

### **Field campaign 7 – late Cenomannian/late Santonian – early Eocene unconformity (October 8-15, 2021)**

On the seventh field campaign, the PALEO and GEO teams explored and sampled the third unconformity (late Cenomannian/late Santonian – early Eocene). The primary focus of this field campaign was to sample the bauxites in the abandoned Minjera mines, together with their foot wall and hanging wall succession while also searching for additional outcrops of the third unconformity. First five days of the field campaign consisted of sampling in the Minjera mines, during which a suitable outcrop was found close to the village of Macinići. The sampling there was then conducted during the rest of the field campaign.



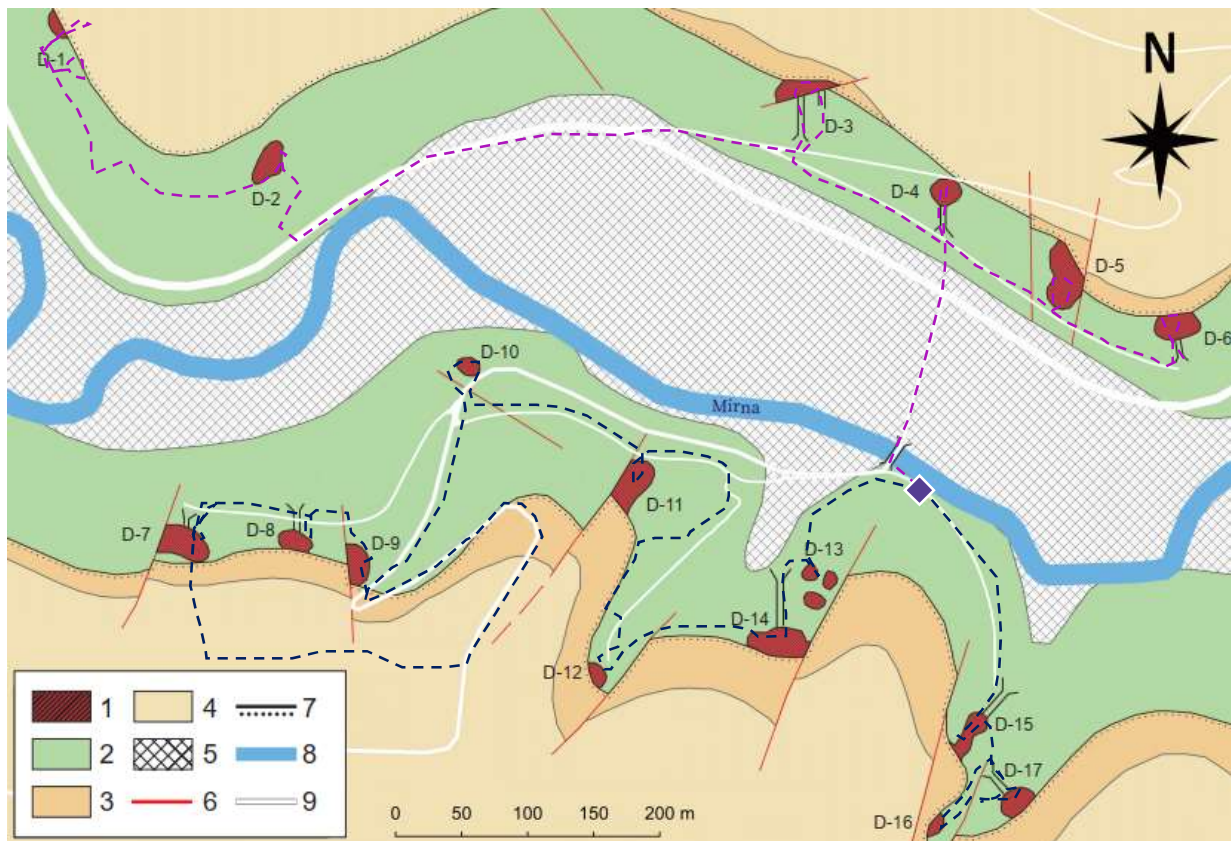
*Figure 1. Inside the D-1 bauxite body from the Minjera mines*

The fieldwork in Minjera started with a field review of known bauxite mines and occurrences, to evaluate their quality as possible sampling locations. Afterwards, two mined bauxite bodies were deemed suitable for sampling. Sampling was extensive and detailed. Several samples were taken as cores, using the handheld drill with corer drill bit. The fieldwork in Macinići included the sampling of several smaller bauxite bodies and accompanying lithologies, together with the sampling of their foot and hanging wall successions.

Out of hanging and foot wall limestone samples  $\delta^{18}\text{O}$ ,  $\delta^{13}\text{C}$  will be analyzed together with thin section study. Out of bauxites a large number of analyses and studies are going to be performed such as SEM, ICP-MS, XRD, micromorphological study, U-Pb zircon dating,  $\delta^{34}\text{S}$  together with heavy and light mineral analysis.

## Minjera mines

Minjera mines are an abandoned group of bauxite mines located in the Mirna river valley (Fig. 2.), close to the city of Sovinjak. This location is recognized as the first instance of bauxite mining in the whole world, as bauxite here was exploited between the end of the 18<sup>th</sup> and the middle of the 19<sup>th</sup> century. The bauxite was used primarily for the production of alum and sulphuric acid, which was derived from its high sulphur content. This is related to the presence of pyrite as the dominant iron-bearing phase. The bauxites themselves were originally red, but during the transgression, which followed their deposition, the reducing pore waters, derived from the overlying marshes, transformed them into grey bauxites. Certain portions of the bauxite bodies likely remained red, but in all of the deposits most of the bauxite was mined out, and only the sections on the fringes of the bauxite bodies were left, which are exclusively of the grey lithotype. In the vicinity of the D-14 and D-13 bauxite bodies (Fig. 2.), several tailing heaps were found, containing the red bauxites, which were certainly derived from the bauxites in the Minjera mines.



**Figure 2.** Area of the Minjera bauxite mines with track outlines; 1 - Bauxite, 2 - Rudist limestones (Cenomanian), 3 - Kozina beds (Lower Eocene), 4 - Foraminiferal limestones (Middle Eocene), 5 - Aluvial beds (Quaternary), 6 - Faults, 7 - Transgressive boundary, 8 - Mirna river, 9 - Roads; modified after Šinkovec et al., 1994

The bauxite deposits formed as from the material accumulated in karstified depressions and pits on the exposed Upper Cenomanian limestones during the third emersion of the Western Istrian anticline. The Bauxites were then overlain with the Palaeocene - Lower Eocene Kozina beds, which were deposited in marshes and depressions mostly present above the bauxite bodies during the beginning of the transgression. As the transgression progressed, the whole area was completely submerged. This initiated

the formation and deposition of foraminiferal limestones in the Lower Eocene, which was followed with the deposition of Transitional beds, and finally the flysch deposition in the Middle and Upper Eocene.

Fieldwork on this site comprised from the selection of suitable sampling locations followed with the sampling of bauxite together with its hanging and foot wall succession. During the first three days, the seventeen locations of abandoned mines and bauxite outcrops were reviewed. All of the visited deposits have been mined out. They differ significantly in dimensions and morphology. Some are of the canyon type geometry while some, mostly smaller ones, are better described as having sinkhole geometries. The largest deposits are at least 20m thick and span areas over 300 m<sup>2</sup>. The smallest deposits are only 0.5m thick and only span several m<sup>2</sup>. In some deposits the upper part of the bauxite is represented with carbonate breccias with bauxite matrix.

On the first day, the area South of the Mirna river was inspected (Fig. 2., dark blue dashed line – track outline from the first day), where eleven bauxite bodies were visited and evaluated. Besides the bauxite, well-defined outcrops of the foot and hanging wall succession were also searched for, mostly in creek throughs, but the best ones were found in the D-15 bauxite deposit, which was also found to be suitable for bauxite sampling. On the second day the area North of the Mirna river was inspected (Fig. 2., purple dashed line – track outline from the second day), where six bauxite bodies were visited and evaluated. On this side of the river, only the D-1 deposit was found to be suitable for sampling. On the third day the area around the D-15, D-16 and D-17 bauxite bodies was revisited, to evaluate the hanging and foot wall succession, and to see if there are some other bauxite occurrences in this section of the area, but none were found. On the following days, the bauxites and their hanging and foot wall succession were sampled in two selected bauxite bodies, the D-1 and D-15 bauxite mines.

Sampling started with the D-15 deposit, which consist of a mined bauxite pit (25x5m in ground plan, 2-6 m in height), joined with the horizontal shaft that extends beyond the bauxite for 20 meters. The bauxite samples were collected from several locations within the bauxite body. Three samples were taken using the handheld drill equipped with the corer drill bit, as the grey bauxite is extremely hard and brittle. This prevented us from taking a sufficiently large sample for the preparation of thin sections, using other tools. The hanging and foot wall succession were sampled on the entrance of the bauxite mine. At the end, the map of the deposit was drawn out, using the methods employed during the construction of cave surveys (compass, inclinometer and measuring tape).

The D-1 deposit was sampled last. The deposit consist of a very large mined-out underground space (40x6m in ground plan and 15-20m in height) and a 15m long horizontal entrance shaft. In this location two profiles were sampled. For the first profile, sampling was conducted at least every 0.5m along the western side of the mined chamber, adding up to the total 4.5m of profile. Several samples were collected using the handheld drill equipped with the corer drill bit. The second profile was sampled immediately below the entrance using the drill setup. Samples were taken every 0.7m, adding up to 3m of profile. At the end, the map of the deposit was drawn out, as for the D-15 deposit.

The bauxite in this deposit consists mainly of grey bauxite, but in its immediate contact with the Kozina beds, it transits to the alternation of black to brownish bauxite and coal lenses. The bauxite is structurally always pizoidic to oolitic, regardless of its colour. The grey bauxite can also contain rhizoconcretions and large clastic grains or veins composed from iron sulphides.



**Figure 3.** a) D-5 bauxite deposit, b) Entrance shaft into the D-7 bauxite pit, c) Lake in the D-3 bauxite deposit, d) Transition from the grey bauxite into the black bauxite and Kozina beds, e) Iron sulphide veins, f) Iron sulphide impregnation

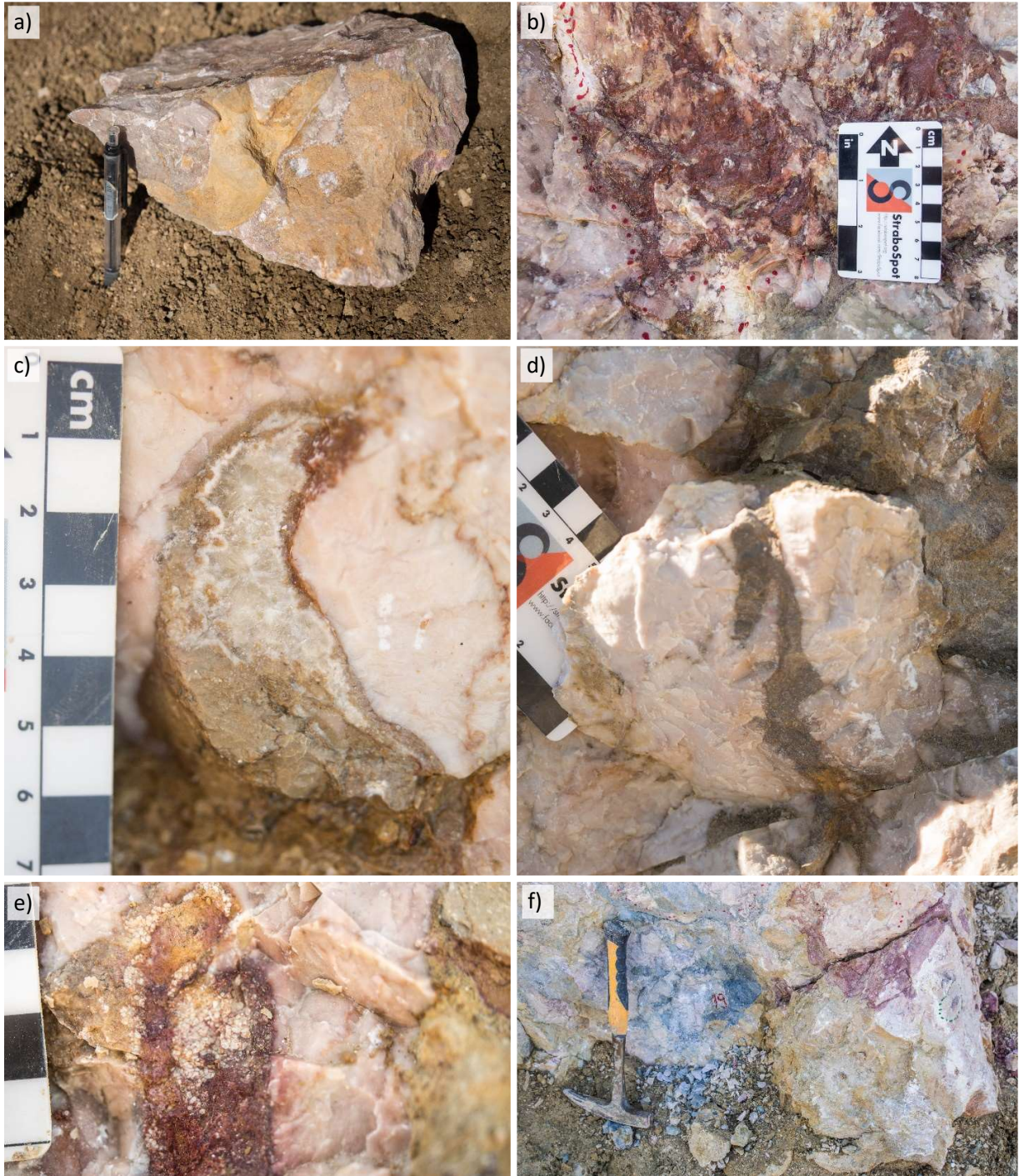
## Macinići

A few members from the GEO and PALEO team went to find other representative outcrops of the third unconformity, while the sampling in the Minjera mines was ongoing. Several locations were visited. The first was the bauxite pit near Labin, close to the village of Zulijani. Here, the bauxite from the bauxite pit was examined, but it was concluded that its quality is not suitable for sampling. The second one was on the outcrop of the roadcut near the village of Bertoši, but it was also deemed unsuitable for sampling. Nevertheless, one sample was collected from both locations, to compare them to other locations. Finally, the third location, also an outcrop on the roadcut, was visited and selected for detailed sampling. This one is located close to the village of Macinići. Here, the unconformity is represented with karstified cracks and depressions filled with bauxitic material, overlain with Foraminiferal limestones and Transitional beds.



**Figure 4.** Panoramic picture of the main section of the outcrop

Detailed sampling was conducted along the outcrop in the bauxitic material and in its foot and hanging wall. There are several varieties of the bauxitic material based on its colour: the grey, the brown-yellow and the red variety. The bauxitic material is also composed from pisoids, ooids and fine grained matrix, regardless of the colour. It often also contains rhizoconcretions, microcodiums and relict speleothems. The bedrock over which the bauxitic material is deposited is strongly karstified, in which the roots visibly participated. This is indicated by the presence of circular channels with oblate cross-sections etched into the bedrock whose shapes correspond well to those of roots. This is also confirmed by the abundance of rhizoconcretions found in the bauxitic material, some of which were found in the aforementioned channels.



**Figure 6.** a) Root borings in the rudist limestone, b) Infillings of bauxitic material, c) Speleotheme (vadose calcite) in the bauxitic material, d) Root borings in the rudist limestone, e) Microcodium, f) Grey, brown-yellow and red bauxite

**References:**

Šinkovec, B., Sakač, K., Durn, G., 1994. Pyritized bauxites from Minjera, Istria, Croatia. *Natura Croatica* 3, 41–65.