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THE STATE OF PETROGRAPHIC STUDIES ON COALS IN POLAND

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The current methods of petrographic studies of coals create larger and larger possibilities to use the obtained results in geology and mining and processing industry (8, 16, 17). Methodical selection and appriopriate interpretation of the results of petrographic studies may be of utmost importance for recognition of structure of coal deposits, especially evaluations of quality and usability of coals. The studies appear indispensable at all the stages of geological, mining and processing activities. Their importance is sometimes understimated but this is usually due to either their detachment from other kinds of studies or attempts to interpret the results without a thorough knowledge of geological or technological processes.

The basic methods in studies on petrography of coals include optical microscopy and reflection and fluorescence microphotometry, supplemented by those of electron microscopy, spectrometry, diffractometry, and thermogravimetry. This complex of analyses is supplemented by standard analyses of chemical, technological and physical properties of coals. Identification of petrographic composition and degree of coalification are the major aims of optical microscopy and microphotometry.

The analyses of petrographic composition and degree of metamorphism of coals are currently widely used in geology, mining and processing industry, which results in the need to standardize petrographic methods, that is, give them the rank of routine analyses (23, 24). The major uses of results of petrographic studies of coals in the geological and industrial practice are as follows:

- identification and prognosis of changes in quality of coals in a given deposit, and in some elements of its geological structure;
- classification of coals on the basis of genetic-economic criteria;
- identification of coal seams and correlation of coal-bearing series;
- identification and prognosis of conditions of exploitation, especially in the case of possibility of natural hazards;
- prognosis and introduction of corrections to coal processing.

The results of petrographic studies on organic matter dispersed in rocks also find use, especially in search for hydrocarbon deposits, but this question is beyond the scope of this paper.

The petrographic studies of coals from the Upper and Lower Silesian and Lublin coal basins, brown coals from the deposits exploited at Turów, Konin, and Bełchatów, and those from still unexploited deposits, carried out in the last years (1980–1986), gave a lot of data important for both the science and practice. The data seem important for geology and regional and economic petrography as well as for the further developments in coal petrography and its research methods. However, it may be noted that scientific and practical results obtained in the country could be much greater and proportional to the diversity and wealth of Polish coal deposits, providing that they were carried out using scientific equipment meeting the current world requirements.

PETROGRAPHIC STUDIES OF BLACK COALS

Petrographic studies of coals, carried out in the Upper Silesian Coal Basin, are mainly focussed on areas of occurrence of:

- coke and highly metamorphic coals,
- coals characterized by the lowest degree of metamorphism.

In the case of southern Rybnik Coal Region, the studies are focussed on shows of strong and diversified influence of agents responsible for metamorphism on coal seams. The influence resulted in co-occurrence of coke coals and anthracite coals, anthracites, and metaanthracites in a relatively small area (6). The other question interesting from the point of view of science and processing industry (especially coking industry) is the occurrence of coal with high content of macerals of the inertinite group in some coal seams. The contents of macerals are sometimes over 50%, which makes the coals similar to those known from Gondwanian deposits. The studies are mainly concentrated at origin and economic value of these coals.

Petrographic studies of coal seams made it possible to distinguish some microfacies types and find a relation between macro- and microfacies development of coal-bearing strata. It appeared that sandstone series are characterized by occurrence of the inertite-durite type, and paralic and mudstone ones mainly yield the vitrain and clarite types. Assemblages of microfacies types well characterize individual lithostratigraphic members in the Upper Silesian Basin (18). A relation between petrographic composition of coal seams and lithostratigraphic structure has been further supported by results of studies in some areas, e.g. the Międzyrzecze–Bieruń perspective area. Coal seams with high content of inertinite occur in the Upper Silesian and Cracow Sandstone Series and further studies should show whether or not this is a regularity in regional scale (27).

Because of marked variability in degree of coalification and high content of intertinite, the hitherto used economic classifications fail to show in a proper way both the position

of coals and their technological properties and economic usability (3). It was found coefficient of capability of light reflection and microhardness are genetic classification indices which may be successfully compensate failures resulting from the use of chemical-technological criteria only (25). The studies also showed that the degree of coal metamorphism as expressed by vitrinite reflectance index increases in the section along with depth but appears unrelated to stratigraphic position in the regional scale. The coalification gradient in south-western Upper Silesian Basin equals 0.06 for the Załęże Beds, 0.07 for Ruda Beds, 0.08 for Main Anticline Beds, and 0.12 ΔR (100 m) for Marginal Beds (26).

Recently in Poland the methods of coal petrography also began to be used to estimate possibilities of enrichment, especially in the case of coke coals. It was found that such estimations should be already made at the stage of geological works connected with demonstration of coal deposits, as one of elements for evaluation of quality of coals in a deposit for the needs of selection of a proper technology of enrichment. At the example of coke coals from the Moszczenica mine it was shown that the effectiveness of that technology depends on content of mineralized microlithotypes and degree of their mineralization (9).

A marked progress was achieved in studies on properties and structure of coals and their petrographic components, transformations of coals in the course of coking, graphitization, extraction, and liquefaction (12). The studies involved SEM analyses of vitrinite, exinite, micrinite, and fusinite from coals of the types 31 – 42, and cokes obtained from these components. They also gave new data on structure, shape and surface of these macerals. Moreover, a correlation was found between optical and electronic anisotropy of coke (13).

The new ground for studies on high-metamorphic coals by electron microscopy methods has been cleared by those on native graphite substances, which made it possible to establish a mineralogical-petrographic classification. The classification comprises pure graphites and transitional phases such as semigraphites, metaanthracites and anthracites (19). Forms differentiating kolinite were studied and their diagnostic features determined with the use of electron microscope (20).

Coal of the lowest degree of coalification, occurring in eastern part of the Upper Silesian Coal Basin, represents some kind of an intermediate link between black coal and hard brown coal. Petrographic studies carried out in the last year mainly in the Siersza and Janina mines, were aimed at determination of:

- the degree of coalification and specific features of microstructure;
- usability for gasification and liquefaction.

Vitrain found in the coal seams displays microstructures and shows of gelification typical of macerals and submacerals of humotelinite from hard brown coal with the degree of coalification equal 0.38 – 0.65% R_m^0. Petrographic and chemical features of that coal correspond to those of hard brown coal formed at early catagenesis stage, under changing facies conditions (4). Finely banded fusain, found in the Janina mine, represent a transition from fusain, to clarain and vitrain. Horizons of the former in individual layers may become a major source of inertinite, which would be highly important for use of coals from that part of the basin in gasification and liquefaction processes (7). Studies on usability of coals from the Janina mine in the liquefaction process, carried out for several years, made it possible to establish criteria for petrographic evaluations. The following criteria were proposed (5):

- share of reactive and nonreactive macerals,
- composition and structure of microlithotypes,
- mode of mineralization,
- share of minerals characterized by catalytic effect,
- share of minerals which impede caking and those regarded as disadvantageous.

The petrographic studies also contributed to adjustment of individual stages in the coal liquefaction process, by presenting quantitative and qualitative characteristics of components of dry residuum after hydrogenation of coal (10). The residuum was found to comprise components of organic origin, formed in the course of the liquefaction process, as well as macerals and minerals. The components of mesophase were analysed in detail to find that they are characterized by a wealth of morphological features and strong diversity of optical features. They include spherulites, pack-like grains, vitrinite-like grains, and isotropic and anisotropic semicokes. The share of individual components in the residuum and the variability in degree of their alteration well characterize the course and effectiveness of the coal liquefaction process.

The petrographic studied carried out in the Lower Silesian Coal Basin are mainly focussed on reserve areas as coal resources under most advantageous geological -mining conditions are almost completely worked out. This made possible recognition of petrographic structure and degree of coalification of coal seams found by drillings in mining fields of the Victoria, Wałbrzych, Thorez and Nowa Ruda mines as well as beyond such fields. The image of regional distribution of petrographic features and degree of metamorphism of coal seams was made more precise and there was found a marked variability in the degree of metamorphism which affected coals from gaseous and coke up to those of the anthracite and graphite phases, inclusively. Moreover, the studies showed a high correlation of vitrinite reflectance index and depth of occurrence of coals. A special problem, requiring further studies, is the influence of contact metamorphism on occurrence of natural coke in some seams, as borehole data show numerous high anomalies in degree of coalification, which may be due to metamorphism of that type (2).

Coal seams in deposit of the Victoria mine yield large quantities of mylonitized coal, coal breccia, and anthracite with very dense network of microfractures, which increases susceptibility of the seams to crushing. Coals from the borehole GV-13 reflect effects of overlapping of regional, thermal, and dislocational metamorphism (31).

The studies carried out in the Lublin Coal hasin were connected with recognition of petrographic structure of coal seams in the vertical and regional scale. In the so-called Central Coal Region, the petrographic studies contributed to recognition of macro- and microstructure and petrographic composition of coal as well as variability in its petrographic character. For example, an increased content of resinite was found in a coal seam from upper part of the Lublin Beds. The degree of coalification is here rather low (mean vitrinite reflectance index equals 0.71 to 0.81%) but a part of coals appears highly susceptible to perching, typical for gaseous-coke coal (22).

The petrographic studies also covered coals with good coking properties, occurring in southern part of the Lublin Coal Basin (14). The analysis of 440 samples from 12 drillings showed that the coals are characterized by high content of vitrinite. This is especially the case of coals of

the Lublin Beds. In turn, seams of the Visean show high content of intertinite, similarly as those of the Bug Beds. Sapropel coals were found in the Komarów, Kumów, and lower Lublin Beds. There were traced some similarities in petrographic structure of coal seams of the Komarów, Bug, and Lublin Beds and petrographic composition of coal seams from the Lower and Middle Carboniferous in the Donetsk Coal Basin, and in petrographic character of coal seams from the Lublin Beds and those of the paralic series in the Upper Silesian Coal Basin (14).

PETROGRAPHIC STUDIES OF BROWN COALS

An original megascopic classification of Tertiary brown coals was recently compiled to replace that of T. Kruszewski, the most widely used in Poland. The new classification may be used in both geological works and those carried out for the needs of industry (1). It is based on extremal features of brown coals, easy to evaluate everywhere in the field. Criteria accepted in that classification include easily observable physical features such as colour, consistency, structure, texture, fracture, share of plant detritus, gelification, mineral admixture, etc. In general evaluation a marked attention is paid to the degree and mode of alteration of coal matter and the degree of consistency of coal is usually treated as the leading feature. Twelve lithotypes identified in that classification include: earthy coal proper, weathering earthy coal, earthy-bituminous coal, subbituminous coal, eumorphic and hemimorphic xylith coal, and geloxylitic, fusine, cuticule, eusapropel, and mineralosapropel coals.

Microscopic studies covered materials from the Konin, Adamów, Legnica, Turów, and Bełchatów deposits (21). The studies involved determinations of composition of macerals and microlithotypes and compilation of models of the deposits, showing relationships of petrographic structure of brown coal and its affinity to a definite structural zone of a seam, as well as of the petrographic structure and technological properties of coal.

The process of gelification of xylith coals appears especially interesting from the point of view of science. The studies by petrographic and physico-chemical methods made it possible to distinguish semi-brittle, brittle, weakly, medium, and strongly gelified xyliths and gel coals. The analysis of spectrophotometric spectra in infrared and oscillatory raman spectra showed that gelification of plant tissue displays features of processes of humification and doppleritization which would suggest clearly chemical nature of the processes. In turn, the concept of gelification suggests physical side of the coalification process (19, 30).

Petrographic studies also covered still not mined deposits as well as small ones, selected to be mined for local purposes. Within the frame of the studies the Liassic brown coal from Poręba near Zawiercie was reanalysed (15). Vitrinite reflectance index, 0.57–0.61%, indicates that this is hard glittering coal, and petrographic composition and chemical-technological properties show that it may be used for both source of energy and low temperature carbonization.

An attempt to adjust terminological concepts connected with classification of brown coal was made for the needs of industry (28), and the range and methods of quality tests were settled for the purposes of identification of brown coal resources (11). Lithotypes identified in macroscopic analyses with reference to colour and texture include black, brown, and yellow, stratified, weakly stratified and unstriatified coals. Lithotype varieties are distinguished with reference to the degree of gelification and content of xyliths and plant detritus. Microscopic petrographic studies involve determinations of content of microlithotypes such as textite, detrite, gelite, inertite and bitumite, and groups of macerals and macerals. The principle of evaluation of usability of coals to produce briquettes, coking, and pressure gasification on the basis of petrographic (microlithotype) composition was introduced to the industrial practice. However, it was mainly the experience gathered by coal petrographers from the G.D.R. which gave the basin for introducing petrographic indices to the current practice in our country.

CONCLUSIONS

The results of petrographic studies of Polish rock and brown coals published in the years 1980–1986 make it possible to state a further progress in the use of petrographic methods in geology as well as mining and processing industry. However, the progress has to be treated as incommensurable with the needs connected with the scale of coal mining, the wealth of coal depoists of Poland, and highly diversified quality and usability of coals of these deposits.

The further developments in applied as well as theoretical coal petrography mainly require continuation or initiation of studies in the following directions:

- studies of physical and chemical-technological properties of macerals and microlithotypes, carried out on their concentrates or directly in coal, and their relation to the degree of metamorphism and quality and economic usability of coals;
- studies of coal seams in the course of geological recognition of deposits, involving analysis of genetic-facies and stratigraphic questions, regularities in structure of coal seams, variability in petrographic composition of coal and degree of its metamorphism;
- working out of more perfect petrographic criteria for prognoses of coal quality, usable in coal classification for geological and economic purposes, especially for unconventional modes of use of coal;
- petrographic studies of post-coal products varying in the degree of alteration, formed in the course of the processing, and the influence of petrographic components of organic and mineral origin of effectiveness of technological processes.

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STRESZCZENIE

W ostatnich latach (1980–1986) uzyskano w Polsce wiele cennych dla nauki i praktyki wyników badań petrograficznych węgli kamiennych z GZW, DZW i LZW oraz węgli brunatnych ze złóż w Turowie, Koninie, Bełchatowie i złóż górniczo nie zagospodarowanych. Najważniejsze wyniki tych badań przedstawiono w niniejszym artykule. Badania te były wykonywane zarówno w trakcie prowadzonych prac geologiczno-rozpoznawczych, jak i dla bieżących potrzeb górnictwa, przeróbki i przetwórstwa węgla. Do praktyki geologicznej i przemysłowej wprowadzono znormalizowane metody analiz petrograficznych węgla kamiennego i brunatnego oraz metodykę badań jakości węgla brunatnego, z wyzyskaniem badań petrograficznych.

РЕЗЮМЕ

За последние годы (1980—1986) в Польше было получено много ценных для науки и практики результатов петрографических исследований каменных углей из Верхнесилезского, Нижнесилезского и Люблинского угольных бассейнов, а также из месторождений бурого угля в Турове, Конине, Белхатове и из месторождений ещё не освоенных горной промышленностью. Самые важные результаты этих исследований представлены в настоящей статье. Эти исследования проводятся как в ходе геологоразведочных работ, так и для текущих потребностей горного дела и переработки угля. В геологической и промышленной практике начато применять нормализированные методы петрографических анализов каменного и бурого угля, а также методику исследования качества бурого угля, основанную на петрографических исследованиях.