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Microscopic identification and classification of organic matter of the Upper Carboniferous Anthracosia Shales, Intra-Sudetic Depression, southwestern Poland

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Detailed microscopic studies of dispersed organic matter in the lower horizon of the Anthracosia Shales (uppermost Carboniferous) from the Intra-Sudetic Depression show that liptinite, especially telalginite and lamalginite, are the most abundant components here. Organic components together with mineral matter constitute the lacustrine sapropelic association, humic association (terrestrial) and intermediary association. The measurements of vitrinite reflectance demonstrate that organic matter has reached the mature stage (R_o = 0.68–0.93%). The character and predominance of alginite and the lacustrine sapropelic association indicate that these deposits were accumulated in an open-lacustrine zone.

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INTRODUCTION

The shales and siltstones rich in organic matter giving them black and dark grey colour. The subject of the investigations were. They represent the lower of two horizons of the Anthracosia Shales characteristic of the Intra-Sudetic Depression and considered to be latest Carboniferous in age. These deposits are believed to have been accumulated in a lacustrine environment (K. Dziedzic, 1959, 1961; A. Bossowski, A. Ihnatowicz, 1994).

The studies were aimed at microscopic identification and classification of organic matter (OM) contained in the lower Anthracosia Shales which were drilled by two boreholes — Ścinawka Dolna IG 1 and Bożków IG 1 (Fig. 1). The results of both microscopic and vitrinite reflectance (R_o) measurements have also enabled the recognition of thermal maturity of organic matter. An attempt has been taken to describe depositional environments in which these sediments were deposited.

REGIONAL AND STRATIGRAPHICAL BACKGROUND

The Intra-Sudetic Depression, also called the Intra-Sudetic Trough or Synclinorium as well as Middle Sudetic Foredeep, is the largest geological unit in the Polish part of the Sudetes Mts. It is surrounded by the following geological units: metamorphic cover of the Karkonosze, metamorphic rocks of the Góry Kaczawskie, Świebodzice Depression, gneiss block of the Góry Sowie, Bardo Structure and Kłodzko metamorphic rocks. To the south, in the Czech Republic, the Intra-Sudetic Depression borders with the rocks of the Sub-Karkonosze Plate and Upper Cretaceous deposits of the Hronov Graben.

The first stage of the evolution of the Intra-Sudetic Depression is related to the tectonic movements of the late Bretonian phases (early Variscan Orogeny). It attained its ultimate geometry during Tertiary tectonic movements (K. Augustyniak, 1970). As a distinct sedimentary basin, the

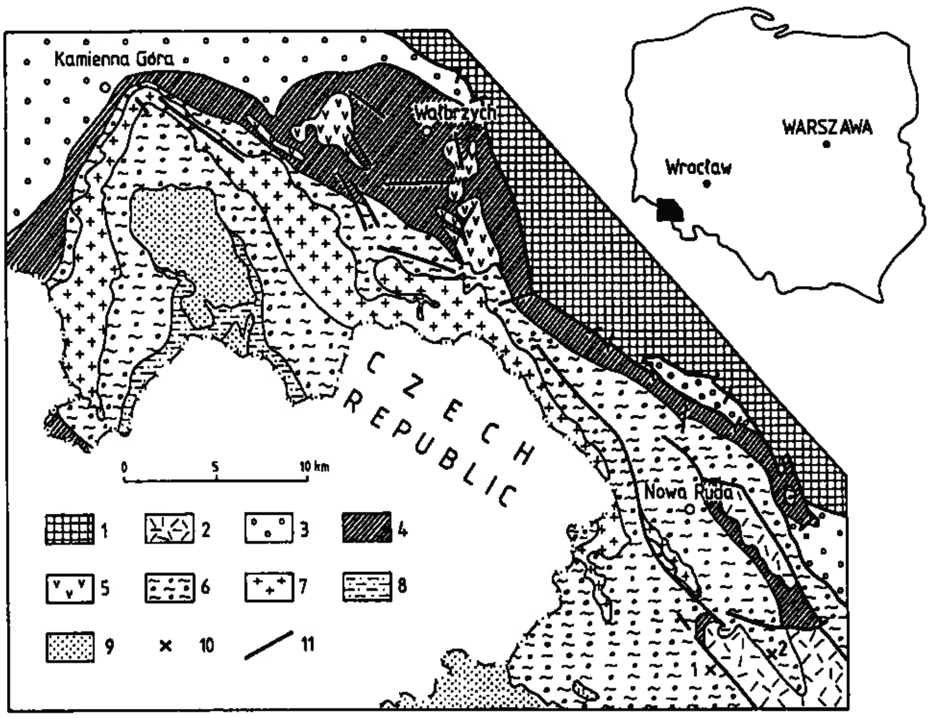

Fig. 1. Generalized geological map of the Intra-Sudetic Depression

Precambrian: 1 — Góry Sowie gneisses; Lower Palaeozoic: 2 — phyllites, amphibolites, gabbros; Lower Carboniferous: 3 — conglomerates and sandstones; Upper Carboniferous: 4 — conglomerates, sandstones, siltstones, shales and coal seams, 5 — rhyolites and trachybasalts; Lower Permian: 6 — sandstones, conglomerates, siltstones, 7 — rhyolites and trachybasalts; Lower Triassic: 8 — sandstones; 9 — Upper Cretaceous; 10 — boreholes (1 — Ścinawka Dolna IG 1, 2 — Bożków IG 1); 11 — faults

Uproszczona mapa geologiczna depresji śródsudeckiej

Prekambr: 1 — gnejsy sowiogórskie; dolny paleozoik: 2 — fyllity, amfibolity, gabra; dolny karbon: 3 — zlepieńce i piaskowce; górny karbon: 4 — zlepieńce, piaskowce, mułowce, łupki ilaste i pokłady węgla kamiennego, 5 — ryolity i trachybazalty; dolny perm: 6 — piaskowce, zlepieńce, mułowce, 7 — ryolity i trachybazalty; dolny trias: 8 — piaskowce; 9 — górna kreda; 10 — otwory wiertnicze (1 — Ścinawka Dolna IG 1, 2 — Bożków IG 1); 11 — uskoki

Intra-Sudetic Depression appeared in the Late Visean (H. Żakowa, 1963; K. Mastalerz, 1987). It is filled with Lower and Upper Carboniferous, Permian, Triassic and Upper Cretaceous deposits. The oldest sediments belong to the Lower Carboniferous "Culm", lacking any palaeontological data.

The Upper Carboniferous deposits are exposed as a continuous belt stretching along the southwestern, northwestern and northeastern flanks of the Intra-Sudetic Depression (Fig. 1). To the south-east, younger sediments appear above the Upper Carboniferous deposits — they are largely Permian and Cretaceous in age.

The Silesian lithological column in the Intra-Sudetic Depression is terminated with the Ludwikowice Formation (Fig. 2). Its lower part is composed of conglomeratic-sandy deposits. The upper part mainly consists of sandy and sandy-silty deposits passing upwards into muddy ones. The Ludwikowice Formation is usually 300–350 m thick.

Stratigraphical position of this formation is controversial due to very poor palaeontological data. Red-brown colour of most of its lithological members was the reason of ascribing this formation to the Lower Permian, basing solely on lithological criteria. The only horizon of this formation with fairly good palaeontological documentation is the so-called 1st — lower horizon of the Anthracosia Shales, terminating its lithological column. This horizon has yielded internal casts of fresh-water bivalves of the genus *Anthracosia* and plant prints, among others *Callipteriss conferta* Stern., a species considered for a long time to have been typical Permian and pointing to the lower boundary of the Autunian. According to the recent views, *C. conferta* Stern. appeared as early as in the Late Stephanian (A. Górecka-Nowak, 1995).

Palynostratigraphical investigations of the Ludwikowice Formation have not yielded any material allowing to determine its age univocally. J. Jerzykiewicz (1973, 1975, 1981, 1987) considered the upper boundary of the Carboniferous to run within this formation and included its uppermost part (i.e. the lower Anthracosia Shales) into the Lower Permian, whereas T. Górecka (1969, 1981, 1982) and A. Górecka-Nowak (1989) tend to consider the whole Ludwikowice Formation as representing the latest Carboniferous. This opinion has been lately supported by the results of palynostratigraphical investigations of the lower Anthracosia Shales from borehole Ścinawka Dolna IG 1 (A. Trzepierczyńska, 1994). They point to the Stephanian C–D.

GENERAL LITHOLOGY AND DISTRIBUTION

THE LOWER (FIRST) HORIZON OF THE ANTHRACOSIA SHALES

This horizon generally consists of two alternating rock-types: grey sandstones and shales (K. Dziedzic, 1959, 1961; A. Bossowski, A. Ihnatowicz, 1994; J. B. Miecznik, 1989; J. Don, 1961). The former are arkosic siltstones and sandstones of various grain size ranging from silt to medium- and even coarse-grained sand (K. Dziedzic, 1959, 1961). The sandstones have clayey and occasionally also marly matrix (K. Dziedzic, 1959, 1961). These rocks form layers ranging from more than 10 up to 20 cm in thickness. They are characterized by parallel or cross-bedding (K. Dziedzic, 1961). The latter are dark grey or black shales. They are characterized by the presence of organic matter causing them to be dark in colour or even forming thin coal laminae. Plant prints are noted here. Thin intercalations of bituminous limestones are also found in the shales. These deposits have yielded fresh-water bivalves of the genus *Anthracosia* which gave the commonly used name to them. The above-described rock types frequently coexist as thin laminae resembling varves. Both these rock types are not limited to any particular zone but they alternate at both in the bottom and at the top of this horizon. The presence of the above-described lithological horizon is known from two areas of the Intra-Sudetic Depression: the Wałbrzych area (Okrzeszyn region) and the Nowa Ruda area (Nowa Ruda region and the area between Krajanów and Ścinawka Dolna).

THE UPPER (SECOND) HORIZON OF THE ANTHRACOSIA SHALES

This horizon is composed of sandy-shaly deposits of different colours ranging from red-brown through dark brown and dark green to black shales (K. Dziedzic, 1959). Shales are predominant in the upper horizon, passing into sandy shales and siltstones and even into fine-grained sandstones. The second horizon, like the first one, has also yielded bivalves of the genus *Anthracosia*. Marly or calcareous intercalations occur here as well. These rocks are also characterized by a considerable amount of organic matter. The upper horizon of the Anthracosia Shales is known from the eastern (Nowa Ruda area — Nowa Ruda and Słupiec regions as well as the area between Krajanów and Ścinawka Górna) and middle part (the area between Rybnica and Unisław) of the Intra-Sudetic Depression (K. Dziedzic, 1961).

LITHOLOGY AND PETROGRAPHY

BOREHOLE ŚCINAWKA DOLNA IG 1

The lower horizon of the Anthracosia Shales in borehole Ścinawka Dolna IG 1 (interval 160.2–36.0 m) forms a 124.5 m thick sequence composed chiefly of siltstones (A. Bossowski, 1994) — Figure 3A. The siltstones, predominating here, show transitions to fine-grained sandstones. At a depth 102.9 to 100.4 m, conglomerates sporadically occur. Shaly interlayers and laminae are also present within the siltstones. Black and dark grey colour is characteristic of these silty rocks and is due to an organic matter content. Locally, only at the bottom of this horizon, brown-red colour appears. The siltstones are characterized by a high degree of fracturing through all the interval with numerous calcite veins filling the fractures. These rocks show a variable petrographic structure — from quartz siltstones occurring at a depth 50 m, to calcareous siltstones at a depth 70.5 m (H. Awdankiewicz, 1994). Sandstones are usually fine-grained in this horizon. Medium- and coarse-grained sandstones have been noted here only occasionally. H. Awdankiewicz (1994) considers them to be sublithic, locally sub-arkosic arenites. They mainly consist of minerals such as quartz, feldspars, muscovite, biotite, opaque minerals, fragments of siliceous rocks, siltstones, limestones and trachyte-type or rhyolite-type volcanic rocks (H. Awdankiewicz, 1994).

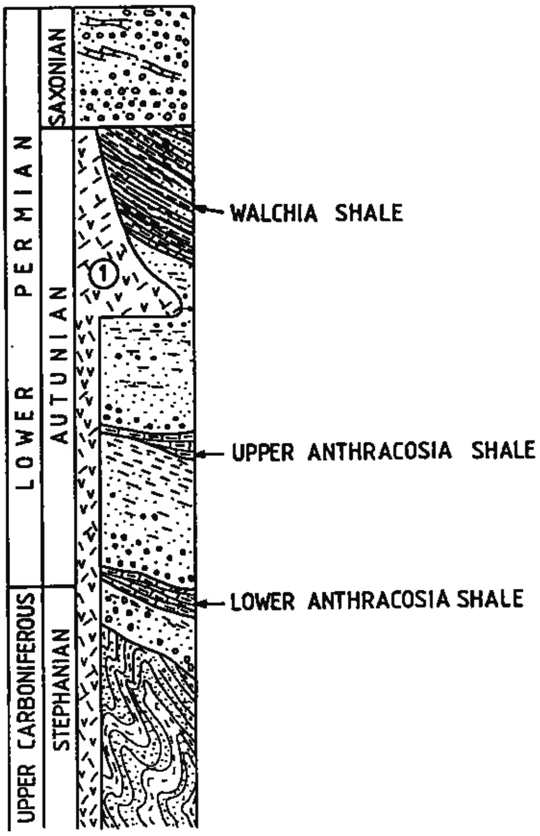

Fig. 2. Lithostratigraphic column of the Lower Permian deposits in the eastern part of the Intra-Sudetic Depression (after K. Mastalerz, J. Wojewoda, 1988; modified by S. Speczik *et al.*, 1994)
1 — volcanites and volcanoclastics

Profil litostratygraficzny utworów dolnopermskich wschodniej części depresji śródsudeckiej (według K. Mastalerza, J. Wojewody, 1988; zmodyfikowany przez S. Speczika i in., 1994)
1 — wulkanity i wulkanoklastyki

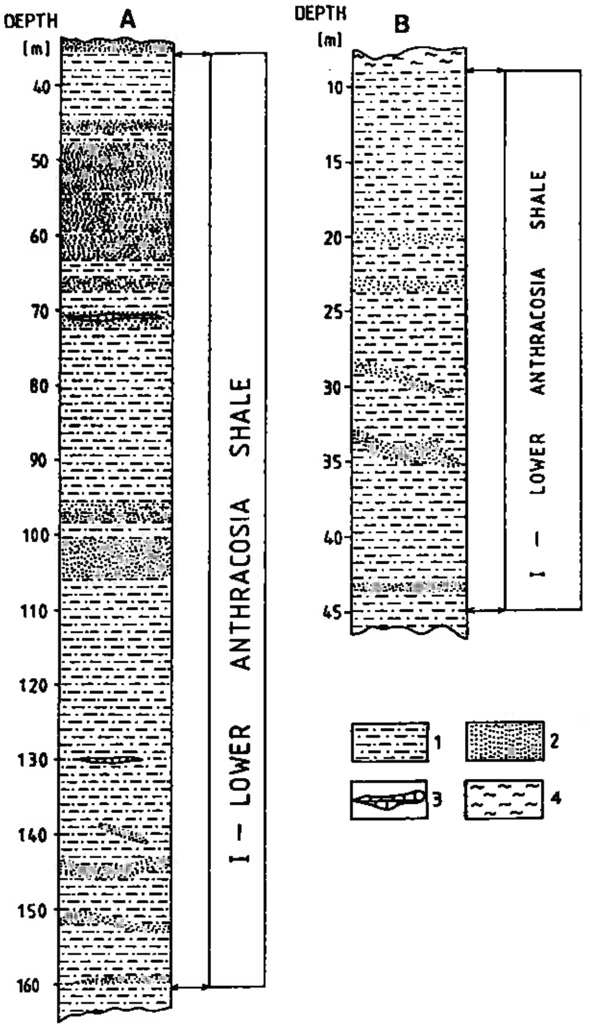

Fig. 3. Lithology of the first lower horizon of the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 (A) and Bożków IG 1 (B)
1 — siltstones and shales, 2 — fine-grained sandstones, 3 — limestones, 4 — siltstones
Profil litologiczny pierwszego dolnego poziomu łupków antrakozjowych z otworu Ścinawka Dolna IG 1 (A) i Bożków IG 1 (B)
1 — mułowce i łupki ilaste, 2 — piaskowce drobnoziarniste, 3 — wapienie, 4 — mułowce

These sediments show usually calcareous or clayey, rarely sericitic matrix (H. Awdankiewicz, 1994).

BOREHOLE BOŻKÓW IG 1

The lower horizon of the Anthracosia Shales, 36.0 m thick in this borehole (A. Bossowski, 1994), has been encountered at a depth interval 45.0–9.0 m (Fig. 3B). It basically consists of a uniform complex of dark grey siltstones, locally passing into red-brown ones. These rocks are strongly fractured and occasionally exhibit poorly marked lamination.

METHODOLOGY AND THE SCOPE OF STUDIES

Results of petrographical studies obtained from microscopic investigations of rocks containing organic matter (OM) depend largely on the methods used. Until the early sixties, such rocks, like other deposits, had been examined in thin sections. That allowed better identification of minerals rather than organic matter.

Nowadays, the commonly used methods employed in organic petrology studies are those used by coal petrologists. They include reflected-light or short-wave ultra-violet light microscopic investigations of polished surfaces of rocks containing organic matter (M. Teichmüller, 1985; P. Bertrand, B. Pradier, 1993; D. G. Murchison, 1987; E. Stach *et al.*, 1982).

Rocks enriched in OM, i.e. dark grey and black, were the main subject of interest when the sampling the lower horizon of the Anthracosia Shales in boreholes Ścinawka Dolna IG 1 and Bożków IG 1. First of all shales, siltstones and fine-grained silty sandstones were sampled.

Polished surfaces of various lithological types (shales, siltstones and fine-grained or silty sandstones) from the lower horizon of the Anthracosia Shales were examined in reflected light. The petrological investigations were carried out using the *MPM — 200 Carl Zeiss* optical-electronic set composed of the *Axioskop* microscope used in reflected-light studies and equipped with a *HBO* lamp emitting short-wave ultra-violet light (wave length 546 nm) which enables observations of fluorescence of macerals during irradiation, a microphotometer used in vitrinite reflectance measurement (R_o) as well as a computer with the original *Carl Zeiss Photan* computer programme installed. Organic matter studies were conducted in compliance with the procedure recommended by the International Committee for Coal and Organic Petrology (ICCP) (E. Stach *et al.*, 1982), distinguishing three groups of macerals: vitrinite, liptinite (exinite) and inertinite. These studies were carried out in white or ultra-violet reflected-light allowing to make a proper recognition of liptinite macerals. Immersion objectives (magnification x 20 and 50) and oculars (magnification x 10) were used. The total magnification was times 200 and 500. Occasionally, dry lenses (magnification x 2.5, 5, 10 and 20) were employed.

Random vitrinite reflectance (R_o) was measured using the above-mentioned microphotometer and the *Photan* computer programme controlling the process. Measurements were made at a temperature of 23°C in non-drying *Zeiss* resin (refracting index n_e = 1.518) as an immersion oil. The GGG Standard No. 93–60 at R_o = 1.662% (in immersion) was used to adjust the equipment. Microphotographs of polished surfaces were taken using the *MC 80 Zeiss* camera and *Konika* films (film speed 100 ASA).

MICROSCOPIC FEATURES OF ORGANIC MATTER

CLASSIFICATION OF ORGANIC CONSTITUENTS

Reflected-light optical research methods of organic matter study enable its proper identification and classification. Such a recognition facilitates determination of the primary source of OM (microfauna, spores, pollens, fragments of plants-tissues etc.). This in turn may be applied in reconstructions of depositional environments. Commonly used coal petrology methods enable the recognition of organic matter as macerals, i.e. microscopic organic constituents observed in reflected-light. According to the recently used classification (ICCP — E. Stach *et al.*, 1982), three groups of macerals can be distinguished: vitrinite, liptinite (exinite) and inertinite. They differ from one another in physical (optical) and chemical properties as well as in their origin. The classification of macerals is shown in Table 1.

Characteristic features of most macerals considerably change due to diagenetic processes to which rocks containing organic matter (macerals) have been subjected. The recognition of particular organic constituents (macerals) is based upon both investigations of their morphological features, colour, texture and estimation of thermal maturity degree (organic metamorphism, coalification degree). The maceral groups listed in Table 1 may be characterized as follows.

Vitrinite is a gelified (or colloidal in the solid state) material originated mainly from plant tissue; terminology and classification used for macerals is based on morphological criteria (such as the presence of primary cellular structure or intercellular spaces which can be seen under a microscope during both reflected-light and ultra-violet light observations) or a degree of preservation of its particular components. Vitrinite is represented by two basic forms — structural telinite and structureless collinite. In general, the highest concentrations of vitrinite occur in terrigenous deposits such as coals and shales of deltaic origin; vitrinite is usually absent in calcareous rocks and pre-Devonian sediments.

Inertinite is a group of macerals showing the highest reflectance values; processes which led to the formation of these macerals (e.g. fusinitization) are quite different from those involved in the formation of vitrinite, although primary plant constituents are the same for both these groups. Other macerals, belonging to this group, are sclerotinite originating from fungal remains, macrinite of uncertain origin (most likely formed by oxygenation of gelified plant material) and micrinite which is a secondary product of diagenetic processes — this maceral is connected with liptinite.

Table 1

Classification of organic matter (macerals) recognizable under the microscope (according to the ICCP system, 1963, 1971, 1975; modified and supplemented with a genetic interpretation of macerals — D. G. Murchison, 1987; D. G. Murchison *et al.*,1985; M. Teichmüller, 1985, 1989)

Group of macerals	Maceral	Origin
Vitrinite	telinite	cell walls remains of wood tissue and roots with variably preserved cellular structure
	telocollinite	
	collinite	amorphous (gel or gelified)
	desmocollinite	
	corpocollinite	filling plant cellules
	vitrodetrinite	detritus
Liptinite (exinite)	sporinite	spores and pollen
	cutinite	cuticles — leave epithelium
	resinite	resins and waxes filling cellules
	fluorinite	plant oils
	suberinite	bark
	alginite	algae
	butiminite	uncertain origin, probably algal
	liptodetrinite	detritus
	exudatinite	secondary, formed from organic matter during the coalification process
Inertinite	fusinite	cell walls, formed as a result of forest fires or in well oxygenated zones
	semifusinite	cell walls, formed in well oxygenated zones, sometimes as a result of forest fires
	sclerotinite	fungal sclerotia
	macrinite	primary amorphous gel, later oxygenated
	micrinite	secondary element, largely formed during oil generation
	inertodetrinite	detritus

Liptinite (exinite) is composed of spores and pollen as well as of epithelium of leaves (cuticles), waxes, algae; these components represent the first sub-group and may be observed and recognized in both reflected-light and ultra-violet light. At a low coalification degree these components are characterized by significantly lower reflectance values compared with that of vitrinite at the same stage of organic metamorphism, their reflectance increases as the coalification degree grows, reaching values of vitrinite corresponding to the second jump in coalification at R_o ~ 1.3–1.4%. Other macerals belonging to this group may be recognized and distinguished from a mineral matter using fluorescent microscopy (UV). They are represented by fluorinite, bituminite and exudatinite. The macerals of this group, especially alginite but also bituminite and other components, are of primary importance in the process of liquid hydrocarbon generation.

Many constituents of organic matter occurring in minerogenic rocks are absent in the classification of coal macerals. Optically dispersed amorphous organic matter which usually accompanies the finest mineral fractions, in particular clay minerals, may be a good example here. Attempts to classify the amorphous-mineral matrix were based upon its appearance — the intensity of fluorescence and colour as recognized under a microscope (P. Robert, 1979, 1981).

The term "kerogen" which originally defined insoluble organic constituents occurring in bituminous shales, has been used in petroleum geology since 1912. Recently, four types of kerogen (I–IV) can be distinguished. These types are characterized by specific chemical parameters. Type I shows high H/C values (about 1.5) and low O/C values (about 0.1); type II displays lower H/C values and low O/C values; for types III and IV: H/C <1 and O/C = 0.2– 0.3. Type I is of algal origin, whereas types III and IV of terrestrial origin. Generally, the following macerals correspond to a particular type of kerogen (B. E. Durand, 1980; E. Stach *et al.*, 1982; A. C. Hutton, 1994): type I — alginite (mainly *Botryococcus*), type II — sporinite, type III — vitrinite, type IV — inertinite.

However, it must be borne in mind that each of the types mentioned is a mixture of different macerals (with one maceral being dominant) and sub-microscopic organic matter which is adsorbed or incorporated in mineral grains.

RESULTS OF INVESTIGATIONS

Relatively diverse composition of organic matter has been recognized in the studied sections of the lower horizon of the Anthracosia Shales. Organic matter is represented here by constituents of three groups of macerals with liptinite being distinctly predominant. This is the case first of all in the Ścinawka Dolna IG 1 section. The variability of organic matter is also related to lithology of the investigated deposits.

The characteristic features of organic matter occurring in the horizon of the Anthracosia Shales from both studied boreholes are described below.

BOREHOLE ŚCINAWKA DOLNA IG 1

The lower horizon of the Anthracosia Shales in borehole Ścinawka Dolna IG 1 is represented by the following deposits containing organic matter: shales, siltstones (occasionally sandy), non-laminated or thinly laminated, and fine-grained or silty sandstones.

Shales are characterized by black or dark grey colour resulting from the increased content of organic matter. Locally, 2–3 mm thick bands, considerably enriched in OM, occur here. Homogeneous intervals, lacking any distinct OM-rich lamination, and with dispersed organic matter, also have been noticed in shales. Siltstones can be subdivided into two sub-groups: the first, characterized by the occurrence of black laminae enriched in OM and grey laminae with mineral matter being predominant, and the second sub-group which is represented by non-laminated rocks with highly dispersed organic matter. The third lithology includes light to dark grey fine-grained or silty sandstones. Organic matter is concentrated in a form of thin (up to 1 mm thick) black streaks visible on a macro-scale. These lithological types occur throughout the whole section of the Anthracosia Shales forming interlayers within the organic-rich complex. To summarize, in the Anthracosia Shales from borehole Ścinawka Dolna IG 1, organic matter is composed of three main constituents: inertinite, vitrinite and liptinite. The last one is the most common (up to 95%) and significantly dominant over remaining two (Fig. 4A).

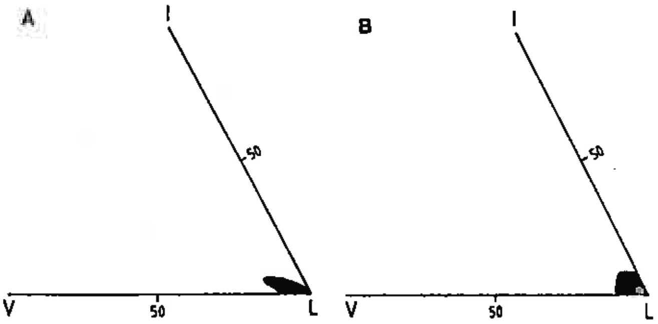

Fig. 4. Contribution of maceral groups to the composition of the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 (A) and Bożków IG 1 (B)
V — vitrinite, I — inertinite, L — liptinite

Udział grup macerałów w budowie łupków antrakozjowych z otworu Ścinawka Dolna IG 1 (A) i Bożków IG 1 (B)
V — witrynit, I — inertynit, L — liptynit

BOREHOLE BOŻKÓW IG 1

The collected rock samples represent black shales, locally silty. They are frequently thinly laminated with laminae enriched in organic matter. These deposits can generally be regarded as black sapropelic shales, occasionally with silt admixture. They are characterized by a high OM content, even up to 20%. Among the three groups of macerals, liptinite is significantly predominant (up to 100%), whereas inertinite and vitrinite are of lesser importance (Fig. 4B).

DESCRIPTION OF ORGANIC CONSTITUENTS

Differences in optical properties (reflectance, morphology, relief and fluorescence) of individual macerals have facilitated the identification of OM.

Inertinite is the rarest group of components in the studied horizon (Pl. I). It is represented by four macerals: fusinite, semifusinite, sclerotinite and inertodetrinite. Inertinite is non-fluorescing.

Fusinite shows primary plant structure represented in the studied samples, by easily recognizable cell walls (Pl. I, Fig. 4). Fusinite is usually represented in this horizon by a thin-walled variety — pirofusinite which, owing to its strong degradation, is a constituent of inertodetrinite. Fusinite is characterized by the highest reflectance in the studied samples. It remains black in UV light.

Semifusinite is a transitional stage between fusinite and telinite belonging to the vitrinite group. Cellular structure is more poorly preserved than in fusinite. Semifusinite frequently occurs as small fragments in the studied samples which makes its identification difficult. It is darker than fusinite and lighter than vitrinite (Pl. I, Fig. 2). Reflectance values of semifusinite are higher compared with those of vitrinite but lower than in the case of fusinite.

Sclerotinite is observed sporadically in trace amounts and forms more or less spherical bodies when recognized in the studied deposits it shows a high degree of degradation. This maceral has most frequently been recorded as fragments with strong reflectance, distinct relief and light grey to white in colour.

Inertodetrinite is the most common of inertinite macerals in the samples from the Anthracosia Shales. It is composed of fragments and detritus of inertinite macerals described above (Pl. I, Figs. 5, 7 and 8).

Vitrinite. Among many macerals belonging to this group (see Table 1), three macerals have been found in organic matter occurring in the lower horizon of the Anthracosia Shales: collinite, corpocollinite and vitrodetrinite which is the most widespread in this horizon.

Collinite is a grey structureless maceral with reflectance lower than that of inertinite. Of macerals belonging to the vitrinite group, collinite is fairly common (Pl. I, Figs. 1 and 2). It forms small-scale fragments which make difficult qualifying it as either telocollinite — vitrinite A (H. R. Brown *et al.*, 1964; E. Stach *et al.*, 1982) also called homocollinite (B. Alpern, 1966) or desmocollinite — vitrinite B (H. R. Brown *et al.*, 1964; E. Stach *et al.*, 1982) also called heterocollinite (B. Alpern, 1966).

Corpocollinite is a sub-maceral of collinite. In the studied samples it occurs sporadically, being considered an accessory component of OM. It has been found in a form of single amorphous grains (Pl. I, Fig. 6). It displays a high degree of degradation — its interior is often destroyed and only its margins remain.

Vitrodetrinite is the most widespread maceral of the vitrinite group in the studied samples from the lower horizon of the Anthracosia Shales (Pl. I, Figs. 5 and 8). It consists of undistinguishable fragments and detritus of other macerals belonging to this group.

Grey vitrinite of reflectance transitional between that of inertinite and liptinite has been recognized during the reflected-light investigations under a microscope using immersion optics. It shows no fluorescence when irradiated with short-wave ultra-violet light. In spite of sporadically recorded fluorescent properties in vitrinite (E. Stach *et al.*, 1982; P. Robert, 1981; R. M. Bustin *et al.*, 1983) related to its ability to adsorb hydrogen, no such a phenomenon has been observed here. Two generations of vitrinite have been recognized in the studied samples: darker and lighter varieties.

Liptinite (exinite). Basically, it has been impossible to recognize individual macerals of this group in reflected-light. Liptinite can be properly distinguished by the observations under the microscope in UV light. Of the above-distinguished macerals belonging to this group (Table 1), sporinite, cutinite, alginite, bituminite and liptodetrinite have been found in the studied samples.

Sporinite is chiefly represented by thin-walled miospores forming tenuisporinite (E. Stach *et al.*, 1982) and displays elongated shapes (Pl. II, Fig. 1). Sporinite occurs as individal fragments in organic-mineral matrix. In short-wave ultra-violet light, sporinite is bright yellow to light orange and orange. Sporinite is a component of primary importance among organic constituents in the studied horizon.

Cutinite is represented by its thin-walled variety, tenuicutinite. It has been sporadically found in the studied samples, occurring together with sporinite, alginite, vitrinite and inertinite. This maceral is dark grey and orange fluorescing.

The term alginite refers to a maceral belonging to the liptinite group (see Table 1) and including both algae and algal material, without defining their form or biological structure. Two types of alginite have been distinguished: alginite A and B (terminology after A. C. Hutton *et al.*, 1980) to which the names of telalginite and lamalginite have been given, respectively, in compliance with the ICCP proposals (A. C. Cook, N. R. Sherwood, 1994). They differ from each other in their size and morphology as well as in the character of fluorescence — telalginite shows slightly brighter fluorescence compared with lamalginite (A. C. Hutton *et al.*, 1980).

Telalginite (alginite A) occurs as lens- and cone-shaped bodies or flattened discs, occasionally revealing its internal structure. It is largely composed of algal colonies representing the family *Botryococcus*. In reflected-light they are practically undistinguishable in the shales whereas. In reflected UV light, they are yellow to orange in colour (Pl. III, Fig. 1).

Lamalginite (alginite B) occurs in a form of thin elongated lamellae. No botanic structure has been recognized in lamalginite. Basically, it is undistinguishable in white light. When irradiated with UV light, lamalginite is yellow to orange in colour (Pl. II, Figs. 2–6; Pl. III, Figs. 2–5). It shows lower fluorescence than alginite A, but higher compared with cutinite or sporinite. Transitional forms between telalginite and lamalginite have also been found.

Bituminite (amorphous organic matter) is widespread in the studied samples. Bituminite is a pure organic constituent, lacking any form and shape (M. Teichmüller, 1974). It is difficult to distinguish in reflected light. Under a microscope, using short-wave ultra-violet light, it is brown and characterized by rather low fluorescence. Bituminite can form elongated lenticles and irregular bands or concentrations of undefined shapes (Pl. II, Figs. 7 and 8). Locally, it may be dispersed throughout a rock. Bituminite is frequently accompanied by alginite, since it originates from a decomposition of alginite, zooplankton and bacteria (M. Teichmüller, K. Ottenjann, 1977; P. Robert, 1979; E. Stach *et al.*, 1982; A. C. Hutton *et al.*, 1980).

Liptodetrinite consists of undistinguishable fragments and detritus of liptinite macerals. It is fairly common in the studied horizon. Liptodetrinite is characterized by yellow and orange fluorescent colours (Pl. III, Figs. 3–5).

* * *

The above microscopic description of organic matter constituents refers to its individual elements — macerals. However, in the rocks of the studied horizon, they usually form natural concentrations and organic-mineral associations whose description is given below.

Organic-mineral associations occurring in the Anthracosia Shales differ in the intensity and kind of fluorescent properties. This is related to the presence, character and quantity of organic matter dispersed within them. Several types of organic-mineral associations have been distinguished in the course of the present studies. They can be characterized as follows:

Lacustrine sapropelic association consists mainly of algal material. The term "sapropelic" should be interpreted according to the ICCP definitions and may be applied to both bogheads (algal type) and cannels (sporinite type). The notion of this term implies some constrains referring to biological and sedimentological features of the material. In the case of the algal type we are dealing with aquatic autochthonous material and sedimentation. For the sporinite type, allochthonous material from the land predominates. In the studied rocks, the former association is predominant. Two different types of this association can be recognized:

1. Organic matter of low fluorescence dispersed in mineral matrix may be mixed with alginite which can form single individual isolated accumulations (Pl. III, Figs. 3–5). Alginite is an organic constituent, whereas the basic matrix is of a mineral (non-organic) origin.

Algal material prevailing here points to the autochthonous subaqueous sedimentation. The proportion of plant material originating from the land is low or completely lacking here.

2. Optically it shows more uniform fluorescence compared with that of the previous type. Algal material is represented by both *Botryococcus* (frequently accompanied by bituminite which is, in turn, abundant in mineral matrix) and individual occurrences of lamalginite (Pl. II, Figs. 2, 7 and 8). Other plant material is rare (sporinite) or absent in this association.

Humic association (terrestrial) can be identified basing upon relatively high abundance of humic coal matter visible in rocks in a form of single thin microbands or fragments and lenticles. Organic matter in this association is of terrestrial origin — it is composed of vitrinite (mainly vitrodetrinite), inertinite (most frequently inertodetrinite) and liptinite (sporinite and liptodetrinite) (Pl. I). This association shows fluorescence related to exinite (most frequently liptodetrinite), but excluding alginite, which impregnates mineral components. This type of OM is called amorphous organic matter by palynologists. OM is highly dispersed in this association, unless it forms coal microbands.

Intermediary association. Mixed associations between sapropelic and humic ones with sapropelic association being predominant have frequently been found in the studied deposits (Pl. III, Figs. 6–8).

Gradual transitions have been often observed between particular associations.

* * *

The analysis of organic matter of the Anthracosia Shales enables determining its relationships with kerogen. These may be summarized as follows:

— the above-described constituents of inertinite represent type IV kerogen;

— vitrinite occurring in the studied samples forms type III kerogen;

— liptinite represents two types of kerogen: type II — formed of sporinite and liptodetrinite, occasionally accompanied by cutinite; type I — composed of alginite and bituminite.

The organic-mineral associations recognized in the course of the studies are the most frequent form of organic matter (i.e. of kerogen) occurrence. Basing upon its characteristics sapropelic association may be considered as belonging to type I kerogen. Humic association (terrestrial) is represented by type II and III kerogen, and also sporadically by type IV. Intermediary association is a mixture of type II + type III (type IV) and type I kerogen, most frequently with the last one predominating.

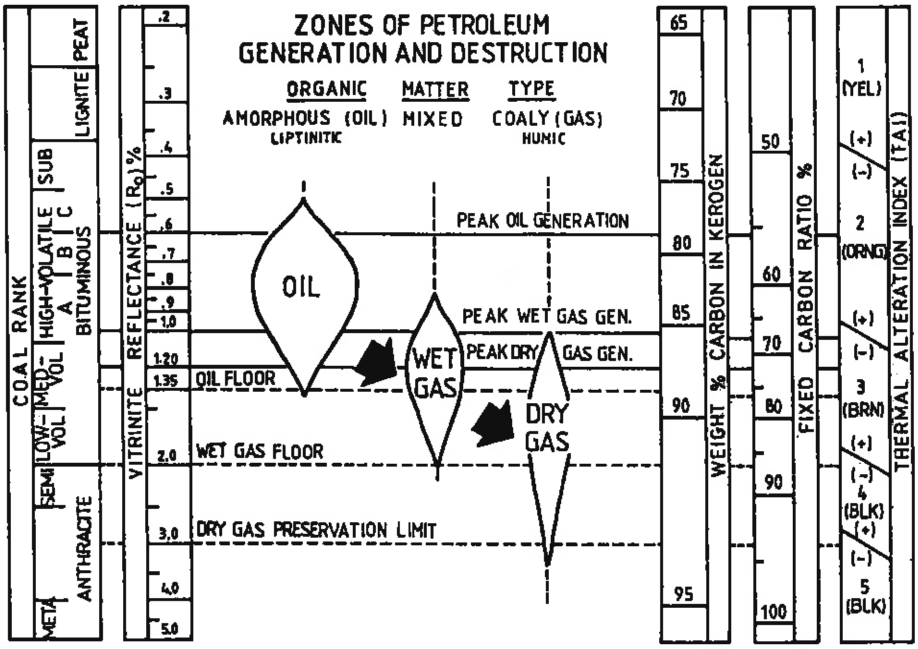

Fig. 5. Relationship between coal rank, thermal maturity parameters (R_o and TAI) and windows of hydrocarbon generation and destruction (after W. G. Dow, 1977)

Zależność między szeregiem uwęglenia, parametrami dojrzałości termicznej R_o i TAI a strefami generacji i zaniku węglowodorów (według W. G. Dowa, 1977)

MICROSCOPIC CHARACTERISTICS OF ORGANIC MATTER AND ITS RELATIONSHIP TO LITHOLOGY

Alginite is the most widespread organic constituent of the studied deposits. Usually it occurs as:

(1) very frequent microbands largely composed of lamalginite (Pl. II, Figs. 5 and 6);

(2) algal *Botryococcus* colonies, being rarer than the concentrations of lamalginite bands mentioned above (Pl. III, Fig. 1);

(3) few occurrences of elongated lamalginite (Pl. II, Figs. 3 and 4; Pl. III, Fig. 2).

Similar observations of alginite in the Anthracosia Shales were also made by S. R. Yawanarajah *et al.* (1993). Such an appearance of alginite has also been recorded from the above-described organic-mineral associations. Alginite of types (1) and (2) often occurs in sapropelic association; (1) and (3) also in intermediary association. Telalginite which appears in sapropelic association is frequently accompanied by bituminite. It may also occur independently as a dominant constituent of sapropelic association. Liptodetrinite and single spores have been found usually in intermediary organic-mineral association. The typical terrestrial constituents such as vitrinite and inertinite (which is rarer than vitrinite) or sporinite and liptodetrinite are the most frequent components of intermediary association or sporadically appearing humic one.

Relationships between OM and lithology have also been recognized:

— sapropelic association occurs mainly in shales, Bożków IG 1 shales are basically represented by type I of this association only;

— in siltstones, most frequent is type II of sapropelic association or intermediary association with predominance of sapropelic component (usually in coarser-grained, more sandy laminae);

— in sandstones, intermediary association is largely represented, with occasional humic one; exinite-sporinite material and liptodetrinite are predominant there.

THERMAL MATURITY OF ORGANIC MATTER

The commonly used parameter of thermal maturity is vitrinite reflectance (R_o). For purposes of petroleum geology, R_o measurements were introduced in the late fourties (M. Teichmüller, R. Teichmüller, 1950). Vitrinite reflectance data allow to distinguish several stages of hydrocarbon generation characterized by specific R_o values (see Fig. 5):

1. Immature stage — generation of early diagenetic gas and insignificant amounts of liquid hydrocarbons (R_o = 0.00–0.50%).
2. Mature stage — main phase of liquid hydrocarbons generation, the so-called oil window (R_o = 0.50–1.35%).
3. Catagenesis — gas generation: wet gas (R_o = 1.30–2.00%), dry gas (R_o = 2.00–4.00%).
4. Overmature stage — barren in hydrocarbons.

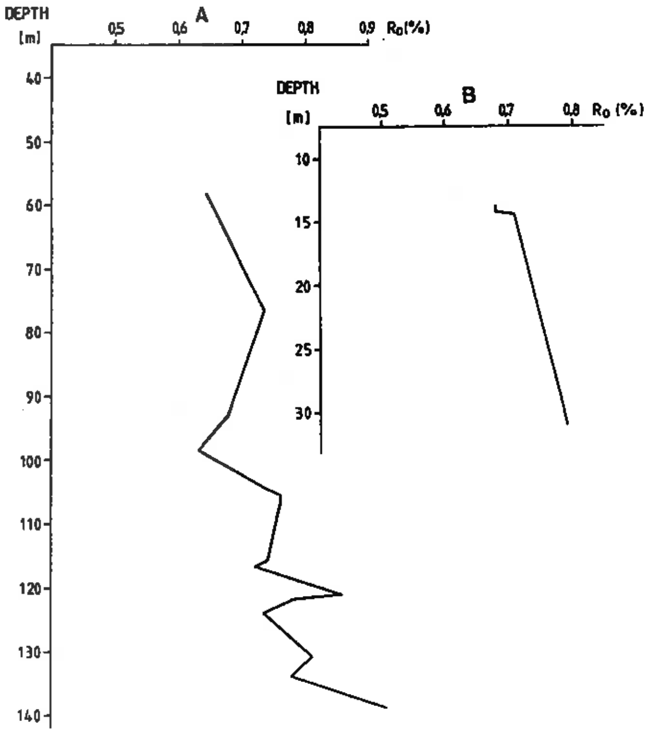

Fig. 6. Vitrinite reflectance values (R_o) of the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 (A) and Bożków IG 1 (B)

Wartości zdolności odbicia światła witrynitu (R_o) łupków antrakozjowych z otworu Ścinawka Dolna IG 1 (A) i Bożków IG 1 (B)

Vitrinite reflectance values increase with the degree of thermal maturity, ranging from 0.20% in slightly altered and "immature" organic matter to 4.00% or more in the overmature phase. The ease with which the method can be applied and the ubiquity of terrestrial organic remains and thus vitrinite in sedimentary rocks caused the R_o parameter to have been commonly employed in of both hydrocarbon exploration and reconstructions of history and development of sedimentary basins (B. P. Tissot, D. H. Welte, 1984; Y. Heroux *et al.*, 1979; J. M. Hunt, 1979; N. H. Bostick, H. H. Damberger, 1971; B. Durand *et al.*, 1986; B. E. Durand, 1980; P. Bertrand, B. Pradier, 1993). Vitrinite reflectance is a better and more accurate parameter compared with chemical analyses (content of volatile constituents and carbon).

A series of measurements of random vitrinite reflectance R_o have also been made in the studied deposits. For these purposes only rock samples with a higher content of vitrinite have been selected.

Two generations of vitrinite have been recognized, as it was mentioned above: dark grey and showing lower reflectance values and the second one, lighter in colour, displaying higher R_o values. This phenomenon is particularly common in the case of Ścinawka Dolna IG 1 shales. Vitrodetrinite occurring in those deposits represents several reflectance classes, but generally R_o values point to a low coalification degree. Similar observations were made by S. Speczik *et al.* (1994). The vitrinite of higher reflectance was probably redeposited and is derived from older, underlying strata. P. Robert

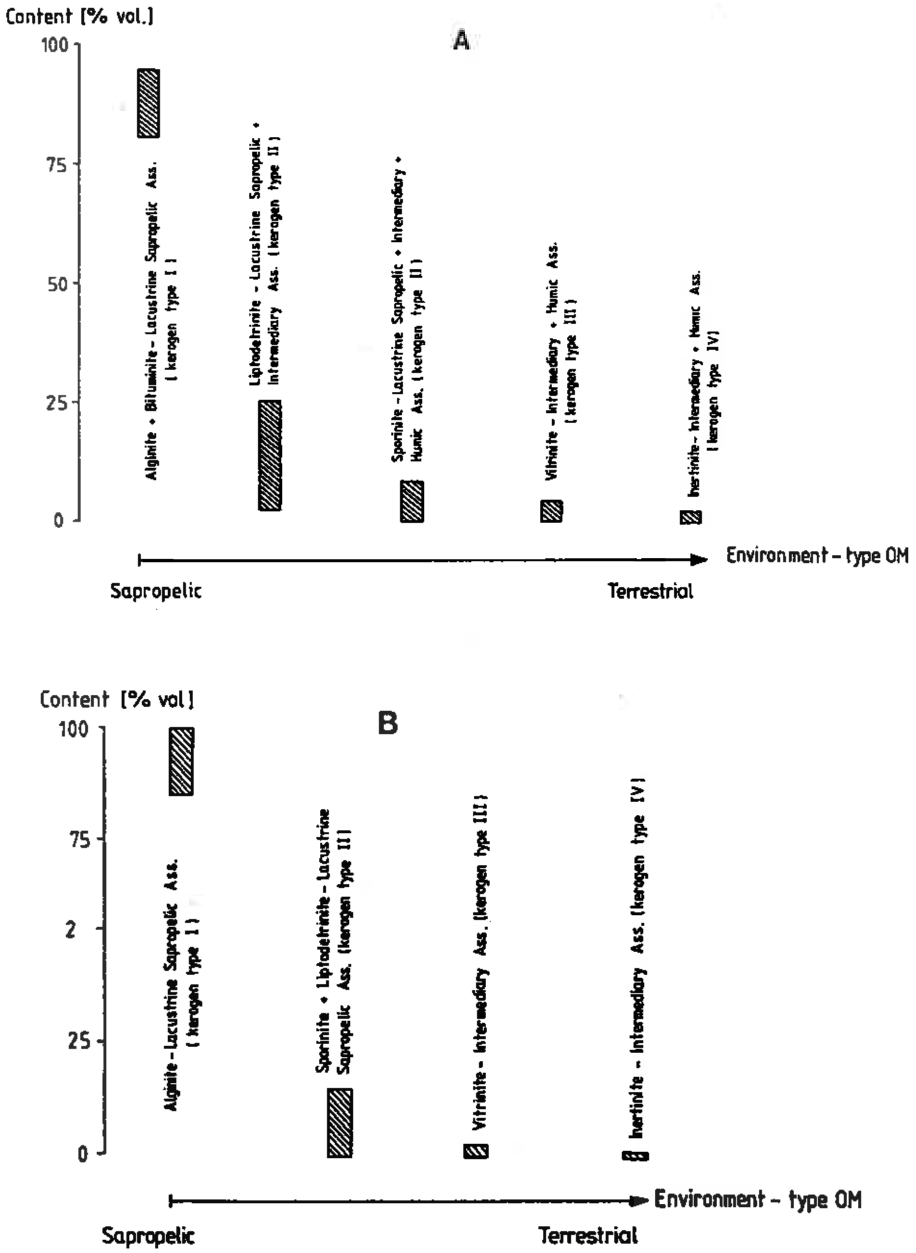

Fig. 7. Contribution of OM constituents and their relationship with depositional conditions; boreholes Ścinawka Dolna IG 1 (A) and Bożków IG 1 (B)

Udział składników materii organicznej i ich zależność od warunków depozycji; otwór Ścinawka Dolna IG 1 (A) i Bożków IG 1 (B)

(1980) names such fragments "allochthonous". They show considerable dispersion of R_o values compared with those of the primary vitrinite. The values are usually higher.

The measured vitrinite reflectance values (R_o) in the Ścinawka Dolna IG 1 shales range from 0.64 to 0.93% (Fig. 6A). They demonstrate that organic matter has reached a thermal maturity stage comprising middle part of the conventional oil window phase. R_o values increase with increasing depth, and their small fluctuations are related rather to changing lithologies. Hence, a serrated shape of the R_o values curve (Fig. 6A).

The measured vitrinite reflectance values (R_o) in the Bożków IG 1 shales are relatively low — 0.68–0.79%. These data indicate that organic matter has reached the stage of organic metamorphism characteristic of the oil window phase, including its early part and the early end of the middle part. R_o values increase linearly with increasing depth (Fig. 6B). This results from the uniform lithology of these deposits.

DISCUSSION

The microscopic investigations have enabled the identification of organic matter and its thermal maturity degree. This

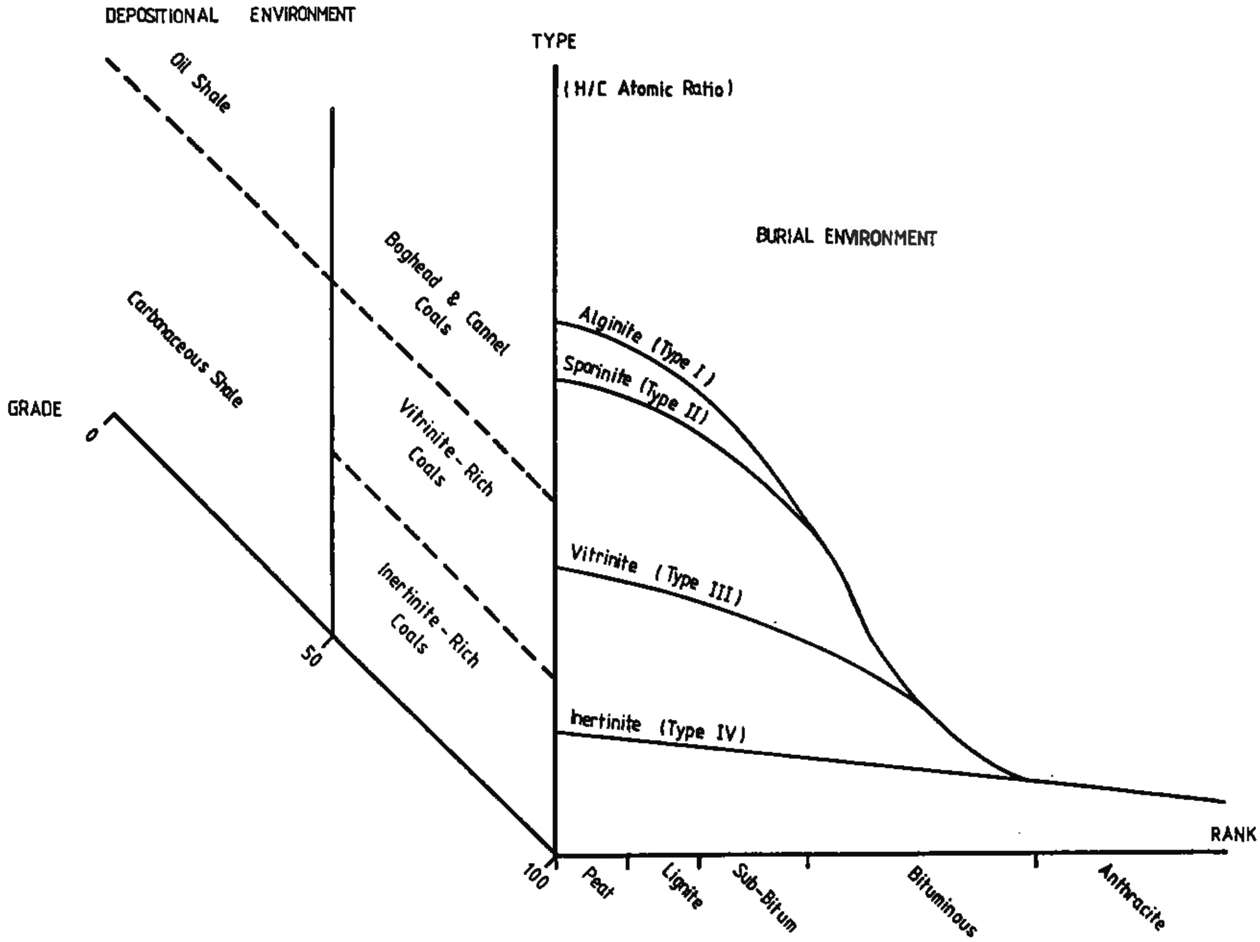

Fig. 8. Relationship between the type of OM, depositional environment and degree of coalification (after B. A. Alpern *et al.*, 1989)

Zależność między typem materii organicznej, środowiskiem a stopniem uwęglenia (według B. A. Alperna i in., 1989)

allows some conclusions on the origin of the studied rocks. Figure 7A and B show that alginite, bituminite and liptodetrinite which, together with a mineral matrix, form lacustrine sapropelic association (considered an equivalent to type I and type II kerogen), are the most common organic components here. Therefore, these rocks should be classified as bituminous shales (Fig. 8). The abundance of lamalginite is typical here, particularly in the finest-grained sediments — shales. The presence of lamalginite points to an open-lacustrine sedimentation under reducing and sapropelic conditions (Fig. 7A, B) where large amounts of algae might have been accumulated. Algal colonies of *Botryococcus* characteristic of lakes and frequently accompanied by bituminite, have occasionally been found together with lamalginite.

Sporinite and particularly liptodetrinite occur in lesser amounts compared with alginite (Fig. 7A, B). They have been usually observed in slightly coarser-grained lithotypes including siltstones. The occurrence of liptodetrinite points to a detrital character of organic matter which was probably either transported from shallower into deeper zones of the Anthracosia basin or formed as a result of reworking in a deeper zone. Sporinite is a terrigenous element which might have been concentrated during transportation.

The occurrence of sporinite in laminated siltstones suggests that palynomorphs tended to accumulate in marginal zones of a lake rather than in its deeper parts. Such material is frequently accompanied by vitrinite and inertinite. These constituents are also widespread but they occur in small amounts and in other associations, indicating that they are of terrigenous origin and were transported into deeper parts of a lake. Greater accumulations of terrestrial constituents, i.e. material derived from the basin margins, have been found in siltstones and finest-grained sandstones.

Unfortunately, the petrographical investigations of OM in the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 and Bożków IG 1 have not been supported by sedimentological studies which could facilitate the recognition of their sedimentary environments as it has been done for such rocks from the North Sudetic Depression (K. Mastalerz, 1990).

The use of vitrinite reflectance measurements (R_o) as a parameter of thermal maturity of OM has enabled the author to determine the stage of organic metamorphism in the studied

Table 2

Petrological features of organic matter of the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 and Bożków IG 1

Lithotype	Organic matter				Locality
	main component	association	kerogen	maturity	
Shales	alginite (lamalginite+ telalginite+ bituminite)	lacustrine sapropelic	type I	oil window	Ścinawka Dolna IG 1
Sapropelic shales	alginite (largely lamalginite)	lacustrine sapropelic	type I		Bożków IG 1
Siltstones	alginite+ liptodetrinite +sporinite	lacustrine sapropelic + intermediary	type I+ II		Ścinawka Dolna IG 1
Fine-grained sandstones	vitrinite+ inertinite+ liptodetrinite (or sporinite)	intermediary sporadically humic	type III+IV+II		

deposits. The Anthracosia Shales from both Ścinawka Dolna IG 1 and Bożków IG 1 represent oil window in view of their thermal maturity expressed in R_0 values. A certain increase in R_0 values with increasing depth is observed here, but differences between measurements from different depths are small and may be related rather to different thermal conductivity in various lithologies. In the case of the studied horizon from borehole Bożków IG 1, these values (R_0) are more uniform and correlate with a lower part of the oil window stage.

Moreover, taking into account the character of organic facies in the studied boreholes, the predominance of type I kerogen or coexistence of type I and type II kerogen, as well as thermal maturity of OM in the oil window stage, these deposits can be considered potential fluid hydrocarbon-source rocks. Such a suggestion should obviously be confirmed. Unfortunately, at this stage of investigations, no data are available on possible migration paths of hydrocarbons or their accumulation in traps.

The separate problem is the character of depositional environments in which these sediments were accumulated and their relationship with geological processes. Organic matter occurring here univocally points to a sapropelic — reducing environment. The horizons of the Anthracosia Shales have been well-known for their poor mineralization — copper in particular. Further investigations should be focused on the relationships between the depositional environments, character of OM — organic facies, degree of organic metamorphism expressed among others in R_0 values and possible mineralization within these deposits. This task, however, significantly exceeds the scope of the present work. Studies on mineralization are in progress now (S. Speczik *et al.*, 1994).

CONCLUSIONS

Petrological investigations of organic matter occurring in the lower horizon of the Anthracosia Shales from boreholes Ścinawka Dolna IG 1 and Bożków IG 1 are summarized in Table 2.

1. In spite of a rather uniform lithology, the following rock-types can be distinguished: shales, sapropelic shales, siltstones (occasionally laminated) and very fine-grained sandstones. They contain the following OM constituents in terms of coal petrology:

— vitrinite — including collinite, corpocollinite and vitrodetrinite;

— inertinite — including fusinite, semifusinite, sclerotinite and inertodetrinite;

— liptinite — including liptodetrinite, sporinite, alginite (represented by lamalginite and telalginite (*Botryococcus* colonies)) and bituminite. No secondary macerals of this group, which were earlier distinguished in the Anthracosia Shales by S. R. Yawanarajah *et al.* (1993), have been recognized.

2. Organic constituents together with mineral matrix form the following organic-mineral associations:

— lacustrine sapropelic association with the main components being alginite (lamalginite, telalginite and bituminite), liptodetrinite and single spores;

— humic association (terrestrial) represented largely by sporinite, liptodetrinite, vitrinite and inertinite;

— intermediary association characterized by the majority of sapropelic constituents.

3. Alginite and bituminite (lacustrine sapropelic association) should be considered an equivalent to type I kerogen, whereas sporinite and liptodetrinite represent type II kerogen.

4. The vitrinite reflectance measurement (R_0) indicates that organic matter has reached its mature stage and represents the oil window with $R_0 = 0.68–0.93\%$.

5. The character and majority of lipoid components, particularly alginite and lacustrine sapropelic association, show that these sediments were largely deposited in an open-lacustrine zone under reducing, sapropelic conditions.

6. The degree of thermal maturity as well as the type of organic matter — type I + type II kerogen may indicate, according to the author, that the studied horizon might be a potential hydrocarbon-source rock provided that other geochemical and geodynamical conditions are favourable.

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MIKROSKOPOWA IDENTYFIKACJA I KLASYFIKACJA MATERII ORGANICZNEJ GÓRNOKARBOŃSKICH ŁUPKÓW ANTRAKOZJOWYCH DEPRESJI ŚRÓDSUDECKIEJ (SW POLSKA)

Streszczenie

Łupki antrakozjowe występują w depresji śródsudeckiej jako dwa poziomy: I, dolny, reprezentujący utwory najwyższego karbonu (T. Górecka, 1969, 1981, 1982; A. Górecka-Nowak, 1989; A. Trzepierczyńska, 1994), i II, górny zaliczany do dolnego permu. Pod względem litologicznym są to łupki ilaste, mułowce czasem drobnoziarniste piaskowce, którym mogą towarzyszyć cienkie wkładki wapieni bitumicznych. Cechą typową tych utworów jest znaczna zawartość materii organicznej, której osady te zawdzięczają charakterystyczną czarną i ciemnoszarą barwę. Uważa się, że powstały w środowisku jeziornym.

Badania mikroskopowe, przeprowadzone zgodnie z procedurą petrologii węgla, dotyczyły materii organicznej dolnego poziomu łupków antrakozjowych, nawierconego w dwu otworach: Ścinawka Dolna IG 1 i Bożków IG 1, usytuowanych w E części depresji śródsudeckiej (fig. 1). W wyniku obserwacji wydzielono trzy grupy składników organicznych: liptynit (egzynit), witrynit i inertynit. Spośród nich najczęściej spotykane są komponenty pierwszej z wymienionych grup, wśród których dominuje alginit wykształcony jako telalginit i lamalginit. Inne macerały tej grupy występujące w badanych utworach to bituminit, a także sporynit i liptodetrynit czy sporadycznie pojawiający się kutynit. Składniki witrynitu i inertynitu wykazują zdecydowanie niższą frekwencję w badanym horyzoncie.

Składniki organiczne tworzą z materiałem mineralnym wspólne asocjacje, które określono jako:

— jeziorną asocjację sapropelową,

— asocjację humusową (terrestrialną),

— asocjację mieszaną.

Pomiary zdolności odbicia światła witrynitu wskazują, że materia organiczna badanych utworów osiągnęła stadium dojrzałe i reprezentuje tzw. okno ropne, gdzie pomierzone wartości R_o zawierają się w przedziale 0,68–0,93%.

Charakter składników lipoidalnych, a zwłaszcza alginitu i jeziornej asocjacji sapropelowej, wskazuje, że dominującym środowiskiem akumulacji badanych łupków antrakozjowych była strefa otwartego jeziora, gdzie depozycja zachodziła w warunkach redukcyjnych — sapropelowych.

EXPLANATIONS OF PLATES

PLATE I

Fig. 1. Fragment of vitrinite (collinite) — humic association

Fragment witrynitu (kolinitu) — asocjacja humusowa

Fig. 2. Band of vitrinite in mineral matrix of siltstone — humic association

Pasemko witrynitu w mineralnym tle mułowca — asocjacja humusowa

Fig. 3. Grey semifusinite with preserved cellular structure — terrestrial association

Semifuzynit szary o zachowanej strukturze komórkowej — asocjacja terrestrialna

Fig. 4. Fragment of fusinite (visible cellular structure) and dispersed fragments of vitrinite (vitrodetrinite) — terrestrial association

Fragment fuzynitu (widoczna struktura komórkowa) i rozproszone kawałki witrynitu (witrodetrynit) — asocjacja terrestrialna

Fig. 5. Vitrodetrinite (grey) and inertodetrinite (white-grey) in the centre — humic association

W centrum fotografii widoczny witrodetrynit (szary) i inertodetrynit (białoszary) — asocjacja humusowa

Fig. 6. Grain of corpocollinite with destroyed interior and fragments of vitrodetrinite dispersed in mineral matrix of siltstone — humic association

Ziarno korpokolinitu o zniszczonym wnętrzu oraz kawałki witrodetrynitu rozproszone w tle mineralnym mułowca — asocjacja humusowa

Fig. 7. Inertodetrinite of terrestrial association

Inertodetrynit asocjacji terrestrialnej

Fig. 8. Detrital fragments of inertinite and dispersed vitrodetrinite in siltstone — humic association

Detrytyczne fragmenty inertynitu i rozproszony witrodetrynit występujące w mułowcu — asocjacja humusowa

Borehole Ścinawka Dolna IG 1, white light; Figs. 1, 3, 4 — magnification x 200; Figs. 2, 5–8 — magnification x 500

Otwór Ścinawka Dolna IG 1, światło białe; fig. 1, 3, 4 — pow. 200 x; fig. 2, 5–8 — pow. 500 x

PLATE II

Fig. 1. Dark yellow fluorescing sporinite

Sporynit o ciemnożółtej barwie fluorescencyjnej

Fig. 2. Orange fluorescing alginite (lamalginite)

Alginit (lamalginit) o pomarańczowej barwie fluorescencyjnej

Figs. 3, 4. Individual lamalginite occurrences in organic-mineral matrix, light orange fluorescing — lacustrine sapropelic association

Pojedynczo występujący lamalginit o jasnopomarańczowej barwie fluorescencyjnej w organiczno-mineralnym tle — jeziorna asocjacja sapropelowa

Fig. 5. Microbands of lamalginite — lacustrine sapropelic association

Mikropasemkowe występowanie lamalginitu — jeziorna asocjacja sapropelowa

Fig. 6. Microbands of lamalginite — dark yellow and light orange fluorescing, and brown fluorescing amorphous organic matter — lacustrine sapropelic association

Mikropasemka lamalginitu o ciemnożółtej i jasnopomarańczowej barwie fluorescencyjnej oraz amorficzna materia organiczna wykazująca brązową barwę fluorescencyjną — jeziorna asocjacja sapropelowa

Fig. 7. Light brown fluorescing bituminite — lacustrine sapropelic association

Bituminit o jasnobrązowej barwie fluorescencyjnej — jeziorna asocjacja sapropelowa

Fig. 8. The same as Fig. 7

Ten sam obraz co na fig. 7

Borehole Ścinawka Dolna IG 1; Figs. 1–7 — UV light, Fig. 8 — white light, Figs. 1–4 — magnification x 500; Figs. 5–8 — magnification x 200

Otwór Ścinawka Dolna IG 1; fig. 1–7 — światło UV, fig. 8 — światło białe; fig. 1–4 — pow. 500 x, fig. 5–8 — pow. 200 x

PLATE III

Fig. 1. Individual lamalginite occurrences (light orange), dark orange fluorescing algal colonies — lacustrine sapropelic association

Pojedynczo występujący lamalginit (jasnopomarańczowy), w tle kolonie algowe o ciemnopomarańczowych barwach fluorescencyjnych — jeziorna asocjacja sapropelowa

Fig. 2. Individual lamalginite occurrences (light orange) in liptodetrinite-mineral matrix

Pojedynczo występujący lamalginit (jasnopomarańczowy) w tle liptodetrynitowo-mineralnym

Figs. 3–5. Lacustrine sapropelic association — lamalginite showing brighter fluorescence as compared with that of liptodetrinite-mineral matrix

Jeziorna asocjacja sapropelowa — widoczny lamalginit o intensywniejszej fluorescencji niż tło liptodetrynitowo-mineralne

Figs. 6–8. Intermediary association — black fragments represent terrestrial organic matter (vitrinite and inertinite), alginite and liptodetrinite-mineral matrix with yellow-orange fluorescence

Asocjacja mieszana — fragmenty o czarnej barwie reprezentują materię organiczną typu terrestrialnego (witrynit i inertynit) oraz alginit i tło liptodetrynitowo-mineralne o pomarańczowo-żółtych barwach fluorescencyjnych

Figs. 1–2, 6–8 — borehole Ścinawka Dolna IG 1; Figs. 3–5 — borehole Bożków IG 1; UV light; magnification x 200

Fig. 1–2, 6–8 — otwór Ścinawka Dolna IG 1; fig. 3–5 — otwór Bożków IG 1; światło UV, pow. 200 x

PLATE I


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Grzegorz J. NOWAK — Microscopic identification and classification of organic matter of the Upper Carboniferous Anthracosia Shales, Intra-Sudetic Depression, southwestern Poland


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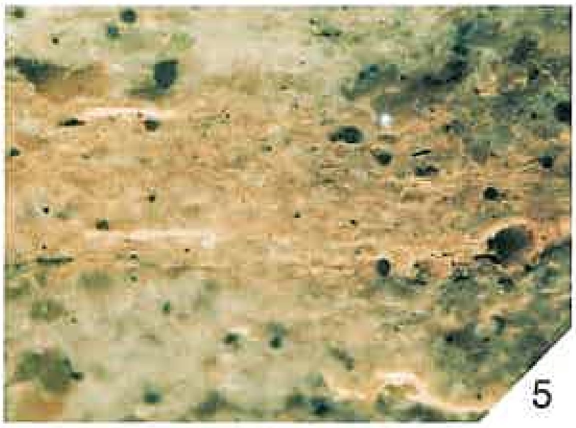
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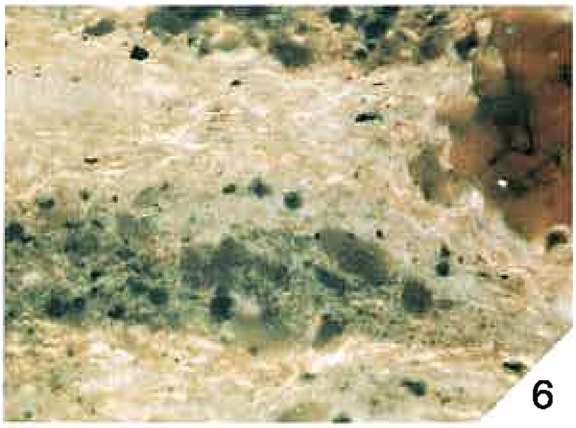
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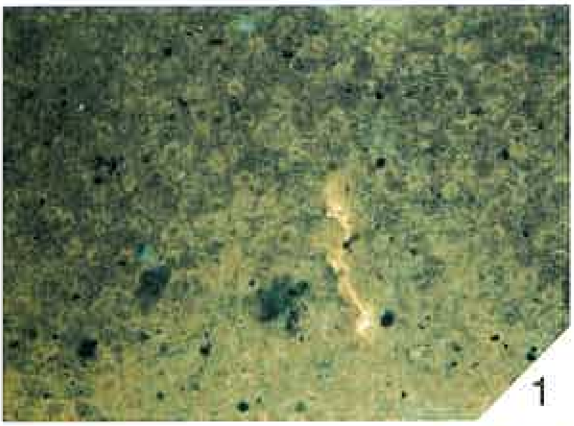
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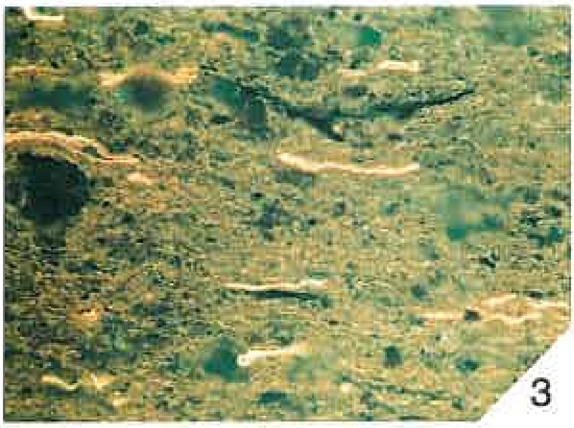
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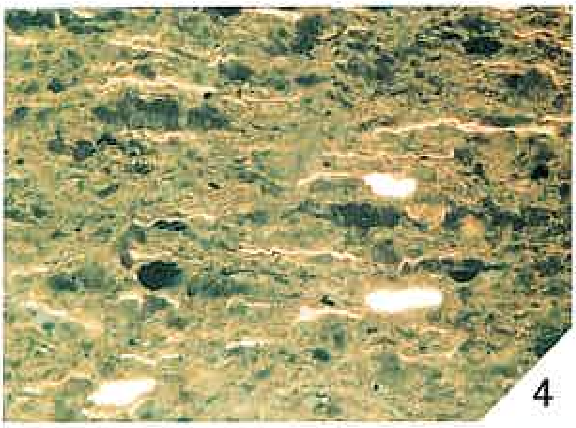
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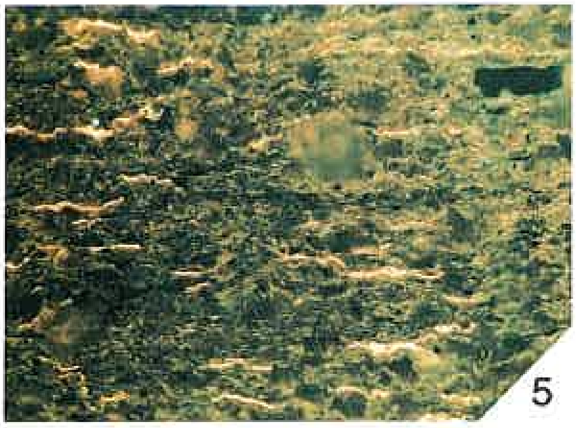
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