Palaeokarst clefts and their filling at the type locality of the Honce Limestone (Turňa Unit): Petrographic analysis and its preliminary interpretation

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Abstract: Palaeokarstic cavities and clefts, filled with sedimentary material, were discovered in the marble quarry near Honce village in the Gemer area. The wall rock is the Honce Limestone, a marble formed by the metamorphism of the Lower Anisian Steinalm Limestone of the Turňa Unit. Analysis of the cavity fillings revealed that initially, they were filled with laminated calcarenites from the wall rock marbles, which later transitioned to siliciclastic sandstones and siltstones. The final filling consists of oligomictic breccias, dominated by non-metamorphosed sandstones and claystones, suggesting that the Lower Triassic Bódvaszilas Formation is the most likely source. This formation represents the basement of the Silica Nappe thrust onto the Turňa Unit. The filling of the clefts likely reflects the thrusting process, most plausibly estimated to occur during the Late Cretaceous to Palaeogene period.

Key words: Turňa Unit, Silica Nappe emplacement, palaeokarst, Lower Triassic

1. INTRODUCTION

The Meliata Superunit is a remnant of the Meliata Ocean, an oceanic domain that existed from the Middle Triassic to the Late Jurassic and bordered the future ALCAPA mega-Unit from the south. Currently, this superunit serves as a suture zone between the Central and Inner Western Carpathians. The remnants form a mélange composed mostly of blocks of Triassic ophiolites and sediments in a Jurassic shaly matrix. One of the commonly occurring blocks is the Honce Limestone, a metamorphosed equivalent of the pre-rift Lower Anisian Steinalm Limestone (Mello et al., 1997). The type area of the limestone is Roveň Hill (690 m a.s.l.) situated east of Honce Village, east of the county centre Rožňava in south-eastern Slovakia. The Honce Limestone was here initially defined as part of the Meliata Unit *sensu stricto* (Gaál, 1987) but later reinterpreted as a transitional Turňa Unit (Mello et al., 1997). At the base of the hill, in the quarry near Honce Village belonging to VSK MINERAL, s.r.o. company, large clefts were uncovered. Previous research visits to the quarry revealed a monotonous mass of white to pale grey marble, which was seldom studied (e.g., Potočný et al., 2023). However, recent mining progress has uncovered clefts ranging from one meter to tens of meters in size, filled with brownish breccias. Some isolated blocks of breccias were found earlier, but their source was unknown. Predominantly allochthonous material of the breccias and their well-lithified nature suggest that they do not represent a Quaternary karst filling, but rather a palaeokarstic one (older than Quaternary and presently inactive – see Bosák et al., 1989). This paper presents the first data on the petrographical analysis of the material that fills the clefts. It is revealed that these findings may be of significant importance for understanding the tectonic evolution of the area.

2. GEOLOGICAL SETTING, SAMPLED SITES, MATERIAL AND METHODS

Roveň Hill, where the studied quarry is located, is considered to be a part of the Turňa Unit. The Silica Nappe was thrust onto this unit (Mello et al., 1997). A recent outlier of the Silica Nappe, known as the Plešivec Plateau, is located approximately 1 km south of Honce village (Fig. 1A). In the quarry only the basal level has briefly been studied and sampled (Fig. 1B). Other potential occurrences of palaeokarstic clefts on different levels have not yet been investigated. The clefts are found in the western part of the basal level. In the northern wall, a cleft about 0.5 m wide can be observed (Fig. 2A,B). Samples 1a-c were taken from breccias found in the scree, with sample 1c showing the transition from the initial laminated filling to the breccia filling of the cleft (Fig. 3A). Samples 2a-c were directly taken from the cleft and represent the laminated initial arenitic fillings of the cleft (Fig. 2F). In the western wall there is a wedging-up cleft (Fig. 2C) filled mostly with laminated arenitic sediment (Fig. 2D). Signs of slight corrosion can be seen on the cleft walls (Fig. 2D). Sample 3a was studied from the breccia filling and sample 3b from the laminated arenite. Honce Limestone wall rock, stained red, was studied in 3 samples, 4a-c. Additionally, a piece of siderite (sample 4d) was found in the scree in this part of the quarry, likely derived from the cleft filling. The southern wall of the studied part of the basal quarry level is entirely formed by a coarse-grained breccia with clasts of up to 10 cm in diameter. Samples 5a-c were taken from less coarse-grained breccias from the scree to allow the petrographic study of as many clasts as possible using thin sections. Thin sections were made from all 17 samples and studied under polarized light.

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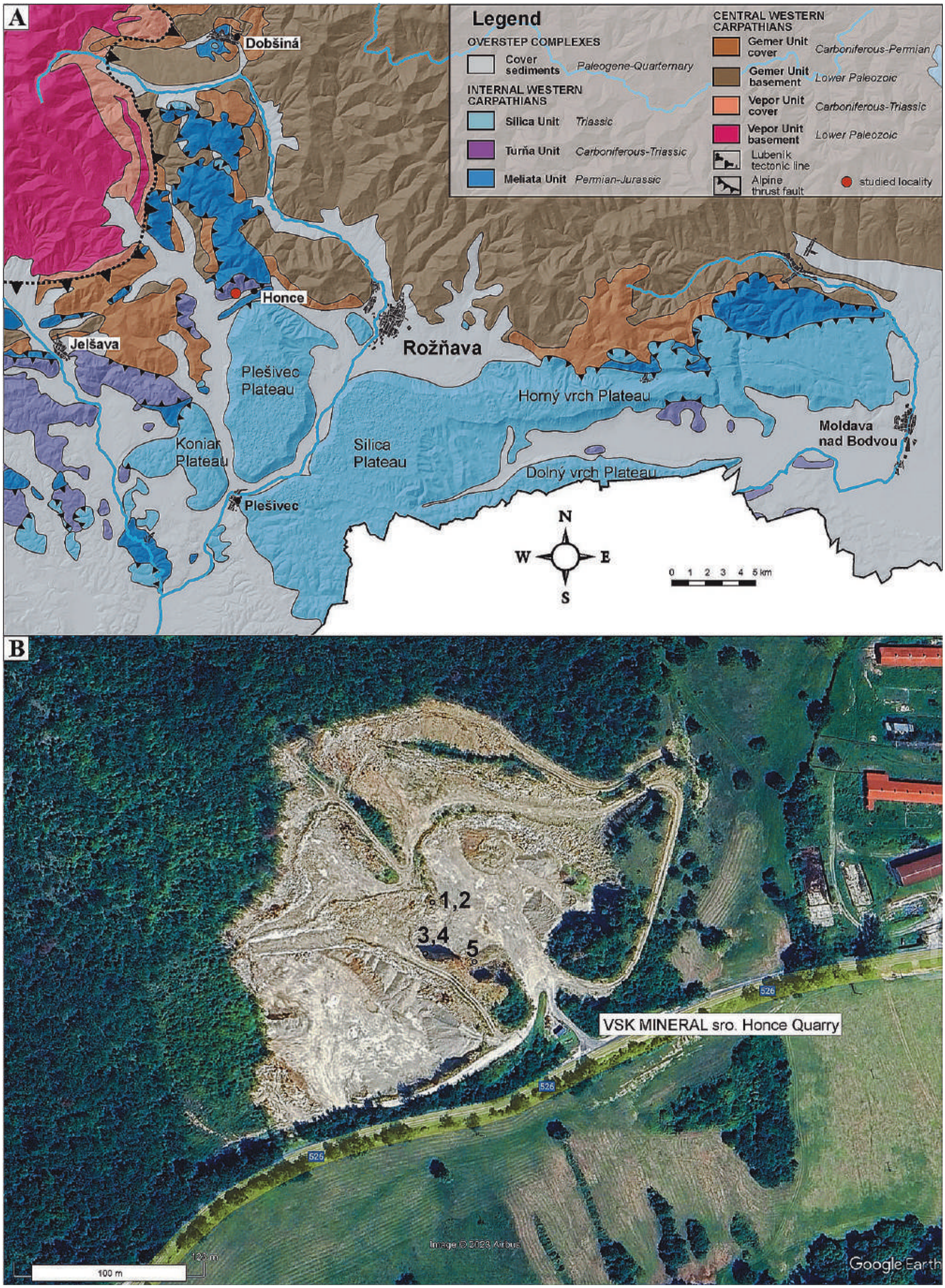

Fig. 1. Position of the examined locality and sampling sites. A – Position of the examined locality within the frame of the tectonic map of south-eastern Slovakia. Basal tectonic map after Bezák et al. (2004) - modified. B – Position of the sampling sites in the Honce quarry. Photo: Google Earth (2023).

3. RESULTS

3.1. Wall rock

The petrographic study focused on the wall rock (Honce Limestone) samples that were in contact with the cleft fillings. Samples 4a-c were specifically studied because of their red staining, which suggested they could be part of the cleft fillings. The marble primarily consists of blocky calcite with few inclusions and faint crystal boundaries (Figs. 4A,5A). However, the red staining in samples 4a-c made the crystal boundaries more visible (Fig. 5B-C). These crystals contain dense inclusions, giving them a dusky appearance. The crystals are mostly isometric in shape and resemble Type 3 calcite found in the marbles studied by Potočný et al. (2023). Some parts of the rock show sheared crystals (Fig. 5C).

3.2. Initial laminated filling of the palaeokarst clefts

The most informative sample of the laminites is sample 3b (Figs. 4B,5D). The earlier laminae consist mostly of marble detritus from the wall rock, with a silty clayey matrix or sparry calcite. These components are gradually replaced by siliciclastic detritus, corresponding to the fine-grained silty to sandy matrix material of the breccias. This includes quartz grains, mica flakes, and small clasts of claystones (Fig. 6A). Between these two phases, a thin (several mm in thickness) sinter crust developed, consisting of brown bladed calcite with thin silty laminae.

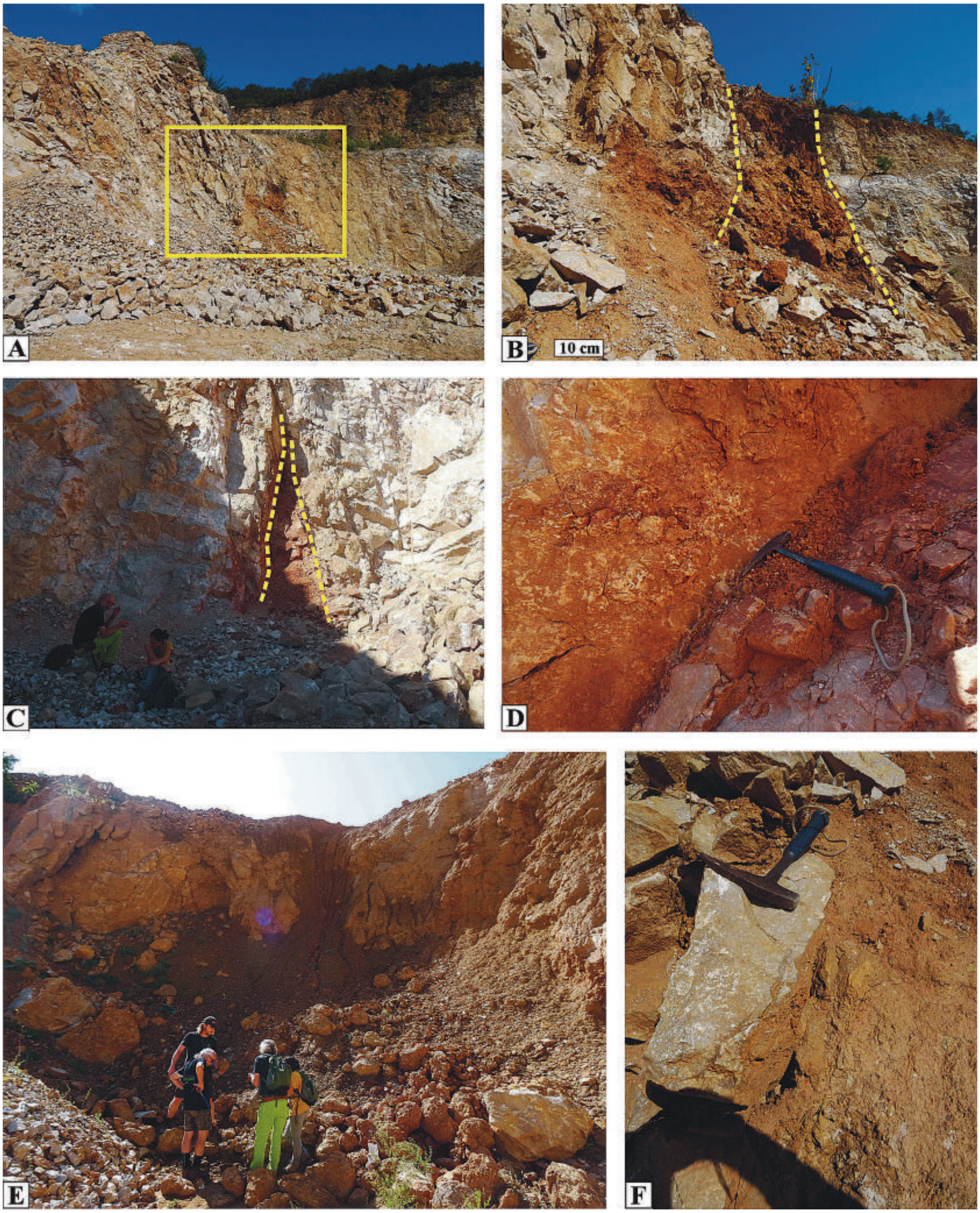

Fig. 2. Field views on the sampling sites on the basal level of the Honce quarry. A – View on the northern side from which samples 1a-c and 2a-c were taken. The yellow rectangle marks the approximate view on B. B – A detailed view of the cleft in the northern part. Dashed lines mark the cleft boundaries. C – View of the cleft in the western part of the quarry base (samples 3a-b and 4a-d). Dashed lines mark the cleft boundaries. D – A detailed view of the initial laminated filling of the cleft. Note the slight corrosion on the wall. The hammerhead marks the cleft boundary. E – View on the southern part of the quarry base. The entire wall is a giant cleft filled mostly with breccia (samples 5a-c). F – Block showing contact of the pale wall rock with a red initial laminated filling of the cleft (see sample 2c).

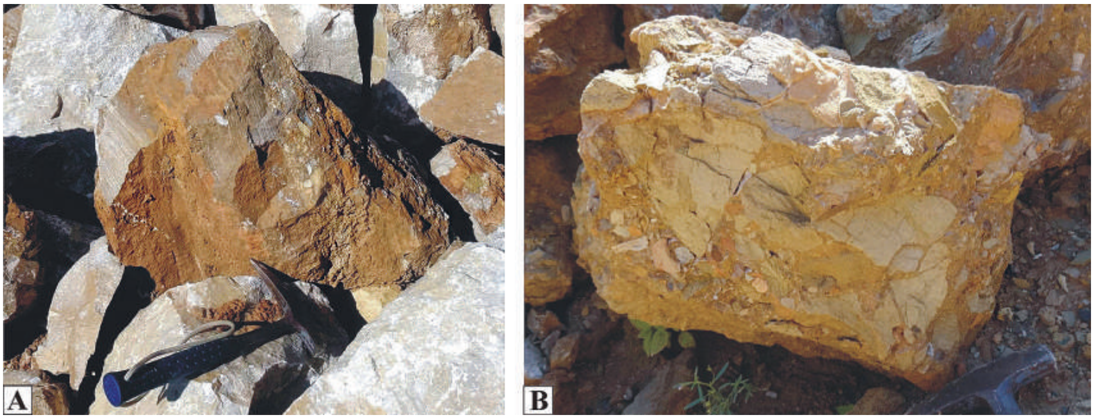

Fig. 3. A – Block with initial laminated filling (left) passing to breccia filling (right). From this block, sample 1c was taken. B – Example of a coarse-grained breccia from the southern part of the quarry base.

The micro-succession is terminated by a thicker sinter lamina.

Other samples from the initial laminites display similar successions and compositions. Some of them also have brownish muddy laminae without silt or sand. The detritic laminae contain numerous opaque Fe-Mn minerals. Some laminae contain fenestral-like voids (Fig. 6B), some of which are partly filled with drusy calcite while others are empty (Fig. 6C). The drusy calcite is sometimes zoned (Fig. 6D). The origin of these voids is unclear, but they likely remained after leached evaporites.

Sinter laminae are common in all the initial laminated fillings. The crystals in these laminae are isopachous and do not show signs of gravity-influenced shapes. Some samples indicate that the precursor of the bladed calcite was fibrous calcite (Fig. 7A-D). In plane polarized light, the fibrous calcite displays very thin fibres perpendicular to the base, similar to erect microbial filaments found in siliceous sinters in sandstone caves in South-American tepuis (Aubrecht et al., 2008a,b, 2012). When observed under crossed polars, only the bladed

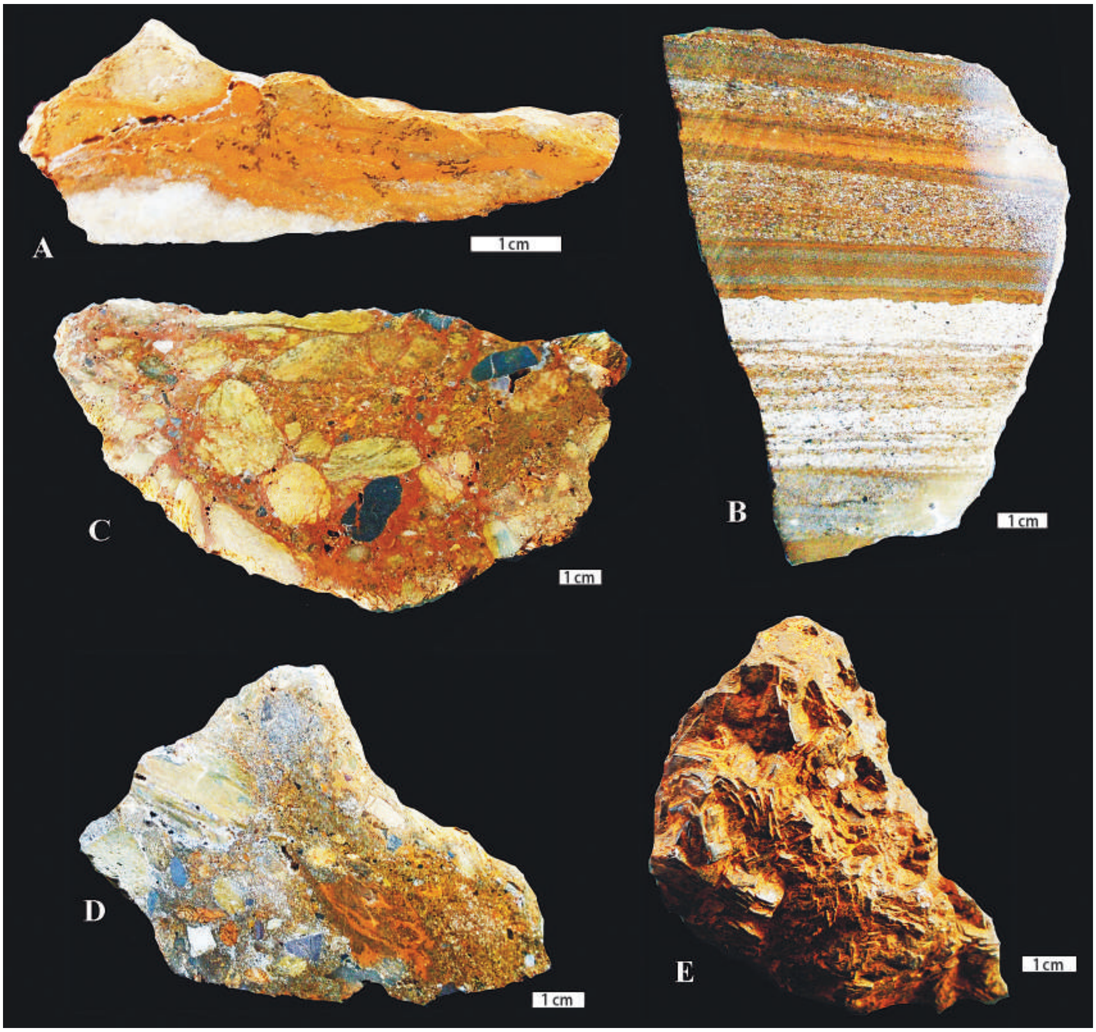

Fig. 4. A – Sample 2c shows a contact between the wall rock marble (white) with laminated initial cleft filling (red). B – Sample 3b shows laminated initial cleft filling from the western part of the quarry base (see Fig. 2D). Note the gradual transition from the marble-dominated clastic laminae (pale) to siliciclastic laminae (brown). C – Breccia sample 3a. D – Breccia sample 5c. E – Sample of siderite (4d) from the western part of the quarry base.

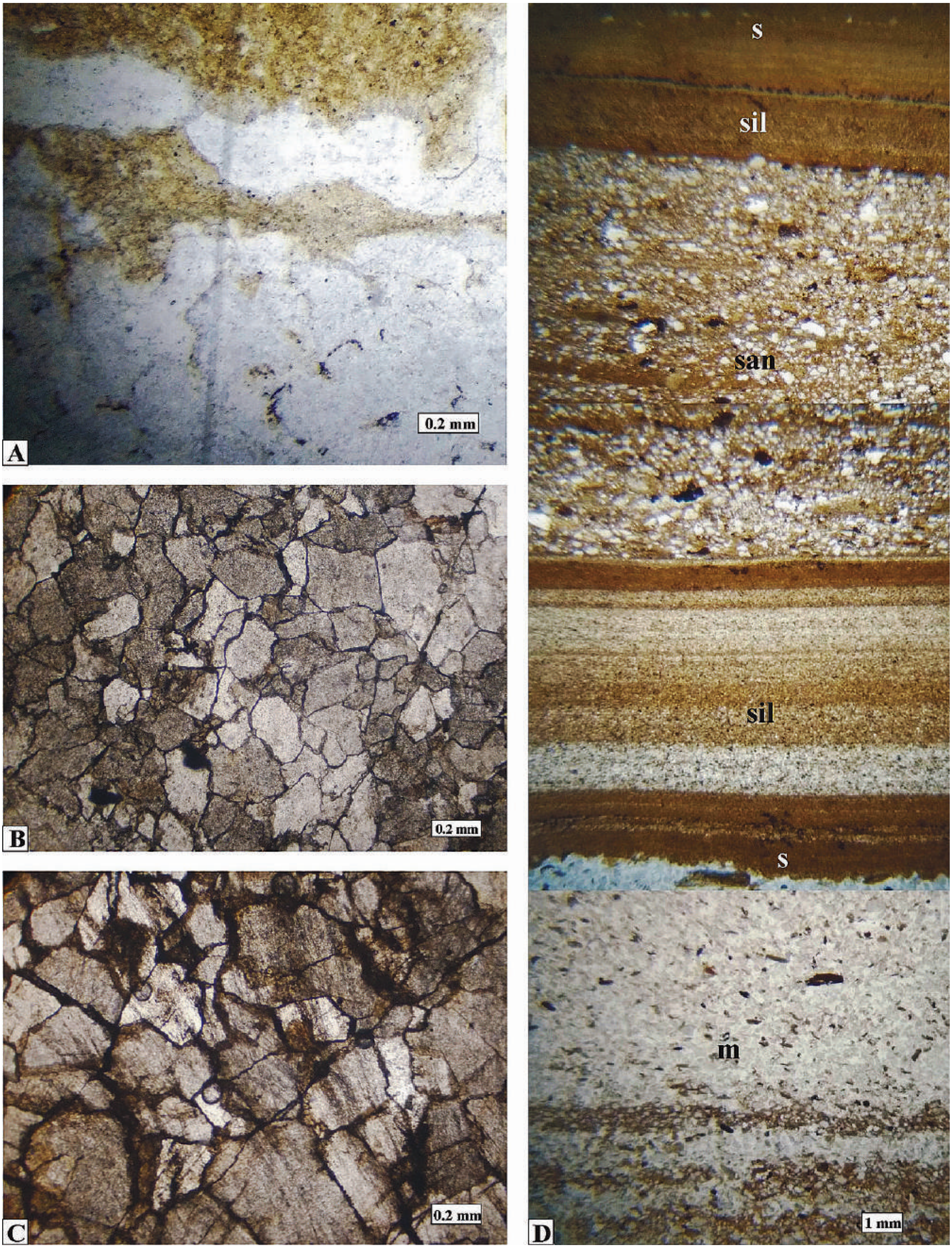

Fig. 5. A – Contact of the initial cavity filling (brownish) with the Honce Limestone wall rock (white). Note very faint crystal boundaries in the marble. Sample 2c. B – Red-stained wall rock marble with isometric crystals and visible crystal boundaries. Sample 4b. C – Local shearing visible on the marble crystals. Sample 4c. D – Enlarged succession of the laminated initial cavity filling in sample 3b. m – marble detritus, s – sinter, sil – siliciclastic silt, san – siliciclastic sand. All photos are under plain polarized light.

structure is visible. Some sinter laminae are discontinuous and patchy, further supporting their possible microbial origin. The microbial activity in the examined palaeokarst cavities is also suggested by the presence of occasional thin layers of peloidal microsparite (see Fig. 7E–F).

3.3. Breccias

The breccias range from clast-supported to matrix-supported (see Figs. 3,4 C-D). The matrix of the breccias is often sandy to silty, clayey, or carbonatic, commonly containing impregnations of opaque minerals likely composed of Fe-Mn oxides. Interestingly, fenestral-like voids resembling those observed in the laminites are frequently found in the matrix. Additionally, discontinuous sinter laminae can be observed within the matrix, which are similar to those present in the laminites, including the fibrous precursors.

The most common clasts found in the breccias are quartzites and sandstones, as well as claystones, which show no signs of metamorphism. The quartzites are composed of tightly packed quartz grains often without any matrix (Fig. 8A). Carbonate rhombohedra of unknown origin are sometimes present in the sandstones and quartzites (Fig. 8B-C). Some of these carbonate crystals have been leached, resulting in empty voids. These rhombohedra are similar to those described by Mišík (1993) in chert nodules. However, it should be noted that the carbonate crystals are independent of the quartzite structure, indicating that they represent a late-stage crystallization phase and do not indicate recrystallized cherts. Corrosion is evident in some quartzite clasts, which also affects the surrounding matrix (Fig. 8D), suggesting that the corrosion occurred within the sediment. The claystones locally display detailed folding patterns (Fig. 9A). Additionally, clasts with alternating laminae of sandstone and claystone (Fig. 9B) suggest that they likely originated from the same formation. One particular claystone clast contains calcite-filled voids (Fig. 9C). However, all of the calcite grains exhibit simultaneous extinction, indicating pervasive calcification rather than simple void fillings. Recrystallized silicites and graphitic quartzite clasts are occasionally present as well. Clasts derived from the wall rock (marble) are rare.

3.4. Fragment of siderite

A fragment of siderite, discovered in the western portion of the quarry base, exhibits a red to dark-brown colour and

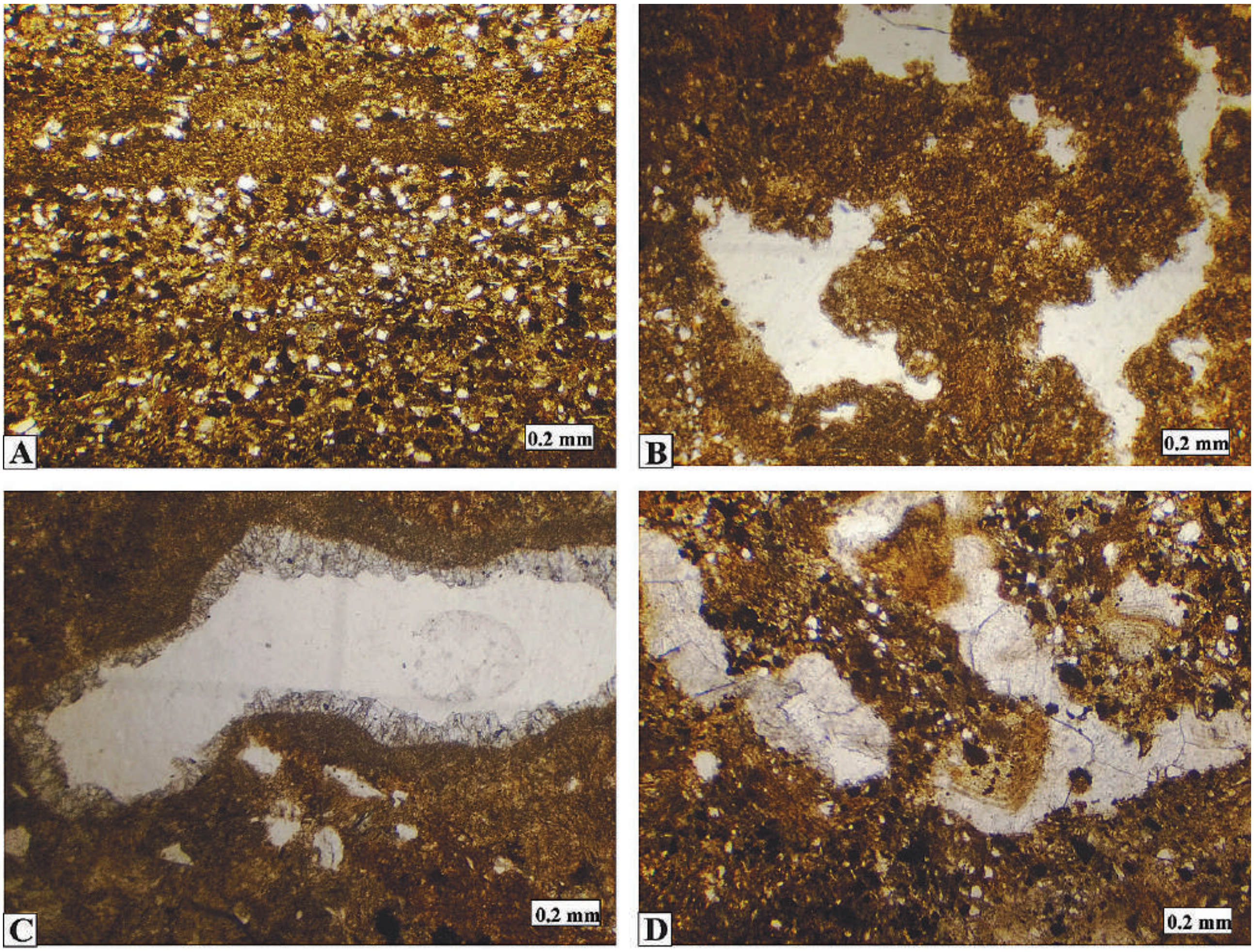

Fig. 6. A – Detailed view of the siliciclastic silty part of laminite. Sample 2a. B – Fenestral-like voids in laminite. Sample 2a. C – An empty void partly filled by initial drusy calcite. Sample 2c. D – Voids filled with zoned blocky calcite. Sample 2a. All photos are under plain polarized light.

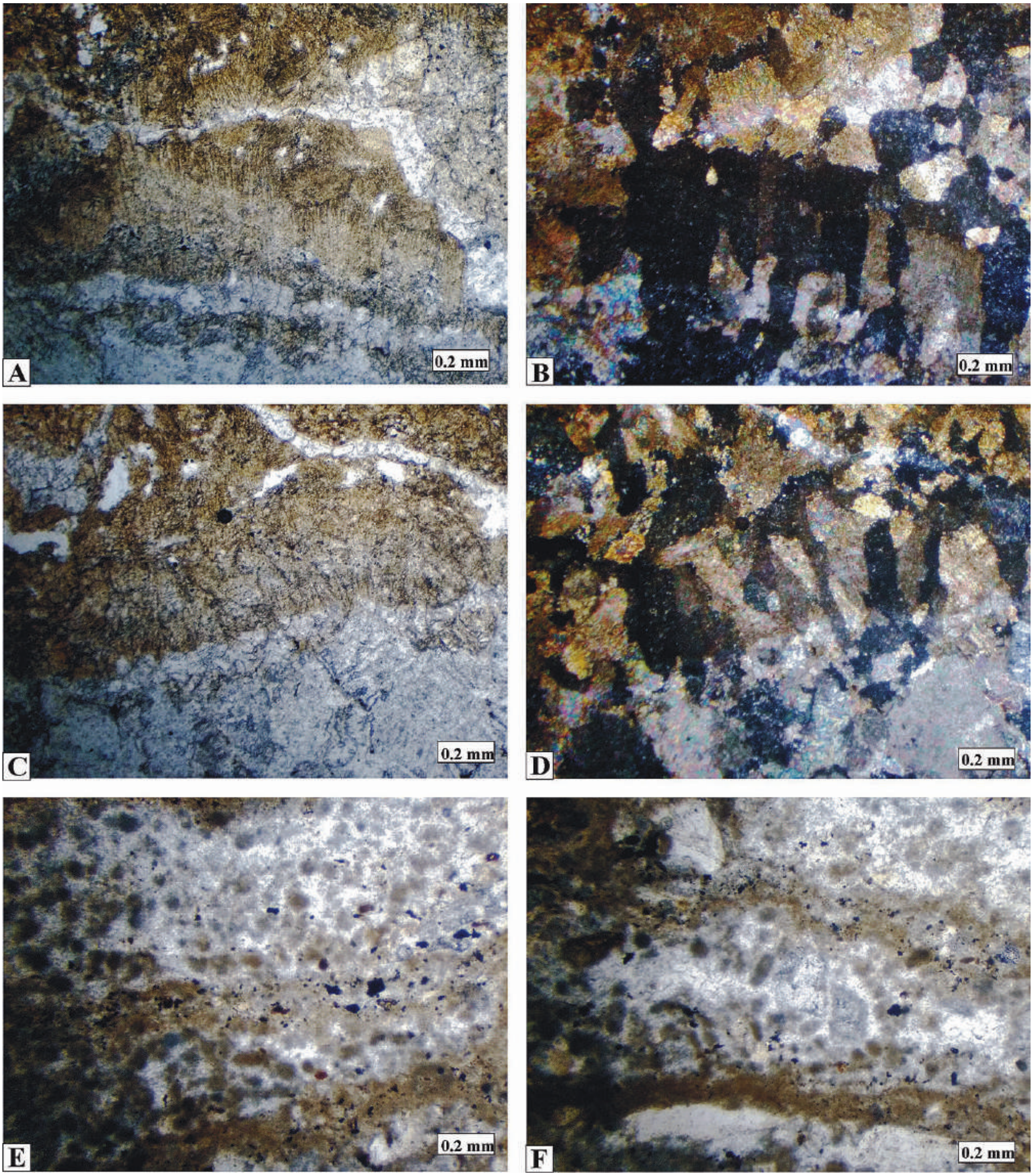

Fig. 7. A – Sinter showing fibrous structure under plain polarized light. B – The same under crossed polars showing the fibres recrystallized to bladed calcite. Sample 2 c. C-D – Other sinter from the same sample. E-F – Peloidal microsparite in the laminated part of sample 1c indicating microbial activity in the palaeokarst cavity. Plain polarized light.

well-developed crystal faces. When observed under plane polarized light, the fragment remains translucent, revealing a visible crystal texture (Fig. 9D-E). Filamentous structures, potentially representing remains of microbial filaments, are visible within the crystals (Fig. 9F). Some of these structures resemble filaments of the common iron bacteria *Gallionella ferruginea* Ehrenberg (cf. Aubrecht et al., 2012).

4. INTERPRETATIONS AND DISCUSSION

Based on a summary of the filling evolution of the studied palaeokarstic clefts and their rock inventory, it becomes evident that the breccias are oligomictic and their clast rocks are well preserved, in stark contrast to the wall rock marbles. The most plausible interpretation is that the clasts originated from the

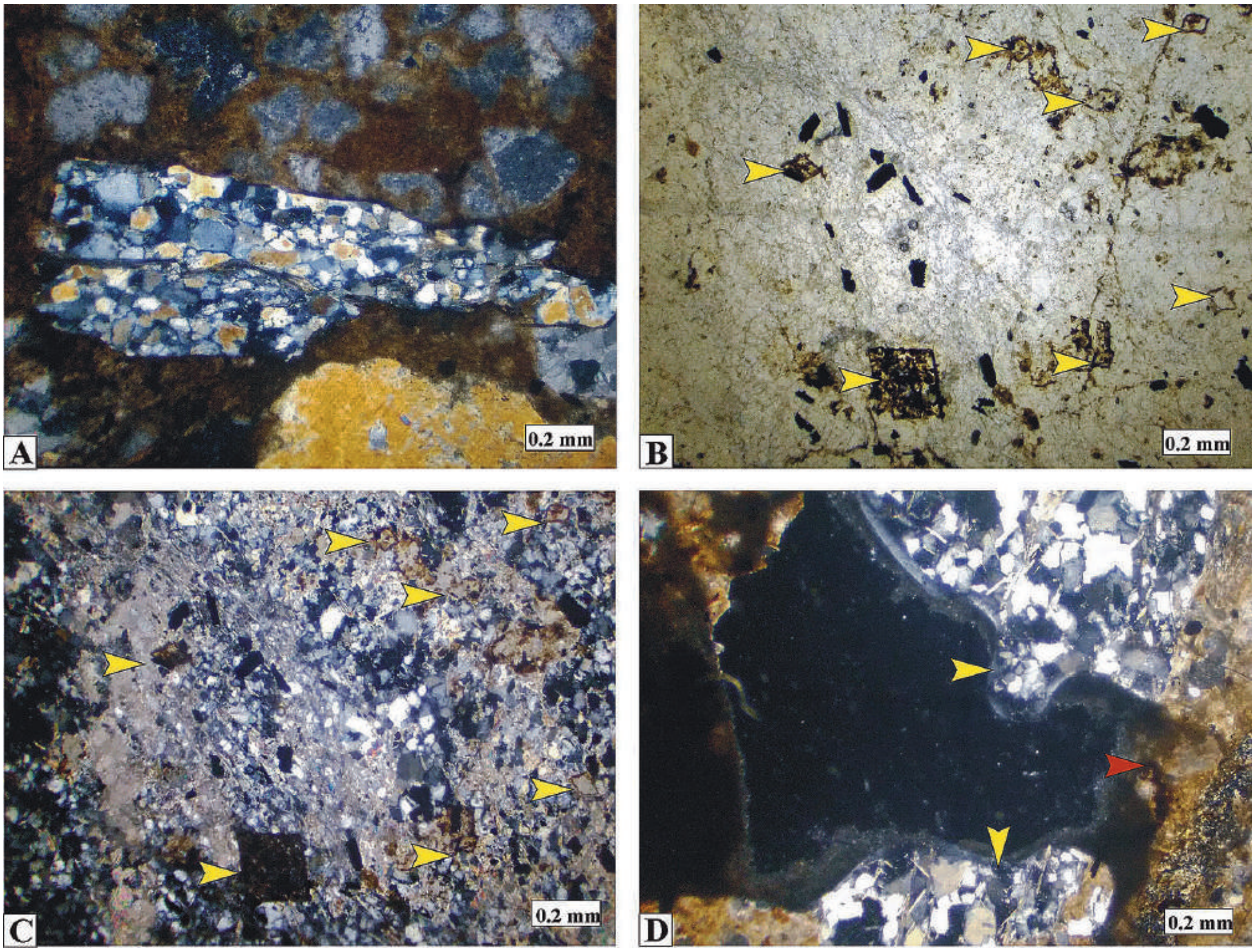

Fig. 8. A – A clast of quartzite in breccia. Sample 1c. Crossed polars. B – Carbonate rhombohedra in a sandstone clast (marked by yellow arrows). Plane polarized light. C – The same under crossed polars. Sample 1d. D – Signs of corrosion on two quartzite clasts (yellow arrows) and on the breccia matrix (red arrow). Crossed polars. Sample 1c.

lower portion of the Lower Triassic strata, specifically the Bódvaszilas Formation (interpreted earlier by Mello et al., 1997 as a lower part of the Werfen Formation from the Eastern Alps), which mainly consists of sandstones, quartzites, and claystones (Kovács et al., 1989; Mello et al., 1997; Hips, 1996, 2001). The perfect state of preservation free of any signs of metamorphism indicates that these clasts were likely derived from the overlying Silica Nappe, which has been thrust onto the Turňa Unit. In this area, the Silica Nappe is structurally the highest unit and has experienced minimal diagenetic or metamorphic overprint. The gradual filling evolution, starting from calcarenites derived from the wall rock marbles and progressing to siliciclastic siltstones and sandstones before culminating in coarse-grained breccia fillings, suggests that the sedimentary record may reflect the final tectonic emplacement of the Silica Nappe, specifically its thrusting onto the Turňa Unit. Very similar breccias in identical tectonic position were described from the Rákoš area, which is situated in the same unit east of the studied locality Honce (Lačný et al., 2015). It indicates that such palaeokarst fillings are not just a local phenomenon, but they are regionally widespread. From this perspective, the studied material holds significant importance. Numerous fenestral voids observed throughout all the filling phases can be interpreted as leached evaporites derived either directly from the Bódvaszilas Formation or from the lower unit - Permian Perkupa Formation, which is predominantly formed by evaporites (equivalent to the Haselgebirge Formation in the Eastern Alps). The presence of an evaporitic basement within the Silica Nappe facilitated its easier thrusting. Alternatively, these fenestral voids may have resulted from fluid overpressure occurring at the nappe basement during thrusting, allowing for easier emplacement (Milovský et al., 1999, 2003). The siderite fragment appears inconsistent with the rock inventory of the Bódvaszilas Formation, as this iron ore is typically abundant in the Palaeozoic complexes of the Gemer Unit. However, recent research indicates that veins of siderite and ankerite also locally intersect the Bódvaszilas Formation of the Silica Nappe (Vojtko et al., 2023).

The origin of the Silica Nappe system remains uncertain, as does the timing of its final emplacement (Plašienka, 2018). The closure of the Meliata Ocean is placed in the Late Jurassic, which is supported by palaeontological data revealing the Middle Jurassic age of its sedimentary mélange matrix (Mock et al., 1998; Aubrecht et al., 2010). Subduction metamorphism is established within the range of 150-170 Ma (Faryad & Henjes-Kunst, 1997;

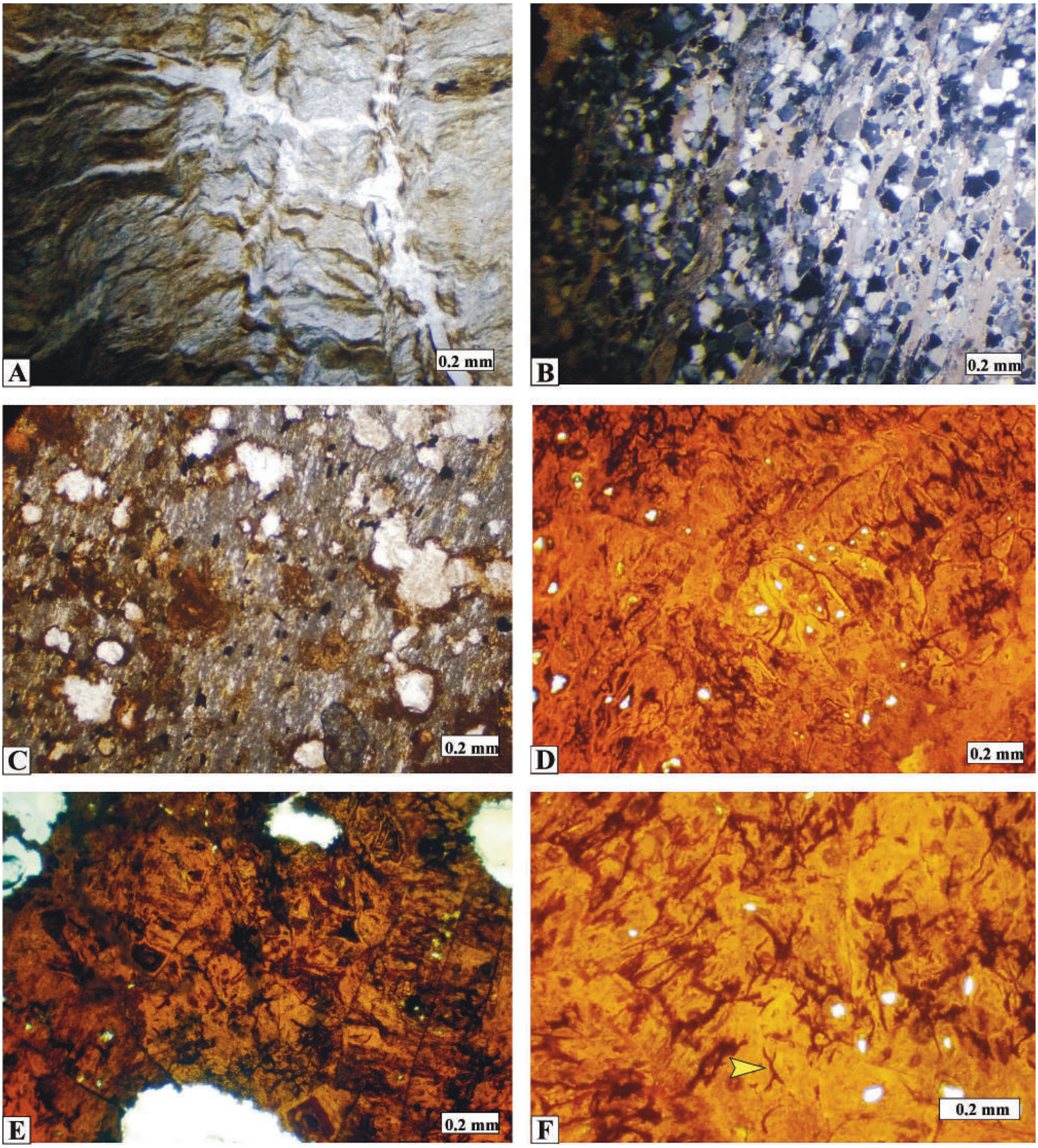

Fig. 9. **A – Detailed folding of laminae in a claystone clast. Sample 1a. Plain polarized light. B – Clast with alternating laminae of sandstone and claystone. Crossed polars. Sample 1a. C – Clast of claystone with uniformly extinguishing calcite crystals. Sample 3a. Plain polarized light.**
D-E – Well-developed crystal structure of siderite. Sample 4c. Plain polarized light. F – Filamentous structures in siderite similar to filaments of iron bacteria *Gallionella ferruginea* **(the most typical one marked by a yellow arrow).**

Dallmeyer et al., 2008; Faryad & Frank, 2011; Putiš et al., 2019, 2022). However, the ultimate emplacement of the Silica Nappe's topmost structural units may have occurred much later, in the Late Cretaceous or even the Palaeogene (Mello & Salaj, 1982; Hovorka et al., 1990; Slavkay & Rohalová, 1993; Vojtko et al., 2016, 2017). This temporal distinction is crucial, given that the entire history of the Honce Limestone, from metamorphism to uplift and karstification, must precede the nappe thrusting. Consequently, the Late Cretaceous to Palaeogene age of the studied cavity fillings seems most plausible.

The data presented in this paper are in the early stages, and all interpretations are preliminary. Subsequent research will concentrate on completing rock inventory data from potential additional clefts, assessing cleft geometry and wall-rock tilting.

Geochemical analyses, including stable isotopes, particularly from sinters, will be applied to evaluate the cleft fillings.

5. CONCLUSIONS

The analysis of palaeokarstic clefts in the Honce marble quarry within the Turňa Unit indicates that their filling initiates with laminated arenites, predominantly composed of calcarenites from wall rock marbles subsequently transitioning to siliciclastic sandstones and siltstones, culminating in oligomictic breccias. The dominance of non-metamorphosed sandstones and claystones in the breccias suggests the Lower Triassic Bódvaszilas Formation as the probable source, representing the basement of the Silica Nappe thrust onto the Turňa Unit. The cleft fillings likely mirror the thrusting process, with a plausible estimation of Late Cretaceous to Palaeogene timing, although certainty is yet to be established.

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