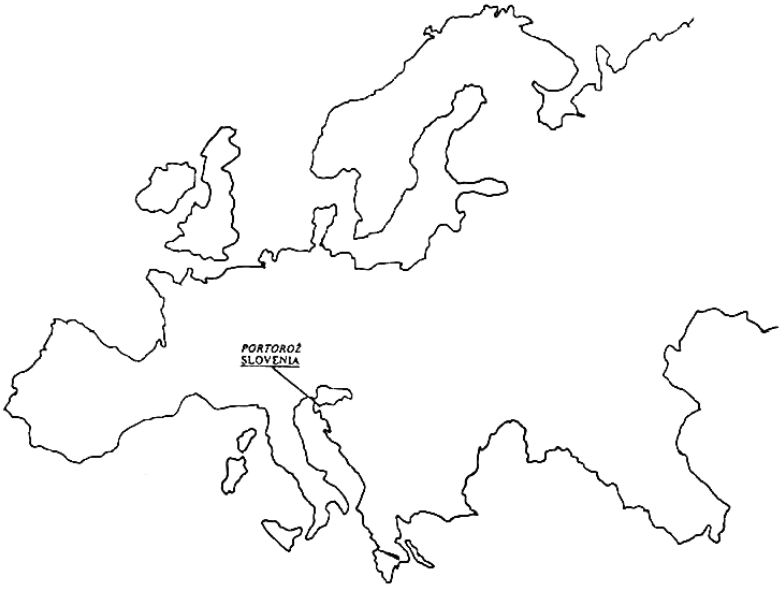
WORKSHOP

ENGINEERING IN KARST



Portorož, Slovenia
September 7 - 9, 1996

During the IMWA 1996 Workshop, fourteen national and international colleagues presented their experience about engineering and mining in karstic regions. The papers presented were not published in a proceedings volume, but handed out to the delegates as paper copies.

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HIGHWAYS AND RAILWAYS IN KARST

by asist.prof.dr. Alojz JUVANC

A great part of our State lies on the karst-land. So we can say that Karst is a typical Slovenian land. It's quite good to see and to know that our people have a special attitude to this specific and very very sensible land. Due to this sensibility the common responsibility for a careful treatment in this land is deeply present. We know that no excuses for the mistakes in land-use are acceptable. The individual mis-actions, like forming rubbish-heaps in the dolines and pits, appears always at dead of night. It shows that even these individuals know very well how bad and wrong their activities are.

BASIC PRINCIPLES FOR CIVIL-ENGINEERING IN KARST

Slovenia has no special regulations for civil-engineering activities and for road and railway constructions in the karst area. It's no doubt that the problems and high sensibility of the karst had great influence to the severity of some articles in new Slovenian regulations for nature environment protection and preservation and for emplacement possibilities. These regulations are extremely strict and introduce also a special location license procedure. We can say that some terms are partially stricter than the European ones.

Each greater earthwork or construction, so as road and railway infrastructure, belongs under the jurisdiction of Ministry of the environment and regional planning, Office for physical planning. In this procedure a special environmental impact assessment is ordered, where all special conditions and demands of a specific land are included. Also the individual ones. All the demands or conditions are treated equally. Instead of terms, conditions and restrictions prescribed in advance in the regulations the possibility of the valuation under specific loco-conditions is given. Appearance of a different problems on each location demands an integral assessment where each impact has its own relative range. It is relative to each location. Loco opinions are involved in this procedure also. The pondus of their impact is different on different locations. This procedure leads to professional decisions and the terms. Where different solutions are usable an agreement is provided. The karst land is no exception. Only the precision of assessment is much higher.

Because of different approach in the field of transport communications we separate:

⇒ railways
⇒ elementary state and loco roads
⇒ motorways

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We don't have much experience in construction of railways. Only a short section from Divača to Koper harbour was built in the sixties. Landscape and environmental impacts are similar to the impacts of highway constructions. We can estimate only that their intensity is lower by railways (width of the cross-profile, stricter traffic control etc).
Construction earth-works on elementary roads are not considerably great. But there exists a constant possibility of spilling of dangerous and poisonous liquids into underground. Here we have some experiences.
Motorway construction, popular named as the Slovene project of the century, appears to be a very demanding one, where everything must be done precisely and consciously. The experiences from previous motorway projects, contemporary principles for environmental emplacement and increased extent of different expertise confirms our belief that motorways will be emplaced with minimum consequences to the environment. We believe that except of microchanges in the relief they will not cause any other problems in the land.
For further talk in this paper the motorway project experiences could be used as typical for construction works in the karst land.

The basic fields which must always be dealt, protected and preserved are (fig. 1):

⇒ restricted regions under authority protection (UNESCO, government etc),
⇒ karst waters (protected by the Water Act)
⇒ natural and cultural heritage (protected by Act and controlled by institution)
⇒ preserving the landscape (sustainable designing)

In Slovenia the region of Škocjanske jame (Škocjan cave) is protected by UNESCO and we wish to get the same protection for the whole region of Triest Karst (classic Karst). Due to that reason the plan for very suitable motorway from Nova Gorica to central Slovenia via Karst (Sežana) was abandoned.
Because of their high vulnerability the karst waters must be treated especially carefully where constructing. Here is no doubt that underground water in Karst must be protected also as drinking water. For this purpose DARS as investor of motorway project issued its own "Directions for dealing with polluted water from carridgeway" where all procedures by designing and all details are given.
The most famous karst phenomena (underground caves, pits, deep dolines, karst springs, ponors etc) are considered as our natural heritage and in rule the designers always avoid to touch them. Only unknown samples rest for later...
Regarding to the fact that the caves were human dwellings in very early historical time the karst region is also the object of archeological research and survey.
It is need in motorway designing that landscape architect would be included in the designer's team to sure the best possible outlook of newly formed slopes. For this purpose we have special Directions and Handbook for roadway landscape sustainable designing (fig. 2). A mistake, we made in past, not including an landscape architect in the design-team, we pay today with reconstruction of road ambient.

It is very important that all this preliminary conditions must be observed in the early studies of possible traces of each motorway. So the corridors could be find which

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entirely or in reasonable range of acceptation ensure the preservation of all values of area, especially in karst.

MOTORWAY DESIGNING ON KARST-LAND

When preparing previous studies it is necessary to collect all data in road corridor. Taking about Karst Slovenia has some advantages because her karst is well researched and literature is rich. All the merits go to the Institute for karst research from Postojna.
This enables us to fulfill all above mentioned basic principles when designing. Additional research of main karst inlets is needed to assure the flow of underground water would not be polluted with roadsurface water. Mostly all important elements of the karst we can save. Optimal corridor normally avoids all greater karst caves and other karst phenomena. Smaller caves and dolines we estimate as less important.

When finalizing the design, all known dolines in the corridor must be well researched and mapped. Their characteristics must be found out to predict and planned proper technical sanation. In this phase underground caves, which as a rule have narrow entrances and they widen in their depth, can be found only by chance with drillings. All dolines, pits and caves can not be previously detected with observation of terrain. Even detecting with geoelectric method is not efficient because the emptiness of cavern can not be defined. Georadar is more efficient but practically useless because the vehicle and attached device can not drive on the rough ground. Impermeable soil layers are additional problem for radiological detection. In the phase of the designing they aren't removed yet.

That's why in the design only type of bridging and filling of the dolines and the caves (fig. 3) as well as estimated costs are given. Normally the estimation of costs is always to low.
Dolines and pits always demand cleaning and bridging with concrete cover or compound rocks. Caves need the mining of cover layer, excavation of mined material and filling in layers to achieve sufficient comprimation of filled material and to avoid later deformations of surface.

Usually many of dolines, pits and caves are found later in the phase of earthworks. To assure proper decisions when constructing the design must foresee the control of the designer, the investor and the experts for karst phenomena and the costs for their work. It is very important and it would be obligatory in previous designs.

Besides problem of saving karst phenomena the designer have to consider some other important characteristics of karst ground as:

⇒ higher specific drain of groundwater (3 to 5 times larger as normal one)
⇒ great sensibility of karst waters (controlled collecting and releasing of roadsurface water by using special ditches and oil separators if the outlet is designed into open spill)

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⇒ a total protection of a single section of motorway against polluted water from roadsurface, where motorway passes the area which has direct flow connection with underground river (watertight canalization leading out of hazardous area)

⇒ to avoid appearance of floods caused by choking the natural inlets or because of damming the area with an embankment

⇒ to foresee proper biotechnical protection of slopes because there is usually not enough humus available

⇒ agromeliorations as a substitution for ruined fertile ground

THE CONSTRUCTION OF MOTORWAY ON KARST-LAND

The constructors of motorways on karst land as a rule face with a lot of unpredictable works, which they must do to assure the stability of the roadbody itself, to protect workers and heavy mechanization from collapses on the trace. The density of dolines might be quite great (fig. 4).
So the first need on the constructing ground is to assure constant monitoring and expert control.

After cleaning of vegetation and of cover layer of soil the terrain must be carefully inspected. A special attention must be given to the underground caves. On terrain surface only its narrow entrance can be found. If when revising the trace we do not discover the hidden narrow entrances into caves. They are discovered later at drilling, mining or when its ceiling collapsed under the weight of heavy mechanization.
All dolines, pits and caves must be marked in place.

Larger dolines are seen as funnel-shaped holes, more or less covered with humus, loam, silt, weather layer and drifts materials brought to it by wind and water. The thickness of all drifts can reach also 10 or more meters. Smaller dolines are mostly always fully filled with weather layer and are hardly noticeable.

Before starting earthworks the dolines and pits must be cleared. After excavation of eroded material and drifts the surveying of dolines must be executed to fulfill the demand to map the dolines into the register of dolines (fig. 5).
When an underground cave is found it is necessary to survey its entrance, to measure the dimensions of its interior and to enlist it into a cadaster of underground caves. The underground caves which are separated from the surface of terrain only with a thin covering layer of stone are the most demanding ones. To assure the protection by earthworks this relatively thin stone layers must be removed by mining in a conic shape to enable further earthworks.
It is necessary to continue the observation during cut-works.

When dolines, pits or caves are located on the ground where dam is provided to execute a special procedure is to be followed. By mining collapsed material must be excavated out of the caves. Then the decision about type of bridging and filling of dolines and caves has to be done (fig. 6). Such a decision can be taken only by a

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monitoring expert and investor's accordance. After bridging the outlet of a doline, a pit or a cave with concrete cover or compound rocks the hole is filled in layers with stone material. The fill must be done properly to achieve the comprimation demanded to enable the conditions for solid construction of dam or pavement over it (fig. 7). It is to underline that full comprimation of the filling is restricted by borders of cave. The settlement must be controlled. A special report of these works is demanded (fig. 8). The final improvement is performed only just before the continuation of the works as dam or as pavement construction. It is advisable the entire trace is continuously controlled by georadar (fig. 9 and 10). Even then some hidden caves could be discovered.
It is to observe that in spite of strict control minor collapses appeared on the construction on the motorway section near Divača where a carriageway was already finished.

The constructing on karst land demands a special and additional constructor attention. The storage of fuel and oils and the depot for heavy mechanization must be planned and maintained to prevent pollution. The situation on the construction section must be constantly inspected and monitor currently informed.

THE EXPERIENCES FROM CONSTRUCTION GROUND

The first motorway from Vrhnika to Postojna, on the karst ground, was being built from 1970 do 1972. All special characteristic of the karst land were considered already at that time. Because of the crossing of an area with the extremely expressive underground river Javorniški tok a controlled collecting of roadsurface water and road outlet were carried as along as 7 km. Inside this section at the length of 1,5 km the roadsurface water was channeled into special collectors which should have prevented the pollution of underground river in case of heavy accidents of vehicles carrying hazardous liquids.

When constructing the last section at Divača which passes very close to Škocjan caves there additionally appeared uneasiness that by mining on the trace the great wealth of the caves might be damaged. Therefore a special observatory was set to control all impacts and to measure the seismic. In spite of being very close no mining influences were detected.

The sanation of dolines and caves is a great burden. Financially for the investor and timely for the contractor and the investor. The dimensions of dolines and caves and their character are never known. It is necessary to dig out a great quantity of useless soil and the transport of this material is very demanding. The "walls" of dolines are usually very steep and special transport ways are needed to construct. The quantity of fill material is great. In such conditions also time planning is a hazard. The only positive is that climatic conditions have practically no impact by executing the earthworks in stone material.

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It is essential for the construction of motorways in Slovenia that all typical phenomena and events when constructing are registered, filmed and photographed (fig. 11). Such material will help at later constructions and they will enrich also our motorway museum which is planned to be open.

To summarize :
motorways construction on karst-land can not be a taboo and with proper access it doesn't cause any greater damage. The construction itself is relatively easy. It is essential that in our projects the amount of additional and sanation works because of karst phenomena is underestimated. The karst-land always brings surprise. In such cases all the surprise goes to the investor because of higher expenses and to the constructor because of the delay which burdens him.

It is the most important to know that all carelessness at work in this land causes great vengeance with incorrigible damages.

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The basic fields

which must always be dealt, protected and preserved already in early studies for emplacement of infrastructure object:

⇒ **restricted regions under authority protection** (UNESCO, government etc) like natural parks, objects of extra value, clear and mineral water areas etc.

⇒ **clean water** (protected by the Water Act)
like avoiding to get dirty water from carriegeway, to assure unbreaked flow, special protection of underground water in karst,

⇒ **natural and cultural heritage** (protected by Act and controlled by institution) like karst phenomena, waterfalls, pre- and antic settlements, canyons, historical points, churches, urban areas etc.

⇒ **preserving the landscape** (Handbook and Directions for landscape design) like sustainable designing of slopes and structures, avoiding to build extra dominant structures, preserving trees and forests, preserving existent riverbeds, to avoid to feel deep canyons, to find proper and designed location for cut-material storage, to assure enough passes for wild animals etc.

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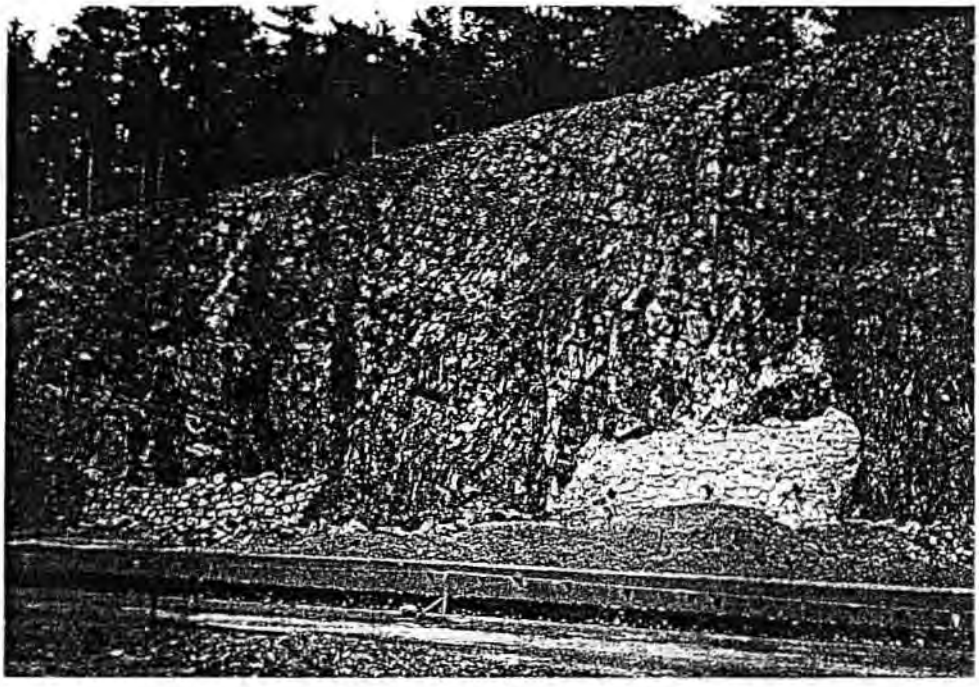

Tipical slopes in cut - Motorway Razdrto - Divača
photo by DDC 1995

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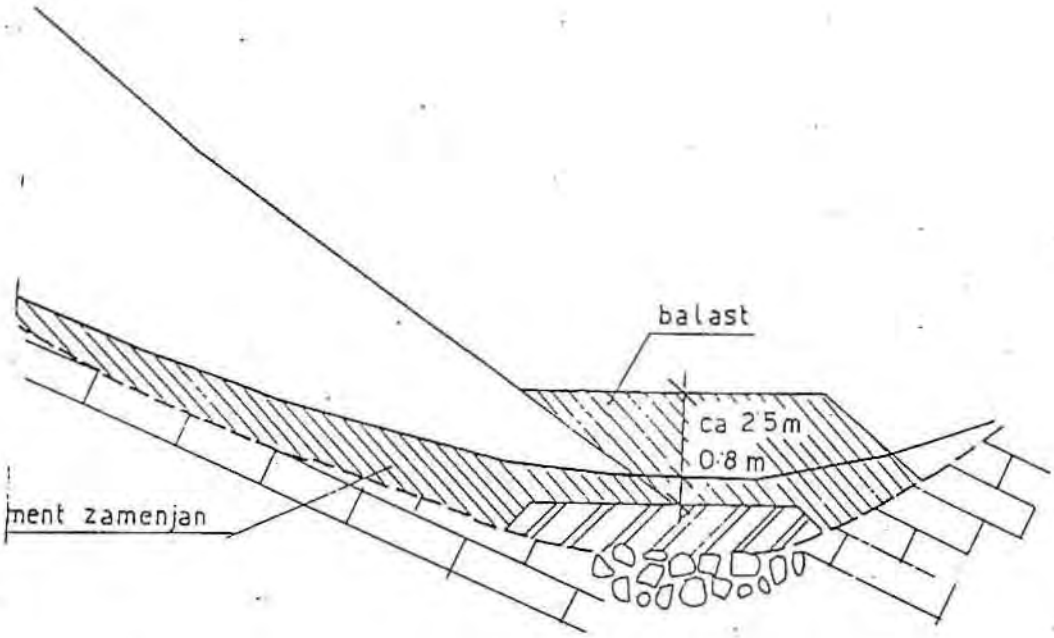
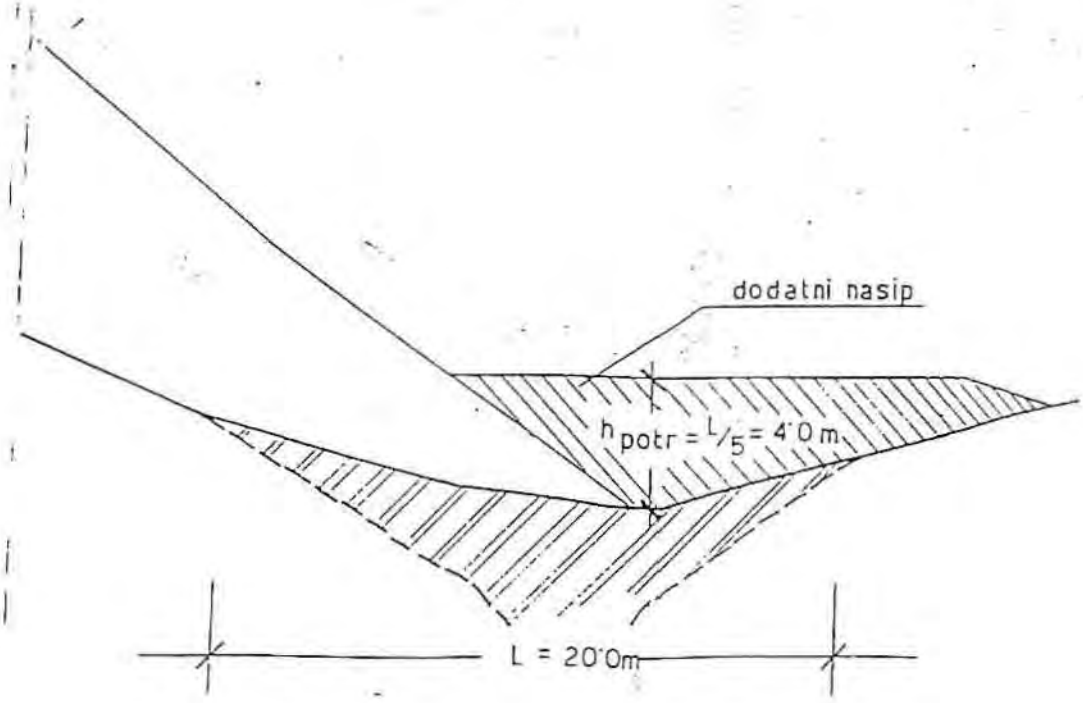
Rešitev III a



Rešitev III b



Types for the bridging and filling of dolines and pits
by ZRMK 19

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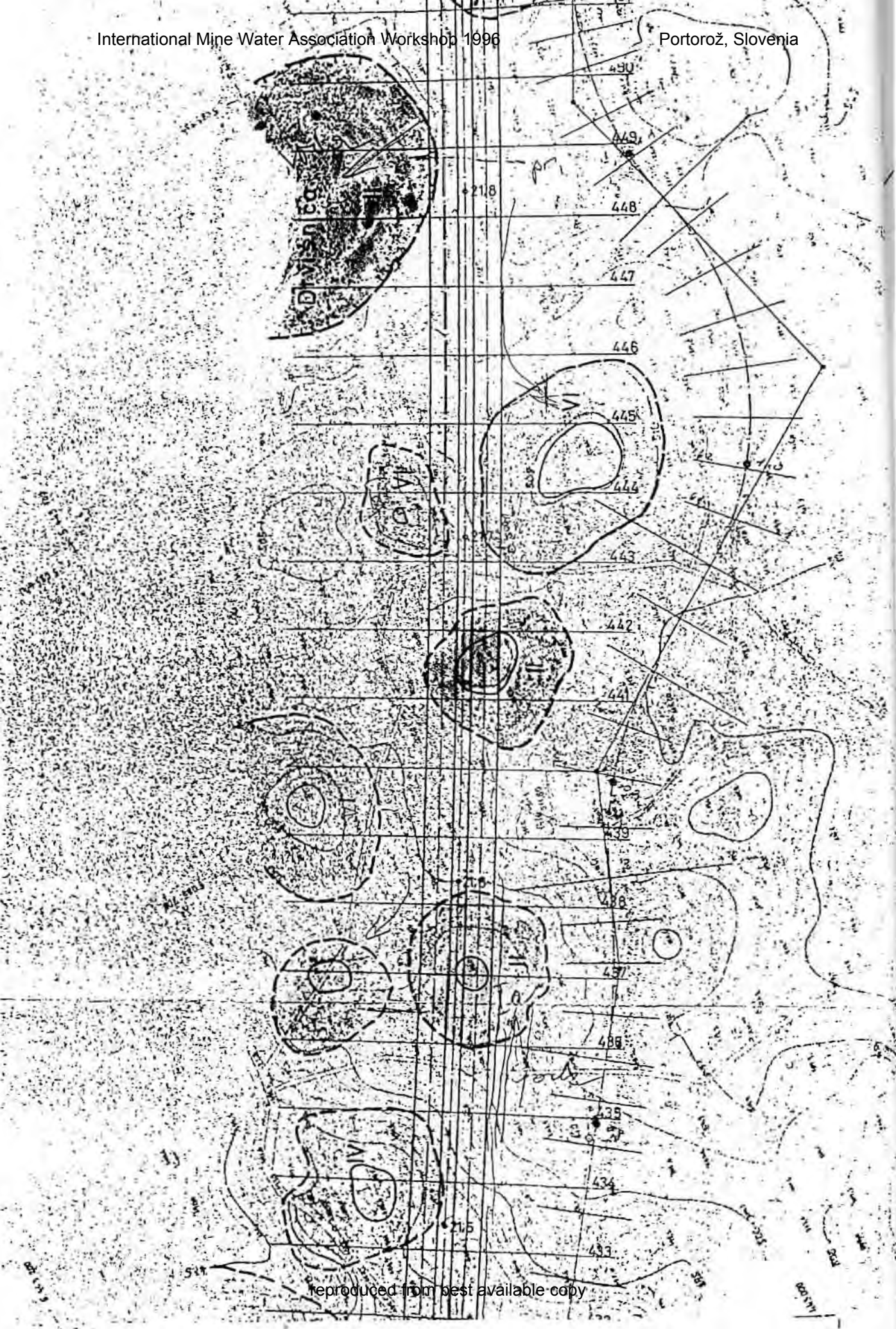

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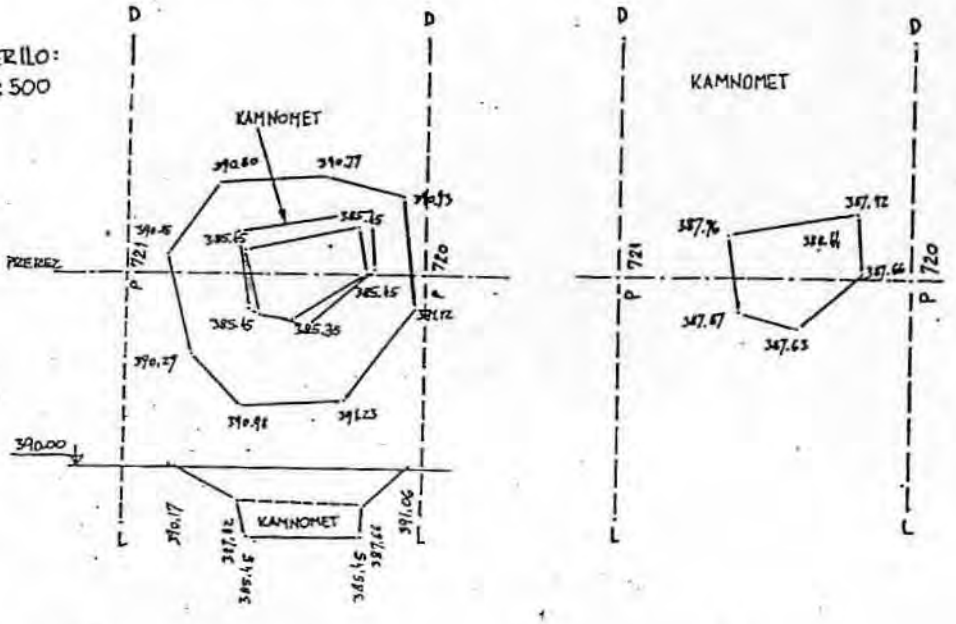
kraški zidar

Splošno gradbeno podjetje p.o.
SEŽANA

OBJEKT: AC DIVAČA - DANE km 14.300 - km 18.250

PRILOGA DNEVNIKA O IZVAJANJU DEL ŠT. .....

Ugotovitve,navodila,sporočila in pripombe nadzornega organa,odgovornega vodje del izvajalske organizacije,odgovornega projektanta in organov inšpekcije (spremembe tehnične dokumentacije,odvzemanje vzorcev za preiskavo gradbenih in drugih materialov,prevzem armature,razične skice in podobno).



NASIP:

POVPREČNA VIŠINA ZGORNJE PLOSKVE JE : 390.78 m
POVPREČNA VIŠINA KAMNOMETA JE : 387.88 m

PLOŠČINA ZGORNJE PLOSKVE JE : 196.45 m^2
PLOŠČINA KAMNOMETA JE : 49.91 m^2

$\frac{196.45 + 49.91}{2} \cdot 2.90 = 357.22\ m^3$

KAMNOMET:

POVPREČNA VIŠINA KAMNOMETA JE: 387.88 m
POVPREČNA VIŠINA SPODNJE PLOSKVE JE: 385.43 m

PLOŠČINA KAMNOMETA JE : 49.91 m^2
PLOŠČINA SPODNJE PLOSKVE JE: 32.60 m^2

$\frac{49.91 + 32.60}{2} \cdot 2.45 = 101.07\ m^3$

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Izračunal:

Bridging the dolines - above: doline with great vertical spill
bellow: doline with small side spill
photo by BDC 1996

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Filling of cleaned dolines must be proper
photo by DDC 1995

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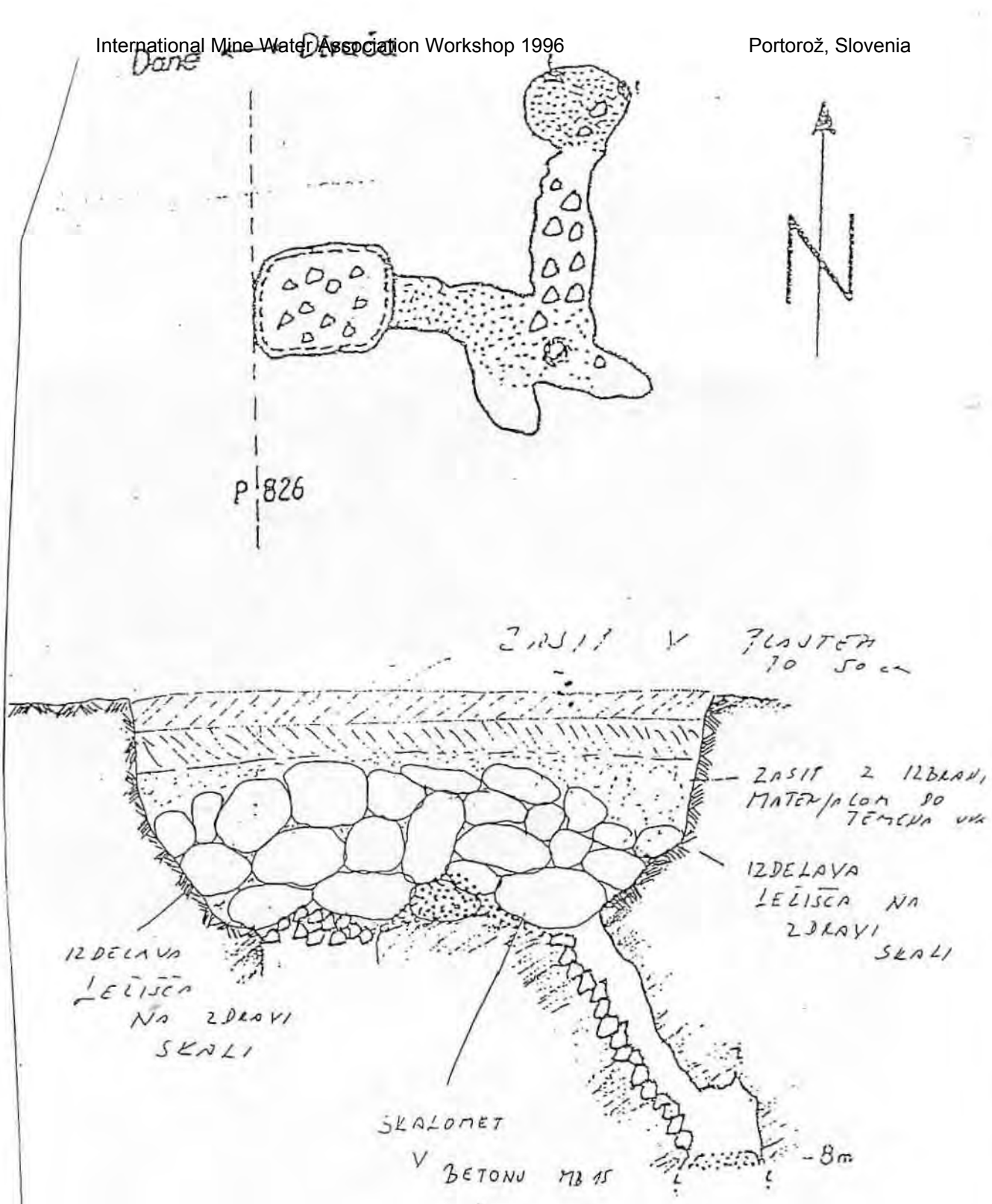

Report of bridging and filling of a doline by Kraški zidar 1994

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Georadar device
photo by DDC 1995

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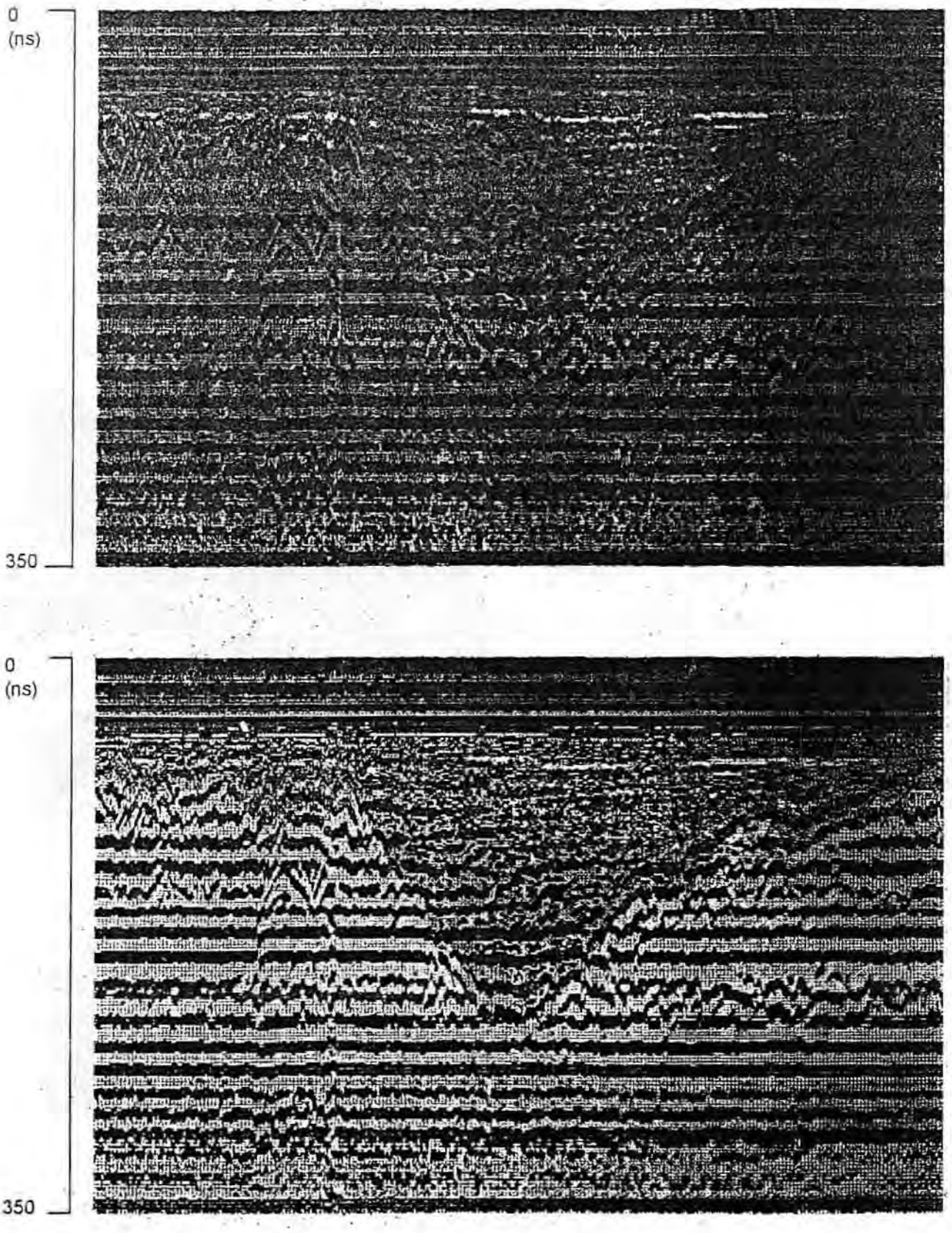

Data-processing: GPR profile unprocessed (above) and processed (below); low velocity (red) and high velocity (green) levels

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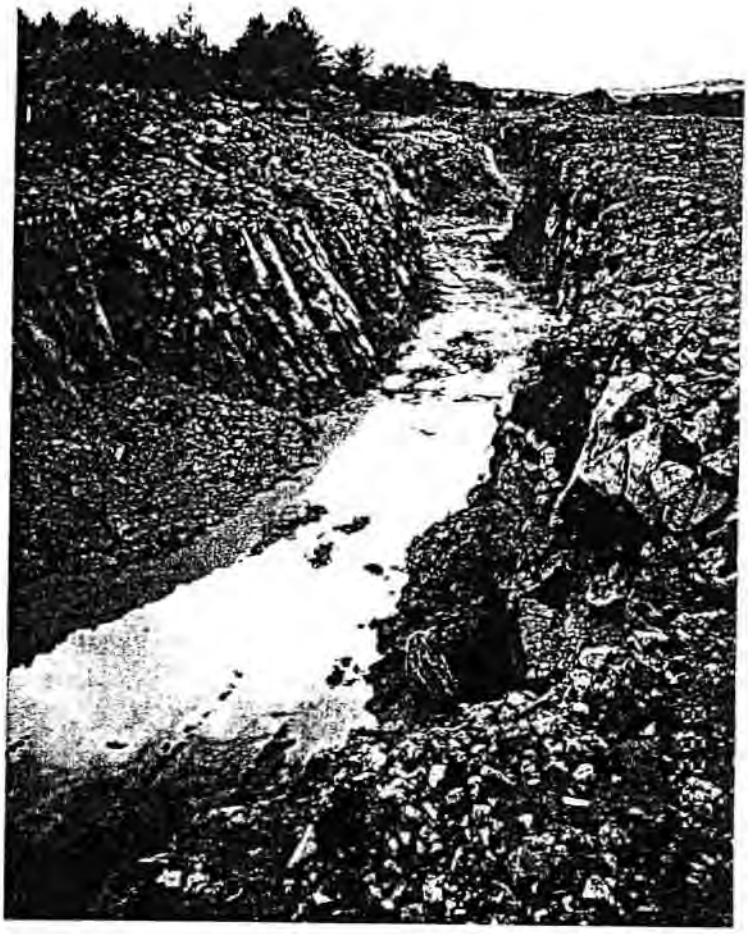
Underground riverbed with typical colour of the underground soil covered by the ceiling of collapsed cave

photo by DDC 1996



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