METHODS OF PROTECTION OF MINE WORKINGS UNDER WATER BEARING HORIZONS OF OSTRAVA - KARVINÁ COALFIELD

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ABSTRACT

The authors deal with two method of protection of mine working and the miners of Ostrava-Karviná Coalfield /Czechoslovak part of Upper Silesian Basin/ against outbursts of water and gases into mine workings. The first, active method, consists in controlled drainage of water and relief of pressure in the water bearing bed in advance of the mining. The second, passiv method, consists in the determination of the thickness of a protective insulation bed to be left between the old relief of the Carboniferous and mine workings. A mathematical model for the optimization of the thickness of such protective insulation bed under water and gas bearing beds was developed by workers of Coal Research Institute using the finite element method. The problem has been solved from a geomechanical point of view, as a problem of stability, considering that undisturb Coal Measures rocks are in fact impervious. The results of mathematical solutions have been compared with the results obtained on physical models from equivalent materials and in the mining practice with a good agreement. Also geophysical and geochemical methods for indirect determination of changes produced in the rock mass under the effects of water and gas bearing horizons are being developed.

HYDROGEOLOGICAL CONDITIONS OF OSTRAVA-KARVINÁ COALFIELD

A considerable part of the Carboniferous encountered in Ostrav Karviná Coalfield /Czechoslovak part of Upper Silesian Basin/ is covered by thick tertiary marine deposits where several water-bearing or water-and-gas bearing horizons were developed. The properties of these horizons, their distance from the surface of the Carboniferous and the possibilities of communication with them affect - in greater or smaller extent - mine planning as well as the drainage of mine workings.

In Ostrava-Karviná Coalfield, the following horizons are found:

- quarternary water bearing horizon related to surface water which has lost significance with the advance of mines in Ostrava-Karviná Coalfield to great depth;

- upper tertiary water-and-gas bearing horizon encountered between +50 and -80 m under Adriatic Sea level. In those parts of Ostrava-Karviná Coalfield where the relief of the Carboniferous is superior to the elevation of +50 m, the upper tertiary horizon is superposed to the surface of the Carboniferous and it may be in hydraulic communication with other inferior horizons, namely with coarse basal clastic sediments /the detritus/. Also this horizon has lost significance with the advance of mines to greater depth but it is necessary to take it into account when sinking new shafts;

- lower tertiary water-and-gas bearing horizon encountered only occasionally approximately 300 m under the upper tertiary horizon;

- detrital water-and-gas bearing horizon situated on the surface of the Carboniferous in buried valleys. The maximum thickness of this horizon is 300 m. The pervious bed is formed by weathered surface of the Carboniferous of a thickness up to 25 m and by a relatively thick bed of basal clastics from the Miocene. Basal clastics are rocks with little or no cementation, of different lithology and different grain size. The proper surface of the Carboniferous is irregular owing to differing resistance of rocks to erosion. Overhangs were formed from erosion resistant rocks and downward cuts were formed in weaker rocks, particularly in coal seams, with a depth up to tens of metres /Fig. 1/.

A schematic representation of the areas where the detrital horizon was found is shown in Fig. 2 and a hydrogeological section of Ostrava-Karviná Coalfield in Fig. 3. In faulted zones, a hydraulic communication between basal clastic sediments and the Carboniferous is possible to the distance of hundreds of metres.

In detrital horizon, water is mineralized. In western part of the Coalfield, the bicarbonate type of mineralization prevails with a salinity of 6 to 8 $g . l^{-1}$. In eastern part, the natrochlorite type prevails with the salinity from 5 to 55 $g . l^{-1}$. The gassy component consists of carbon dioxide and methane /CO and CH_4/. Reservoir pressure in water and gas retaining bed attains 8 MPa.

In the Carboniferous, water-bearing or gas-be..ing zones occur in connexion with germanotype faults, dirt bands, weathered zones on the surface of the Carboniferous and with some thick beds of sandstone. These water or gas bearing zones have a thickness from 3 to 10 m, in extreme cases up to 25 or 30 m. They can have their own hydraulic system with a mineralization from 80 to 160 g . l^{-1} or an indirect communication with all the above described horizons.

Owing to the perforation of these horizons by means of development drifts and exploratory drill holes and especially by the effects of coal winning, there is a considerable water inflow into mine workings. The inflow has been measured systematically since 1961. It is evident that the quantities of water inflow are increasing permanently. In addition to it, the proportion of water with little mineralization is decreasing and the proportion of more mineralized water is increasing. An example: in the year of 1978, more than 100.000 tons of chlorites were found in a total of more than 21 million cubic metres of water drained from Ostrava-Karviná mines. The high inflow of water into mine workings affects adversely working environments for the miners. Moreover, if the detrital horizon or a fault interconnected hydraulically with it is perforated in an unexpected place, a sudden outburst of water and gas may occur and create a hazardous situation both for the miners and for further mining operations.

PROTECTION TO MINE WORKINGS SITUATED IN THE VICINITY OF WATER AND GAS BEARING HORIZONS

Such a protection is made in two ways - either draining water from the excavations or at least reducing reservoir pressure, or leaving a protective insulation bed between the excavation and the horizon and eventually reducing the pressure in the water-and-gas bearing stratum.

The possibility of water drainage is given by natural factors /i.e. thickness and dip of water-and-gas bearing bed, its permeability, pressure, gas content, etc./ and by technical and economic factors /access to the bed, method of drainage, pumping capacity, the time needed to attain depression, etc./

In Ostrava-Karviná Coalfield, the following experience with water drainage has been gained:

- If dewatering a greater hydrogeological complex of strata, an advance of 10 to 15 years is needed.

- It is more efficient to dewater erosion furrows than all buried valleys /see Fig. 2/ if there is not a good hydraulic communication between them.

- The quality and the quantity of coal reserves made accessible for excavation must be in a good relation with the cost of dewatering. If not, it is more advantageous to leave an insulation bed under coarse clastic basal sediments.

The first experience with an insulation bed was gained in Ostrava-Karviná Coalfield in the sixties. Such a bed was left in a number of mines and it was proved by the mining practice that it is a safe method of protection both of the miners and of mine workings.

The following conclusions were drawn from a number of cases where reservoir pressure attained 7 MPa, the coefficient of filtration was $5 \cdot 10^{-3}$ cm . s^{-1} /i.e. approximately 4,3 m . day^{-1}/, the thickness of water bearing stratum was 20 to 30 m, the thickness of the insulation bed left for protection was 40 m and exceptionally /over the initial heading in retreat working/ 30 m and the thickness of coal seams varied from 1,2 to 1,5 m:

- In Ostrava-Karviná Coalfield, the use of an insulation bed is a viable method of protection of mine workings. All roads driven in the vicinity must be protected by advance drilling.

- The stability of the insulation bed depends first of all on the lithology of the rocks composing it and on their tectonic disturbance.

- If water inflow into mined area of a coal face is inferior to 0,5 l . s^{-1}, the insulation capacity of such a protective bed left may be considered as satisfactory. If water inflow is from 0,5 l to 3 l . s^{-1}, the insulation capacity of the bed has been reduced considerably. Water inflow over 3 l . s^{-1} means that the effects of the insulation bed are not felt any more and what is in fact made is the dewatering of the area of water bearing horizon over the coal face.

- On the basis of coarse basal clastic sediments, a bed of clay rocks is encountered in some places. Their thickness is from 0,5 to 1 m. The presence of this bed of clay rocks causes considerable decrease of water inflow or prevents it completely.

METHODS USED TO DETERMINE OPTIMUM THICKNESS OI PROTECTIVE INSULATION BED

The purpose of such a bed is to prevent outbursts of water and gas into mine workings and to reduce inflow from the water bearing horizon or to insulate it completely. On the other hand, coal left in such a bed will not be taken out any more. Therefore, the determination of the thickness of an insulation bed is a question of safety and also of economy in view of coal reserves lost.

In 1965, an amendment to safety regulations valid for Czechoslovak mines made it possible to win coal from seams lying under coarse basal clastic sediments in Ostrava-Karviná Coalfield without dewatering them. Since then, on the basis of the results of geologic survey, the thickness of the protective insulation bed and its development in space has been determined geometrically for each individual case. Calculation of the height of the zone of disturbed rocks above the coal seam being worked is made taking into account petrographic characteristics of the rocks, geological structure, mechanical properties of rocks, seam thickness, etc. In Ostrava-Karviná Coalfield, an important circumstance is the presence or absence of the above mentioned impervious bed of clay rocks on the basis of coarse basal clastic sediments, the character of the contact with the Carboniferous as well as the effects of the mining. There is another approach known in the world mining practice, i.e. the determination of permitted longitudinal deformation with a view to geological parameters.

In the first half of the seventies, workers of the Coal Research Institute of Ostrava-Radvanice developed a procedure for the optimization of the thickness of the protective insulation bed left under water-and-gas bearing beds. They built a number of models from equivalent materials. From such model studies, the following conclusions were drawn:

- If undisturbed, Coal Measures rocks are practically impervious, but they loose insulation capacity if they are disturbed with an open fissure. The danger of water and gas outbursts is greater in rocks of a sandy character.

- Longwall faces worked in quasihorizontal strata with na insulation bed left should have a uniform advance. If coal winning is interrupted, the effects of the breaking edge in the coal face must be taken into account.

The method of modelling gives reliable results for the solution of plane problems. But it is time consuming and has a high labour content.

At present, a mathematical model based on finite element method is being developed by workers of Coal Research Institute. In the model, the behaviour of the rock mass exposed to the effects of static loading is simulated. The rocks are described as elastoplastic creeping materials.

As a result of the above mathematical modelling, values of the state of stress in the elements and of strain in nodal points of triangular elements are obtained. From these values and from a set of "discarded" elements /i.e. elements where there was a failure by the effect of the loading/, the height of failed strata overlying the coal seam being mined is determined and the danger of a possible water outburst is assessed.

The results of mathematical modelling were compared with the results of modelling with equivalent materials. A good agreement was found between them. At present, additional measurements of permeability of waste area are performed in several Ostrava-Karviná mines to study the characteristics of failure and opening of the overlying strata. Boreholes drilled from mine workings in the vicinity of the seam being mined are injected with water and the retaining capacity /or permeability/ of the borehole is measured in cubic metres per second. These in-situ measurements will serve for the confirmation of the validity of the mathematical model developed for the optimization of the thickness of the protective insulation bed.

Another problem to solve is to find an objective method to determine what is the distance of the contact of the Carboniferous with the water bearing horizon or the danger of contact between mine workings and a water bearing faulted zone. Up to now, the so called protective drilling ahead of mining faces was applied as the main method for such determinations. It has been proved by the practice that if the contact with water bearing horizon is not a regular one, even three boreholes are not enough to have complete confidence. That is why indirect methods are being developed at present, namely seismic measurements. These measurements are performed by workers of Coal Research Institute in Ostrava-Karviná mines to detect faults in coal panels ahead of mining faces, i.e. only in small parts of the field of a mine. In addition to it, geochemical procedures are being developed. They consist in the determination of gas aureole of water bearing zones and in the determination of alterations produced in coal substance and in rocks.

CONCLUSIONS

For a safe coal winning from seams situated in the vicinity of water-and-gas bearing horizons of Ostrava-Karviná Coalfield, a method to determine the thickness of protective insulation bed left between mine workings and such a horizon is needed. The method must allow for a quick and reliable determination. That is why workers of Coal Research Institute of Ostrava-Radvanice have developed a mathematical model for the physical reality of the situations in the mining next to water-and-gas bearing horizons. Also geophysical methods to detect the contact between the Carboniferous and coarse basal clastic sediments as well as geochemical methods for indirect determination of changes produced in the rock mass under the effects of water and gas bearing horizons are studied.

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List of figures

Figure 1 : Schematic section across the surface of the Carboniferous and tertiary sediments
a/ claystones in the cover
b/ gravel-sand
c/ coarse basal clastic sediments :detritus/
d/ sandstones
e/ mudstone
f/ coal seam

1/ water bearing horizon in Baden
2/ coarse basal clastic sediments
3/ the Carboniferous

Figure 2 : Czechoslovak part of Upper Silesian Basin with schematic representation of the boundaries of coarse basal clastic sediments on the surface of the Carboniferous

a/ delimitation of mining fields of Collieries
b/ delimitation of mining fields of mines belonging to different Collieries
c/ delimitation of fields being explored
d/ section I - I´

A/ buried valley of Bludovice
B/ buried valley of Dětmarovice
1/ erosion furrow of Svinov-Zábřeh
2/ erosion furrow on Michálkovice fault- South
3/ erosion furrow on Orlová fault - South
4/ erosion furrow of Stonava
5/ erosion furrow next to Polish border
6/ erosion furrow of Darkov
7/ erosion furrow on Orlová fault - North
8/ erosion furrow on Michálkovice fault - North
9/ erosion furrow of Vrbice

Figure 3 : Hydrogeological section in direction NE to SW of Ostrava-Karviná Coalfield with delimitation of coarse basal clastic sediments and of Beskydy overthrust mountains. Elevation above sea level is indicated in Balt system.
A/ buried valley of Bludovice
B/ buried valley of Dětmarovice
3/ erosion furrow on Michálkovice fault - South
a/ the Carboniferous
b/ gravel-sand
c/ pelitic cover
d/ overthrust mountains of Beskydy
H_{st}-initial hydrostatic level in coarse basal clastic sediments
H_d- dynamical hydrostatic level in coarse basal clastic sediments in 1979

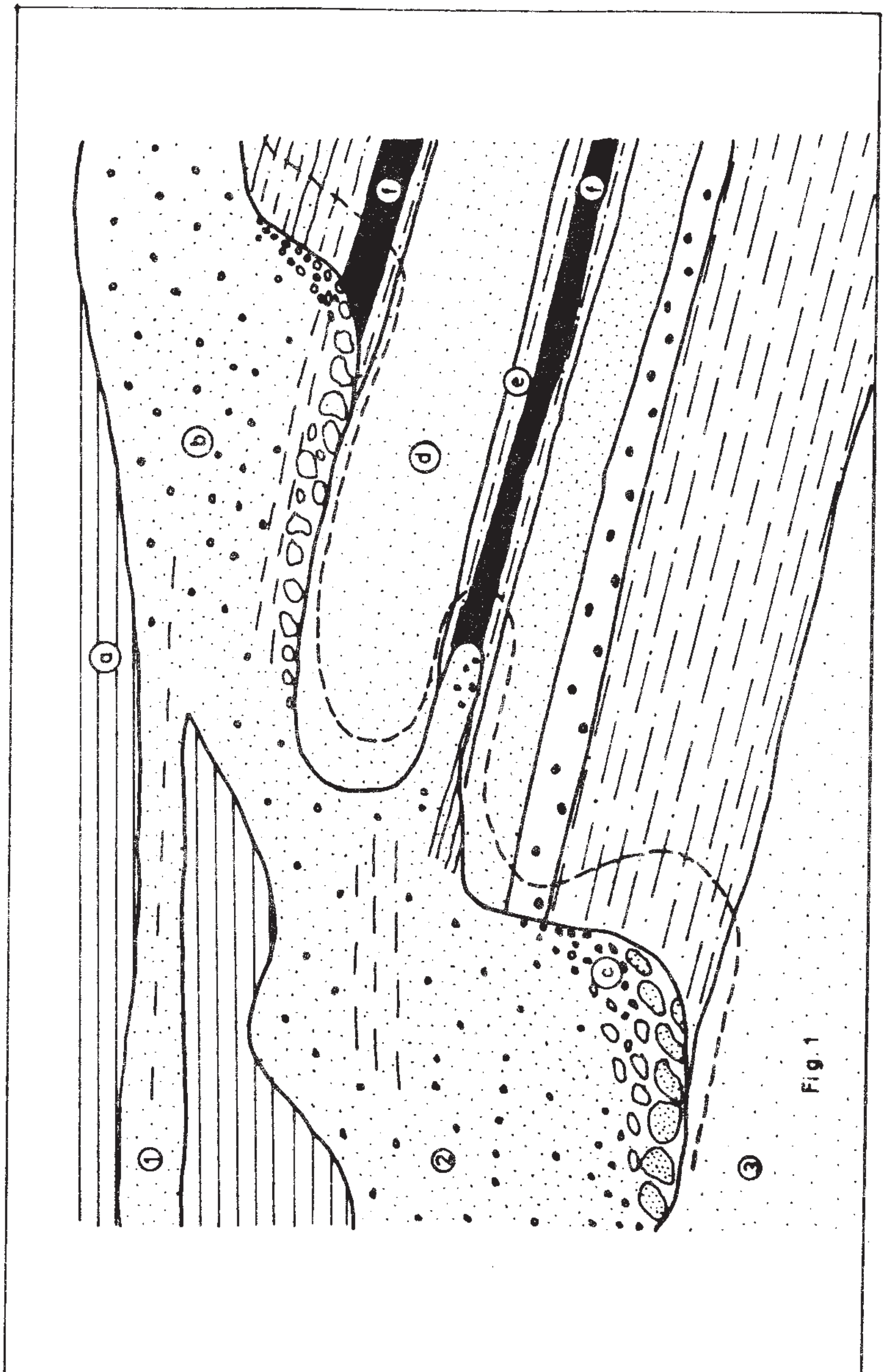

Fig. 1

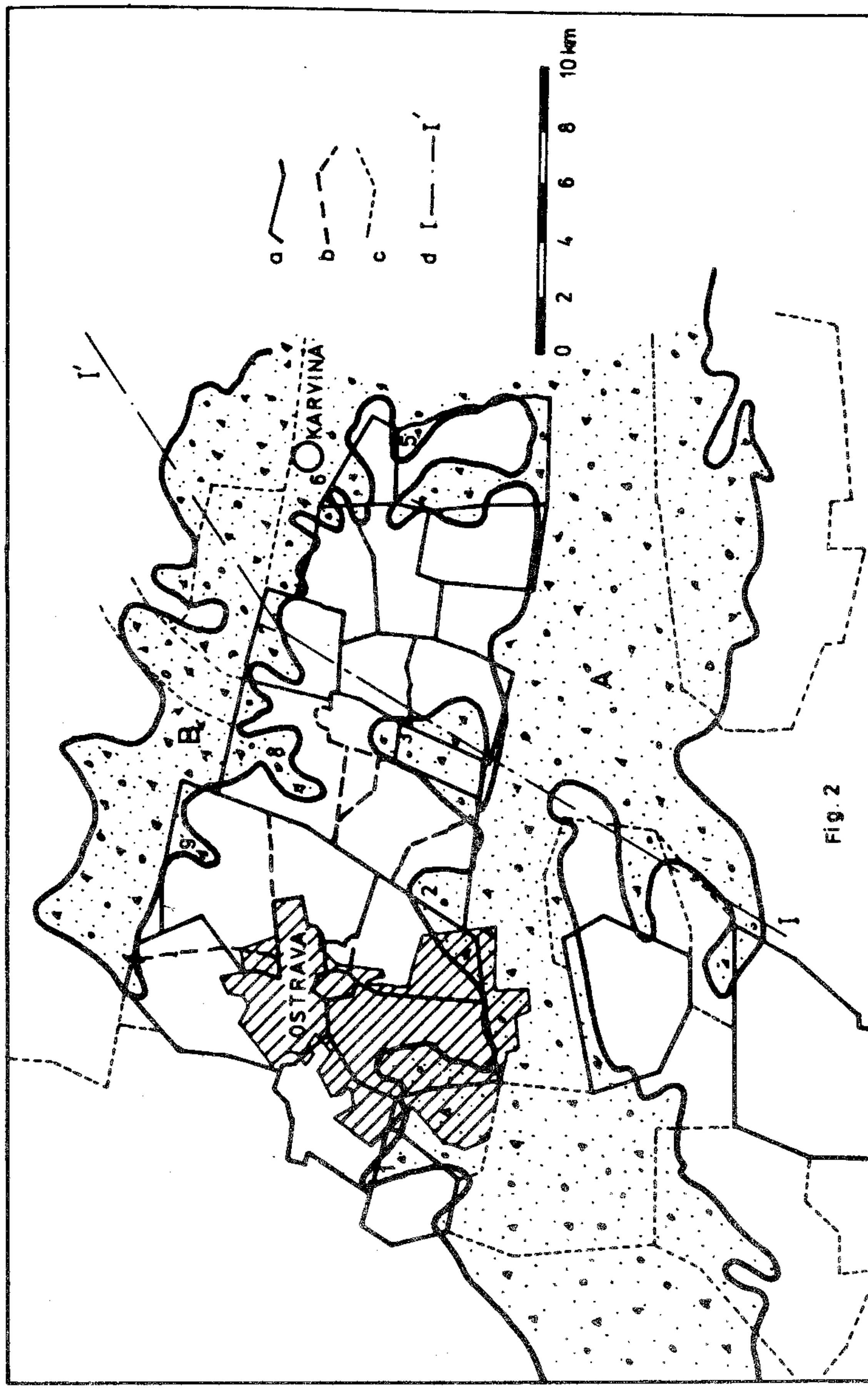

Fig. 2

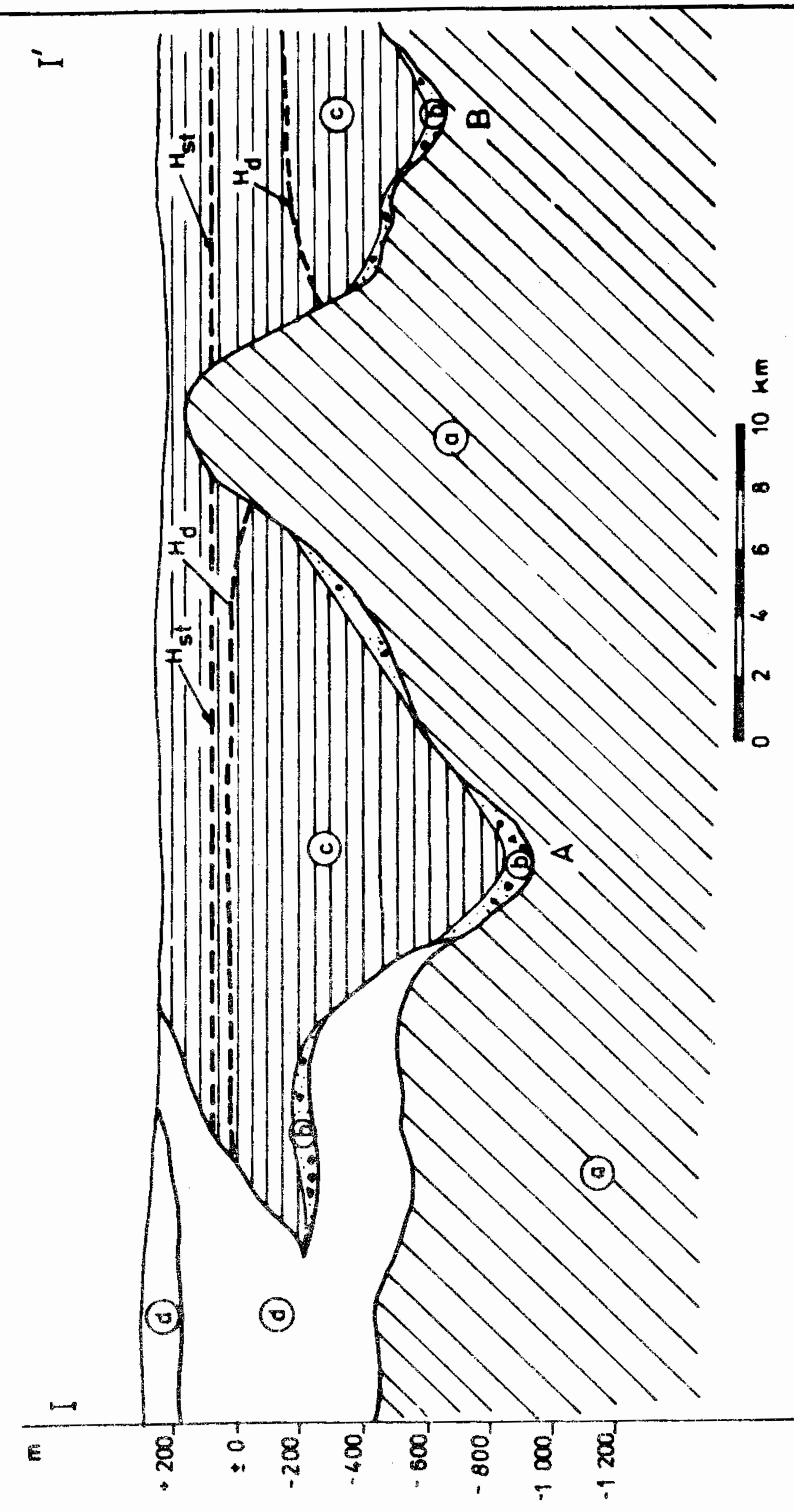
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Fig. 3