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Lithofacies palaeogeography and sedimentology

Palaeogeographical zonation of gypsum facies: Middle Miocene Badenian of Central Paratethys (Carpathian Foredeep in Europe)

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Abstract Studies on Middle Miocene Badenian gypsum in various parts of Central Paratethys, the oldest widespread primary marine gypsum, in western Ukraine, southern Poland and Moravia (Czech Republic) indicate that there are three principal gypsum facies: crystalline gypsum, stromatolitic gypsum and clastic gypsum. The latter typically occurs between crystalline and stromatolitic gypsum and between stromatolitic gypsum and the land. In addition, it is common in channels within gypsum microbialites, and is the main facies during the deposition of the upper part of Badenian gypsum when important bathymetric differences existed within the marginal part of the Carpathian Foredeep Basin, the largest foredeep basin in Europe. Within crystalline gypsum facies, it is observed the overall size of the crystals increases and that the layering declines towards the permanent, stabilized brine body, and thus the giant gypsum intergrowths–non-layered coarse-crystalline selenite – is the end-member of gypsum facies continuum. Typically it passes into layered selenites although owing to fluctuations of pycnocline level, some transitional gypsum subfacies may be missing both in the vertical section as well as in particular outcrops. The following important controls on the development of gypsum facies have been identified: pycnocline level fluctuations, brine level fluctuations including brine sheets and floods, rare marine transgressions, pedogenesis leading to "alabastrine" gypsum development, and rate of inflow of continental water.

Key words gypsum, depositional environments, facies, Badenian, palaeogeography

1 Introduction

One of major problems encountered during the palaeogeographic interpretation of ancient big evaporite basins is the lack of their proper analogs and hence the reasoning based on the study of modern counterparts, limited in size, has to be applied. Modern small salina-type evaporite basins are well studied (*e.g.*, Arakel, 1980; Warren, 1982; Orti Cabo *et al.*, 1984; Logan, 1987) and have been successfully applied in the past to interpret the palaeogeography and sedimentary history of the Middle Miocene mid-Badenian gypsum (initiated to form 13.81 Ma ago) of the Carpathian Foredeep Basin, the largest foredeep basin in Europe, a part of the Paratethys−an epicontinental sea that developed as a relic of the Tethys , which existed between the Early Oligocene and late Middle Miocene times. This gypsum is the oldest widespread primary gypsum facies and hence it is important for interpretation of older sulphate deposits, also because its facies have been studied in great detail by a number of workers in the past (*e.g.*, Kwiatkowski, 1972; Bąbel, 1987, 1991, 2004, 2005a, 2005b; Kasprzyk, 1989, 1991, 1993a, 1993b, 1999; Peryt, 1996, 2001, 2006; Petrichenko *et al.*, 1997; Bąbel and Bogucki, 2007). Previous studies indicated that Badenian gypsum was mostly deposited, particularly in the lower part of the stratigraphic

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section, in a vast brine pan, and although individual depositional features and facies types in the Badenian may be explained by comparison with modern salinas, the lateral persistence of thin beds over large areas with only minor changes in thickness and facies indicates that they formed on broad, very low relief areas which could be affected by rapid transgressions (Peryt, 2001, 2006). In this paper the newest results on a selected site, Młyny (Busko) PIG1 borehole section, in southern Poland are reported and their implications for the interpretation of the gypsum section in southern Poland as well as in other parts of the Carpathian Foredeep basin are discussed; those gypsum sections are ca. 700 km apart (Fig. 1).

2 Geological setting

The Badenian evaporites of Central Paratethys have been subjected to studies for almost two centuries. During the last decades the research was focused on the Carpathian Foredeep Basin system and thus this basin, the largest of the Badenian evaporite basins has become the best studied, and known, evaporite basin of the Central Paratethys (Peryt, 2006). The Carpathian Foredeep basin stretches for more than 1300 km from the environs of Vienna to the NW part of Bulgaria. The Badenian evaporites are mainly underlain by usually deep-marine siliciclastics and carbonates (several tens to several hundreds of metres thick) although in the Carpathian foreland area (as well as in some parts of the Foredeep) gypsum deposits overlie the Mesozoic or Paleozoic rocks. The evaporites are overlain by thick deep-marine to brackish siliciclastic deposits (Ney *et al.*, 1974; Porębski *et al.*, 2003) that attain up to 5 km in thickness (Kurovets *et al.*, 2004).

Badenian evaporites in the northern part of Carpathian Foredeep show a regular spatial facies pattern (Peryt, 2006). In the northern and northeastern parts of the Carpathian Foredeep primary gypsum (Krzyżanowice Formation in Poland and Tyras Suite in Ukraine; Fig. 2) forms

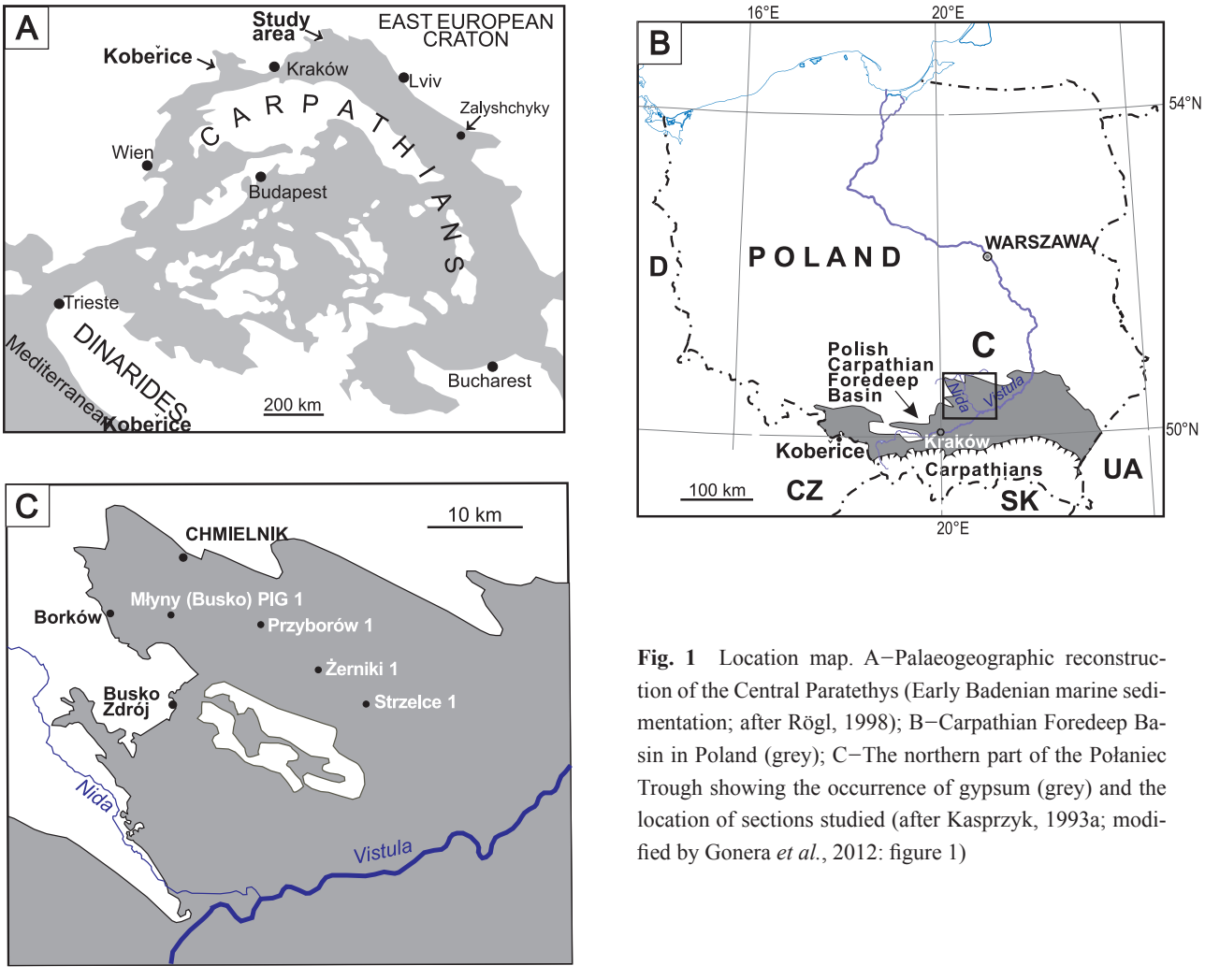

Fig. 1 Location map. A−Palaeogeographic reconstruction of the Central Paratethys (Early Badenian marine sedimentation; after Rögl, 1998); B−Carpathian Foredeep Basin in Poland (grey); C−The northern part of the Połaniec Trough showing the occurrence of gypsum (grey) and the location of sections studied (after Kasprzyk, 1993a; modified by Gonera *et al.*, 2012: figure 1)