The lithostratigraphy of Pieniny Klippen Belt units and Peri-klippen units

Ján SCHLÖGL and Roman AUBRECHT

The sedimentary history of Pieniny Klippen Basin can be divided in three stages, with (1)? Hettangian–Aalenian mostly oxygen-depleted dark terrigenous deposits within an undifferentiated epicontinental sedimentary basin, (2) Bajocian to Lower Cretaceous crinoidal, reefal, Ammonitico Rosso, siliceous (cherty limestones and radiolarites) and "biancone or maiolica-like" deposits sedimented in the platform-through system, and (3) synorogenic Late Cretaceous marly and flysch deposits (Fig. 10).

The swell (Czorsztyn) Unit

The Czorsztyn Unit represents sedimentary succession, with Lower Jurassic–Aalenian part sedimented in the relatively shallow epicontinental conditions, and Bajocian–Lower Jurassic deposited in the shallow parts of the former pelagic carbonate platform (PCP) called Czorsztyn Swell. Late Cretaceous is represented by marly and flysch deposits. The Middle–Upper Jurassic sedimentary history was accompanied by numerous synsedimentary

Fig. 10. Start of the Czorsztyn swell sequence: crinoidal limestone of the Smolegowa Fm. Slávnické Podhorie–Skalica (photo by J. Michalík).

tectonic features; such as neptunian dykes and scarp-breccias.

The only possible Triassic deposits of the Czorsztyn Unit are dolomites preserved in the small klippe Michalova Hora near Dolná Maríková, but their attribution to this unit is disputable, mainly due to different Upper Jurassic development of the here-preserved succession. Similarly, the stratigraphical and paleogeographical position of the quartzites occurring near the Mariková klippen remains unclear, although their assignement to the Upper Triassic Keuper facies seem to be most probable.

Lower Jurassic deposits are preserved at a few localities only, mainly in the Slovak and Ukrainian parts of the Pieniny Klippen Belt. Upper Sinemurian Fleckenmergel–Fleckenkalk deposits with *Echioceras raricostatum* were documented behind the Vršatec Klippen. Lower Sinemurian dark organodetritic limestones and Upper Sinemurian/Pliensbachian Fleckenmergel–Fleckenkalk facies were described from Dolný Mlyn near Stará Turá (W Slovakia), Beňatina (E Slovakia) and Priborzhavskoje and Velyky Kamenets (Ukraine) (Hlôška 1992; Schlögl et al. 2004).

Middle and Upper Jurassic deposits display some important sedimentary turnovers (Fig. 5). Uppermost Liassic to Lower Bajocian grey spotted marly limestones, marlstones and black shales (Krempachy Marl Fm and Skrzypny Shale Fm) were "suddenly" replaced by white and red crinoidal limestones during the late Lower and Upper Bajocian (Smolegowa and Krupianka Lst Fms; Fig. 10), which probably mirrors both the sea level drop and the local extensional tectonics, associated with the tilting of the crustal blocks. The crinoidal limestones contain more or less rich clastic admixture, derived from the still emerged parts of the Czorsztyn Swell. In addition to quartz grains, maily dolomite clasts prevail, indicating that the Triassic rocks were present in the source area. The extension and the platform breakdown were accompanied by the deposition of the syntectonic scarp-breccias on the toes of the rising blocks. This facies is restricted to the West Slovak part of the PKB only, called the Krasin Breccia (Aubrecht & Szulc 2006), and probably also Vršatec peri-biohermal breccia (Ivanova et al. 2019). The latter represents the facies derived from the coral–calcareous sponges biohermal limestones (the Vršatec Lst). The age of this unique facies was recently estimated as Early Bajocian (Schlögl et al. 2006) and not Oxfordian as it was thought before (Mišík 1979).

Later sedimentary turnover during the latest Bajocian and Bathonian was probably related to a global sea-level rise and/or breakup unconformity at the beginning of thermal subsidence period (Plašienka 2003). The platform and slope deposition was replaced by pelagic deposition of Ammonitico Rosso or by red non-nodular micritic limestones (the Czorsztyn Lst Fm, the Bohunice Fm; Fig. 11). Their sedimentation, although interrupted by the Late Bathonian to the Early Oxfordian sedimentary break, continued until the Early Tithonian. This long-lasting hiatus was probably controlled by both, eustasy and rapid paleogeographic rearrangement of the host basins, as indicated by recently acquired paleomagnetic data from various sections from Slovakia, Poland and Ukraine (Lewandowski et al. 2005, 2006). The contemporaneous deposits are almost completely missing, and can be traced only by detailed observations of

Fig. 11. Start of the Ammonitico Rosso sedimentation in the Údol section (photo by R. Aubrecht).

neptunian dyke infillings, extensively developed especially in the Púchov segment of the PKB (Vršatec, Štepnická skala, Vieska–Bezdedov). Evolution to the overlying Dursztyn Lst Fm is gradual; the formation shows a large facies variability from micritic and sparitic coquinas (Rogoza Coquina and Rogoznik Coquina) to micritic, more or less bioclastic limestones (Korowa Lst and Sobotka Lst) of the Tithonian age. They were followed by bioclastic Lysa Lst Fm of the Berriasian and Valanginian age and by crinoidal Spisz Lst Fm of the Hauterivian age. The carbonate sedimentation was interrupted by the period of emersion, with sedimentary break covering the Barremian–Aptian. At least local subaerial exposition was documented by paleo-karst surfaces (Aubrecht et al. 2006). Albian and Cenomanian red marly limestones and marlstones and cherts (the Chmiełowa and the Pomiędznik Fms) overlie directly the paleokarst surface.

Basinal (Kysuca and Pieniny) units (Fig. 9a,b)

Deposits of the deepest central parts of the Pieniny Klippen Basin south of the Czorsztyn Swell are represented by the Lower Jurassic to Upper Cretaceous pelagic and flysch formations of the Kysuca–Pieniny Unit (the Branisko Unit was distinguished as an equivalent of the Kysuca Unit in Poland – Birkenmajer 1977).

Although the Lower Jurassic part of the succession was documented at numerous sections, their assignment to this unit is not always clear, due to prevalent disconnection of the Lower Jurassic strata from the Middle Jurassic strata. Continuous sections are very rare. Another reason is that some rock bodies belonging to different klippen units, such as Orava or Drietoma units were formerly erroneously included into the Kysuca–Pieniny Unit.

The Early Jurassic age of the Zázrivá Beds was rejected recently, due to

the new biostratigraphic data suggesting their Aalenian age (Aubrecht et al. 2004). Therefore, the oldest known Lower Jurassic deposits are sandstones, arkoses and quartzites of the Sinemurian age (the Gresten Fm, Orava, Ukraine), overlain by Fleckenmergel–Fleckenkalk deposits of the Pliensbachian to Early Bajocian age (Krempachy Marl Fm, Skrzypny and Harcygrund Shale Fms). The time of deposition of dark shales with abundant thin-shelled bivalves *Bositra* (Harcygrund Shale Fm, former *Posidonia* Beds) in the Kysuca-Pieniny Basin is represented in the Czorsztyn Unit by hiatus, separating the oxygen-depleted dark deposits and platform slope biodetritic deposits. While the Sinemurian–Lower Bajocian sedimentation indicates still undifferentiated depositional basin, the next sedimentary history already points to dissection of the Pieniny Klippen Basin into elevations (Czorsztyn Swell) and troughs (Kysuca–Pieniny Basin).

Deposition of the Bajocian deep-water cherty limestones and spongiolites (the Podzamcze Lst Fm) are laterally replaced by cherty crinoidal limestones. In the Kysuca-Pieniny Basin these crinoidal limestones are represented by distal turbidites only (the Flaki Lst Fm). Siliceous deposition related to rise of the CCD level in the whole Tethys is represented by black, red and green radiolarites stratigraphically ranging since the Callovian until the Kimmeridgian or Early Tithonian (the Sokolica Radiolarite Fm and the Czajakowa Radiolarite Fm). Similar deep-water deposits are widespread in the basinal successions of the whole Western Carpathians. During the Kimmeridgian, the sedimentation of radiolarites still continued in the Pieniny Unit, but it was replaced by red nodular limestone in the Kysuca Unit (the Czorsztyn Lst Fm). The following depositional stage is uniformly represented by grey micritic limestones of the "biancône" or the "maiolica" type, locally with cherts, with the stratigraphic range from the Tithonian to the Barremian (the Pieniny Lst Fm).

This Pieniny Fm composed of *Calpionella* or calcareous nannoplankton-bearing facies is overlain by Barremian to Aptian dark shales (the Koňhora Fm, Michalík et al. 2008). Albian to Lower Cenomanian of the Kysuca Unit is represented by bluish to greenish marls with limestone beds (the Rudina Fm), followed by red marls and marlstones of the Middle and Upper Cenomanian age (the Lalinok Fm); the end of marly sedimentation is represented by red marls with thin sandstone intercalations of the Lower and Middle Turonian age (the Púchov Fm). The start of turbiditic deposition in the Turonian (the Snežnica Fm) marks the change of the sedimentation. These sandstone turbidites are followed by psammitic to psefitic deposits of the Coniacian and Santonian age (the Śromowce Fm), which are analogous to the Upohlav Conglomerate of the Klape Unit, suggesting the tectonic approximation of these units. The upper limit of the overlying Campanian red marls represents a sedimentation break, caused by orogenic phase related to collision of the Inner and Central Carpathians and the Oravic Block. The southernmost Kysuca-Pieniny Unit was the first one affected by this orogenic movements. Sandstones, breccias (the Jarmuta Beds) and limestones with *Orbitolina* are deposited on folded pre-Maastrichtian strata.