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Stratigraphic distribution of macerals and biomarkers in the Donets Basin: Implications for paleoecology, paleoclimatology and eustacy

A. Izart [a,*], R.F. Sachsenhofer [b,*], V.A. Privalov [c], M. Elie [a], E.A. Panova [d], V.A. Antsiferov [c], D. Alsaab [a], T. Rainer [b], A. Sotirov [b], A. Zdravkov [b], M.V. Zhykalyak [e]

[a] *UMR 7566G2R, Université Henri Poincaré, BP239, F-54506, Vandoeuvre-les-Nancy, France*
[b] *Institut für Geowissenschaften, Montanuniversität Leoben, A-8700 Leoben, Austria*
[c] *Donetsk National Technical University, Artem str. 58, UA-83000 Donetsk, Ukraine*
[d] *UkrNIMI, National Academy of Science of Ukraine, Tchelyuskintsev str. 291, UA-83121 Donetsk, Ukraine*
[e] *Donetsk State Regional Geological Survey, Sybirtseva str. 17, UA-84500 Artemovsk, Ukraine*

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Abstract

More than one hundred and thirty coal seams and coaly layers occur in the Donets Basin (Donbas). Twenty-eight (52 samples) of them, ranging in age from Serpukhovian (Late Mississipian) to Gzhelian (Late Pennsylvanian), 33 clastics and three limestones were studied in terms of maceral composition, sulphur contents, and biomarker distribution. Diterpanes are used to estimate the contribution of different groups of plants and the height of the water table in the swamp; hopanes are a measure of bacterial activity in the peat; and steranes indicate the relative input of wood and algae. Stratigraphic trends in these parameters are discussed in relation to paleoenvironment, climatic changes, and eustacy. A tropical climate prevailed in the Donbas from Serpukhovian to Kasimovian times. Nevertheless, periods with drier and wetter conditions can be distinguished based on maceral and biomarker data. Relatively dry conditions are observed during Serpukhovian and Vereian times, whereas wetter climates with a maximum of coal deposition occurred during the (late) Bashkirian, most of the Moscovian, and the earliest Kasimovian. No economic coal seams are hosted in upper Kasimovian and Gzhelian deposits, a result of a change to an arid climate. Our data also suggest climatic changes during sequences of different order. For the second-order, third-order, and fourth-order sequences, relatively dry or wet conditions occurred during coal deposition in the lowstand systems tract, an intermediate climate during the transgressive systems tract and the maximum flooding, and a wet climate during the highstand systems tract. The results for high frequency sequences support the Cecil's paleoclimatic model: an intermediate paleoclimate during LST (sandstone and levee siltstone), a wet climate during early TST (coal), and a dry climate during late TST (limestone), MFS (claystone), and HST (deltaic siltstone). Coals deposited

* Corresponding authors.
E-mail address: izart.alain@wanadoo.fr (A. Izart).

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during maximum flooding periods are more enriched in C_{27} steranes derived from algae, and contain lower proportions of C_{29} steranes derived from the wood of higher plants.
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1. Introduction

The Donets Basin (Donbas), located mainly in the Ukraine with the eastern part of the basin extending into Russia, contains one of the major coal fields in the world. The basin covers an area of 60,000 km^2 and is located between the Dniepr–Donets Basin and the buried Karpinsky Swell (Fig. 1).

The Carboniferous succession in the Donbas hosts about one 130 seams, each with a thickness of over 0.45 m. Coal rank is generally high and reaches the meta-anthracite stage. Low-rank coals are restricted to the western and northern basin margins (Fig. 1; Sachsenhofer et al., 2002). Main aim of a former paper (Sachsenhofer et al., 2003) was to reconstruct the depositional environment of nine seams.

In the present paper, 28 coal seams, 33 clastic rocks and three limestones are studied using a multidisciplinary approach involving organic petrographical and geochemical techniques. The seams range from Serpukhovian (Late Mississippian) to Gzhelian (Late Pennsylvanian) in age and include the economically most important coals. Main aim of this paper is to describe stratigraphic variations of maceral composition, sulphur content, and biomarker distributions in Donbas coal seams and associated rocks, and to discuss them in relation to changes in paleoenvironment, paleoclimate and eustacy. Our data from Donbas will be compared with samples from other paralic and limnic coal basins of western Europe and the paleoclimatic model of Cecil et al. (2003) that described the mid-Pennsylvanian climate across North America.

2. Geological setting and sequences

The Donets Basin forms part of the Pripyat–Dniepr–Donets–Karpinsky Basin (Fig. 1), which is a late Devonian rift structure located on the southern part of the Eastern European craton (Stovba and Stephenson, 1999; Stephenson et al., 2001). Some important aspects of the evolution of the basin are summarized in Fig. 2. Total thickness of Devonian pre- and syn-rift rocks is 750 m at the margins of the Donets Basin, but reaches 6 km along the basin center (Maystrenko et al., 2003).

Major post-rift subsidence occurred during the Permo-Carboniferous. The Carboniferous sequence, up to 14-km thick, 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). Their correlation with the standard time-scale is presented in Fig. 2. A sequence stratigraphic frame for the Permo-Carboniferous rocks was provided by Izart et al. (1996, 1998, 2003). The coal-bearing sequence is composed of fluvial sandstone, coal, marine claystone or limestone, and deltaic claystone and siltstone. Sequences of different order can be distinguished in the Donbas: high frequency (HFS, fifth and fourth order, < 200 ka), fourth order (FOS, 100 ka to 1 Ma), third order (TOS, 1 to 5 Ma), and second order (SOS, 5 to 10 Ma). The durations of sequences are average durations obtained by division of duration of stages by number of sequences and also calculated durations by spectral analysis (Izart et al., 2003). The radiochronologic data charts of Hess and Lippolt (1986) and Menning et al. (1997) were chosen for the Carboniferous. A HFS is equivalent to a parasequence of the sequence stratigraphy (Van Wagoner et al., 1988), FOS consist of several HFS, TOS of several FOS, and SOS of several TOS.

3. Samples and methods

The samples represent 28 Serpukhovian to Gzhelian coal seams including seven Moscovian and two Serpukhovian seams studied by Sachsenhofer et al. (2003). Most Moscovian seams are represented by 5 to 11 samples (see Sachsenhofer et al., 2003 for

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