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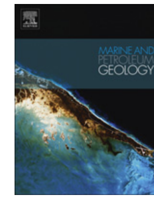

Maturity modelling integrated with apatite fission-track dating: Implications for the thermal history of the Mid-Polish Trough (Poland)

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ABSTRACT

The Mid-Polish Trough (MPT) is situated in the easternmost part of the Central European Basin System (CEBS) and stretches NW–SE across the Polish Basin. It was characterised by pronounced subsidence and thick sediment accumulation between the Permian and the Late Cretaceous. Late Cretaceous–early Paleogene basin inversion led to the formation of the Mid-Polish Swell (MPS). The study area is located within the Pomeranian segment of the MPT/MPS (NW Poland) and experienced up to 7 km Permian-Mesozoic subsidence. PetroMod 1-D modelling was performed on several well-sections in order to study Permian to recent burial-uplift evolution. The modelling was calibrated with new vitrinite reflectance (VR_r) data and allowed to constrain the magnitude of uplift and related erosion as well as provided a first overview of the temperature history. The base of the studied Permian–Mesozoic successions attained maximum burial depths of 4800–5400 m before the onset of the inversion, less than in the axial trough area. The thickness of pre- and most probably also syn-inversion Upper Cretaceous deposits is estimated as 300 m. Erosion associated with inversion processes removed between 900 and 1400 m of the Mesozoic sediments, i.e. 1000–1500 m less than in the most inverted central part of the trough. VR_r data suggest constant Permian–Mesozoic heat flows corresponding to present-day values (40–45 mW/m^2). Apatite fission-track (AFT) ages modelled with the PetroMod module PetroTracks show a good fit with AFT ages directly measured on well samples, and further support the assumption of steady heat flow in the range 40–45 mW/m^2. Palaeotemperatures appear to have decreased towards the East European Craton margin, which is compatible with the present day distribution of heat flow. Thermal history modelling shows a relatively simple Permian–Mesozoic heat flow pattern in the Pomeranian segment of the MPT. Such a scenario implies that the present-day heat flow distribution has not changed essentially since Mesozoic times.

1. Introduction

The Polish Basin (PB) forms the easternmost termination of the Central European Basin System (CEBS). Its Permian–Mesozoic sedimentary infill extends over western and central Europe reaching the North Sea and British Isles in the west. In Poland, the distinct depocentre of the PB is developed as the Mid-Polish Trough (MPT) striking NW–SE. At the turn of the Mesozoic and Paleogene the MPT was uplifted forming the Mid-Polish Swell (MPS), an inversion structure developed along with many other CEBS sub-basins (Littke et al., 2008). Both trough and swell owe their elongated shape to the particular location along the margin of the East European Craton (Teisseyre-Tornquist Zone). This lithospheric boundary (Dadlez et al., 2005; Dadlez, 2006; Guterch and Grad, 2006) controlled the Permian–Mesozoic subsidence pattern followed by Late Cretaceous–early Paleogene inversion (Dadlez et al., 1995; Scheck-Wenderoth and Lamarche, 2005).

Since the MPT constituted one of the most prominent features of the CEBS, the issues concerning its development, structural style, timing and scale of its inversion have been often addressed in previous research (for summary and discussion see Dadlez, 2001; Krzywiec, 2002, 2006 and Lamarche et al., 2003). Less emphasis has been, however, put on revealing thermal history of the MPT, which is mostly the scope of this paper.

The study area is located in northwestern Poland within the Pomeranian segment of MPT/MPS (Fig. 1). Our goal was to study the Permian to recent burial and uplift history of the region on the base of the reconstruction of its temperature history. In a previous study

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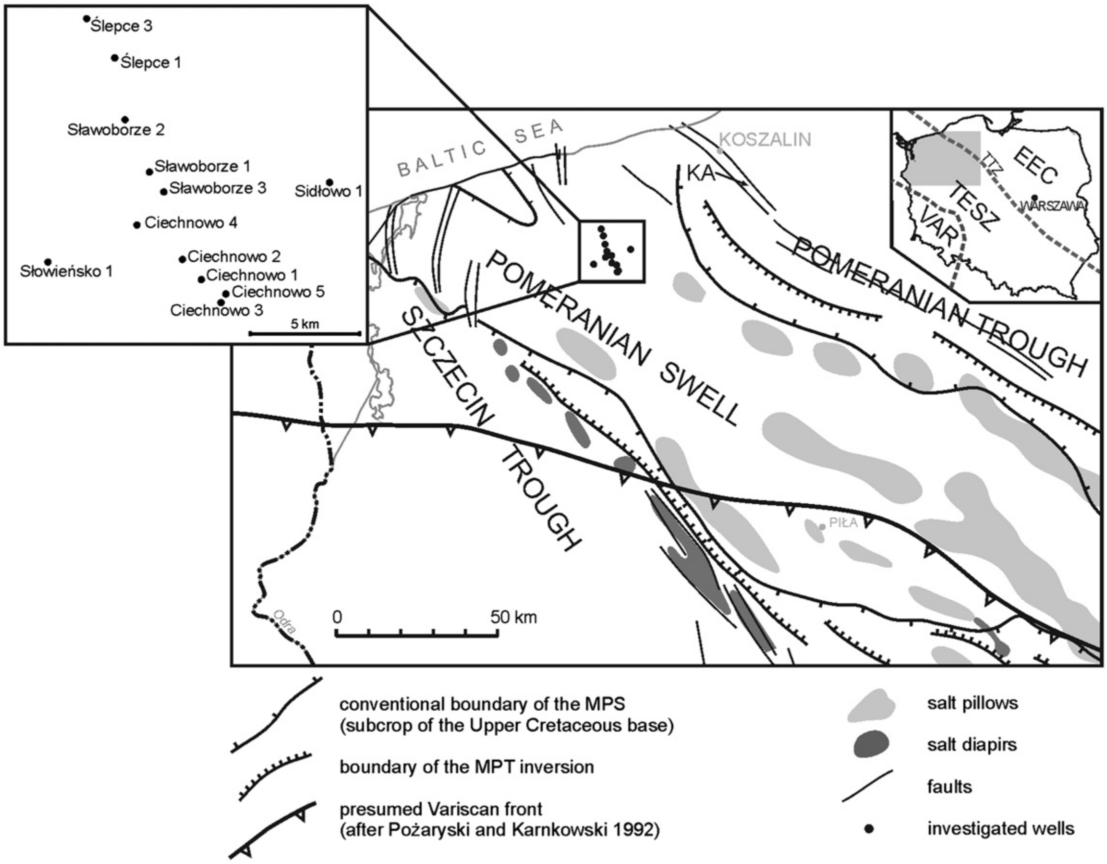

Fig. 1. Map of the NW part of the Polish Basin with well location (modified after Dadlez, 2003). Enlarged square shows the location of wells sampled for AFT dating. EEC – East European Craton, KA – Koszalin Anticline, MPT – Mid-Polish Trough, MPS – Mid-Polish Swell, TESZ – Trans-European Suture Zone, TTZ – Teisseyre-Tornquist Zone, VAR – Variscan Internides.

(Resak et al., 2008) numerical 1-D modelling allowed to constrain quantitatively the maximum burial depths as well as the magnitude of inversion and heat flows histories. Here, additional vitrinite reflectance (VR_r) data integrated with original apatite fission-track (AFT) ages allow a refined calibration of our thermal history modelling. For this purpose we chose several wells from the central inverted part of the MPT and performed numerical 1-D basin modelling by using the PetroMod® software code. Furthermore, the PetroTracks® module was used to predict AFT ages by using the t-T history revealed by the 1-D basin modelling. The modelled AFT ages were finally compared to the measured data.

2. Geological overview

MPT development was preceded by a formation of extensive volcanics and volcanoclastic deposits which covered the external part of the Variscan Orogen and its foreland in central Europe. Volcanogenic rocks were formed between 302 and 293 Ma, i.e. near the Carboniferous/Permian boundary (Breitkreuz and Kennedy, 1999; Breitkreuz et al., 2007). The volcanic succession is overlain with a considerable hiatus by Upper Rotliegend (late Permian) red-beds of aeolian, fluvial and playa origin. The overlying Zechstein cyclic carbonate-evaporite strata are of latest Permian age. Both Rotliegend and Zechstein deposits reached maximum thicknesses of more than 1000 m (Warren, 2008). Mesozoic sedimentation took place in a wide-spread basin in which clastic deposits developed as shallow-marine, lagoonal, fluvial or lacustrine facies interspersed with carbonates. Carbonate deposition prevailed in the Middle Triassic (Muschelkalk), Late Jurassic and Late Cretaceous.

Thickness of the Permian to Upper Cretaceous sediments can be estimated as 10 km in the most deeply buried parts of the MPT. In the studied Pomeranian segment, the sediments reached a maximum thickness of about 7 km (Resak et al., 2008). Apart from the eroded uppermost part, the Permian-Mesozoic succession is almost complete. Minor stratigraphic gaps correspond to erosional events in the latest Middle–Late Triassic, Early/Middle Jurassic and at the Late Jurassic/Early Cretaceous transition, particularly in the area to the NE of the MPS.

Development of the MPT ended in the Late Cretaceous–Early Paleogene when its axial part was uplifted forming the MPS. In the Pomeranian segment, the erosion exposed the Lower Jurassic and locally even Upper Triassic. The amount of eroded sediments, corresponding to the inversion amplitude, was estimated as 3000 m by Kutek and Głazek (1972) based mainly on the Holy Cross segment of the MPT/MPS. On the other hand, compaction analysis of clastic deposits performed by Stefaniuk et al. (1996) yielded up to 900 m and locally 2000 m of erosion, while shale compaction interpreted from seismic velocities by Dadlez et al. (1997) indicated a magnitude of inversion in the Pomeranian region in the range of 1400–2300 m. Dadlez (2003) examined Mesozoic thickness distribution within the Pomeranian and Kujavian segments of MPT. Furthermore, he interpolated thicknesses of non-eroded sediments in the central area of the trough where they are lacking. His estimates yielded between 1300 and 3100 m of Lower Jurassic-Lower Cretaceous deposits. The case of the Upper Cretaceous sediment thickness was left open for a discussion. Latest modelling results by Resak et al. (2008) demonstrated 2400 m of eroded Mesozoic sediments including 200 m of Upper Cretaceous deposits. The interpretation of