THREE-DIMENSIONAL GEOLOGICAL MODEL OF POLAND AND ITS APPLICATION TO GEOTHERMAL RESOURCE ASSESSMENT

Zbigniew Malolepszy
Department of Fundamental Geology, University of Silesia, Bedzinska 60, 41-200 Sosnowiec, Poland
Minnesota Geological Survey, University of Minnesota, 2642 University Ave., St. Paul MN 55113; malol@us.edu.pl

INTRODUCTION

Poland is located in Central Europe between the Baltic Sea and the northern part of the Carpathian Mountains. The NW-SE Teysere-Tornquist tectonic zone runs across Poland, separating the East European Craton from Paleozoic Europe. Along this zone, a Permian and Mesozoic sedimentary basin has developed in the Polish Lowlands as the SE part of the Danish-Polish basin, consisting of a sequence of deposits whose thickness has been estimated as up to 7000 m. During the second part of the past century, extensive exploration for oil and gas in this area resulted in completion of several thousand deep drillholes and seismic profiles that were used to construct detailed lithostratigraphic and structural analyses. Subsurface models of bedrock geology were created, such as horizontal slice maps (Kotanski, 1997), and isoline maps of lithostratigraphic horizons (Sokolowski, 1987). These models, created using previously available subsurface mapping methods, effectively depicted deep geology, including complex structures. The limitations of the methods, however, resulted in inconsistencies based in most cases on differing map scales and projections, as well as uncertainty in the location of drillholes. This previous generation of models has, however, served as the basis and inspiration for a new three-dimensional (3D) geological model of Poland (Figure 1) that is now being used for many applications, including geothermal resource assessment.

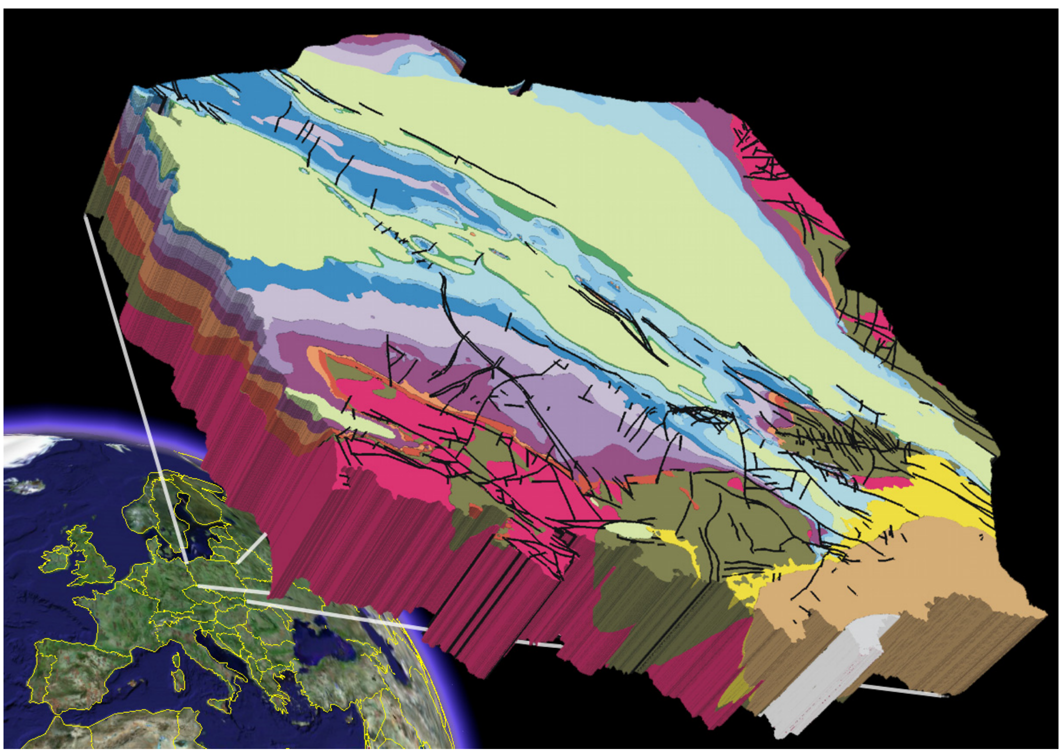

Figure 1. 3D, digital geological model of Poland for the depth interval from -500 to -6000 m (Piotrowska, et al., 2005); see figure 3 for color legend.

3D GEOLOGICAL MODEL OF POLAND

For some time, the escalating availability of subsurface geological data collected in or converted to digital formats and stored in large databases has required development of new methods for processing and visualization. Previously, however, these data commonly lacked information on their elevation. In recent years, 3D geological mapping has therefore come into more common use, and new techniques for multidimensional mapping in geological cartography have been extensively utilized for detailed mapping. Regional-scale models remain, however, limited in their development, due in part to the challenges presented by construction of high-resolution grids that depict structural, lithologic, and stratigraphic features whose scale ranges widely (Malolepszy, 2005). The methods presented here therefore are being developed to deal with this challenge, and concurrently to deal with the need for regular grid techniques using data of variable quality and quantity.

The current 3D geological model of Poland, developed by the Polish Geological Institute and the University of Silesia (Piotrowska, et al., 2005), is one of the first country-scale models in Europe. It was built using regular grid solids with a horizontal resolution of 500 m, a depth interval from -500 to -6000 m, an extent of 649 km from north to south and 689 km from east to west, and an area of 312,000 km^2. Previously completed horizontal slice, tectonic structure, and isoline subsurface maps as well as cross-sections were used for model construction (Figure 2). A filtered drillhole database with nearly 9000 records was used as the major source of data for new interpretations and refinement of the compiled materials. Depicted stratigraphy was simplified to the subsystems of the Permo-Mesozoic sequence, and older rocks were divided into Paleozoic and Precambrian sedimentary rocks and crystalline basement (Figure 3). Current plans call for refinement of the model to a higher horizontal and vertical resolution.

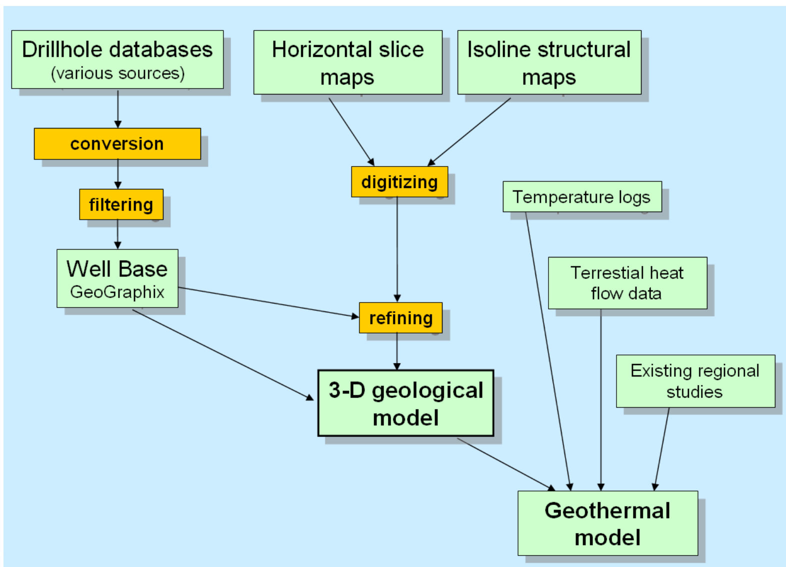

Figure 2. Data sources and workflow chart for the 3D geological model of Poland

GEOTHERMAL RESOURCES OF POLAND

Both detailed and regional 3D geological models have recently been increasingly used for application to natural resource assessment and management. In addition to their principal use in petroleum exploration, significant advances in multidimensional geological mapping have occurred in the field of mineral resource and groundwater exploration. These applications have required incorporation of large databases of geological, geophysical and hydrogeological data into 3D geological models. Methods developed for subsurface analysis of oil and groundwater resources are now being extended for application to geothermal resource assessment. The distribution of reservoir and petrophysical rock properties, as well as thermal regime of rock units, are a significant factor for assessment of geothermal reservoirs as a potential source of renewable energy. Regular grid solids created in a 3D model can be converted into a tetrahedral mesh for finite element modeling of reservoir properties as well as complex mass and heat flow analyses. Thus, application of 3D geological modeling in hydrogeology of geothermal waters is becoming increasingly important in natural resource assessment.

A geothermal model therefore has been developed on the basis of the current 3D geological model of Poland. This model has been used to assess potential geothermal energy resources to a depth of 5000 m. The formation temperature distribution in the range of 8 to 180ºC, and terrestrial heat flow density in the range of 20-95 mW/m^2, were interpolated from well and surficial measurements. Reservoir and petrophysical rock properties were used to characterize the thermal and hydrogeologic regime of rock units. Formations characterized by positive thermal anomalies and relatively high porosity and permeability were selected as having potential for geothermal exploration, and detailed maps of their formation temperature and geothermal gradients were extracted from the

3D property model (Figure 4). These maps show the close relationship between geologic structures and geothermal anomalies, thus drawing attention to the critical need for optimal 3D geological mapping in the field of natural resource assessment.

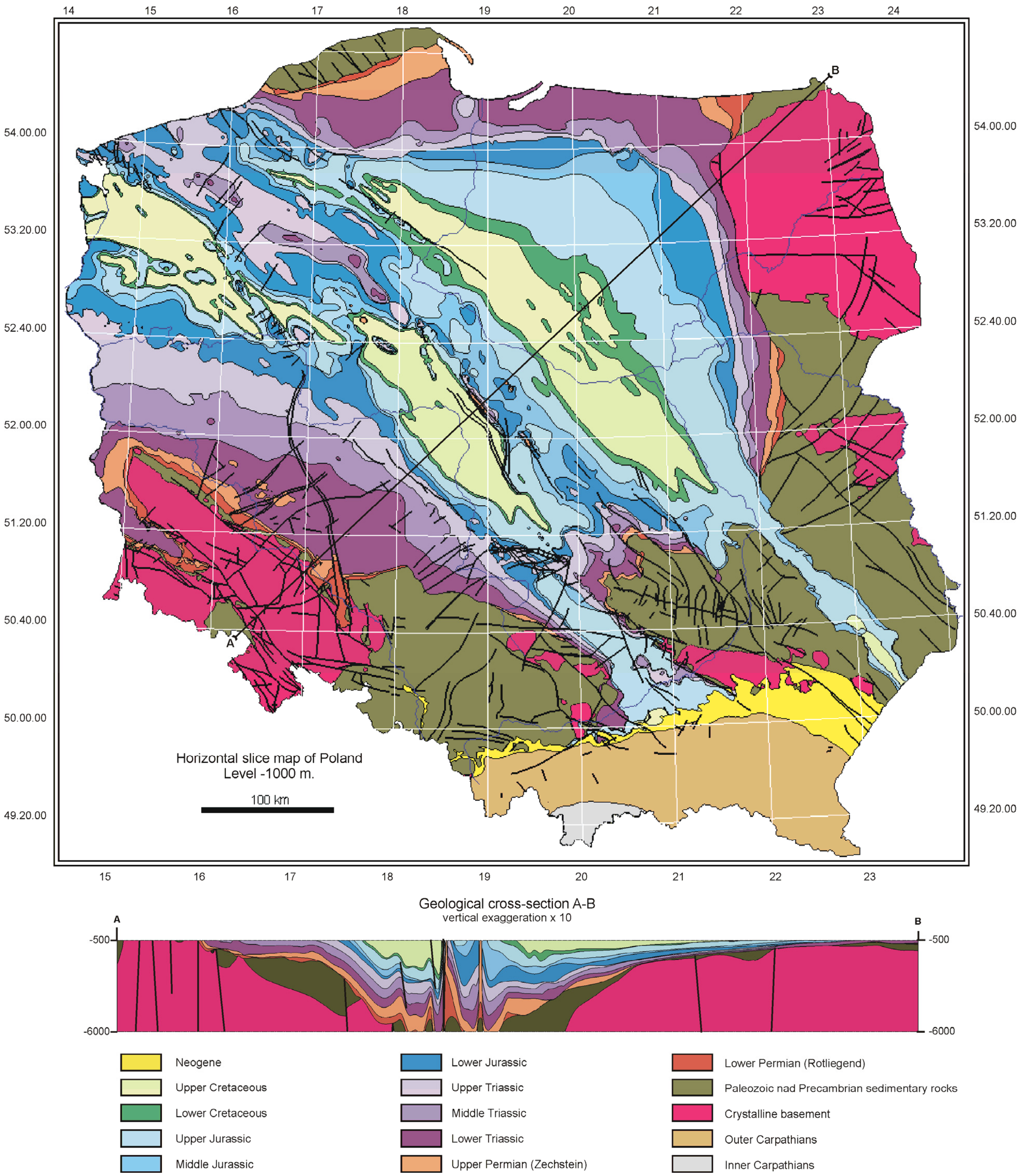

Figure 3. 3D geological model of Poland presented as a horizontal slice map for -1000 m and as a cross-section orthogonal to the axis of the Polish Lowlands sedimentary basin.

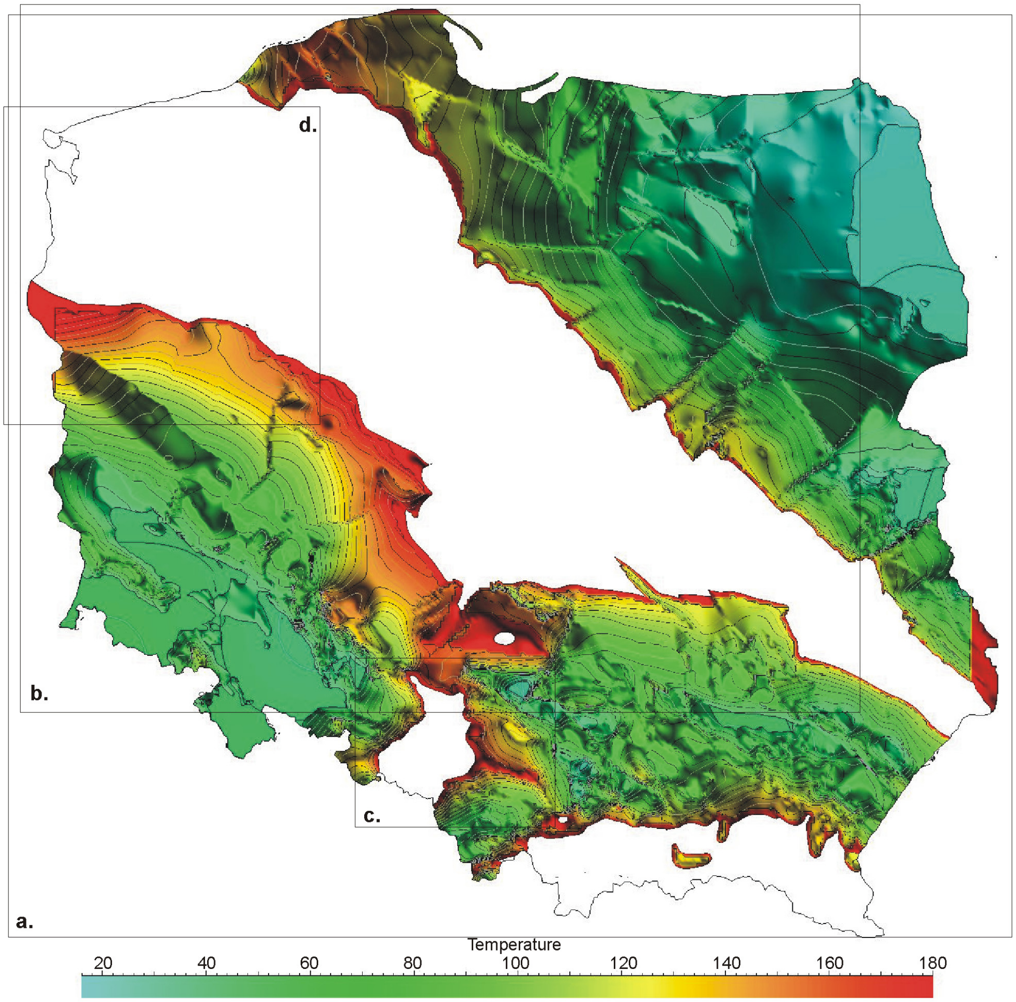

Figure 4. Formation temperature map for the top of Polish crystalline basement the depth interval from -500 to -5000 m; showing extents of study areas for previous detailed geothermal data compilations: a. Sokolowski et al. (1995); b. Gorecki et al. (1995); c. Malolepszy (2000); d. Kurowska (2005).

REFERENCES

Gorecki W., Kuzniak T., Strzetelski W., Szklarczyk T., Ney, R., and Mysko A. 1995. Evaluation of geothermal resources in the Polish lowlands. Proceedings of World Geothermal Congress, Florence, p. 593-597

Kotanski, Z. 1997. Geological atlas of Poland, horizontal section maps. Wydawnictwa Geologiczne, Warszawa

Kurowska, E., 2005. Use of Old Data for Innovative Mapping Techniques in Geothermal Exploration. In: Ostaficzuk S. (Ed.), The Current Role of Geological Mapping in Geosciences, Springer, ISBN: 1-4020-3550-0

Malolepszy, Z. 2000. Geo-synoptic model of geothermics in the Upper Silesian Coal Basin. Technika Poszukiwan Geologicznych, Geosynpotyka i Geotermia, nr 3, Krakow, p. 1-35, 20 maps

Malolepszy Z. 2005. Three-Dimensional Geological Maps. In: Ostaficzuk S. (Ed.), The Current Role of Geological Mapping in Geosciences, Springer, ISBN: 1-4020-3550-0

Piotrowska, K., Ostaficzuk, S., Malolepszy, Z., 2005. 3D geological model of Poland. Archives of Polish Geological Institute, Warsaw

Sokolowski, J. [ed.] 1987. Structural atlas of Poland. Wydawnictwa Geologicze, Warsaw

Sokolowski, J. [ed.] 1995. Geothermal Provinces and Basins in Poland. Krakow. pp. 90