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Basin evolution and coal geology of the Donets Basin (Ukraine, Russia): An overview

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ABSTRACT

The Donets Basin is a major coal-mining district in eastern Ukraine and adjacent portions of Russia. It comprises the Donbas Foldbelt, which is the uplifted and compressionally deformed part of the Pripyat–Dniepr–Donets (PDD) Basin, and the significantly less deformed Western Donbas region. The PDD Basin is a Late Devonian rift structure located within the East European Craton. Thick coal-measures formed during the post-rift stage of the basin in Serpukhovian to Moscovian times, when about 130 seams, each with a thickness over 0.45 m, have been deposited.

Early Serpukhovian coal accumulated in a relatively narrow shore-zone. It is rich in inertinite and liptinite and very low in ash. Bashkirian and Moscovian coal have a significantly wider lateral extension and are generally rich in vitrinite. Bashkirian and Moscovian coal seams usually have high ash yields (12–18%) and high sulfur contents (2.5–3.5%), but these data vary significantly depending on peat facies.

Coal rank ranges from subbituminous to anthracite and is mainly controlled by the depth of the seams and the heat flow during maximum (Permian) burial. Permo-Triassic thermal events locally overprinted the resulting coalification pattern. Coked coal occurs at the contact to presumed Permian sills and dikes southwest of Donetsk. Deep Permian burial was followed by major Permian and Mesozoic uplift events.

The Donets Basin hosts proven reserves in the order of 60 Gt at the exploitable depth. The thickness of coal seams currently mined is in the range of 0.6 to 2.5 m. Production during 2009 was 68.7 Mt in the Ukrainian and 4.9 Mt in the Russian part of the basin. Coal mines in the Donets Basin are among the gassiest in the world. The average methane content of coal is 14.7 m^3/t, but numerous seams have significantly higher gas content. The high methane content presents a severe mine safety problem. On the other hand, it represents also a high potential for coal mine bed methane projects. Emissions of coal gas released by mining and related structurally induced underground hazards (coal and gas outbursts) are a major problem for safe and efficient coal exploitation in the basin.

1. Introduction

The Donets Basin, also known as Donbas or Donbass, is a major coal-mining district in eastern Ukraine and adjacent portions of Russia. In geological terms it comprises the Donbas Foldbelt, which is the uplifted and compressionally deformed part of the Pripyat–Dniepr–Donets Basin, and the significantly less deformed Western Donbas (Zapadniy Donbassky) region near Pavlograd (Fig. 1A).

The Carboniferous section of the extremely thick sedimentary fill of the Donets Basin hosts one of the major coal fields in the world. The coal, subbituminous to meta-anthracite in rank (Levenshtein et al., 1991a) contains variable, but generally very high methane contents. The high gas content presents both, a severe mine safety problem and a high potential for coal mine and coal bed methane projects (e.g. Antsiferov et al., 2004).

Apart from the economic significance, the Donbas Foldbelt provides an excellent example of intraplate sedimentary basin inversion, which has been studied intensively during the last decade (e.g. Danisik et al., 2010; Maystrenko et al., 2003; Saintot et al., 2003; Stephenson et al., 2006).

The Donets Basin has a centuries-long history of coal exploration and mining. Nevertheless the evolution of the Donets Basin, its coal geology and mining industry are poorly known outside the area of the former Soviet Union. Main aim of the present contribution, an updated version of an earlier overview paper (Privalov et al., 2004), is to distribute the knowledge of different coal geological aspects among the scientific community.

2. Basin evolution and basin structure

The Donets Basin forms part of the Pripyat–Dniepr–Donets Basin (Fig. 1A), a Late Devonian rift structure located in the southern part of

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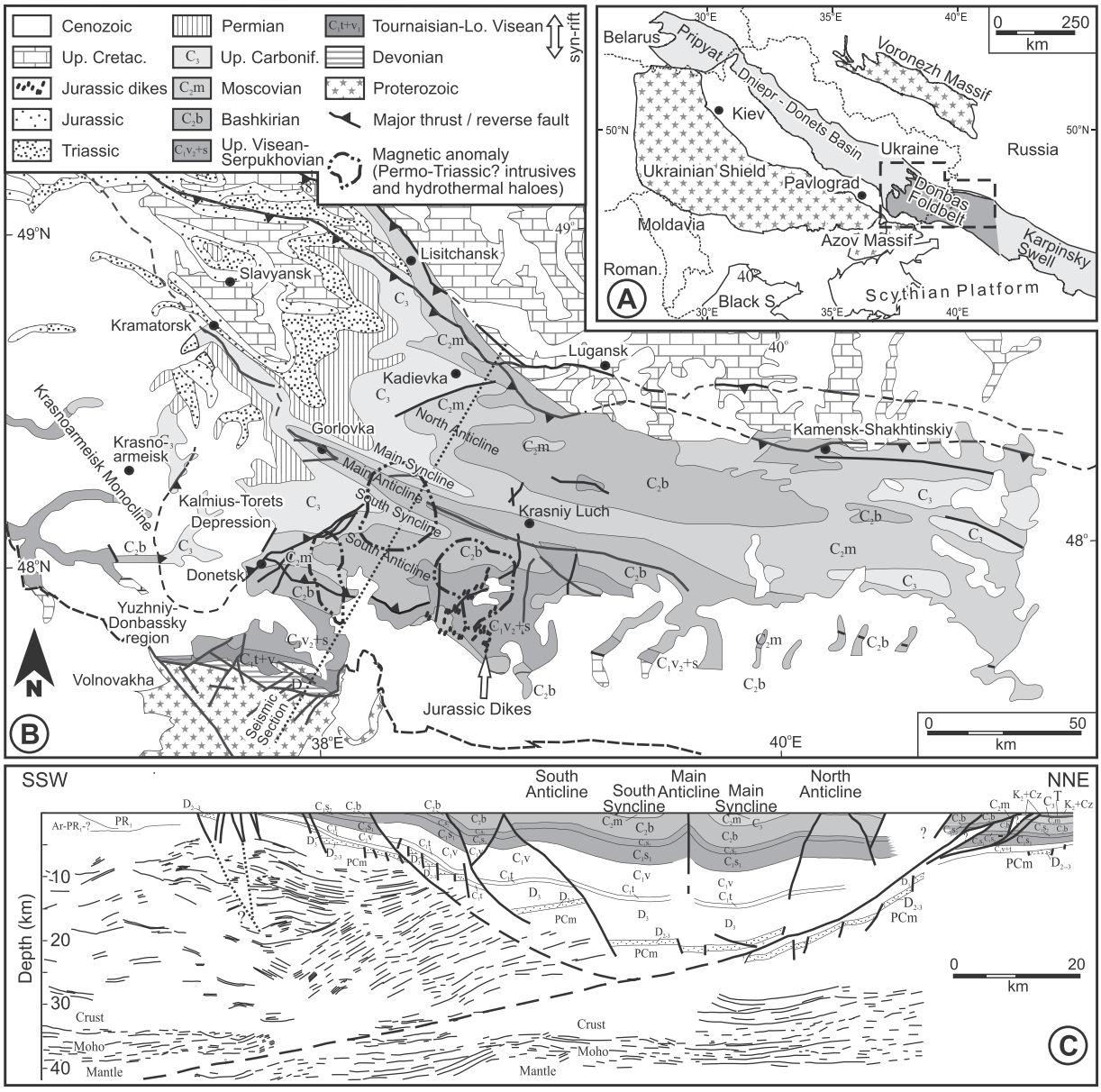

Fig. 1. (A) Location of the study area within the southern part of the Eastern European Craton (after Stovba and Stephenson, 1999). (B) Geological sketch map of the DF (modified after Popov, 1963). Location of Jurassic dikes and magnetic anomalies [interpreted as Permo-Triassic(?) intrusions and their hydrothermal haloes] are shown after Aleksandrov et al. (1996). (C) Interpreted and depth-converted reflection seismic line after Maystrenko et al. (2003).

the East European Craton (Stephenson et al., 2001; Stovba and Stephenson, 1999). Some important aspects of the evolution of the basin are summarized in Fig. 2.

2.1. Paleozoic

Basin formation was initiated by Late Devonian (Frasnian) rifting, which was related either to plume activity beneath the East European Craton (e.g. Chekunov et al., 1992) or to back-arc extension related to subduction along its southern margin (e.g. Ziegler, 1990; see discussion in Stephenson et al., 2006). Total thickness of Devonian pre- and syn-rift rocks as exposed on the southern basin margin is 750 m (McCann et al., 2003), but 5 to 6 km along the basin axis (Maystrenko et al., 2003). The succession comprises volcanic and intrusive rocks, carbonates, and continental clastic and volcaniclastic sediments. Salt is an important constituent of the Devonian succession in the Dniepr–Donets Basin (Stovba and Stephenson, 2003). Its presence in the Donbas Foldbelt has not yet been confirmed, but cannot be excluded.

Major phase of thermal post-rift subsidence occurred during the Permo-Carboniferous. The Carboniferous succession is up to 14 km thick and consists mostly of shallow-marine and continental sediments interbedded with c. 130 workable coal seams. The unusual thickness is partly a result of tectonic reactivations (Stephenson et al., 2006). The Carboniferous succession is subdivided into lithostratigraphic units named suites A (C_1^1), B (C_1^2), C (C_1^3), to P (C_3^3) (Lutugin and Stepanov, 1913; Fig. 2). The coal-bearing succession consists of elementary sequences, composed of fluvial sandstone, coal, marine limestone or claystone, and deltaic claystone and siltstone (Shirokov, 1963a; Shulga, 1981). The sequences are controlled by sea level variations due to glaciations on the Gondwana supercontinent (Izart et al., 1996, 2003a,b). The percentage of continental deposits is