THE PALYNOLOGY AND PALEAEONVIRONMENT
OF THE UPPER TRIASSIC DOLOMITIC-MARLY SEQUENCE OF DOGNA VALLEY
(UDINE, FRIULI-VENEZIA GIULIA, NE ITALY)
WITH REPTILE TRACKWAYS

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Key-words: biostratigraphy, Upper Triassic, Carnian, Tuvalian, Julian Alps, Southern Alps, palynology, vertebrate tracks, palaeoenvironment.

Riassunto. Vengono riportati nuovi dati e considerazioni sulla biostratigrafia e il paleoambiente di una sezione stratigrafica costituita da alternanze dolomitiche-marnose del Triassico superiore affioranti nella Val Dogna (Udine, Friuli, NE Italy). In particolare è stato investigate un intervallo con uno strato contenente piste di rettili arcosauromorfi terrestri. Nel livello soprastante, quello che direttamente ricopre le impronte, è stata rinvenuta una abbondante associazione palinologica tuvalica (Carnic superiore) con Enzonalasporites vigens; Vallasporites ignaci; Patinaasporites densus, Zonalasporites cinxius, Pseudozonalarasporites summius, Samaropolinocites spectabilis, Camerosporites secatus; Partisporites spp. Evidenze floristiche e sedimentologiche indicano un clima arido e un ambiente di deposizione costiero soggetto a ripetute emersioni.

Abstract. New data and considerations about the biostratigraphy and the palaeoenvironment of a section in the Late Triassic dolomitic-marly sequence cropping out in the lower Dogna valley (Udine, Friuli, NE Italy) are reported. In particular a unit with a surface bearing tracks of archosauromorph terrestrial reptiles has been investigated. In the layer immediately overlying the track-bearing one, a rich palynological assemblage with Enzonalasporites vigens; Vallasporites ignaci; Patinaasporites densus, Zonalasporites cinxius, Pseudozonalarasporites summius, Samaropolinocites spectabilis, Camerosporites secatus; Partisporites spp. was found, indicating a Tuvalian age (Late Carnian). Microlfloral and sedimentological evidence indicate a dry climate and a coastal depositional environment subject to repeated emersions.

Introduction.

The Canale di Dogna (Dogna Channel), usually reported as "Val Dogna" (Dogna Valley), is an E-W oriented incision in the Julian Alps and is run through by the Dogna creek, near the village of Dogna, Udine Province (Fig. 1). Ladinian dolostones (Dolomia dello Sciliar), some poorly known units of Carnian age, and the Dolomia Principale (Hauptdolomit of German authors) outcrop in the Dogna valley (Selli, 1963; Jadoul et al., 1995). The discovery of reptile tracks in the dolomitic-marly sequence cropping out in the lower Dogna valley (Dalla Vecchia, 1996a, b) created new interest in this lithostratigraphic unit. The present note concerns the stratigraphy, in particular the biostratigraphy, and the palaeoenvironment of the section containing the footprints.

G. Roghi contributed the palynological work and F.M. Dalla Vecchia the palaeoichnological study; other parts of the account were written jointly.

Stratigraphy and sedimentology.

The well bedded alternations of black marls and grey and dark grey dolostones cropping out along the lower Dogna valley were attributed to the Monticello formation by Jadoul et al. (1995). They are considered laterally equivalent or even coinciding with the Carnizzia Formation (Jadoul et al., 1995, fig. 2) which crops out at the nearby Valbruna and Cave del Predil (former-ly Raibl) localities. These alternating beds appear to lie below the Dolomia Principale, but this is difficult to confirm because of the steep morphology of the valley. No biostratigraphical and palaeoenviromental data have been published about this formation in the Dogna valley.

The Monticello formation is well exposed along the Dogna valley downstream from the aqueduct intake situated to the east of the small village of Chiuso di Puppe. Near the second waterfall downstream from the intake the following succession is exposed (from the top downwards; Fig. 2A):

1) well bedded grey dolostones with black marls in tabular, centimetric-decimetric layers (about 70 m); in the lower part of this unit the pelitic intercalations are more frequent and there is often evidence of mud-cracking on the upper and lower surfaces
of the dolomitic layers; in the study area in the Dogna valley the sequence ends at a prominent ledge which may be related to a change in lithology; 

2) grey dolostones in banks with faint and irregular joints possibly representing the "orizzonte di Mestrì" (Giannolla, pers. comm.; see Jadoul et al., 1995) (about 20-25 m); in the upper part in a passage to the overhanging unit (3) there is a 1-3 cm-thick greenish dolostone;

1) some metres of well bedded, tabular, centimetric-decimetric alternations of grey dolostones and black marls, the lower limit of which we have not verified because unimportant for the scope of this paper.

The reptile tracks occur in the middle part of unit 3 (Fig. 2A), in the valley floor on the north side of Dogna valley, upstream from the intake of the aqueduct. The beds dip about 30° SSW. The section containing the tracks is shown in fig. 2B. At the base of the section there is a breccia layer (DGA98) with millimetric clasts, followed by two layers of marly-dolomitic mudstone (DGA99-100). The track-bearing layer (DGA100) is a disturbed mudstone with spots of wackestone at the top and deep mud-crack fissures; microfossils are completely absent. The track-bearing layer is overlain by black silty marls (DGA101) which were sampled for palynomorphs. Above this level there is a mainly marly unit with thin intercalations of sterile, black dolomitic mudstones (DGA102-103). The upper part of the section comprises beds of fine grained dolostone, sometimes separated by very thin intervals of black silty marls; structures indicating subaerial exposure (fenestrae with vadose silt) are common at this level. Ostracods are the most frequent microfossils (DGA104, 107, 108 and 110) foraminifers (Autothorita, Nodosariidae) are less common (DGA104, 105 and 110).

The depositional environment could be a restricted lagoon, represented by beds with only ostracods, sometimes more open (DGA110), which passed to a tidal flat represented by beds with fenestrae, fine grain dolomitization due to strong evaporation, perhaps stromatolitic lamination (DGA104) and with long lasting supratidal exposure represented by vadose silts. This environment was involved in the repeated arrival of pelitic sediment which was probably deposited in a reducing environment, indicated by a black colour and the presence of well preserved palynomorphs. The lack of marine fossils in the carbonate layers of the lower part of the section, where black marls are prevalent, could suggest a brackish or even fresh water environment. The frequent subaerial exposures, even in the layer with a more marked marine influence (DGA110) are noteworthy. They testify to the oscillating emergence of the zone and are in agreement with the presence of terrestrial reptiles. The Monticello formation is considered to represent deposition on the inner platform (Jadoul et al., 1995) and the existence of an emergent area to the S and SW of the
Dogna valley during the deposition of the Carnizza Formation was suggested by the same workers (ibidem, p. 87).

Vertebrate Paleontology.

The reptile trackways were described by Dalla Vecchia (1996a, b). There are at least four trackways and two of them are 2.40 m and 2.80 m long. They were produced by a quadrupedal plantigrade reptile, with a pentadactyl pes 17-20 cm long and a tetradactyl or, most probably, pentadactyl manus at least 50% smaller than the pes (Fig. 3A,B; see also Dalla Vecchia, 1996b, fig. 3-5). The free portions of the toes are rather short, narrow and sharply pointed. Digit V is short, thin, placed rather posteriorly and is not laterally oriented but is curved forward; digits I-IV have similar lengths but digit III is the longest and I the shortest (Fig. 3A,B; see also Dalla Vecchia, 1996b, fig. 3-5). In the best preserved trackway the pace is 43-47 cm, the stride 67-72 cm and the width about 30 cm; the pace angulation of pedes is about 100°. Tracks not strongly outwardly directed, no evidence of feet dragging and absence of tracks of the tail, of the chest and of the belly indicate a relatively erect posture and a non-sprawling gait. Therefore the trackmaker was well adapted to locomotion on land. The relation between tracks and mud cracks (Dalla Vecchia, 1996b) shows that these reptiles walked across a surface on which mud was drying or had just dried (see Thulborn, 1990, fig. 5.19).

Another bed surface with mud-cracks and probable reptile tracks occurs in the creek bed, between the intake of the aqueduct and the first waterfall downstream (R. Azzola, pers. comm.). Unfortunately this bed, which is at a stratigraphically lower level, is at present covered by debris.

Track morphology and, to some extent, the parameters of the trackways are reminiscent of those of the crocodiles (see Dalla Vecchia, 1996b, fig. 8) and suggest a phytosaur or primitive crocodylomorph affinity (Dalla Vecchia, 1996b).
The tracks do not correspond exactly to any described ichnotaxon (Haubold, 1971, 1984, 1986; Olsen & Padian, 1986). Their formal description and the institution of a new ichnotaxon is beyond the scope of this paper and will be made elsewhere (Dalla Vecchia, in progress).

Crocodylomorphs are known from Upper Carnian deposits but are relatively small, delicate reptiles represented by poor remains (Long & Murry, 1995). Primitive crocodylomorphs of the Late Triassic and Early Jurassic were small, cursorial animals. It is unlikely that the earliest crocodylomorphs were larger than the succeeding Late Triassic and Early Jurassic forms and had a body shape and posture more similar to that of present crocodiles. The pes of primitive crocodylomorphs is functionally tetradactyl, with digit V reduced to a metatarsal spur (see Dalla Vecchia, 1996b, fig. 7). The position of digit V in the pes tracks from Dogna could be in agreement with its position in the primitive crocodylomorphs but this digit is more strongly developed in those tracks.

Phytosaurs were typical Late Triassic reptiles, with a distribution ranging from the Middle Carnian in North Carolina to the Rhaetian in Switzerland, Germany, New Jersey and Connecticut; maximum diversity was reached during the Late Carnian (Tuvalian) (Benton, 1995). Even if the general shape of the pes print is similar to the reconstruction of a phytosaur footprint (Parrish, 1986, fig. 4.9A), the pedal skeletons of Parasuchus Lydkeker, 1885 and Rastiodon tenius Camp, 1930 (see Parrish, 1986, fig. 4.4) and Pseudopalatus pristinus Mehl, 1928 (Long & Murry, 1995, figs 53, 55) do not correspond exactly to the footprints from Dogna valley, mainly in respect of the position and shape of digit V.
(Fig. 3; cf. Dalla Vecchia, 1996b, fig. 3). Therefore, comparison should be made with a phytosaur with a digit V characteristically placed very posteriorly and such a phytosaur is not known amongst the available skeletal remains.

A third possible trackmaker considered by Dalla Vecchia (1996b) is an aetosaur. Aetosaurs were typical terrestrial quadrupedal plant-eaters of Carnian to Norian times. The oldest remains are from the Middle Carnian of North America, the youngest are from the "Rhaetian" of Argentina and England, with a higher diversity during Late Carnian-Early Norian (Benton, 1995, Long & Murry, 1995; Lucas & Heckert, 1996). Large aetosaurs are usually reconstructed as plantigrade and have a short and rather posteriorly placed digit V of the pes, with a curved metatarsal V. Stagonolepis Agassiz, 1844 and Paratypotonax. Long & Ballew, 1985 are Late Carnian aetosaurs with a size comparable to that of the trackmaker of Dogna tracks (Long & Murry, 1995).

The rauisuchians are excluded as the potential trackmaker because of the different parameters of their trackways.

The possibility remains that the trackmaker was an unknown taxon.

Trackmaker length on the base of the body proportions of the well-known phytosaur Parasuchus, can be roughly estimated as slightly less than 3 m. On the basis of the reconstruction of the aetosaur Stagonolepis the length was about 2.5 m.

The morphological peculiarity of the tracks may make them useful for the biostratigraphic correlation of non-marine units (Haubold, 1986) and for correlation of the Monticello formation with non-marine formations.

Palynology.

The black silty marls (DGA 101; Fig. 2B) just above the track-bearing surface were sampled for palynological investigation. A rich and very well preserved miospore association was found. Seventeen taxa have been identified and a quantitative analysis on more than 200 isolated grains was made. In the sample, the miospore are organized in single grains (85%) and in tetrads (15%). Treatment of the monosaccate group follows that adopted by Scheuring (1970; 1978) and Brugman (1983) and the specimens found are in agreement with the descriptions of these authors. Some problems exist in the taxonomy of the bisaccate group. The descriptions of Van der Eem (1983) and Brugman (1983) have been used for the identification of the circumpoles; taxonomy is problematic when the grains are organized in tetrads.

A detailed taxonomic treatment will be given in an account of the palynological study of the whole section.

The results of the quantitative analysis are as follows:

<table>
<thead>
<tr>
<th>Type of Pollen</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumpollen</td>
<td>56%</td>
</tr>
<tr>
<td>Unidentified bisaccate pollen</td>
<td>27%</td>
</tr>
<tr>
<td>Monosaccate and bisaccate pollen</td>
<td>8%</td>
</tr>
<tr>
<td>Alete bisaccate pollen</td>
<td>7%</td>
</tr>
<tr>
<td>Ovalipollis group</td>
<td>1%</td>
</tr>
<tr>
<td>Tetrates bisaccate pollen</td>
<td>0.5%</td>
</tr>
<tr>
<td>Trilete spores</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

The following taxa have been recognised (the recognised taxa are listed in Fig. 1 and the most significative miospore are illustrated in Plate 1):

**Monosaccate:**
- *Enzonalasporites vigens* Leschik, 1956 (Pl. 1, fig. 1)
- *Vallaspores ignaci* Leschik, 1956 (Pl. 1, fig. 2-3)
- *Patinasporites densus* Leschik, 1956 Scheuring, 1970 (Pl. 1, fig. 6)
- *Zonalarispites cinctus* Leschik, 1956
- *Pseudoenzonalasporites summus* Scheuring, 1970 (Pl. 1, fig. 4-5)

**Bisaccate:**
- *Samaropolenites speciosus* Goubin, 1965 (Pl. 1, fig. 9)
- *Ovalipollis pseudolatus* (Thiergart, 1949) Schuurman, 1976 (Pl. 1, fig. 7)
- *Chordasporites ssp.*
- *Lueckisporites ssp.*
- *Lanaspores acatus* Leschik, 1956
- *Klausipollenites ssp.*
- *Alepsetasporites / Enzonalasporites ssp.*

**Circumpolen:**
- *Camrerasporites secatus* Leschik, 1956 (Pl. 1, fig. 12)
- *Paritispores malliuwinae* (Klaus, 1960) Van der Eem, 1983 (Pl. 1, fig. 11)
- *Paritispores nonimundanus* Leschik, 1956
- *Paritispores quadruplicis* (Scheuring, 1970) Van der Eem, 1983
- *Corollina aff. sp. A (ovisn Schuurman, 1977) (Pl. 1, fig. 10)

The combined occurrences of *Enzonalasporites vigens*, Vallaspores ignaci, Patinasporites densus, Pseudoen- zonalasporites summus, Samaropolenites speciosus and Camrerasporites secatus are indicative of Tuvalian age (Late Carnian).

This palynoflora is nearly identical to that described by Visscher & Krystyn (1978) in the Carnian-Norian transition sequence of Monte Triona, Sicily, corresponding to the boundary between the ammonoid Trorites subsullatus and Anatropites bereichei Zones (Krystyn, 1974, Tuvalian 2-3 boundary). A microfloral association containing all the taxa found in sample DGA 101 was described from a Carnian evaporite succession in Albania (Girilli & Montanari, 1994) at a stratigraphic level attributed to the Tuvalian. The same taxa are found from Litwin & Ash (1993) in the Chattam Group, Deep River Basin (North Carolina, USA), and are, with the exception of *Samaropolenites speciosus* (Dunay & Fisher, 1974), present in the Chinle Formation and Dockum Group (SW USA). Fisher & Dunay (1984) reported the presence of *Samaropolenites conicus*, a form similar to *S. speciosus*, in a microflora from the Blue Mesa of Arizona, which contains all the taxa found in sample DGA 101.
Dunay & Fischer (1978) reported a microflora with Camerosporites secatus, Enzonalsporites vigens, Patina-
sporites densus, Vallaspores ignaci and Brodispora
striata (Pseudoenzonalsporites summissus and Samaron-
oplemites speciosus are not present) in levels of the Oppe-
nizeter-Kalk (Austria) of Tuvalian age (Tropites subbul-
dula Zone). Following these authors, Brodispora striata
has a particular biostratigraphic significance since it was
found with the above mentioned association only in the
Late Carnian Arden Sandstone of England (Clarke,
1965; Fisher, 1972; Warrington, 1970) and in some loca-
lities of the Chine Formation and Dockum Group of
SW USA (Dunay & Fisher, 1974; 1979; Fisher and Dun-
ay, 1984). However, Brodispora striata was not found
in the Late Carnian microfloral assemblages of the South-
ern Alps (this work), Sicily (Visscher & Krystyn,
1978) and Albania (Cirilli & Montanari, 1994). There-
fore the presence of Brodispora striata could be attri-
buted to palaeogeographical causes.

In sample DGA101 a form very similar to Corollina
sp. A, sensu Schuermann 1977 and Van Erve 1977
(- Circulina sp. A) has also been recorded as cf. Corollina
aff. sp. A. The specimens are organized in tetrads, have a
subequatorial circular furrow, a smooth sexine and faint
equatorial infrastrutture; a distal pseudopore is absent,
or is ill-defined (Pl. 1, fig. 10).

Palaeogeography and Palaeoenvironment.

The palynological assemblage reported here shows a
noteworthy likeness with the Onslow Microflora
(Dolby & Balme, 1976). The latter is a mixed associa-
tion with elements belonging to the Gondwana and to
the Laurasia continents and is different to the high lati-
tude boreal and austral microfloral associations. All the
taxa found in sample DGA101 are present in the On-
slow Microflora but in different proportions. Bisaccate
pollen such as Sulcatisporites are prevalent in the On-
slow Microflora, while circumpolles are most abundant in
data DGA101.

Visscher & Van der Zwan (1981) identified three
Late Triassic floristic zones: a northern one charac-
terized by Camerosporites and Ovalipollis, a middle one
with Camerosporites, Ovalipollis and Samaropollenites,
and a southern one with Camerosporites and Samarop-
ollenites. Since the DGA101 microflora includes Camero-
sporites, Ovalipollis and Samaropollenites it belongs to
the middle belt, known mainly from localities in North
Africa.

The DGA101 microflora consist almost entirely of
circumpolles, bisaccate and monosaccate pollens,
which belong to the typical triassic conifers; only one
spore was observed.

The monosaccate forms have been found associat-
ed with the conifer Brachyphyllum (Van KonijnenburgV.
Cittert, 1971). The circumpolles show affinities with Cheirolepidiaceae; in fact Corollina was found in
association with the conifer Hirmeriella (Francis, 1983;
Van Konijnenburg-V. Cittert, 1971).

The pollen, particulary the circumpolles, are typi-
cal xerophytic elements, which indicate an arid climate
(Cirilli & Montanari, 1994; Visscher et al., 1994). Aridi-
ty is also indicated by the total lack of miospore produ-
ced by hygrophytic plants (ferns or aquariales).

This is in agreement with the position of the Me-
diterranean region near the palaeotropical, where the cli-
imate was arid and warm during the Late Triassic
(Robinson, 1973). The presence of gypsum in the Upper
Carnian of Carnia (Pisa, 1971) and of Aupa valley (Bi-
chin et al., 1980) is additional evidence of aridity (Hal-
lam, 1984).

The microflora is representative of the vegetation
living at or near the site where the reptiles walked lea-
ving their tracks. This is indicated by the relatively high
number of tetrads, as these usually disarticulate during
prolonged transport and generally form a very low pro-
portion of a palynomorph association.

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Zanche; 60% Mietto).

PLATE I

The slide collection. Coordinates of the figured specimens were taken with the England Finder using Leitz Wetzlar no. 3345 with attached
camera. All the slides are housed in the Dipartimento di Geologia, Paleontologia e Geofisica of the University of Padua. 1) Enzonalsporites
vigens Leschik, 1956, (45 µm); Slide Dogna1 II, G 31/4; 2-3) Vallaspores ignaci Leschik, 1956 (48 µm); Slide Dogna 1 II, W 40/1; 4-5) Pseudoen-
zonalsporites summissus, Schuermann, 1970 (38 µm); (4, single grain, Slide Dogna 1 V, L 46/1; 5, tetrad, Slide Dogna 1 V, N 48); 6) Patina-
sporites densus Leschik, 1956) Schuermann, 1970, (40 µm), Slide Dogna 1 III, K 39/1; 7) Ovalipollis pseudolatus (Thierryg, 1949) Schuermann, 1976 (length 81 µm), Slide Dogna 1, III, M 42/1; 8) Lueckisporites sp. (48 µm), Slide Dogna 1, S 48/3; 9) Samaropollenites speciosus Goubin, 1965, (length 62 µm), Slide
Dogna 1, I, S 34/3; 10) cf. Corollina aff. sp. A (sensu Schuermann, 1977), (diameter of single grain in tetrad is 38 µm), Slide Dogna 1 II, K 41/1; 11) Paritsisporites malaychaeus (Klaus, 1960) Van der Eem, 1983, (diameter in single grain in tetrads is 40 µm), Slide Dogna 1 V, D 41/4; 12) Camerosp-
orites secatus Leschik, 1956, (45 µm), Slide Dogna IV, G 31/4.
Palynology and reptile trackways in Dogna Valley
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