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DETAILED EVALUATION OF DEFORMATION BEHAVIOUR ON THE BOTTOM OF THE OPEN-PIT MINE JIŘÍ

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ABSTRACT. 3–D physical models were used for long-range predicting of deformations of an open-pit mine bottom endangered by the overpressure of artesian groundwater. More detailed analysis was carried out on places where many geological dislocations occurred. The possibility of the local failure originating and water outflowing along the geological faults was studied. Parametric models, based on similarity of effects, were constructed. For measuring of the changes of stress in the model body tensometric measurements were used. The deformations of the shape of the model surface were determined by the trigonometric method.

1. Introduction

On the basis of the government decrees, which should be kept during brown coal mining in preservation zones of natural curative water sources of the spa area of Karlovy Vary, a number of activities has been carried out for protection of water sources in this area. First of all it concerns complex geological and hydrogeological surveys, further levelling on the bottom of open-pit mines and in purpose-made (drainage) adits, set up of observation or drainage wells, etc. Evaluation of stability and prediction of vertical deformations of the bottom of open-pit mines by using methods of mathematical and physical modelling also form a part of these activities (Doležalová 1985, Skořepová 1987).

The most complex situation has occurred particularly in the open-pit mine "Jiří". During the open-pit exploitation of a coal seam, the impermeable group of strata of a thickness of 40 to 80 m has been temporarily uncovered on the open-pit bottom. These layers form an artesian roof of thermal gas-bearing waters. Uncovered overpressure of artesian water locally reached up to 0.4 MPa, in spite of decreasing their free level by lowering it from original level of 367 m above sea level to the 350 m, above sea level. On 3–D physical models representing the area of up to 1500 × 700 m, a global prediction of deformation behaviour for about five year periods was carried out in the past years. The deformations on models were measured in an equivalent of drainage adit, in which levelling has been continuously carried out on the mine

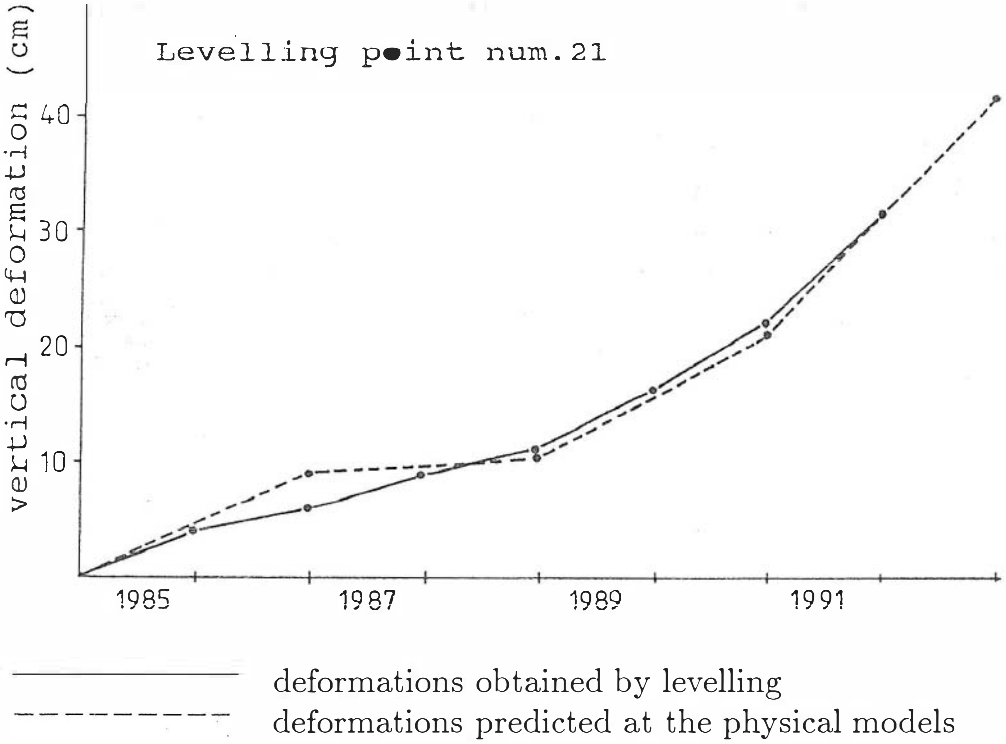

FIG 1. Vertical deformations of the bedrock of coal seam

(Skořepová 1992). It was shown later that the deformations predicted on the models were in very good agreement with levelling (Fig.1).

Numerous geological dislocations have passed through the area of mining field (Fig.2). They have interrupted continuity of tuffitic impermeable layers. The increased deformations occurred at the open-pit bottom especially in the localities of tectonic line crossing. With respect to very complicated geological structure, it is necessary to investigate in detail the process occurring in dangerously situated tectonic lines and to define the possibility of formation the local deformation and failure of water tightness of tectonic faults as a result of their separation. It was the reason, why small models were suggested.

2. Modelling equipment

For construction of models used modelling equipment consisting of a box of bottom dimensions of 47×97 cm and with the height of 50 cm was used (Fig.3). A metal construction was attached to the box which enabled induce lateral pressure of a desired magnitude to a freely movable solid plate located inside the modelling box. Pressure was transferred by this plate to an equivalent material in the model. A dynamometer was installed on the construction to measure this pressure. The box was fixed against shifting. It was possible to supply the box with water through the holes in the bottom over a movable overfall and to regulate free water level by movement of the overfall.

A linear scale 1:500 was used. The same types of equivalent materials were utilized as those used in 3–D models. The lowest part of models, representing

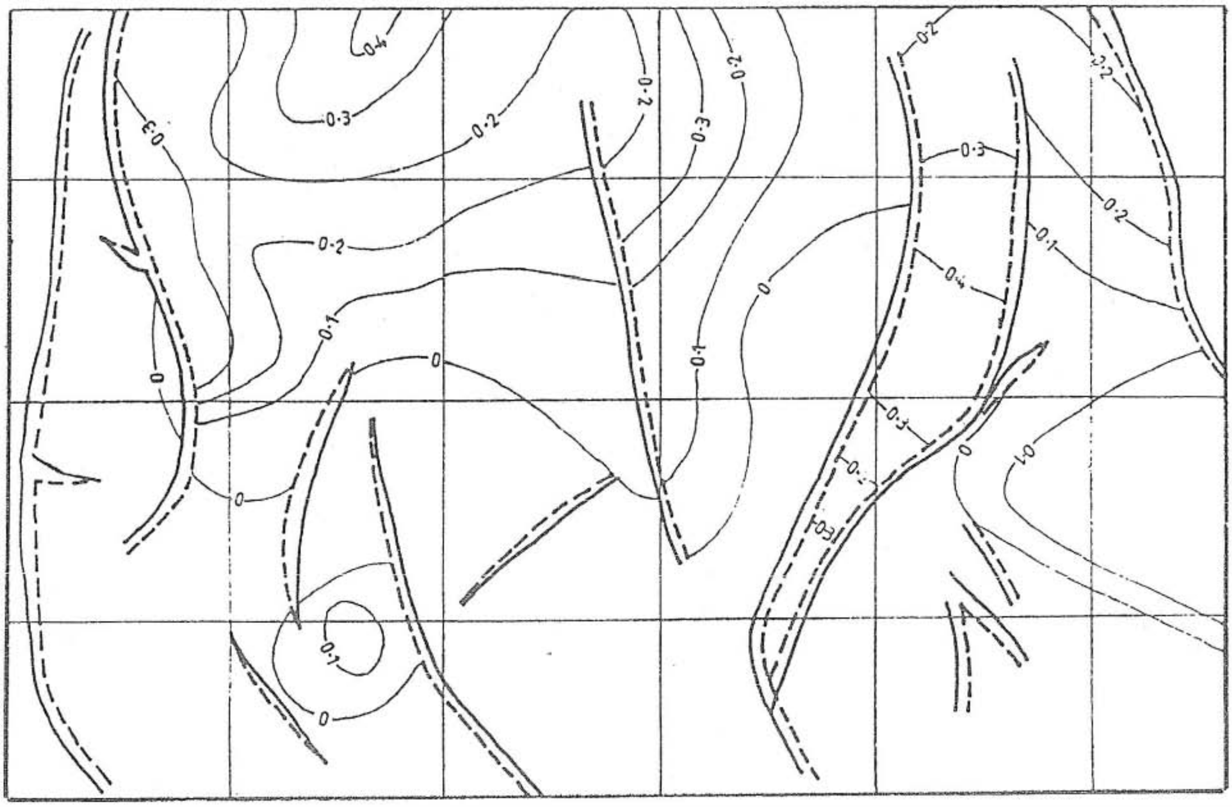

FIG 2. Situation of geological dislocations and izolines of uncovered overpressure of artesian waters (MPa). Water level lowered to 350 m above sea level

aquiferous bedrock, was modelled using stone debris and its surface was reinforced by an epoxide resin. A polybutadiene membrane was laid on the shaped surface of the bedrock. It created an artesian aquifer and prevented water from entering to the equivalent material, which substituted impermeable tuffitic layers. The membrane was laid so that it made possible outflows of water along tectonic line and did not prevent possible fault separation, as a result of deformations caused by overpressure of artesian water (Fig.4). To determine shear properties of the membrane a classical shear box test was carried out. Cohesion of two dry membranes as they were laid on the fault lines in the model was $C_m = 0.004 - 0.01\,\mathrm{MPa}$, (it correspond cohesion of $C_r = 2 - 5\,\mathrm{MPa}$ for a scale of 1:500), and the angle of an internal friction $\varnothing_{\mathrm{dry}} = 18^o$. The cohesion did not virtually alter after water penetrated between the membranes, however, a marked decrease of the angle of the internal friction occurred; $\varnothing_{\mathrm{wet}} = 5^o$. The equivalent of impermeable tuffitic layers was applied above the membrane formed of a mixture of balotine, ferrosilicon, and grease, together with the equivalent of coal seam.

3. MEASUREMENT

Not only surface deformations of tuffitic layers were measured in a close proximity of geological failures, but also the redistribution of stress in a model body, was

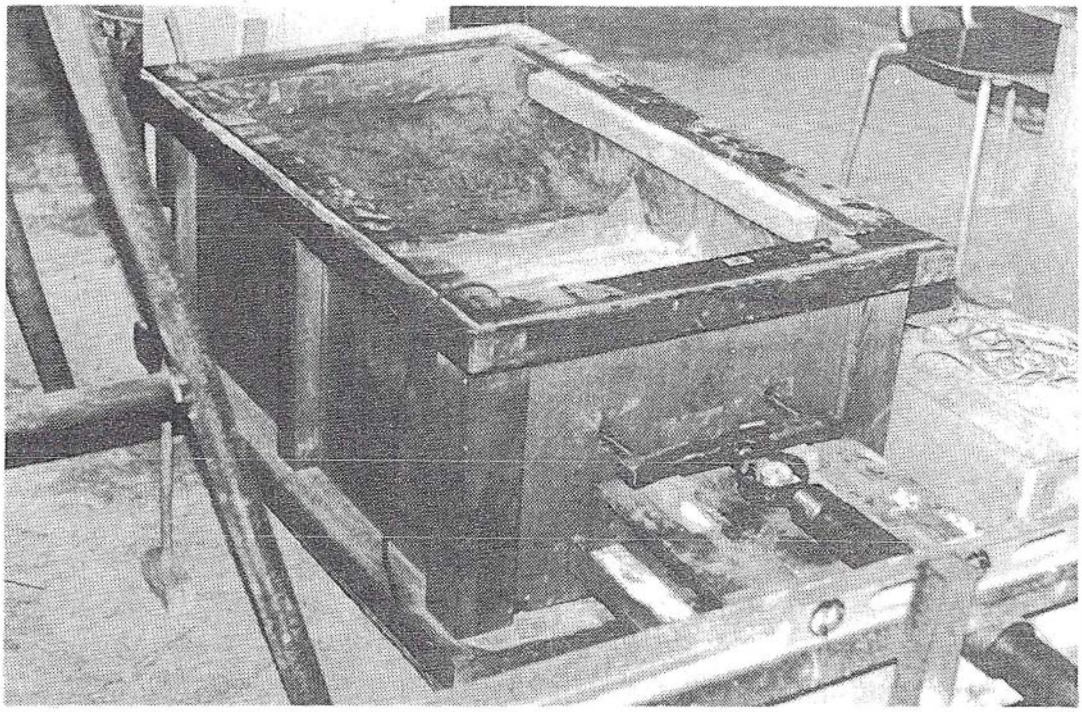

FIG 3. Modelling equipment

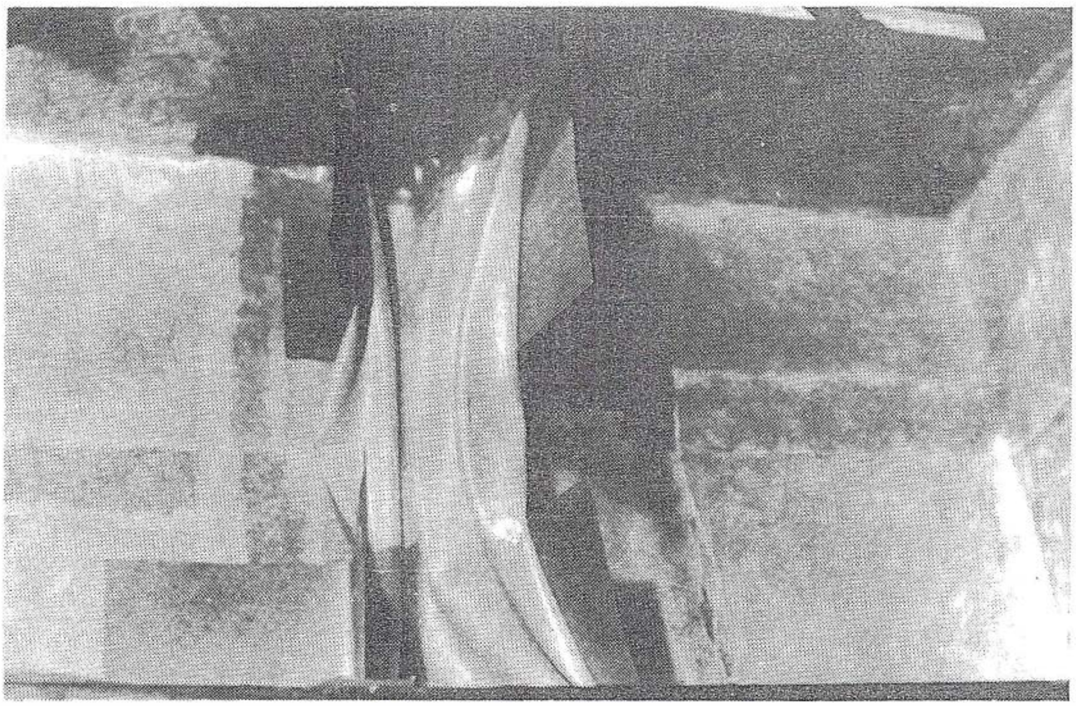

FIG 4. Polybutadiene membrane folds

investigated on these models.

Geodesic methods were used for measuring of deformation of model surfaces.

After every change of deformation relationships in the model, the changes of position of measuring marks located on the model surface were determined by a forward intersection method.

The changes of state of stress in the model body were determined on the basis of tensometric measurements. Semiconduct sensors TM 440/2 of a nominal range of 20 kPa were used for these measurements. They were located in the exposed places of the model during its construction. They were designed for registration of stress changes both in vertical and horizontal directions, according to a manner of their setting. The data-acquisition and automated measuring equipment Unilog 2500 was used.

Semiconduct sensors were installed in half of the thickness of the equivalent of tuffitic intermediate layers during model construction. The mass of overlaying layers up to the original surface was simulated by an external load – metal weights – among them which the measuring marks were located (Fig.5).

FIG 5. Model surface with metal weights and measuring marks

4. SIMILARITY OF EFFECTS

The model solution was based on modelling the similarity of effects. It means that the aim was to achieve a similarity of the effects on the physical model by a change of boundary conditions. In this case, by a change of lateral pressure applied to the model. Therefore, firstly locality was modelled in which the coal seam was extracted and bottom deformations of the open-pit were known from the periodic levelling (Fig.6a). There was also weak outflow of water observed which occurred near the fault line after coal seam had been extracted. These facts were taken into consideration, at comparing the effects on the models. The conditions leading to corresponding vertical deformations in the model and also to similar water outflows along the line of modelled fault, were determined by the change of model lateral pressure.

After each change of deformation conditions in the model, the horizontal and vertical angles were measured by theodolites to the measuring marks located on the model surface. The data-acquisition system recorded the data of three pairs of semi-conduct sensors. The model surface was visually observed with a special attention to the creation of water outflows in membrane folds of fault lines.

The coefficient of lateral pressure $K_0 = \sigma_{\text{horiz}}/\sigma_{\text{vert}} = 1$ was assumed when the original surface of the area was modelled in the beginning of each model experiment. A stress of 7.2 kPa was applied to a side of a modelling stand by a loading device before filling water to the equivalent of aquiferous bedrock. It approximately corresponded to the maximum vertical stress at the lowest part of intermediate layers for given model scale. After filling water to the level corresponding to elevation of 340 m above sea level (or 350 m), metal weights were gradually taken away from the model surface. It caused deformations of impermeable layers and subsequent redistribution of stresses in the model.

The lateral pressure was reduced until the value was reached, which had induced similar effects in the first test model, as those observed in the open-pit mine (i.e. corresponding deformations and slight imperceptible water outflows along the fault line) Tab.I.

TABLE I.. Redistribution of stress – detailed model of section A–A'

Internal pressure [kPa]	Free water level [m] above sea	changes of internal stress in %		
		near the model wall	in front of fault	between faults
7.24	350	100	100	100
4.82	350	90	78	77+
2.41	350	60	54	49++

\+ weak outflow of water occurred along fault line
++ more intense outflow of water occurred along both fault lines

Under above mentioned conditions three other localities were tested. These localities were situated in the forefield of the open-pit mine (6b,c,d). For them the effects were necessary to be predicted, which could be occur there after extraction of the coal seam. It concerned localities, in which undesirable increase of deformations could be expected, after the tuffitic layers will be discovered on the open-pit mine bottom. The possibility of creation of water outflow due to higher overpressure of artesian water and adverse geological conditions was considered, too (Fig.7).

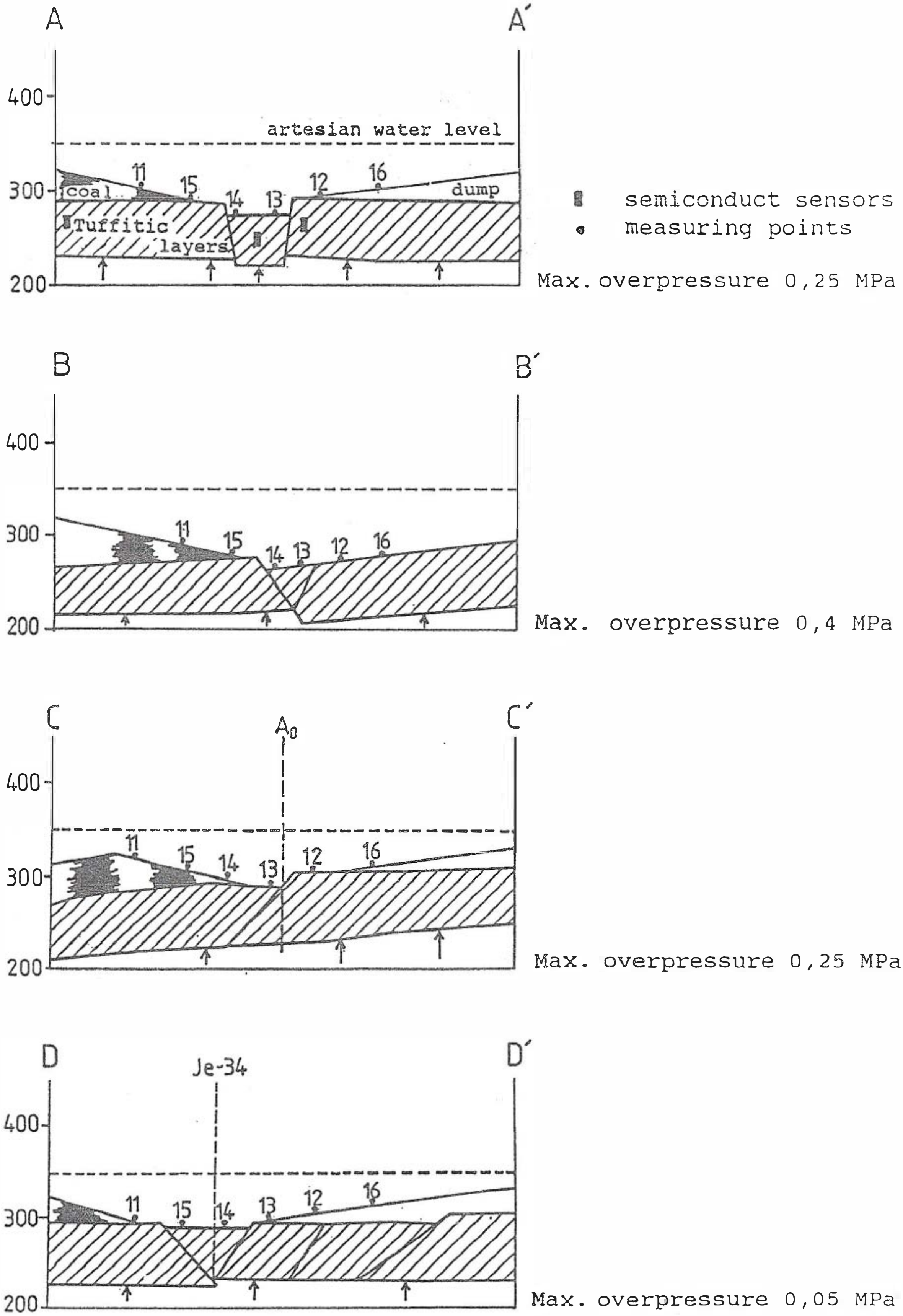

FIG 6. Sections through the physical models

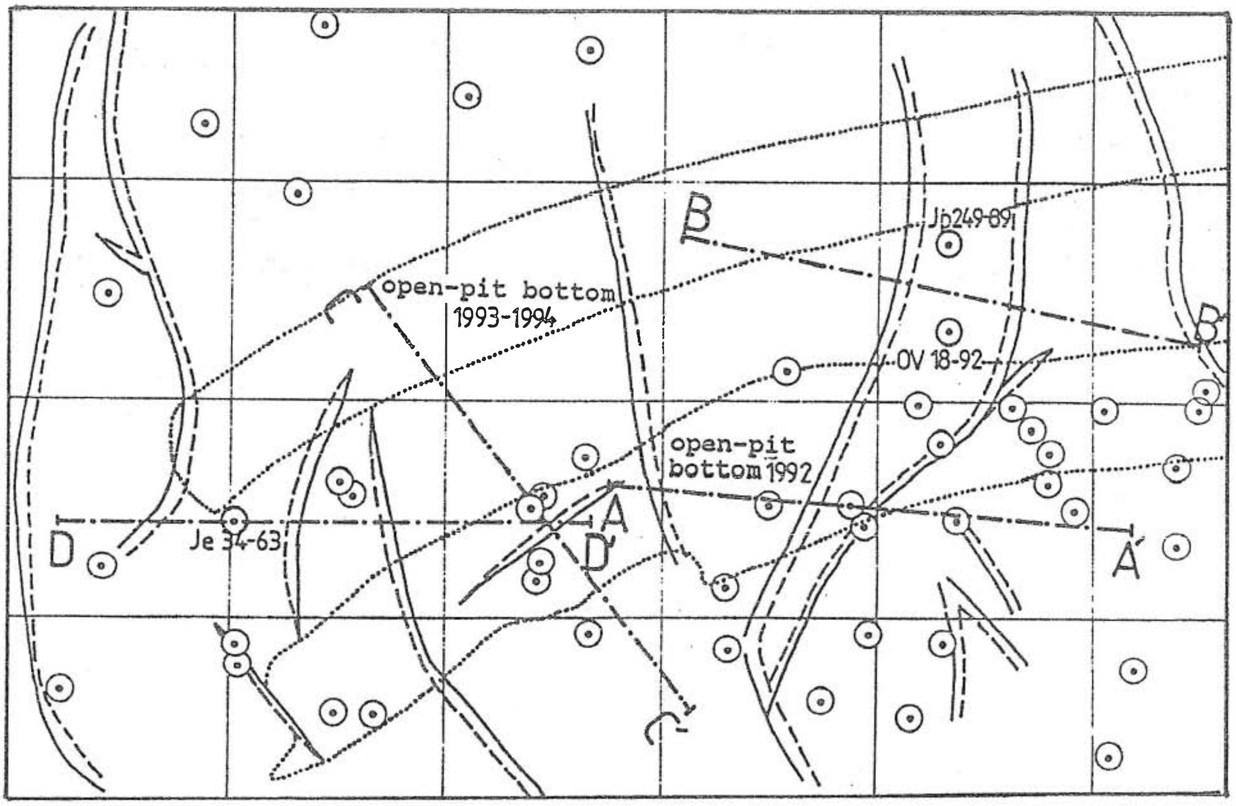

FIG 7. Location of the model sections, ⊙ – hydrogeological wells

5. EXPERIMENTAL RESULTS AND CONCLUSION

It can be concluded from the comparison of results obtained from these physical models that the most dangerous locality studied in detailed model experiments is the cross-section B–B' (Fig.6). The contact failure on the faults and "slipping out" of the parts of bedrock between the faults occurred there, together with water outflows along the faults, even though the free water level in the model was reduced to the elevation corresponding to 340 m above sea level (Tab.II).

TABLE II.. Redistribution of stress – detailed model of section B–B'

Internal pressure [kPa]	Free water level [m] above sea	changes of internal stress in %		
		near the model wall	in front of fault	between faults
7.24	340	100	100	100
4.53	340	74	62	67 +
2.41	340	50	2	−13 ++

+ weak outflow of water occurred along fault line

++ more intense outflow of water occurred along both fault lines

The inacceptable vertical deformations were measured in the area between the faults of the counterslope — more than 0.9 mm. No inacceptable deformations were recorded for water level in the model corresponding to 350 m above sea level in two other modelled localities (vertical section C–C', D–D'). No significant changes in redistribution of stress in the model body and disproportionate movements on the faults were observed. N● outflows of water occurred along fault lines.

The results obtained from the model experiments will be used as a part of the date for elaborating the suggestions of precaution to be taken both for safe exploitation of coal seam of the open-pit mine "Jiří", and for providing protection of curative springs.

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Detailní posouzení deformačních projevů na dně dolu Jiří

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Při lomové těžbě hnědého uhlí se na přechodnou dobu na dně lomu obnažuje nepropustné tufitické souvrství, které tvoří artéský strop proplyněným termálním vodám. Následkem nekrytého přetlaku artéských vod dochází k deformacím dna lomu. Vzhledem ke složité geologické stavbě oblasti je třeba detailně sledovat deformační procesy probíhající na dně lomu, posoudit možnost vzniku lokálních porušení a narušení vodotěsnosti tektonických zlomů následkem jejich rozevírání.

Pro predikci deformací povrchu tufitického souvrství v těsné blízkosti geologických poruch a studium přerozdělování napětí byly konstruovány detailní fyzikální modely v měřítku 1:500 nejohroženějších míst na dně lomu. Řešení bylo založeno na modelování podobnosti jevů. Pro měření přetvoření povrchu modelů bylo využito geodetických metod. Změny napjatosti v tělese modelu byly registrovány polovodičovými snímači umístěnými do exponovaných míst modelu.

Výsledky získané z modelových pokusů budou využity jako jeden z podkladů pro vypracování návrhů ochranných opatření pro bezpečnou těžbu uhelné sloje a pro zajištění ochrany lázeňských pramenů.