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Research paper

Lower Cretaceous black shales of the Western Carpathians, Czech Republic: Palynofacies indication of depositional environment and source potential for hydrocarbons

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ABSTRACT

Uppermost Jurassic and Lower Cretaceous strata of the Silesian Nappe of the Outer Western Carpathians contain large amounts of shale, which can, under favourable conditions, become source rocks for hydrocarbons. This study analysed 45 samples from the area of Czech Republic by the means of palynofacies analysis, thermal alteration index (TAI) of palynomorphs and total organic carbon (TOC) content to determine the kerogen type, hydrocarbon source rock potential, and to interpret the depositional environment. Uppermost Jurassic Vendryně Formation and Lower Cretaceous Formations (Těšín Limestone, Hradiště and Lhoty) reveal variable amount of mostly gas prone type III kerogen. Aptian Veřovice Formation has higher organic matter content (over 3 wt.%) and oil-prone type II kerogen. Organic matter is mature to overmature and hydrocarbon potential predisposes it as a source of gas. Aptian black claystones of the Veřovice Fm. are correlatable with oceanic anoxic event 1 (OAE1).

1. Introduction

The aim of this paper is to give a simple hydrocarbon potential evaluation of the Lower Cretaceous part of Silesian Nappe of the Outer Western Carpathians.

The Silesian Nappe belongs to the Flysch Belt of the Western Carpathians. The flysch (turbiditic) sediments contain large amounts of shale, which can, under favourable conditions, become source rocks for hydrocarbons. The geological age of the Silesian Nappe ranges from Uppermost Jurassic (Oxfordian) to Miocene.

Most of the hydrocarbon potential studies in the Silesian Nappe had, so far, been focused on an Oligocene Menilite Formation, which is believed to be the main source rock of hydrocarbons in Carpathians (see Pícha et al., 2006 and references therein). Much less attention had been paid to the Lower Cretaceous formations, which also contain some potential source rocks. They had been studied by some authors in Polish and Ukrainian Carpathians (Koltun et al., 1998; Kosakowski et al., 2009; Kotarba et al., 2013; ten Haven et al., 1993), however in Czech Carpathians there is a gap in knowledge of their hydrocarbon potential.

The Lower Cretaceous formations encompassed in this work are following: Vendryně Fm., Těšín Limestone, Hradiště Fm., Veřovice Fm. and Lhoty Fm. The most perspective of these formations is the Veřovice Fm. which was deposited during an extreme anoxia.

The methods used in this study are (i) palynofacies analysis to determine the kerogen type, (ii) observation of thermal alteration (TAI) of palynomorphs for thermal maturity assessment and (iii) TOC content measurement for a rough estimate of the quantity of organic matter.

2. Geological setting

The Outer Western Carpathians represent the most external zone of the Western Carpathian mountain chain. They comprise a structurally-complex area which consists of folded and thrusted strata of latest Jurassic to Late Miocene age. In its present form, the Outer Carpathians consist of two groups of nappes (from the lowest to the highest): the Outer Group of Nappes (divided from lowest to highest into the Subsilesian, Silesian, and Ždánice nappes) and the Magura Group of Nappes (divided into the Rača, Bílé Karpaty, and Bystrica nappes, see Fig. 1). The whole nappe allochthon is thrust

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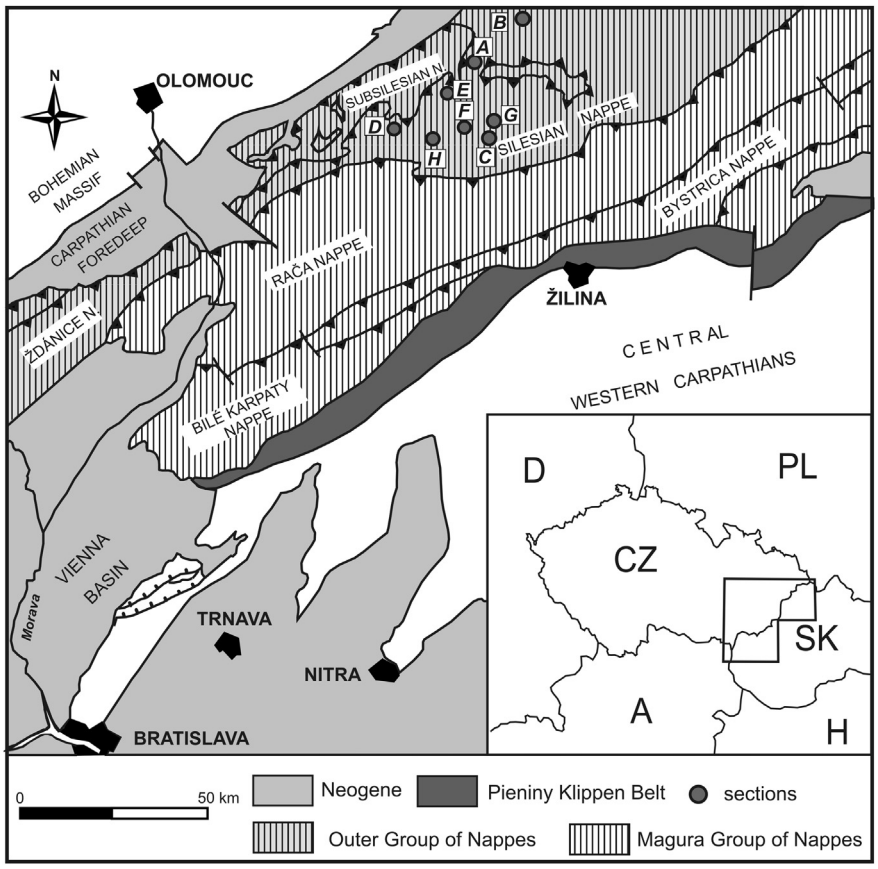

Figure 1. Tectonic map of the Outer Western Carpathian area in the eastern part of the Czech Republic (its position in the frame of middle Europe is indicated in the lower right corner). Explanations: studied sections: A – Skalice, B – Jahodná, C – Nová Dědina, D – Lichnov, E – Soběšovice, F –Kunčice pod Ondřejníkem, G – Satina, H – Pindula.

more than 60 km over the Miocene sediments of the Carpathian Foredeep (Pícha et al., 2006).

The Silesian Nappe consists of Upper Jurassic to Oligocene-Miocene sediments deposited in the Silesian Basin (Pícha et al., 2006). The Silesian Basin developed from Jurassic times under the extension regime along the southern edge of the western part of the Paleoeuropean Platform. The maximum extension most likely occurred during the Hauterivian and Barremian, as documented by the intensity of the basic submarine volcanism of the teschenite association. A gradually diminishing supply of clastic sediments in the course of the later part of the Early Cretaceous, the deepening of the depositional site, global influences and other factors lead to the creation of a dysoxic and later anoxic environment in the basinal part of the Silesian Basin. The sedimentation of a thick complex of grey to dark grey pelitic deposits took place from the Hauterivian to Albian.

Three fundamentally different facies are preserved in the present-day structure of the Silesian Nappe (Pícha et al., 2006): the Godula facies (basinal setting), the Baška facies (frontal slope setting), and the Kelč facies (continental slope setting). These facies differ in their stratigraphic extent, in the overall thickness of their depositional sequences and in their lithostratigraphy. The Godula facies was deposited as thick turbidite fans in the continental rise setting. The lower part is mainly pelitic (Oxfordian to Albian). The typical flysch of proximal turbidites dominates in the upper part (Cenomanian to Oligocene). Sedimentation below the calcite compensation depth – CCD predominates from the Barremian to Eocene (Uchman et al., 2006). The Godula development reaches a total thickness of up to 6000 m. The Baška facies was deposited in the turbidite fan adjacent to the carbonate ramp. The thickness of the whole sequence (Tithonian-Maastrichtian) is estimated to be 1600–1800 m. The Kelč facie represents slope shales (Valanginian–Danian). Its thickness reaches several hundred metres.

The following text gives the basic characteristics of deposites of Godula facies and an approximate age in Ma according time scale of Gradstein et al. (2004).

The oldest deposits of the Godula facies are represented by Upper Jurassic Vendryně Formation (earlier, Lower Těšín Member of Eliáš et al., 2003), consisting of dark brown-grey calcareous claystones with a total thickness of up to 400 m. According to the observed macrofauna (aptychi, ammonites), these layers belong to the Oxfordian – early Berriasian (159–145.5 Ma; Skupien and Smaržová, 2011; Vašíček, 1972).

Sedimentation continuously proceeds with the deposition of a muddy calcareous facies designated as the Těšín Limestone (early Berriasian – early Valanginian; 145.5–139 Ma; Boorová et al., 2003), which, mainly in its lower part, is composed of light grey micritic limestones alternating with light grey or green-grey calcareous claystones. Laterally, these muddy facies pass into facies of detrital limestones with occasional calcareous sandstones, and intercalations of calcareous claystones. The Těšín Limestone passes upward into the Hradiště Formation (earlier, the Těšín-Hradiště Formation), assigned, based on non-calcareous dinoflagellates, to the early Valanginian to lower part of the late Aptian (139–114 Ma; Skupien, 1999). The chronostratigraphy of the upper part of the formation (Barremian to Aptian) is based on the presence of ammonites as well (Skupien and Vašíček, 2002; Vašíček and Skupien, 2002). In its lower part, it consists of calcareous dark