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Nodular calcrete from the Lower Permian Korpád Sandstone Formation (borehole Dinnyeberki 9015, Mecsek Mts, Hungary) and its palaeoenvironmental significance

VARGA Andrea[1,2], RAUCSIK Béla[1,2], BAJNÓCZI Bernadett[3]

[1]University of Pécs, Department of Geology, 7624 Pécs, Ifjúság útja 6., e-mail: andrea.varga.geol@gmail.com
[2]University of Szeged, Department of Mineralogy, Geochemistry and Petrology, 6722 Szeged, Egyetem utca 2–6.
[3]Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, 1112 Budapest, Budaörsi út 45.

Abstract

The Korpád Sandstone in the 9015 drill core situated in the Mecsek Mts consists of red mudstones and interbedded calcrete crusts with sandstones and conglomerates. Calcrete microfabrics reveal micritic mottles, rhizocretions, smaller root casts and *Microcodium*-like aggregates. These features, together with the mineralogy, suggest a relatively dry climate with a low amount of rainfall (100–500 mm/year) during pedogenesis. Calcite cements are interpreted to have precipitated first in an oxidizing meteoric environment; then, after initial burial, under reducing conditions.

Keywords: beta calcrete, rhizoliths, Microcodium, early diagenesis, Permian, Mecsek Mts

Introduction

In southern Transdanubia, SW Hungary, Permian sequences are represented mostly by continental siliciclastic and volcaniclastic rocks. They were deposited in continental strike-slip and rift-related basins, belonging to the internal part of the Variscan orogenic domain (SZEDERKÉNYI 2001; VOZÁROVÁ et al. 2009). The syn-eruptive Cisuralian volcaniclastic deposits have a complex stratigraphic architecture and can be subdivided into three lithostratigraphic units: the upper part of the Korpád Sandstone, the Gyűrűfű Rhyolite, and the lower part of the Cserdi Conglomerate (BARABÁS & BARABÁSNÉ STUHL 1998; VARGA 2009). Among these units, the fine-grained siliciclastic deposits of the Korpád Sandstone are distinctive with respect to the presence of palaeosols (VARGA 2009).

The alluvial Korpád Sandstone occurs in the subsurface of southern Transdanubia and ranges up to 700 m in thickness, consisting of polymictic conglomerate, breccia, sandstone and mudrocks. This formation contains a sparse Early Permian macroflora (e.g. *Pecopteris, Voltzites*) and a lowermost Permian microflora composed of the *Potonieisporites* and *Vittatina* assemblage (BARABÁS & BARABÁSNÉ STUHL 1998). Despite a long history of research (BARABÁS & BARABÁSNÉ STUHL 1998 and references therein; SZEDERKÉNYI 2001), no palaeosols were ever recognized in this unit; however, a large amount of individual dolomite concretions and concretion aggregates together with animal burrows were described by JÁMBOR (1964) from the red siltstone samples (drill core Dinnyeberki 9015; *Figure 1, A* and *B*). Related to a current research project VARGA (2009) reported that these carbonate concretions are, at least partially, of rhizogenic origin, representing nodular horizons of calcrete profiles.

The general characteristics and palaeoclimatic significance of the Korpád calcrete

The studied calcrete sample is characterized by the presence of root traces and associated biogenic structures (*Figures 1* and *2*), showing beta microfabrics (*sensu* WRIGHT 1990). Its microscopic features reveal micritic mottles, rhizocretions, smaller root casts and *Microcodium*-like aggregates (KLAPPA 1980, KABANOV et al. 2008). The rhizocretions are complex tubular structures up to 6–9 mm in diameter, with a wall structure of irregular micritic laminae; these form roughly concentric layers around the central hollow filled by drusy calcite spar cement (*Figures 1, D* and *2*). In the pedogenic micritic laminae of rhizocretions, carbonate is replaced by tiny authigenic (non-luminescent) quartz, and this is present with euhedral crystal terminations. Root cast cements are predominantly equant calcite spar with a typical drusy fabric. Crystal sizes may reach 400–500 µm towards the centre of the pores. A distinct pattern of cathodoluminescence zoning, representing different cement

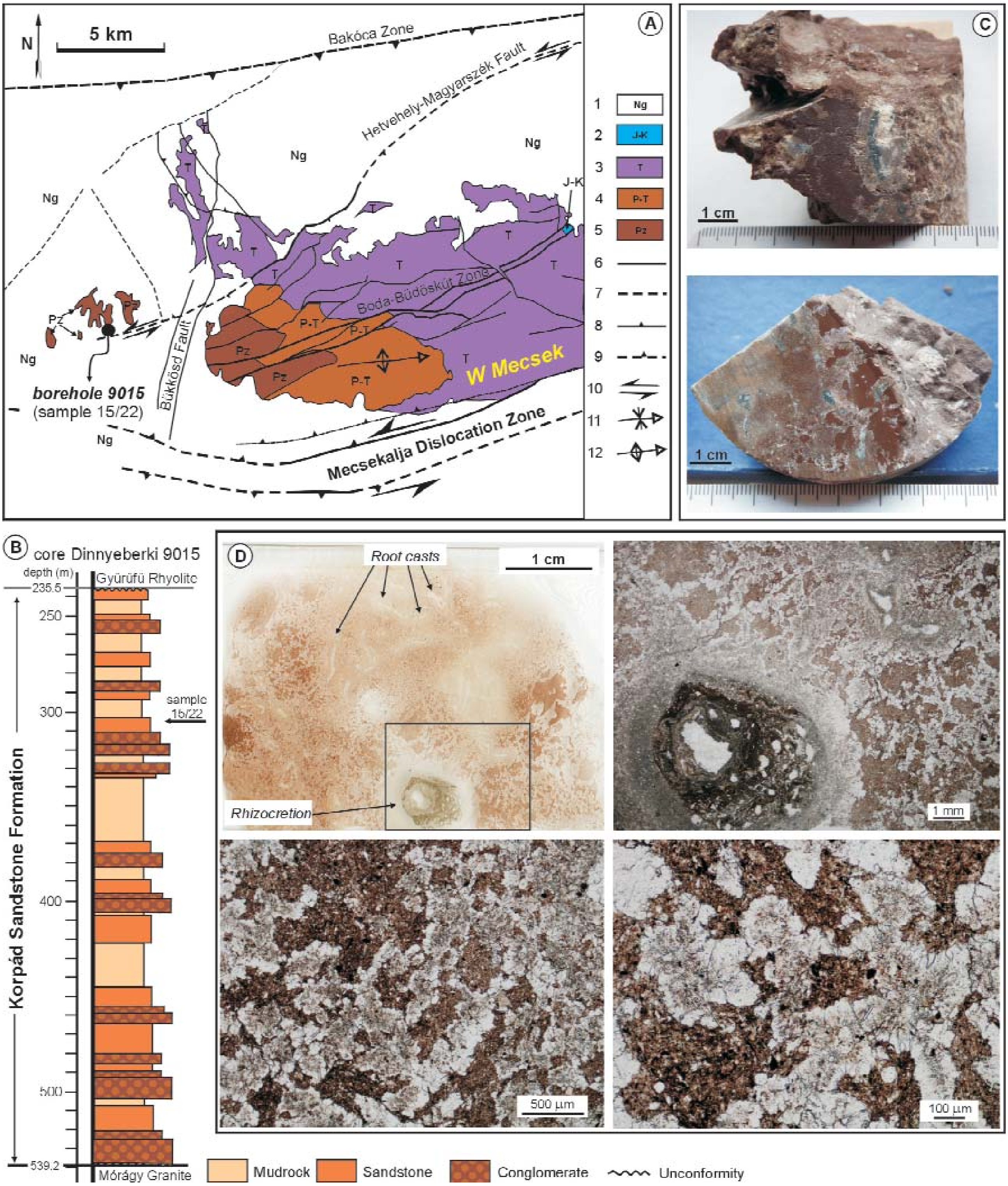

Figure 1. *A) Structural framework and generalized geological map of the Mecsek Mts (Konrád & Sebe 2010) and sample locality (sample code: 15/22; sample depth: 305.1 m). 1 = Neogene; 2 = Jurassic and Cretaceous; 3 = Triassic; 4 = Upper Permian – Lower Triassic; 5 = Palaeozoic in general; 6 = observed fault; 7 = compiled fault; 8 = observed reverse fault; 9 = compiled reverse fault; 10 = strike-slip fault; 11 = syncline; 12 = anticline; B) Generalized lithological column of the Korpád Sandstone Formation in core 9015 (Varga 2009); C); Red mudrock with pedogenic calcite nodules. Carbonate precipitation took place only in discontinuous areas in close association with roots; D) Photomicrographs of the Permian calcrete sample 15/22/1. The biological components of the soil became calcified forming rhizoliths (rhizocretions, root casts), calcified filaments, and nodules (upper photos). Rhizoliths occur in close vicinity to Microcodium-like calcite aggregates with relics of dark finely dispersed inclusions (lower photos)*

generations, can also be observed (*Figure 2*). The initial generation of the root cast cements is non-luminescent or has a very dull luminescence; the second generation is brightly luminescent and contains thin, dull or non-luminescent bands; the third generation has a homogeneous bright orange CL. This cement occurs as the last void-fill in large pores; additionally, it can also be seen around the large rhizoliths (*Figure 2, C* and *D*).

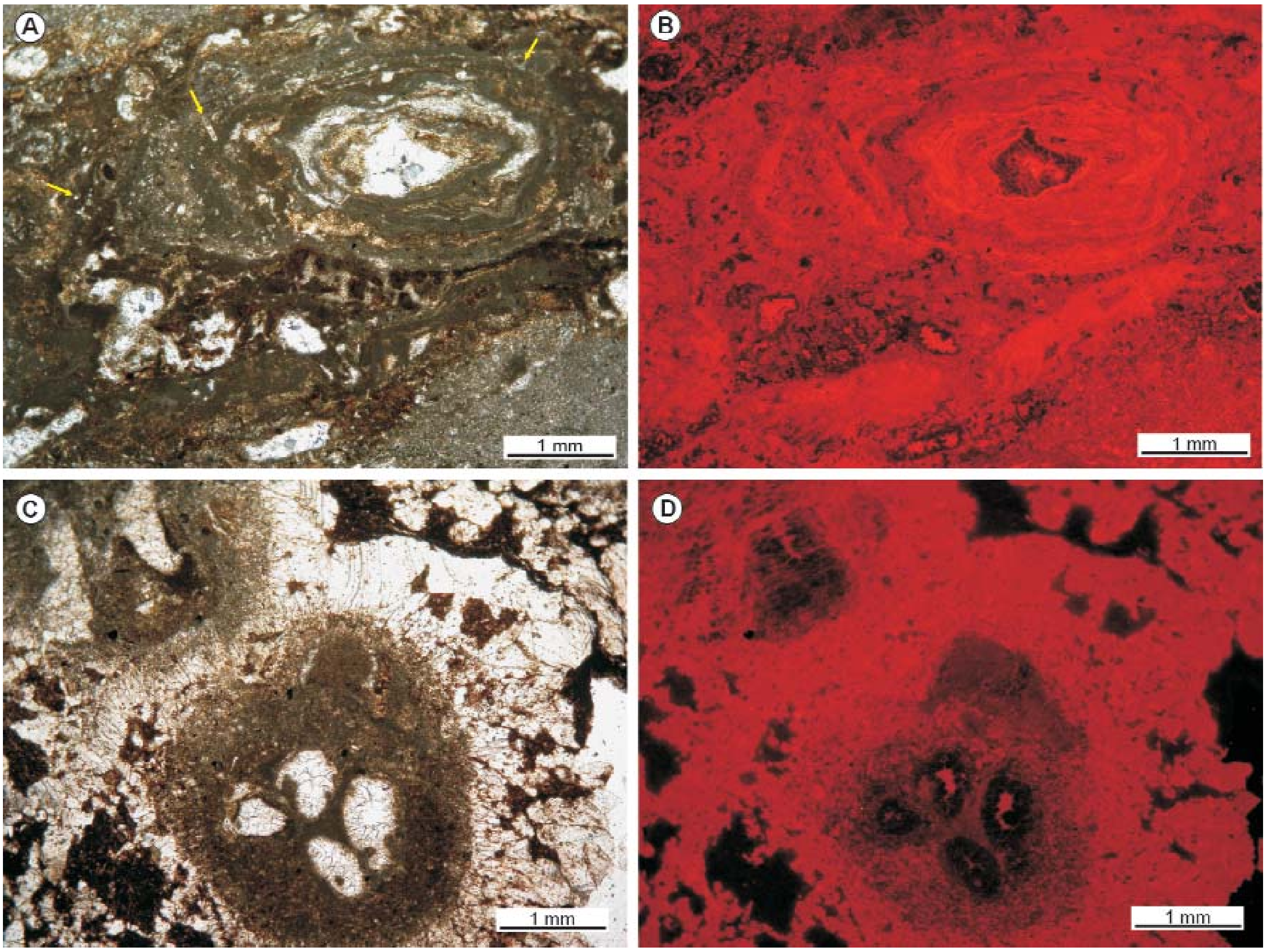

Figure 2. *Optical (left) and cathodoluminescence (CL; right) photomicrographs of the Permian calcrete sample 15/22/2. A–B) Rhizocretion with complex tubular structure (XPL and CL). In the central hollow filled with drusy calcite spar cement, a distinct pattern of luminescence zoning representing different calcite cement generations is observed. Authigenic quartz crystals are marked by arrows; C–D) Rhizolith with calcite spar cement filled voids (PPL and CL). Note the inclusion-rich calcite cement with homogeneous bright orange CL around the rhizolith*

The surroundings of the rhizocretions are enriched in the relic structure of *in situ Microcodium* aggregates (*Figure 1, D*). Unfortunately, *Microcodium* appears as partly to totally recrystallized calcite grains, so primary morphology could not be determined; however, relics of dark, finely-dispersed inclusions are obvious. The shape of the aggregates is variable, ranging from spherical clusters to larger cylinders ('corn-cob'-like) around 150–200 μm in diameter, showing very similar characteristics to the typical kind of *Microcodium* ('*Microcodium* a'; KABANOV et al. 2008). Occasionally, some aggregates are replaced by limpid calcite spar with coarse anhedral crystals showing sutured contacts. It should be noted that the Cisuralian calcrete occurs about 70 m below the boundary of the Korpád Sandstone and Gyűrűfű Rhyolite (*Figure 1, B*). In the western part of the Mecsek Mountains, the ~200 m thick overlying complex is interpreted by VARGA (2009) as a strongly to moderately welded (high-grade) ignimbrite, so the recrystallization of *Microcodium* might have been caused by the heating effect (?) of the subsequent volcanic activity.

X-ray diffraction (XRD) studies of the calcrete indicate that the mineral assemblage of the parent material (mudstone which is rich in strongly altered glass-shards) is dominated by calcite and, subordinately, quartz. Albite, haematite, illite±muscovite, dolomite, smectite and chlorite are minor to trace components. Its clay fraction (<2 μm) consists of illite±muscovite (~80%), chlorite (~10%) and mixed-layer illite/smectite (5–10%). In calcrete nodules, calcite is the dominant mineral; quartz, albite and illite±muscovite are present in small proportions.

Carbonate palaeosols which form only when evaporation exceeds precipitation are generally considered as reliable palaeoenvironmental and palaeoclimatic indicators. Microbial decomposition releases CO_2 that controls the dissolution and precipitation of pedogenic carbonate (ALONSO-ZARZA 2003). Drusy calcite spar commonly develops in a phreatic meteoric environment, representing the very early diagenetic events. Meteoric cements are typically non-luminescent with minor bright CL zones, reflecting the generally oxidizing nature of shallow meteoric waters. After initial burial, reducing conditions develop and these result in luminescent calcites (ELIASSEN & TALBOT 2005). The observed features in the rhizolith cements are consistent with this model.

Chemical weathering of primary silicates in the parent material such as albite results in the formation of clay minerals like smectite (APPELO & POSTMA 2009). Regarding hydrological conditions, smectite is predominantly formed in relatively dry climates with low amount of rainfall, where the rate of flushing of the soil is low, so that the solute concentrations become higher. Its formation is further enhanced when rapidly dissolving material such as volcanic rock is available (ALONSO-ZARZA 2003, APPELO & POSTMA 2009). When calcretes are associated with soils containing oxidized iron, smectite and illite — corresponding to the composition of the studied Permian calcrete — they probably indicate semiarid climates with rainfall averages of 100–500 mm/year (RETALLACK 1990, ALONSO-ZARZA 2003).

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