Sbor. geol. věd	Geologie 45	Pages 123—150	7 figs.	1 tab.	12 pls.	Praha 1990 ISSN 0581-9172

Clastic dikes in the brown coal seam near Most in the North Bohemian Basin (Miocene)

Klastické žíly v hnědouhelné sloji u Mostu v severočeské pánvi (miocén)

Stanislav Hurník[1]

Received April 29, 1988

1 : 50 000
02-32
02-34

Clastic dikes
Synsedimentary deformations
Brown coal seams
North Bohemian Basin
Tertiary

Hurník, S. (1990): Clastic dikes in the brown coal seam near Most in the North Bohemian Basin (Miocene). — Sbor. geol. Věd, Geol., 45, *123—150*. Praha.

Abstract: Clastic dikes mainly with clay filling have been recently uncovered in the brown coal seam in the opencast mine Most in the North Bohemian Basin. They are bound to an intensive deformatin of the main coal seam. During this deformation, part of the coal seam was uplifted and overlying clays were squeezed below it. From this body of clayey sediments clay was pushed up in the form of veins and dikes into the deformed part of the coal seam. This type of filling (from below) strongly prevails whereas the filling from above is very rare. Clastic dikes were formed during the last stage of synsedimentary deformation of the coal seam, in some cases immediately after covering of the whole deformational structure with a thick layer of the overlying sediment. Thus only exogenous factors were responsible for the origin of the investigated clastic dikes. Their genesis is being compared to the creation of well known mudlumps in the Mississippi River delta. According to their form, six types of dikes were distinguished. Secondary processes influenced the form of dikes and from the intensity of the deformation the intensity of diagenetic processes can be deduced. Today's thickness of the coal seam is about two thirds of that in the time of dike formation.

[1] *Výzkumný ústav pro hnědé uhlí, k. ú. o., 434 37 Most*

Introduction

Clastic dikes belong to the sedimentary structures which are not so often found during the geological investigations. Czech geological literature mentions this phenomenon only rarely. Clastic dikes occur, however, in many sedimentary formations and also in some igneous rocks.

They indicate specific processes which influence the primary sedimentary sequence.

In the North Bohemian Brown Coal Basin clastic dikes have been uncovered for the last ten years but their description and documentation are not available. Well known occurrences were mainly from the opencast mine Ležáky near Most, where the brown coal seam is cut by clay dikes. Some sand dikes were also found in the abandoned opencast mine M. Gorkij at Braňany (nowadays part of the giant mine M. Gorkij at Bílina). These dikes cut through layers of sandy clays. From the same place also veinlets of volcanic breccia are known which penetrate the Miocene coal-bearing sedimentary complex (Hruška 1929, Elznic - Hurník 1980).

In the last years clastic dikes and different clayey intrusions into the coal seam are being uncovered in the opencast mine Most. They are bound to the zone of the synsedimentary deformation of the main coal seam. Vast masses of overlying clays and partly also sands were squeezed below the uplifted part of the seam. Clastic dikes and clayey injections are of different strike and different form. Also sandy filling of clastic dikes was observed in some places.

General information on clastic dikes

In Czechoslovak literature clastic dikes are described mainly by Marschalko (1965, 1972) and Pešek (1978). Minor information is offered by some other authors. That is why we find it necessary to discuss clastic dikes first in general.

Clastic dikes were described already in the last century. First notes appeared in literature as early as in 1821 by Strangways (about clastic clay dikes near today's Leningrad — the USSR). Darwin (1851) in his notes about the voyage on the vessel Beagle (1831—1836) described the occurrence of clastic dikes in the Galápagos and Patagonia. One of the principal papers on the clastic dikes is that by Diller (1890). It concerns clastic dikes in California. Apart from the clastic dikes in the sediments, also some occurrences in magmatic and metamorphic rocks were described. It was recognized that clastic dikes occur very often in carbonaceous and namely coal-bearing deposits. There is some contradiction, however, between the number of occurrences and the types described in literature. In fact, most papers deal with clastic dikes from sediments which are not coal-bearing.

The fill of clastic dikes is variable. Sand dikes strongly predominate. That is why sand dikes and clastic dikes are sometimes taken for synonyma. For instance, in the Atlas of sedimentary structures (Pettijohn - Potter 1964) only sand dikes are mentioned as sand bodies which form the filling of fissures. In the second edition of their book Potter and Pettijohn (1977) keep this approach.

As seen from literature, the genesis of clastic dikes in the coal-bearing deposits is often explained in a different way than the genesis of the others. The origin of clastic dikes in coal-bearing sequences is explained mostly by the action of exogenous processes. Sometimes some importance is also given to the effect of the initial seismic shock. On the other hand, in non coal-bearing sediments the earthquake shocks are taken for the primary and most important mechanism of the genesis.

Slumping, sliding, erosion and sometimes seismicity are regarded as the most important factors influencing the origin of clastic dikes in coal-bearing deposits. Some protrusions into the underlying or overlying layers are often explained only as erosion-induced. Some authors, however, do not include these purely erosional features into clastic dikes. Some examples from literature can be mentioned: Clastic dikes cutting through a coal seam were first described from the coal basin in Saxony (Weissenbach 1850) and later from the American continent, from western Pennsylvania (Stevenson 1875 after Newsom 1903). Hausse (1892) described in detail clastic dikes in the Döhlen Basin near Dresden (Saxony) which were later investigated by Reichel (1970). The dike fill is called „Kämmen“ in German and consists of clay shale, arcosic or conglomeratic shale. Based on their structure, Reichel (1970) distinguished massive, bedded and breccia dike fillings. As to him, the origin of dikes was related to primary slides and seismic shocks during a certain tectonic stage of the basin development. Damberger (1973) also associates seismic shock effects with the clastic dike origin in the eastern parts of the Central Basin (Illinois, USA). On the other hand, Wanless (1952) favours the origin resulting from the erosion of a coal seam. The same factor Richardson (1877 after Newsom 1903) considered principal in the case of sand dikes from the coal fields Nanimo and Comax in Canada. Pešek (1978) explained in the same way the genesis of clastic dikes in the Carboniferous sediments of the Plzeň (Pilsen) Basin of Czechoslovakia. As to him, erosion caused disruption of pressure equilibria in the coal seam. Moreover, the coal seam deformation followed after the sliding of the material into the erosional depressions. Fissures, which had developed, were filled with clastics during the following transgression. Dzens-Litovskaja (1954) described vertical joints several tens of centimetres thick from a many-metres thick coal seam of the Karaganda Basin (USSR). As to her, the dike filling in the lower parts of the coal seam represents erosional wash-outs, whereas in the upper parts of the seam the filling represents a narrow stream flowing across the swamp.

Diagenetic processes are considered principal in the formation of clastic dikes by Newsom (1903), Lambrecht-Thorez (1966), Pruvost (1943). Nelson and Ledvina (1984) prefer the explanation by means of a process of mud diapirism.

Many occurrences of clastic dikes in coal-bearing sedimnts perhaps from all the states of the USA are described by Shrock (1948). Also in the USSR numerous occurrences are known (e. g. along the Volga River — Pawlow 1896, in the environs of the Aral Sea — Gareckij 1956, in the Fergana Basin — Verzilin 1963, in the Caucasus Mts. — Ružencev 1932). Clastic dikes are known from many occurrences in Japan (Hayashi 1966). African outcrops were described by Oomkens (in Libya — 1966) and Brunn-Talbot (in Natal — 1986). Laubscher (1961) described clastic dikes from Venezuela.

Apart from exogenous factors, also endogenous factors are often mentioned. Seismic shocks are probably the main factor discussed. In the paper by Laubscher (1961) all the genetic possibilities are enumerated. This author gives six possible sources of energy when describing the sand dikes in bituminous shales from the San Antonio Formation in Venezuela: chemical, seismic, tectonic, volcanic, gravity, and cosmic energy. The concept of chemical energy is interesting, because it is connected with the accumulation of organic matter. During the bacterial decomposition gases use to escape and partial pressure in the rock is increased. Laubscher (1961) compared this process to mud volcanoes in Trinidad, where during 20 minutes 0.5 million cubic metres of mud ejected and destroyed forests on the area as large as 100 acres. Moreover, mud volcanoes of Trinidad are dwarfs in comparison to some giant Asian mud volcanoes. Laubscher (1961) also added that diapirism often triggers the activity of mud volcanoes. He mentioned also the eruption of gases in the swamps of Venezuela, where the gas escaped from buried subrecent mangrove swamps. According to him, earthquake often deforms porous sediments which are prone to liquefaction. He referred to some cases when during an earthquake a great amount of water, sand and coal was ejected, or when alluvial sediments were liquefied. After this, intensive land subsidence followed. As to the cosmic energy, its source Laubscher (1961) regarded in meteorite impacts which might deform liquefied sediments and which also might propagate the pressure wave in the pore waters. He referred to some observations of the eruption of mud volcanoes during the explosion of bombs.

From the described it follows that clastic dikes may be formed due to various processes, both endogenous and exogenous. Great importance should be ascribed to pressure fluidization of the material which fills the fissures. It means that the clear erosional wash-outs, filled with the synsedimentary and postsedimentary material, should not be taken for clastic dikes but only for the erosional features. Cryogenic features, too, should not be included into clastic dikes (for instance some till wedges, described by Mörner 1972). From this viewpoint also some other structures could not be included into clastic dikes, as frost wedges, frost joints and polygons in hard rocks (e. g. Birman 1952). On the other hand, dikes and wedges formed through the loading of an advancing glacier (Kruger 1938, Dione - Shilts 1974, Brunn - Talbot 1986) fully correspond to the concept of clastic dikes.

Jaroš - Vachtl (1978) defined clastic dikes as protrusions of liquefied sand or clay into the fissures of the overlying rocks. In the Encyclopedic Geological Dictionary (Vachtl 1983), clastic dikes are defined as the filling of fissures with clastic sedimentary material, washed into them from the surface or pushed into them by pore pressure.

There are wide ranges in the thickness of clastic dikes (from millimetres up to 10 metres) as well as of their length (up to more than 14 kilometres) and depth below the land surface (up to several hundreds of metres).

Clastic dikes in the coal pit Most

Clastic dikes can be observed in the accessible parts of this opencast mine since 1983. Before, they had been registered also in the neighbouring pit Ležáky in the pit face adjoining the opencast mine Most. In the two cases the clastic dikes occur only within the sector where the coal seam is subjected to intensive synsedimentary deformatioin. In this zone the coal seam is uplifted to the form of a brachyanticline and is also separated into several blocks and slices. Overlying claystones have been squeezed and pushed into this part of the coal seam. The uplift of the coal seam, or better to say, of primordial material in the peat stage, was accompanied by lateral movements which tore up the peat material, bended, folded and thrust the individual parts of this body.

The coal seam which was deformed in this way, was penetrated by claystones in the form of simple clastic dikes and also in the form of large intrusions. Clayey fillings have infiltrations, intrusions, and in many cases they represent in fact the matrix of coal breccia. The term "intrusion" is used here according to Laubscher (1961, p. 289), i. e. penetration of a mobile mass into immobile and more cohesive material.

Description of the deformation structure of the coal-bearing Miocene sediments is out of the scope of this paper. It should be only mentioned, that the deformation took place after covering of the original mass of the coal mass was not yet finished during these deformation processes. Clay ed to the original thickness of uncompacted clays). This can be proved by the discordance (unconformity) between the deformed claystones and the overlying younger sediments (see pl. VI-2). This deformation possibly represents a structure comparable to mud diapirism (Hurník 1982), and to mudlumps of the Mississippi River delta. The process of coalification as well as the diagenetic reduction of the thickness of the coal mass was not yet finished during these deformational processes. Clay intrusions into the disrupted coaly mass of the present coal seam accompanied the development of the synsedimentary deformational structure. Clay material penetrated into the coal seam from the bottom, from the top, and also laterally from the side. That is why such a morphological diversity of dikes can be observed. From the genetical viewpoint, the clayey breccia matrix in the coal seam belongs to clastic dikes, even though there is only a slight morphological resemblance between them. It is well known, however, that breccia structure was often encountered in the dike fills.

Description of clastic dikes

Till the year 1985 only clay fillings of clastic dikes had been known. Later, however, as the opencast mine approached to the initial place of the coal seam deformation, some sand dikes appeared. Petrographical composition of claystones in the dike filling equals to that of the overlying claystones. They consist of kaolinite and illite with quartz admixture (M. Sloupská — X-ray laboratory of the Brown Coal Institute at Most). Siderite admixture is also present and in some cases it increases considerably. Samples of claystones from the dike filling, from the overlying layers and the subthrust claystsone body were compared. The results of X-ray investigation and determination of physical properties are tabulated (see tab. 1). According to the bulk and mineral densities of claystones the primary predenudational thickness of the Miocene sediments covering the main coal seam can be estimated at 270—300 m.

Sand or sandstone fillings of dikes are according to their grain-size similar to the sandstones of the overlying complex. Fine-grained sands predominate. In the overlying complex also medium-grained sandstone can be found whereas coarse-grained sand occurs only locally. Sandstone cement consists mostly of silica in the overlying complex, but of carbonate (siderite) in the dike filling. Sand dikes do not differ morphologically from clay dikes.

Table 1

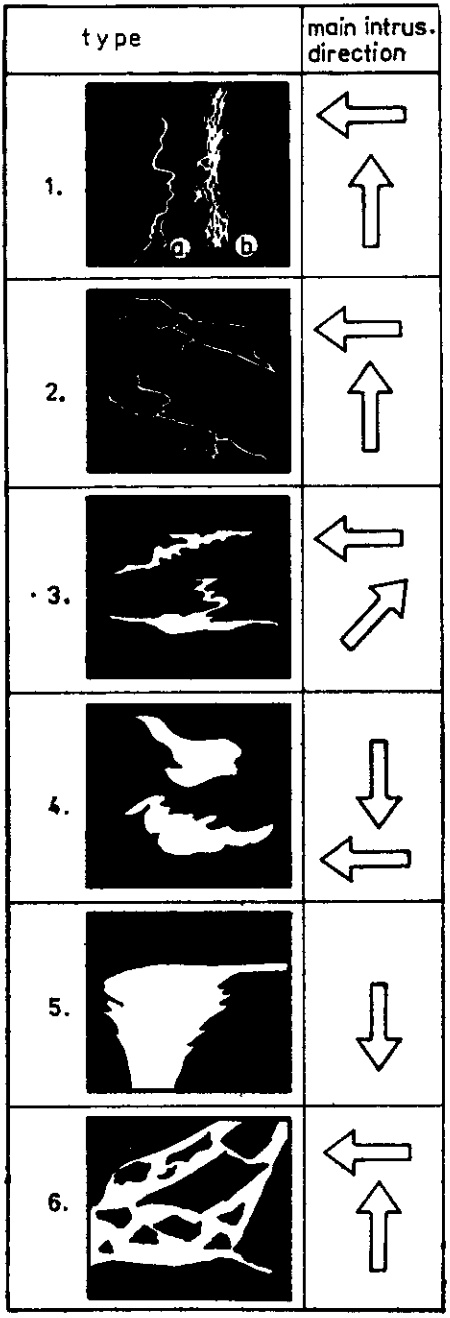
Petrographic and physical properties of claystones

Macroscopic description	Location	Kaolinite illite %	Quartz %	Siderite %	Bulk density $.10^3$ kg.m^{-3}	Mineral density $.10^3$ kg.m^{-3}
silty and sandy claystone, grey — brown	above the seam	63	27	5	2.03	2.69
sandy claystone with fragments of coal, grey — brown	breccia (vein)	62	26	6	1.74	2.23
silty and sandy claystone, grey — brown	clastic vein	53	27	14	1.98	2.51
sideritic claystone, light grey	body of downthrust claystones	57	12	27	2.26	2.85

The internal structure of dikes is mostly massive, sometimes fluidal. As to their morphology, the following six types of dikes were recognized (see also fig. 1):

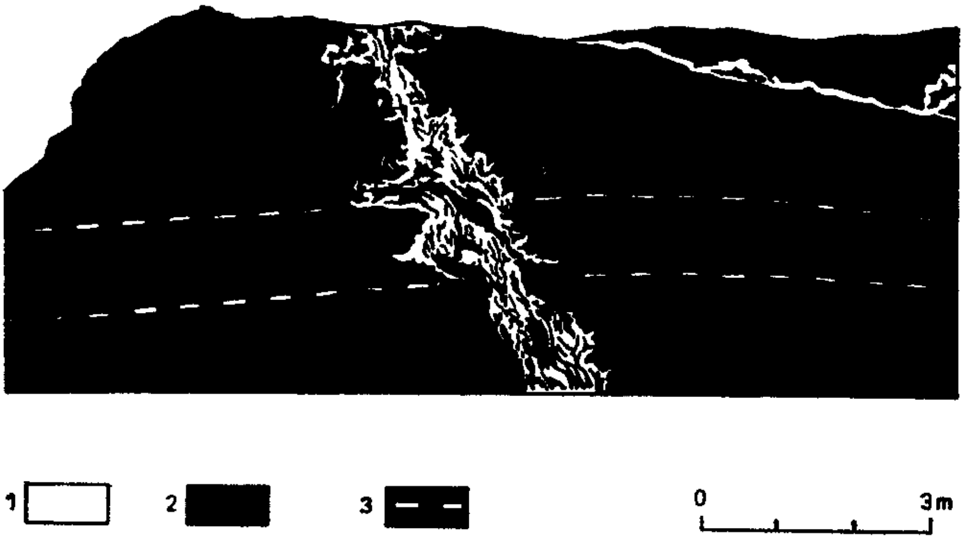
1. The first type included intrusions and injections which are generally vertical and cut the coal seam across. They have a character of veins. They are sometimes also oblique with angles up to 30° related to the vertical plane. They are vertical even in the case when they cut a folded coal seam (pl. I-1, 2, pl. II-1). Their length is generally several metres. Sometimes they are not connected to the overlying and underlying sediments on the pit face and wedge out inside the coal seam. This lens-like appearance is, however, only apparent. Sometimes they are connected to claystones which fill the fissures between the individual segments of the coal seam. S-like bending and irregular detailed folding are typical of them. The detailed folding occurs mainly in the coal seam with ash-rich layers. The dikes of this type occur throughout the deformed seam, but they are most frequent near the seam base, close to the downthrust mass of the originally overlying clays.

Two subtypes of dikes of the first type can be distinguished taking into account their thickness. The thickness of the first subtype is of a centimetre order and the dikes have a character of simple hair-like in-



1. **Morphological forms of clastic dikes in the opencast mine Most**
Typical features: *1* — always cutting the stratification of the coal seam, sinusoidal bending; vertical length in metres; thickness a) in millimetres, centimetres b) tens of centimetres; *2* — parallel or subparallel to the coal stratification, often with oblique up to vertical offshoots (always with sinusoidal bending); vertical length in metres, thickness in millimetres, centimetres; *3* — zig-zag form of dikes with changing thickness, often subhorizontal with many offshoots; length in metres, thickness in centimetres, tens of centimetres; *4* — irregularly deformed bodies with rounded outlines with S-like bending; length tens of centimetres, metres, thickness tens of centimetres; *5* — funnel-like filling, size in metres; *6* — breccia, vertical length in metres, thickness metres up to tens of metres

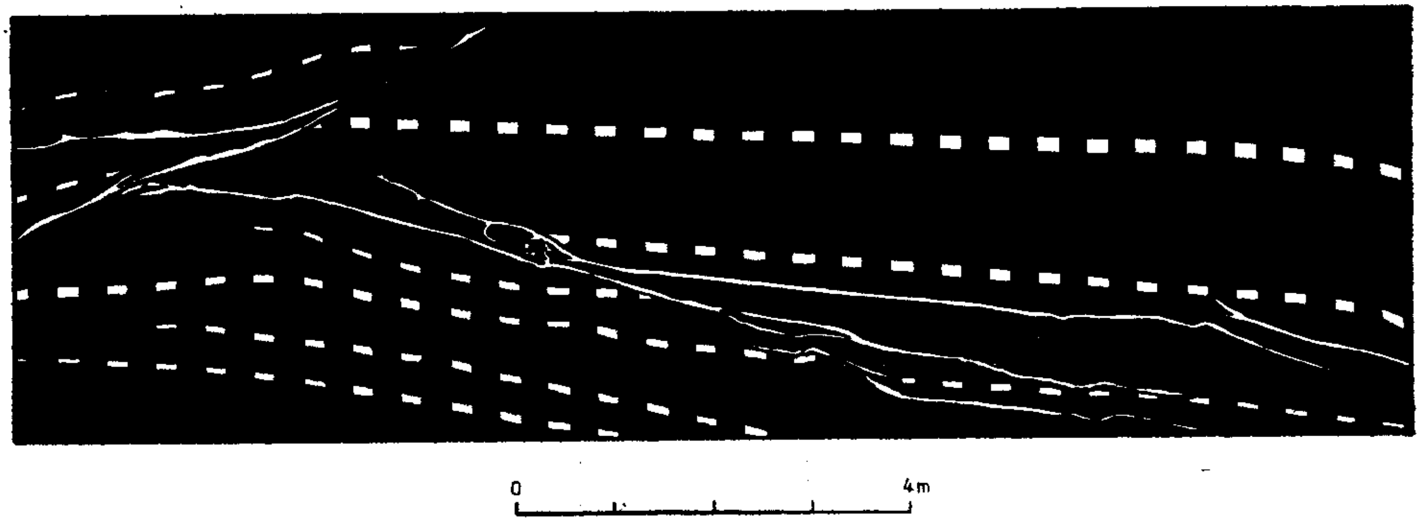
trusions. Millimetre thick bodies are also present. The second subtype has a thickness of several tens of centimetres. The dikes of this subtype are not sharply bordered and their margins have a character of a swarm of hair-like intrusions (fig. 2). Only two occurrences of this type were registered. Similar dikes were described already by G r e s l e y (1898) from Pennsylvania.



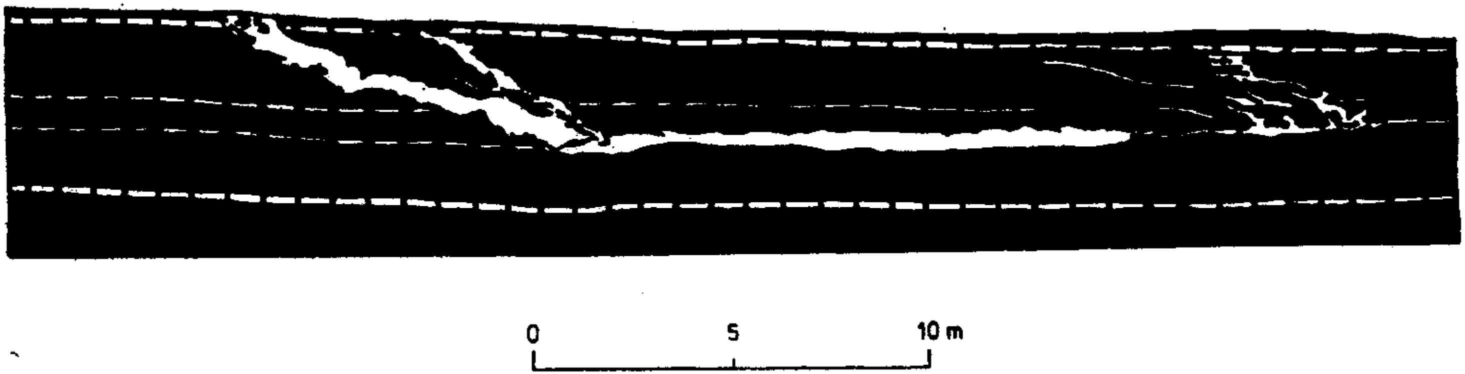
2. Clastic dike of the second subtype of the first type; the third section through the coal seam
1 **— claystones;** *2* **— coal;** *3* **— clayey interlayers and ash-rich coal**

2. The second type has a character of genuine dikes parallel to the coal mass stratification. In some cases the dikes of this type follow the bedding joints (fig. 3, pl. III). Their thickness is similar to that of the first type (pl. III-2). They are often irregular but not with S-like bending as in the case of the first type. This bending can be observed only in some vertical off-springs which connected two parallel dikes on different levels. The dikes which are connected to the claystones below the seam, are markedly thicker (pl. IV-1). Some claystones which accumulated along slip faces between the seam segments, can be included into this type (pl. III).

3. The third type is represented by irregularly folded and cut-off accumulations of claystone striking across the coal seam as well as almost parallelly to it (pl. IX). Their thickness is variable, usually within the ranges of centimetres and several tens of centimetres. Some internal structure accentuated by finely dispersed organic matter can be observed.



3. Clastic dike of the second type. In the left part the dikes follow the planes along which segments of the coal seam have been thrust over; the second section through the coal seam

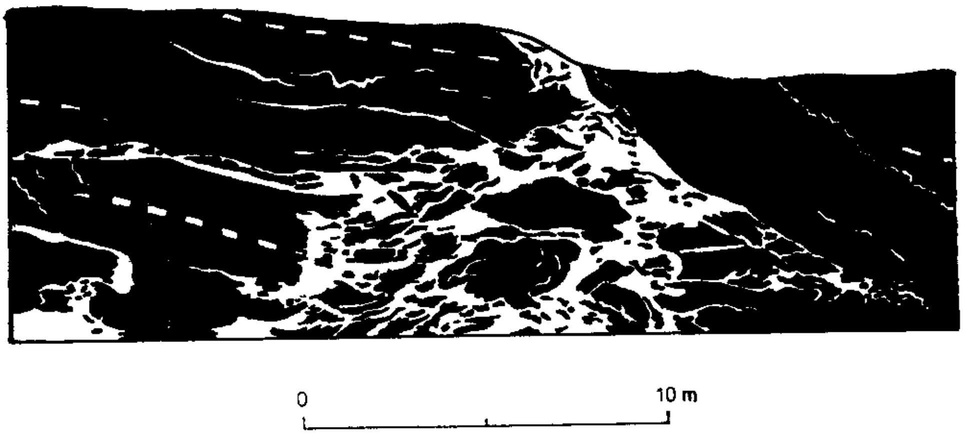


4. Sand dike in the main coal seam about 200 m to the SW of the deformational zone, the first section through the coal seam

These dikes could be compared to pinch-and-swell clastic dikes described from Japan (H a y a s h i 1966). Morphologically they represent transition between the second and the fourth types.

4. The fourth type is close to the preceding one, but its thickness is greater and its form more rounded (pl. IV-2, pl. X). The dikes form deformed lens-like bodies. Sometimes they are gently isoclinally folded. In places they are almost undistinguishable from deformed clay bands (pl. V-1).

The two remaining types are genetically related to the preceding types but their form and size make them very specific.

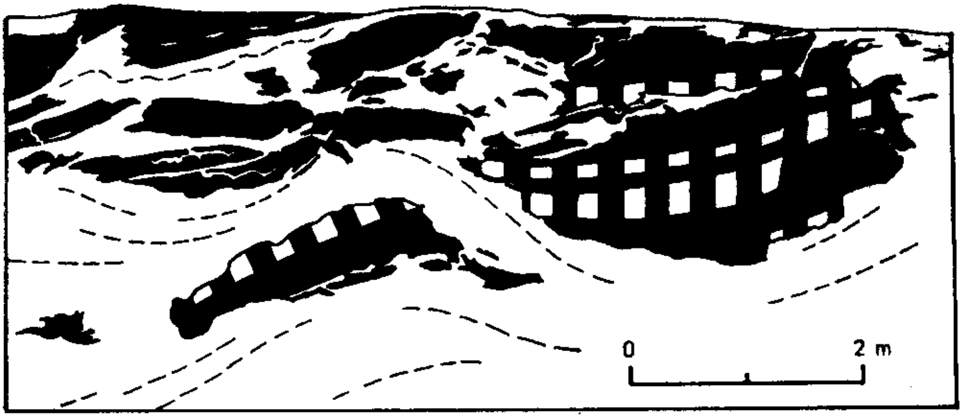


5. Breccia-like fill of the clay intrusion from the underlying parts of the fragmented seam. In the coal blocks the dikes of the second type occur, the second section through the coal seam

5. The fifth type is represented by a unique structure uncovered recently. A claystone fill, several metres thick, is situated between undeformed (even though uplifted) part of the coal seam and neighbouring, strongly tectonically affected part of it. Claystones were pressed into this place from above (pl. V-1). The material of this dike fill is intensively mixed up. The dike walls are not even, but irregularly jagged with the coal seam.

6. The sixth type is represented by coal breccia cemented by clays and claystones. It occurs near the base or in the basal parts of the uplifted coal seam. Clay material intruded into the deformed seam from below (fig. 5). In "breccia lenses" lateral penetration into the deformed part of the coal seam can be observed (pl. VII-1). Great blocks and fragments do not bear any traces of rounding during the transport. They

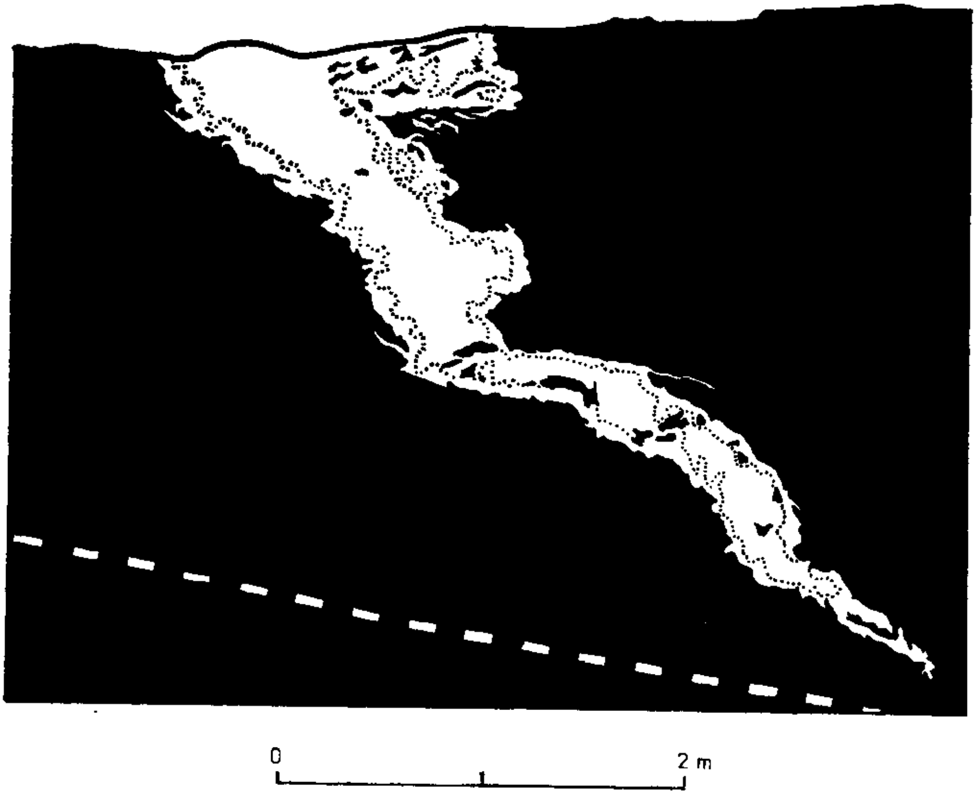
are mostly angular, sometimes with flaggy margins which follow the coal seam stratification. The size of fragments is variable, even some several metres large blocks were found (pl. VII-2, pl. XII, fig. 6). In some cases the dike fill exhibits slight bending and even rolling up.



6. Topmost part of the underthrust body of overlying claystones with coal breccia. Coal block on the right side is dislocated. *Dashed line* indicates an apparent stratification of claystones. The second section through the coal seam

This classification does not exclude the presence of transitional forms, or, on the other hand, of some unique and specific types. A specific form of a wedge-shaped clastic dike, uncovered in the NE part of the pit can serve as an example (fig. 7). This dike resembles somewhat the structure described by H a v l e n a (1964, p, 235, fig. 118) in the Carboniferous sediments of the Plzeň (Pilsen) Basin. It is, however, about five times larger and differs also in its fill. The Carboniferous structure in the so called Radnice Coal Seam contains sandstone with quartzite pebbles as large as 5 cm, whereas the Miocene filling is only clayey. This clayey filling has a pale rim about 10 cm thick. The inner structure is fluidal, sometimes very distinctly.

Breccia fillings are often accompanied by hair-like dikes in the surrounding mass of the coal seam. Associations of the two types of breccia are numerous (pl. VIII-1). The character of outcrops does not allow to reconstruct exactly the orientation of the structures. Even though the coal-bearing complex forms a flat brachyanticline here, it is not possible to prove the radial and concentric orientation of the structures which was described in a similar structure of the Döhlen Basin by H a u s s e (1892). The haphazard orientation is more probable in the studied area.



7. Wedge-like fill of the fissure. *Dotted line* indicates limits of the marginal leached zone, the third section through the coal seam

There is no preferred orientation of the dikes, as proved by numerous readings. Breccia types and fillings of slip joints are often oriented in the N up to NW direction. This means that this orientation is more or less oblique to the axis of the claystone body below the deformed coal seam.

Recently a sand dike near the base of the middle part of the main coal seam has been uncovered, about 200 m to the SW of the deformed zone (fig. 4). This dike belongs to the second type. Its thickness is about 50 cm and its dip is zero, because it is layered parallelly to the stratification of the coal seam. Near its SW termination, however, a marked bed can be observed and the dike cuts the coal seam by a thick offshooting tongue at an angle of 40°. On the opposite end a system of thin, hair-like, irregularly folded dikes can be observed, protruding into the coal seam at the angle of 20° with the same dip direction.

Clastic dikes and mud diapirism

As stated before, clastic dikes can originate under various circumstances. Many factors have been enumerated, namely tectonic dilatation, diagenesis, slides and slumps, very often also seismicity. Two factors are important for mobilization of the clastic material: adequate tension and physical consistency of competent rock on one side, and the initial impulse triggering a disequilibrium on the other side. Dott (1963) suggests, that the intrusion of a dike fill requests overpassing of a liquid limit of the metastable sediment (spontaneous liquefaction). In this case fluidized flow originates (as in the case of turbidity currents). The external impulse may be represented either by overloading, or an earthquake, or hydraulic pressure. Even a plastic flow cannot be excluded judging from the observation of clastic dikes with a stratified filling where the strata are roughly parallel to the dike walls. This means that the clastic material exceeded only the plasticity limit before the intrusion.

The two described types of movement of intruding clayey mass took place in the studied area, because apart from prevailing massive fillings also fills with a fluidal structure were observed. Plastic flow occurred mainly in the underthrust body of the originally overlying claystone (pl. VI-1).

Dott (1963) described mudlumps in the Mississippi River delta as an example of a plastic flow triggered by overloading. Even though mud lump models as a cause of clastic dike genesis were not accentuated in literature up to now, some remarks by various authors have a certain relation to them. Laubscher (1961) suggested chemical source of energy for the mobilization of clastic dike fillings, as well as seismic source. In all the discussed cases the mud explosion, extrusion of fluidized sands or liquefied clastic sediments which were overloaded naturally or anthropogenically, are taken into consideration. Laubscher (1961) added that mud volcanoes have relation to diapirism (see also Hedberg 1974). Structures of mud lumps represent a classical example of mud diapirism. This structure is a deformational one and originates due to the reverse density gradient in sedimentary sequences. It means that local overloading plays an important role. Not only large structures such as convolute bedding and ball-and-pillow structure and also clastic dikes (Smith - Rast 1958). At the locality Most they represent large diapiric deformations.

As the investigated structures are related to the mudlump genesis, it is necessary to describe mudlumps in detail. In Czech geological literature they are mentioned first by Vitásek (1958) who writes about them as about mud volcanoes. Kukal (1962) used the proper term mud lumps and recently Havlena et al. (1979) have introduced a Czech term for this structure. From the Mississippi River delta they have been known already for several centuries and were described thoroughly by Russel (1936). They appear above the sea level as elongated islets in the delta front or along the main delta branches. They are as long as several hundreds of metres and reach only several metres above sea level. They consist only of clayey sediments and are derived from the deeper parts of the delta. Sometimes marine clays with marine fauna from the underlying deltaic body were found. Mudlumps use to appear and grow above the sea level for several days up to several months. Some of them later stabilize, some of them are quickly destroyed. In the past their origin was being related to the expulsion of mud gases. Today it is explained by local accumulation of sands, especially during the floods. These sands load locally underlying clays and protrude downwards into them. This sudden loading is compensated by diapiric upward protrusion of clays. Protrusions can result into small overthrust, as in the South Pass, where the clays were thrust over by 140 m (Morgan et al. 1968). In the clayey extrusions intensive brecciation often takes place accompanied by bending and breaking of sedimentary structures. Broad synclinal depressions were filled with sand which was found between the individual diapiric structures. The rate of downward protrusion of sands can be as much as 1.4 m per year. Within one group of mudlumps three diapiric extrusions originated during the last years.

It is necessary to add that diapiric structures are known also from some other places, such as from the delta of the Magdalena River in Columbia (Shepard et al. 1968). "Gravitational tectonics" described in the Miocene deltaic sequences on the coast of the Gulf of Mexico in Lousiana (Courtis 1970) or in the Carboniferous sediments of the Birmingham anticlinorium in Alabama (Thomas 1968) belongs to the same group of structures. Another examples are given by Potter et al. (1980).

The origin of clastic dikes in the coal pit Most

The investigated clastic dikes in the opencast mine Most in northern Bohemia are bound to the vast deformational structure of the basal part of the Miocene coal-bearing complex. These dikes can serve as an example of the relation between the origin of dikes and synsedimentary deformations.

It is important to note that clayey dike fillings strongly predominate. Petrographical investigation proved that the clayey fill has the same composition as the clays which lie over the coal seam. Our fifth type is even in a direct continuation of the overlying clays (pl. V-1). In the original primary sequence the underlying parts of the coal seam consisted of tuffitic claystones. During the deformational processes the overlying clays were pressed into the immediate base of the coal seam. Tuffitic clays are sporadic in the deformational structure, occurring only near its margins.

The primary material of dike filling is thus represented by the overlying clays but the filling took place both from below and from above. The filling often took place from below, from the downthrust claystone body. Apart from the vertical movement of the clay mass also lateral movement should be considered. This concerns some dikes which have no apparent connection to the clay mass. In many cases, however, this connection in fact exists and is hidden behind the pit face (pl. IV-1). A small general lateral movement is very probable because all the deformational structures moved a little laterally.

The liquid limit in the downthrust claystone body was locally overstepped during the development of deformational structures, mainly in its marginal parts. Clayey material thus intruded as viscous fluidized flow into the coal seam which was in the state of fragmentation. The origin of clastic dikes was thus coincidental with the origin of the deformational structure, but some injections followed after the deformational movement. This is proved by the transversal section in the southern flank of the pit (pl. IV-1).

Injections into the coal seam which was thrust over the underformed coal seam occurred during the last stages of the deformational process. This is proved by clastic dikes which penetrate the folded parts of the seam (pl. I). Clastic dikes, parallel to the seam and offshooting from the front of the downthrust claystone body into the seam originated also only after the main phases of the deformation.

Claystone intrusions did not evidently cause the fragmentation of the coal seam. This is proved by the fact that the contact between the dikes and the coal mass exhibits neither deformation of the inner structure of the seam, nor crushing. The clayey mass penetrated the seam along with the movement which affected the coal seam, even though with some retardation. The clayey mass decreased the friction along the shear faces and thus facilitated the movements like overthrusting of the individual seam slices.

From the described facts it follows that the intruding clayey mass was in a quasiliquid state. The overlying claystone body, squeezed beneath the deformed seam, moved as a slurry, because it exhibits rolling and plastic deformation (pl. IX-2) together with the fragments of coal, which are usually deformed in the same way as claystones. It is probable that in the time of the origin of the deformational structures the claystones were in the stage of an early diagenesis.

The necromass of the coal seam was only slightly diagenetically changed, too. The degree of coalification was also low, because the seam was still capable of plastic deformation, like folding. During the dike formation, however, it behaved sometimes as a plastic material, sometimes as a cohesive material.

Nowadays the studied outcrops in the pit are advancing towards the initial place of deformation, i. e. towards the places where sands protruded into the underlying sediments. The appearance of sand intrusions in coal seam could be expected. They were encountered in the year 1986. As to their form, they do not differ considerably from clay dikes. The main difference can be seen in the fact that sand dikes penetrate also the undeformed zone. Morphological resemblance of sand and clay dikes shows that their ways of origin were similar and the main difference was only in the source material. In some cases the dikes were filled both with sand and clay. All the process of dike origin took place bellow water level, because no primary oxihumolite, i. e. oxidized coal was found.

The importance of the occurrence of clastic dikes

The clay dikes described above do not represent only an interesting specific phenomenon but they enable us to solve principle questions concerning the process of deformation, mainly the diagenetic stage of Neogene sediments during the deformation and also the correlation between the processes. In this respect the dikes of the first and the sixth type are of main importance. Sinusoidal bending which is distinct in the first type of dikes is very important. It is mostly being explained by a differential compaction which means that this structure represents secondary deformation of clastic dikes. According to Hayashi (1966) they represent a special type in his classification. He classified them as penecontemporaneously deformed clastic dikes and designated them ptygmatic clastic dikes. The author mentioned and also Saito et al. (1954), which described such dikes from the coal seam in the Honbets deposit (Hokkaidó), explained their origin by different intensity of compaction of coal material and dike material. Ramberg (1956) stressed the importance of vertical pressures for the origin of "folded" veins on the basis of the investigation of ptygmatic veins in Greenland. His observations were also completed with experiments.

Reichel (1970) described similar folding of clastic dikes in the

Döhlen Basin near Dresden (Saxony). As to him, the folding resulted from the initial slides or minor lateral movements. He drew attention to the fact, that in the layers of combustible shales or in the clay bands in the seam the joints became narrower, whereas above them they exhibited swelling. Similar features were observed also in the opencast mine Most. In the places, where the folded dike penetrated clay bands in the seam, or coal of bad quality, the folding was less intensive or absent at all. This speaks in favour of diagenetically induced deformation, or of folding due to terminating compaction after a dike intrusion. That is why we suggest diagenetic compaction was a main cause of dike folding. This can be proved also by the dikes of the second type. Horizontal and subhorizontal subtypes are not folded at all, whereas their oblique offsprings are bent. The angle from the vertical plane depends evidently on the thickness of the coal mass.

In order to determine the compaction of the coal mass after the deformation and dike intrusion, true length of the vein was measured. Also the ratio between the dike length and the thickness of the coal seam interval was calculated. The calculated ratio ranges from 1.4 to 1.7. This means that in the time of the dike formation the necromass of the coal seam was almost compacted. If the value of the coefficient of compaction coal was 6 (Hurník 1972), its value in the moment of the dike origin was more than 4. These calculations support the concepts of Wagenbreth (1958) and Wagenbreth - Bellmann (1983) which favour the immediate thickness reduction of the coaly plant material already during its accumulation. This is valid namely in the case of a very thick seam (in the coal pit Most the thickness of the coal seam is as much as 40 m).

Even though the thickness reduction of the necromass before the deformation was considerable, the degree of coalification was probably very low. The seam was probably at a postpeat stage. This indicates the digital margin of coal in the direction of the coal stratification in the fifth and partly in the sixth type of dikes (figs. 5, 6). This feature is very distinct on the fragments of the coal seam near the surface of the deformational structure (pl. VI-2). The movement itself was very slow, because in the case of rapid movement a sharp, even shear-like boundary would form. This happens only in exceptional cases. Such shear-like faces can be seen in claystones. Their absence in dikes could be explained also by liquefaction of the intruding clayey material (viscose liquefied flow), but it is probable that rapid movement would rip and cut and move away some offsprings of coal seams.

The sixth type of dikes indicates, that the clayey material does not often represent only an intergranular fill between fragments and blocks of coal, but that there is a clear clay supporting structure and not fragment-supporting structure. It is thus probable, that the necromass of the coal seam behaved as lighter material which was in suspension. In some cases, as seen from the orientation and position of coal fragments, the whole mass suffered a unique movement (figs. 5, 6).

The necromass of the coal seam might be easily deformed during the deformation as seen from recumbent and overturned folds the beds of which are not fragmented. When they are penetrated by clastic dikes, the dikes, run across folded beds of coal (pl. II) not being parallel with shear joints which would originate in the case of folding of a coalified coal seam.

Present jointing of the coal seam is secondary, probably postsedimentary, because it is not conform with the trend of clastic dikes. It originated after the termination of the process of coalification. The described clastic dikes are younger than the deformation of the coal seam.

Some dikes which exhibit increasing thickness in the upward direction (fig. 7) originated probably in the last stages of the diagenesis, after burying of the whole deformational structure under a thicker sedimentary cover. The dike, cropping out in the NE part of the structure, is a good example of this type (pl. VIII-2). The dike runs first transversally-oblique to it, then it turns into vertical direction and immediatelly bends horizontally. In the topmost parts of the outcrop the dike passed into breccia with angular coal fragments. The clay matrix of his dike is infiltrated by finelly disseminated coal material and sometimes contains also larger coal fragments. Along its walls a leached pale rim can be observed. This speaks about the origin of a joint from ripping of the coal seam at the stage of advanced coalification. The ripping was related to the terminating diagenesis of the whole Miocene sedimentary complex, when the uplifted part of the seam in the deformational zone of the structure was adjusted to the loaf-like claystone body below it. A temporary break in sedimentation in the zone of deformation could evoke an anomaly in the density gradient of the Miocene sedimentary complex. During a certain depositional phase the clayey sediments immediately overlying the deformational structure could become more diagenetically compact (lower porosity, greater bulk density) than claystone downthrust below the deformed seam. A certain part could be played by gases escaping during the seam coalification. Increasing pore pressure could serve as a source of energy of intrusion at the later stage of diagenesis.

In the last stages of diagenesis, however, the clay material from the dikes reached the highest intensity of diagenetic changes. The claystones immediately overlying the coal seam exhibit the bulk density of $2.0 . 10^3$ $kg . m^{-3}$ whereas clays from the dike fills 2.13 or $2.17 . 10^3$ $kg . m^{-3}$.

Claystones from the base have bulk density of $2.06 \cdot 10^3$ kg . m^{-3}. This difference may be explained by the drainage effect of the coal seam.

R e i c h e l (1970) suggested that the dikes in the Döhlen Basin formed in two stages.

Clastic dikes and the process of coalification

Clastic dikes might be useful in solving the problem of the rate of coalification. In literature there is no agreement on the rate of this process. According to some authors the coalification should have been a very long process, according to others it passed over very quickly. The latter opinion was suggested mainly due to finds of coal pebbles in the roof of the Carboniferous coal seams. We regard the source of this disagreement in the lack of information about the necromass in the early stages of geochemical and physical changes. The necromass compaction and the chemical phase of the coalification process should not be mixed at all and compaction, as mostly a physical process of coalification, should be separated from the geochemical process. According to our investigations in the coal pit Most the two processes were not synchronous. If we take into consideration also W a g e n b r e t h ' s (1958) investigations, the mechanical compaction of the plant mass was very quick and was nearly terminated by the onset of the geochemical phase. By means of this we can explain, why during the synsedimentary deformation as well as during the erosion described in some other basins, in the course of a comparatively short time span, the coal seam (better the necromass) behaved once as a plastic, another time as a rigid material. Intensive coalification and substantial part of this process, i. e. the change of the necromass into coal, was only subsequent to this.

Conclusion

Clastic dikes in the coal seam in the environs of Most represent a specific phenomenon in the area of the Miocene Bílina delta. Their origin is related to the vast synsedimentary deformation of the coal-bearing beds. Their formation following up the main development phase of the deformational structure, was dying out still during the subsequent diagenetic processes which affected the whole Miocene sedimentary complex.

Practical importance of investigations of clastic dikes was proved by many outcrops in the opencast mine Most. The presence of dike swarms generally decreases the coal quality (pl. XI-1). Besides at the surveying stage, the dikes can be erroneously explained as coal seam splitting or wedging out. The calculation of reserves and the estimates of technological qualities of coal can thus be influenced by such a misinterpretation. That is why the existence of clastic dikes must always be taken into consideration. In the vicinity of clastic veins coal of higher quality usually occurs.

The erroneous evaluation of the occurrence of clastic dikes might also affect the planning of mining works, as it has happened already in the investigated opencast mine Most. The presence of swarms of clastic dikes always brings about difficulties as they do not exhibit any preferred orientation in space. Thus the adjustment of the coalface in this case is always problematic.

The help of RNDr. Zdeněk Kukal, PhD. in all the stages of the preparation of this paper and also in the translation of the manuscript is deeply acknowledged.

K tisku doporučil A. Elznic
Přeložil Z. Kukal

References

Birman, J. H. (1952): Pleistocene clastic dikes in weathered granite-gneiss, Rhode Island. — Amer. J. Sci., 250, *721—734*. New Hawen.

Brunn, V. - Talbot, C. J. (1986): Formation and deformation of subglacial intrusive clastic sheets in the Dwyka Formation of northern Natal, South Africa. — J. sed. Petrology, 56, 1, *35—44*. Tulsa.

Courtis, D. M. (1970): Miocene deltaic sedimentation, Louisiana gulf coast. — Deltaic Sedimentation, Soc. Econ. Paleont. Min., Spec. Publ. No. 15, *293—308*. Tulsa.

Damberger, H. H. (1973): Physical properties of the Illinois Herrin. Coal before burial, as inferred from earthquake-induced disturbance. — 7ème Congr. Int. Strat. Geol. Carbon., 2, *342—350*. Krefeld.

Darwin, Ch. (1851): Geological observations on coral reefs, volcanic islands, and on South America. Parts II, III. — London.

Diller, J. S. (1890): Sandstone dikes. — Bull. Geol. Soc. Amer., 1, *411—442*. New York.

Dionne, J. C. - Shilts, W. W. (1974): A Pleistocene clastic dike, Upper Chaudiere Valley, Quebec. — Canad. J. Earth Sci., 11, *1594—1605*. Ottawa.

Dott, Jr., R. H. (1963): Dynamics of subaqueous gravity depositional processes. — Bull. Amer. Assoc. Petrol. Geol., 47, 1, *104—128*. Tulsa.

Dzenslitovskaja, O. A. (1954): Genetičeskie osobennosti plasta Verchnjaja Mariana Karagandskogo uglenosnogo bassejna. — Trudy Lab. Geol. Uglja, 2, *321—331*. Moskva.

Elznic, A. - Hurník, S. (1980): Deformační jevy v produktivním miocénu severočeské hnědouhelné pánve a jejich vztah k tektonice. — Váźnejšie problémy geol. vývoja a stavby Československa, II, *229—246*. Bratislava.

Fisk, H. N. - Farlen, Mc, E. - Kolb, C. R. - Wilbert, L. J. (1954):

Sedimentary framework of the modern Mississippi Delta. — J. sed. Petrology, 24, 2, *76—99*. Tulsa.

Gareckij, P. G. (1956): Klastičeskie dajki. — Izv. Akad. Nauk SSSR, Ser. geol., 13, 3, *81—103*. Moskva.

Gresley, W. S. (1898): Clay veins vertically intersecting coal measures. — Bull. Geol. Soc. Amer., 9, *35—58*. New York.

Hausse, R. (1892): Erläuterungen zur geologischen Spezialkarte des Königreiches Sachsen. Profil durch das Steinkohlenbecken des Plauenschen Grundes (das Döhlener Becken) bei Dresden. — Leipzig.

Havlena, V. (1964): Geologie uhelných ložisek, 2. — Nakl. Čs. akad. věd. Praha.

Havlena, V. - Hurník, S. - Pešek, J. (1979): Návrh českého názvosloví pro říční deltové a proluviální sedimenty a jejich morfologické formy. — Sbor. Čs. geogr. Společ., 84, 1, *72—84*. Praha.

Hayashi, T. (1966): Clastic dikes in Japan. — Jap. J. Geol., Geogr., 37, *1—20*. Tókyó.

Hedberg, H. D. (1974): Relation of methane generation to undercompacted shales, shale diapirs, and mud volcanoes. — Assoc. Petrol. Geol. Bull., 58, *661—673*. Tulsa.

Hruška, O. (1929): Odvodňování břešťansko-braňanské kuřavky v theorii a praxi. — Horn. Věst. (zvláštní otisk), XI. Praha.

Hurník, S. (1972): Koeficient sednutí některých hornin v SHR. — Čas. Mineral. Geol., 4, *365—372*. Praha.

— (1982): Dosavadní představy o zjalovění a zvětšení mocnosti hnědouhelné sloje na Mostecku. — Uhlí, 30, 9, *374—379*. Praha.

Jaroš, J. - Vachtl, J. (1978): Strukturní geologie obecná a systematická, I. — St. pedag. nakl. (skripta). Praha.

Kruger, F. C. (1938): A clastic dike of glacial origin. — Amer. J. Sci., 5, 35, 208, *305—307*. New Haven.

Kukal, Z. (1962): Recentní deltové sedimenty. — Anthropozoikum, 10, *249—271*. Praha.

Lambrecht, L. - Thorez, J. (1966): Filons clastiques intraformationnels dans le Namurien de Belgique. — C. R. hebd. Séanc. Acad. Sci., Sér. D, 263, *1556—1559*. Paris.

Laubscher, H. P. (1961): Mobilisierung klastischer Massen. — Eclogae geol. Helv., 54, 2, *283—334*. Basel.

Marschalko, R. (1965): Clastic dykes and their relations to synsedimentary movements. — Geol. Práce, Zpr. 36, *139—148*. Bratislava.

— (1972): Termín: Klastické žíly. — Geol. Práce, Zpr., 58, *231—238*. Bratislava.

Morgan, J. P. - Colemann, J. M. - Gagliano, S. M. (1968): Mudlumps: Diapiric structures in Mississippi delta sediments. — Diapirism and diapirs, 8, *145—161*. Tulsa.

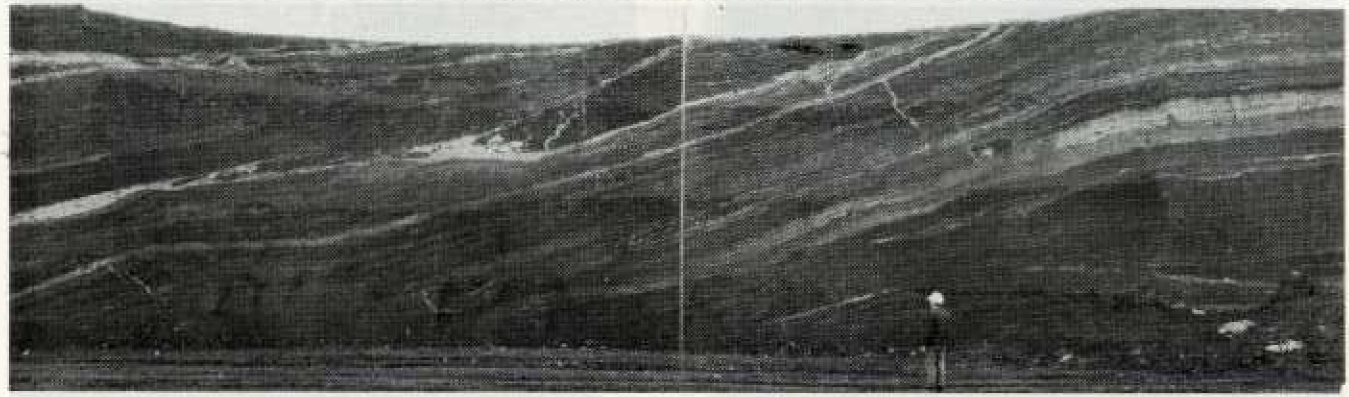
Mörner, N. A. (1972): The first report on till wedges in Europe and Late- Weichselian ice flows over southern Sweden. — Geol. Fören. Förh., 94, *581—587*. Stockholm.

Nelson, W.J. - Ledvina, Ch. (1984): A gravitational slide in the Energy Shale Member overlying the Herrin. No. 6: Coal member in southern Illinois. — Compte Rendu of the 9th Int. Congr. Carbon. Strat. Geol., 3, 2: Paleogeography and Paleotectonics, *303—315*. Carbondale.

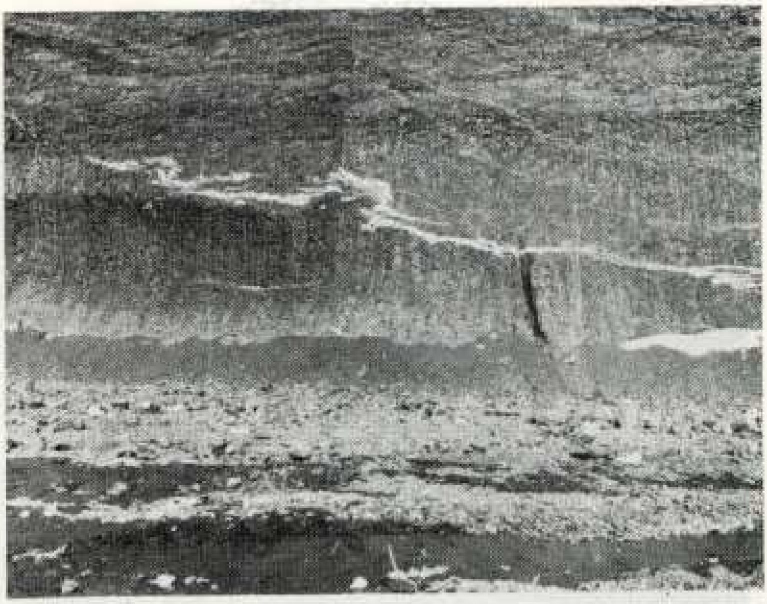
Newsom, J. F. (1903): Clastic dikes. — Bull. Geol. Soc. Amer., 14, *227—268*. New York.

Oomkens, E. (1966): Environmental significance of sand dikes. — Sedimentology, 7, *145—148*. Amsterdam.

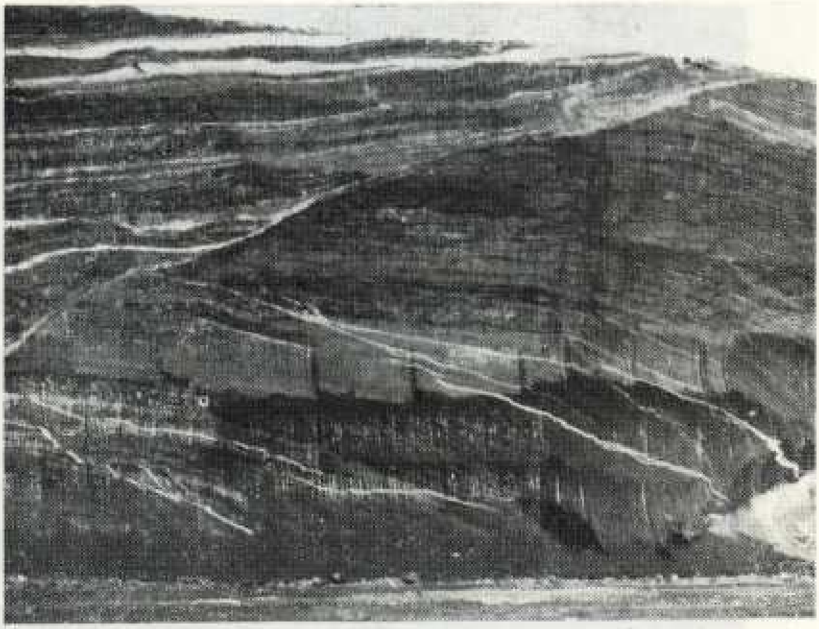
1, 2. Clastic dikes of the first type cutting the folded coal seam. The secon
section through the coal seam



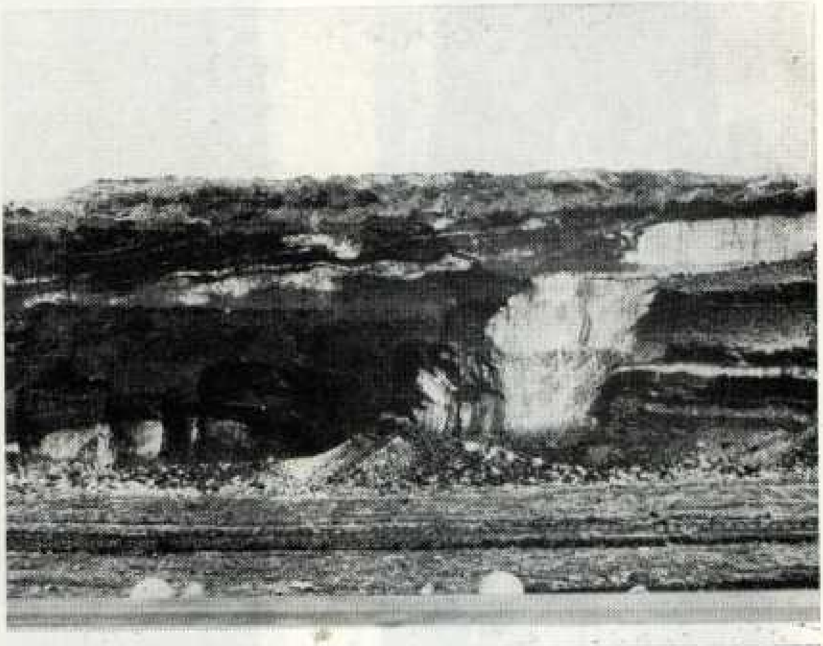
1. Clastic dikes of the first type. One of them penetrates into the folded block of the seam from the clastic dike of the second type which is situated on the shear plane. The second section through the coal seam
2. Association of dikes of the first, second, and third types which accompany thrust planes between the coal seam slices. The second section through the coal seam

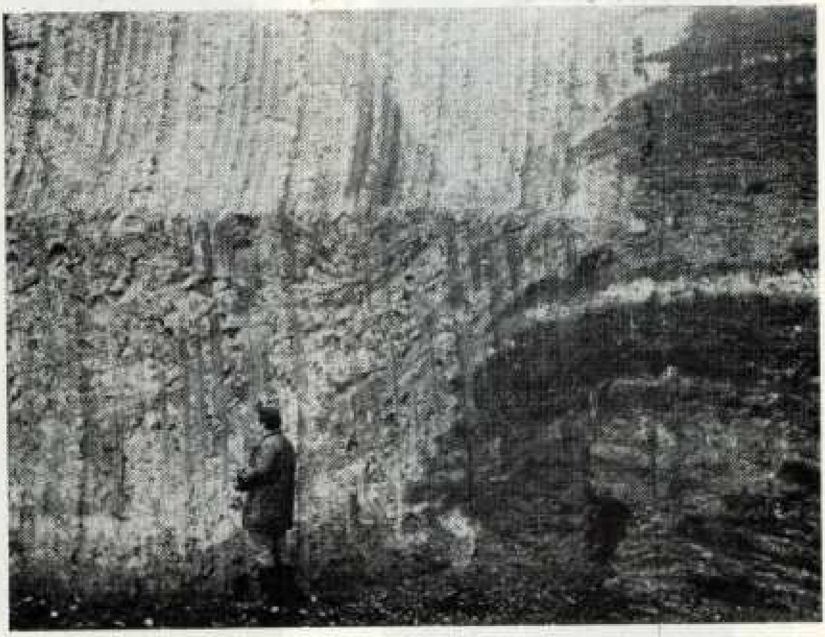


1. Clastic dike of the second type with many offshoots. On the right slide and lower part of the picture the topmost parts of the underthrust body of claystones are visible. From this claystone body the clastic dike was derived. The third section through the coal seam
2. Detail of the preceding photograph

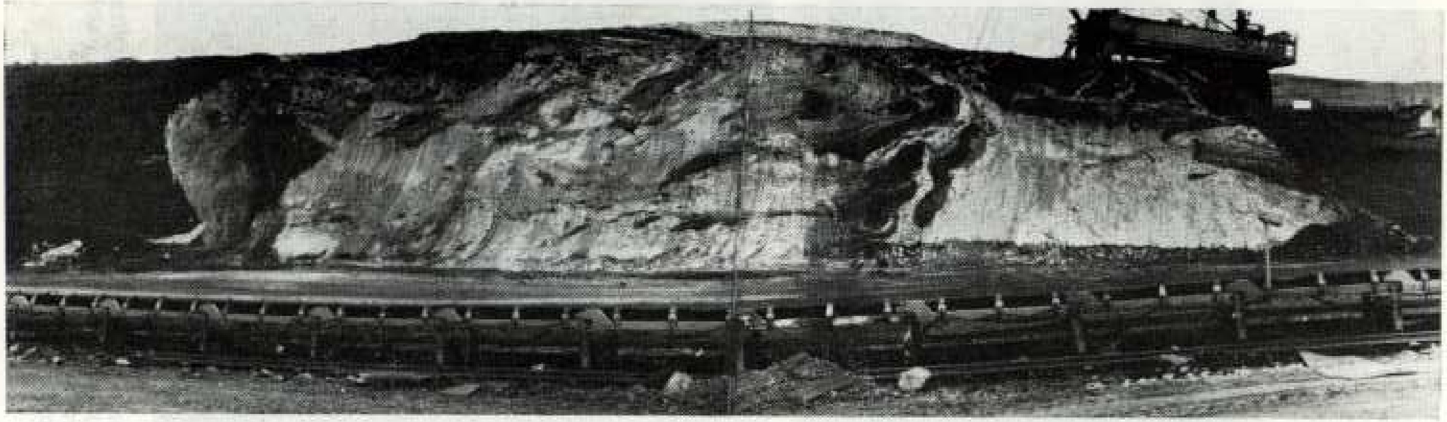


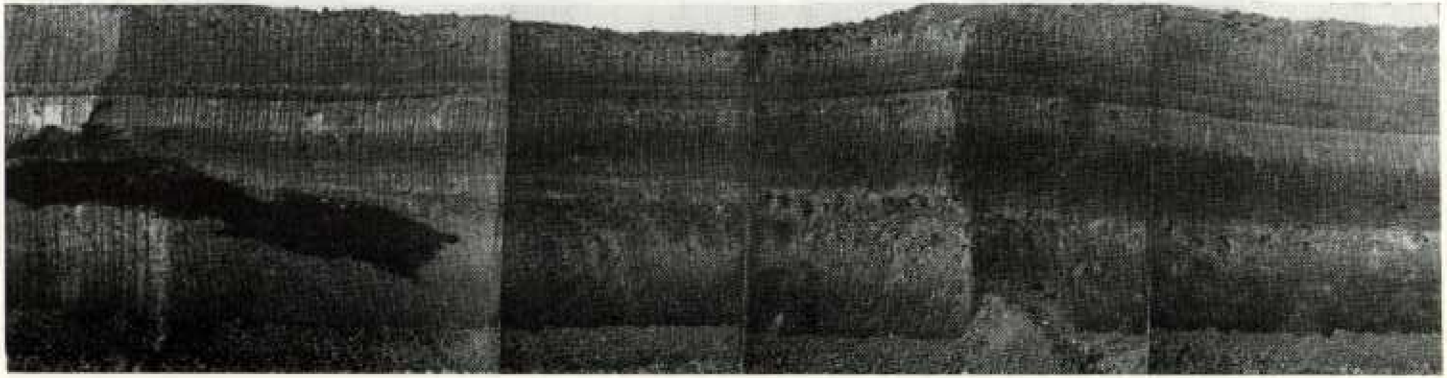
1. Clastic dikes of the second type. Part of them, on the right side, is connected with the underlying body of claystones. The third section through the coal seam
2. Clastic dikes of the fourth type. The first section through the coal seam



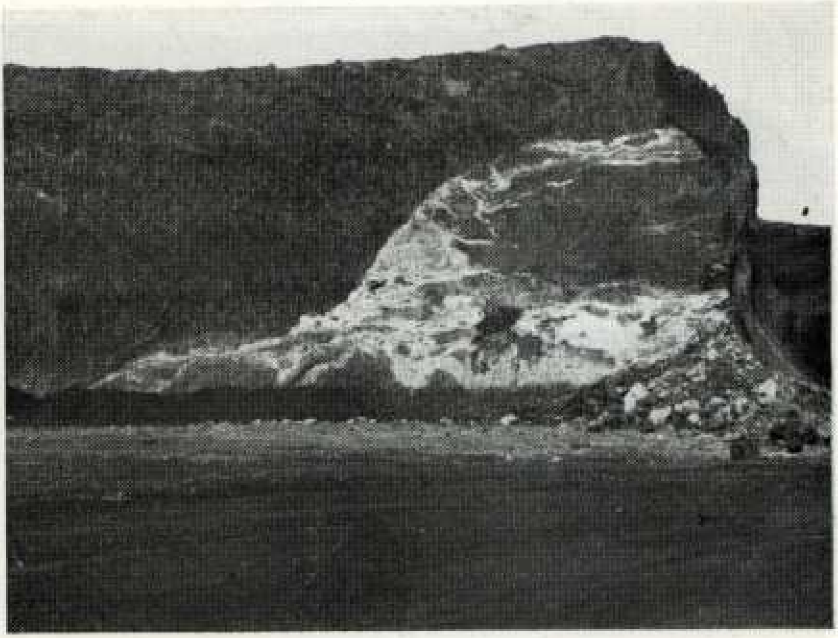


1. Funnel-like infill of claystones into the disrupted coal seam from above. In the upper part the intrusion of the fourth type is visible. The first section through the coal seam
2. Detail of the preceding photograph

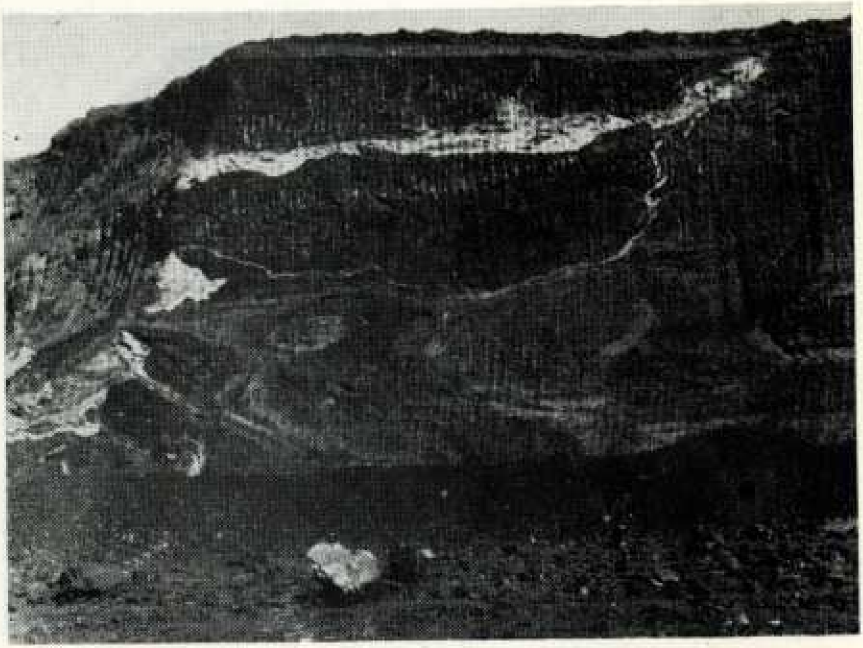


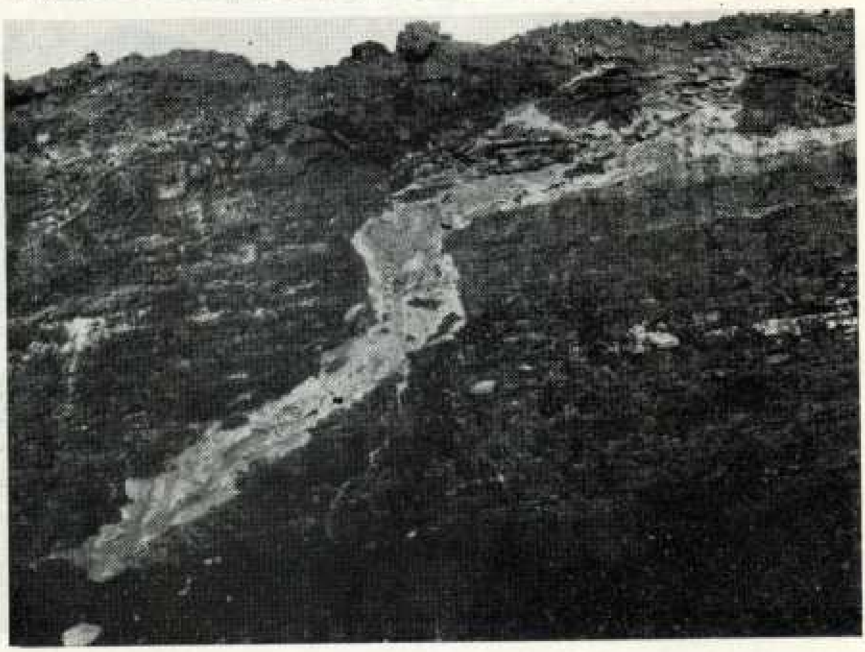


1. Marginal part of the body of underthrust claystones with many types of clastic dikes. The third section through the coal seam
2. Unconformity between the overlying younger sediments and underlying deformed sediments with a fragment of coal seam. The third stripping section

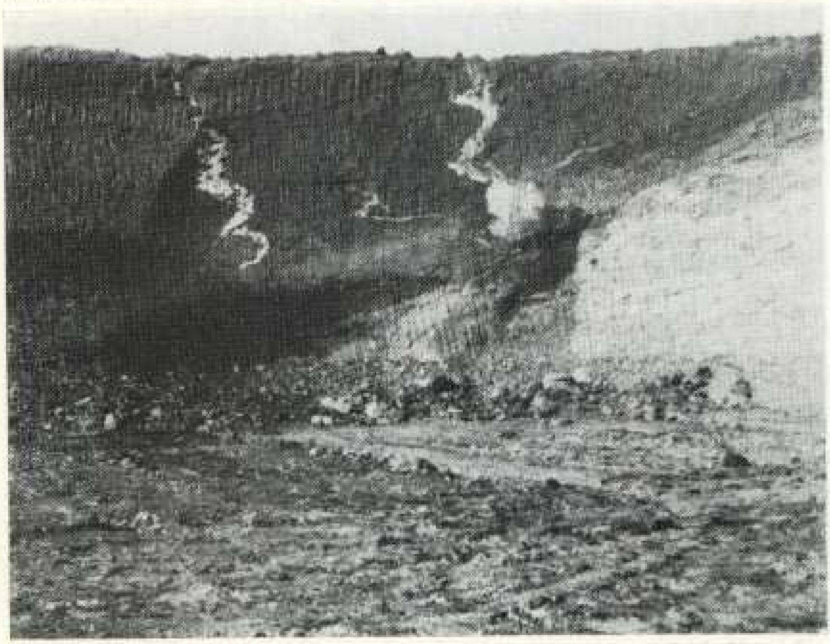


1. Breccia between two blocks of the coal seam. The second section through the coal seam
2. Breccia in the ripped part of the coal seam, accompanied by clastic dikes of the first and second types. The second section through the coal seam



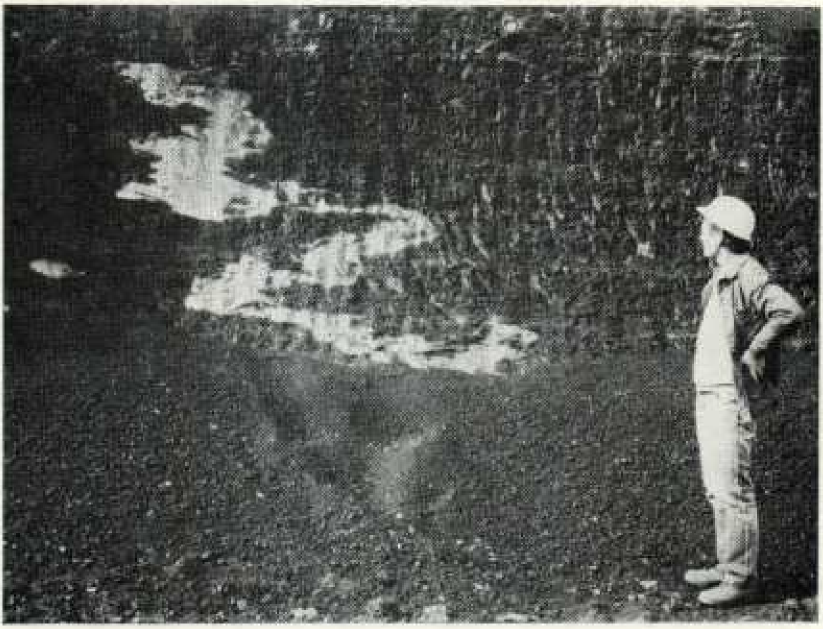


1. Clastic dikes of the first and second types with breccia. The lower parts of the overthrust part of the coal seam are intensively mixed up. The second section through the coal seam
2. Clastic dike of younger generation with a bleached rim. The third section through the coal seam

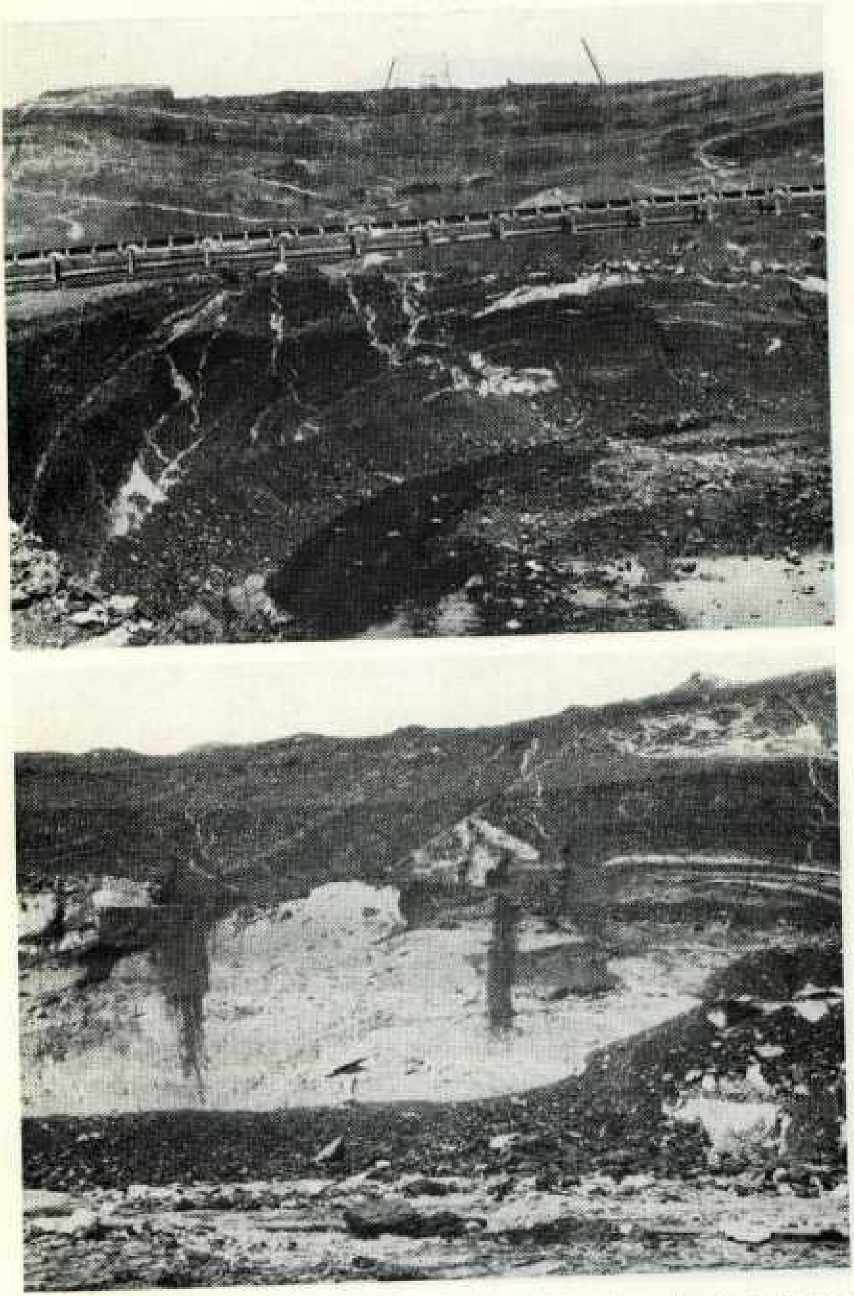


1. Clastic dike of the third type connected with the overlying claystone along the shear plane between the two slices of the coal seam. The first section through the coal seam
2. Clastic dikes of the third type. In the lower right corner the claystone body underlying uplifted blocks of the coal seam is cropping out. The third section through the coal seam

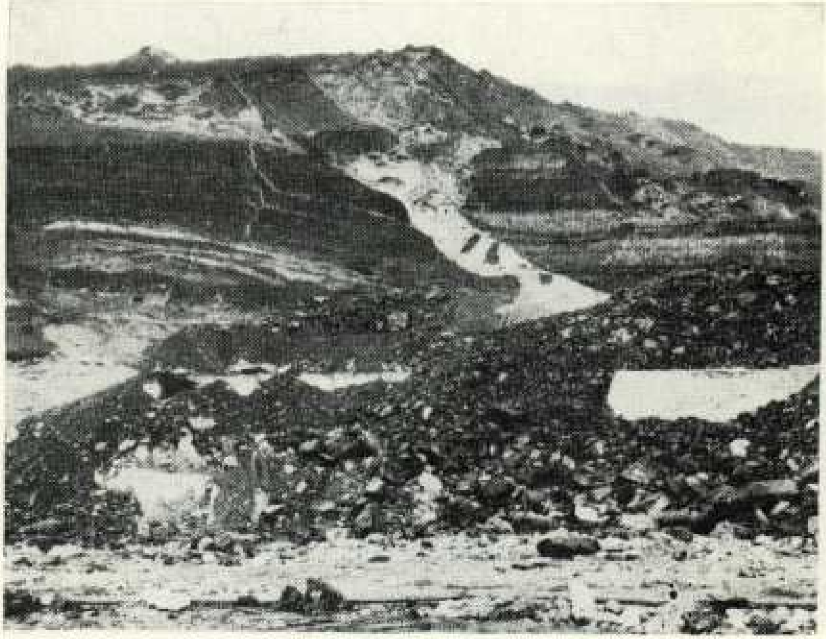
Pl. X



1. Sand dike of the fourth type connected to the sandstone along the shear plane between two slices of the coal seam. The second section through the coal seam
2. Clay dike of the fourth type. The first section through the coal seam



1. Swarm of clastic dikes along the first and second section through the coal seam
2. Clastic dikes of the first type and breccia in the ripped coal seam above the downthrust body of the overlying claystones. The first section through the coal seam



1, 2. Zones with coal breccia near the base of the overthrust blocks of the coal seam. In the lower part of the upper photograph underthrust body of the overlying claystones is cropping out. The third section through the coal seam All photos by S. Hurník

Pawlow, A. P. (1896): On dikes of Oligocene sandstone in the Neocomian clays of the district of Alatyr in Russia. — Geol. Mag., 3, *49—53*. Cambridge.

Pešek, J. (1978): Erosion and clastic dikes in coal seams of the central Bohemian basins and their significance for the determination of plant substance coalification. — Folia Mus. Rer. natur. Bohem. occident., Geol., 12. Plzeň.

Pettijohn, F. J. - Potter, P. E. (1964): Atlas and glossary of primary sedimentary structures. — Springer Verlag. Berlin, Göttingen, Heidelberg, New York.

Potter, P. E. - Maynard, J. B. - Pryor, W. A. (1980): Sedimentology of shales. — Springer Verlag. New York, Heidelberg, Berlin.

Potter, P. E. - Pettijohn, F. J. (1977): Paleocurrent and basin analysis. — Springer Verlag. Berlin, Heidelberg, New York.

Pruvost, P. (1943): Filons clastiques. — Bull. Soc. géol. France, (5[e] sér.), 13, *91—104*. Paris.

Ramberg, H. (1956): Pegmatites in West Greenland. — Bull. Geol. Soc. Amer., 67, *185—214*. New York.

Reichel, W. (1970): Stratigraphie, Paläogeographie und Tektonik des Döhlener Beckens bei Dresden. — Abh. Staatl. Mus. Mineral. Geol., 17. Dresden.

Russel, R. J. (1936): Physiography of lower Mississippi River Delta. — Geol. Bull., 8, *3—199*. Baton Rouge.

Ružencev, V. E. (1932): Benotsko-Datachskij neftenosnyj rajon. — Trudy Neft. geol.-razv. Inst., Ser. A 7. Leningrad.

Saito, R. et al. (1954): On stone intrusions in the 2nd coal seam at the Honbets coal-mine, Hokkaidó (in Japanese). — Bull. Geol. Comm., 26, *25—32*. Hokkaidó.

Shepard, F. P. - Dill, R. F. - Heezen, B. C. (1968): Diapiric intrusions in foreset slope sediments of Magdalena delta, Columbiia. — Amer. Assoc. Petrol. Geol. Bull., 52, 11, *2197—2207*. Tulsa.

Shrock, R. R. (1948): Séquence in layered rocks. — Mc Graw-Hill Book Co., New York, Toronto, London.

Smith, A. J. - Rast, N. (1958): Sedimentary dikes in the Dalradian of Scotland. — Geol. Mag., 95, *234—240*. London.

Strangways, T. H. F. (1821): Description of strata in the Brook Pulcovea near the village of Great Pulcovea in the neighbourhood of St. Petersberg. — Trans. Geol. Soc. London, 5, *382—408*. London.

Teisseyre, A. K. (1967): Clastic wedges in the Lower Carboniferous of the intrasudetic basin. — Bull. Acad. pol. Sci., Sér. Géol. Géogr., 15, *15—22*. Warszawa.

Thomas, W. A. (1968): Contemporaneous normal faults on flanks of Birmingham anticlinorium, Central Alabama. — Amer. Assoc. Petrol. Geol. Bull., 52, 11, *2123—2136*. Tulsa.

Verzilin, N. N. (1963): Melovye otloženija severa Ferganskoj vpadiny i ich neftenosnosť. — Trudy Leningr. Obšč. Estestvoispyt., Otd. Geol., 72. Leningrad.

Vitásek, F. (1958): Fyzický zeměpis II. — Nakl. Čs. akad. věd. Praha.

Wagenbreth, O. (1958): Beziehungen zwischen dem Tertiär und dem prätertiären Untergrund im Weißelsterbecken. — Freiberg. Forsch.-H., R. C, 53. Berlin.

Wagenbreth, O. - Bellmann, H. J. (1983): Zur diagenetischen Setzung von Braunkohle und Ton. — Z. geol. Wiss., 11, 6, *687—714*. Berlin.

Wanless, H. R. (1952): Studies of field relations of coal beds. — The 2nd conference on the origin and constitution of coal. *148—180*. Nova Scotia.

Weißenbach, L. G. A. (1850): Über Gangsformationen, vorzugsweise Sachsens. — *In* B. Cotta (Hrsg.): Gangstudien oder Beiträge zur Kenntnis der Erzgänge. Freiberg.

Klastické žíly v hnědouhelné sloji u Mostu v severočeské pánvi (miocén)

(Résumé anglického textu)

Stanislav Hurník

Předloženo 29. dubna 1988

Klastické žíly jsou v severočeské pánvi ojediněle zjišťovány desítky let, avšak jejich dokumentace se neprováděla. Dosud se objevovaly vždy výhradně v areálu miocenního tělesa bílinské delty. Jejich výskyt je zpravidla spjat s rozsáhlými synsedimentárními deformacemi slojového a spodní části nadložního komplexu. Podobně je tomu i na lomu Most, kde byl v posledních letech zaznamenán jejich hromadný výskyt.

V současné době jsou povrchovou těžbou uhlí na lomu Most zpřístupňovány koncové partie rozsáhlé synsedimentační deformace. V tomto prostoru se jedná o brachyantiklinálně vyzdviženou část sloje, potrhanou do četných ker a šupin. Pod tuto partii jsou do původní úrovně sloje podsunuty a zahněteny nadložní jílovce. Místy se objevují i písky. Výzdvih části sloje (resp. nekromasy, nejspíše v postrašelinném stadiu) byl doprovázen laterálními pohyby, při nichž se sloj trhala a jednotlivé segmenty se navzájem přesouvaly, ohýbaly až vrásnily. Deformovaná část sloje (její segmenty) je místy prostoupena jílovci jak ve formě jednoduchých klastických žil, tak rozsáhlých intruzí, dotvářejících destrukci sloje.

Deformace terciérních sedimentů představuje geneticky nejspíše strukturu, porovnatelnou se strukturami bahenních ostrůvků (mudlumps). Intruze jílů do potrhané organogenní masy sloje jsou doprovodným jevem mechanismu vzniku synsedimentační deformační struktury.

Žíly mají charakter záteků, rozmanitých intruzí a v některých případech jsou jílovce tmelícím médiem roztrhané sloje v typickou brekcii. Klastické žíly jsou tvarově i rozměrově velmi variabilní. Bylo rozlišeno 6 typů (viz obr. 1). Pro typ 1. je charakteristické esovité zklikacení. Směrová orientace je zřejmě nahodilá, neboť z provedených měření je patrný značný rozptyl.

Jílový materiál (výjimečně písky) pronikal do porušené sloje shora, zdola i z boku. Podle dokumentovaných odkryvů nejčastěji zdola, z podsunutého tělesa nadložních jílovců.

Klastické žíly jsou sice synchronní se vznikem deformační struktury, ovšem až s její závěrečnou fází při doznívání deformace. Markantním dokladem jsou žíly, pronikající napříč ležatými až překocenými vrásami, vytvořenými zjevně ve vrcholné fázi deformace. Podobně v brekciích, kde jílová hmota netvoří pouhou intergranulární výplň mezi úlomky až bloky uhlí, mnohdy uhelný materiál v jílové hmotě „plave". Názorné je to u některých rozlámaných bloků, jejichž jednotlivé segmenty bývají navzájem posunuty až oddáleny. Žíly tedy nejsou příčinou potrhání sloje. Fragmentace sloje vesměs předcházela jílovým intruzím.

Část klastických žil vznikla až v pozdější fázi diageneze, kdy byla celá deformační struktura překryta mocnějším nadložím. K potrhání sloje tehdy došlo v důsledku diferenciální kompakce vyzdvižených částí sloje a podsunutého tělesa jílů. Tyto žíly mají zpravidla konformní průběh stěn (příl. VIII-2), jílová hmota je prostoupena rozptýlenou uhelnou příměsí a podél stěn je patrné vybělení jílovců.

Klastické žíly na lomu Most nejsou pouze zajímavým specifickým fenoménem, doprovázejícím rozsáhlou deformační strukturu, nýbrž objektem, umožňujícím řešit některé další otázky procesu deformace. Je to zejména stupeň diageneze neogenních sedimentů v době deformace. V tomto směru lze považovat za nejvýznamnější esovité zprohýbání žil 1. typu. Esovité zprohýbání je možno jednoznačně vztahovat k doznívající kompakci nekromasy sloje. Průkazné jsou v tomto směru zejména žíly 2. typu, u nichž subhorizontální průběh je víceméně přímkový, zatímco vertikální či šikmé spojovací žilky a odmrsky jsou zpravidla rovněž esovitě zprohýbané. S redukcí mocnosti organické hmoty souvisí mnohdy zřejmě i odklon žil od svislice.

Pro možnost posouzení hodnoty kompakce uhelné hmoty po vzniku deformace a žil byla u většiny žil 1. typu proměřena skutečná délka a vypočten její poměr k mocnosti příslušného intervalu sloje. Tento poměr kolísal v rozmezí 1,4—1,7, tzn. že v době vzniku žil byla nekromasa téměř uhelná (hodnota kompakce s $\geqq$ 4). Přesto, že redukce mocnosti nekromasy byla před deformací značná, stupeň prouhelnění byl pravděpodobně velmi nízký. Poukazuje na to roztřepený okraj uhlí na stěnách 5. typu žil a u některých bloků v brekciích. Na značnou tvárlivost nekromasy sloje v době deformace poukazují ležaté až překocené vrásy, jejichž ohybové partie (temena) jsou kontinuální a nevykazují stopy střihového namáhání. Žíly, které do vrás intrudovaly až po deformaci, probíhají napříč ohnutými vrstvami uhlí.

Nekromasa uhelné sloje se tedy v poměrně velmi krátkém časovém intervalu (vznik synsedimentační deformace až po vznik klastických žil) chovala dvojím způsobem. Jednak plasticky (vrásové deformace, zahnětení nekromasy do podsunutých nadložních jílovců), jednak jako soudržný až křehký materiál (potrhání, vznik puklin, brekcie). S dvojím chováním uhelné hmoty souvisí otázka rychlosti prouhelňovacího procesu: zda probíhal velmi rychle (valouny černého uhlí ve stropových vrstvách karbonských slojí), či zda se jednalo o dlouhodobý proces. Podle výsledků studia klastických žil na lomu Most, s přihlédnutím k výzkumům Wagenbretha, je zřejmé, že bude účelné odlišovat kompakci nekromasy od geochemické fáze prouhelňovacího procesu. Kompakce, jakožto dominantně fyzikální stránka procesu, probíhala rychle a pravděpodobně doznívala při nástupu geochemické fáze. Teprve potom nastala rozhodující fáze vlastní geochemické přeměny nekromasy v uhlí.

Vysvětlivky k tabulce 1 a obrázkům

Tabulka 1. Petrografické a fyzikální vlastnosti jílovců.

1. Přehled tvarových typů klastických žil na lomu Most.
   Typické znaky: *1* — vždy napříč vrstevnatostí sloje, vesměs esovité zprohýbání; vertikální délka m, mocnost *a)* mm, cm, *b)* dm; *2* — zhruba konformní s vrstevnatostí sloje, časté šikmé až vertikální odmrsky (vesměs esovitě zprohýbané); vertikální délka m, mocnost mm, cm; *3* — nepravidelně zklikacené proniky s proměnlivou mocností, častý subhorizontální průběh s četnými apofýzami; délka m, mocnost cm, dm; *4* — nepravidelně esovitě deformovaná tělesa oblých tvarů; délka dm, m, mocnost dm; *5* — trychtýřovitá výplň, rozměry v m; *6* — brekcie, vertikální délka m, šířka m až desítky m.
2. Klastická žíla druhého podtypu 1. typu; III. uhelný řez.
   1 — jílovce; *2* — uhlí; *3* — jalové proplástky a popelovinové uhlí.
3. Klastické žíly 2. typu. V levé části sledují plochy nasunutí segmentů sloje; II. uhelný řez.
4. Pískovcová klastická žíla v hlavní sloji ca 200 m jz. od deformační zóny; I. uhelný řez.
5. Brekciová výplň intruze jílovců z podloží potrhané sloje, doprovázená v blocích uhlí žílami 2. typu; II. uhelný řez.
6. Stropní partie podsunutého tělesa nadložních jílovců s uhelnou „brekcií". Blok uhlí vpravo je zřetelně dislokován. *Čárkovaně* je vyznačen deformovaný průběh nepravé vrstevnatosti jílovců; II. uhelný řez.
7. Klínovitá výplň trhliny. *Tečkovaně* je naznačen obrys okrajové vybělené zóny; III. uhelný řez.

Vysvětlivky k přílohám

Příl. I

1, 2. Klastické žíly 1. typu, prorážející zvrásněnou sloj. II. uhelný řez.

Příl. II

1. Klastické žíly 1. typu, z nichž jedna proniká do zvrásněné kry sloje z klastické žíly 2. typu na smykové ploše. II. uhelný řez.
2. „Asociace" žil 1.—3. typu, které doprovázejí přesuvné plochy mezi šupinami uhelné sloje. II. uhelný řez.

Příl. III

1. Žíla 2. typu, doprovázená četnými odžilky. Vpravo dole strop podsunutého tělesa jílovců, z něhož žíla intrudovala. III. uhelný řez.
2. Detail žíly z obr. 1.

Příl. IV

1. Žíly 2. typu, z nichž část (vpravo) navazuje na těleso jílovců v podloží. III. uhelný řez.
2. Žíly 4. typu. I. uhelný řez.

Příl. V

1. Celkový pohled na trychtýřovitý „zátek" jílovců z nadloží do roztržené sloje. Nahoře uprostřed intruze 4. typu. I. uhelný řez.
2. Detail z obr. 1.

Příl. VI

1. Boční partie tělesa podsunutých jílovců, doprovázená po obvodu různými typy žil. III. uhelný řez.
2. Diskordantní nasedání mladšího sedimentačního cyklu nadložních jílovců na deformovanou spodní partii s fragmentem uhelné sloje. III. skrývkový řez.

Příl. VII

1. Brekcie na styku dvou ker nasunuté části sloje. II. uhelný řez.
2. Brekcie v potrhané partii sloje, doprovázená žilami 1. a 2. typu. II. uhelný řez.

Příl. VIII

1. Žíly 1. a 2. typu a brekcie. Spodní partie nasunuté části sloje jsou prohněteny. II. uhelný řez.
2. Žíla mladší generace se zřetelným vyběleným lemem. III. uhelný řez.

Příl. IX

1. Klastická žíla 3. typu navazující na nadložní jílovce podél smykové plochy mezi dvěma šupinami uhelné sloje. I. uhelný řez.
2. Klastické žíly 3. typu. Dole v pravém rohu se objevuje těleso nadložních jílovců, zvedající bloky uhelné sloje. III. uhelný řez.

Příl. X

1. Písková žíla 4. typu spojená s pískovci na smykové ploše mezi dvěma šupinami uhelné sloje. II. uhelný řez.
2. Jílová žíla 4. typu. I. uhelný řez.

Příl. XI

1. Roje klastických žil podél I. a II. uhelného řezu.
2. Klastické žíly 1. typu a brekcie v roztrhané sloji nad podsunutým tělesem nadložních jílovců. I. uhelný řez.

Příl. XII

1, 2. Zóny s uhelnou brekcií při bázi vysunuté kry uhelné sloje. Ve spodní části horního snímku vystupuje podsunuté těleso nadložních jílovců. III. uhelný řez.

Všechna foto S. Hurník

Кластические дайки в буроугольном пласте около г. Мост в Северочешском бассейне

В буроугольном пласте Северочешского бассейна в карьере Мост в последние годы обнаруживаются кластические дайки с выполнением, сложенным аргиллитами. Их распространение связано с обширной синседиментационной деформацией главного пласта. В течение этой деформации была приподнята часть пласта и под нее из висячего бока вдавились глинистые отложения. Из подстилающего тела пелитов глинистый материал затем выжимался в трещины разрушенных частей пласта в виде даек, следовательно, чаще всего снизу вверх, а лишь в единичных случаях глины проникали прямо сверху из висячего бока. Кластические дайки образовались преимущественно в связи с окончательным сформированием синседиментационной деформации угольного пласта, а в некоторых случаях — лишь только после перекрытия всей деформационной структуры более мощной кровлей, в течение продолжающегося диагенеза горного массива. Так как обширная деформация продуктивных отложений сравнивается со структурами грязевых островов, образование здешних кластических даек связывается исключительно с экзогенными факторами. В связи с изменчивостью их форм было различено шесть типов. На основании вторичных изменений и формировании даек обсуждается степень диагенеза отложений в течение деформации. Некромасса пласта слежалась до времени образования кластических даек больше, чем до 2/3 общего уплотнения.

Přeložil A. Kříž