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Deeply concealed half-graben at the SW margin of the East European Craton (SE Poland) — Evidence for Neoproterozoic rifting prior to the break-up of Rodinia

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Abstract Baltica was one of continents formed as a result of Rodinia break-up 850–550 Ma. It was separated from Amazonia(?) by the Tornquist Ocean, the opening of which was preceded by Neoproterozoic extension in a network of continental rifts. Some of these rifts were subsequently aborted whereas the Tornquist Rift gave rise to splitting of Rodinia and formation of the Tornquist Ocean. The results of 1-D subsidence analysis at the fossil passive margin of Baltica provided insight in the timing and kinematics of continental rifting that led to break-up of Rodinia. Rifting was associated with Neoproterozoic syn-rift subsidence accompanied by deposition of continental coarse-grained sediments and emplacement of continental basalts. Transition from a syn-rift to post-rift phase in the latest Ediacaran to earliest early Cambrian was concomitant with deposition of continental conglomerates and arkoses, laterally passing into mudstones. An extensional scenario of the break-up of Rodinia along the Tornquist Rift is based on the character of tectonic subsidence curves, evolution of syn-rift and post-rift depocenters in time, as well as geochemistry and geochronology of the syn-rift volcanics. It is additionally reinforced by the high-quality deep seismic reflection data from SE Poland, located above the SW edge of the East European Craton. The seismic data allowed for identification of a deeply buried (11–18 km), well-preserved extensional half-graben, developed in the Palaeoproterozoic crystalline basement and filled with a Neoproterozoic syn-rift volcano-sedimentary succession. The results of depth-to-basement study based on integration of seismic and gravity data show the distribution of local NE–SW elongated Neoproterozoic depocenters within the SW slope of the East European Craton. Furthermore, they document the rapid south-eastwards thickness increase of the Neoproterozoic succession towards the NW–SE oriented craton margin. This provides evidence for extensive crustal thinning occurring prior to the break-up of Rodinia and formation of the Tornquist Ocean.

Keywords Rodinia, Baltica, Tornquist rift, Orsha-Volyn Aulacogen, Tornquist Ocean, Neoproterozoic, Seismic data, Gravity data

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1. Introduction

Neoproterozoic volcano-sedimentary syn-rift successions have been extensively studied in many parts of the world, due to their hydrocarbon potential (*e.g.*, Craig *et al.*, 2010, 2013) or association with important ore deposits (*e.g.*, Emetz *et al.*, 2004; Gibson *et al.*, 2016, 2017). Often, owing to a complex geological evolution during consecutive Paleozoic, Mesozoic or Cenozoic tectonic events, original Neoproterozoic rift-related structures might have been partly or completely obliterated by younger tectonic features. Neoproterozoic rift structures, because of continued subsidence, might have been also buried to a great depth and could be presently concealed under several kilometers thick successions of younger rocks. All this makes seismic reflection imaging of such structures very challenging, with a relatively few examples of fully or at least partly preserved Neoproterozoic extensional structures that have been imaged on seismic data (*e.g.*, Craig *et al.*, 2010; Jinhu and Wenqing, 2016, 2016; Gibson *et al.*, 2016, 2017; Lassen *et al.*, 2001).

Neoproterozoic (850—550 Ma) breakup of supercontinent Rodinia gave rise to formation of several continental plates including Baltica and Amazonia, separated by the Tornquist Ocean (Bogdanova *et al.*, 2008; Nikishin *et al.*, 1996). Neoproterozoic rifting in present-day SE Poland and W Ukraine led to the formation of two major rift zones: the Tornquist Rift — a precursor of the Tornquist Ocean, and the Orsha-Volyn Aulacogen that became dormant towards the middle of the Neoproterozoic and eventually became aborted (Fig. 1; Bogdanova *et al.*, 2008). Previous models of formation of the Neoproterozoic volcano-sedimentary basin fill in SE Poland, based on well data, indicated a classic syn-to post-rift scenario consistent with a triple junction model postulated for the Tornquist and Orsha-Volyn Rifts (Nawrocki and Poprawa, 2006; Poprawa and Pacześna, 2002; Poprawa, 2006a).

The SW slope of the East European Craton (EEC), covered by a thick pile of Ediacaran and Phanerozoic sediments, was extensively studied using deep refraction data that provided information regarding the top of basement configuration and deep crustal architecture (Guterch and Grad, 2006; Guterch *et al.*, 2010; Janik *et al.*, 2009). Recently, the regional POLCRUST-01 deep seismic profile (Malinowski *et al.*, 2015) and the PolandSPAN™ survey (*e.g.*, Krzywiec *et al.*, 2017a, 2017b) provided additional information on the structure of the sedimentary cover overlying the EEC in SE Poland. In this paper, we present new evidence based on the PolandSPAN™ seismic profile and gravity data that documents the presence of two superimposed structural trends associated with Neoproterozoic rifting in accordance with the model proposed by Poprawa and Pacześna (2002).

2. Geological setting

The SW margin of the EEC is defined by the Teisseyre-Tornquist Zone (TTZ) that corresponds to a transition between the thick crust of the EEC and the thinner crust underlying the West European Paleozoic Platform (*e.g.*, Grad *et al.*, 2002; Guterch *et al.*, 2010). In SE Poland, it is covered by a thick pile of Neoproterozoic, Paleozoic, Mesozoic and Cenozoic sediments. As evidenced by deep refraction data, the TTZ in SE Poland is related to a south-westward shallowing of Moho, from 42 to 50 km in the east, beneath the EEC, to 31—38 km in the west, below the West European Paleozoic Platform (Guterch and Grad, 2006; Guterch *et al.*, 2010). This zone of Moho rise coincides with a

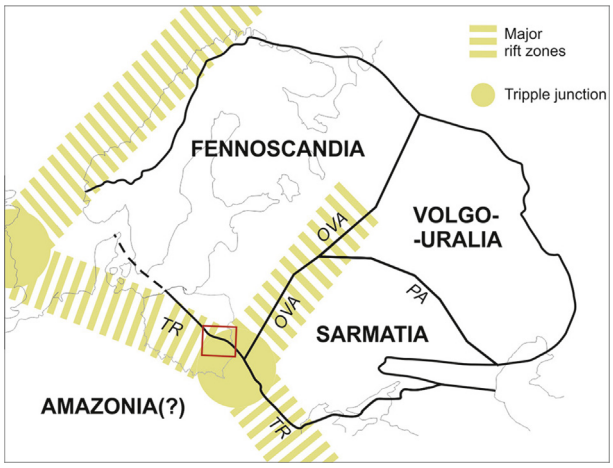

Fig. 1 Rodinia breakup — a model (based on Poprawa, 2006a). Structure of Baltica after Bogdanova *et al.* (2008). TR: Tornquist Rift; OVA: Orsha-Volyn Aulacogen; PA: Pachelma Aulacogen. Red rectangle in SE Poland and W Ukraine represents area shown on maps in Figs. 5 and 6.

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