

I. SÝKOROVÁ, I. ČERMÁK,

Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic,
V Holešovičkách 41, 182 09 Prague 8

V. DANĚK

Institute of Geology and Paleontology, Faculty of Science, Charles University, Albertov 6, 12
843 Prague 2, Czech Republic

PETROGRAPHIC DETERMINATION OF COAL WEATHERING

Summary. Changes of organic matter of bituminous coal and brown coal induced by weathering has been evaluated by micropetrographic methods. It has been found that all weathered brown and bituminous coal samples exhibit changes in their chemical composition, optical properties and morphology of macerals. Higher reflectance and oxidation cracks of vitrinite and huminite have been identified.

BADANIA PETROGRAFICZNE WĘGLI ZWIETRZAŁYCH

Streszczenie. Zmiany składników węgla kamiennego i brunatnego spowodowane wietrzeniem oszacowano metodami mikropetrograficznymi. Stwierdzono, że wszystkie zwietrzałe próbki węgla wykazują zmiany w swoim składzie chemicznym, własnościach optycznych i morfologii macerałów. Stwierdzono wyższą releksyjność oraz występowanie szczelin wietrzeniowych w wityrynicie i huminicie.

Introduction

In contact with air in various conditions (temperature, humidity, pressure), coal matter undergoes weathering. Changes in the organic matter induced by weathering can be observed in a microscope and evaluated by micropetrographic methods (Chandra, 1982). Examining the

number and shape of cracks, colour, and oxidation rims, Gray (1982) divided coal into 3 categories: slightly, moderately, and badly oxidized. During coal oxidation, the light reflectance and microhardness of huminite in brown coal and vitrinite in bituminous coal increase with reaction temperature increasing up to 200 - 250 °C (Calemma et al., 1995). The effect of oxidation can be observed on macerals of the liptinite group, on sporinite and cutinite in particular (Chandra, 1982).

Klika and Krausová (1993) developed a classification of altered coals from Carboniferous red beds in the Upper Silesian basin, dividing them into 4 oxidation and thermal alteration stages based on the light reflectance of vitrinite, shape and number of cracks, porosity, colour, oxidation rims, and chemical and technological parameters.

In the present work the organic matter in samples was examined microscopically and the degree of their weathering was determined.

Experimental

Changes induced in the organic coal matter by weathering were examined for bituminous coal samples from the Carboniferous Plzeň basin (tab. 1). Samples of brown coal from Antonin seam were taken in the Tertiary Sokolov basin (tab. 2). An overview of the samples, sampling sites, and relative weathering periods is given in tables 1, 2. The beginning of weathering was identified with the time of termination of mining or the time of heaping the spoil banks.

Table 1

The Carboniferous Plzeň basin

| Sample | Time of weathering (years) | Description |
|--------|----------------------------|---|
| JP-1 | 5 | Dobré Stěsí mine, Nýřany seams, taken from the side of the banks |
| JP-2 | 91 | Bayer mine, decayed skeleton, Radnice and Nýřany seams |
| JP-3 | 65 | Josef mine, Klecany, highly weathered coal and coal sediments |
| JP-4 | 75 | Hilde mine, Nýřany seams, small spoil banks by the railroad |
| JP-6 | 115 | Hyrův Důl mine, Bílá Hora, Radnice seams, spoil banks grown by vegetation |
| JP-7 | 72 | Soudný mine, Merklínean relict |
| JP-8 | 60 | sample from a weathered artificial seam outcrop, Soudný |

Table 2

The Tertiary Sokolov basin

| Sample No. | Time of weathering (years) | Description |
|------------|----------------------------|---|
| R-14 | 0 | Marie mine |
| R-16 | long-term weathering | oxihumolite, Antonin seam, Marie mine |
| R-17 | 0 | unweathered coal, Antonin seam, Jifi mine |
| R-21 | long-term weathering | oxihumolite, Antonin seam, Medard mine |

Maceral analyses were performed on UMSP 30 petrological microscope-microphotometer (Opton-Zeiss) in incident light with immersion objective on the leaf section. The light reflectance was measured on homogenous surfaces of vitrinite and huminite at 546 nm with immersion objective (magnification 45x) in an oil immersion ($n = 1.518$). Fluorescence analyses of liptinite macerals of coals were made with the same microscope using the HBO discharge lamp and FI 07 reflector (Opton-Zeiss).

For a crude characterization of the degree of weathering we employed the classification of coals from Carboniferous red beds in the Upper Silesian basin (Klika, Krausová, 1993) and the classification by Gray (1983). We suppose that in the collection examined, weathering consisted in low-temperature oxidation. We discriminate 3 degrees:

- **zero to low** - isolated contraction cracks,
- **low to medium** - contraction and oxidation cracks, increased vitrinite reflectance, porous liptinite nature, secondary mineralization of cracks, isolated oxidation rims
- **high** - oxidation rims, porous nature of liptinite and vitrinite, increased vitrinite and liptinite reflectance, distortion of vitrinite, clarite and durite strips.

Results and discussion

Table 3 demonstrates that the samples taken from the Plzeň basin are bituminous coal and cannel type sapropelite. Random light reflectance of samples taken from the Nýřany and Radnice mine spoil banks varies over the range of $R_r = 0.64\%$ to 0.76% . Sample JP-2 is an exception in which the individual maceral groups - vitrinite, liptinite and inertinite - cannot be discriminated. This sample contains fragments of organic matter exhibiting an average reflectance of $R_r = 1.69\%$, dispersed through the mineral matter, which also displays signs of

thermal alteration. Coal from the shortest-age (5 years) spoil banks is rather compact, with scarce contraction cracks in vitrinite. Random light reflectance of vitrinite is slightly higher in sample JP-1 than in the seam sample as published by Sýkorová et al. (1996), viz. $R_r = 0.74\%$ vs. 0.70% . The fluorescence colour of liptinite (sporinite and cutinite, occasionally also alginite) is bright-yellow to orange. The coal matter in this sample is apparently consistent with the normal development in the seam, although a weak oxidation alteration is conceivable. The JP-3 coal from the Nýřany mine spoil banks which are 65 old is partly weathered. Although the reflectance of vitrinite, $R_r = 0.69\%$, corresponds to the normal development of the seam, the numerous contraction and oxidation cracks in vitrinite and the lighter colour and porous nature of liptinite, megaspores in particular, point to oxidation and dehydration changes. The effect of weathering is also apparent on sample Jp-4 from the smaller spoil banks (75 years old) of the Nýřany seams, which is of sapropelitic nature. In cannel, spots rich in light-colour, porous sporinite with vitrinite strips alternate irregularly with pronounced contraction and oxidation cracks. The light reflectance of vitrinite, $R_r = 0.71\%$, is the same as in the sample from the seam. The sample taken from the oldest spoil banks of the Radnice seam (115 years) represents highly weathered coal matter. Microscopical examination revealed the occurrence of a network of contraction and oxidation cracks, distortion of vitrite and clarite strips, and secondary mineralization. The JP-7 and JP-8 coals are partly weathered. Vitrinite is disturbed by clear-cut contraction cracks.

Table 3

Petrographic characteristics of bituminous coal samples

| Sample | R_r (%) | Vitrinite (%) | Liptinite (%) | Inertinite (%) | The grade of alteration of organic matter |
|--------|-----------|---------------|---------------|----------------|---|
| Jp - 1 | 0.74 | 58 | 13 | 29 | zero to low |
| Jp - 2 | 1.69 | | | 100 | high thermal alteration |
| Jp - 3 | 0.69 | 66 | 24 | 10 | medium |
| Jp - 4 | 0.71 | 54 | 30 | 16 | medium |
| Jp - 6 | 0.64 | 64 | 26 | 10 | high |
| Jp - 7 | 0.76 | 73 | 23 | 4 | low to medium |
| Jp - 8 | 0.64 | 62 | 20 | 18 | low to medium |

In the Sokolov basin, weathering was examined on oxihumolite and coal samples. Sample R-14 is bituminous shale, coal claystone with various types of alginite, sporinite in mineralized detrite, and with small pieces of humified and fusitized wood. Oxihumolite R-16 is liptodetritic coal with highly disturbed strips of ulminite and gelinite and clear-cut contraction and typical oxidation cracks. The maceral group of liptinite is highly diverse. Sporinite is porous and

lighter in colour, its fluorescence is more yellow-brown, whereas cutinite exhibits red-brown fluorescence. Appreciable differences were detected in resinite. The spherical to oval resinite formations are unchanged, they are degassed and porous and some have oxidation rims. Their fluorescence colour is from yellow to green and brown. Oxidation rims were observed on macerals of the inertinite group, on macrinite and fusinite.

Sample R-17 displays a higher huminite reflectance and includes contraction cracks in gelinite and ulminite and densinite. No other manifestations of oxidation were detected. Oxihumulite R-21 is huminite coal, appreciably cracked. There are numerous cracks in the gelinite and eu-ulminite (huminite). The liptodetrinic strips are lighter in colour and porous in nature.

Table 4

Petrographic characteristics of coal claystone and brown coal

| Sample No | R _r (%) | Huminite (%) | Liptinite (%) | Inertinite (%) | Mineral Matter (%) | The grade of alteration of organic matter |
|-----------|--------------------|--------------|---------------|----------------|--------------------|---|
| R - 14 | 0.39 | 28 | 12 | 2 | 58 | zero to low |
| R - 16 | 0.43 | 50 | 40 | 3 | 7 | low to medium |
| R - 17 | 0.46 | 89 | 7 | 1 | 3 | zero to low |
| R - 21 | 0.41 | 89 | 9 | 1 | 1 | low to medium |

Conclusions

1. All weathered brown and bituminous coal samples exhibit the same patterns: higher random reflectance, cracks in vitrinite or huminite, porous nature of liptinite, and lighter colour in normal light and ochre to red-brown colour of fluorescence of liptinite.
2. Secondary mineralization and crack fillings have been identified in weathered bituminous coal from the oldest spoil banks.
3. Oxidation rims were found only scarcely on macerals of the inertinite groups - on macrinite and fusinite in the oxihumulite R-16 and fusinite in the coal sample JP-6.

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Streszczenie

Przeprowadzono badania mikropetrograficzne próbek zwietrzałego węgla kamiennego z karbońskiego złoża Plzeń oraz zwietrzałego węgla brunatnego z trzeciorzędowego złoża Sokolov z pokładu Antonin. Czas wietrzenia, który liczono od rozpoczęcia kopalnictwa lub zwałowania, był różny (5 do 115 lat i dłużej).

Stwierdzono, że wszystkie próbki zwietrzałego węgla, kamiennego i brunatnego, charakteryzują się podobnymi zmianami, a mianowicie: wyższą refleksyjnością, porowatym charakterem liptymtu, obecnością spękań w witryniecie lub humimicie, jaśniejszą barwą w normalnym świetle, zmianą barwy fluorescencyjnej liptymtu na ochrową do czerwono-brunatnej.

Próbki węgla kamiennego pochodzące z najstarszych zwałowisk wykazały wtórną mineralizację spękań. Na macerałach grupy inertynit, głównie na makrynicie i fuzynie, obserwowano obecność obwoidek utlenienia, jednak tylko w niektórych próbkach zwietrzałego węgla brunatnego. Zakres obserwowanych zmian cech mikropetrograficznych próbek węgla pozwala sądzić, że ich wietrzenie zachodziło w większości przypadków w niskiej temperaturze i odpowiada niskiemu do średniego, stopniowi wietrzenia, w skali 3-stopniowej.