## Stop 4 – Biała Woda valley (near Brysztan Klippe) and Berriasian phosphatic structures (Figs 30, 31)

(*Michał Krobicki*)

The present stop includes data from Niedzica Succession situated in the eastern part of the Polish sector of the PKB. The Dursztyn Limestone Formation, subdivided into the Korowa Lime stone Member and the Sobótka Limestone Member (Birkenmajer, 1977), represents the Tithonian/Berriasian boundary strata of the Niedzica Succession. East of Jaworki (Fig. 27) the Niedzica Succession occurs as a large sheet (nappe) thrust over the Czorsztyn Succession. The out crops studied expose white, massive, micritic lime stone which grades upwards into thin-bedded, micritic limestone rich in bioclasts (crinoids, brachiopods, ammonites, small gastropods) of the Sobótka Limestone Member. At the top part of this member, a 10–20 cm thick layer composed of green micritic limestone, rich in phosphorite occurs.

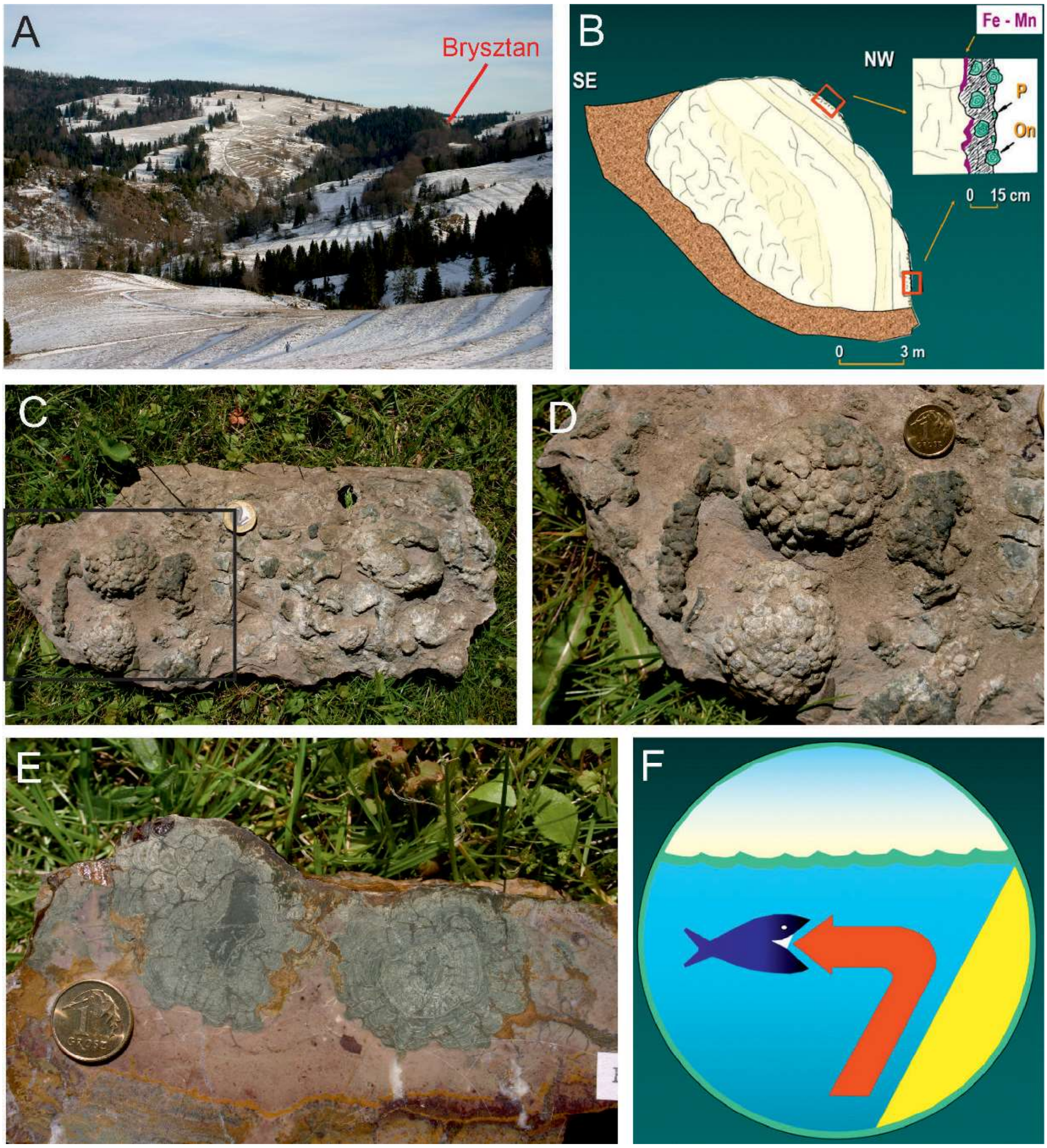


Fig. 30. Location of the Biała Woda-Brysztan section (A); outcrop of the Dursztyn Limestone Formation, Sobótka Limestone Member (Berriasian), Niedzica Succession (B): in enlargement – top of last bed (after Krobicki, 1993, 1994): Fe-Mn – Fe-Mn crusts, P – phosphorites, On – phosphatic macrooncoids. On the photos C–E: phosphatic macrooncoids, and F – upwelling logo (after Krobicki, 2022b; modified)

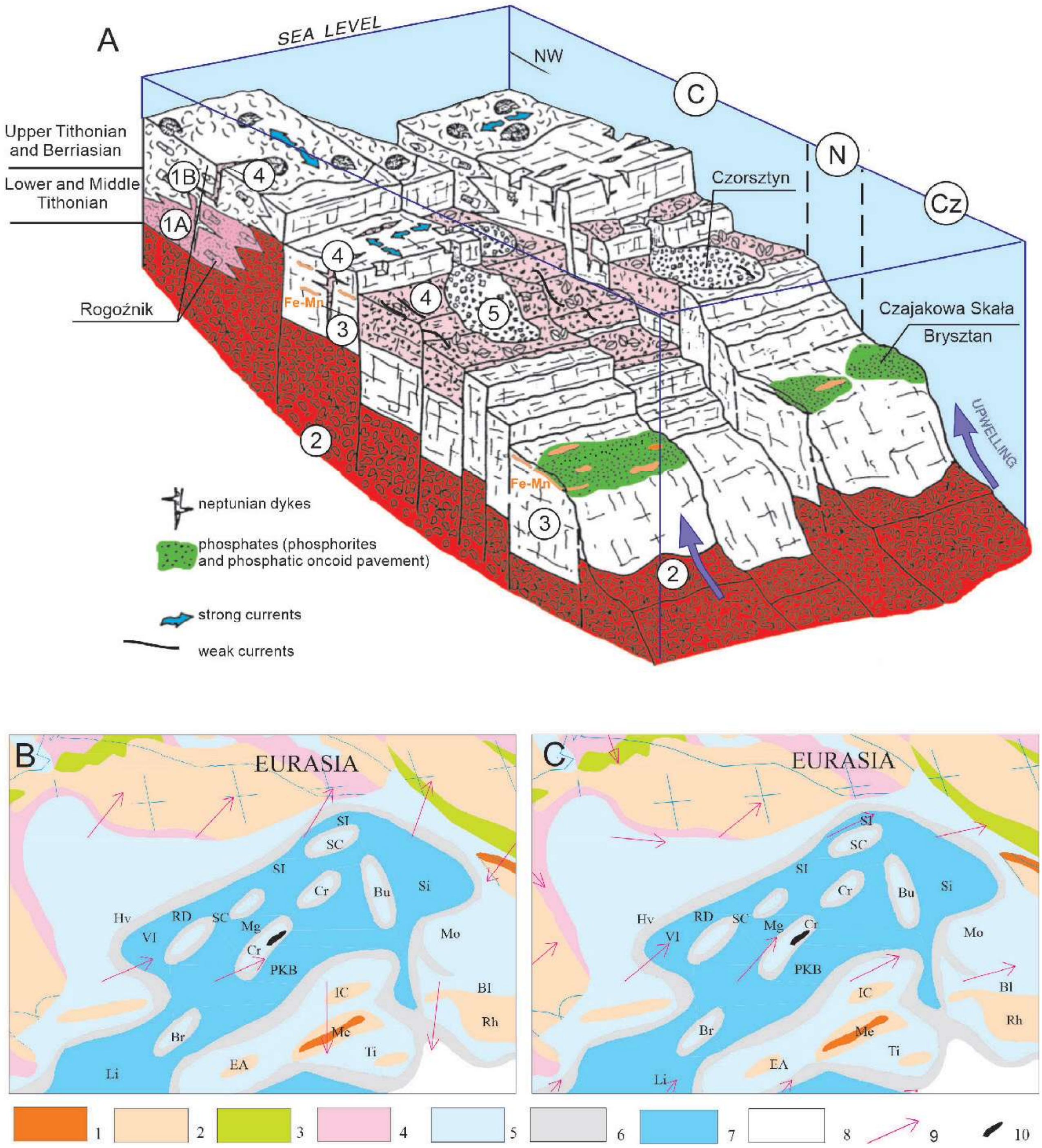


Fig. 31. Model of sedimentation on the intraoceanic Czorsztyn pelagic swell in Berriasian (A) with effects of pronounced Neo-Cimmerian tectonic movements and upwelling currents (after Krobicki, 1996, modified): 1 – Rogoźnik Coquina Member (Dursztyn Limestone Formation: A – sparitic coquina, B – micritic coquina); 2 – Czorsztyn Limestone Formation (*Ammonitico Rosso* facies); 3 – Sobótka Limestone Member (Dursztyn Limestone Formation); 4, 5 – Łysa Limestone Formation (4 – Harbatowa Limestone Member, 5 – Walentowa Breccia Member); successions: C – Czorsztyn, Cz – Czertezik, N – Niedzica. Palaeoenvironments, wind direction and upwelling zones of the Carpathian area during Tithonian-Berriasian time (palaeogeography after Golonka *et al*., 2000, modified): summer Northern Hemisphere (C), andwinter Northern Hemisphere (B): 1 – mountains/highlands (active tectonically), 2 – topographic medium-low (inactive tectonically, non-deposit), 3 – terrestrial undifferentiated, 4 – coastal, transitional, marginal marine, 5 – shallow marine, shelf, 6 – slope, 7 – deep ocean basin with sediments (continental, transitional, or oceanic crust), 8 – deep ocean basin with little to no sediments (primarily oceanic crust), 9 – wind directions, 10 – upwelling zone; abbreviations of oceans and plates names: Bl – Balcans, Br – Briançonnais terrane, Bu – Bucovinian terrane, Cr – Czorsztyn Ridge, EA – Eastern Alps, Hv – Helvetic zone, IC – Inner Carpathians, Li – Ligurian (Piemont) Ocean, Me – Meliata suture, Mg – Magura Basin, Mo – Moesia Plate, PKB – Pieniny Klippen Belt Basin, RD – Rheno-Danubian Basin, Rh – Rhodopes, SC – Silesian Ridge (cordillera), Si – Siret, Sl – Silesian Basin, Ti – Tisa Plate, Vl – Valais Trough

At this level large (8–10 cm across), phosphatic macrooncoids form an oncolitic pavement (see Krobicki, 1993, 1994, 1996a, 2022). On bedding surfaces, large ammonites (up to 30 cm in diameter) are visible. The rock is strongly fractured; Fe-Mn crusts cover the irregular surfaces of the sedimentary discontinuities (Fig. 30). The rock record from PKB shows that upwelling happened in the earliest Cretaceous time. The inception of upwelling may be associated with the time of plate tectonic reorganisation. Tectonic movements generated shallow platforms and islands along the NE–SW trending ridges between the main part of Tethys and the Eurasian Platform. Palaeoclimate modelling (Fig. 31) suggests that the Jurassic-Cretaceous prevailing wind directions in the Circum-Carpathian Tethys area were north-north-east, parallel to the ridges.

Upwelling may have been in duced at the south-eastern margin of the ridges. This type of oceanic circulation has been recorded in a specific association of deposits. These are, given the extremely high biological productivity associated with upwelling, mainly biogenic rocks with high contents of organic matter, silica, and phosphates in different forms, and deposits with elevated contents of some trace elements. The coincidence of these factors in a given palaeogeographical situation might help to re construct the palaeoceanographical conditions of a specific type of upwelling circulation. Upwelling areas are marine regions, in which masses of cold sea waters, rich in nutrients, are lifted from ocean depths to ward more shallow zones, situated most often along the continent margins. Such a nutrient-rich water circulation facilitated growth of zoo- and phytoplankton. Organic production at the lowest trophic level might have been very high, as it caused flourishing growth of benthic organisms along several hundreds of the kilometres-long, intraoceanic Czorsztyn pelagic swell. At the same time, at the Tithonian-Berriasian boundary, a microplankton (mainly calpionellids) explosion took place in the sedimentary basins of the Western Carpathians, triggered by palaeogeographic changes related to Neo-Cimmerian tectonics (Reháková & Michalík, 1994). The presence of phosphate-rich deposits (phosphorites and microbial phosphate structures macrooncoids) in the Berriasian deposits of the Niedzica Succession, which in a palinspastic reconstruction represents a shelf-edge/slope boundary, supports this idea (Figs 7, 31).

## Stop 5 – Biała Woda valley (waterfall) – Berriasian crinoidal limestones and synsedimentary breccia and Valanginian crinoidal limestones (Fig. 32)

(*Michał Krobicki, Andrzej Wierzbowski*)

The deposits of the uppermost Jurassic–lowermost Cretaceous of the Czorsztyn Succession are represented by: the Dursztyn Limestone Formation, the Łysa Limestone Formation (including the Harbatowa Limestone Member, the Walentowa Breccia Member and the Kosarzyska Limestone Member), and the Spisz Limestone Formation (Fig. 11). The age of the Spisz Limestone Formationwas poorly known some years ago. The study by Wierzbowski (1994), Krobicki (1996b) and Krobicki & Wierzbowski (1996) have shown that the lowermost part of the Spisz Limestone Formation reveals in many sections signs of stratigraphic condensation, containing ammonites characteristic of the Early Valanginian and, locally even of the early Late Valanginian age.

The sections studied in the Biała Woda Valley are located in its western (left) slope, at the waterfall (see Fig. 22). The sequence ofthe deposits corresponds strictly to that exposed at the waterfall, in the eastern (right) slope of the valley (see Birkenmajer, 1963, 1977). The oldest deposit in the section A is a grey and grey-brown breccia consisting of angular limestone clasts some millimeters in diameter. The ciasts are calcareous mudstones with abundant calpionellids, mostly *Calpionella alpine* Lorenz, and *Globochaete*. This breccia bed is exposed at water level of the stream. The discussed part of the section is now referred to the Walentowa Breccia Member of the Łysa Limestone Formation (denoted as WBM in Fig. 32A; comp. Birkenmajer, 1977). The overlying beds numbered 1–4 in section A, and 3–4 in section B (Fig. 32), 3.65 m thick, consist of brown, red-brown, and red-violet-brown crinoid-brachiopod limestones. They are packstones and grainstones with abundant crinoid ossicles (up to 5 mm in diameter), shells of brachiopods and, less commonly, tests of benthic foraminifers. The rare ammonites, brachiopods, and calpionellids, such as *Calpionellopsis* sp., *Tintinnopsella carpathica* (Murgeanu and Filipescu) and *Remaniella* sp., are indicative of Late Berriasian. These deposits were originally attributed to the lower part of the Spisz Limestone Formation by Birkenmajer (1963, 1977). In fact, they are almost identical in their lithological development and stratigraphic position to those of the Kosarzyska Limestone Member of the Łysa Limestone Formation (Krobicki & Wierzbowski, 1996; comp. Wierzbowski & Remane, 1992; Wierzbowski, 1994). This sections in the Biała Woda Valley yielded brachiopods of the lowermost Cretaceous. The brachiopods were collected bed by bed, starting from crinoid-brachiopod limestones of the Walentowa Breccia Member of the Łysa Limestone Formation and proceeding up to the middle part of the Spisz Limestone Formation (bed 5).

On the other hand, brachiopods are infrequent in the Spisz Limestone Formation (Krobicki, 1994, 1995, 1996b). The dominating brachiopod species in assemblages from crinoid limestones of the Spisz Limestone Formation are the same as those occuring in the Tithonian and/or Berriasian strata (Barczyk, 1972a, 1972b, 1979a, 1979b, 1991; Krobicki, 1994). The Valanginian brachiopod assemblages are useful for ecostratigraphy. Comparison of the Valanginian and Late Berriasian assemblages from the PKB shows that they are also useful in palaeoenvironmental reconstructions.