PS Diagenesis of a Late Triassic - Early Jurassic Drowning Succession Overprinted by Late Paleofluid Migration Events (Tata, Hungary)*

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Abstract

Late Triassic platform carbonate succession is exposed at Tata, in the Transdanubian Range (Hungary), unconformably covered by Early Jurassic neritic carbonates. From the Early Jurassic on, the succession is continuous in the pelagic facies, up to the Early Cretaceous.

The succession is characterized by neptunian dykes and peculiar dissolution and cementation phenomena. This study is focussed on the diagenetic history of the exposed Mesozoic carbonates and the associated paleofluid migration events. The applied techniques included petrography, fluid inclusion and stable isotope analysis.

Deposition of the Late Triassic Dachstein Limestone was interrupted by high-frequency sea-level falls resulting in a Lofer-cyclic succession. During shallow diagenesis early, non luminescent calcite filled the intergranular pore space of the limestone, showing marine isotope signals ($\delta^{13}C$ = 1.85 to 2.67, $\delta^{18}O$ = (-1.39) to 0.19).

The most spectacular dissolution-cementation phenomena occur along the unconformable boundary of the Late Triassic platform and the overlying hemipelagic Early Jurassic beds. Dissolution resulted in bed parallel vugs filled by radiaxial fibrous calcite on their walls and red mudstone in the remaining space. Their formation might have been associated either with a paleo-watertable or with a boundary between fluids of different composition. Stable isotope values of the radiaxial calcite clearly show marine origin ($\delta^{13}C$ = (1.61) to (3.40), $\delta^{18}O$ = (-3.45) to 0.21). Red micritic infill in the vugs and in the neptunian dykes of the Late Triassic limestone is supposed to be identical to the overlying Jurassic lime mud.

The whole section is criss-crossed by several, 1 to 20 cm wide late calcite-veins. Stable isotope values of white-yellow calcite, filling the first generation of veins, suggest late diagenetic fluids associated with burial diagenesis ($\delta^{13}C$ = (-8.42) to (-5.51), $\delta^{18}O$ = (-0.18) to 1.86). The presence of all-liquid inclusions indicates low temperature burial fluids (T<50°C) about 0 to 1.05 NaCl equ. w% salinity.

Fractures characterized by NE-SW and E-W strike are filled by transparent calcite crystals associated with tabular-habit barite. Stable isotope values of calcite are in the range of (-4.06) to (-3.45) $\delta^{13}C$ and (-14.10) to (-6.23) $\delta^{18}O$, suggesting meteoric origin. Low temperature (<50 °C) and low salinity (0 to 0.53 NaCl equ. w%) of their parent fluids imply that they could be related to the subrecent karstwater system.

DIAGENESIS OF A LATE TRIASSIC–EARLY JURASSIC DROWNING SUCCESSION OVERPRINTED BY LATE PALEOFLUID MIGRATION EVENTS (TATA, HUNGARY)

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1. Introduction

A Late Triassic – Early Jurassic drowning succession is exposed at the NW part of the Transdanubian Range, Hungary, in the town of Tata (Fig. 1,2). The Upper Triassic (Lower Rhaetian) carbonate platform is unconformably overlain by Lower Jurassic (Upper Hettangian) hemipelagic limestone (Fig. 3). Both formations are characterized by neptunian dykes and peculiar dissolution and cementation phenomena (Fig. 7). In addition several calcite veins crosscut the section.

The Transdanubian Range and the adjoining areas are part of the so called ALCAPA Unit, which has a South Alpine affinity.

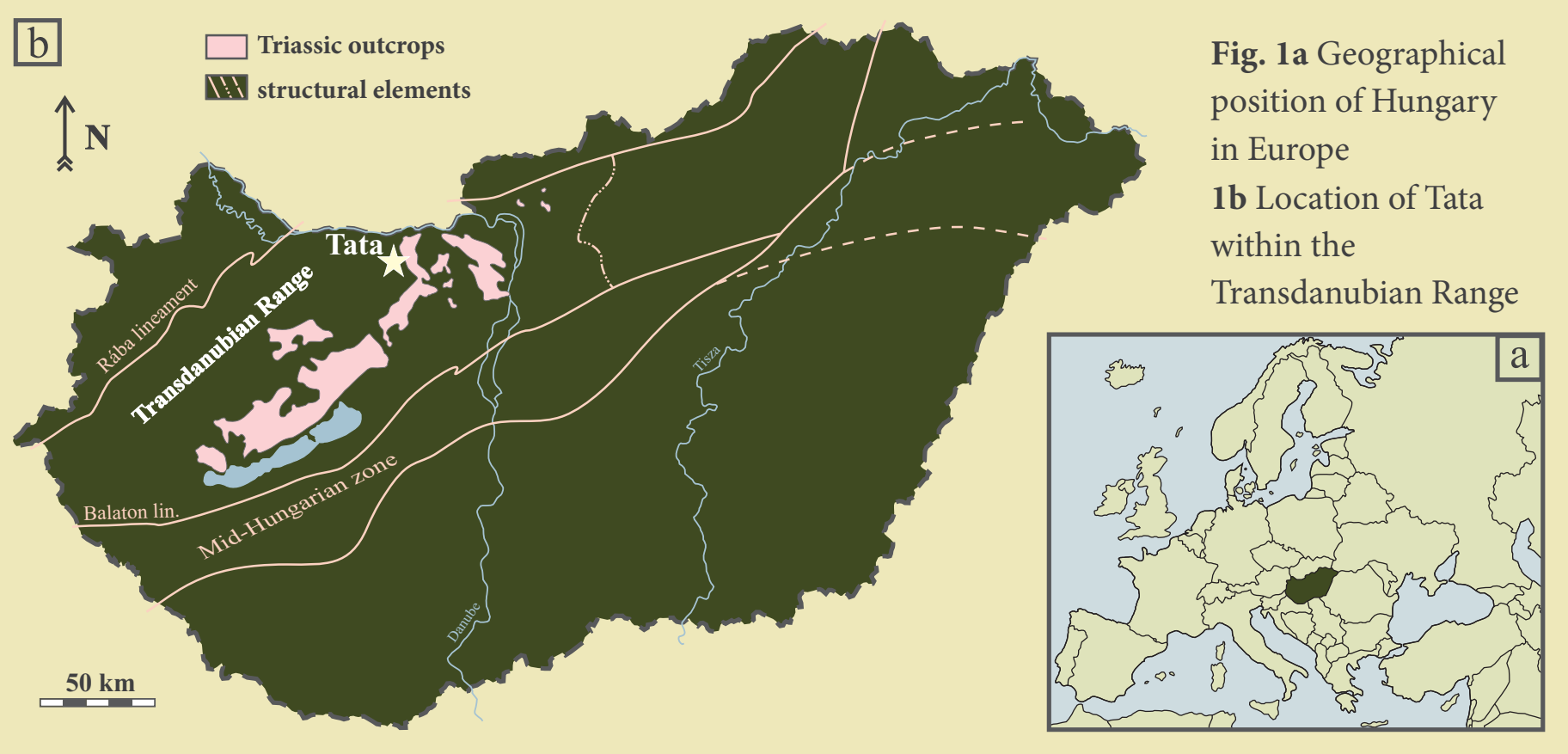


Fig. 1a Geographical position of Hungary in Europe **1b** Location of Tata within the Transdanubian Range

Fig. 3 The drowning succession of the Kálvária Hill, Tata

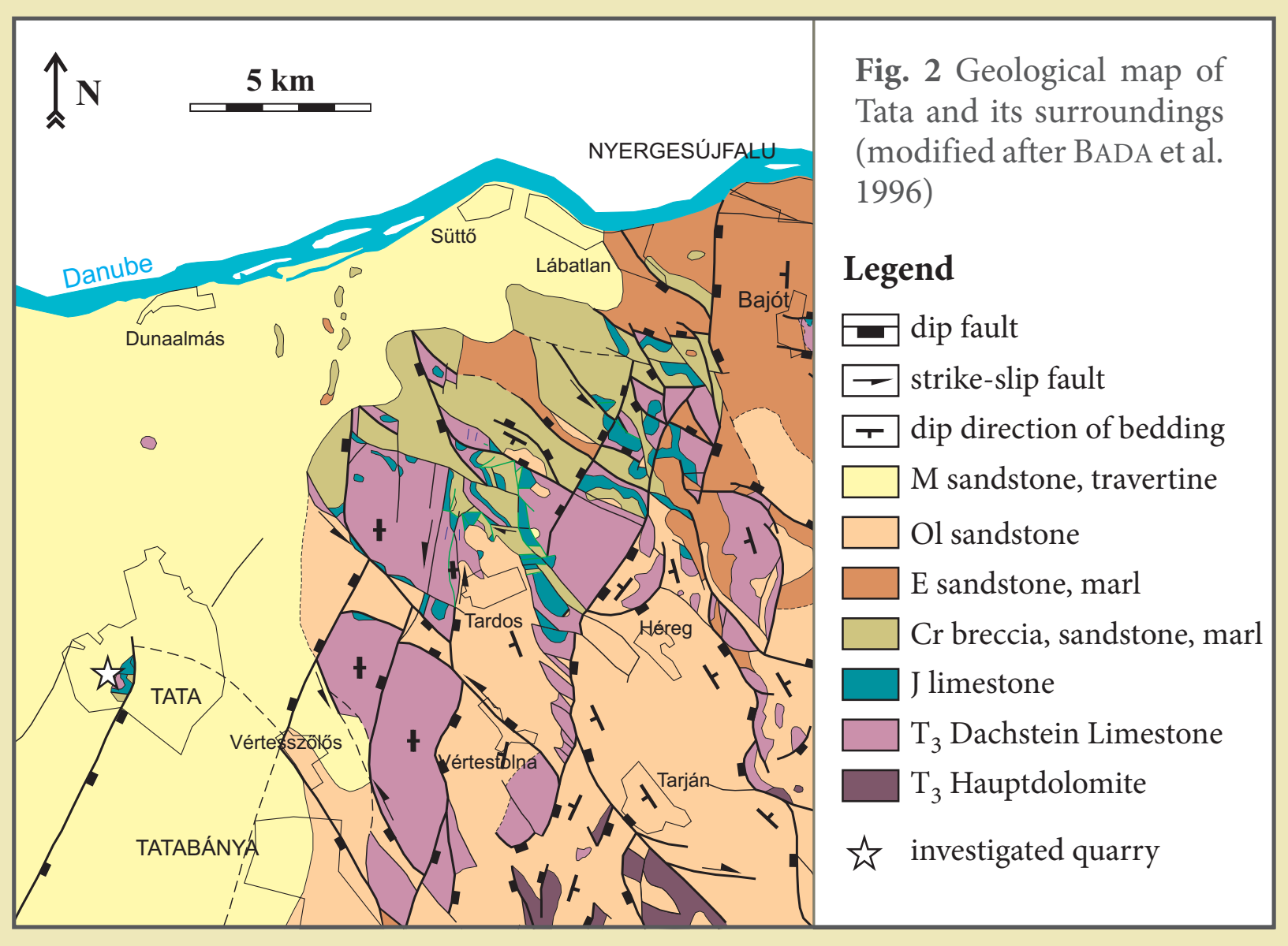


Fig. 2 Geological map of Tata and its surroundings (modified after BADA et al. 1996)

The investigated quarry exposes an uplifted block of the Mesozoic basement, which is surrounded by Cenozoic sediments (Fig. 2). The aim of this study is to describe the cements and to reconstruct the diagenetic processes having affected the above drowning succession.

2. Early cementation in the T_3 limestone

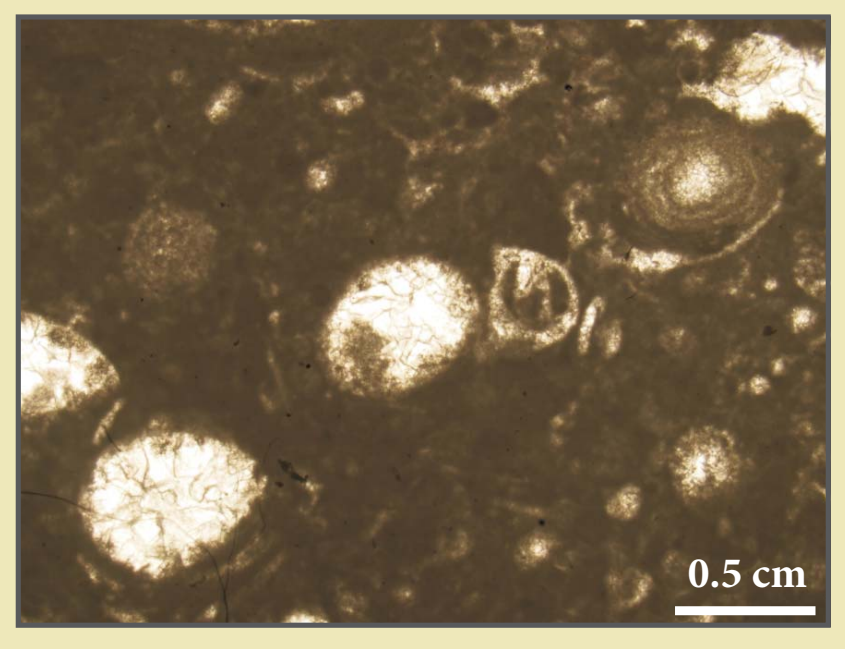


Fig. 5 Biomolds, after *Triasina* filled by transparent calcite in the subtidal member of the Lofer-cyclic Dachstein Limestone

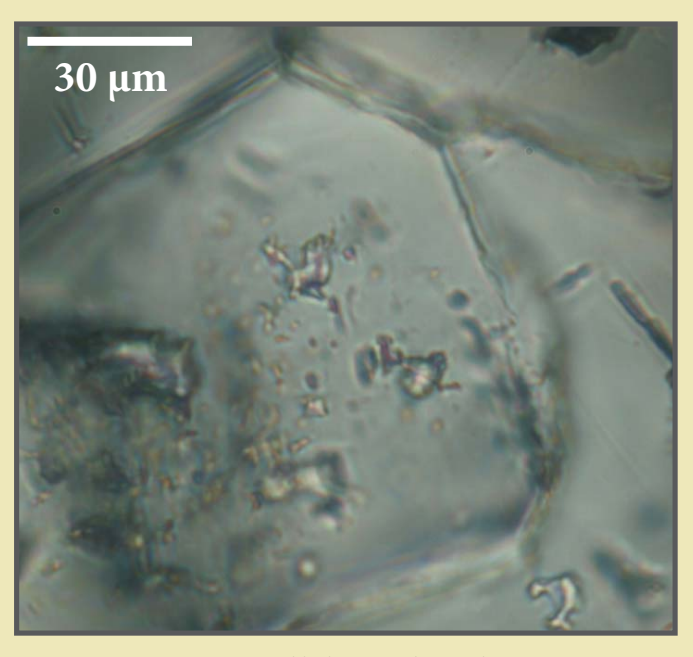
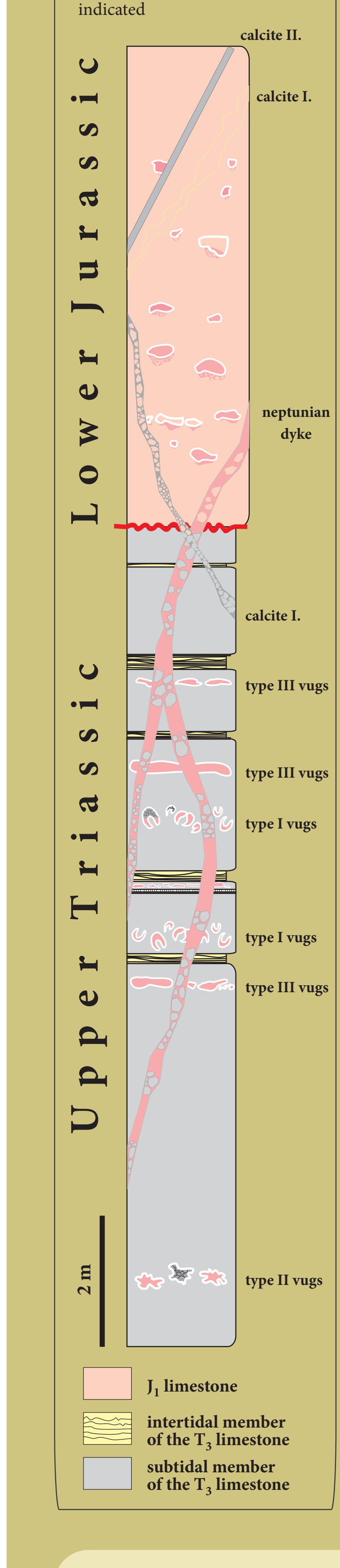


Fig. 6 Primary all-liquid inclusions in the calcite filling biomold porosity

Transparent sparry calcite fills both the fenestral pores of the peloidal, laminated intertidal horizons (Fig. 4) and the biomolds after *Triasina* (Fig. 5). High $\delta^{18}O$ values of this cement phase (Fig. 21) suggest the effect of evaporation (i.e. it is of early diagenetic origin, related to the formation of the Lofer-cycles). All liquid primary fluid inclusions represent the low temperature parent fluid (Fig. 6)

Fig. 4 Fenestral pores in the intertidal member of the Lofer-cyclic Dachstein Limestone

Fig. 7 Schematic stratigraphic column of the Kálvária Hill, Tata with the cavities and calcite veins indicated



3. Vugs in the T_3 limestone

Three types of vugs were observed in the Upper Triassic Dachstein Limestone exposed at Tata. Type I is characterized by biomoldic vugs after aragonite shelled Bivalves (*Megalodon*) in the subtidal members of the Lofer-cycles (Fig. 8a).

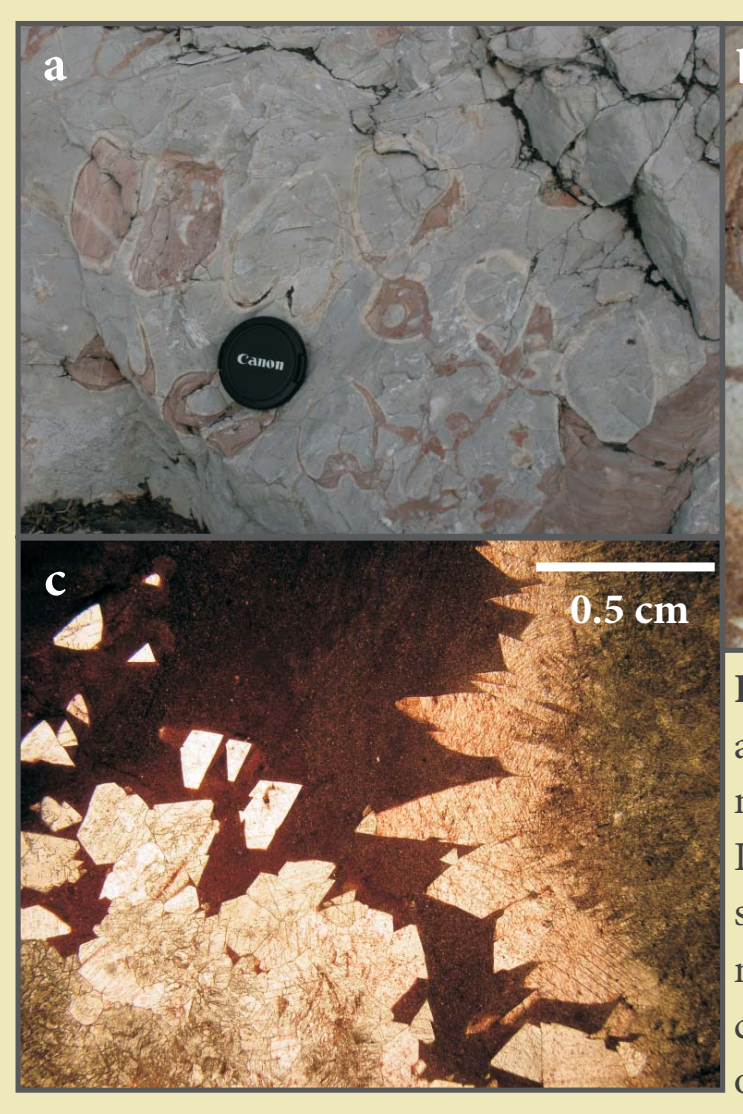


Fig. 8 ~~Type I vugs~~, **a** Biomolds after *Megalodon* in the C-member of the Dachstein Limestone, **b** Red crinoidal sand and pink laminated micrite, **c** Inclusion rich calcite and scalenohedral overgrowth in biomoldic vug

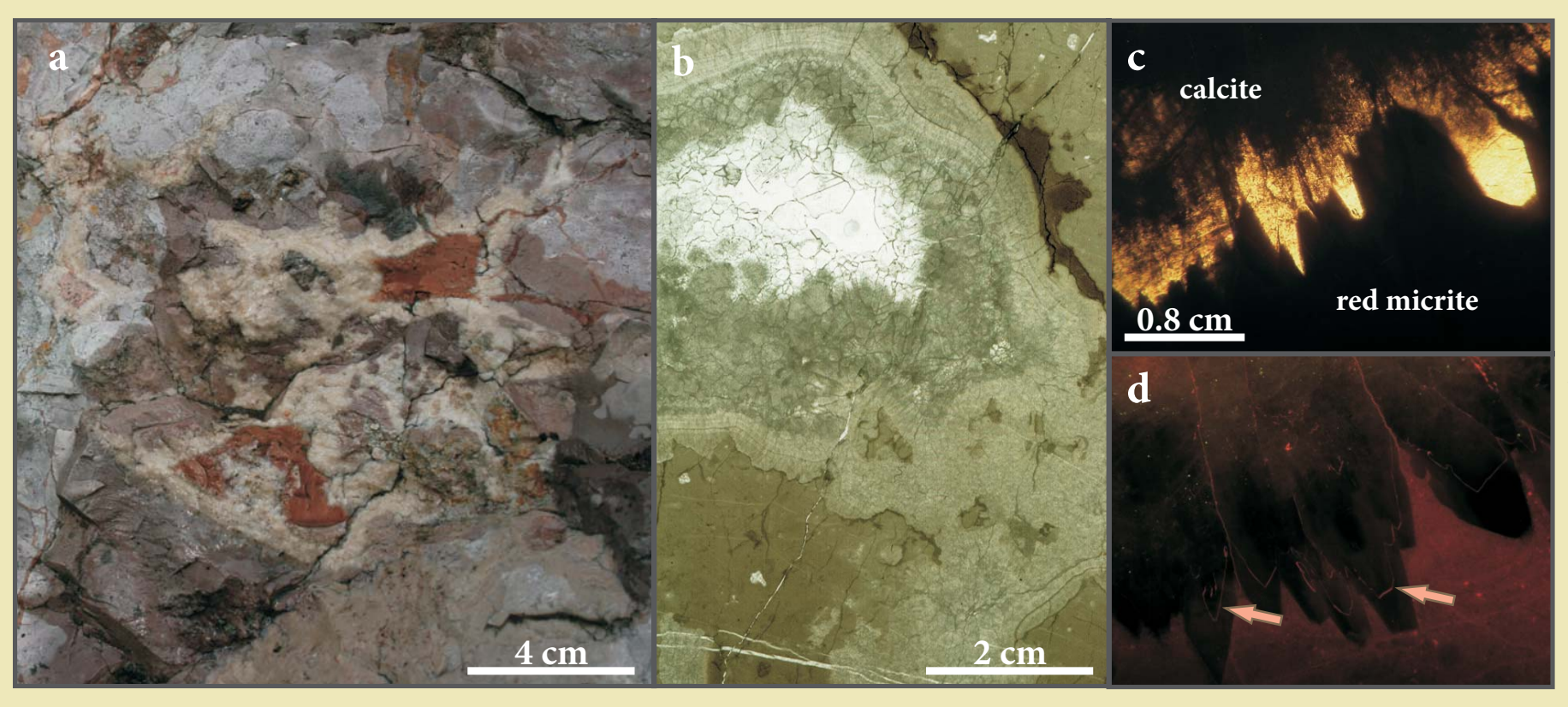


Fig. 9 ~~Type II vugs~~ **a** Vugs in the subtidal member of the Dachstein Limestone, **b** Multi-generation calcite cement in type II vugs (Note the irregularly corroded surface of the host rock), **c** Scalenohedral overgrowth on fluid inclusion rich RFC, **d** CL picture of **c**

These 5 to 15 cm-sized vugs are filled by either thin (<5 mm) fibrous calcite crust or wider (1 to 3 cm), isopachous fibrous calcite cement on their walls, and several generations of laminated pink to red micrite fill the remaining pore space (Fig. 8a,b). Both calcite cements are non-luminescent and have scalenohedral overgrowth (Fig. 8c). In some of the type I vugs the first filling is crinoidal sand, though this sediment is missing from the bottom of the Jurassic succession (Fig. 8b).

The size of type II vugs range from 1 to 8 cm (Fig. 9a). These always have irregular boundaries, suggesting dissolution prior to cementation (Fig. 9a,b). The infill consists of wide, fibrous zoned calcite crust on the wall and either transparent calcite (with fluid inclussion rich core) or red micrite in the remaining pore space (Fig. 9c). Scalenohedral overgrowth of the zoned calcite exhibits bright luminescence at the termination of the crystals, suggesting slightly reducing conditions (Fig. 9d).

Based on the depleted stable C isotope data of the host rock next to type II cavities, as compared to those of the calcite cement, brackish or meteoric fluids might have been the reason for the dissolution (Fig. 21). Zones in the calcite suggest that several dissolution events interrupted the growth of the mineral (Fig. 9b).

Type III vugs are bed-parallel, showing preferential distribution as they are restricted to the uppermost four cycles of the Dachstein Limestone (Fig. 7). These cca. 3 to 5 m wide and 10 to 30 cm high cavities are elongate and may be either contiguous or disconnected (Fig. 10a). They always occur 20 to 30 cm below the intertidal members. The irregular boundary of these cavities suggests dissolution. The first infilling phase in type III vugs is usually a thin layer of red micrite. It is followed by a 1 to 3 cm thick calcite crust, which seems to be recrystallized based on micropetrographic observations (Fig. 10b,c). The remaining space is filled by multi-generation pink to red micrite. The calcite crust often spalled off the top, and its fragments are embedded in the infilling material.

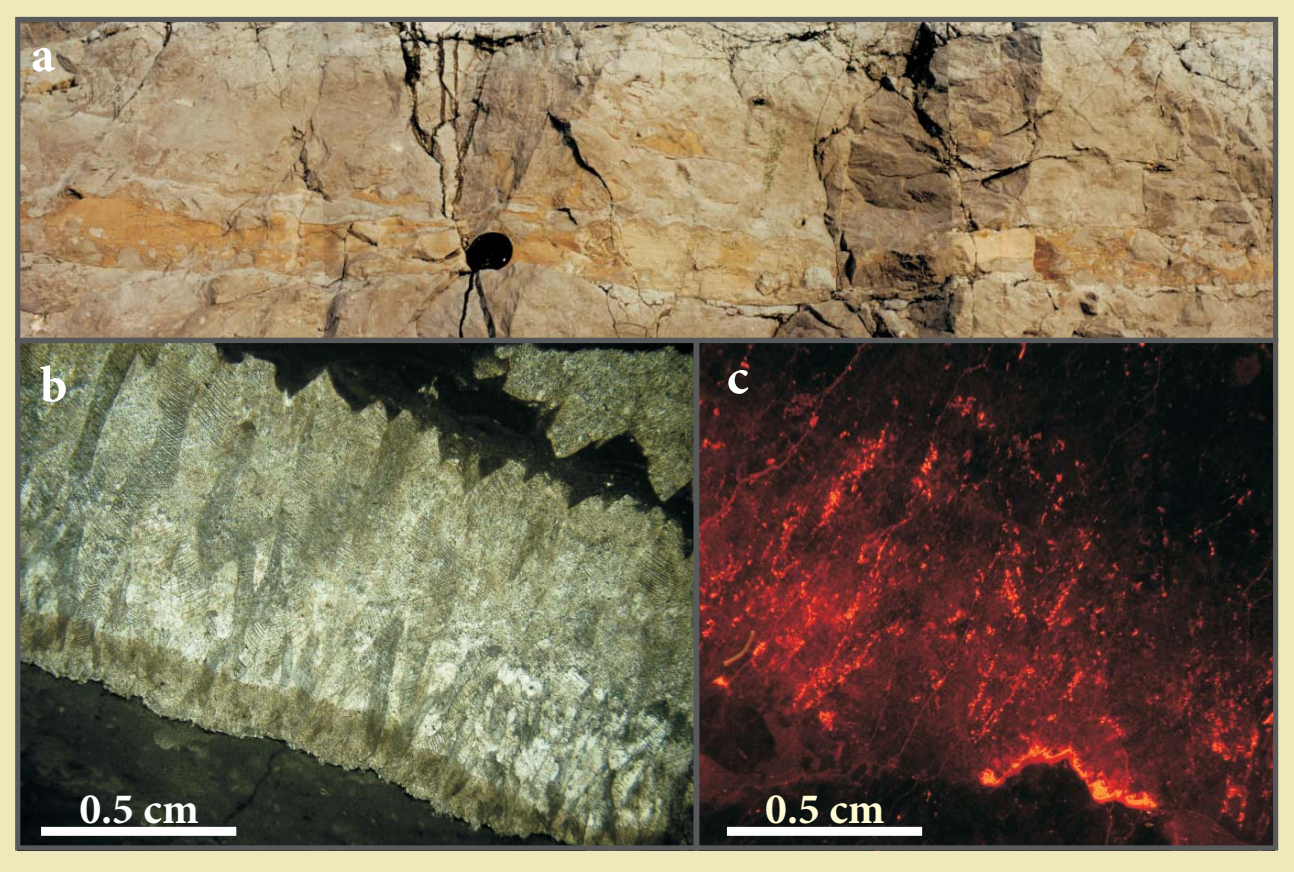


Fig. 10 ~~Type III cavities~~ **a** Elongated cavity in the subtidal member of the Dachstein Limestone filled by fragmented clasts of the calcite crust and pink micritic sediment, **b** RFC filling the bottom of a type III cavity, **c** Mottled CL pattern of the recrystallized RFC

4. The interface between T_3/J_1

Between the youngest beds of the Lower Rheatian Dachstein Limestone and the overlying Upper Hettangian sediments there is an erosional and a gentle angular unconformity. Type I vugs (*Megalodontid* biomolds filled by calcite and pink micrite) are cut half at the boundary (Fig. 11). Imprints of bioerosion in the form of few µm-sized cylindrical borings on the surface of the uppermost bed could be found, too. The faunistic turnover is characterized by the disappearance of *Megalodon* and *Triasina* and the appearance of the characteristic fauna of the hemipelagic facies (such as Jurassic Brachiopods, Forams and Ammonoids).

Fig. 11 The boundary of the T_3 and J_1 sediments (arrows indicate the signs of bioerosion)

5. Vugs in the J_1 limestone

Fig. 12a, Vug filled by laminated micrite, white isopachous calcite crust and a second generation of micrite, **12b** Vug filled by laminated micrite, white ispoachous calcite and yellow epigenetic calcite, **12c** Vug filled by laminated micrite, white isopachous calcite and crinoidal sand, **12d** Vug filled by rounded clasts of the host rock and fine-grained, laminated sediment.

The infilling of the vugs occuring in the Lower Jurassic limestone is similar to those in the Dachstein Limestone, but their morphology is different. Common feature of the vugs is the presence of rounded clasts of the host rock at their bottom (Fig. 12a,b,d). The lower boundary of the vugs is either sharp (Fig. 12c) or gradual (Fig 12d, 13) towards the host rock, while the upper limit is irregular. Some of the vugs are completely filled by multi-generation pink micritic sediment (Fig. 12d). In others, the upper part is filled by isopachous, white, bladed calcite (Fig. 12b). Based on the above observations these vugs were probably formed in a semi-lithified sediment in contrast to those found in the Dachstein Limestone.

Fig. 13 Base of a vug in J_1 limestone

6. Neptunian dykes

Fig. 14 Neptunian dyke in the Dachstein Limestone

Several generations of neptunian dykes crosscut the Upper Triassic and Lower Jurassic rocks (Fig. 14). These dykes are filled by brecciated clasts of the host rocks and by pink multi-generation laminated micritic sediment. As to the origin of these dykes two interpretations were proposed by LANTOS & MALLARINO 2000. Part of them are “ordinary” sedimentary dykes supposed to have formed along the margins of a fault block of the platform under extension. The others are injection dykes, formed by hydraulic fracturing due to earthquakes, triggered by sudden tectonic movements. Both the “ordinary” and the injection dykes were most probably associated with the rifting of Neotethys.

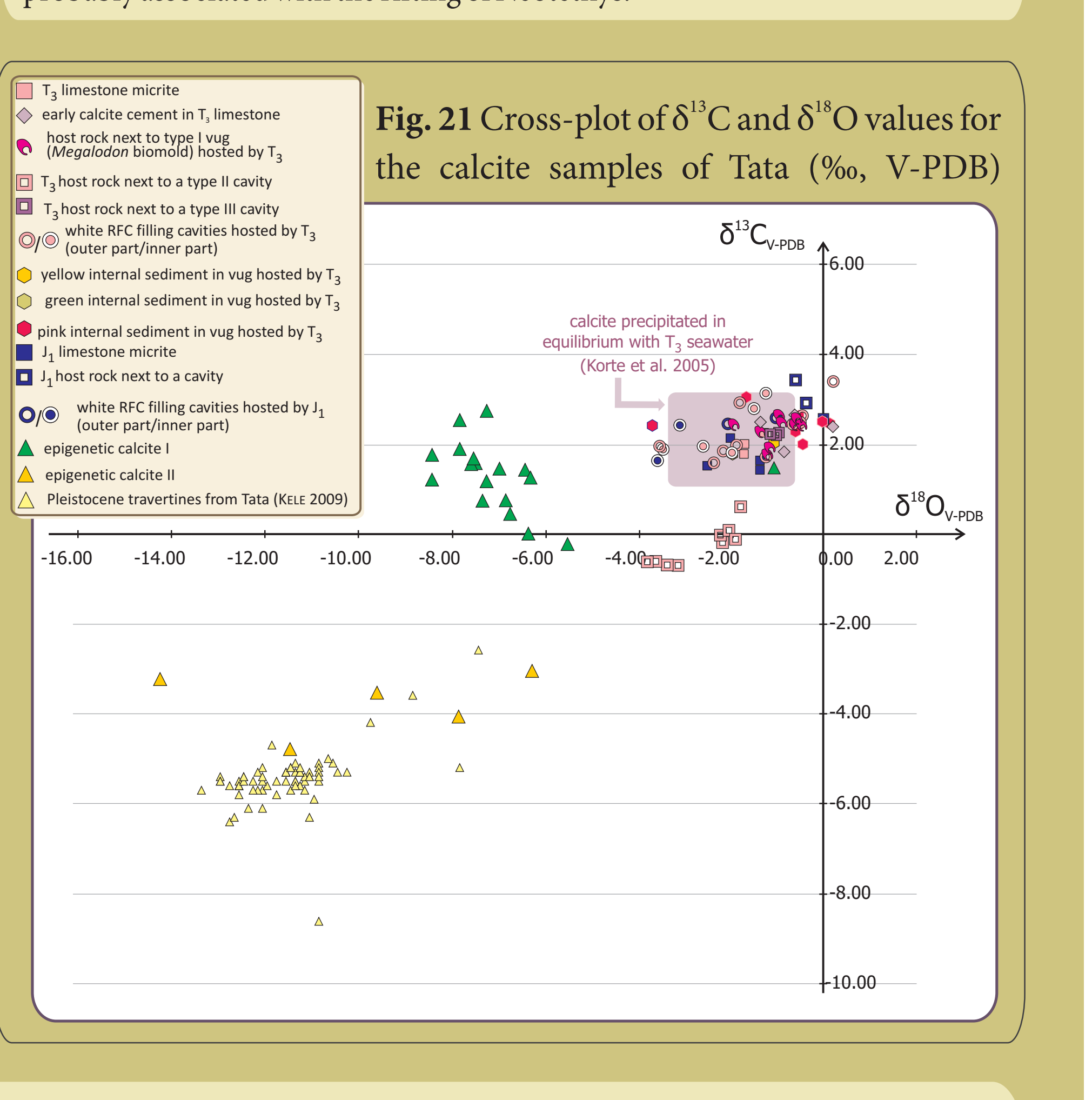


Fig. 21 Cross-plot of $\delta^{13}C$ and $\delta^{18}O$ values for the calcite samples of Tata (‰, V-PDB)

7. Epigenetic calcite I

1 to 20 cm wide late calcite veins crisscross the whole section (Fig. 15). The calcite is equigranular and either transparent or white to yellow (Fig. 16, 18a). The latter contains few micrometer sized spherical hematite inclusions (Fig. 18b). Transparent calcite is associated with minor amounts of euhedral pyrite. Staining of the samples by Dickson's solution revealed elevated iron-content for both.

CL pattern of the calcite samples shows alternating bright and dull zones (Fig. 17).

Stable isotope values of these epigenetic calcite veins are in the range of -0.18 to 1.86 $\delta^{13}C$, and -8.42 to -1.07 $\delta^{18}O$ (Fig. 21). Stable isotope values of sparry calcite filling the remaining porosity of some of type I and II vugs fall within the same range as values of these calcite veins do. The presence of primary all-liquid inclusions along spongy growth zones (Fig. 19) in these calcites indicates low temperature fluids (T<50°C) about 0 to 1.05 (2.57) NaCl equ. w% salinity (Fig. 20).

Fig. 15 Breccia zone in Lower Jurassic limestone, cemented by calcite I

Fig. 16 Calcite I, filling the remaining pore space in biomoldic vugs after *Megalodontids*

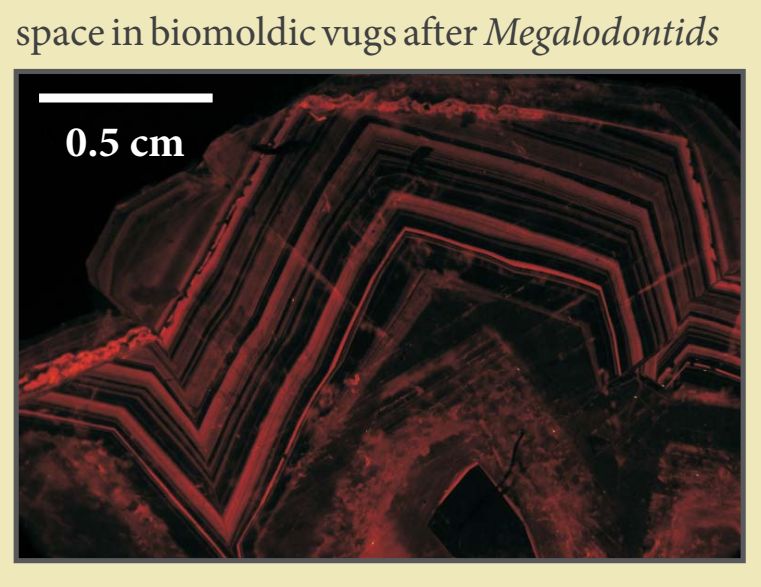


Fig. 17 Alternation of bright, dull and non-luminescent zones in epigenetic calcite

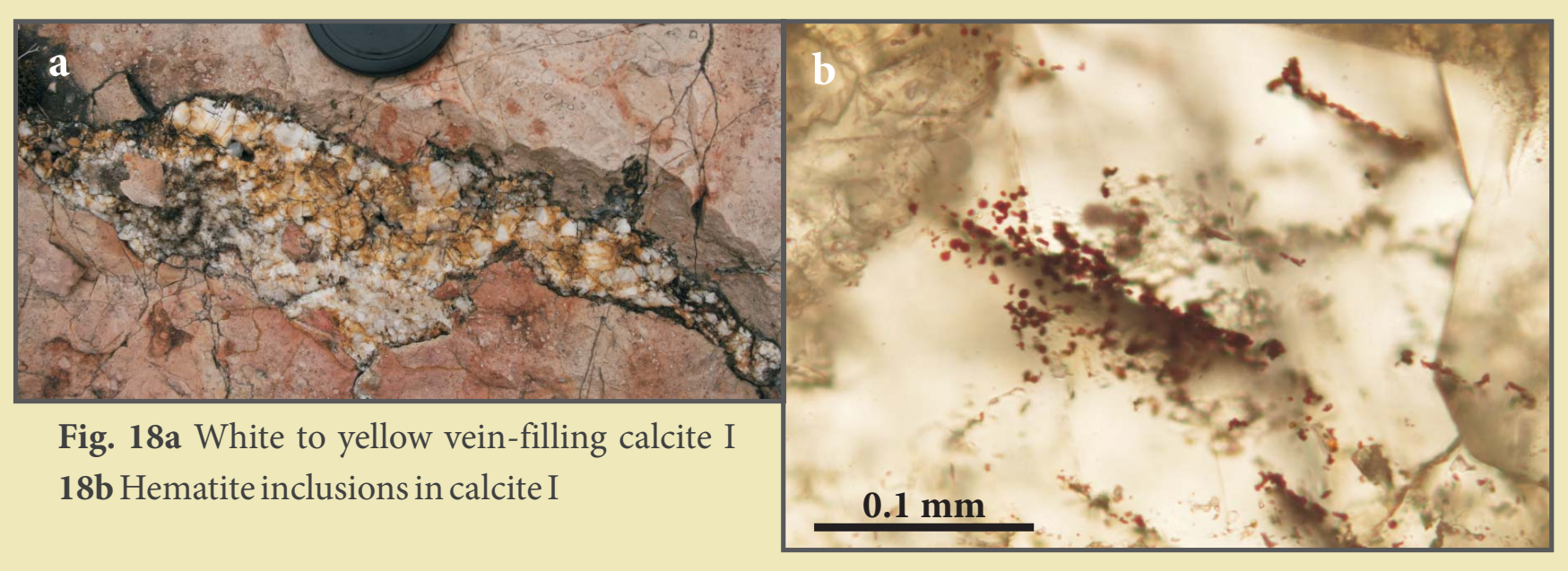


Fig. 18a White to yellow vein-filling calcite I **18b** Hematite inclusions in calcite I

Fig. 19 Primary fluid inclusions along growth zone in calcite I

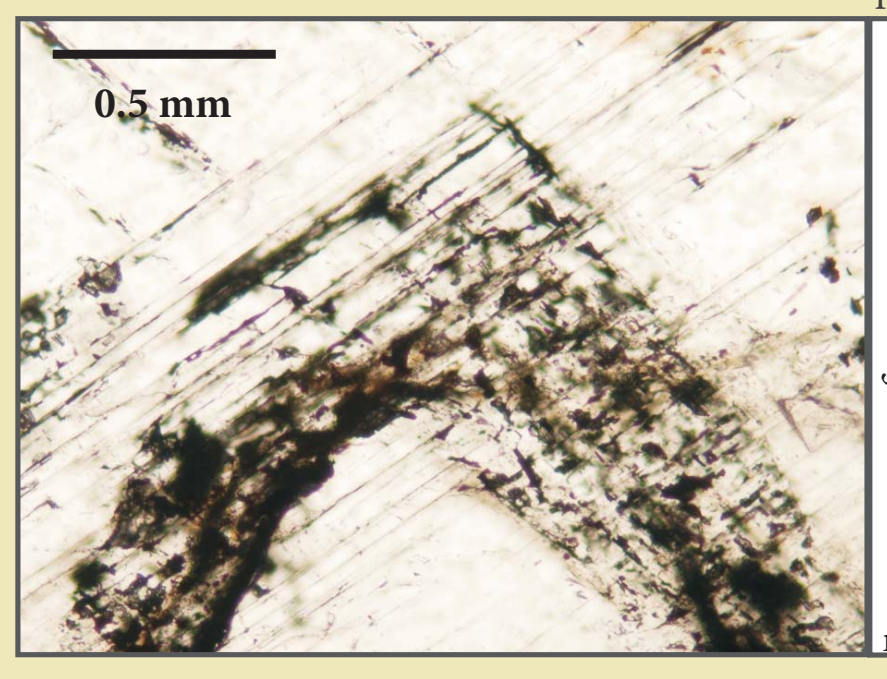
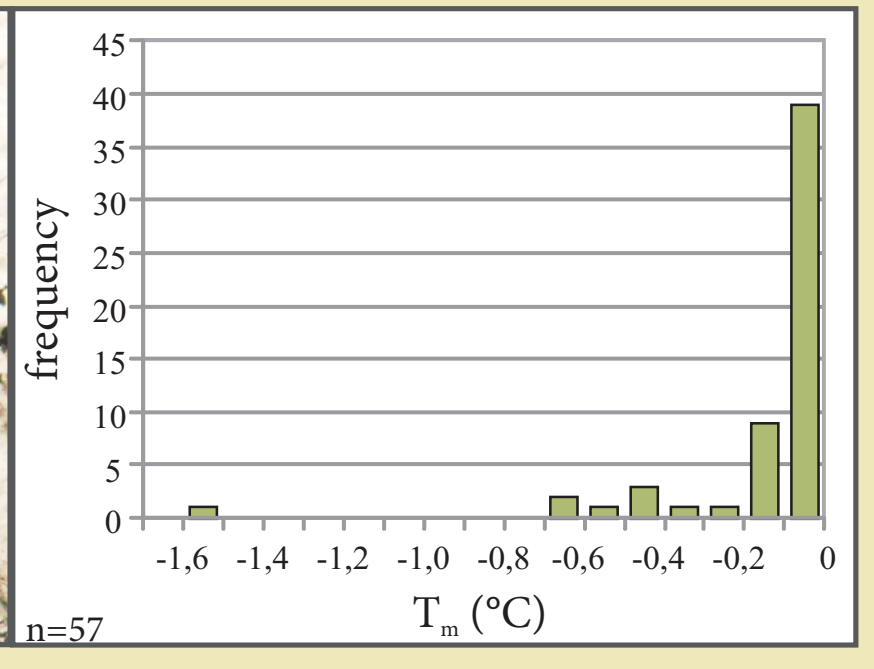


Fig. 20 Distribution of final melting T of ice in primary fluid inclusions of calcite I



8. Epigenetic calcite II

NE-SW and E-W striking narrow fractures are filled by transparent calcite crystals (Fig. 22b) associated with minor barite (Fig. 22c). This calcite occurs also as cavity fill (Fig. 22a). The cavities are isopachously filled with white bladed-fibrous calcite and are parallel to the strike of the main neokarstic cave system of Tata. The calcite has slightly elevated iron-content as revealed by staining and CL. Stable isotope values of this vein and vug-filling calcite are in the range of -4.76 to -3.01 $\delta^{13}C$ and -14.10 to -6.23 $\delta^{18}O$, suggesting meteoric origin (Fig. 20). Low temperature (<50 °C) and low salinity (0 to 0.53 NaCl equ. w%) (Fig. 23) of their parent fluids imply that they may be the part of the sub-recent karstwater system. Similar stable isotope values of Pleistocene travertines from the surroundings further confirm this theory (Fig. 21).

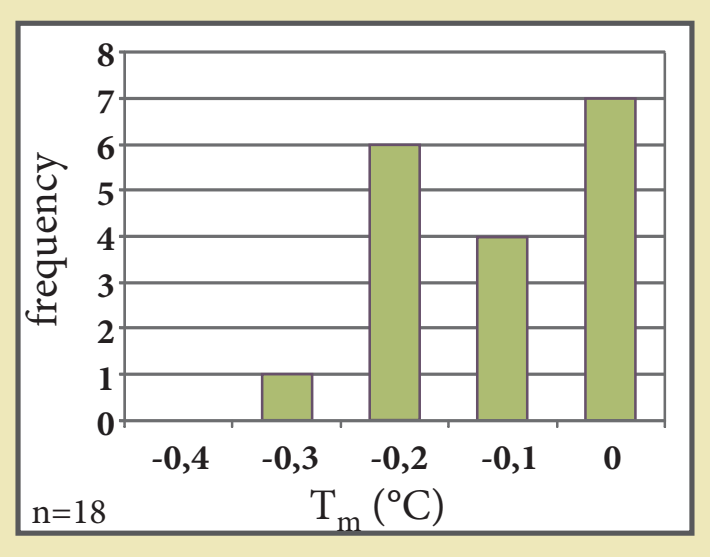


Fig. 23 Distribution of final melting T of ice in primary fluid inclusions of calcite II.

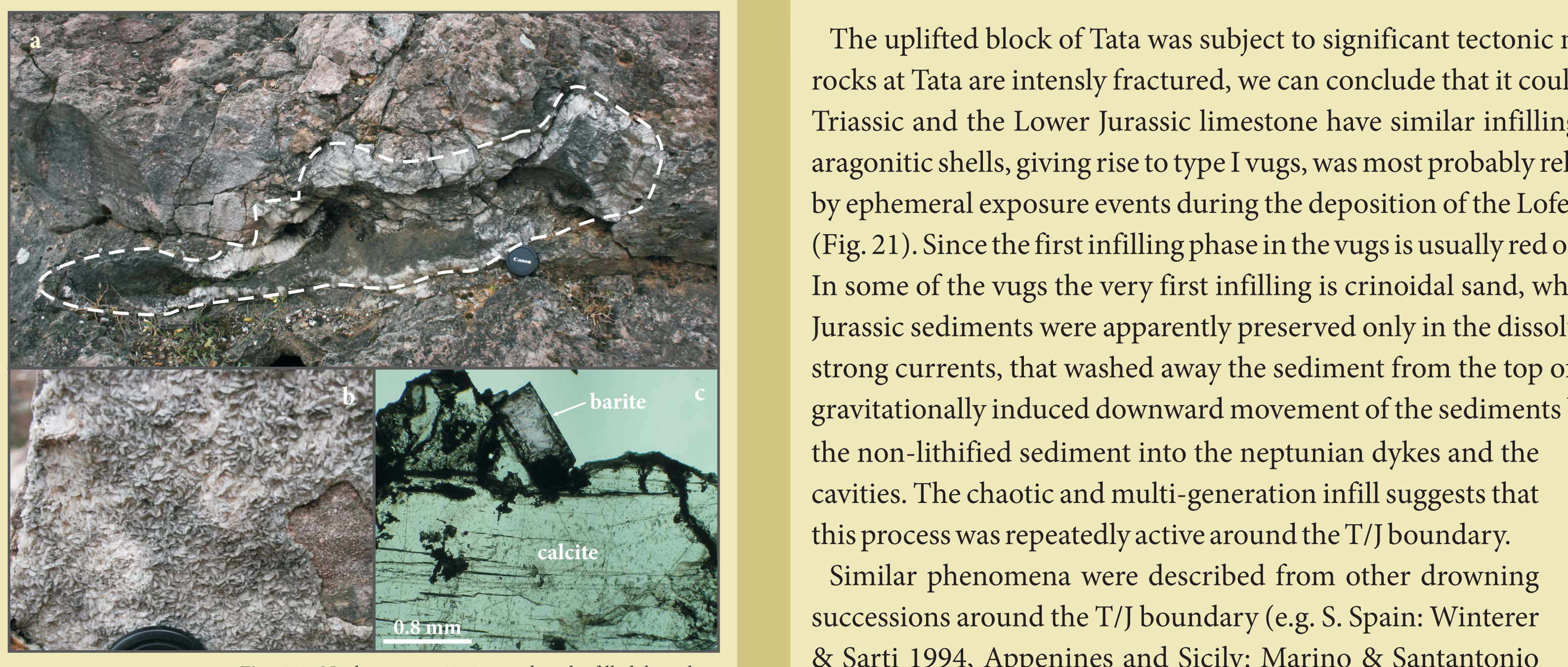


Fig. 22a Neokarstic cavity, isopachously filled by white fibrous-bladed calcite **22b** Rhombohedral calcite cementing breccia zone **22c** Tabular habit barite associated to calcite

9. CONCLUSIONS

The uplifted block of Tata was subject to significant tectonic movements around the T/J boundary related to the rifting of Neotethys. Since the rocks at Tata are intensly fractured, we can conclude that it could have been a margin of a fault block at that time. Although the vugs in the Upper Triassic and the Lower Jurassic limestone have similar infillings it may be assumed that they are of different origin. Dissolution of metastable aragonitic shells, giving rise to type I vugs, was most probably related to early diagenetic processes (Fig. 24). Dissolution of type II vugs was induced by ephemeral exposure events during the deposition of the Lofer-cyclic sediment as shown by the stable isotope data of the host rock next to them (Fig. 21). Since the first infilling phase in the vugs is usually red or pink like the Jurassic sediments above, we suggest that they are Jurassic in age, too. In some of the vugs the very first infilling is crinoidal sand, which is missing from the base of the Jurassic. Therefore we assume that the earliest Jurassic sediments were apparently preserved only in the dissolution vugs and neptunian dykes. The reason for this could be either bioerosion or strong currents, that washed away the sediment from the top of the drowned platform, or both. The exact process of infilling was not simply the gravitationally induced downward movement of the sediments but most probably earthquakes enhanced the efficiency of the process by injecting the non-lithified sediment into the neptunian dykes and the cavities. The chaotic and multi-generation infill suggests that this process was repeatedly active around the T/J boundary.

Similar phenomena were described from other drowning successions around the T/J boundary (e.g. S. Spain: Winterer & Sarti 1994, Appenines and Sicily: Marino & Santantonio 2010), suggesting that anomalous dissolution and cementation may have some causal relationship to the drowning event.

Late epigenetic fluids affected the succession as well (Fig. 24). Based on the fluid inclusion analysis of the cements we suggest that the precipitation of these calcites was driven by a regional paleo-groundwater flow. The formation of the younger calcite veins could be related to neokarstic processes. The presence of barite in the paragenesis suggests that exotic fluids (of basinal origin?) might have also played a role in the mineralization

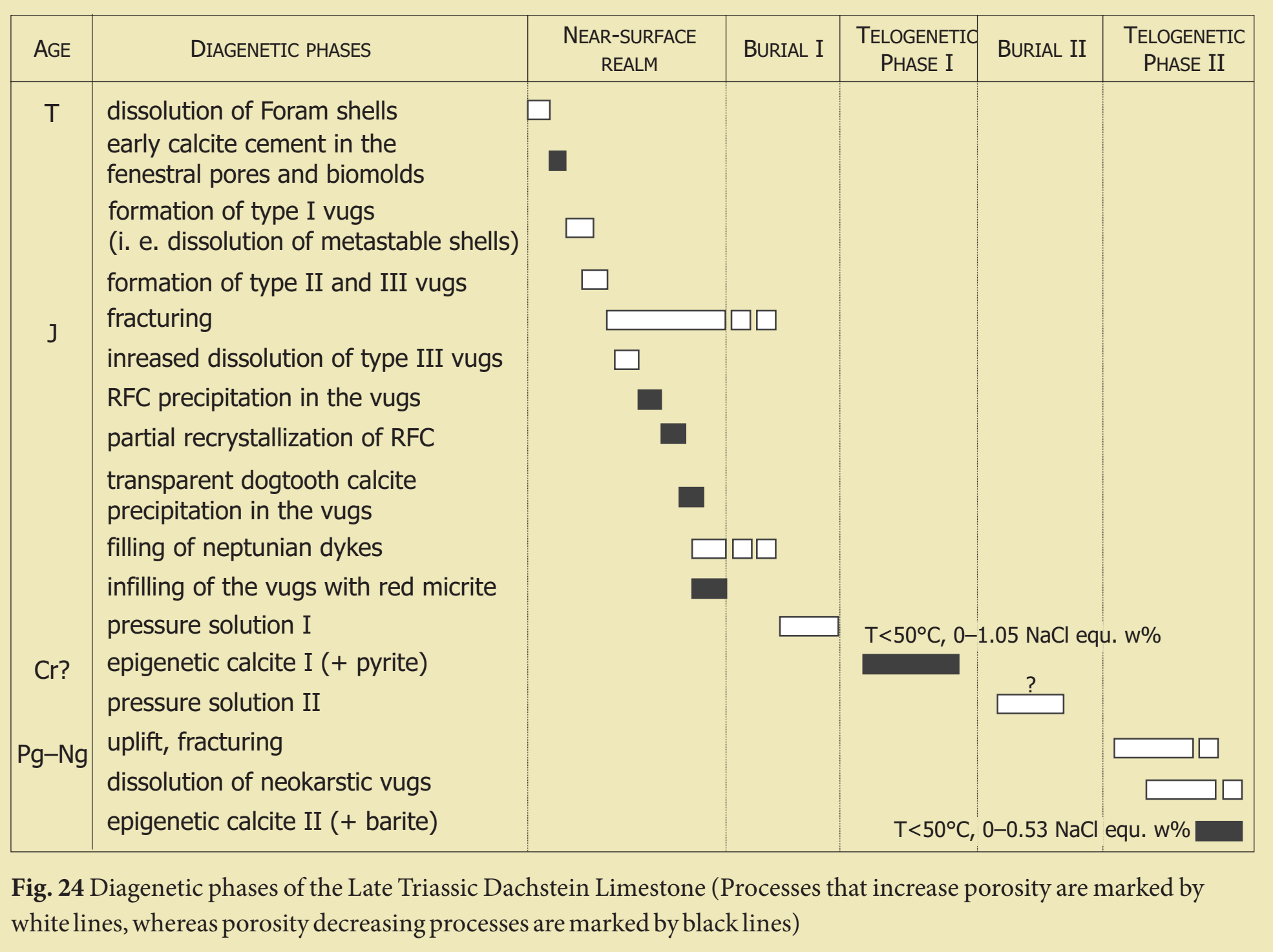


Fig. 24 Diagenetic phases of the Late Triassic Dachstein Limestone (Processes that increase porosity are marked by white lines, whereas porosity decreasing processes are marked by black lines)

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