P237 EXPLORATION STRATEGY IN THE DONETS BASIN (UKRAINE): DEFINITIONS FROM THERMAL AND BURIAL HISTORY RECONSTRUCTIONS

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Summary

Coal mines in the Donets Basin (Ukraine) are among the gasiest in the world. As basic tool for definition of exploration strategy in the Donets Basin the numerical basin modelling technique was used. Organic maturity data (vitrinite reflectance) of coals and dispersed organic matter in the Carboniferous sediments were applied for the calibration of the simulated heat flows and to characterise magnitude of erosion and thickness of Carboniferous measures. Of particular significance to further exploration and development potential are sites of methane accumulations associated with post-inversion "thermal event" impulse, as well as moderately uplifted areas with the abnormal levels of pre-inversion heat flow.

Introduction

In gross structural terms, the Donets basin (Donbas) is the segment of the Pripyat-Dnieper-Donets-Karpinsky Late Devonian rift system located on the southern part of the Eastern European craton. However, only here the recurrently repeated palae-environments from swampy coastal-marine plains with huge peatbogs to shallow sea basins resulted in accumulation of thick (up to 14 km) paralic coal-bearing Carboniferous (post-Early Visean) formation containing about 300 coal seams and layers. Thermal maturation of concentrated in coal seams and dispersed in the Carboniferous host clastic rocks organic matter (Ukrainian Donbas: ~1 trillion tons of coaly mass) has led to formation of an enormous methane resource about 278 trillion m^3 *(Uziyuk et al., 2001),* which retention potential after Permian inversion and Cimmerian-Alpine tectonic events is estimated by several investigating entities in range of 12-27 trillion m^3 *(Privalov and Panova, 2001).* Almost the all coal fields of the Donets Basin excluding most eastern anthracite regions are characterised by high coalbed methane content *in situ* (from 8-10 to 25-35 m^3/t). Some seams during underground coal mining demonstrate more than 100 m^3 per ton of mined coal. Domal structures along the northern marginal fault of the Donets Basin and in the southern Krasnoarmeisk and Yuzhno-Donbassky regions host conventional gas deposits *(Privalov et al., 2004)*.

Using 1-D and 2-D numerical models on the basis of the vitrinite reflectance trends within 23 wells, *Sachsenhofer et al. (2002)* reconstructed the heat flow history of the south-western part of Ukrainian Donbas. According to these models, heat flow during maximum burial was in the range of 40 to 75 mW/m^2 (Fig. 1). Maximum burial occurred during early Permian time and was followed by a major exhumation phase. The resulting coalification pattern in some areas of the basin was overprinted by thermal events. *Spiegel et al. (2003)* used zircon and apatite fission track dating to reconstruct the post-depositional thermal evolution of the inverted basin. Modelling of the fission track data, combined with modelling of vitrinite reflectance data, reveal that large parts of the basin were affected by a Permo-Triassic (~250

Ma) heat flow event, which was related to Permo-Triassic andesitic magmatism. Whereas rocks west of the city of Donetsk (Krasnoarmeisk Monocline) experienced Permo-Triassic temperatures in the range of 90 to 105°C, rocks northwest of Donetsk were heated to up to more than 240°C. No methane, but abundant CO (up to 35 m^3/t coal), occurs in the southeastern part of the basin. Perhaps, this is due to de-gasification during Cretaceous uplift (*Sachsenhofer et al., 2004)*.

The aim of this paper is the definition of exploration strategy from standpoint of the heat flow, subsidence, and erosion history of the Donbas with incorporating into existing models results of new 1-D numerical basin modelling based on the data of our own measurements of organic maturity data of coals and dispersed organic matter within wells MC-598, MC-599 and interpretation of unpublished reflectance data from additional 6 exploration wells provided by the industry.

Methods

The numerical modelling of the thermal and burial history was conducted with the PDI-1D™ and PetroMod 6.0 software packages of IES, Jülich. Calibration of the burial and heat flow histories was performed using vitrinite reflectance data and recent formation temperatures. Input data for numeric models include the thickness of stratigraphic units, lithologies, rock physical parameters (e.g. thermal conductivities), the temperature at the sediment-water interface, and heat flow at the base of the Carboniferous sequence.

Results and Discussion

The major oil-and gas prone sources in the Donbas are some coal beds and restricted, while the gas-prone sources are dominant within the most of the Carboniferous succession. Revealed heat flow patterns during maximal burial and "thermal event" (Fig. 1, A) demonstrate the significant inhomogeneity and have contributed to the presence of thermogenic gas (methane) hydrocarbon system.

Geologically, the basin stands out by its up to 22-24 km sedimentary column and its prominent inversion. The significant tectonic element of intrabasional architecture is WNW-ESE trending principal displacement zone (PDZ) consisting of a set of dextrally *en echelon* arranged deep basement faults with oversteps superimposed on depressions (pull-aparts) in the basement *(Privalov et al., 1998)*. During post-rift stage strike-slip pulses within PDZ affected local depositional environments in the vicinity of pull-aparts and influenced on depositional and inversion trends across the entire basin.

The most prominent deep fault within PDZ is expressed in Palaeozoic strata as the Main Anticline, which is the largest and most pervasive fold with steeply dipping limbs, complicated by faults developed at its hinge, in which dextral movement has been recognised. The obtained results showed (Fig. 1, A) that along the Main anticline during maximal burial the heat flow was in range of 64-66 mW/m² and even >70 mW/m² (in area of pull-apart *PA4*). This suggests an activity of this structure even during post-rift sedimentation stage, which can be recognised also from analysis of regional deference in burial history. According the results of modelling the Main anticline between pull-aparts *PA3* and *MA1* has been partially formed as synsedimentary antiform, because of the local minimum of thickness of Middle-Late Carboniferous (suites G to P) and early Permian rocks (Fig. 1, B). In the region gravitated to pull-apart PA3 we revealed the abnormal post-inversion heat flow <150 mW/m², which could be responsible to hot aqueous solutions and formation of epigenetic mercury-antimony deposits within this area. Taking into account, that to the west from pull-apart *PA3* coals were lower in rank and had not attained enough thermal maturity during pre-inversion stage, this anomaly may have induced the generation of large amounts of thermogenic coalbed methane with its further trapping into the Druzhkovka-Konstantinovka (DK) anticline, wherein numerous prospective high-permeability and fractured reservoirs are present.

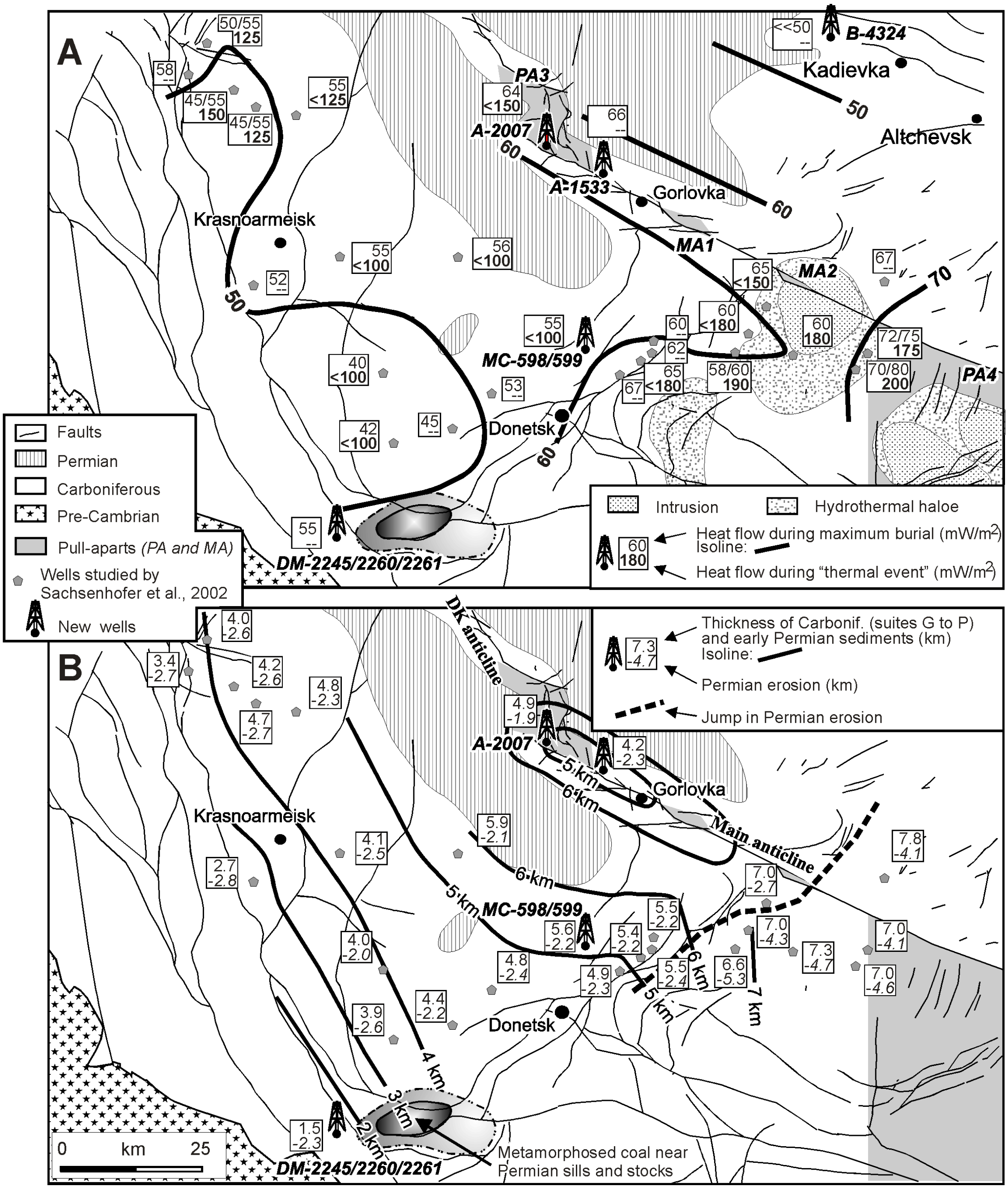

Fig.1. Results from 1-D models: A) Heat flow distribution during maximum burial; B) Map showing thickness of Middle/Late Carboniferous (suite G to suite P) and early Permian rocks. The thickness of rocks removed during Permian erosion is also indicated (negative numbers).

In an area of wells MC-598/599 the post-inversion heat flow is estimated on the level of <100 mW/m². Here the evidence for occurrence of methane associated with coal seams includes direct measurements in wells and coal cores, surface venting of gas, gas-related explosions and fires in underground coal mines. Most of retained gas accumulations here are structurally focused onto crests of high hinges on monoclines, flexures and hangingwalls of reversed faults with strong respect on lithologically related permeability contrasts. The moderate magnitudes of inversion (Permian erosion) in range of 2.2 km (Fig. 2) and caused by this cooling were enough to create an additional resource of gas-storage capacity in coals. It suggests the sufficient retention potential of methane of pre-inversion generation. However, the input of postinversion methane of secondary generation related with "thermal event" has not to be excluded.

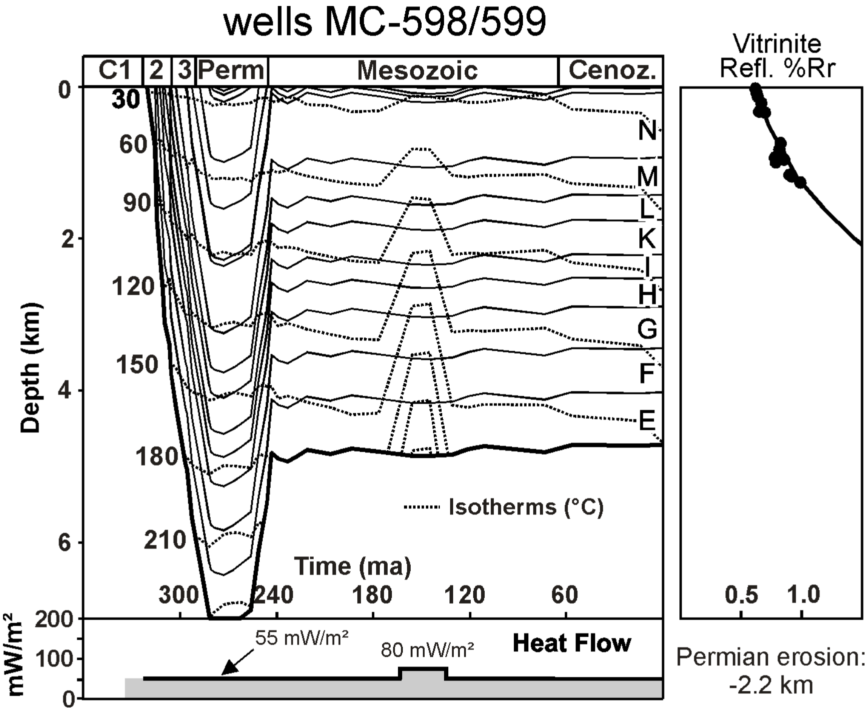

Fig.2. Subsidence and heat flow histories of wells MC-598/599. On the right, measured (dots) and calculated (lines) vitrinite reflectance data are shown.

Conclusions

Results of new burial and thermal history reconstruction can be used as a useful exploration tool in the Donets Basin. Revealed patterns of pre- and post-inversion heat flows, magnitudes of inversion uplift allow to target new prospective areas for coal bed methane capture and further utilisation. Of particular significance to further exploration and development potential are sites of methane accumulations associated with post-inversion "thermal event" impulse, as well as moderately uplifted areas with the abnormal levels of pre-inversion heat flow.

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