Polish Geological Institute Special Papers, 7 (2002): 63–78
Proceedings of the IV European Coal Conference

COAL CLASTS IN THE BOLSOVIAN (WESTPHALIAN C) SEQUENCE OF THE KLADNO–RAKOVNÍK CONTINENTAL BASIN (CZECH REPUBLIC): IMPLICATIONS FOR THE TIMING OF MATURATION

Vilém DANĚK[1], Jiří PEŠEK[2], Pavla VALTEROVÁ[3]

A b s t r a c t . Angular coal clasts confined to coarse-grained feldspathic sandstone deposited in the Tuchlovice Mine pit in the Kladno-Rakovník basin were studied. These fragments of various orientation consisting of banded, dull and bright coal of Bolsovian age (=Westphalian C) occur as an admixture being some tenths of a millimetre up to 40x30x20 mm large. The clasts are coalified into high volatile bituminous coal showing an average reflectance corresponding to vitrinite (R_r = 0.64%). They reveal no signs of progressing diagenetic changes after their redeposition. Some clasts exhibit cracks filled with clay minerals, which constitute common admixture in coal seams of this basin. Cracks do not extend into the adjacent sediment. Their origin is connected with coalification processes in original coal seam, which occurred prior to erosion. The investigation of miospores showed that the coal clasts come from the eroded Lubná coal seams of Bolsovian age. Since the Radnice Member is the oldest unit of the central and west Bohemian basins, the coalification of organic matter into high volatile bituminous coal must have occurred within this member, i.e., during some hundred thousand years at a depth of only a few tens, maximum first hundred metres. The achieved results argue for a high paleotemperature gradient, which must have existed during the Carboniferous in the Bohemian Massif. Similar conditions are known, e.g., from South Wales basin in UK (Gayer *et al*., 1996) and from the Upper Silesian basin (KoŽušníková *et al*., 1999).

K e y w o r d s : coal clasts, time span of coalification, Bolsovian.

INTRODUCTION

Erosion of the upper Radnice coal (equivalent of the Main Kladno coal) is known from the Radnice Member of Bolsovian age (=Westphalian C) in several mines in the Radnice basin (Feistmantel, 1869, Fig. 3d, p.73), from the Plzeň basin (abandoned Týnec Mine and Obránců míru Mine) and from the Kladno-Rakovník basin (e.g., abandoned Max and Klement Gottwald mines; Pešek, 1978 and Pešek *et al*., 1978). Interconnection of erosional levels in entries of individual mines allowed to trace a part of drainage pattern whose streams eroded the corresponding coal seams. Pešek (1978) reported also finds of coal clast in mines of the Plzeň basin, which were not studied in detail. Pašek (1984) described erosion of coals of the Nýřany Member in the Antonín Uxa Mine at Vejprnice in the Plzeň basin. This author found coal clasts which, according to micropaleontological studies of P. Valterová (in Pašek, 1984), belong to the Westphalian D, thus indicating that they originated through erosion of coal seam(s) of a unit of the same age and were deposited in feldspathic sandstones of the Nýřany Member.

[1] Institute of Rock Structure and Mechanics, Academy of Sciences, V Holešovičkách 41, 182 09 Praha 8, Czech Republic
[2] Faculty of Science, Charles University, Albertov 6, 123 43 Praha 2, Czech Republic, e-mail: ir@natur.cuni.cz
[3] Geofond, Kostelní 26, 170 00 Praha 7, Czech Republic

INVESTIGATION OF COAL CLASTS

Macroscopic description

Coal clasts were found by the first author in the Tuchlovice Mine pit in 1998 in a few fragments confined to whitish coarse-grained feldspathic sandstones. All studied coal clasts are angular, and form randomly oriented fragments of banded coal showing no signs of any compaction after their deposition. The approximate number of clasts exceeds 100. About 15 clasts are larger than 1 cm^3. The largest clast is 40x30x20 mm in size (Plate I, Phots. 1, 2, 17).

Clasts, coalified into high volatile bituminous coal with intercalations of carbonaceous shale to claystone, are mostly composed of dull banded coal and dull coal, to lesser extent bright banded coal and rare bright coal. Vitrain bands are maximum 4 mm thick. Coal clasts composed completely of fusite were not identified, although fusite is abundant in coal seams of this locality. Fusite bands, however, are in general less stable and once being exposed they easily weather and disintegrate in to fine coal detritus. The clasts seem to have been transported for only short distance. No preferred orientation was observed in coal clasts (Plate I, Phot. 1). Some cracks in mostly banded coal are filled with light clay minerals (Plate I, Phot. 3). Spudil (in Žáková, 1968) identified dickite, jarosite and kaolinite. Cracks must have been mineralized before coal seam erosion because the mineralization or the cracks themselves do not extent into adjacent sediment.

Microscopic investigation

Applied methods

Micropetrographic studies were carried out at laboratories of the Institute of Rock Structure and Mechanics. In order to characterize and define coal samples, each coal clast and randomly collected sample from a coal seam were crushed to a grain size of 1 mm. Polished sections of each comparative seam and about 15 coal clasts were prepared according to specifications of the International Organization for Standardization. Vitrinite reflectance was measured on polished sections using a UMSP 30 Petro microscope-microphotometer Opton-Zeiss under reflected light at a wave-length of $\lambda = 546$ nm in oil immersion n = 1.515. Total magnification was 750x. Fluorescent analysis was executed on the same equipment using a halogen discharge lamp, dry objective and a F109 filter set. In order to correlate the results of vitrinite reflectance and maceral analysis, the image analysis Lucia in 4.22 jointing Nikon Eclipse MR600 microscope with black and white digital camera DVC-1300 model and scanning microscope Märzhäser EK were used. Measurements were done under reflected light at the same wave-lenght and same oil immersion as mentioned above. Total magnification was 40–1000x. The random vitrinite reflectance was measured using an automated and semi-automated system (vitrinite modulus software). The software is based on the measurement of digitalized reflection of a light beam, which, using standardization, allows to obtain very accurate results. Maceral analysis was undertaken using the point counting method on an Opton-Zeiss microscope and a maceral modulus system of image analysis. The values obtained by both systems were averaged using weighted mean, and correlated.

Petrographic characteristics of coal clasts

Trimacerite with transition into clarite to clarodurite with vitrinite bands prevail in all studied clasts (Table 1, samples A+B; Plate II, Phot. 4). Minor is vitrinite whereas fusinite and vitrinertite are rare. Vitrinite occurs in form of colotelinite (Plate II, Phot. 5), whereas telinite with fairly preserved or partly gelified cellular structure are rare. Pure clarite was identified only occasionally. It always contains small admixture of inertodetrinite or micrinite. Liptinite is represented by randomly distributed but locally concentrated miospores (Plate I,

Table 1

Maceral analysis [in vol. %] of coal clasts (A+B), upper Radnice (Main Kladno) coal seam (C), lower Lubná (Dolín) coal seam (D+E)

Sample	A+B	C	D	E
Telinite	<1	<1	0	1
Colotelinite	16	38	24	17
Vitrodetrinite	9	9	7	6
Colodetrinite	18	19	16	22
Corpogelinite	2	6	2	1
Gelinite	<1	<1	<1	1
Vitrinite	43	72	49	48
Sporinite	25	6	22	11
Cutinite	0	<1	<1	0
Resinite	1	<1	1	<1
Suberinite	0	0	0	0
Fluorinite	0	0	0	0
Bituminite	0	0	0	0
Exsudatinite	<1	0	<1	0
Alginite	<1	<1	0	<1
Liptodetrinite	8	3	6	4
Liptinite	34	9	28	15
Fusinite	7	7	2	1
Semifusinite	2	3	5	8
Macrinite	<1	0	<1	<1
Micrinite	1	1	1	1
Sclerotinite	<1	<1	0	<1
Inertodetrinite	15	8	15	16
Inertinite	21	19	22	25
Clay-sandy impurity	2	<1	1	1
FeS_2	<1	0	<1	<1
Carbominerite	2	0	1	1

Phot. 16) simultaneously accompanied by an increase in liptodetrinite (Plate II, Phot. 6). Large amounts of megaspores are sporadic (Plate II, Phot. 7). Minor resinite and exsudatinite occur in addition to sporinite. Transition phases of duroclarite contain various proportions of miospores and megaspores with higher concentrations of inert macerals, particularly those of fusinite, micrinite, semifusinite and sclerotinite. The major component of the studied clasts is represented by a group of vitrinite[4] macerals. Telinite occur only in transition into colotelinite, which is the major constituent of vitrinite. Colodetrinite and vitrodetrinite are major constituents of trimacerite in which they form thin bands or separate tiny bodies. Fusinite is least resistant against mechanical weathering. It often disintegrates into smaller fractions during the transport (Plate II, Phot. 9). Some microscopic pores (Plate III, Phot. 10) about 2–10 µm large and in a number of 50 to 1000 pores per sq. mm are developed in some macerals, particularly those of trimacerite. A number of microtextures were identified showing obvious signs of weathering. Macerals of vitrinite group were found to be most sensitive to weathering processes. Bands of colodetritinite are usually disturbed by cracks parallel to contact planes but short perpendicular contraction microcracks were also observed. Colotelinite, which suffered from weathering shows, reduced reflectance in marginal parts (as much as down to $R_{min} = 0.46\%$) and also exhibits fine network of microcracks accompanying structural destruction and microbends (Plate II, Phot. 5). Weathered sporinite shows lesser optical definition in marginal parts and increased porosity (Plate III, Phot. 11). Fluorescent activity is also reduced relative to coal samples collected from the nearest coal seam. Transitions of fluorescent colours from light yellow into yellow-brown with darker margins can be seen in studied samples. Macerals of colodetritinite and corpogelinite (Plate III, Phot. 15) were found to be mineralized with clay minerals. Weathering of gelinite results in variation in reflectance values. Inertinite is relatively stable. Signs of strong weathering were observed only on macrinite.

Coal clasts built of sediments of transition series coal--claystone are rare. Among them, relatively most abundant are claystones with tiny bands of colotelinite with an admixture of detrital mica, carbonate and pyrite (Plate III, Phot. 12). Vitrodetrinite together with inertodetrinite, which constituted an admixture in clayey matrix, are very accessoric. Very rare isolated miospores and migrating exsudatinite were also identified in the clayey matrix.

Petrographic character of the Tuchlovice Mine coals

Samples of coal from the upper Radnice (Main Kladno) coal seam (C) and the lower Lubná (Dolín coal seam D+E) were studied for comparison. The micropetrographic character of the above-mentioned coal seams was found very similar, and no marked differences in their structure were identified to provide evidence of consanguinity of individual clasts to certain coal. All lithotypes identified in coal clasts are common constituents of all coal seams at this locality.

Bituminous coal exhibits characteristic banding. Coal seams are composed mostly of dull banded coal, which prevails over bright banded coal. Pure dull coal is minor. Fusinite forms tiny lenses or even continual layers. The occurrence of clay minerals is a characteristic feature of the local coal. Clay minerals fill contraction cracks. Similar fillings were also reported from the studied clasts. Dirty coal was occasionally found to occur in these coal seams. Detailed macro- and micropetrographic studies of coal from the former Nosek (Tuchlovice Mine) were carried out by Žáková (1974).

Correlation between petrographic character and structure of the Tuchlovice Mine coals and coal clasts found in the Tuchlovice Mine pit

Relative proportions of macerals in coal seams of the Tuchlovice Mine correspond to mean values reported earlier from this locality. Maceral analysis of coal clasts revealed enhanced content of liptinite macerals (Plate II, Phots. 4, 6) which can be explained by higher resistance of these constituents to weathering (Fig. 1).

Micropetrographic studies revealed only two features, which may indicate or support close relation of clasts to individual coals:

— occurrence of microscopic pores in trimacerite layers of the lower Lubná (Dolín) coal seam (Plate III, Phot. 13), similar

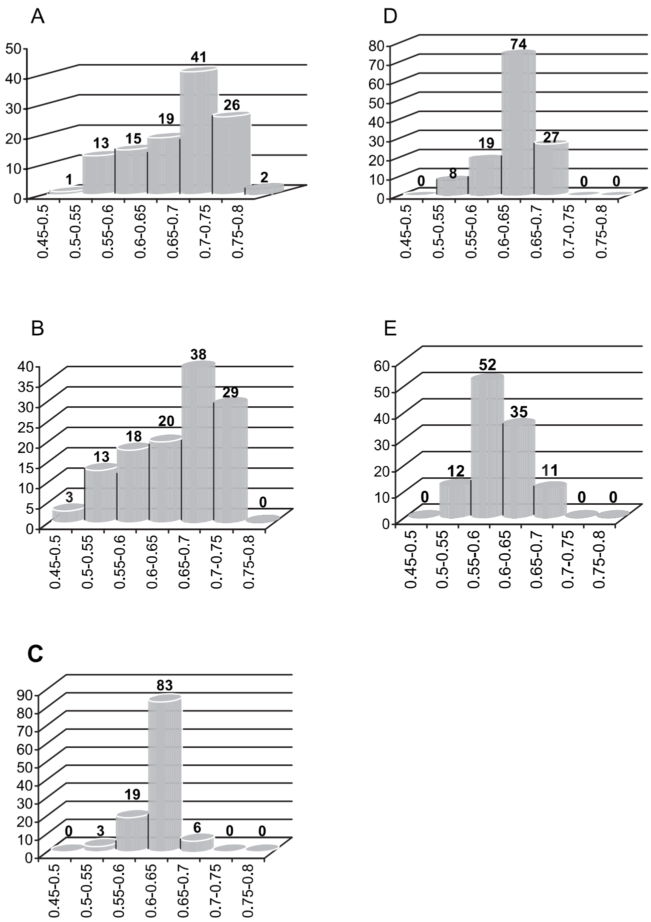


Fig. 1. Reflectograms showing the reflectance scatter in vitrinite of coal clasts (A+B), upper Radnice (Main Kladno) coal seam (C), lower Lubná (Dolín) coal seam (D+E)

[4] The ICCP System (1998) was used for description and classification of macerals of vitrinite group.

Table 2

Random reflectance of vitrinite (R_r) and sulphur dry (S^d) of coal clasts (A+B), upper Radnice (Main Kladno) coal seam (C), lower Lubná (Dolín) coal seam (D+E)

	R_r [%]	S^d [%]
A	0.65	0.07
B	0.64	0.07
C	0.62	0.03
D	0.62	0.04
E	0.60	0.03

to those identified in coal clasts (Plate III, Phot. 10); such pores were not found in other coals;

— trimacerite was found to be the major microlithotype in the studied clasts (Plate II, Phots. 4, 6); its microstructure markedly resembles that one found in samples from the lower Lubná (Dolín) coal seam (Plate III, Phot. 14); however, other microlithotypes occurring together with trimacerite in coal clasts show to certain extent similar features.

Comparison between vitrinite reflectance of coals of the Tuchlovice Mine and coal clasts found in the pit of this mine

The reflectance of vitrinite (Table 2) and maceral composition (Table 1) were measured and established in about 20 selected clasts including the determination of average reflectance of vitrinite in a colotelinite maceral (R_r = 0.64%). The reflectance of vitrinite in coal of the upper Radnice (Main Kladno) and the lower Lubná (Dolín) coal seams was also measured. The mean reflectance of vitrinite measured on coal clasts is slightly higher than that of vitrinite of coal seams (R_r = 0.60–0.64%), but still within the standard deviation. Our values, however, differ from data reported from the South Wales and Upper Silesian basins. Coal clasts of these basins show slightly lower vitrinite reflectance than that measured in neighbouring coal seams (*cf.* Gayer, Pešek, 1992; Gayer *et al.* 1996; KoŽušníková *et al.*, 1999). The presently measured reflectance of vitrinite in coal clasts from the Kladno–Rakovník basin shows greater scattering of values relative to those in coal seams (Fig. 1). This is attributed to the weathering of clasts and to variation in several different lithotypes occurring in one sample.

Palynological studies

Proportion of miospores in coal seams of the Radnice Member in the Tuchlovice Mine and its neighbourhood

Five palynozones, corresponding to major groups of seams and occurring in the Kladno–Rakovník basin, were distinguished on so far executed studies of miospores in the Radnice Member of the central Bohemian Carboniferous. The two first zones belong to the lower Radnice and upper Radnice (Main Kladno) coal seams. The remaining three zones include coal

Table 3

List of miospores of the Radnice and Lubná group of coals in the Kladno coalfield

Radnice group of coals		Lubná group of coals			List of miospores of the Radnice and Lubná group of coals
lower Radnice coal	upper Radnice (Kladno) coal	lower Lubná coal	middle Lubná coal	upper Lubná coal	+ present * constant, but rare findings ^^ common/abundant findings # dominant form (up to 95%)
+	+	+	+	+	*Sporonites unionus*
*	*	*	*	*	*Leiotrioletes*
*	*	*	*	*	*Calamospora*
*	*	*	*	*	*Granulatisporites*
+	+	+	+	+	*Cyclogranisporites aureus*
+	+	+	+	+	*Punctatisporites*
+	+	+	+	+	*Lophotriletes*
+	+	+	+	+	*Planisporites kosankei*
+	+	+	+	+	*Apiculatisporis*
+	+	+	+	+	*Acanthotriletes*
+	+	+	+	+	*Raistrickia*
+	+	+	+	+	*Verrucosisporites*
+	+	+	+	+	*Microreticulatisporites*
+	+	+	+	+	*Knoxisporites polygonalis*
#	#	^^	^^	^^	*Lycospora*
*	*	*	*	*	*Cirratriradites saturni*
^^	^^	^^	^^	^^	*Laevigatosporites* (not *L. minimus*)
+	+	+	+	+	*Latosporites latus*
+	+	+	+	+	*Endosporites* (not *E. formosus*)
+	+	+	+	+	*Alatisporites*
+	+	+	+	+	*Florinites*
+	+	+	+	+	*Reinschospora*
+	+	+	+	+	*Anapiculatisporites spinosus*
+	+	+			*Pustulatisporites pustulatus*
+	+				*Convolutispora*
+	+	+			*Dictyotriletes densoreticulatus*
+	+	+			*Dictyotriletes bireticulatus*
	+	+			*Reticulatisporites castaneaeformis*
+	+	+			*Savitrisporites* (inclusive of transition forms)
+	+				*Simozonotriletes*
+	+				*Ahrensisporites minutus*
+	+				*Ahrensisporites querickei*
	*	#	+	+	*Densosporites*
	#	+			*Cristatisporites indignabundus, saarensis*
+		+	+	*	*Westphalensisporites*
+	+	+		+	*Reticulatasporites*
+	+	+			*Vestispora cancellata*
	+	+	+	+	*Vestispora costata*
			+	*	*Cyclogranisporites orbicularis*
			*	^^	*Laevigatosporites minimus*
				+	*Dictyotriletes cingulatus*
				+	genus *Triquitrites* of many species
				^^	*Punctatosporites*
			+	^^	*Torispora*
				+	*Speciososporites*
			+	+	*Microreticulatisporites nobilis*

Table 4

List of the most important miospores of the Radnice and Lubná group of coals in the Kladno coalfield

+ present ^^ common/abundant findings # dominant form (up to 95%)	Lány region (Boháčová, 1961)		Pecínov, Nové Strašecí and Rynholec regions, upper Lubná coal (Valterová, 1996)	Kačice mining field (Boháčová, 1959; Valterová, 1964, 1968, 1974)			Zdeněk Nejedlý Mine (Valterová, 1977, 1978, 1980; Spudil, Valterová, 1985)			Tuchlovice (formerNosek) Mine (Spudil, Valterová, 1985), lower Lubná group of coal	Valterová (1974)			
											Zdeněk Nejedlý Mine	Klement Gottwald Mine – Mayrau mining field – Vinařice mining field	ČSA Mine	Antonín Zápotocký Mine
	lower Lubná coal	upper Lubná coal		lower Lubná coal	middle Lubná coal	upper Lubná coal	lower Lubná coal zone	middle Lubná coal zone	upper Lubná coal zone		upper Radnice (Main Kladno coal)			lower Radnice coal
Laevigatosporites minimus (Wils. et Coe) Pot. et Kremp		^^	^^			^^		+	^^					
Punctatosporites Ibr.		^^	^^			^^			^^					
Cyclogranisporites orbicularis (Kos.) Pot. et Kremp			^^		+	+	+	+	+					
Westphalensisporites irregularis Alp.			^^		+	+	+	+	+					+
Torispora (Bal.) Doub. et Horst		^^	^^		+	^^		+	^^					
Densosporites (Berry) Butt., Jans., Smith et Stapl.	^^		+	#	+	+	#	+	+	#	^^	^^	+	
Reticulatisporites (Ibr.) Pot. et Kremp			+	+		+			+	+	+	+		+
Anapiculatisporites (Pot. et Kremp) Smith et Butt.			+	+		+				+	+	^^	+	^^
transform to the genus *Ahrensisporites–Savitrisporites–Triquitrites*							+			+	+			+
Cristatisporites (Pot. et Kremp) Butt., Jans., Smith et Stapl.				+						+	#	^^	#	
Pustulatisporites pustulatus Pot. et Kremp	+			+			+				+	+		+
Dictyotriletes densoreticulatus Pot. et Kremp	+			+						+	+	+		+

seams of the group of lower Lubná coal seams (particularly the so-called Dolín coal seam), and then the middle and upper Lubná coal seams.

Spore assemblages of the Radnice group of coal seams (Table 3) are characteristic of total prevalence of trilete types, which are very much alike. Percentage proportion of *Lycospora*, *Cristatisporites*, *Densosporites* and *Laevigatosporites*, accompanied by Bolsovian spore elements, is important for distinguishing individual coals of the Radnice group of coal seams, specifically the lower Radnice seam from the upper Radnice coal seam. Large accumulation of the spore genus *Cristatisporites* (*C. indignabundus*, *C. saarensis*) is characteristic of the upper Radnice coal seam. The *Densosporites* genus is rare, whereas abundant are *Lycospora* and *Laevigatosporites* (medium to large forms), the latter two are of no stratigraphic significance. The genera *Cristatisporites* and *Densosporites* have not yet been found in the lower Radnice coal seam.

The Lubná group of coal seams contains common spore elements of Bolsovian age. However, the established palynozones exhibit specific character. The lowest zone, which represents group of the lower Lubná coal seams, is characteristic of striking to prevalent proportion of spores *Densosporites* constituting as much as 95% of all miospores.

The palynozone of the middle group of the Lubná coal seams contains mostly inexpressive spore assemblages of the Bolsovian. New elements representing young vegetation mostly confined to the Westphalian D (i.e., the Nýřany Member), started to appear, although they are rare. They include miospores of the *Cyclogranisporites orbicularis, Laevigatosporites minimus*, and *Westphalensisporites* sp. and the *Torispora* genus.

Completely specific assemblages, occurring in the group of the upper Lubná coal seams, represent the third uppermost miospore zone of the group. This zone is not only characteristic of Bolsovian elements but it also contains numerous tiny monolete forms of *Punctatosporites, Laevigatosporites*, and *Torispora* (in some cases dominating) which are important for the youngest interval of Bolsovian sedimentation and for the Westphalian D.

Correlation between miospore compositions of the Tuchlovice Mine coal seams and coal clasts found in pit of this mine

Altogether four samples of coal clasts were analysed palynologically. Three of them come from a sample depicted on Plate I, Phot. 1 (for location of sample no. 1 see Phots. 1, 2), samples nos 2 and 3 come from its reverse side. The fourth sample is a mixture of coal fragments hand picked from feldspathic sandstones found in the local pit. Palynological analysis of the sample no. 1 shows that the studied coal clast comes from the upper Radnice Member, most likely from a palynological zone of the group of the lower Lubná coal seams (Table 4). It is characteristic of the dominant spore genus *Densosporites*, without younger spore elements (e.g., the *Westphalensisporites, Torisporites* genera), and small monolete forms of the *Laevigatosporites, Punctatosporites* genera and others, which also occur in the Late Bolsovian in which the *Densosporites* genus is very rare. Single finds of *Densosporites* are also known from the Radnice group of coals. Similar palynological spectrum was also identified in sample no. 2, but it is qualitatively less varied. Sample no. 3 provided only single fragment of *Laevigatosporites desmoinesensis*. Sample no. 4 showed no conspicuous palynological spectrum. Only single finds of stratigraphically not important taxa were recorded. Slightly more abundant is the *Lycospora* genus. Only single problematic occurrence of *Densosporites* was identified. However, this character of palynological spectrum does not allow more precise stratigraphic identification. Such a spectrum occurs in the entire profile of Carboniferous sediments.

DISCUSSION AND RESULTS

The discovery of coal clasts is essential as they have not been studied in detail in the Radnice Member of the central Bohemian Late Palaeozoic basins, and particularly important because the Radnice Member is their basal, thus the oldest unit (Table 5). Since the nearest coal seams older than the Bolsovian in the Bohemian Massif are known from the Intra Sudetic basin (Late Namurian to Langsettian) which is about 150 km away from the site of their find, their origin in the above-mentioned basin can be excluded which is also supported by angular shape of the clasts (Plate I, Phot. 1). The results of micropetrographic studies, maceral composition, microstructure and reflectance of vitrinite showed that coal clasts of the Tuchlovice Mine pit and coals of the Tuchlovice Mine exhibit similar features. The length of transport and rate of sedimentation are thought to have been short assuming from weak manifestations of weathering and erosion. Only the origin of contraction cracks in vitrinite layers, secondary microporosity in detrital parts, slight dispersion of reflectance and negligible changes in fluorescent colours in sporinite can be observed. Alginite retained its original fluorescent properties. Plastic deformation of macerals described by KoŽušníková *et al*. (1999) in coal clasts of the Upper Silesian basin have not been found in the studied region. Secondary mineralization of organic matter is very weak but slightly increases mostly in trimacerals exhibiting in places increased microporosity.

Compactness of clasts had been completed already in the coal seam, which was later eroded and did not continue after their redeposition. This is supported by both the shape and various orientation of the banding in single clasts. Various orientation of coal clasts, into which the megaspores were embossed, also argues for completed process of consolidation in original coal seam.

Similarly, the palynological studies show that the studied clasts are likely to come from the lower Lubná coal seam of the Radnice Member (Table 5). Consequently, the clasts can be considered redeposited relics of coal seams which formed prior to the erosion[5]. All studied clasts exhibit preserved original signs of seam lithotypes (banding, maceral structure, microlithotype texture) which indicates that they could have originated only within a coal seam, not as isolated fragments of organic matter which are common in sediments of this locality.

As the Radnice Member of Bolsovian age represents the oldest unit in the central and western Bohemian basins, the

Table 5

Stratigraphy of the Kladno–Rakovnik basin

Age		Formation	Member	Group of coals
Stephanian	C	Líně		
	B	Slaný	Otruby Malesice Jelenice	Kounov Mělník
	Barruellian	Týnec		
	Cantabrian	Kladno	Nýřany	Nevřeň Chotikov Nýřany Touškov
Westphalian	D			
	Bolsovian		Radnice*	Lubná Radnice Plzeň**

----- break in deposition
* thickness of Radnice Member in the Kladno–Rakovnik basin up to 260 m
** not developed in the Kladno–Rakovnik basin

coalification of organic matter into highly volatile bituminous coal must have occurred during the Bolsovian, i.e., during some hundred thousand years at the latest, and at a maximum depth of a few hundred metres below the surface. This finding supports the idea, already reported by Havlena (1963) and manifested by discovery of clastic dikes in coal seams of the Radnice Member in the Plzeň basin (Pešek, 1978), about very fast coalification of organic matter in the Kladno–Rakovník basin and its transfer into a seam of bituminous coal during the geological stage. This process can only be explained by extremely high values of temperature gradient in the Carboniferous of the Bohemian Massif[6]. The fast warming-through of the organic matter may be connected with the occurrence of numerous late Variscan plutons in the basement of the Kladno–Rakovník basin.

High values of temperature gradient (7–8°C/100 m) were also reported from several boreholes in the Rhine Valley (Teichmüller, 1979). The predominant role of temperature for coalification can be best studied in young basins where the thermal history and the present heat flow are well known. According to Barker (1979), young sediments of the Colorado Delta are in the process of being coalified in the Cerro Prieto field of Baja California (Mexico). The area belongs to a rift system with high geothermal gradients (up to 160°C/km) caused by magmatic intrusions less than 6 Ma in age. The huminite/vitrinite reflectance increases from 0.12% R_r (peat stage) at 240 m depth to 4.1% R_r (anthracite) at 1,700 m. Thus, the coalification gradient is equal to 0.29% R_r/100 m.

Any considerable influence of tectonics on coalification of organic matter can be explicitly excluded in the central Bohemian basins. Coal seams are subhorizontally deposited and only locally disturbed by more significant faulting mostly of normal fault character. The legitimacy of the above-mentioned ideas about very fast process of coalification of organic matter is in the Bohemian Massif also supported by finds of coal clasts in psammites of the Saddle Member (Middle Namurian) reported by KoŽušníková *et al*. (1999) from the Czech part of the Upper Silesian basin. Some tens of clasts identified in the Saddle Member come mostly from eroded coal seams of the Ostrava Formation (Early Namurian), and in one case even from the Saddle Member of Middle Namurian age. Finds of numerous coal clast of mostly Bolsovian and/or Westphalian D age in sediments of the same age are also known from other basins (e.g., from South Wales basin, Gayer, Pešek, 1992; Gayer *et al*., 1996). Van Krevelen and Schuyner (1957) and Teichmüller (1958) also brought evidence, derived from the course of isovoles in the folded Sonneschein coal seam of the Bochum syncline in Ruhr region, that coalification into bituminous coal occurred in relatively short time interval already before the Asturian phase of Variscan folding.

CONCLUSIONS

Finds of coal clasts in basal unit of the Kladno–Rakovník basin, i.e., in the Radnice Member of Bolsovian age formed of angular fragments of banded coal with no differences in diagenesis when compared with kaolinized feldspathic sandstone in which they occur, together with earlier known clastic dikes found in a unit of the same age of some central and western Bohemian basins, argue for very fast coalification of organic matter and its transfer into high volatile bituminous coal. The coalification of organic matter must have occurred at relatively shallow depth (tens, maximum the first hundreds of metres). As the coalification of organic matter into subbituminous coal deserves a temperature of minimum 85–130°C (Taylor *et al*., 1998), the above-mentioned discovery argues for high temperature gradient during Carboniferous in the Bohemian Massif. The temperature is the major factor influencing the rank of coal, playing the most important role in the process of coalification. It can be concluded for sure that the process of formation of coal seams was relatively fast during geological times.

Acknowledgements. The authors are grateful for financial support obtained within the project: “Program aimed at upgrading scientific equipment” No. P2055920 and project No. A3012703 subsidized by the Grant Agency of the Academy of Sciences of the Czech Republic.

[5] With respect to these facts we inquired the managing geologist of the Tuchlovice Mine Mr. P. Ulrych who provided an information that underground workings were driven only in the Radnice Member in the last few years.

[6] Even if we admit that the coal clasts come from the succeeding unit, i.e. from the Nýřany Mamber deposited after a hiatus in the Westphalian D, then this discovery would be another evidence of very fast coaliffication of Carboniferous organic matter in the Bohemian Massif.

REFERENCES

BARKER C.F., 1979 — Vitrinite reflectance geothermometry in the Cerzo Prieto geothermal systeme, Baja California (Mexico). MS Dept. of Earth Sci., Uni. of California, PhD Thesis: 127 pp.

BOHÁČOVÁ M., 1959 — Palynologická zpráva k problému Kačice. In: J. Spudil, 1980, Závěrečná zpráva úkolu Kačice (černé uhlí). MS Geofond ČR, Praha.

BOHÁČOVÁ M., 1961 — Paleontologicko-stratigrafická zpráva k problému Lány. MS Archiv posudků n.p. Geoindustria, Praha.

BOHÁČOVÁ M., 1964 — Palynologické zjištění lubenského horizontu na Slánsku a Novostrašecku a problematika tzv. kačické sloje. *Čas. Mineral. Geol*., **9**: 143–152.

FEISTMANTEL K., 1869 — Kamenouhelná ložiště v okolí Radnic. Komitét pro přírodní výzkum Čech. Praha.

GAYER R., PEŠEK J., 1992 — Cannibalisation of coal measures in the South Wales coalfield — significance for forland basin evolution. *Proc. Ussher Society*, **8**, 1: 44–49.

GAYER R., PEŠEK J., SÝKOROVÁ I., VALTEROVÁ P., 1996 — Coal clasts in the Upper Westphalian sequence of the South Wales coal basin: implication for timing of maturation and fracture permeability. In: Coalbed methane and coal geology (R. Gayer, I. Herris, Eds.). *Geol. Soc. Spec. Publ*., **109**: 103–120.

HAVLENA V., 1963 — Geologie uhelných ložisek 1. Nakl. Čs. Akad. věd. Praha.

ICCP Systém, 1998 — The new vitrinite classification. International Committee for Coal and Organic Petrology (ICCP). *Fuel*, **77**, 5: 349–358.

KOŽUŠNÍKOVÁ A., MARTINEC P., PEŠEK J., VALTEROVÁ P., 1999 — Coal clasts in the Carboniferous sediments of the Upper Silesian basin. *Bull. Czech Geol. Surv*., **74**: 25–30.

PAŠEK J., 1984 — Erosion of coal seams in the Vejprnice mine field in the Plzeň Basin. *Folia Mus. Rer. Natur. Bohem. Occident., Geol*., **20**: 30 pp. Západočeské Muz. Plzeň.

PEŠEK J., 1978 — Erosion and clastic dikes in coal seams of the Central Bohemian Basin and their significance for the determination of plant substance coalification. *Folia Mus. Rer. Natur. Bohem. Occident., Geol*., **12**: 34 pp. Západočeské Muz. Plzeň.

PEŠEK J. *et. al*., 1978 — Uhelně petrografický a geologický výzkum hlavní kladenské sloje na Dolu Klement Gottwald. MS Geofond. Praha.

SPUDIL J., VALTEROVÁ P., 1985 — K identifikaci slojí lubenského souslojí v kladenské pánvi. *Geol. Průzk*., **27**: 138–142.

TAYLOR H.G., TEICHMÜLLER M., DAVIS H., DIESSEL F.C.K., LITTKE R., ROBERT P., 1998 — Organic petrology. Gebrüder Borntraeger. Berlin, Stuttgart.

TEICHMÜLLER M., 1958 — Inkohlungsuntersuchungen und ihre Nutzanwendung. *Geol. en Mijnbouw*, **20**: 41–66.

TEICHMÜLLER M., 1979 — Die Diagenese der kohligen Substanzen in den Gesteinen des Tertiärs und Mesozoikums des mittleren Oberrhein-Grabens. *Forschr. Geol. Rheinld. u. Westf*., **27**: 19–49.

VALTEROVÁ P., 1964 — Paleontologická zpráva k lokalitě Kačice. In: J. Spudil, 1980, Závěrečná zpráva úkolu Kačice (černé uhlí). MS Geofond ČR, Praha.

VALTEROVÁ P., 1966 — Zpráva o výzkumu miospor v oblasti mezi obcemi Pecínov, Nové Strašecí a Rynholec. In: A. Kollert *et al*., 1975, Ložisková studie kladensko-rakovnické pánve (KRP) — černé uhlí. MS Geofond ČR, Praha.

VALTEROVÁ P., 1968 — Palynologicko-stratigrafická zpráva k úkolu Kačice – sever. *Ibidem*.

VALTEROVÁ P., 1974 — Palynologicko-stratigrafický výzkum v kladensko-rakovnické pánvi. *Ibidem*.

VALTEROVÁ P., 1977 — Palynologické zhodnocení vzorků z Dolu Zd. Nejedlý. In: J. Spudil, 1980, Závěrečná zpráva úkolu Kačice (černé uhlí). MS Geofond ČR, Praha.

VALTEROVÁ P., 1978 — Stratigrafické vyhodnocení rostlinných mikrofosilií z důlního pole Dolu Zd. Nejedlý v Libušíně. *Ibidem*.

VALTEROVÁ P., 1980 — Biostratigrafické zhodnocení uhelných slojí z důlního pole Dolu Zd. Nejedlý v Libušíně (II. etapa). *Ibidem*.

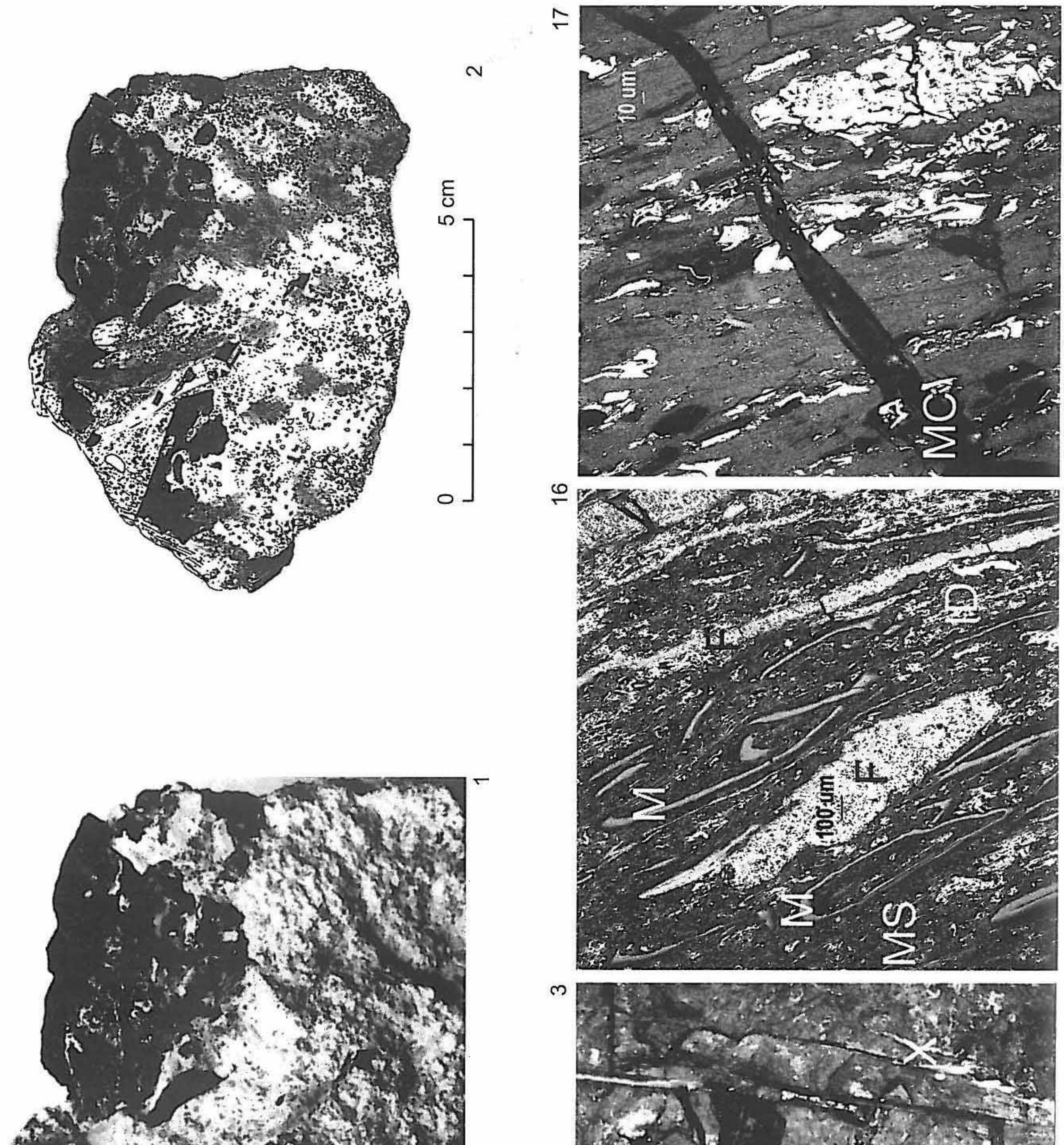
van KREVELEN D.W., SCHUYNER J., 1957 — Coal science. Elsevier. Amsterdam, New York.

ŽÁKOVÁ B., 1968 — Závěrečné zhodnocení nýřanské sloje; Slaný – nýřanská sloj.: 71–87. MS Geofond ČR, Praha.

ŽÁKOVÁ B., 1974 — Petrografický výzkum uhelných slojí v kladensko-rakovnické pánvi. MS Geofond ČR, Praha.

PLATES

All digital photomicrographs were taken on polished sections under reflected light at a wavelenght of λ = 546 mm in oil immersion n = 1.515 by V. Daněk. Magnification 40–1000 x.



Vilém DANĚK, Jiří PEŠEK, Pavla VALTEROVÁ — Coal clasts in the Bolsovian (Westphalian C) sequence of the Kladno–Rakovnik continental basin (Czech Republic): implications for the timing of maturation

PLATE I

Phot. 1. Coal clasts in the kaolinized feldspathic sandstone. Vertical dimension corresponds to 60 mm.

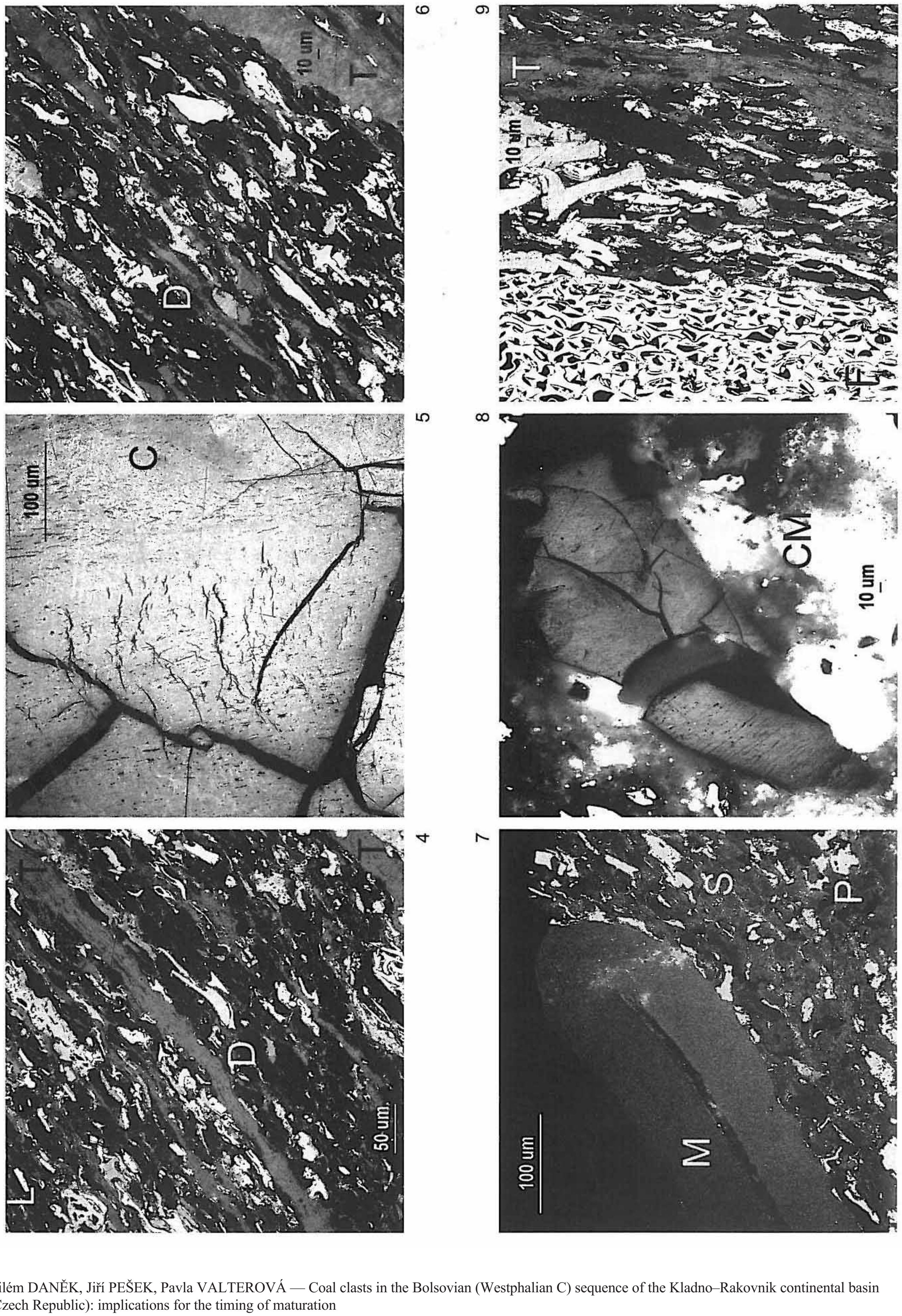
Phot. 2. A drawing of kaolinized feldspathic sandstone with coal clasts showing the similar part as depicted on Fig.1 but with details of banding and cracking of clasts which are not seen on the photograph (drawn by B. Valeš).

Phot. 3. Detail of a crack in coal clast (V vitrinite band) mineralized by white clay (X). Vertical dimension corresponds to 10 mm.

Phot. 16. Durite part of a coal clast containing megasporinite (M), inertodetrinite (ID), body and bands of fusinite (F) and miosporinite (MS).

Phot. 17. Microcrack (MC) filled with clay mineral penetrating a banded coal clast.

 Pol. Geol. Inst. Special Papers 7, 2002



Vilém DANĚK, Jiří PEŠEK, Pavla VALTEROVÁ — Coal clasts in the Bolsovian (Westphalian C) sequence of the Kladno–Rakovnik continental basin (Czech Republic): implications for the timing of maturation

PLATE II

Phot. 4. Colotelinite (T) indicates the original woody cellular structure, and collodetritinite (D) filling of the groundmass formed by sporinite, liptodetritinite (L) and inertodetrinite (bright).

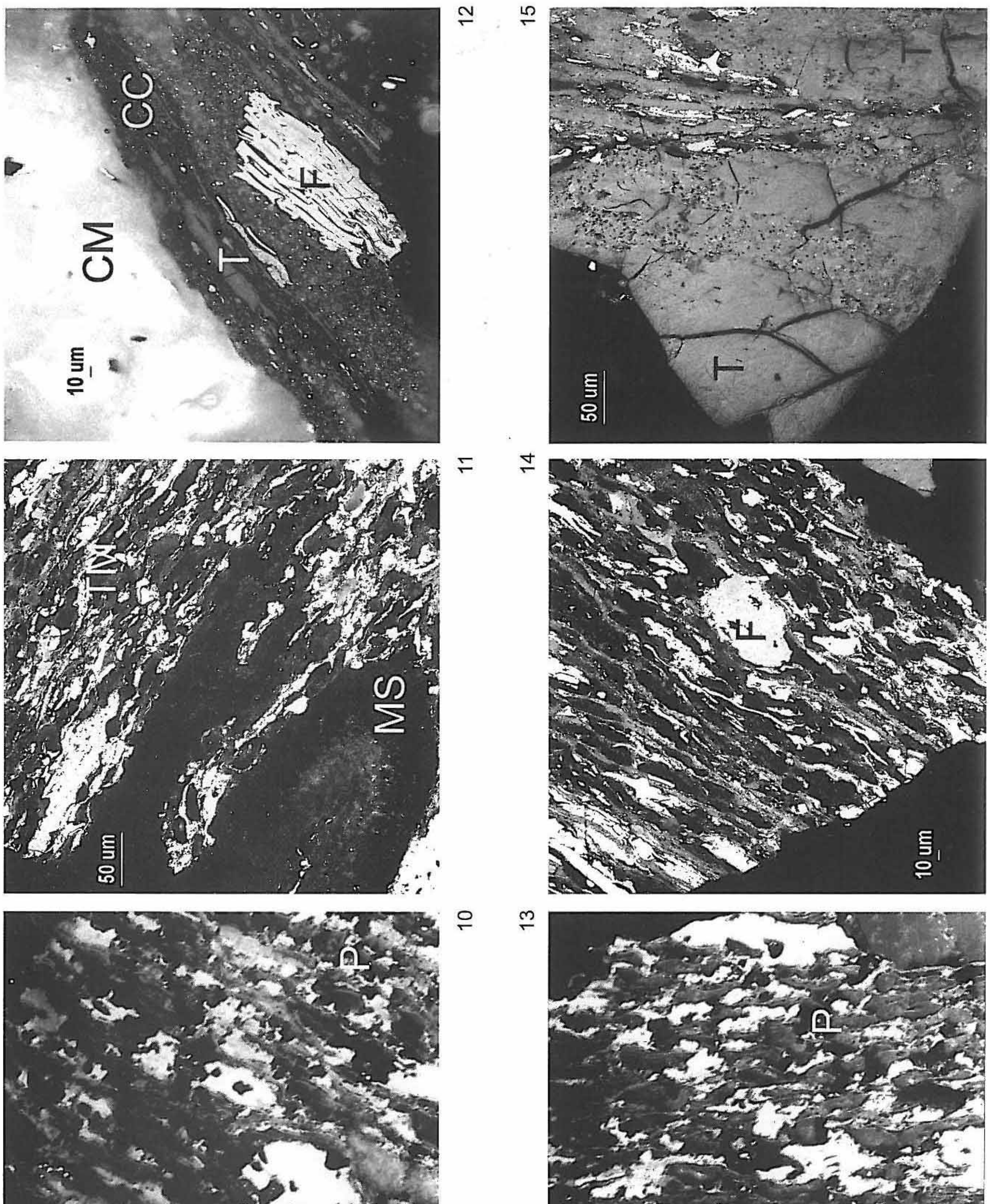
Phot. 5. Colotelinite showing weathered marginal part of a coal clasts; the degree of weathering increases from the right to the left; right part exhibits cellular structure (C).

Phot. 6. Colotelinite (T) indicates the original woody cellular structure, and colodetrinite (D) fills gaps as groundmass for sporinite, liptodetrinite (dark) and inertodetrinite (bright).

Phot. 7. Megasporinite (M) in durite band of a coal clast. A system of pores (P) is developed in sporinite-rich band (S).

Phot. 8. Isolated coal clasts in clayey matrix (CM) of a sandstone.

Phot. 9. Fusinite (F, bright, left part) forms marginal part of a coal clast, trimacerite (right part) with colotelinite (T, dark).



Vilém DANĚK, Jiří PEŠEK, Pavla VALTEROVÁ — Coal clasts in the Bolsovian (Westphalian C) sequence of the Kladno–Rakovnik continental basin (Czech Republic): implications for the timing of maturation

PLATE III

Phot. 10. Broad network of pores (P) in trimacerite. Vertical dimension is equal to 0.5 mm.

Phot. 11. Porous megasporinite (MS) with partly weathered margins in trimacerite (TM).

Phot. 12. Carbonaceous shale (CC) (dark) clast contains fusinite (F), micrinite and collotelinite (T) (dark) in clayey matrix (CM) (bright) of a feldspathic sandstone.

Phot. 13. Broad network of pores (P) in trimacerite of the lower Lubná coal seam. Vertical dimension is equal to 0.5 mm.

Phot. 14. Trimacerite grain with fusinite (F) from the lower Lubná coal seam showing similar structure as trimacerite microlithotypes of coal clasts.

Phot. 15. Detail of a clast picked up from clay matrix of a sandstone. Colotelinite (T) is penetrated by microcracks.