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REVEALING PALAEO-HEAT FLOW AND PALAEOOVERPRESSURES IN THE BALTIC BASIN FROM THERMAL MATURITY MODELLING

Abstract: For 11 well sections from the western Baltic Basin thermal maturity of the Mesozoic and Palaeozoic successions was analysed, and modelling of thermal history was performed. The reconstructed Variscan heat flow was slightly higher than recent one, particularly in the southern and eastern part of the analysed area. The Mesozoic heat flow was higher than a recent one in the western part of the studied area. Significant palaeooverpressures, related to high deposition rates of the argillaceous sediments, led to development of the zones of retardation of organic maturation.

Keywords: Baltic basin, Palaeozoic, Mesozoic, thermal history, maturity modelling, overpressure

INTRODUCTION

The Baltic basin is the late Neoproterozic-Phanerozoic multi-stage and polygenetic sedimentary basin, developed at the western slope of the East European Craton. Its characteristic feature is a presence of the Silurian succession of relatively high thickness, significantly increasing from the east to the west, were it could reach more than 3000 m. In the Polish part of the Baltic basin the late Palaeozoic deposits are not preserved as a result of the late Carboniferous and/or early Permian erosion. However judging from the development of the basin further to the east, *i.e.* in the Lithuanian-Latvian borderland, the Devonian to Lower Carboniferous sedimentary cover was present also in the western Baltic basin. During the Permian-Mesozoic the studied area was a north-eastern part of the Polish basin, again characterised by general thickness increase towards the west.

Previous studies of thermal history of the Baltic basin concluded presence of relatively high heat flow at the stage of the Variscan burial (Kosakowski *et al.* 1998; Poprawa *et al.* 2002; Karnkowski 2003). A possibility of a high Cambrian heat flow, related to the syn-rift tectonic phase of the basin, afterwards systematically decreasing in time due to post-rift cooling was also discussed (Kosakowski *et al.* 1998; Poprawa *et al.* 1999). The idea was however difficult to justify from the available data. In the recent study the thermal evolution of the Baltic basin is revaluated based on much extended database of the thermal maturity measurements.

METHODOLOGY

Thermal maturity profile of the argillaceous sediments was analysed for 11 deep well sections from the Polish part of the Baltic basin (Fig. 1). The wells are spread across the basin, therefore each individual zone of the basin was included in analysis. Each well was sampled throughout the Mesozoic and the Palaeozoic section with at least several samples.

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That was possible due to relatively dense coring of the wells. Reflectance of vitrinite and vitrinite-like macerals was measured on polished slices in reflected light in oil immersion with use of Axioscop microscope (Zeiss).

Modelling of thermal maturity/history was performed with use of Sweeney, Burnham (1990) algorithm. Correction for decompaction was calculated according to model of Baldwin, Butler (1985), particularly suitable for fine-fraction siliciclastic sediments. Thermal conductivity and heat capacity for each type of lithology were adopted from published values, based on averaged results of laboratory measurements for their equivalents. Both the parameters were changing in time in a model as a function of mechanical compaction. To constrain recent heat flow constant temperature logs were used. History of surface temperature was included in the modelling.

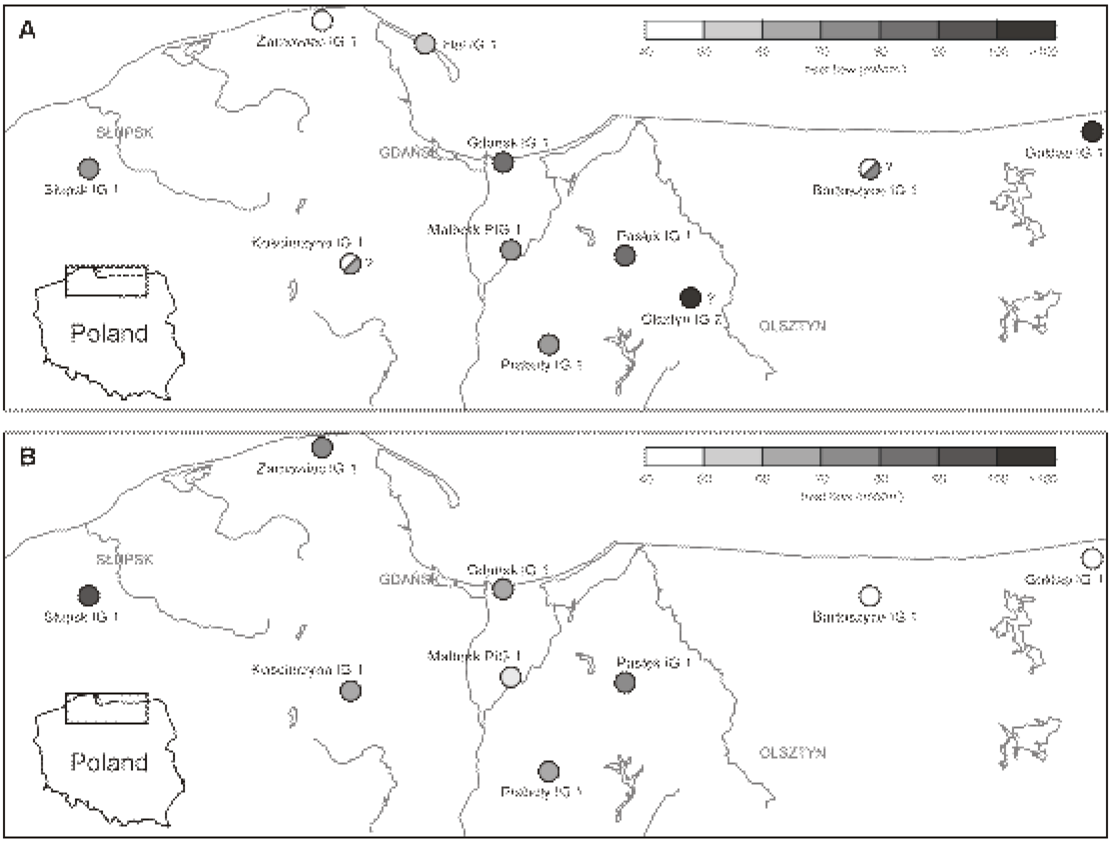

Fig. 1. Location of the analyzed well sections and calculated palaeo-heat flow distribution for the time of (A) the Variscan burial and (B) the Mesozoic burial.

RESULTS AND DISCUSSION

The measured thermal maturity of the Permian-Mesozoic succession is commonly higher than it could be expected from its burial history with heat flow constant in time. In some cases steep or sub-vertical maturity gradients result with difficulties in proper calibration of the models with the analytical data. However to fit a model to a general rage of maturity values it is necessary to assume that during the late Jurassic and/or Cretaceous time surface heat flow was higher than a recent one (Fig. 2). The revealed late Jurassic and/or Cretaceous heat flow anomaly increases towards the west (Fig 1B). This is however

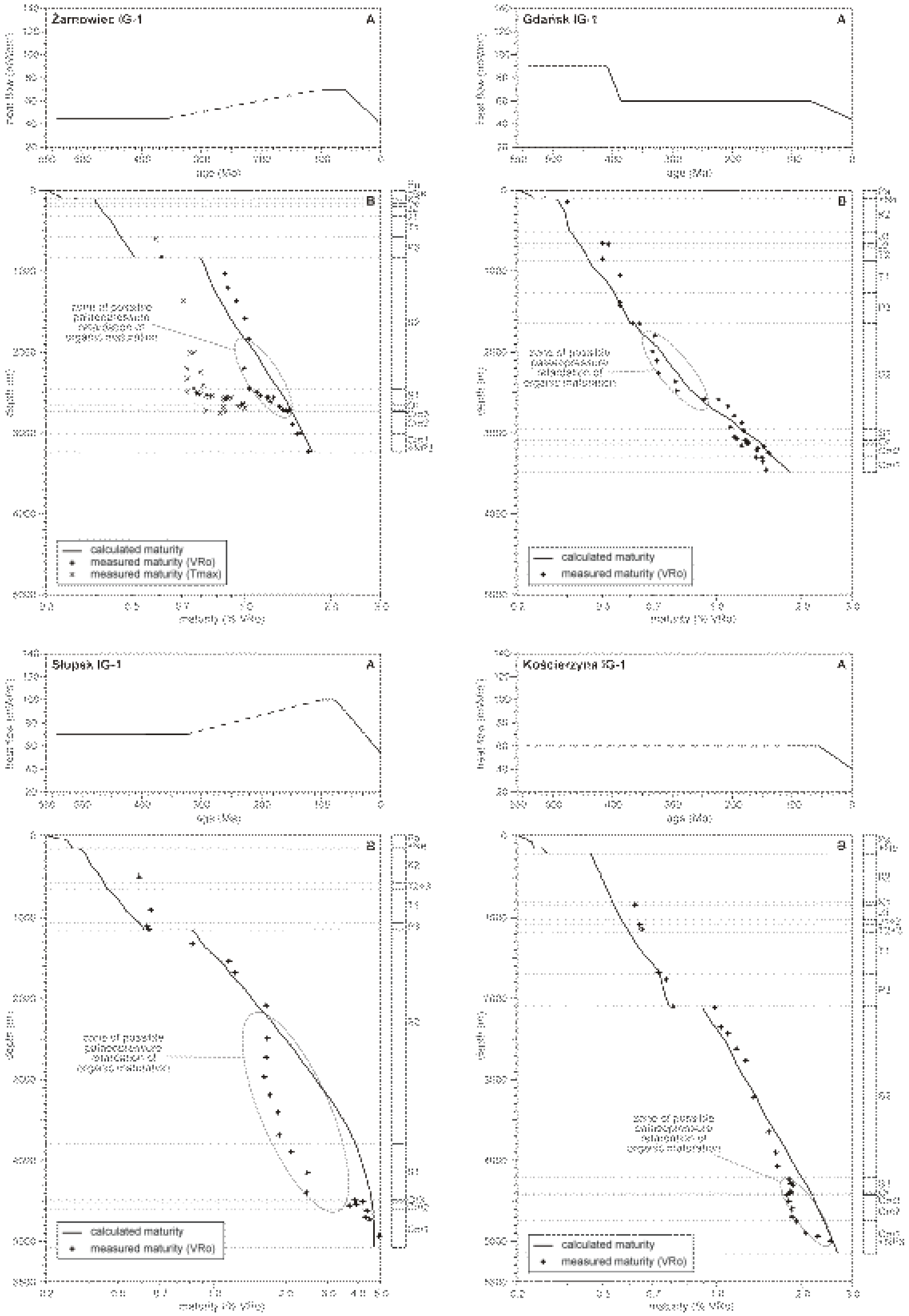

Fig. 2. Reconstructed heat flow histories (A) and calibration of the relevant thermal maturity models (B) for exemplary well sections form the Baltic basin. T_{max} data after Kosakowski *et al*. (1998).

in contrast with results of Karnkowski (2003), who suggested a very low Mesozoic heat flow in the Baltic basin, equal to recent one.

Relation between the thermal maturity gradients observed for the Mesozoic and the Palaeozoic successions (Fig. 2) often does not allow to exclude an option, that both reflect one thermal event in the Jurassic and/or Cretaceous time. This is truth particularly for the eastern part of the analysed area. However to the west it becomes more clear that the Lower Palaeozoic succession attained its ultimate maturation during the Late Palaeozoic burial, which is here a preferred interpretation. Surface heat flow distribution for that time (Fig. 1A) indicates presence of the positive thermal anomaly (Kosakowski *et al.* 1998; Poprawa *et al.* 2002; Karnkowski 2003). This is interpreted here in terms of the late Variscan thermal event, affecting broad foreland of the orogen. Higher palaeo-heat flow towards the south and east, i.e. outwards of the most buried zones, might suggest that in a palaeo-heat transfer there were also participating waters released by mechanical compaction of the Silurian shales and muds.

The most intriguing feature of the maturity profiles of the Baltic basin are their significant negative anomalies in the lower part of the Silurian, Ordovician and, in a few cases, also Cambrian succession (Fig. 2). This is interpreted here as an effect of retardation of organic maturation by palaeopressures. This phenomena could both retard chemical coalification reactions (*e.g.* Horvath 1983) and sustain undercompacted zones with anomalously high porosity and low thermal conductivity, which could act as thermal insulator to the flow of heat (*e.g.* Mello, Karner 1996). The cause for development of the overpressures were very high deposition rates of the thick pile of upper Silurian argillaceous sediments, which in the western part of the basin could exceed 1000 m/My (Poprawa *et al.* 1999). This interpretation assumes that overpressures, which developed in the late Silurian time, maintained until the late Devonian and/or early Carboniferous time, when the ultimate thermal maturation of the succession developed.

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