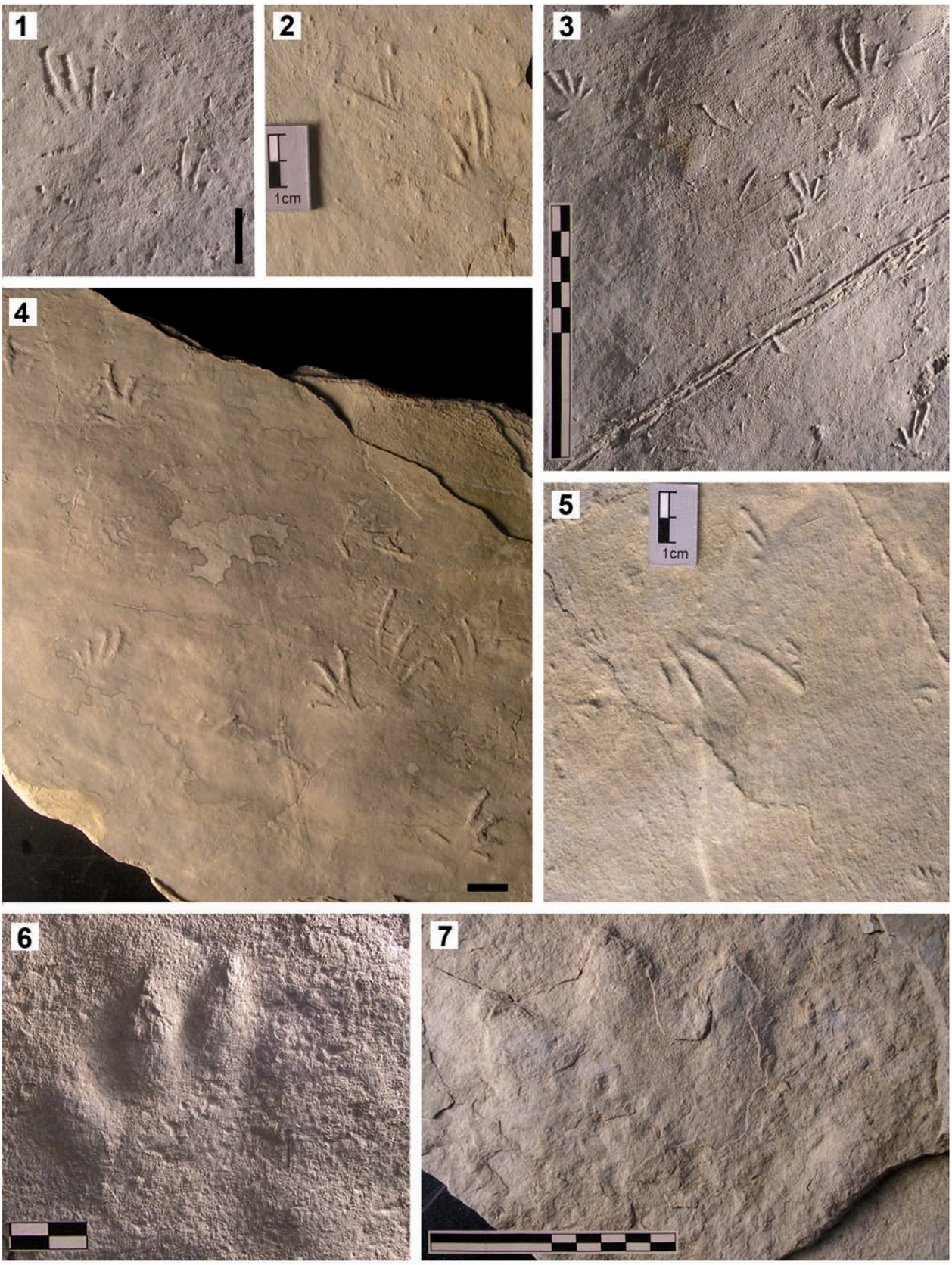
Plate 1

Fig. 1 *Rhynchosauroides tirolicus* Abel 1926, manus imprint with skin impressions, scale bar: 1cm.
Fig. 2 *Rhynchosauroides* sp. Morph. C, manus-pes set, Scale bar: 1cm.
Fig. 3 Slab with several manus and pes imprints of *Rhynchosauroides tirolicus* Abel 1926, *R.* sp. Morphotype A and *R.* sp. Morphotype B imprints, scale bar: 10 cm.
Fig 4 *Rhynchosauroides* sp. Morph A trackway, scale bar: 1cm.
Fig 5 *Rhynchosauroides tirolicus* Abel 1926, pes imprint with associated very small *Rhynchosauroides* sp. manus and pes imprints (immature?). scale bar: 1cm.
Fig. 6 Chirotheroid manus imprint, scale bar: 2 cm.
Fig. 7 Chirotheroid manus imprint, scale bar: 10 cm.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2
1cm
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4
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1cm
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7

Plate 2

Fig. 1 Chirotheroid manus-pes set with well preserved skin traces, scale bar: 5 cm.

Fig. 2 *Isochirotherium delicatum* Courel and Demathieu 1976, poorly preserved manus-pes set of a robust form, scale bar: 5 cm.

Fig. 3 *Isochirotherium delicatum* Courel and Demathieu 1976, well preserved pedal imprint of a slender form with typical skin texture, scale bar: 2 cm.

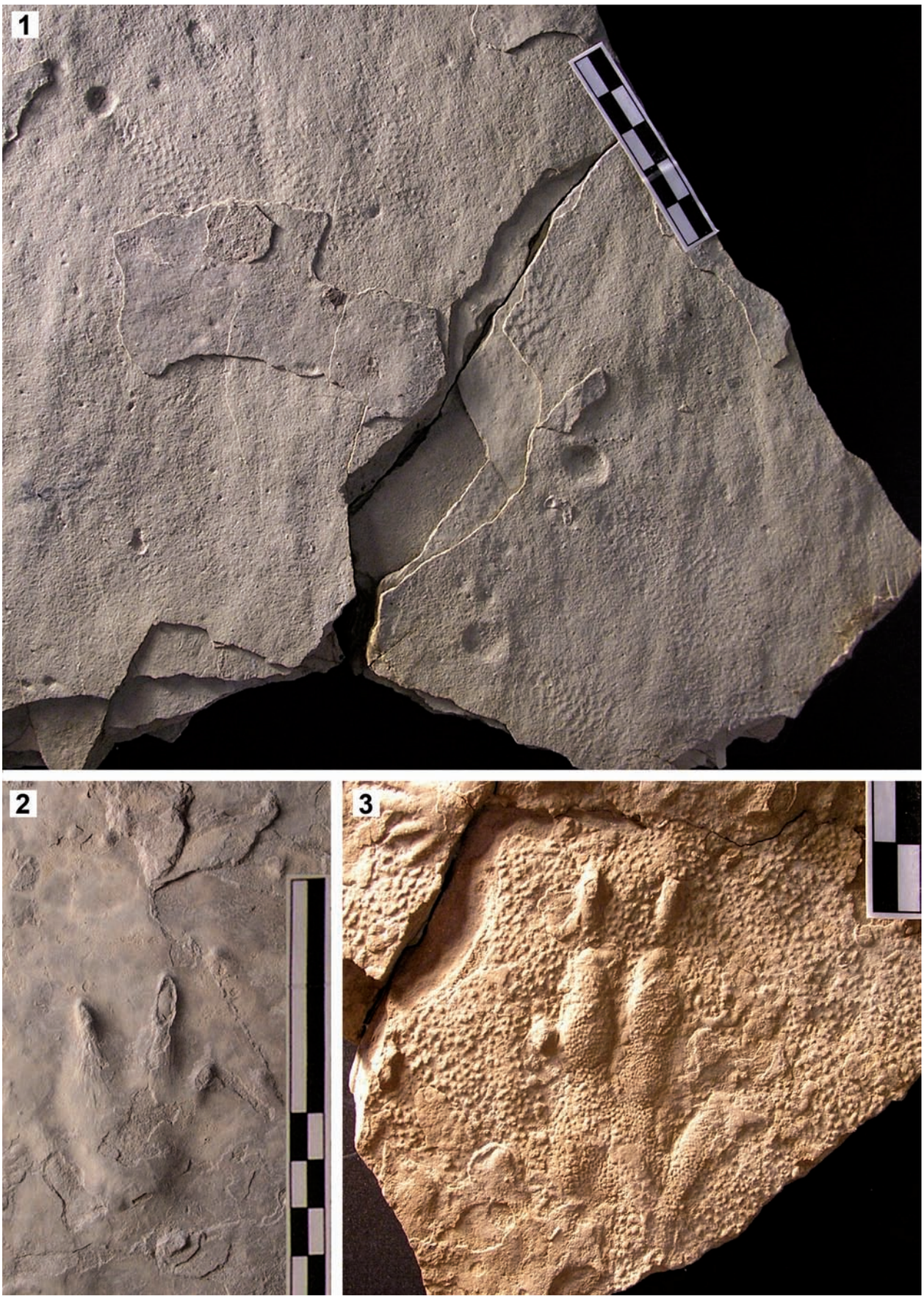
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Plate 3

Fig. 1 Stem fragment of *Equisetites sp.* (PIZF 14), x 1,
Fig. 2 Frond fragment of *Scolopendrites* sp. (PIZF 47), x 1.5.
Fig. 3 Frond fragment of *Neuropteridium voltzii* (Brongniart) Schimper 1879 (PIZF 54), x 1.5.
Fig. 4 Putative aphlebia from *Anomopteris mougeotii* Brongniart 1828 (PIZF 7), x 2.
Fig. 5 Leaf fragment of *Bjuvia dolomitica* Wachtler and Van Konijnenburg-Van Cittert 2000 (PIZF 24), x 1.

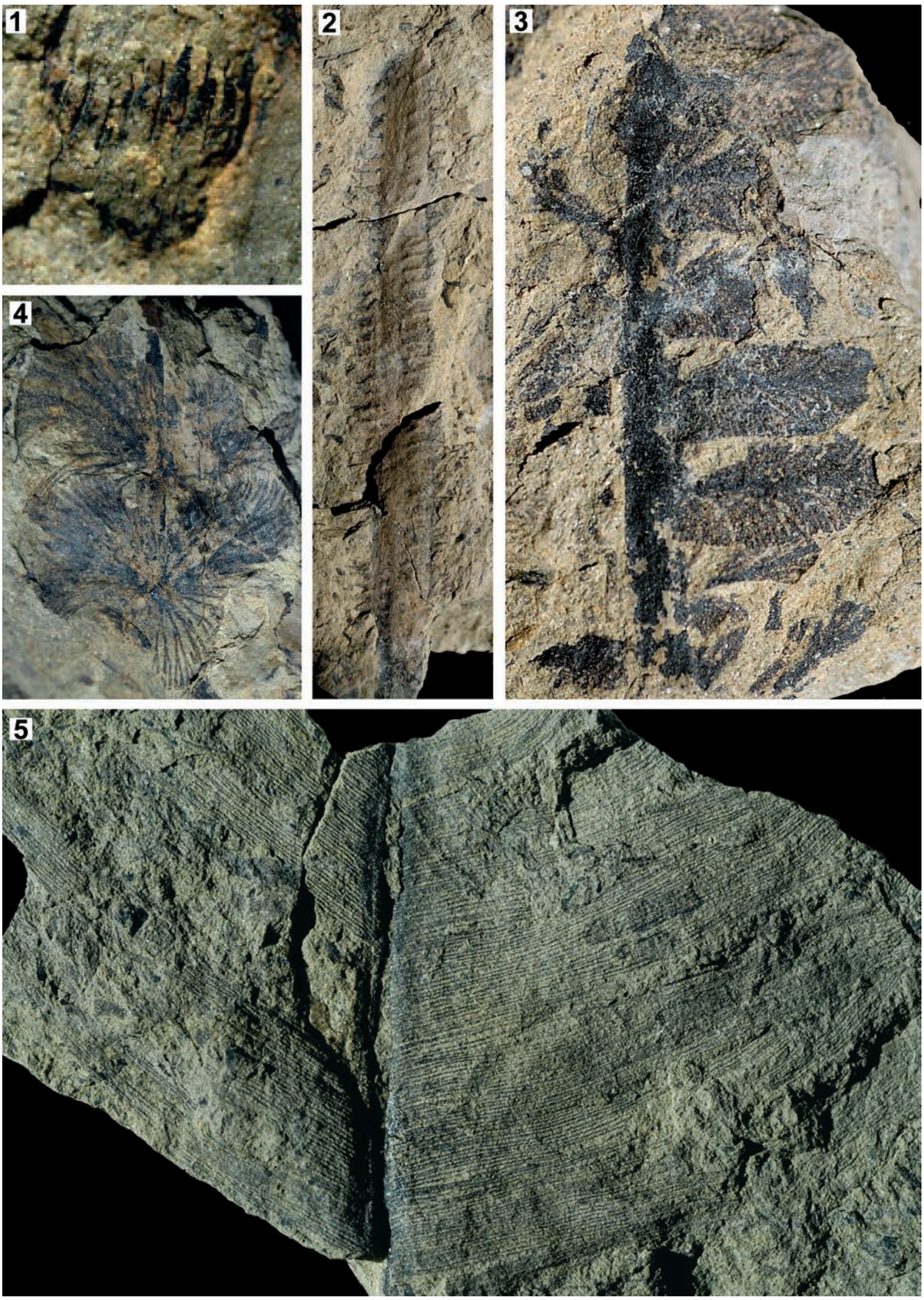
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Plate 4

Fig. 1 *Peltaspermum bornemannii* Kustatscher *et al.* 2007 (PIZF 8), x 4.
Fig. 2 Upper partly pinnate fragment of *Dioonitocarpidum* sp. (PIZF 18), x 2.5.
Fig. 3 Lower, fertile fragment of *Dioonitocarpidum* sp. (PIZF 6), x 2.5.
Fig. 4 Ovuliferous bract of *Voltzia recubariensis* (De Zigno) Schenk 1868 (PIZF 3), x 2.
Fig. 5 Shoot of *Voltzia recubariensis* (De Zigno) Schenk 1868 (PIZF 53), x 1.5.
Fig. 6 Shoot of *Voltzia recubariensis* (De Zigno) Schenk 1868 with attached male cone (PIZF 45), x 1.


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