THE KÜHWIESENKOPF/MONTE PRÁ DELLA VACCA (PRAGS/BRAIES DOLOMITES, NORTHERN ITALY): AN ATTEMPT TO RECONSTRUCT AN ANISIAN (LOWER MIDDLE TRIASSIC) PALAEOENVIRONMENT

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INTRODUCTION

THE FUNDAMENTAL feature that characterises the Anisian geology of the Dolomites is the change from the relative palaeogeographical uniformity that prevailed during the Early Triassic (Werfen Formation) and the earliest Anisian (Lower Serla Dolomite). The later Anisian successions record a variable palaeogeographical picture in which synsedimentary tectonics created carbonate platforms, deep basins and outcrops (even in restricted areas). A number of generations (at least three) of continental or costal conglomerates, evolving into shelf deposits and finally into carbonate platforms (or their basinal equivalents) toward the top of the sequence, have been documented in the Prags/Braies Dolomites (e.g. Pia 1937; Bechstadt and Brander 1970; De Zanche *et al*. 1992; Senowbari-Daryan *et al*. 1993; Zühlke 2000). During the Anisian, this area was located at about 5-15° N (e.g. Muttoni *et al*. 2001) with palaeoclimatic indicators that show a widespread arid climate interrupted by rare humid intervals.

Palaeogeographical reconstructions (e.g. Bosellini 1968, Senowbari-Daryan *et al*. 1993; Zühlke 2000) of the Prags/Braies Dolomites indicate that exposed land was dominant in the southwest area, while the eastern zones were mostly covered by marine basins of variable depth. In this context, even relatively small variations in sea level caused different biotic reactions based on the type of palaeoenvironment involved.

The area of Kühwiesenkopf was located in a marginal basin environment during the Anisian. The plant bearing bed at Kühwiesenkopf is placed in the middle part of the Dont Formation corresponding to the uppermost part of the Lowstand System Tract (LST) or at the base of the Transgressive System Tract (TST: An 3 in Gianolla *et al*. 1998). Physical basin-wide constraints allow a good landward correlation between these basinal sediments and the marginal marine and continental deposits of the Voltago Conglomerate. The latter unit is formed mainly by polygenic clasts, sandstones, reddish arenaceous dolostones, laminated calcisiltstones and pelite; towards the top of the sequence fine arenite, quartz silts and arenaceous-silty limestone (often bioturbated) form the transition to the Dont Formations above. Sandy clays with roots and plant debris, and palaeosoils rich in black organic matter document the presence of flourishing vegetation. Additionally, traces of insects and animal tracks (e.g. *Rhynchosauroides* sp., basal archosaurs) are found.

Plant remains were mentioned by Mojsisovics (1879, p. 47), but not discussed. The recent discovery of a rich plant-bearing horizon allowed detailed studies of the fossil plants (e.g. Broglio-Loriga *et al*. 2002). Due to very rapid burial events, various members of both terrestrial and marine biotas, which normally grew in different palaeoenvironments, accumulated in a single layer that reached up to 1 m in thickness. This, and the composition of the macroflora, renders the locality an important study area for Anisian palaeobotany (lower Middle Triassic).

Four different environmental zones with four different vegetational communities can be discerned. We will describe them briefly, including the gross morphology of their main components.

COASTAL VEGETATION

As the name implies, 'Coastal Vegetation' is represented by communities growing in coastal regions, tidally influenced areas and habitats that were never submerged but which were under the constant influence of salt spray. The 'Coastal Vegetation' is a low diversity flora composed of

three lycophytes, two of which were herbaceous while the third was arborescent.

Isoetites is a distinctive herbaceous to shrub-like form (e.g. Grauvogel-Stamm and Lugardon 2001), resembling the recent genus *Isoëtes* with long lanceolate leaves disposed spirally around a short stem with micro- and macrosporangia at their base. *Annalepis* resembles *Lepacyclotes circularis* (Bock 1969), which was reconstructed with a flat arrangement of 4-5 concentric rosettes of largely overlapping leaves and/or sporophylls. More recently, however, *Annalepis* has been reconstructed with sporophylls inserted on the apex of some stems and with roots that were up to 100 mm in length (Grauvogel-Stamm and Lugardon 2001). However, the sporophyll anatomy seems to suggest a possible floating habit for this plant (Meng *et al*. 2000).

The only (semi)arborescent lycophyte (Lycophyta gen. indet.) is characterised by hypogenous rhizomes that give off a few apically dichotomised stems, up to 2 m high, with spirally arranged long lanceolate leaves. The stems and leaves of this taxon resemble *Pleuromeia*, a plant characterised by an undivided, straight stem (up to 2 m long) and a quadrilobate bulb-like rhizophore (e.g. Grauvogel-Stamm 1993). It is likely that *Pleuromeia* was an opportunistic plant that quickly colonised pioneer niches (e.g. Grauvogel-Stamm 1993).

LOWLAND VEGETATION

'Lowland Vegetation' is represented by plant communities growing on plains that can be divided into periodically inundated "wetter" and never inundated "drier" zones. The lowland vegetation exhibits the highest taxonomic variability. Part of the overstorey is formed by pteridosperms such as *Scytophyllum*. Its bipinnate fronds, which arise spirally from a stem that can reach several metres in height, are characterised by a wide heteromorphy that was a response to differences in solar exposure (sun- and shade-leaves). Arborescent cycads (*Bjuvia*) and bennettitaleans (*Pterophyllum*) were also part of the overstorey. *Bjuvia* was characterised by a large trunk (up to 1 m tall), bearing long leaves that could reach lengths of 0.70 m (e.g. Florin 1933). *Pterophyllum* leaves, with their linear, parallel-margined segments, probably arose from a narrow stem, which could reach several meters in length (e.g. Mägdefrau 1948). In the "drier" zones conifers (*Voltzia*) might have grown in the canopy, with horsetails (*Equisetites*, *Neocalamites*) in the swampiest areas.

The understorey was probably composed of small ferns such as *Neuropteridium*/*Scolopendrites*, which has an oval epigeous or semi-epigeous rhizome and pinnate leaves that reached lengths of up to 0.30-0.40 m (e.g. Kustatscher *et al*. 2003). Ferns with *Cladophlebis*-like fronds might also represent understorey plants or may have grown in fluvial to estuarine environments (Falcon-Lang *et al*. 2001). Some shrubby conifers could also have been part of the understorey of the 'Lowland Vegetation'. *Pelourdea* seems to have been herbaceous or shrub-like in nature (e.g. Mägdefrau 1948; Ash 1987), although some authors consider it tree-like, similar to *Cordaites* (Gall and Grauvogel-Stamm 1984). The conifer genus *Albertia*, on the other hand, is characterised by multiply branched shoots with spirally attached elliptical leaves (Gall and Grauvogel-Stamm 2000), features suggesting a shrub-like nature.

Larger herbaceous ferns occupied the open areas. *Anomopteris* is probably a rhizomatous fern (Mägdefrau 1948) with bipinnate leaves reaching almost 1 m in length and 0·5 m in width, which arose from a rhizome that was up to 100 mm thick and 1 m long (Gall and Grauvogel-Stamm 2000). This species populated either the riverbanks (Gall and Grauvogel-Stamm 1984, 2000) or temporarily swampy lowland areas (Fuchs *et al*. 1991). *Gordonopteris*, characterised by tripinnate leaves up to 0.5 m long and 0.4 m wide, is also considered of to be herbaceous and rhizomatous in nature.

UPLAND VEGETATION

The 'Upland Vegetation', formed by communities on higher terrain well above the groundwater table, is dominated by conifers and shows a low diversity of taxa. The main component of the overstorey is *Voltzia*, a conifer with falcate to needle-like small leaves spirally attached to the shoots and female strobili with imbricate, five-lobed ovuliferous scales with three ovules (e.g. Miller 1977). The features and dimensions of the shoots suggests that they are arborescent plants which reached a few metres in height (Gall and Grauvogel-Stamm 2000), although some of the species could have also have had a shrub-like habit. The understorey was formed by the herbaceous taxa discussed previously (*Albertia*, *Pelourdea*).

RIVER VEGETATION

The 'River Vegetation' is characterised by the most hydrophilic taxa, growing on riverbanks or along freshwater channels. These highly unstable areas would have been submerged periodically and

subjected to erosion. Horsetails (*Equisetites*, *Neocalamites*), herbaceous ferns (*Neuropteridium/ Scolopendrites*, *Anomopteris*, *Gordonopteris*) and lycophytes (*Isoetites*) probably grew in such areas.

Equisetites and *Neocalamites* are composed of a hypogeous rhizome with short internodes that produced vertical, articulated stems that projected upwards and long roots that extended vertically downwards. Both genera could reach 6-8 m in height (see Kelber and Hansch 1995), although some authors reconstruct them as smaller plants (e.g. Mägdefrau 1948). They formed thickets in and alongside lakes and swamps (Mägdefrau 1948) or along riverbanks near to deltas with brackish and fresh water influences (Gall and Grauvogel-Stamm 2000).

REFERENCES

ASH, S. R. 1987. Growth habit and systematics of the Upper Triassic plant *Pelourdea poleoensis*, Southwestern USA. *Review of Palaeobotany and Palynology*, **51**, 37-49.

BECHSTÄDT, T. and BRANDNER, R. 1970. Das Anis zwischen St. Vigil und dem Höhlensteintal (Pragser- und Olanger Dolomiten, Südtirol). 9-103. *In* Mostler, H. (ed). *Beiträge zur Mikrofazies und Stratigraphie von Tirol und Vorarlberg* (*Festband des Geologischen Institutes, 300-Jahr-Feier Universität Innsbruck)*. Wagner, Innsbruck.

BOCK, W. 1969. The American Triassic Flora and global distribution. *Geological Center of Research Serie*, **3-4**, 1-406.

BOSELLINI, A. 1968. Paleogeografia pre-anisica delle Dolomiti centro-settentrionali. *Memorie della'Accademia Nazionale dei Lincei*, **365** (ser. 8, sez. 2a, 4/1), 1-33.

BROGLIO LORIGA, C., FUGAGNOLI, A., VAN KONIJNENBURG-VAN CITTERT, J. H. A., KUSTATSCHER, E., POSENATO, R. and WACHTLER, M. 2002. The Anisian macroflora from the Northern Dolomites (Monte Prà della Vacca/Kühwiesenkopf, Braies): a first report. *Rivista Italiana di Paleontologia e Stratigrafia*, **108**, 381-390.

DE ZANCHE, V., FRANZIN, A., GIANOLLA, P., MIETTO, P. and SIORPAES, C. 1992. The Piz da Peres Section (Valdaora-Olang, Pusteria Valley, Italy): a reappraisal of the Anisian stratigraphy in the Dolomites. *Eclogae Geologicae Helveticae*, **85**, 127-143.

FALCON-LANG, H. J., KVACEK, J. and ULICNY, D. 2001. Fire-prone plant communities and palaeoclimate of a Late Cretaceous fluvial to estuarine environment, Pecinov quarry, Czech Republic. *Geological Magazine*, **138**, 563-576.

FLORIN, C. 1933. Studien über die Cycadales des Mesozoicums nebst Erörterungen über die Spaltöffnungsapparate der Bennettitales. *Kungliger Svenska Vetenskapsakademien Handlingar*, *Series 3*, **12** (5), 1-119.

FUCHS, G., GRAUVOGEL-STAMM, L. and MADER, D. 1991. Une remarquable flore à *Pleuromeia* et *Anomopteris in situ* du Buntsandstein moyen (Trias Inférieur) de l'Eifel (R. F. Allemagne), Morphologie, Paléoécologie et Paléogéographie. *Palaeontographica, Abteilung B*, **222**, 89-120.

GALL, J. C. and GRAUVOGEL-STAMM, L. 1984. Genèse des Gisements fossilifères du Grès à Voltzia (Anisien) du Nord des Vosges (France). *Geobios, Memoires Special*, **8**, 293-97.

—— and —— 2000. L'Arenaria ("Gres") a Voltzia. 71-77. *In* PINNA, G. (ed). *Alle Radici della Storia Naturale d'Europa, Seicento Milioni di Anni Attraverso i Grandi Giacimenti Paleontologici*. Jaca Book, Milan.

GIANOLLA, P., DE ZANCHE, V. and MIETTO, P. 1998. Triassic sequence stratigraphy in the Southern Alps (Northern Italy): definition of sequences and basin evolution. 719-747. *In* DE GRACIANSKY, P. C., JACQUIN, T. and VAIL, P. R. (eds). *Mesozoic and Cenozoic Sequence Stratigraphy of European Basins*. *SEPM, Special Publication* **60**.

GRAUVOGEL-STAMM, L. 1993. *Pleuromeia sternbergii* (Münster) Corda from the Lower Triassic of Germany – further observations and comparative morphology of its rooting organ. *Review of Palaeobotany and Palynology*, **77**, 185-212.

—— and Lugardon, B. 2001. The Triassic Lycopsids *Pleuromeia* and *Annalepis*: Relationships, Evolution, and Origin. *American Fern Journal*, **91** (3), 115-149.

KELBER, K.-P. and HANSCH, W. 1995. Keuperpflanzen. Die Enträtselung einer über 200 Millionen Jahre alten Flora. *Museo*, **11**, 1-157.

KUSTATSCHER, E., VAN KONIJNENBURG–VAN CITTERT, J. H. A. and WACHTLER, M. 2003. Ricostruzione di *Neuropteridium*, una felce del Triassico medio. 35. *In* ANONYMOUS (ed). *4ª Giornate della Paleontologia 2003*. Società Paleontologica Italiana, Alessandria.

MÄGDEFRAU, K. 1948. *Vegetationsbilder der Vorzeit*. Gustav Fischer Verlag, Jena, 18 pls.

MENG, F.-S., ZHANG, Z.-L., NIU, Z.-J. and CHEN, D. 2000. *Primitive lycopsid flora in the Yangtze Valley of China and systematics and evolution of Isoetales*. Hunan Science and Technology Press, Changsha, 87 pp.

MILLER, C. N. 1977. Mesozoic conifers. *Botanical Review*, **43**, 218-271.

MOJSISOVICS, E. 1879. Die Dolomit-Riffe von Südtirol und Venetien: Beiträge zur Bildungsgeschichte der Alpen. A. Hölder Verlag, Wien, 551 pp.

MUTTONI, G., GARZANTI, E., ALFONSI, L., CIRILLI, S., GERMANI, D. and LOWRIE, W. 2001. Motion of Africa and Adria since the Permian; paleomagnetic and paleoclimatic constraints from northern Libya. *Earth and Planetary Science Letters*, **192**,159-174.

PIA, J. 1937. *Stratigraphie und Tektonik der Pragser Dolomiten in Südtirol*. Wien, 248 pp.

SENOWBARI-DARYAN, B., ZÜHLKE, R., BECHSTÄDT, T. and FLÜGEL, E. 1993. Anisian (Middle Triassic) buildups of the northern Dolomites (Italy): the recovery of reef communities after the Perm/Triassic crisis. *Facies*, **28**, 181-256.

ZÜHLKE, R. 2000. Facies, hochauflösende Sequenzstratigraphie und Beckenentwicklung im Anis (mittlere Trias) der Dolomiten (Südalpin, Italien). *Gaea heidelbergensis*, **6**, 1-368.