P235 PENNSYLVANIAN SOURCE ROCKS FROM THE DONETS BASIN (UKRAINE)

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Summary

Petrographical and geochemical methods were applied to characterise source rocks from the Donets basin (Ukraine/Russia), which contains one of the major coal fields in the world and significant methane resource. Studied coal samples are oil and gas prone, meanwhile clastic host rocks (mostly lacustrine siltstones, marine and deltaic claystones) have only a gas potential, and these source rocks have contributed to the presence of thermogenic gas (methane) hydrocarbon system. Productive and prospective reservoirs include a number of fractured sandstones, as well as coalbed methane reservoirs. Source rocks were diverse in the Donbas in terms of palaeoenvironments because of presence of higher plants, algae or bacteria, influence of an eustacy and palaeoclimatic variations.

Introduction

The Donets Basin (Donbas) is one of the major late Palaeozoic coal and methane provinces in the world. The basin, located mainly in the Ukraine (Fig.1) with the eastern part of the basin extending into Russia, covers an area of 60,000 km² and contains one of the major coal fields in the world with proven reserves in the order of 60 Gt (*Privalov et al., 2004*).

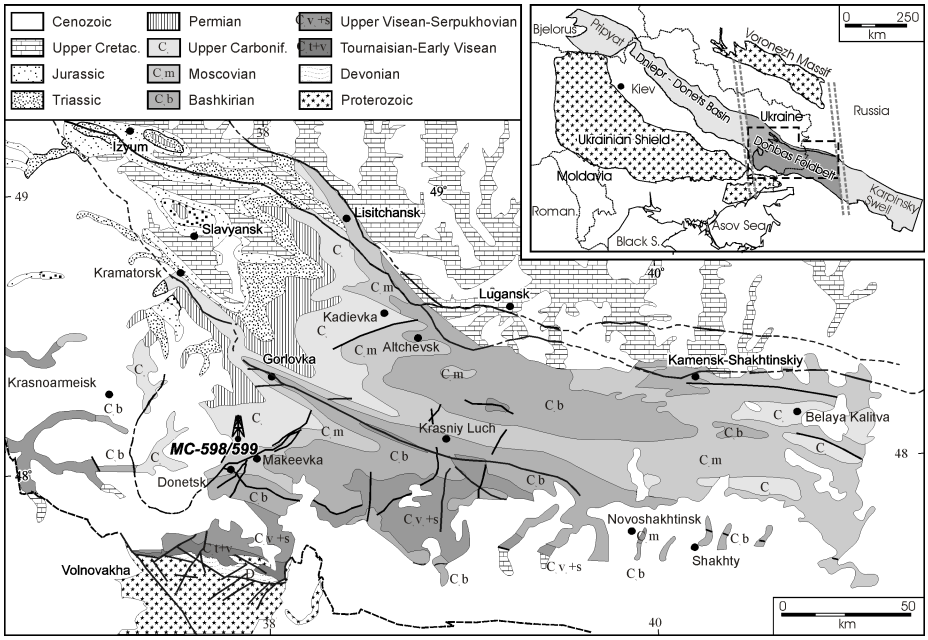

Fig.1. Geological sketch map of the Donets Basin with the shown position of studied wells.

The Carboniferous basin fill hosts more than 130 seams, each with a thickness over 0.45 m. Low-rank coals are restricted to the western and northern basin margins and high-rank coals (anthracites) in the eastern part. The average methane contents in coal seams of different

ranks are in range of: 5-7 m^3/t (sb), 7-9 m^3/t (hvb), 9-15 m^3/t (mvb), 15-17 m^3/t (lvb), 14-16 m^3/t (sa), 17-20 m^3/t (low ranked anthracites), 0.5-1 m^3/t (anthracites and superanthracites). Numerous seams have significantly higher gas content, presenting a high potential for coal mine methane projects.

The isotopic and chemical composition of carbon clearly indicates the thermogenic origin of the methane. Methane occurs within the coal seam, but also within fractured sandstone reservoirs. The study of these sandstone reservoirs is important, because the coal gas migrated into the sandstone reservoir can come back into coal galleries during exploitation by fractures.

Previous investigations were devoted to : i) the reconstruction of depositional environment of 9 coal seams (*Sachsenhofer et al., 2003)*; ii) the genetic identification of thermogenic methane in terms of the interpretation of carbon isotopic ratio versus the dryness of gas for 2 wells (*Privalov et al., 2003)*; iii) the study of 28 coal seams (52 samples), ranging in age from Serpukhovian (Late Mississipian) to Gzhelian (Late Pennsylvanian) in terms of maceral composition, sulphur contents, and biomarker distribution *(Izart et al., submitted)*. The aim of this paper is the study of 21 clastics and associated coals in the wells MC-598 and MC-599 (Donetsk-Makeevka region, Kalmiusky Rudnik site) to precise the diverse source rocks in the Donbas and their relationship with eustacy and palaeoclimates.

Methods

At least 300 points were counted on a Leitz microscope using reflected white and fluorescent light to provide data for maceral analyses. For chemical analysis, a representative portion of the sample was crushed to <250 μm to determine total organic carbon (TOC) contents on a Leco CS-300 instrument. Rock Eval pyrolysis was performed in Leoben University in duplicate using a RockEval 2+ instrument. The amount of free hydrocarbons (S1) and the amount of hydrocarbons released from kerogen during gradual heating (S2) were normalized to TOC to give the bitumen index (BI = S1/TOC) and the hydrogen index (HI = S2/TOC). To characterise the molecular fraction, the powdered whole sediments were extracted. The extract obtained was fractionated by liquid chromatography on a silica column into saturates, aromatics and polars, which were analysed by gas chromatography-mass spectrometry.

Results and Discussion

The Donbas was a paralic basin during the Pennsylvanian located in eastern Europe under equatorial latitude as western Europe and North America. The two boreholes, as other sections and wells from the Donbas *(Izart et al., 2003)*, exhibit high frequency sequences (HFS) composed with fluvial sandstone (LST: lowstand systems tract), coal (early TST: transgressive systems tract), limestone (late TST) , marine claystone (MFS: maximum flooding surface), and deltaic siltstone (HST: highstand systems tract). These HFS are stacked into fourth order (FOS), third order (TOS) and second order (SOS) sequences (Izart et al., 2003), that we also found in the two boreholes (Fig. 2).

Petrographical study of coals and clastics, conducted in Leoben University, showed the presence of vitrinite (highest percentage), liptinite (spores and algae) and inertinite. The vitrinite reflectance of samples increase with depth from 0.62 to 0.99. Geochemical analysis (TOC, Rock-Eval) were also used. TOC is higher in coals (80%), intermediate in claystones (0.5 to 6%) and siltstones (0.5 to 16%) and lower in sandstones (<0.1%). The effective HI ranges from 50 to 200 mgHC/gTOC for deltaic siltstones, lacustrine and marine claystones; and it is equal to 190-258 mgHC/gTOC for coalbeds (Fig. 3). These values are linked with the high percentage of vitrinite. This suggests that coal seams can be considered as gas and oil prone source rocks, meanwhile some from clastic host rocks possess only gas potential. The lowest and even zero values of HI are typical for clastic rocks of alluvial origin and palaesols.

Saturates and aromatics were analysed in the laboratory of the UMR G2R, diverse ratio were calculated and their stratigraphic changes presented in the figure 3. Highest values of

Pristane/Phytane (Pr/Ph) ratio are located into coals and lowest in the marine or lacustrine claystones. Swampy environment presented oxic conditions and marine or lacustrine environments reduced conditions. For HFS (Fig. 3), Pr/Ph ratio is high during early TST (mean: 5.75), intermediate during LST (1.55) and HST (2.21), and low during MFS (1.42). The R_{dit} ratio *(Fleck, 2001)* allows to estimate the level of the water table in the swamp (low: R_{dit} <1; medium to high: R_{dit} >1) for coals and the palaeoclimate. For HFS (Fig. 3), the R_{dit} exhibits intermediate values during LST (mean: 1.33), high to intermediate values during early TST (1.5 for the interval Podolskian-Kasimovian, but 1.16 for all the Carboniferous), low value during MFS (1.22) and intermediate value during HST (1.27). The R_{dit} suggests for HFS an intermediate climate during LST and HST, a wet to dry climate during early TST (coal) and a dry climate during MFS (marine claystone). The hopanes/steranes ratio, that is high when bacterial activity is important, is low for HFS (Fig. 3) during LST (mean: 5.35), intermediate during MFS (7.55) and HST (7.69), and high (11.15) during early TST. For HFS (Fig. 3), the maximum of C_{27} steranes (37%) and the minimum of C_{29} steranes (41%) are observed in rocks deposited near the MFS, whereas the C_{28} steranes present only a small change. Coals deposited near the MFS contain the highest amount of C_{27} steranes linked to algae and the lowest amount of C_{29} steranes derived from wood of terrestrial higher plants. Eustacy controls the distribution of steranes in rocks of the Donbas. The results for HFS support the palaeoclimatic model of *Cecil et al. (2003)* with some modifications: a wet or dry palaeoclimate during LST and early TST (coal), a dry climate during MFS (marine claystone), and a wet palaeoclimate during HST (deltaic siltstone).

Conclusions

Source rocks were diverse in the Donbas according to the palaeoenvironments, presence of higher plants, algae or bacteria, eustacy and palaeoclimates. Of particular significance to further exploration and development potential is conclusion, that numerous mostly gas prone source rocks in the Donbas include coalbeds, as well as a spectrum of clastic rocks.

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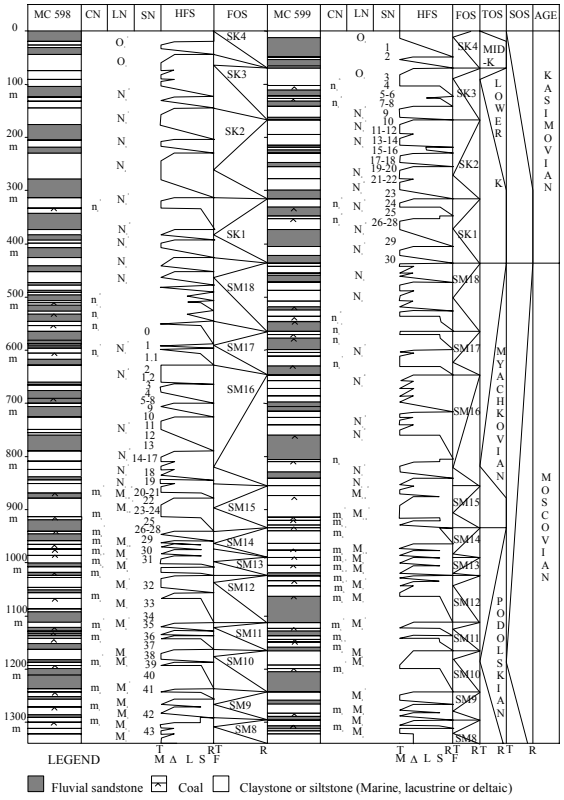

Fig.2. Lithostratigraphic colums of MC-598 and MC-599 wells, palaeoenvironmental curves and sequences. CN: coal seam number, Δ: deltaic environment, F: fluvial environment, FOS: fourth order sequence, HFS: high frequency sequence, L: lacustrine environment, LN: marine band number, M: marine environment, R: regression, S: swampy environment, SN: sample number, SOS: second order sequence, T: transgression, TOS: third order sequence.

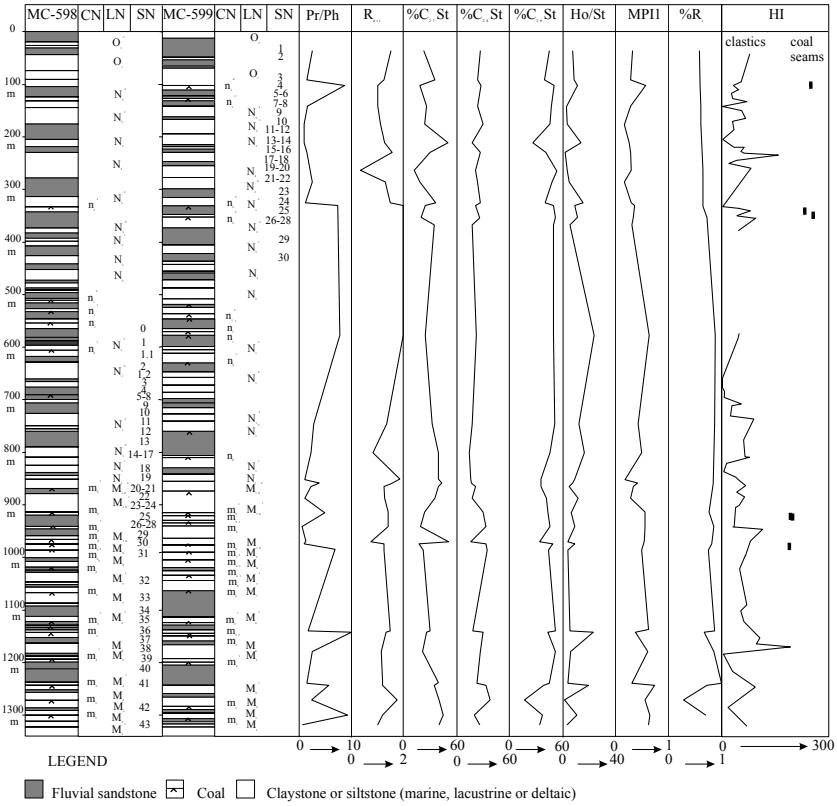

Fig.3. Stratigraphical changes of biomarkers, vitrinite reflectance and hydrogen index in wells MC-598 and MC-599. CN: coal seam number, Ho/St: Hopanes/Steranes, LN: marine band number, MPI1: Methyl-Phenantrene Index, Pr/Ph: Pristane/Phytane, $\%R_r$: Vitrinite reflectance, R_{dit}: Diterpanes ratio (Fleck, 2001), SN: sample number, St: Steranes, HI: hydrogen index.