PREVENTION AGAINST WATER OUTBURSTS IN UNDERGROUND MINES AND AGAINST POLLUTION OF UNDERGROUND WATERS BY SLAG DUMPS FROM POWER PLANT-TUZLA

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ABSTRACT

The Power plant Tuzla is located within the area of Kreka Coal Basin. The power plant capacities are 780 MW, with a coal consumption of 4,900,000 t/year, and the specific production of slag and ash of 0.4 m^3/MWh, on average, i.e. around 1,700,000 m^3 of slag and ash is produced a year.

The underground mines "Bukinje" and "Dobrnja" are located within the area of existing and anticipated slag dumps. Depending on the development dynamics of mining works and slag dumping, it comes to close contacts between mining workings and the slag storage areas (slag dumps). Because the slag storage area is located above the mining workings, it results in an intensified hazard for the mines which reflects in the following ways:

- intensified inflow of water into the mines, which is infiltrated from the slag dumps;
- potential outburst of water and slag in the mines with collapsing of the roof layers;
- deterioration of the physical-mechanical characteristics of the roof layers due to the presence of water,

with many following effects.

The work elaborates the way how to adapt the slag dumps to the mining works, in a view of safety, prevention against water outburst and hydrogeological aspect of protection against pollution of underground water by the pollution materials from the slag dumps.

GENERAL GEOLOGICAL AND HYDROGEOLOGICAL CHARACTERISTIC OF THE DUMPING AREA

Slag and ash dumps from the Power Plant "Tuzla" are located within the Kreka Coal Basin. This coal basin was formed in lower Pliocene at the southern outskirts of the Panonian Sea. Frequent changes of the sedimentary conditions resulted in specific lithostratigraphic relations in the basin and cyclic changes of various lithologic units. Cyclic deepening and shallowing of the sedimentary basin resulted in replacing of the deeper water sediments (clay) with sediments of the shallow basins (sands), with a characteristic humid phases in the process of forming of the coal deposits.

In principle, there are four major phases in forming of the four coal seams, with clay in the roof and sands in the floor. This principle scheme was locally disturbed during the phase of forming of the fifth seam, partially due to the absence of clay or sands. **Clay** is mainly greasy and mixed with marl, grey-green coloured. **Sands** are of various granulometric features. In the horizontal levels, the sand grading is heterogene, while in the vertical section, as a general rule, big sized sands are closer to the coal seam floor and small sized sands are prevailing in the sections away from the floor.

From structural-tectonic point of view, there is mainly occurrence of compressive forms without faults. The entire basin has a shape of a complex synclinorium with a lot of secondary synclinal and anticlinal structures.

Up-to-date hydrogeological research show that water-bearing sands, located in the coal seam floor, are the basic hydrogeological structures with a significant accumulations of water. These hydrogeological collectors are separated by the impervious seams (hydrogeological insulators) such as clay and coal. Thus, it is identified presence of five separate water-bearing seams (hydrogeological collectors).

Comprehensive research is carried out up-to-date, especially in the sections of basin where the active exploitation of coal is taking place. Furthermore the spatial, hydrogeological, filtration and hydrodynamic features of the water-bearing seams have been explored, since they are a basis for design of dewatering methods and systems. A detailed presentation of these relations is given in some of the previously published works (4th IMWA Congress-Austria) and it is not the subject of this work.

Illustration of the interrelation between the lithologic units is shown in a characteristic section. (Figure 2.)

DUMPING METHODS AND CREATION OF SLAG DUMPS

Slag and ash are inevitable products of the Power plant production. The slag specific production depends on a number of factors (quality of the coal, technology of combustion, etc.). The slag production in the Power Plant-Tuzla is between 0.3 and 0.4 m /1 MWh, on average. For the existing capacities of the Power plant of 780 MWh, and the annual coal consumption of 4.9 million of tons a year, it comes to the amount of 1.7 millions of m^3 a year (1660 m^3 per day). The dumping sites are located in the surrounding valleys, but some of the constraints are to be met. One of these constraints is to bring this action in conformity with the underground mining works in coal, located within the area under the influence of slag dumps.

Transport and dumping of the slag and ash is carried out hydraulically, thus the suspension of water-slag-ash is brought into the sedimentary ground. Ratio water and solid phase is 11:1 (15:1 to 7:1)., thus around 37 m^3 /min of water is used in the open system of circulation. Surplus of water from the dump overflows and empties into nearest water flows, i.e. river Jala.

Prior to creation of a dump at chosen site, has to be built an earth dam, of height up to 12 meters. After that the area within the dam is being filled with slag and ash, with drainage of the surplus water. During this phase the dump presents a water accumulation (hydrotechnical object) with an intense process of sedimentation of the solid materials. When the area is filled up to the top of the dam, the dumping process shifts to another, previously prepared site, and within the first one drainage and consolidation process is then taking place. This mass of slag and ash is porous, with a void ratio n = 0.56, and with a filtration coefficient of $k = 2{,}5 \times 10^{-5}$ m / sek.

After the drainage and consolidation phase is completed, an earth dam is being built for the next stage of dumping. Overall eventual height of such a dump is up to the spot height 282 m (initial spot height is 225-230 m).

The water assumes a number of pollution materials from slag and ash, and carries that further, both to the surface water flows and infiltrates into the sub-surface collectors and mining works. Here is an outline of some of the most detrimental parameters: high pH value, high content of sulphates, hydrocarbonates, calcium and magnesium. It is important to emphasise a high content of heavy metals: lead, cadmium, manganese, chromium and nickel, and possible occurrence of radioactivity, which is still not confirmed definitely.

CHARACTERISTICS OF THE UNDERGROUND COAL EXCAVATION

The shallow parts of the Kreka coal deposits are exploited by the surface mining methods. Deeper coal deposits are excavated by underground mining.

Slag and ash produced in the Power Plant-Tuzla are dumped in the slag dumps located in the valleys of the streams flowing over the deeper parts of the deposits. Underground coal excavation under the slag and ash dumps is related to the mines "Dobrnja" and "Bukinje". The slag dump "Divkovi i" is located at the boundaries between these two mines, and the slag dump "Jezero" is located at the eastern outskirts of the mine "Bukinje" (Figure 1).

Lignite mines "Bukinje" and "Dobrnja" were opened with an incline from the surface, level 227 m, to the horizon at the level 40 m. Development works were completed with the main gate, oriented to the strike of seams, located at the level 40 m, and the airway, at the levels 110 m and 160 m. Haulage system includes chain conveyors in the panels and belt conveyors in the mine fields. Haulage of materials from the surface to the panels is carried out by the hanging rail, containers and diesel hydraulic hanging locomotive. The ventilation of the mines includes the axial-flow fans located in the airways. Dewatering is performed by the centrifugal pumps located in the pump stations at the lowest mine horizon.

Room and pillar method is used in the mines with blasting and caving of the roof layers (Figure 3.).

Mined out areas (cavities of $7 \times 6 \times 6 = 252\ m^3$) are filled by caving of the iimediate roof. The roof of the seam above the stopes collapse, both without control (without blasting) and with control (with blasting of the immediate roof).

Within the area of slug dumps two or three coal seams are being excavated, with thickness between 7 and 17 m. The overall thickness of the seams excavated within the slag and ash dump areas is between 19 and 26 m.

The coal recovery ratio is around 51 %, what causes the subsidence of the terrain beneath the slag and ash dumps in the final phase of consolidation for 7.5 to 11 m.

There are two phases of the roof subsidence process:

- phase of the immediate roof caving
- the immediate roof consolidation phase

During the roof caving phase, the immediate roof disintegrates, with gradual creation of the cavities in the seam, the immediate roof becomes porous and permeable. This phase lasts between 2 and 5 days, depending on the immediate roof thickness.

The consolidation phase of the immediate roof begins upon the occurrence of cavities at the surface of the terrain beneath the slag dumps and it continues for 3 to 5 years. The porosity and permeability of the caved roof is lessening gradually in the consolidation phase.

HAZARDOUS EFFECTS OF THE SLAG DUMPS ON UNDERGROUND MINE WORKS AND WATER-BEARING SEAMS

Mining works in the "Bukinje" and "Dobrnja" mines are located beneath the slag dumps. It comes to very close contacts between the mine works and the dumping areas, depending on the advancing dynamic of the works and the slag dumping. Since the accumulation zone, permanently saturated with water, is located above the mine works it results in increased risks for the mines which reflects in the following ways:

- increased flow of water in the mines, caused by the infiltration from the slag dumps,
- weakening of the physical-mechanical features of the working area, due to the presence of water,
- Infiltration in the water-bearing seam and increment in the level of the underground water in the floor of the coal seam.

Large quantities of water infiltrated from the slag dumps through the disintegrated roof into the mine works endanger workers and machinery in the mines. Water from the slag and ash dumps, passing through the porous roof layers turns it into a mobile liquid clay mass which fills the mine rooms and makes them unoperational.

Water infiltrated through the roof, passes through the stopes, assumes the fine fraction of the coal and takes it to the sump. To enable an unimpeded flow of the water to the sump it is necessary to maintain regularly drainage canals in the mines. The water in the stopes make the excavated coal wet and such a coal has a detrimental effect on the transport means and transport rooms, which results in malfunction of the transport means and transport roads being difficult to pass.

Presence of water makes the coal winning process very difficult due to the problems caused by that for the blasting and loading of mined out coal in stopes, and it requires additional safety means.

Excessive inflow of water into the mine sump affects the process of dewatering, especially if the water carries coal and abrasive materials. A great amount of aggressive water requires installation of specially designed high capacity pump stations.

Special problem and hazard for the miners and equipment in stopes presents the occurrence of liquid clay. This kind of clay files up the mine rooms quickly, it is very hard to prevent its inflow efficiently and promptly, and it can cause closure of a number of mine rooms in the short period of time, sometimes even mine fields or the entire mine.

There are some chemical materials in the water infiltrated from the slag dumps which affects the health of workers and equipment, hence it requires additional safety measures.

If the dip of rooms is irregular water fills up the holes in the floor of rooms and affects passage of the workers, and it can result in occurrence of excessive mine pressures, deformation of rooms and, sometimes, complete closure of mine rooms.

Special attention is to be paid on pollution of underground waters due to the influence of slag dumps. Depending on local hydrogeological conditions, water infiltrates into the water collectors and changes the existing hydrodynamic regime. The water from slag dumps comprises a number of components whose concentration is not in accordance to the standards of drinkable water. Changes in quality of underground water, directions and distance of the transport of pollution materials are the subject of hydrogeological research, carried out for every specific case.

Therefore, there are multiple detrimental influences of the slag dumps on underground mine works, underground waters and life environment in total. Slug dump becomes a consisting part of hydrological systems with connections with each of directions. Figure 4. illustrates the water balance in the zone of influence of slag dumps.

Quantitative presentation of individual elements balance is complex and it is subject of continuos monitoring.

Inflow into the underground mine works and possible outburst of water into the mine depends on a number of factors, especially on:

- Contact area between caved roof layers and slag dump,
- depth of the active mine works performance, which include caving of the immediate roof,
- drainage of the dumped slag.

Previous research, related to the stopes located close to the land surface, shows that the specific inflow into the mines is q = 0.0000186 m^3 /min, and in the following period of coal excavation in deeper horizons it is expected a decreased specific inflow (with increase of infiltration area).

SAFETY MEASURES

As aforesaid, slag dumps have detrimental effects on mining works in many ways. Thus, there are various safety measures based on:

- safety measures in mines;
- preceding dewatering and drainage of slag dumps at the surface;
- prevention and control of pollution of the surface and underground waters.

The water from the slag dumps, located in the vicinity of mining works, infiltrates through the roof layers and put the miners in workings, rooms and equipment in danger.

Basic task of these measures against the detrimental influence of slag dumps is prevention against the sudden outburst of water from the dumps through the caved roof layers into the mine rooms.

- The basic safety measures against such an outburst is choice of pump stations of adequate capacities, with the water dams placed near the pump stations;
- Protection of the mine rooms and equipment against the water is done by design of a proper section and dip of the rooms, including the drainage canals;
- Protection against filling of sumps with solid materials from water. It is done by construction of settling tanks before sumps;
- Protection against the mobile liquid clay is done by construction of wooden dams in stopes and in the stope access rooms.
- Design of workers withdrawal/evacuation plan with carefully designated routes.

Preceding drainage of slag dumps includes drainage of large quantities of water before its infiltration into the caved/collapsed roof layers, water-bearing seams, and mine workings. This is a much more rational method because it saves the energy required for the water pumping and it prevents the aforesaid detrimental effects. However, it is not possible to achieve the complete drainage of slag dumps and to avoid the possible infiltration of water into the mine works with the rational technical measures.

Drainage of slag dumps is carried out in the following ways:

- with the horizontal drainage pipes,
- vertically drilled wells,
- observation wells.

Protection against the pollution of surface and underground waters is a very complex issue, and it is not performed completely in the current conditions. The water circulation system, used for transport of slag and ash, is opened, hence the water from slag dumps inflows into the river Jala, what results in a high degree of pollution of the river downstream the slag dumps .

Demands for protection of waters, as an important component of ecological system, increasingly impose the need for safety measures and control of pollution. The planned measures are:

- Closed circulation systems of waters from the slag dumps;
- Adequate choice of locations for the slag dumps with water impervious layers beneath them;
- Controlled drainage and return of drained water into the closed circulation system.

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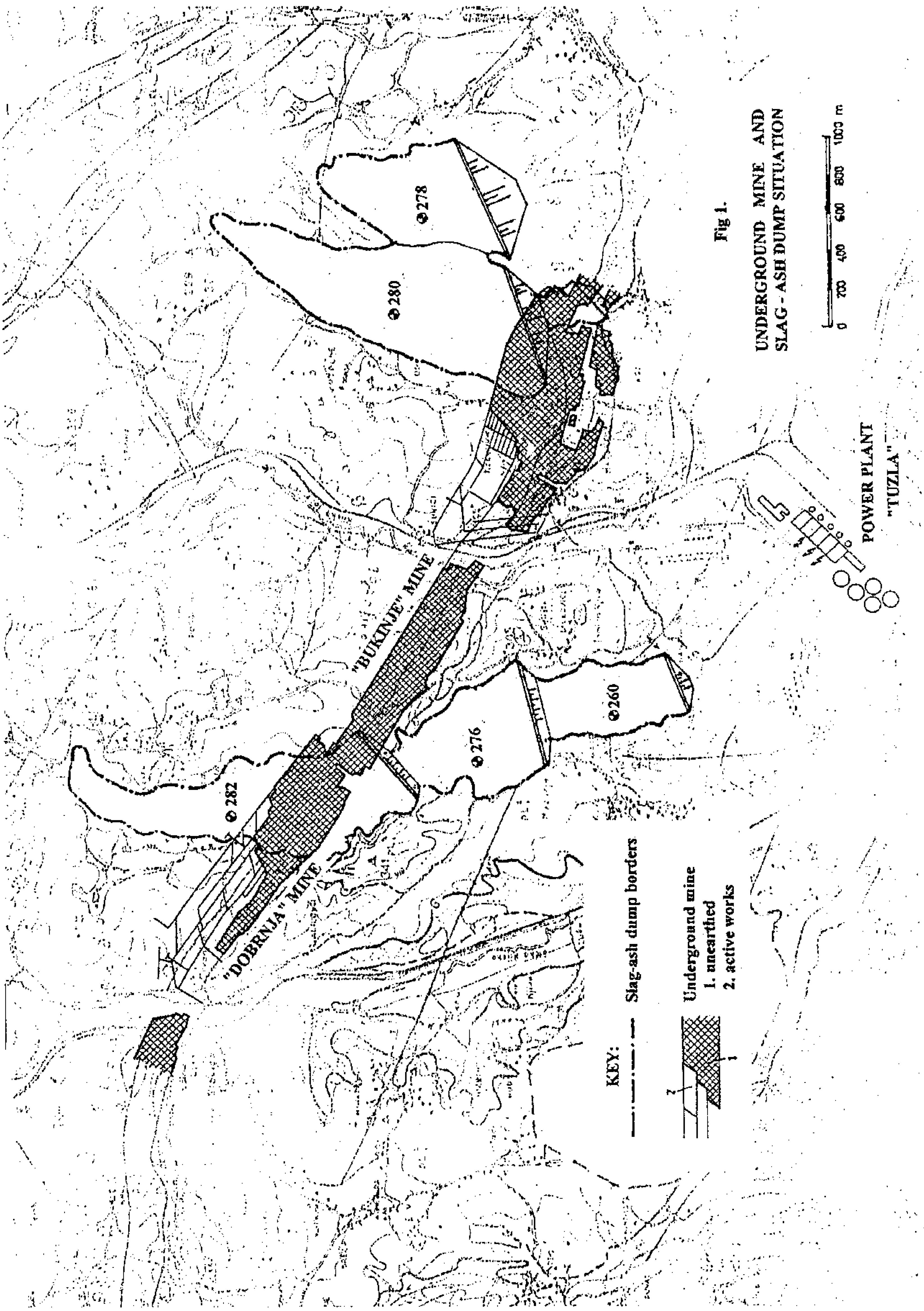


Fig 1.
UNDERGROUND MINE AND
SLAG - ASH DUMP SITUATION
0 200 400 600 800 1000 m
POWER PLANT
"TUZLA"
278
280
260
276
282
"BUKINJE" MINE
"DOBRNJA" MINE
KEY:
Slag-ash dump borders
Underground mine
1. unearthed
2. active works

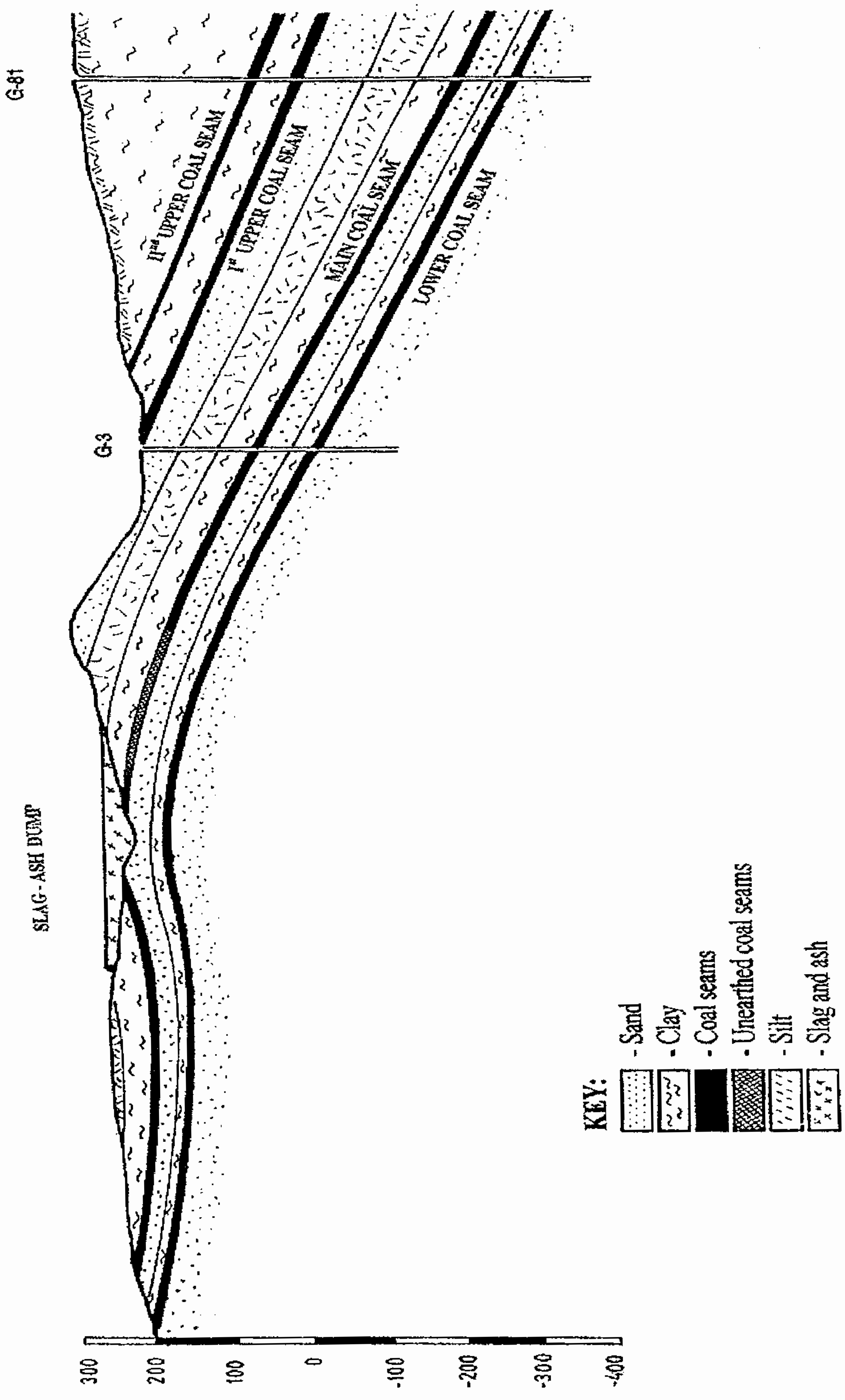
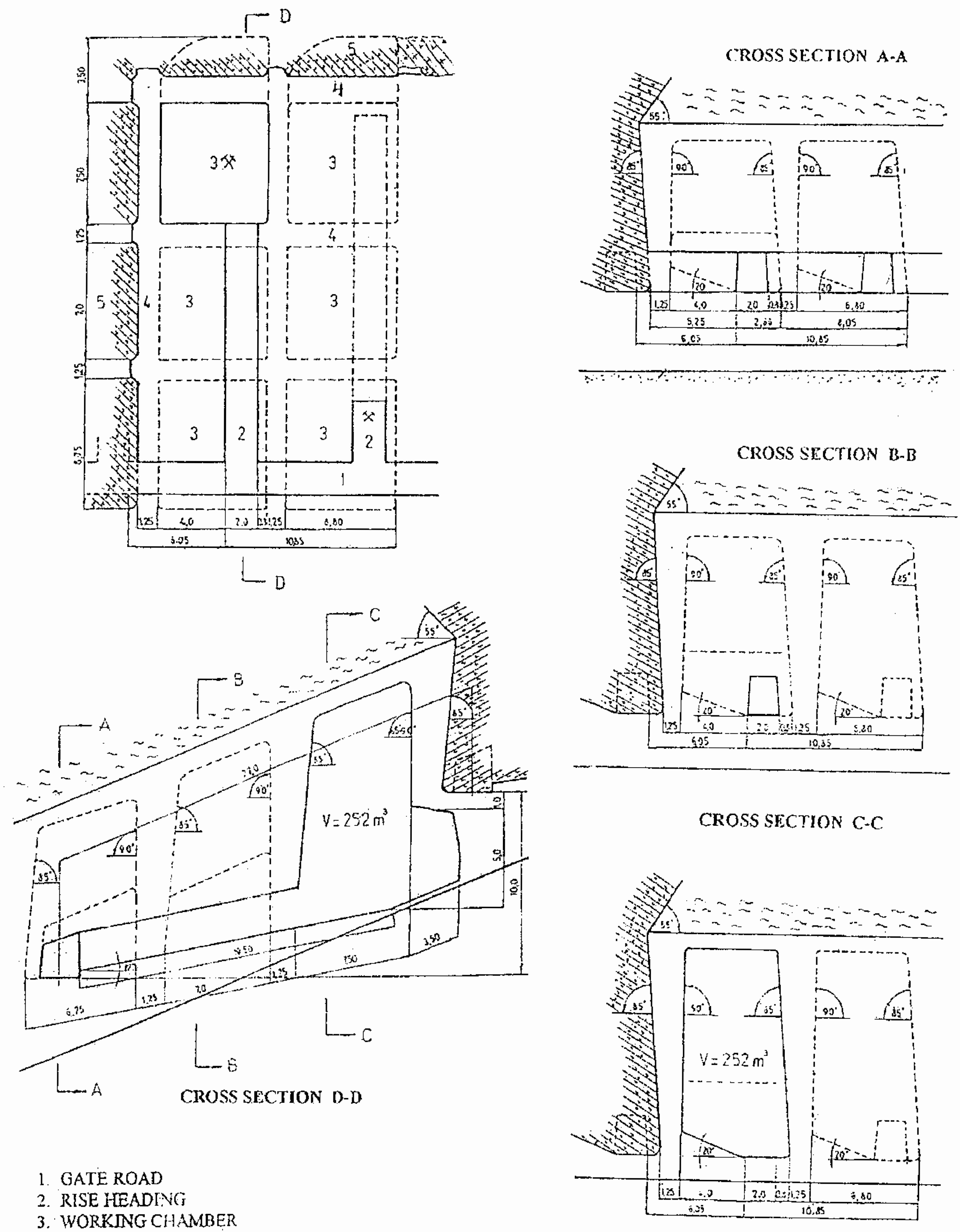


Fig 2.
GEOLOGIC CROSS - SECTION

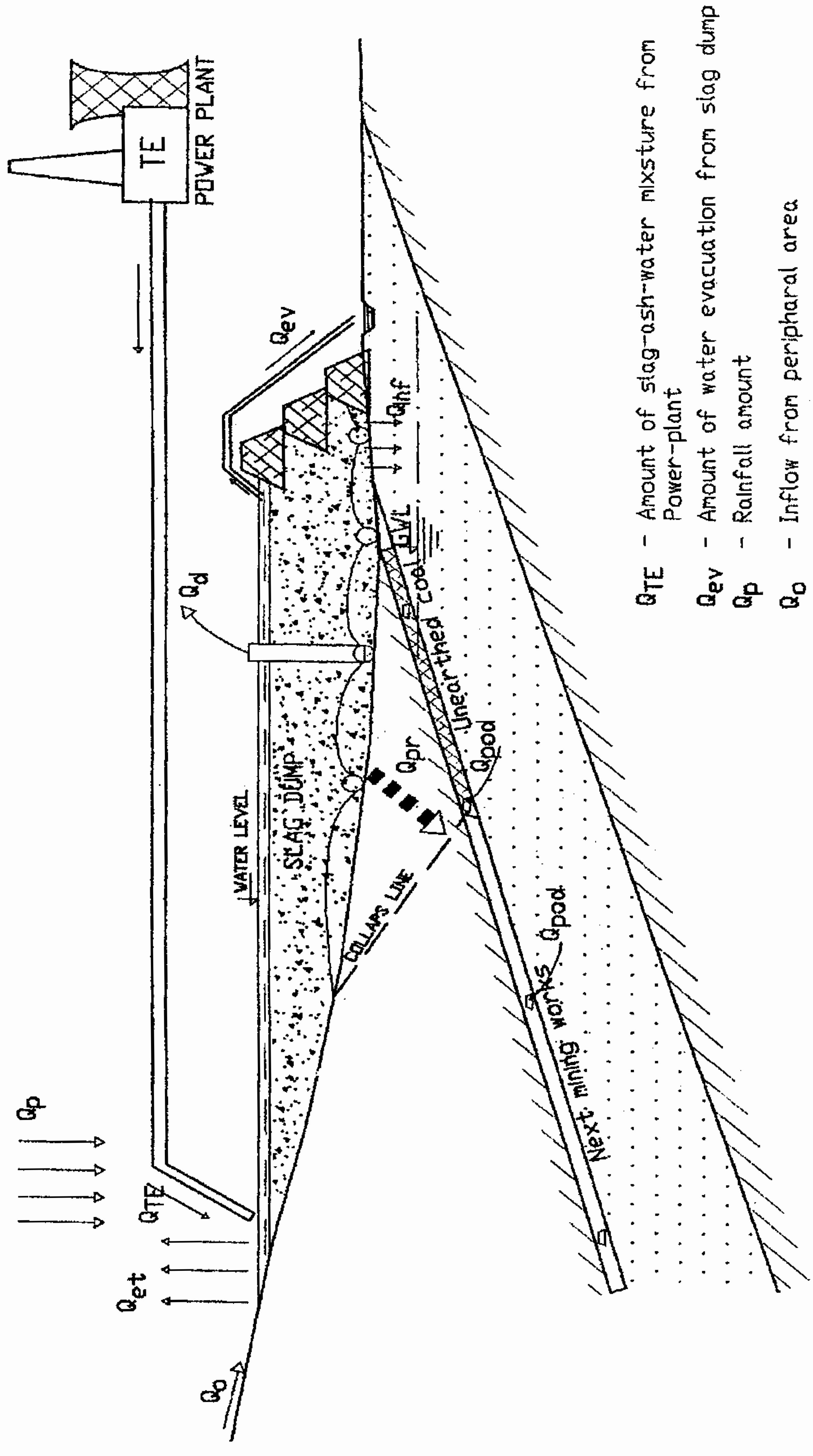


1. GATE ROAD
2. RISE HEADING
3. WORKING CHAMBER
4. SAFETY PILLAR
5. CAVED IMEDIATE

Fig 3.

Lignite Mine "Bukinje" - Mine 2nd Roof Seam

Room and pillar method with caving of roof layers



Q_{TE} - Amount of slag-ash-water mixsture from Power-plant

Q_{ev} - Amount of water evacuation from slag dump

Q_p - Rainfall amount

Q_o - Inflow from peripharal area

Q_{et} - Evapotranspiration

Q_d - Drenage system capacity

Q_{inf} - Infiltration from slag dump into water bearing collectors

Q_{pod} - Inflow to underground mine from water bearing collectors

Q_{pr} - Possible water outburst from slag dump across collapsed over layers

Fig. 4 Water balance sheme