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Tectonophysics 397 (2005) 73–91

TECTONOPHYSICS

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3D structural model of the Polish Basin

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Received 11 February 2004; accepted 19 October 2004
Available online 8 January 2005

Abstract

A 3D structural modelling of the Permian–Mesozoic Polish Basin was performed in order to understand its structural and sedimentary evolution, which led to basin maturation (Permian–Cretaceous) and its tectonic inversion (Late Cretaceous–Paleogene). The model is built on the present-day structure of the basin and comprises 13 horizons within the Permian to Quaternary rocks. The analysis is based on 3D depth views and thickness maps. The results image the basin-scale symmetry, the perennial localization of the NW–SE-oriented basin axis, the salt movements due to tectonics and/or burial, and the transverse segmentation of the Polish Basin. From these observations, we deduce that salt structures are correlated to the main faults and tectonic events. From the model analysis, we interpret the stress conditions, the timing, and the geometry of the tectonic inversion of the Polish Basin into a NW–SE-oriented central horst (Mid-Polish Swell) bordered by two lateral troughs. Emphasis is placed on the Zechstein salt, considering its movements during the Mesozoic sedimentation and its decoupling effect during the tectonic inversion. Moreover, we point to the structural control of the Paleozoic basement and the crustal architecture (Teisseyre–Tornquist Zone) on the geometry of the Polish Basin and the Mid-Polish Swell.

Keywords: Polish Basin; Mid-Polish swell; 3D structural modelling; Basin subsidence; Tectonic inversion; Salt; Structural inheritance; Poland

1. Introduction

The Polish Basin is the easternmost branch of the assemblage of Central European Permian–Mesozoic Basins extending from the Southern North Sea across the North German Basin to Poland. Intense geodynamic study of these basins since many years has produced extensive literature, and several syntheses have been published (e.g., Ziegler et al., 1995; Gee and Zeyen, 1996; Pharaoh and Bayer, 1999; van Wees et al., 2000; Winchester et al., 2000; Bayer et al., 2002). The basins were initiated in late Carboniferous, post-Variscan phase of wrench faulting between the Apalachians and the Urals (Arthaud and Matte, 1977). Later Permian–Mesozoic evolution was due to thermal subsidence interrupted by pulses of tectonic subsidence, ending with final tectonic inversion in the latest Cretaceous. Although the main

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0040-1951/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2004.10.013

lines of its geodynamic evolution are comparable to the German and Danish basins since Permian times, in detail, the Polish Basin presents specific characteristics due to its peculiar geological location above the Teisseyre–Tornquist Zone, a Paleozoic crustal boundary that underwent multiple reactivations. In addition, the basin development was complicated by :(1) the stress patterns changing with time; (2) repeated tectonic events coupled with salt movements; (3) a mosaic-type Paleozoic basement inducing a pronounced structural inheritance; and (4) superposition of the Caledonian, the Variscan, and the Alpine deformation fronts. This complex tectonic setting resulted in a complicated basin structure, the understanding of which is strongly improved by an integrated 3D visualisation. At the present day, most of the Permian–Mesozoic Basin is buried beneath a Tertiary and Quaternary cover, hampering direct observations. As a consequence, understanding the concealed structure of the Polish Basin implies the use of subsurface data (boreholes, seismics) and 3D visualization tools.

Lately, several paleogeographic and paleotectonic atlases of the Permian–Mesozoic Polish Basin have been published (Marek and Pajchlowa, 1997; Dadlez, 1998a,b; Znosko, 1999). They constitute a precious data base for the 3D modelling of the Polish Basin. However, instead of using only data of the preserved geologic record, most of these atlases include interpreted and reconstructed data in areas where Cenozoic erosion removed the primary geologic column. Such reconstructions imply a priori presumptions on the kinematics and type of basin. Other attempts for understanding the evolution of the basin in relation to its basement are based on present-day data and provide kinematic models that are not a priori-based (e.g., Kotanski, 1997; Dadlez et al., 1995; Dadlez, 1997, 2001; Grabowska et al., 1998; Karnkowski, 1999; Krzywiec, 2000). Unfortunately, the description of basin evolution rarely includes the entire Polish Basin and its margins, or, the descriptions are based on 2D sections. In addition, most of them focus either on Permian–Mesozoic basin development, or on Late Cretaceous tectonic inversion, or on crustal structures. Each of these aspects, however, had an influence on the others and, consequently, should not be treated independently. Hence, in this paper, we describe a 3D structural model, the originality of which is (1) the consideration of the Polish Basin as a whole, and (2) that the input is based only on observed strata. From this, a conceptual model is inferred, which considers all steps of structural and depositional development of the basin.

A first attempt to establish a 3D structural model of the Polish Basin with a coarse resolution (five layers for the Permian–Cenozoic succession) was focused on basin-scale processes and on the related crustal-scale consequences (Lamarche et al., 2003). However, the vertical resolution of this first model allows neither for a detailed analysis of Mesozoic subsidence, nor for an analysis of salt structures, which played an important role in the development of the Polish Basin. Here, a new detailed 3D structural model composed of 13 layers from Lower Permian to Quaternary is presented. The horizontal resolution of this new model is four times higher than in the previous one and thus enables us to describe details of the present-day basin structure, and to refine the discussion of the Permian–Mesozoic history including the influence of the salt layer.

After a review of the geological setting and explanation of the modelling procedure, a description of the basin structures as displayed in the 3D model is presented. In a further step, interpretations of basin fill and structure are deduced. Finally, the results are discussed with respect to the subsidence indicators and basin development, to the time and style of the tectonic inversion, to the role of salt and of tectonic inheritance, and to the segmentation of the basin.

2. Geological setting

The Polish Basin evolved on a mosaic of crustal domains ranging in age from Precambrian to Carboniferous (Ziegler, 1990; Franke, 1995). To the east, the basin overlies the Precambrian East European Craton (Early Paleozoic continent “Baltica”). To the northwest, the basin evolved on Caledonian crust. To the southwest, the basin developed on the Variscan foreland superimposed on the Caledonian fold-and-thrust belt and on Gondwana-derived blocks. The Paleozoic units amalgamated during Paleozoic times at the margin of Baltica along the so-called Teisseyre–Tornquist Zone, underlying the Polish Basin axis (Guterch et al., 1983; Grad et al., 1999).