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Review papers

Palynofacies and geochemical analysis of Oligo-Miocene bituminous rocks from the Moldavidian Domain (Eastern Carpathians, Romania): Implications for petroleum exploration

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ABSTRACT

A palynological, palynofacies and geochemical investigation conducted on Oligo-Miocene bituminous rocks of the Lower Dysodilic Shale Formation and the Upper Dysodilic Shale Formation (Eastern Carpathians) has allowed recovery of pollen and spore assemblages associated with marine palynofossils (dinoflagellates and prasinophyte algae) and phytoclasts. The general composition of the assemblages suggests an anoxic depositional environment from a distal basin to a highly proximal shelf. The palynological assemblage identified in the Lower Dysodilic Shale Formation exhibits an abundance of dinoflagellate cysts and prasinophyte algae, with some taxa, such as *Wetzeliella gochtii*, *Rhombodinium draco* and *Cordosphaeridium gracile*, indicating a Rupelian–early Chattian age for these deposits. In contrast, the Upper Dysodilic Shale Formation displays diverse assemblages of palynomorphs (more pollen and spores) and its age is older than middle Aquitanian. Geochemical (Total Organic Carbon content and Rock-Eval pyrolysis) and palynofacies (optical and scanning electron microscopy) analyses performed on samples from the Lower Dysodilic Shale Formation suggest that it contains type II kerogen (oil prone), consisting of abundant amorphous organic matter (AOM), extracellular polymeric substances (EPS) and coccoid bodies (bacteria or algae). This kerogen comes from a marine source (derived from phytoplankton and bacteria), and likely accumulated in a distal suboxic-anoxic basin. The Total Organic Carbon (TOC) content suggests good to excellent petroleum potential, especially for generating mixed oil and gas. The level of kerogen maturation (inferred from the Thermal Alteration Index, T_{max} and prasinophyte algae fluorescence) lies at the boundary between immature and mature phases. The Upper Dysodilic Shale Formation is abundant in translucent and opaque phytoclasts, suggesting a continental organic matter source and type III kerogen, and thus would yield mainly gas. This organic matter was principally deposited in a highly proximal shelf setting.

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1. Introduction

The main types of bituminous rocks in the Eastern Carpathian region are menilites, brown marls and the bituminous shale belonging to the Tarcău and Vrancea Nappes. These rocks, which have a high content of organic matter, were formed under anoxic conditions in the sedimentary basin that occurred along the Carpathian Chain during the Oligocene. Their organic content in relation to oil production and degree of maturity have been documented by Nacu et al. (1970), Balteş (1983), Stănescu and Morariu (1986), Grasu and Catană (1989), Ştefănescu et al. (2006) and Grasu et al. (2007). Based on geochemical studies (TOC amounts and Rock-Eval parameters), recent papers (Belayouni et al., 2009; Amadori et al., 2012) have shown that the bituminous rocks from this area can be regarded as having good petroleum potential, being in a sub-mature to mature thermal stage, and generally containing type II kerogen (lipidic organic matter, good oil and gas-prone source rocks). The present study focuses on the analysis (optical and geochemical) of organic matter from Oligocene–Miocene bituminous rocks, in an attempt to provide new data regarding the palynofacies, palynological assemblages and hydrocarbon potential of these formations. It is the first detailed description of the optical appearance in transmitted light microscopy and scanning electron microscopy (SEM) of the organic matter contained in the main hydrocarbon source rocks from the Eastern Carpathian Flysch zone.

The aims of the present study are thus the following: (1) identify palynological taxa (derived from either terrestrial or marine environments), and reconstruct palaeoecological conditions; (2) use the assemblages for biostratigraphic age assignment and correlation; (3) analyze the palynofacies characteristics of the sedimentary formations studied, using various microscopic techniques; (4) determine the source rock potential for hydrocarbons generation based on geochemical analyses; and (5) identify the different kerogen types and determine their thermal maturity.

2. Geological settings

The Carpathian Chain in Romania resulted from a collision between the African–Arabic and European plates, which led to the gradual closure of the Tethys Ocean during the Cretaceous and Miocene convergence events (Săndulescu, 1984). According to Săndulescu (1984), the deformation in the Romanian Carpathians took place in two stages: (a) — in the Cretaceous period, when the Transylvanide and Dacide Units were built up; (b) — during the Miocene, when the Moldavidian Unit in the Eastern Carpathians was formed. The Moldavidian Unit includes, from west to east, the following tectonic nappes: Teleajen, Macla, Audia, Tarcău, Vrancea and the Pericarpathian Nappe (Fig. 1).

The Paleogene–Miocene deposits included in various structural units of the Moldavide sometimes display considerable lateral facies variation. Thus, three distinct lithofacies have been identified (Băncilă, 1958; Ionesi, 1971) in the Tarcău Nappe: the Fusaru Lithofacies in the west, Moldoviţa Lithofacies (mixed) in the center, and the Kliwa Lithofacies in the eastern part. In the lithological profiles analyzed from Tarcău Nappe, the samples were collected only from the Kliwa Lithofacies (Fig. 1).

The Kliwa Lithofacies sedimentary deposits consist of quartzarenites (of the Kliwa type), composed of mineral particles with a possible external (cratonic) source. In the case of the bituminous rocks (of Oligocene–early Miocene age), the sediment consist mainly of pelitic, bituminous marls and black shales that are generally silty-clayey, and menilites containing a silicious material. These were deposited under anoxic conditions, which enhanced organic matter preservation. This organic matter is considered to be autochthonous (marine); its accumulation being uniform throughout the External Flysch basin (Grasu et al., 2007).

In the Kliwa Lithofacies, the limit of erosion reached the Kliwa Formation, while newer sedimentary deposits than this can be identified in the Vrancea Nappe, and are assigned to the Upper Dysodilic Shale and Gura Şoimului Formations (Fig. 1).

In the Eastern part of the Kliwa Lithofacies, corresponding to the Tarcău Nappe, a second lithofacies (named Pietricica) included in the Vrancea Nappe, was identified. This nappe is structurally interposed between the Tarcău and Pericarpathian Nappes, and is found below the Tarcău Nappe (Fig. 1 — Geological section). It occurs in outcrops as a tectonic window or as half-windows, resulting from erosion of the covering nappe (Fig. 1). Stratigraphically, the deposits assigned to the Vrancea Nappe are of Senonian, Paleogene and early Miocene age (Ionesi, 1971; Grasu et al., 1988). These deposits are generally similar to those of the Kliwa Lithofacies. However, there are certain differences, such as the reduction in thickness of the Kliwa Formation or the appearance of ruditic facies with “green schists” of the Central Dobrogea type (Ionesi, 1971; Grasu et al., 1999).

Fig. 1. Geological map with the locations of the stratigraphic sections studied (noted LS1–LS5). Geological cross-section according to Bădescu (2005). Lithological column according to Grasu et al. (2007). Geological maps: A. Humor Half-window (after Ionesi, 1971), B. Bran-Dumesnic tectonic window (after Grasu et al., 1976), C. Bistriţa Half-window (Micu, 1976), D. Slănic-Oituz Half-window (after Dumitrescu et al., 1968).