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Konrad Ziemianin

*Oil and Gas Institute – National Research Institute*

# Characteristics of dispersed organic matter in the Menilite Beds from the Skole Unit

Composition and thermal maturity of organic matter components from Menilite Beds (Skole Unit) were analyzed. Samples (26) were collected from 9 outcrops within the investigated area. Samples represented several lithologies – clay and marly shales, mudstones, sandstones/siltstones, micritic limestones and cherts. Macerals of three groups (vitrinite, inertinite and liptinite) are present in the analyzed samples. Macerals of the liptinite group are the most numerous. Within this group, bituminite is most common, while alginite and liptodetrinite are less often observed. Macerals of the vitrinite (collotelinite, telinite, vitrodetrinite) and inertinite (fusinite, semifusinite, inertodetrinite) groups are also present, but their content is significally lower compared to the macerals of the liptinite group. Organic matter within all the investigated area is clearly immature, which is confirmed by both vitrinite reflectance $R_o$ and $T_{max}$ parameters. The composition of organic matter relates mostly to kerogen type II and III (and their mixture). Several relations between Rock-Eval parameters and maceral composition were identified. The obtained results were compared to data from Menilite Beds of the Silesian Unit.

Key words: Menilite Beds, Skole Unit, macerals, vitrinite reflectance, Rock-Eval pyrolysis.

## Charakterystyka rozproszonej materii organicznej w warstwach menilitowych jednostki skolskiej

W artykule przeanalizowano skład i dojrzałość materii organicznej obecnej w warstwch menilitowych jednostki skolskiej. Przebadano 26 próbek pochodzących z 9 odsłonięć. Próbki reprezentowały różne odmiany litologiczne – od łupków ilastych, przez ilasto-węglanowe, mułowce, piaskowce/pyłowce, po utwory węglanowe i rogowce. W próbkach obserwuje się macerały wszystkich trzech grup tj. witrynitu, inertynitu i liptynitu. Macerały grupy liptynitu zdecydowanie dominują w składzie materii organicznej. Najczęściej jest tu spotykany bituminit, a rzadziej alginit i liptodetrynit. Udział macerałów grupy witrynitu (kolotelinit, telinit, witrodetrynit) oraz inertynitu (fuzynit, semifuzynit oraz inertodetrynit) jest wyraźnie niższy. Materia organiczna jest na całym badanym obszarze niedojrzała, na co wskazują pomiary refleksyjności witrynitu oraz parametr $T_{max}$. Skład materii organicznej odpowiada głównie II oraz III typowi kerogenu, a także ich mieszaninie. Wykazano szereg zależności pomiędzy parametrami geochemicznymi (analiza Rock-Eval), a składem i dojrzałością materii organicznej określonej przy użyciu mikroskopu optycznego. Zbadano również podobieństwa i różnice pomiędzy materią organiczną łupków menilitowych w obrębie jednostki skolskiej i śląskiej.

Słowa kluczowe: warstwy menilitowe, jednostka skolska, macerały, refleksyjność witrynitu, piroliza Rock-Eval.

## Introduction

Petrographic characterization of the dispersed organic matter has become particularly important since the perception of fine-grained rocks such as shales or mudstones, in the context of hydrocarbon systems has expanded its traditional meaning from source rocks to rocks that act as both source and reservoir. And most importantly – reservoir rocks, from which liquid and gaseous hydrocarbons can be obtained with economic benefits. The consequence of this change in perception was the need for a much more intense collaboration of professionals representing a wide spectrum of scientific fields – from stratigraphers, paleontologists, geochemists, petrophysists, petrographers, reservoir engineers to drillers and chemists. Apart from the geochemical aspects [3, 26, 31], more and more attention is paid to pore space analysis [23, 30, 33] as well as the associated permeability [17, 24, 25]. In these studies, the analysis of dispersed organic matter is extremely important, which is expressed not only by analyzing its composition and maturity, but also by applying high-resolution imaging techniques to investigate its porosity. [5, 22, 34].

The aim of this paper is to add the new information to the Menilite Beds investigations, which are carried on for decades. This new data is extending the actual state of knowledge by adding organic petrography investigations to the results, which were so far focused on stratigraphic-paleontological and geochemical aspects.

There are many reasons to choose Menilite Beds as a formation for dispersed organic matter investigations. Menilite Beds are one of the most interesting rocks in the Carpathians. That is due to their complex lithology, their presence in different nappes and most important – their high content of organic matter. The content of organic matter and also its composition and maturity level allows to consider them as one of the most important possible source rocks for Carpathians oil fields. These facts are the reasons why Menilite Beds are a subject of detailed investigations [2, 6–10, 13, 14, 16, 18, 19, 21, 27–29, 32]. Most investigations are focused on geochemistry and some authors have analyzed hundreds of samples, which is a great database [10].

Menilite Beds were first distinguished by Glocker in Moravia and described as "rocks with menilite" [20]. These are mainly clay and marly shales and mudstones, with characteristic cleavage, fish fossils and intersections of cherts. Very fine sandstones and micritic limestones are also observed. The organic matter content may reach up to 20% [1, 13, 15]. In the area of Polish Outer Carpathians, Menilite Beds begin the last stage of flysch sedimentation. They are common in Skole, Silesian, Subsilesian and Dukla Units and rather rare in Magura Unit [20]. The thickness of Menilite Beds varies from 100 m in the Silesian Unit up to 500 m in the Skole Unit [2]. Paleontological research revealed that only the base of the Menilite Beds is isochronous. Sedimentation was finished earlier in the southern and later in the northern basins [11, 20]. Paleobathymetry was very variable and depths must have been in range from 200 up to at least 1500 m [12].

## Methods and materials

### *Research material*

The research material consisted of 26 samples collected from 9 outcrops within the Skole Unit. These outcrops were: Bandrów, Bircza, Dynów, Leszczawa Górna 1 and 2, Malawa, Tarnawka, Wojtkowa and Wola Węgierska (Figure 1). From each outcrop samples representing different lithological variations were collected. It was to investigate, if there are any differences in content and composition of organic matter dispersed in various types of rock within the same formation. Chosen outcrops cover the investigated area in a way so that result interpretations can go beyond the scale of an outcrop and regional trends are possible to be investigated. Collected samples are represented mainly by different types of shales and mudstones, while limestones, sandstones and cherts are not that numerous.

### *Microscopic and geochemical analyses*

The analyses were based mostly on microscopic observations. They were divided into two stages. The first stage involved the analysis in both reflected white light and also in fluorescence mode, with the use of polished sections. They were performed on a Zeiss Axioplan optical microscope, at a magnification of 500x, in immersion oil (immersol 518 N, n = 1.518). Firstly, a point-counting method was performed (min. 600 points were counted). It was done to examine both amount and ratio between macerals of the three groups – vitrinite, inertinite and liptinite. Secondly, the measurements of the vitrinite reflectance ($R_o$) were performed. Before performing the measurements, the microscope was calibrated with the use of two reflection standards ($R_o$ = 0.429 spinel, garnet $R_o$ = 0.905). The second stage

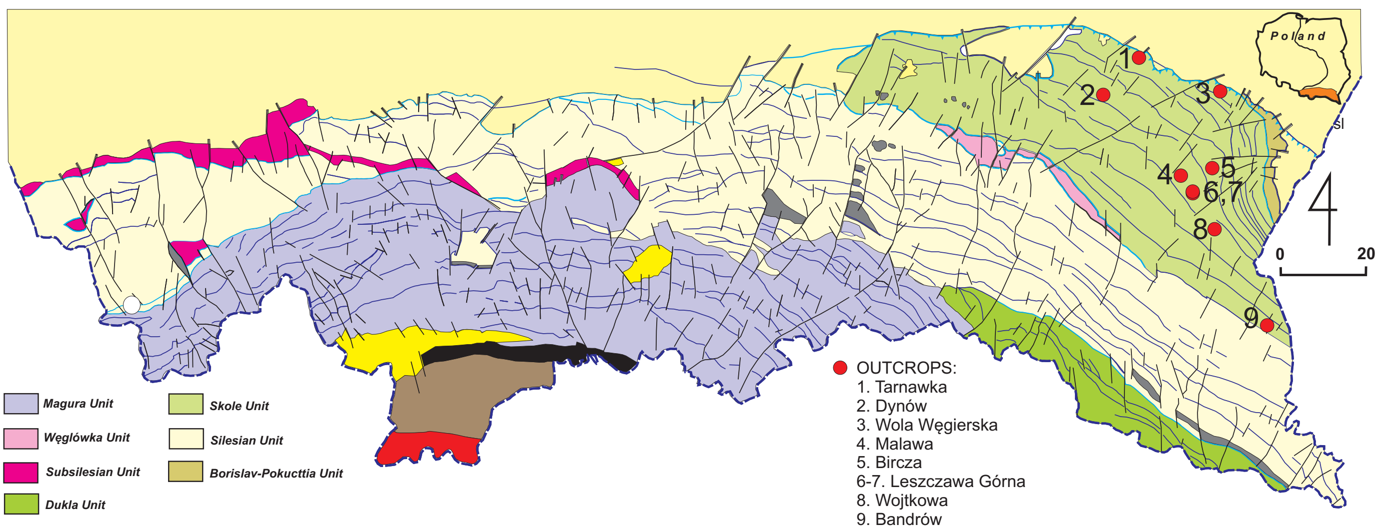



Fig. 1. Localization of the outcrops within the Polish part of the Carpathian Mts [4, edited]

was performed in transmitted light, with the use of thin sections that were analyzed with the Nikon Eclipse LV100 POL optical microscope, at magnifications 50-1000x. The point-counting method was used again, this time to determine the type of rock and its mineral composition (min. 500 points were counted). The results obtained during the work on both microscopes were supplemented with photographic documentation.

Microscopic analyses were also supplemented with the results of the Rock-Eval pyrolysis, performed on the Rock Eval – 6 apparatus (standard model). Among the obtained parameters, a special attention was put to TOC (Total Organic Carbon), $T_{max}$ and HI (Hydrogen Index), as these are very important in organic matter characterization and petroleum generation modeling.

## Results

From the lithological point of view analyzed samples represent different lithological types. These are clay shales (15 samples), mudstones (3 samples), marly shales (2 samples), very fine sandstones/siltstones (2 samples), chert (1 sample), micritic limestones and carbonate-clay shales (altogether 3 samples). Sometimes assessing one lithological type to a sample was rather difficult, as within the area of one thin section various lithologies may occur, for example intersections of siltstone and mudstone within clay shales.

Maceral composition of analyzed samples is rather monotonous, the difference is noticed mainly in proportion between different macerals (Table 1, 2). Macerals of all three groups (vitrinite, inertinite and liptinite) are observed. In many samples solid bitumen (exhibiting yellow fluorescence, sometimes very bright) are present (plate I, A).

Macerals of the liptinite group are the most numerous in the analyzed samples (Table 1, 2). Their maximum content in rocks is up to 37.3% vol., while average content is 16,7% vol. For 20 samples macerals of this group cover more than 90% of organic matter (Table 2). Among macerals from liptinite group, bituminite, alginite and liptodetrinite are observed (plate I, B, C, D). Bituminite is the most common (up to 28% vol.). It usually forms thin laminae and exhibits brown fluorescence. Alginite occurs in a form of lamalginite (thin, elongated algal bodies) and telalginite (single algae with very thick cellular walls – *Tasmanites sp.*). Both exhibit yellow fluorescence, but in case of telalginite it is much brighter. Lamalginite is much more common than telalginite. Altogether alginite content reaches up to 9% vol. (average 1.5% vol.). Apart from bituminite and alginite, fine particles (< 10 μm) of liptodetrinite are also common. It most likely derives from mechanical disintegration of an alginite and has a similar fluorescence color. Average content of liptodetrinite is 1% vol., but it can reach as high as 3.9% vol.

Apart from macerals of the liptinite group, macerals of the vitrinite group are also present (mainly collotelinite and vitrodetrinite). However, these macerals are much less common, and their maximum content is 5.8% vol. What is even more, for 21 samples it does not exceed 1% vol. Macerals of the vitrinite group usually do not exceed 10% of the total

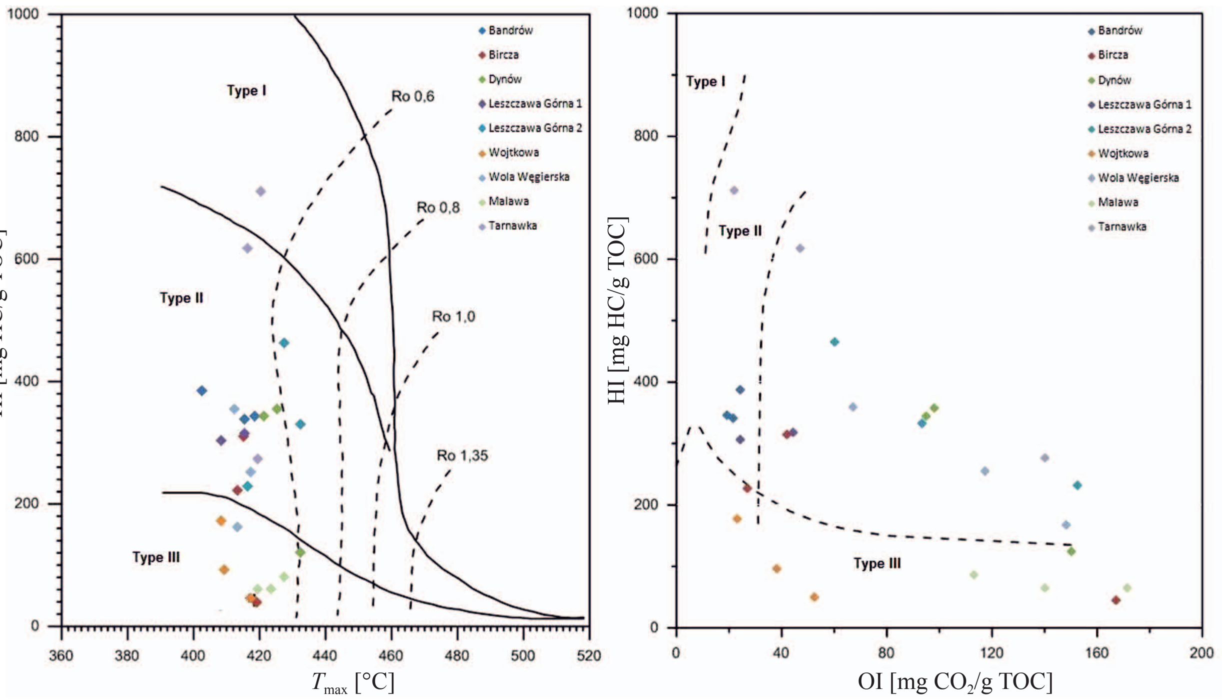



Fig. 2. Organic matter type in $T_{max}$–HI (left) and OI–HI diagrams

Table 1. Maceral content in analyzed rocks

| Localization | Sample ID | Lithology | Vitrinite [% vol.] | | | Inertinite [% vol.] | | | Liptinite [% vol.] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | alginite | | | |
| | | | collotelinite | telinite | vitrodetrinite | fusinite | semifusinite | inertodetrinite | lamalginite | telalginite | bituminite | liptodetrinite |
| Bandrów | 13185 | Marly shale | 0.64 | n.o. | 0.16 | trace | TRACE | trace | 1.27 | trace | 18,92 | 1,11 |
| | 13186 | Marly shale | 0.67 | trace | 0.67 | trace | trace | trace | 2.00 | n.o. | 21,46 | 0,83 |
| | 13187 | Clay shale | 1.46 | n.o. | 0.81 | trace | n.o. | n.o. | 5.19 | trace | 22,37 | 0,97 |
| Bircza | 13190 | Clay shale | TRACE | n.o. | TRACE | trace | trace | trace | 0.32 | trace | 18,81 | 0,16 |
| | 13193 | Mudstone | 2.98 | n.o. | 0.17 | TRACE | trace | n.o. | 0.50 | n.o. | 23,68 | 0,33 |
| | 13194 | Clay shale | 0.97 | n.o. | TRACE | trace | trace | trace | 1.46 | trace | 13,92 | 0,65 |
| Dynów | 13195 | Micritic limestone | trace | n.o. | trace | n.o. | n.o. | n.o. | 5.37 | n.o. | 0,16 | 2,12 |
| | 13196 | Carbonate shale | trace | n.o. | trace | n.o. | n.o. | n.o. | 3.57 | n.o. | n.o. | 2,48 |
| | 13197 | Micritic limestone | trace | n.o. | trace | trace | trace | n.o. | 2.01 | n.o. | n.o. | trace |
| Leszczawa Górna 1 | 13200 | Clay shale | TRACE | n.o. | TRACE | n.o. | n.o. | n.o. | 8.97 | n.o. | 24,52 | 3,85 |
| | 13201 | Mudstone | 5.67 | n.o. | 0.17 | trace | trace | n.o. | 1.67 | trace | 27,17 | 0,67 |
| Leszczawa Górna 2 | 13202 | Chert | trace | n.o. | trace | n.o. | trace | n.o. | TRACE | n.o. | n.o. | trace |
| | 13203 | Clay shale | trace | n.o. | TRACE | n.o. | n.o. | n.o. | 0.16 | n.o. | 28,06 | 0,82 |
| | 13204 | Clay shale | trace | n.o. | TRACE | n.o. | n.o. | n.o. | 1.07 | n.o. | 24,20 | 0,61 |
| Wojtkowa | 13207 | Sandstone/Siltstone | TRACE | 0,15 | TRACE | n.o. | trace | n.o. | 0.46 | trace | 12,39 | TRACE |
| | 13208 | Sandstone/Siltstone | 0.16 | n.o. | TRACE | trace | trace | n.o. | trace | trace | 0,16 | trace |
| | 13210 | Clay shale | 0.17 | n.o. | 0.33 | trace | trace | n.o. | 2.99 | trace | 20,27 | 1,00 |
| Wola Węgierska | 13211 | Mudstone | 0.65 | trace | 0.32 | trace | n.o. | n.o. | 0.65 | n.o. | 21,84 | 0,32 |
| | 13212 | Clay shale | 2.83 | trace | 0.33 | n.o. | n.o. | n.o. | 0.50 | n.o. | 11,67 | 0,50 |
| | 13215 | Clay shale | TRACE | n.o. | TRACE | n.o. | n.o. | n.o. | TRACE | n.o. | trace | trace |
| Malawa | 13450 | Clay shale | trace | n.o. | TRACE | trace | n.o. | n.o. | 0.17 | n.o. | 11,28 | 0,50 |
| | 13451 | Clay shale | trace | trace | 0.16 | trace | 0,16 | n.o. | 0.16 | n.o. | 13,94 | trace |
| | 13453 | Clay shale | trace | n.o. | TRACE | trace | n.o. | n.o. | TRACE | trace | 0,16 | TRACE |
| Tarnawka | 13454 | Clay shale | trace | n.o. | TRACE | n.o. | n.o. | n.o. | 0.32 | n.o. | 22,47 | 1,27 |
| | 13455 | Clay shale | 0.16 | trace | TRACE | trace | n.o. | n.o. | 0.97 | n.o. | 21,56 | 0,97 |
| | 13456 | Clay shale | 0.16 | n.o. | TRACE | n.o. | n.o. | n.o. | 0.16 | n.o. | 16,77 | 0,16 |

TRACE – several particles in sample; trace – one particle in sample; n.o. – not observed

Table 2. Composition of organic matter particles

| Localization | Sample ID | Organic matter composition [%] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vitrinite [%] | | | Inertinite [%] | | | Liptinite [%] | | | |
| | | collotelinite | telinite | vitrodetrinite | fusinite | semifusinite | inertodetrinite | alginite | | bituminite | liptodetrinite |
| | | | | | | | | lamalginite | telalginite | | |
| Bandrów | 13185 | 2.88 | n.o. | 0.72 | trace | TRACE | trace | 5.76 | trace | 85.61 | 5.04 |
| | 13186 | 2.60 | trace | 2.60 | trace | trace | trace | 7.79 | n.o. | 83.77 | 3.25 |
| | 13187 | 4.74 | n.o. | 2.63 | trace | n.o. | n.o. | 16.84 | trace | 72.63 | 3.16 |
| Bircza | 13190 | TRACE | n.o. | TRACE | trace | trace | trace | 1.67 | trace | 97.50 | 0.83 |
| | 13193 | 10.78 | n.o. | 0.60 | trace | trace | n.o. | 1.80 | n.o. | 85.63 | 1.20 |
| | 13194 | 5.71 | n.o. | TRACE | TRACE | trace | trace | 8.57 | n.o. | 81.90 | 3.81 |
| Dynów | 13195 | trace | n.o. | trace | n.o. | n.o. | n.o. | 70.21 | n.o. | 2.13 | 27.66 |
| | 13196 | trace | n.o. | trace | n.o. | n.o. | n.o. | 58.97 | n.o. | n.o. | 41.03 |
| | 13197 | trace | n.o. | trace | trace | trace | n.o. | 100.00 | n.o. | n.o. | trace |
| Leszczawa Górna 1 | 13200 | TRACE | n.o. | TRACE | n.o. | n.o. | n.o. | 24.03 | n.o. | 65.67 | 10.30 |
| | 13201 | 16.04 | n.o. | 0.47 | trace | trace | n.o. | 4.72 | trace | 76.89 | 1.89 |
| Leszczawa Górna 2 | 13202 | trace | n.o. | trace | n.o. | trace | n.o. | TRACE | n.o. | 0.00 | trace |
| | 13203 | trace | n.o. | TRACE | n.o. | n.o. | n.o. | 0.56 | n.o. | 96.63 | 2.81 |
| | 13204 | trace | n.o. | TRACE | n.o. | n.o. | n.o. | 4.14 | n.o. | 93.49 | 2.37 |
| Wojtkowa | 13207 | TRACE | 1.18 | TRACE | n.o. | trace | n.o. | 3.53 | n.o. | 95.29 | trace |
| | 13208 | 50.00 | n.o. | TRACE | trace | trace | n.o. | trace | n.o. | 50.00 | TRACE |
| | 13210 | 0.67 | n.o. | 1.34 | trace | trace | n.o. | 12.08 | trace | 81.88 | 4.03 |
| Wola Węgierska | 13211 | 2.72 | n.o. | 1.36 | trace | n.o. | n.o. | 2.72 | n.o. | 91.84 | 1.36 |
| | 13212 | 17.89 | n.o. | 2.11 | n.o. | n.o. | n.o. | 3.16 | n.o. | 73.68 | 3.16 |
| | 13215 | TRACE | n.o. | TRACE | n.o. | n.o. | n.o. | TRACE | n.o. | trace | trace |
| Malawa | 13450 | trace | n.o. | TRACE | trace | n.o. | trace | 1.39 | n.o. | 94.44 | 4.17 |
| | 13451 | trace | n.o. | 1.12 | trace | 1.12 | trace | 1.12 | n.o. | 96.63 | trace |
| | 13453 | trace | n.o. | TRACE | trace | n.o. | trace | TRACE | trace | 100.00 | TRACE |
| Tarnawka | 13454 | trace | n.o. | TRACE | n.o. | n.o. | trace | 1.32 | n.o. | 93.42 | 5.26 |
| | 13455 | 0.68 | n.o. | TRACE | trace | n.o. | trace | 4.11 | n.o. | 91.10 | 4.11 |
| | 13456 | 0.90 | n.o. | TRACE | n.o. | n.o. | n.o. | 0.90 | n.o. | 97.30 | 0.90 |

TRACE – several particles in sample; trace - one particle in sample; n.o. – not observed organic components. The morphology of the collotelinite is rather diverse. Mainly elongated (from tens to hundreds µm) particles with brownish fluorescence are present (plate I, E, F), but rounded, reworked particles (showing no fluorescence) are also noticed. There is a great variety in the reflectance observed for these particles. It starts from rather low reflectance (< 0.2%) for particles highly impregnated with lipoid matter and rises as the impregnation gets lower (0.2÷0.5%). Finally, the highest reflectance is observed for reworked particles (> 0.6÷0.7%). Beside larger particles of collotelinite, smaller (< 10 µm) vitrodetrinite is also common. Particles of telinite (with cellular structure preserved) were also noticed in few samples.

Macerals of the inertinite group are observed very rarely – up to few particles in most samples. Fusinite, semifusinite and inertodetrinite are noticed (plate I, G, H). Fusinite has the highest reflectance among all the macerals. It usually has few cellulars preserved. Semifusinite has a lower reflectance, but the same state of preservation as fusinite, while inertodetrinite occurs in form of very small (< 10 µm), sharp-edged particles of high reflectance.

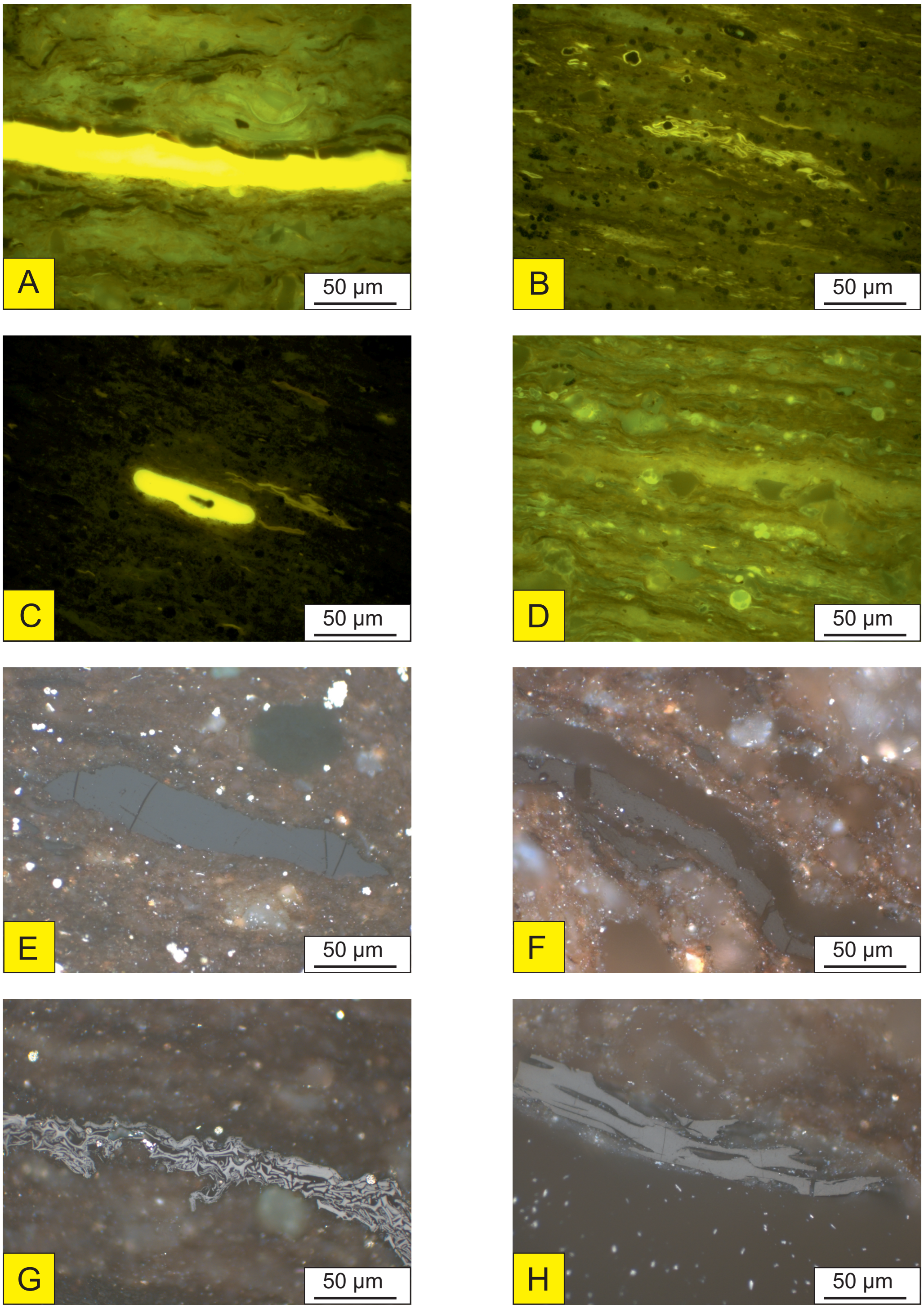
Measured vitrinite reflectance is in range of 0.26 up to 0.45% (Table 3), which means that the organic matter in all the samples is immature. In case of 6 samples it was impossible to obtain reliable reflectance data, as a result of too few measurements (not enough vitrinite particles in the sample). The results of reflectance measurements are confirmed by Rock-Eval pyrolysis (Table 3), where $T_{max}$ parameter is always below 435°C. The content of organic matter (TOC parameter) is in range from 0.21 to 13.29% (average 4.84%). Hydrogen index (HI) is changing in high range from 46 to 713 and most samples represent kerogen type II, III and its mixtures.

Table 3. Most important geochemical parameters obtained from Rock-Eval pyrolysis and vitrinite reflectance measurement results

| Localization | Sample ID | Rock-Eval parameters | | | | Vitrinite reflectance | |
|---|---|---|---|---|---|---|---|
| | | $T_{max}$ [°C] | TOC [%] | HI | OI | $R_o$ [%] | St. dev. |
| Bandrów | 13185 | 418 | 5.09 | 348 | 19 | 0.37 | 0.04 |
| | 13186 | 415 | 6.54 | 343 | 21 | 0.37 | 0.06 |
| | 13187 | 402 | 10.99 | 389 | 24 | 0.31 | 0.08 |
| Bircza | 13190 | 419 | 1.93 | 46 | 167 | 0.40 | 0.09 |
| | 13193 | 413 | 9.99 | 228 | 27 | 0.41 | 0.07 |
| | 13194 | 415 | 8.38 | 315 | 42 | 0.41 | 0.08 |
| Dynów | 13195 | 421 | 1.58 | 347 | 95 | x | x |
| | 13196 | 425 | 1.28 | 359 | 98 | x | x |
| | 13197 | 432 | 0.66 | 126 | 150 | x | x |
| Leszczawa Górna 1 | 13200 | 415 | 5.57 | 319 | 44 | 0.28 | 0.10 |
| | 13201 | 408 | 8.59 | 308 | 24 | 0.27 | 0.04 |
| Leszczawa Górna 2 | 13202 | 416 | 0.46 | 233 | 152 | x | x |
| | 13203 | 432 | 3.62 | 334 | 93 | 0.39 | 0.06 |
| | 13204 | 427 | 4.95 | 466 | 60 | 0.29 | 0.09 |
| Wojtkowa | 13207 | 409 | 2.49 | 98 | 38 | 0.35 | 0.08 |
| | 13208 | 417 | 0.21 | 52 | 52 | 0.38 | 0.09 |
| | 13210 | 408 | 6.48 | 178 | 23 | 0.33 | 0.06 |
| Wola Węgierska | 13211 | 417 | 4.13 | 257 | 117 | 0.37 | 0.06 |
| | 13212 | 412 | 9.2 | 360 | 67 | 0.40 | 0.05 |
| | 13215 | 413 | 0.84 | 169 | 148 | 0.39 | 0.07 |
| Malawa | 13450 | 427 | 1.55 | 87 | 113 | 0.41 | 0.05 |
| | 13451 | 423 | 2.27 | 67 | 171 | 0.45 | 0.05 |
| | 13453 | 419 | 0.43 | 67 | 140 | x | x |
| Tarnawka | 13454 | 416 | 11.88 | 620 | 47 | 0.26 | 0.05 |
| | 13455 | 420 | 13.29 | 713 | 22 | 0.27 | 0.04 |
| | 13456 | 419 | 3.56 | 279 | 140 | x | x |

x – no reliable data

# PLATE I




A. Wola Węgierska, sample 13212. Solid bitumen exhibiting very bright yellow fluorescence.

B. Bandrów. sample 13187. Association of fine particles of lamalginite, liptodetrinite and bituminite laminae.

C. Wojtkowa, sample 13210. Thick-walled telalginite, exhibiting very bright yellow fluorescence. Lamalginite in a background.

D. Malawa, sample 13451. Bituminite in a form of thin laminae.

E. Bandrów, sample 13186. Large particle of collotelinite.

F. Wojtkowa, sample 13208. Elongated particle of collotelinite.

G. Bircza, sample 13193. Large fusinite lamina.

H. Wojtkowa, sample 13208. Cellular structure relicts in semifusinite.

***Dispersed organic matter in lithological aspects***

The relations of organic matter composition with lithology of the rocks within it is dispersed for sure is an interesting issue to investigate. However, it is not an easy task to do. This is due to the fact that collected samples represent wide range of lithological varieties – from clay shales, marly shales, mudstones, sandstones/siltstones to cherts and carbonates. What's more, quite often different lithologies can be observed within the scale of thin section. Such a large diversity in addition to relatively small amount of samples does not provide a reliable statistical data that can be used in the mentioned issue. The problem is further complicated by the fact that within the same lithological type, the content of organic matter may vary within quite a large range, and these ranges may overlap when comparing different lithologies. A possible solution is to compare the maceral composition with the mineralogical composition determined by more precise methods than optical microscopy, like XRD or mineral mapping with the use of electron microscope (QEMSCAN). However, such studies go beyond the scope of this paper. For this reason, the observations presented below should be treated as a general and preliminary to be developed as part of other works on Menilite Beds.

On the basis of obtained results, it can be stated that:

- macerals of the vitrinite and inertinite groups in all the lithological types have a rather low content. It seems that collotelinite is particularly frequent in mudstones, where its maximum content reach 5.7% vol. and also its average content is 3.1% vol. The lowest content of macerals from vitrinite and inertinite groups is observed in carbonate rocks (micritic limestone, carbonate shale), sandstones/siltstones and in chert;
- liptinite group is particularly interesting, due to very variable content of macerals of this group. Alginite seems to be very numerous in carbonate rocks and also in some clay shales. The lowest content is observed in chert and sandstones/siltstones. Bituminite is most common in clay shales, marly shales and mudstones. It is less often observed in sandstones/siltstones. In other lithologies it is practically absent;
- the average values of the TOC parameter allow to divide the examined rocks into relatively rich in organic matter group (mudstones, clay and marly shales) and rather poor (carbonates, sandstones/siltstones, cherts).

***Relations between the most important geochemical parameters and the vitrinite reflectance***

- The obtained results allow to investigate relationships between geochemical and microscopic data. The most interesting relations are those between the most numerous macerals of the liptinite group and TOC, HI, $T_{max}$ parameters and vitrinite reflectance (Table 4). The correlation investigations show that:
- there is a strong (correlation index 0.86) relation between the content of alginite and liptodetrinite, which is not surprising, as these two macerals are commonly observed together and also there is a reasonable suspicion that liptodetrinite present in analyzed samples has algal origin and it is a product of mechanical degradation of algal bodies,
- there is a relation between bituminite content and TOC (correlation index 0.53), which confirms its significant content in organic matter composition,
- macerals of the liptinite group show correlation with vitrinite reflectance (correlation index –0.46÷–0.54). It seems to be very interesting, as lipoid impregnation reduces reflectance of vitrinite particles.

***Organic matter maturity***

One of the most important aspects in potential source rock analyses is a determination of maturity of the dispersed organic matter. In this paper, two different methods were used to determine this parameter – vitrinite reflectance measurements and Rock-Eval pyrolysis. The obtained data were used to extrapolate results from local to regional scale. The regional approach is presented in Figure 3. Both parameters ($T_{max}$, $R_o$) clearly show that all the analyzed samples contain organic matter being in so called immature phase of thermal changes. In addition, there are no regional trends in the variability of both $T_{max}$ and vitrinite reflectance.

Table 4. Correlation index between petrographic and geochemical data

| | $T_{max}$ [°C] | TOC [%] | HI | $R_o$ [%] | Liptinite | Lamalginite | Bituminite |
|---|---|---|---|---|---|---|---|
| $R_o$ [%] | 0.25 | –0.53 | –0.69 | x | | | |
| Liptinite | –0.03 | 0.53 | 0.50 | –0.56 | x | | |
| Lamalginite | –0.38 | 0.25 | 0.17 | –0.46 | 0.61 | x | |
| Bituminite | 0.07 | 0.53 | 0.51 | –0.49 | 0.96 | 0.37 | x |
| Liptodetrinite | –0.06 | 0.31 | 0.40 | –0.54 | 0.67 | 0.86 | 0.46 |

***Organic matter of Menilite Beds from Skole and Silesian Units***

The results presented in this paper can be referred to the data from similar study of organic matter from Menilite Beds of the Silesian Unit [32].

In the context of maceral composition, menilite rocks from both units show many common features. First of all, in both units the same maceral association can be observed. Another common feature is the very low content of the macerals from vitrinite and inertinite groups and clear domination of the

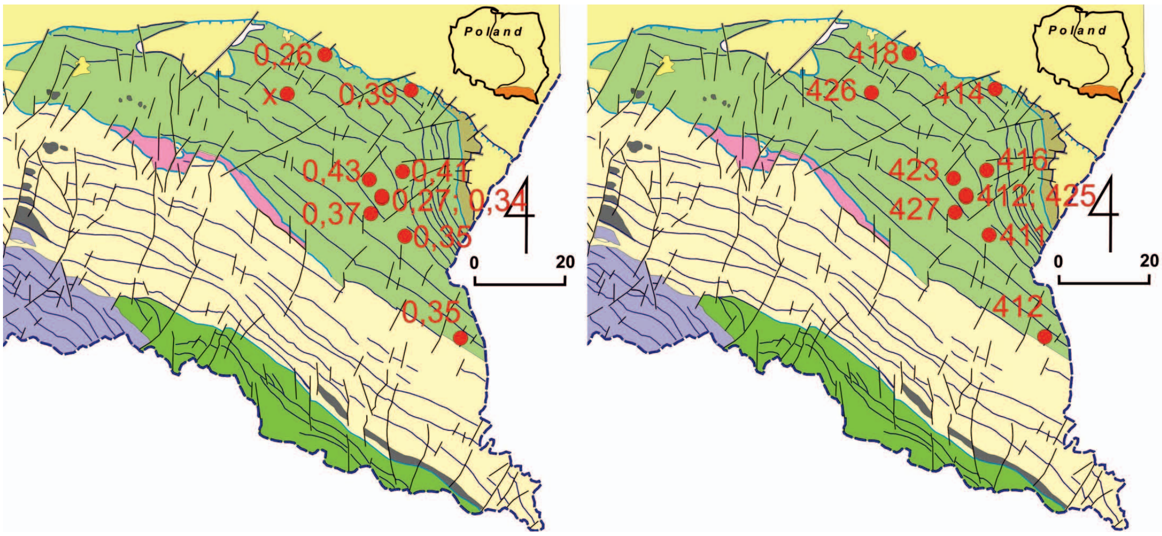



Fig. 3. Average values of vitrinite reflectance (left) and $T_{max}$ (right) within the investigated area

macerals from liptinite group. Maceral composition of the liptinite group appears to show some differences in terms of the quantity. In the Silesian Unit (apart from Pre-Dukla Zone) a higher average (and maximum) content of alginite is observed in relation to other analyzed areas. At the same time, the bituminite content is the lowest. The Pre-Dukla Zone is characterized by the lowest content of alginite and the average content of bituminite, while within the Skole Unit, the content of bituminite is the highest and content of alginite is average. The content of liptodetrinite in both units is comparable.

In terms of the organic matter maturity, the Pre-Dukla Zone can be clearly distinguished, as it contains organic matter being in the main oil phase, which is confirmed by both $T_{max}$ and $R_o$ parameters. The remaining area of the Silesian Unit is similar to the Skole Unit – menilite formations of both units are immature. In the case of the Silesian Unit, the vitrinite reflectance values are generally slightly lower (average 0.28%) with a slightly higher $T_{max}$ (average 425) than in the case of Skole Unit (average $R_o$ = 0.35%, average $T_{max}$ = 418), but it does not change the interpretation of the obtained results.

## Conclusions

1. Macerals of all three groups (vitrinite, inertinite and liptinite) are observed. Investigated rocks, in terms of organic matter composition, differ mainly in proportions between the identified macerals. Macerals of the liptinite group are most common (usually 90% or more of the organic matter particles), while the content of macerals of two other groups – vitrinite and inertinite is much lower.
2. The most often association of macerals observed in the samples is bituminite + alginate + liptodetrinite + collotellinite + fusinite/seminfusinite/inertodetrinite.
3. Among the investigated samples, the richest in organic matter are mudstones and also clay and marly shales. Other investigated lithlogies (carbonates, sandstones/siltstones, cherts) are rather poor in organic matter.
4. The investigated organic matter is immature, which is confirmed by low values of both $T_{max}$ (< 435°C) and vitrinite reflectance (< 0.5%). These two parameters do not show any regional changes.
5. Macerals of the liptinite group show several correlations with both geochemical parameters and vitrinite reflectance.
6. In terms of organic matter composition and its maturity, Menilite Beds from Skole and Silesian Units share several common features (e.g. domination of macerals of the liptinite group, immaturity of organic matter).

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Konrad ZIEMIANIN M.Sc.
Assistant at Geology and Geochemistry Department
Oil and Gas Institute – National Research Institute
ul. Lubicz 25 A
31-503 Kraków
E-mail: *ziemianin@inig.pl*