STRIPA PROJECT 83-04

Buffer Mass Test – Site Documentation

Roland Pusch
University of Luleå and Swedish State Power Board

Jan Nilsson
AB Jacobson & Widmark, Luleå

October 1983

INTERNAL REPORT

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STRIPA PROJECT

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SUMMARY

The purpose of this report is to compile test site data that are assumed to be of importance for the interpretation of the Buffer Mass Test. Since this test mainly concerns water uptake and migration processes in the integrated rock/backfill system and the development of temperature fields in this system, the work has been focused on the constitution and hydrology of the rock.

The major constitutional rock feature of interest for the BMT is the frequency and distribution of joints and fractures. Earlier investigations by Lawrence Berkeley Laboratory offer comprehensive fracture data which are sufficiently detailed for BMT purposes with respect to the interaction between the rock and the tunnel backfill. However, the development of models for water uptake into the highly compacted bentonite in the heater holes requires a very detailed fracture survey. The present investigation shows that two of the holes (no. 1 and 2) are located in richly fractured rock, while the others are located in fracture-poor to moderately fractured rock.

The hydrologic conditions of the rock in the BMT area are characterized by water pressures of as much as 100 m water head at a few meters distance from the test site. The average hydraulic conductivity of the rock that confines the BMT tunnel has been estimated at about 10^{-10} m/s by Lawrence Berkeley Laboratory. The actual distribution of the water that enters the tunnel has been estimated by observing the successive moistening after having switched off the ventilation, and this has offered a basis of predicting the rate and uniformity of the water uptake in the tunnel backfill. As to the water inflow into the heater holes the detailed fracture patterns and various inflow measurements have yielded a similar basis.

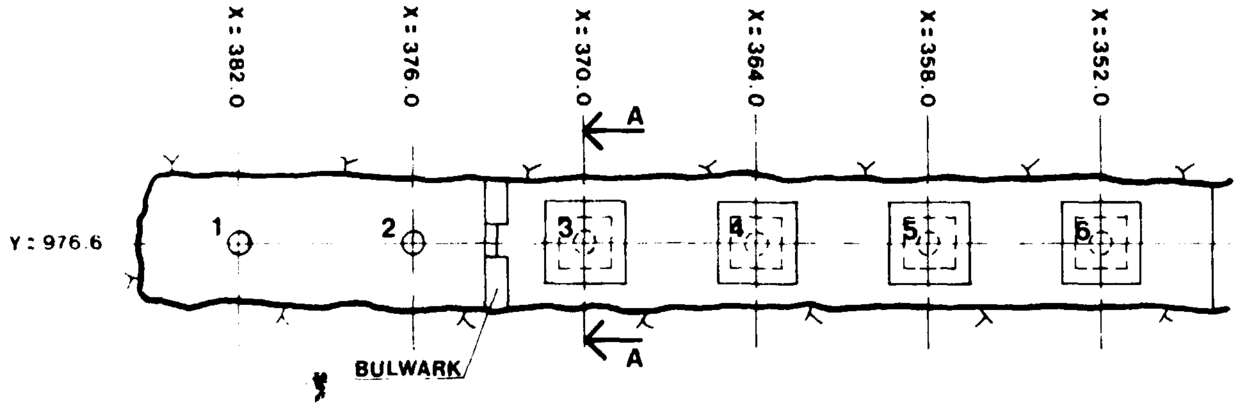
The report also gives major data on the rock temperature, gas conditions, mineralogy, rock mechanics, and groundwater chemistry for BMT purposes.

INTRODUCTION

In the course of the preparation of this report it became obvious that a huge material is available for site documentation from various sources, particularly from a number of careful and comprehensive field tests ran by the Lawrence Berkeley Laboratories California, USA, in conjunction with earlier Swedish-American joint ventures in the Stripa mine. For the sake of clarity and in order to make the present report handy for BMT purposes, only really essential data for this test have been compiled here. Thus, mineralogic and petrologic reporting as well as information of geochemical properties will be very sparse, while fracture mappings and hydrologic surveys are given considerable space.

1. SURVEYING

The BMT area was abandoned by the Lawrence Berkeley Laboratory (LBL) in October 1980 and the first measures to prepare for the buffer mass test were taken a couple of weeks later. These activities involved removal of some LBL installations and application of reference bolts for measuring purposes, as well as running a comprehensive measuring program for all the planned drilling operations /1/. Figs.1 and 2 serve as general layouts of the BMT test tunnel, and of the main reference system, respectively. The location of all constructions and measuring units are referred to this system throughout the test.



HORIZONTAL SECTION
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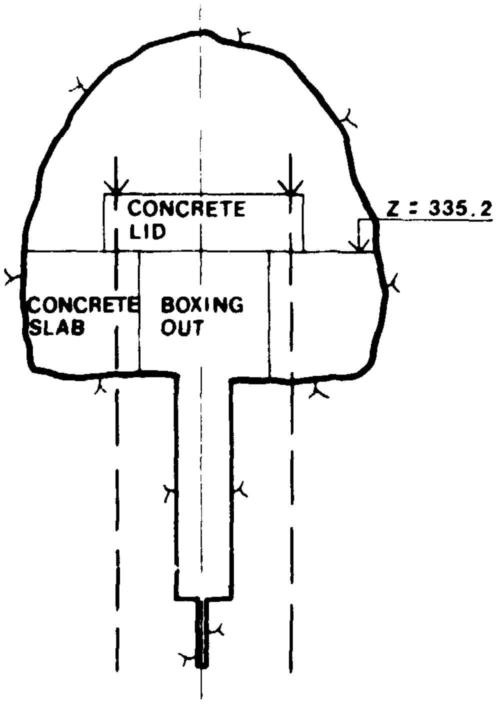

A CROSS SECTION
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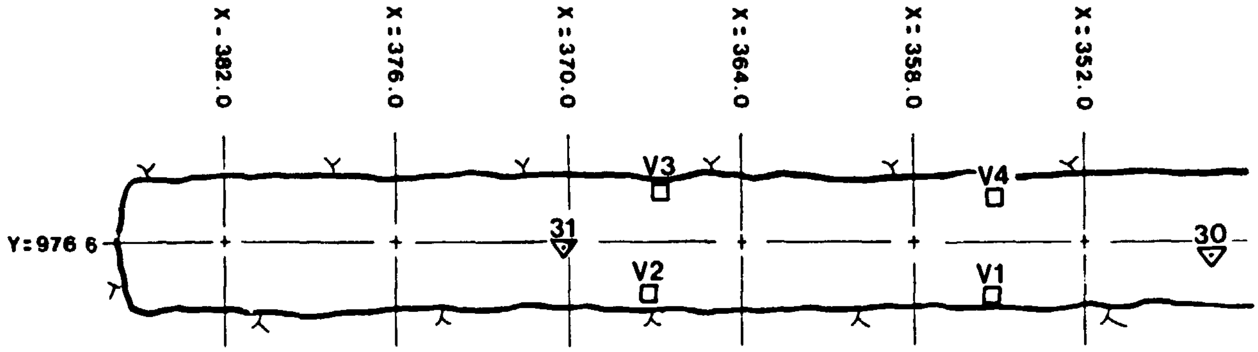
Fig.1. Schematic sections through the BMT tunnel.



LEGEND

□ POLYGON POINT

▽ FIXED POINT (LOCATED IN THE ROOF OF THE TUNNEL)

POLYGON AND FIXED POINT COORDINATES			
Point No	X (m)	Y (m)	Z (m)
V1	355.346	974.651	
V2	367.283	974.827	
V3	366.932	978.256	
V4	355.271	977.917	
30	347.627	976.281	332.408
31	370.106	976.414	332.246

Fig.2. Location and coordinates of polygon and fixed points.

2. TEMPERATURE CONDITIONS

The average rock temperature in the mine has been found to be in the range of 10 - 13 °C at the depth where the BMT tunnel is located. The "Macropermeability Test", which preceded BMT in the same place, involved heating of the tunnel to 20, 30, and 45 °C in different tests lasting for somewhat less than one year. After a fourth test at 20 °C, the ordinary ambient air temperature 15 °C prevailed for a few months before the installation phase of the BMT started. The rock temperature had then dropped to 12.5 - 13.0 °C, which can therefore be taken as the initial temperature of the buffer mass test.

The test area has been ventilated throughout the test by which the air temperature was maintained at approximately 15 °C and the relative humidity at about 65 - 75 %.

3. GAS CONDITIONS

Gas was noticed in a number of boreholes, particularly in some of the Ø 76 mm LBL holes that extend from the BMT tunnel. These holes, which will be discussed in some detail in Chapter 5.2.1, were equipped with gas-operated packers that had probably been leaking nitrogen gas into rock joints extending tens of meters from the holes for quite a long time. It is anticipated, however, that the deflating and replacement of the original packers ultimately led to a high degree of water saturation of joints and fractures before the BMT backfilling operations started.

It should be mentioned that radon emanates from the rock to an extent that requires continuous ventilation when field tests are under way.

4. ROCK CONSTITUTION

4.1 General mineralogy

The BMT tunnel is dominated by a medium-grained, massive grey/ /reddish granite. In addition to color variation, grain size - typically about 3 mm - varies between 1 and 5 mm /2/.

LBL chemical analyses of reddish and grey granite in the area show the following representative compositions expressed in volume % /2/.

Reddish granite		Grey granite	
Quartz	44	Quartz	35
Partly sericitised plagioclase	39	Partly sericitised plagioclase	35
Microcline	12	Microcline	24
Chlorite	3	Subordinate: biotite, muscovite, chlorite, epidote	
Muscovite	2		
Accessory: zircon, opaques		Accessory: zircon, opaques	

Table 1 shows the outcome of a number of chemical analyses of the Stripa granite /2/.

Table 1. Chemical characteristics of the Stripa granite, (percent)

Sample	S 3	S 2	S 6	S 4	S 12
SiO_2	75.3	74.8	74.0	74.3	74.9
TiO_2	0.06	0,05	0,06	0.06	0.05
Al_2O_3	12.09	13.1	13.5	13.3	13.3
Fe_2O_3	1.8	1.7	1.6	1.0	1.7
MnO	0.03	0.02	0.02	0.06	0.03
CaO	0.6	0.4	0.5	0.7	0.7
MgO	0.22	0.22	0.18	0.20	0.18
K_2O	4.5	4.6	4.8	4.6	4.5
BaO	0.02	0.03	0.03	0.03	0.02

4.2 Joints and fractures

4.2.1 General

The Stripa granite has been extensively investigated by LBL and the stochastic character of the joints and fractures of crystalline rock in general is thereby well demonstrated. The average spacing of four major sets of discontinuities that were identified by LBL is illustrated in Table 2.

Table 2. Fracture spacing parameters of Stripa granite /2/.

Set no.	Mean vertical spacing, m	Mean dip angle (°)	Normal spacing, m
1	0,73	41	0.55
2	0.50	59	0.25
3	0.32	39	0.25
4	0.42	0	0.42

The persistence of joints, or the trace length, was also determined by LBL for the Stripa granite and it can be concluded from this study that the persistence of the large majority of joints is remarkably small. Actually, only 15 % of the total number of discontinuities, closed or open, persist more than 4 meters, and only about 2 % have an extension of 7 m. This is a determinant of the gross hydraulic conductivity and porosity of the rock as well as of its stress/strain properties and this points, in turn, to the importance of the degree of cross-linking of the joints. At present, there is practically no information on the latter property.

The only practical means of determining or estimating the aperture of joints and fractures is by steady-state injection testing. It yields equivalent "hydraulic" apertures assuming ideally smooth, parallel plate flow. They are somewhat smaller than the actual aperture, which can hardly be measured in a direct way. The data from Stripa are presently being prepared for publication by LBL but some results, which were kindly put to the authors´disposal by Charles R. Wilson, LBL, are presented in Table 3.

Table 3. Single open rock joint apertures (mm) in Stripa granite as interpreted from 320 m packer-sealed borehole tests (LBL). Total number = 169.

Interval d,mm	Fraction %
≤ 0.01	78.7
$0.01 < d < 0.05$	13.6
$0.05 \leq d < 0.10$	6.5
$0.10 \leq d < 0.20$	1.2
≥ 0.20	0

It is obvious from Table 3 that this particular granite, although fairly rich in discontinuities, contains very few large passages. Even if it is assumed that the theoretical derivation underestimates the aperture by 100 % it would still mean that only 15 % of all joints have an aperture larger than 0.2 mm and only about 2.5 % of all joints be as wide as 0.2 - 0.4 mm.

4.2.2 Tunnel

The orientation of joints and fractures in the BMT tunnel has been determined by LBL in an early survey, their projected site being illustrated by the histogram in Fig.3. Detailed mapping of the more prominent discontinuities was later made by LBL as well as by the Division of Soil Mechanics, University of Luleå.

LBL:s detailed study was aimed at providing data for the interpretation of the macropermeability test which was run by that organization in the period 1979 - 1980 (cf.Fig.4),/2/. The main observed feature was a zone of closely spaced (2-5 cm), subparallel joints which trends approximately N 15°E and dips about 70° to the west. This study also showed that two directions of the joints dominated: 1) a W-NW direction with joints dipping steeply to the north or to the south, and 2) a N-NE direction with joints that generally dip 50 - 60° to the west. Most joints and fractures were found to show evidence of groundwater seepage in the form of either drops or moist planes. The first-mentioned set of joints (the W-NW-trending set that dips to the south) consisted of discontinuities that were either planar or slightly curved and with an extension of at least 2 m.

The set of W-NW-trending joints that dip to the north were seen to be continuous over at least 4 m, and they show evidence of movement according to the LBL study. Joints with the N-NE trend are generally curved and continuous over 3-4 m, and they show evidence of shear displacements.

A representative example of the frequency and distribution of discontinuities in the rock close to the tunnel periphery is given by Fig.5, which shows LBL:s mapping of a Ø 56 mm core (DbH2) taken parallel to the tunnel at about 1m distance from its eastern wall.

A general conclusion from these studies is that the rock is rich in fractures in the inner part of the BMT tunnel and that heater holes no 1 and 2 are located in particularly water-bearing zones.

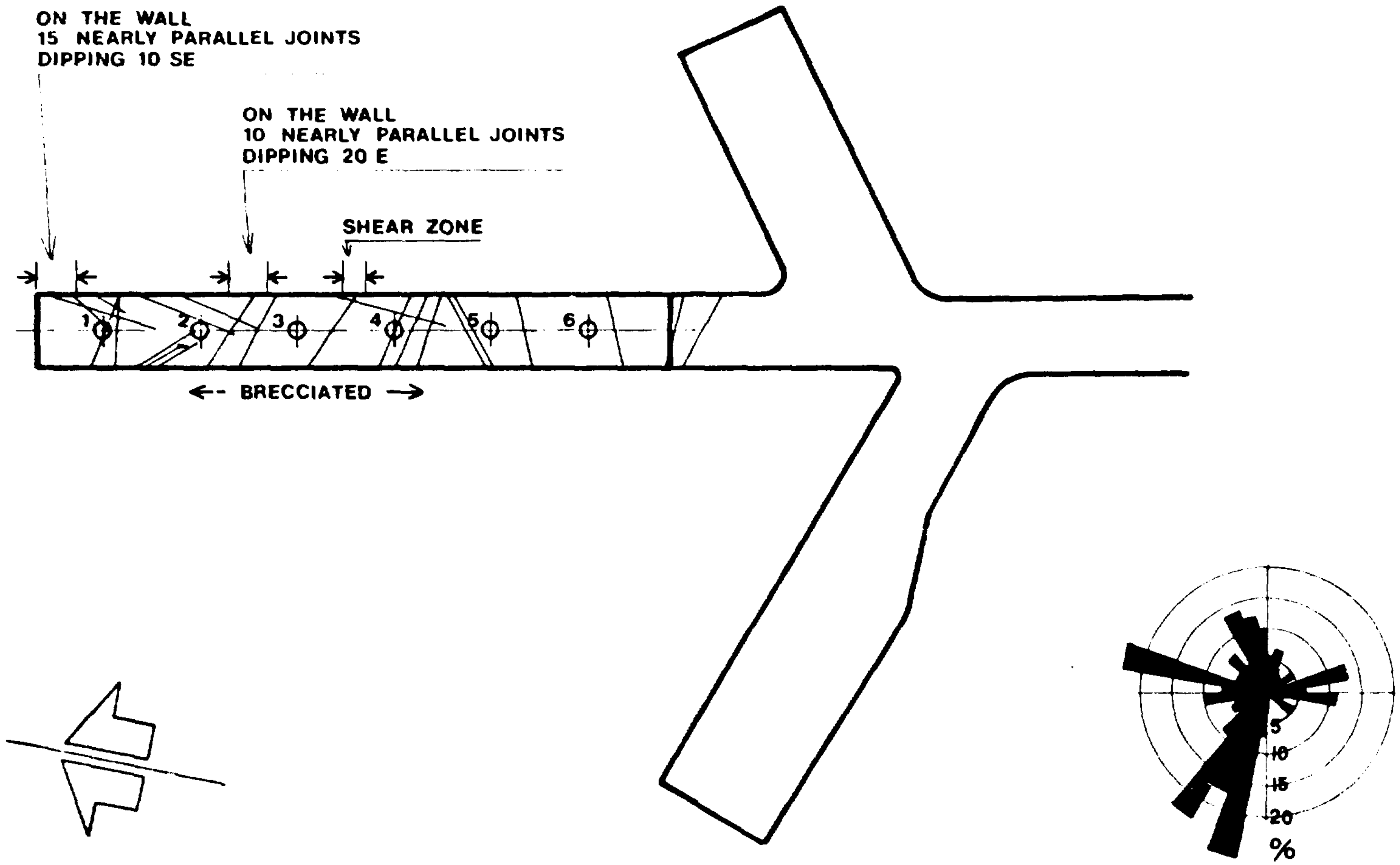


Fig.3. Major rock structure features in the BMT area according to LBL surveys.

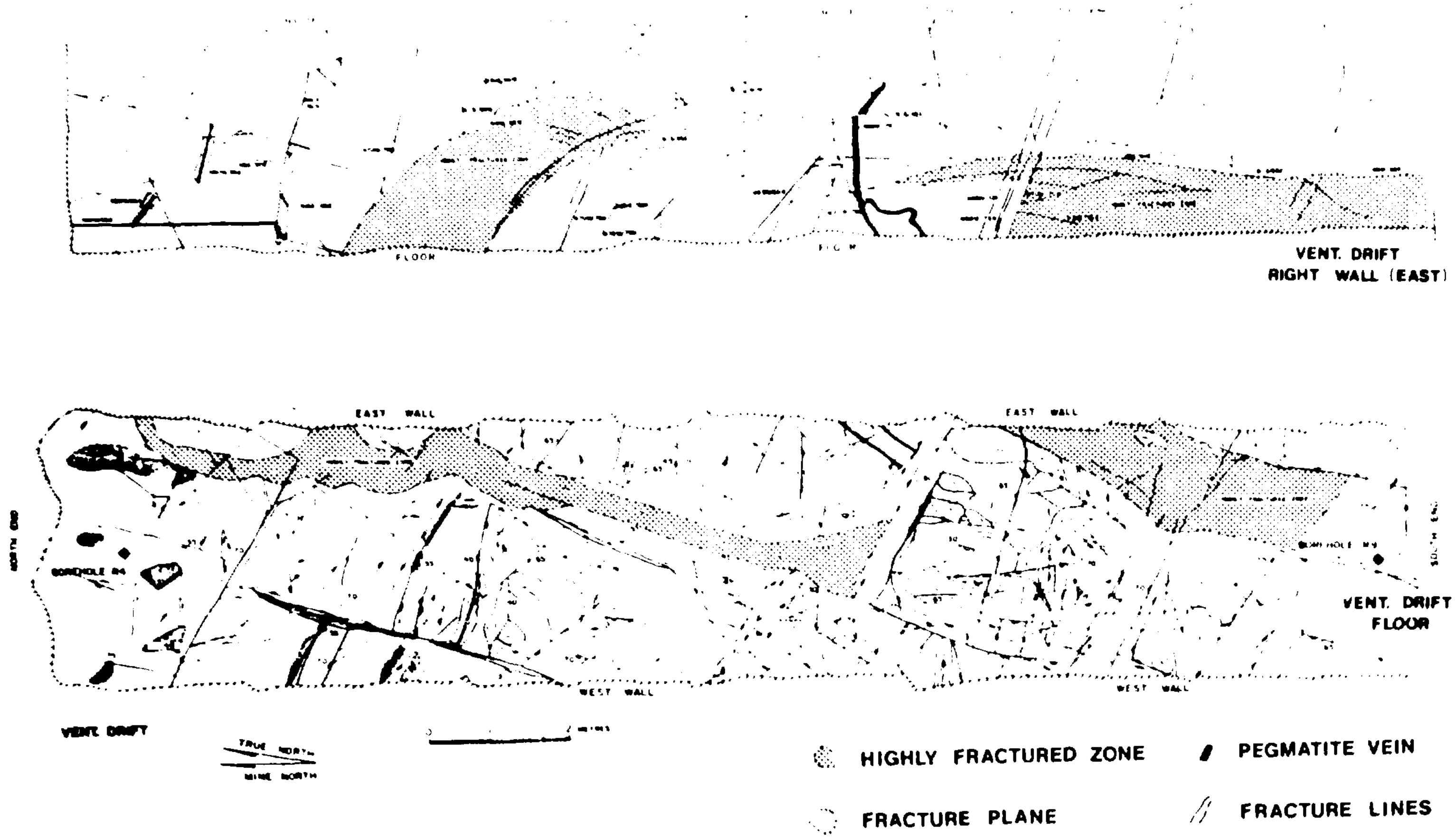
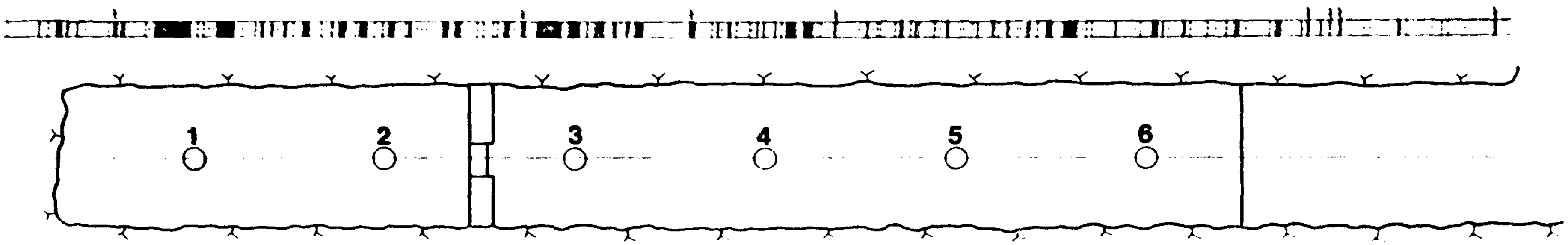


Fig.4. Detailed fracture map of the east wall and floor of the BMT tunnel (LBL).



LEGEND

CRUSHED ZONE

xxxxxx FRACTURE ZONE WITH MAINLY COATED FRACTURE SURFACES

xxxxxx FRACTURE ZONE WITH CLEAN, IRREGULAR FRACTURE SURFACES

SHEAR ZONE

SLICKENSIDE (STRIATED SURFACE)

Fig.5. Structural features of the rock adjacent to the eastern wall as interpreted from mapping of the DbH2 core (LBL).

The current BMT study has involved a recent derivation of the apertures of the joints and fractures in the tunnel by LBL. Fig.6, offered by Charles Wilson, LBL, shows a preliminary, generalized element model based on LBL:s mapping and evaluation of the inflow of water into the tunnel. Current computer-based derivations of the aperture of the major discontinuities show that it ranges from about 0.003 to 0.013 mm with a distribution similar to that of Table 3.

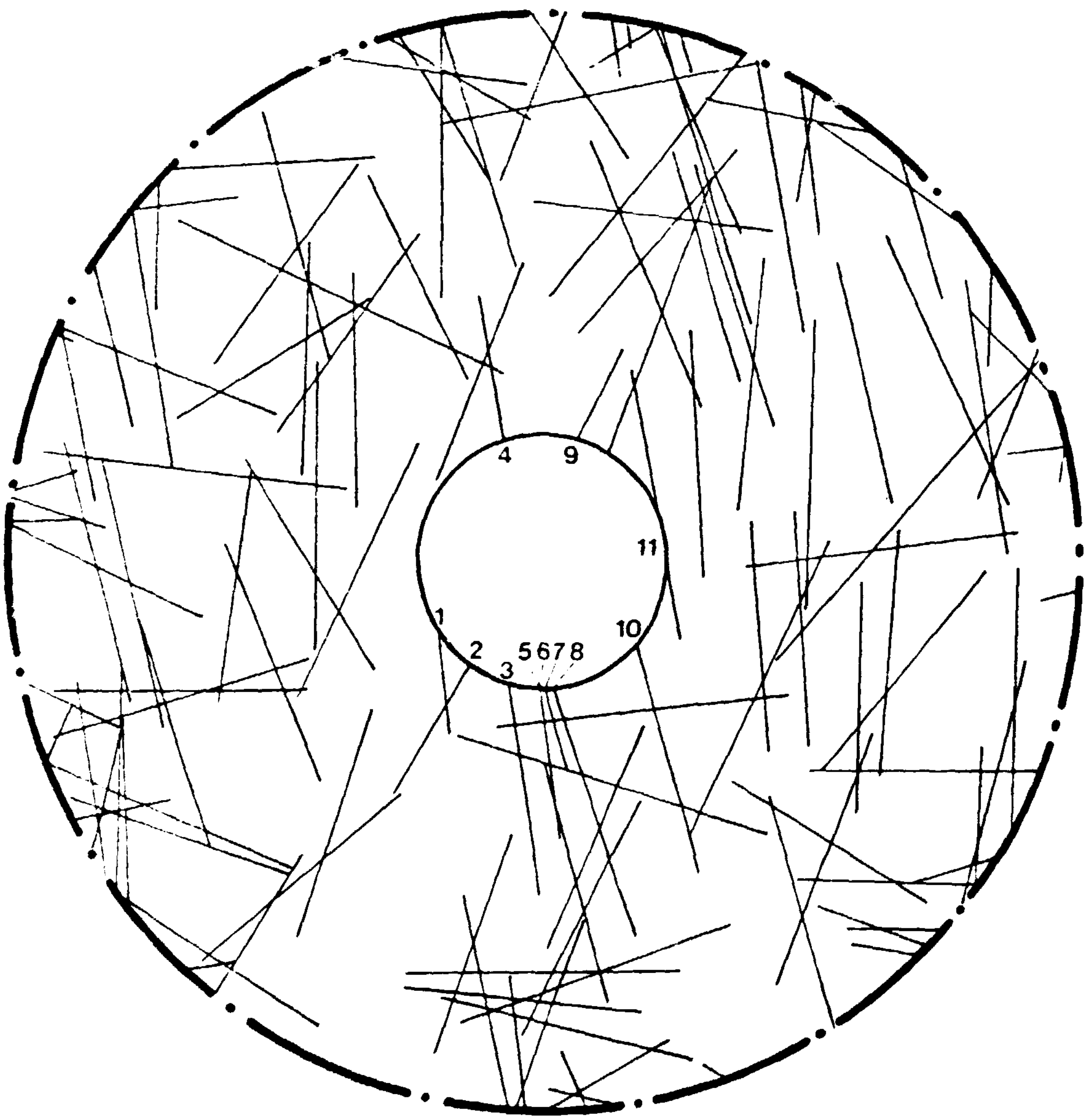


Fig.6. Generalized fracture mesh showing numbered fractures intersecting the tunnel (LBL).

4.2.3 Heater holes

The selection of suitable sites for the heater holes was based on simple hydrologic tests in a number of Ø 56 mm pilot boreholes (cf. chapter 5.3.1). These tests also involved core mapping which indicated that large differences in rock constitution could be expected in the finally chosen heater holes. This was confirmed when these holes, which have a diameter of about 0.76 m and a depth of about 3 m, were mapped with special reference to the presence of water-bearing joints and fractures (Fig.7 - 13). Holes no 1 and 2 were thus found to be located in rather richly fractured rock, while very few water-bearing discontinuities were observed in holes no 4 and 6. Holes no 3 and 5 were found to be located in moderately fractured rock

The fracture frequency is at maximum in the upper part of all the holes as can also be expected since the tunnel had been blasted with no particular caution. A few steeply oriented, intersecting joints or fractures were identified in all the holes. The correlation between the mapping of joints and fractures on one hand and the inflow of water on the other will be discussed in chapter 5.

The mineralogical examination showed that most fractures were sealed by or coated with epidote, chlorite or calcite. Only little attention has been paid to such features in the present study, however, since they are assumed to be of very minor importance with respect to the rock/backfill interaction.

KEY TO FRACTURE LOGS

OPEN FRACTURE WITHOUT INFILLING MATERIAL. THE FRACTURE CAUSED BY BLASTING (NO INFILLING MATERIAL, IRREGULAR FRACTURE SURFACES)

DISTINCT WATER-BEARING OPEN FRACTURE. NATURAL FRACTURE WITH INFILLING MATERIAL OR FRACTURE INDUCED BY BLASTING (←·—·—→)

OPEN, NOT WATER-BEARING FRACTURE. NATURAL FRACTURE WITH INFILLING MATERIAL

CLOSED, DRY NATURAL FRACTURE WITH INFILLING MATERIAL

HIGH CONCENTRATION OF INFILLING MATERIAL

PEGMATITE

CONCRETE PLATE NECESSARY FOR DRILLING OF DEPOSITION HOLE

INFILLING MATERIAL IN FRACTURES

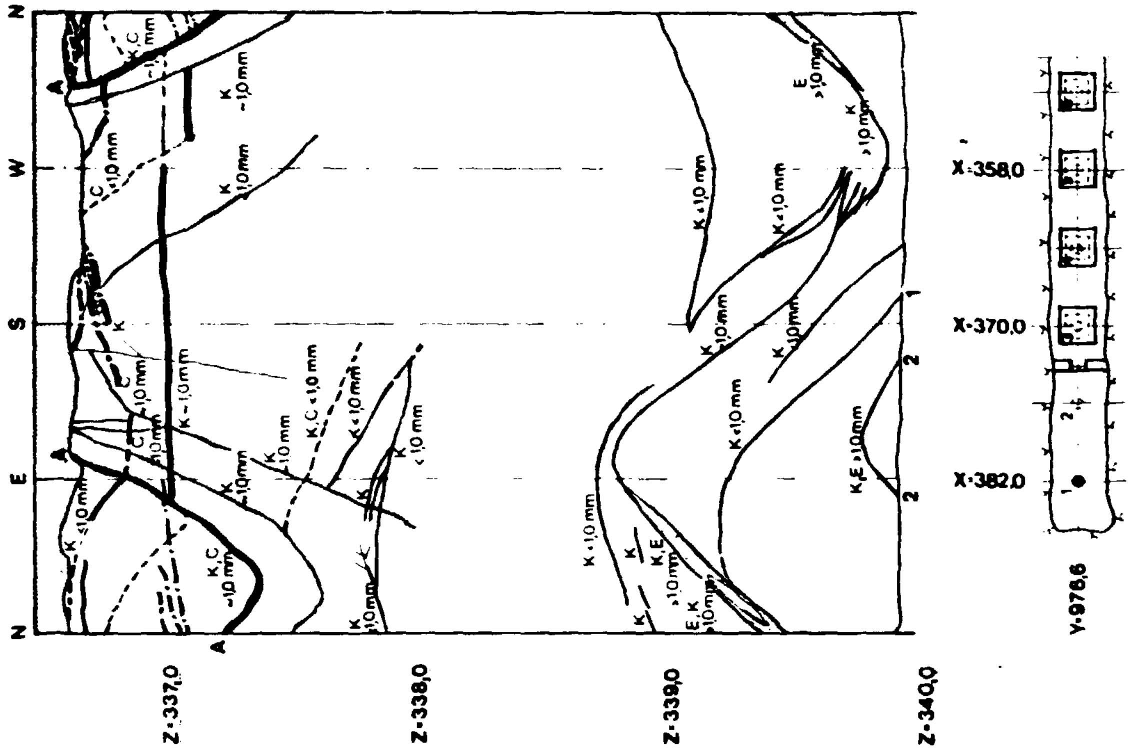
LIST OF ABBREVIATIONS

C	CALCITE
K	CHLORITE
E	EPIDOTE
Pe	PEGMATITE

REMARK

THE MAPPING IS EXECUTED BY SWEDISH GEOLOGICAL SURVEY

Fig.7. Key to fracture logs for the heater holes (Fig.8 - 13).



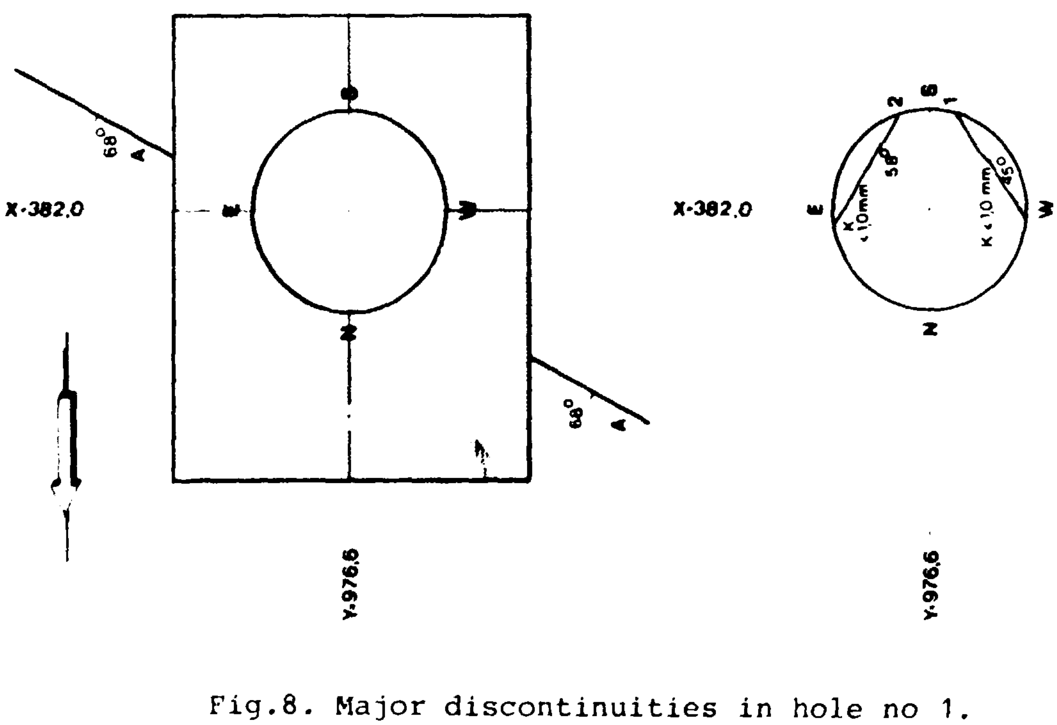


Fig.8. Major discontinuities in hole no 1.

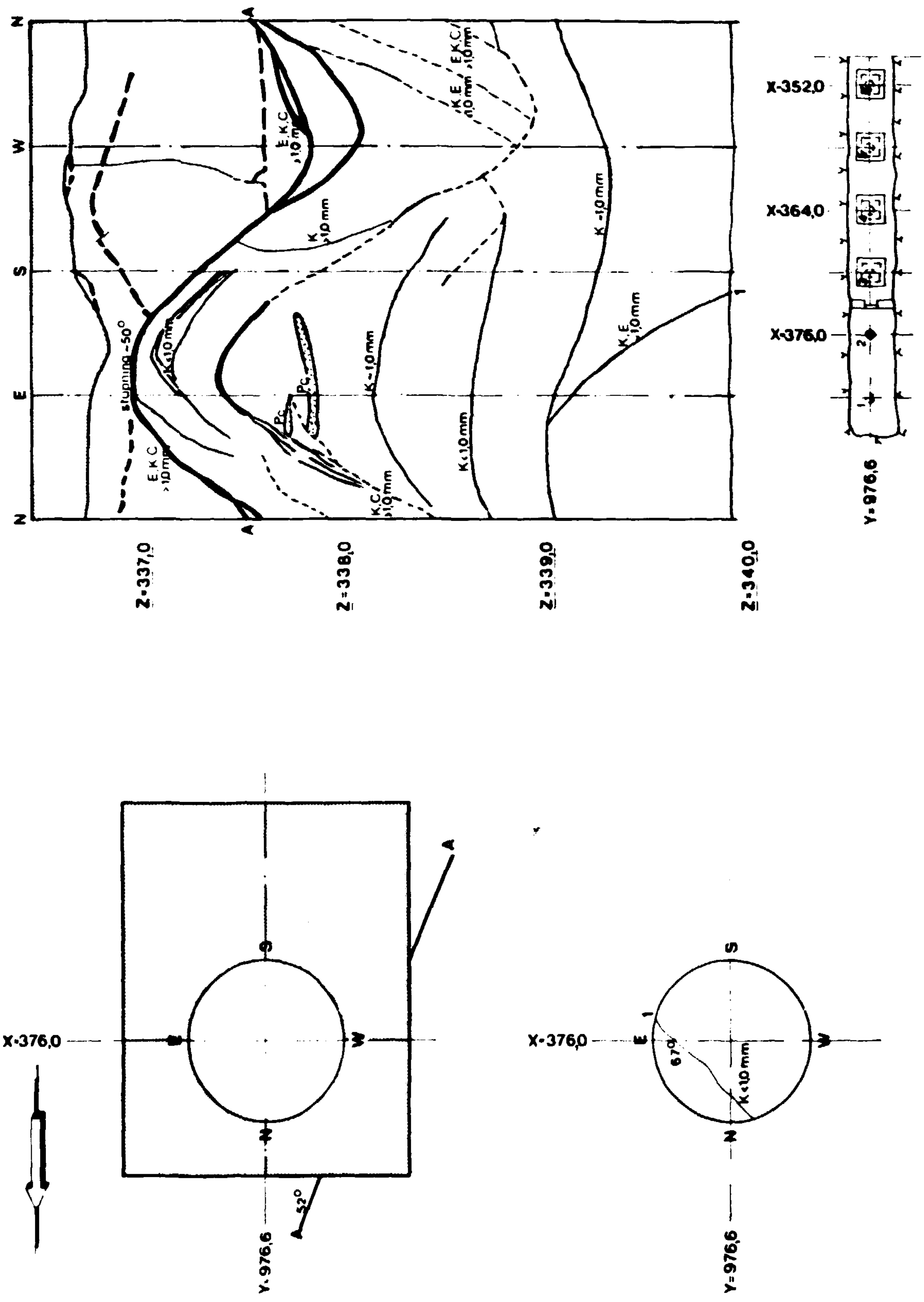


Fig.9. Major discontinuities in hole no 2.

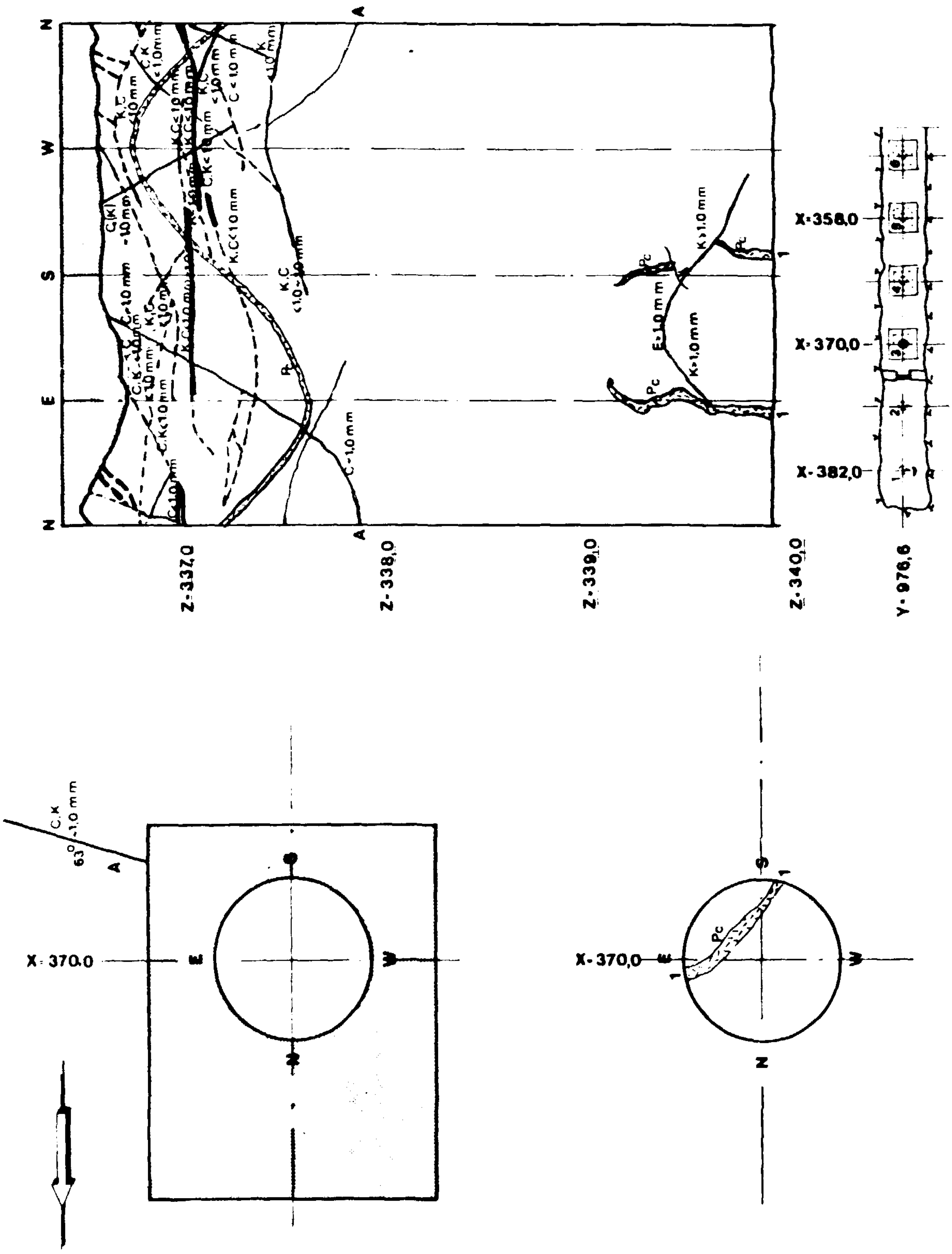


Fig.10. Major discontinuities in hole no 3.

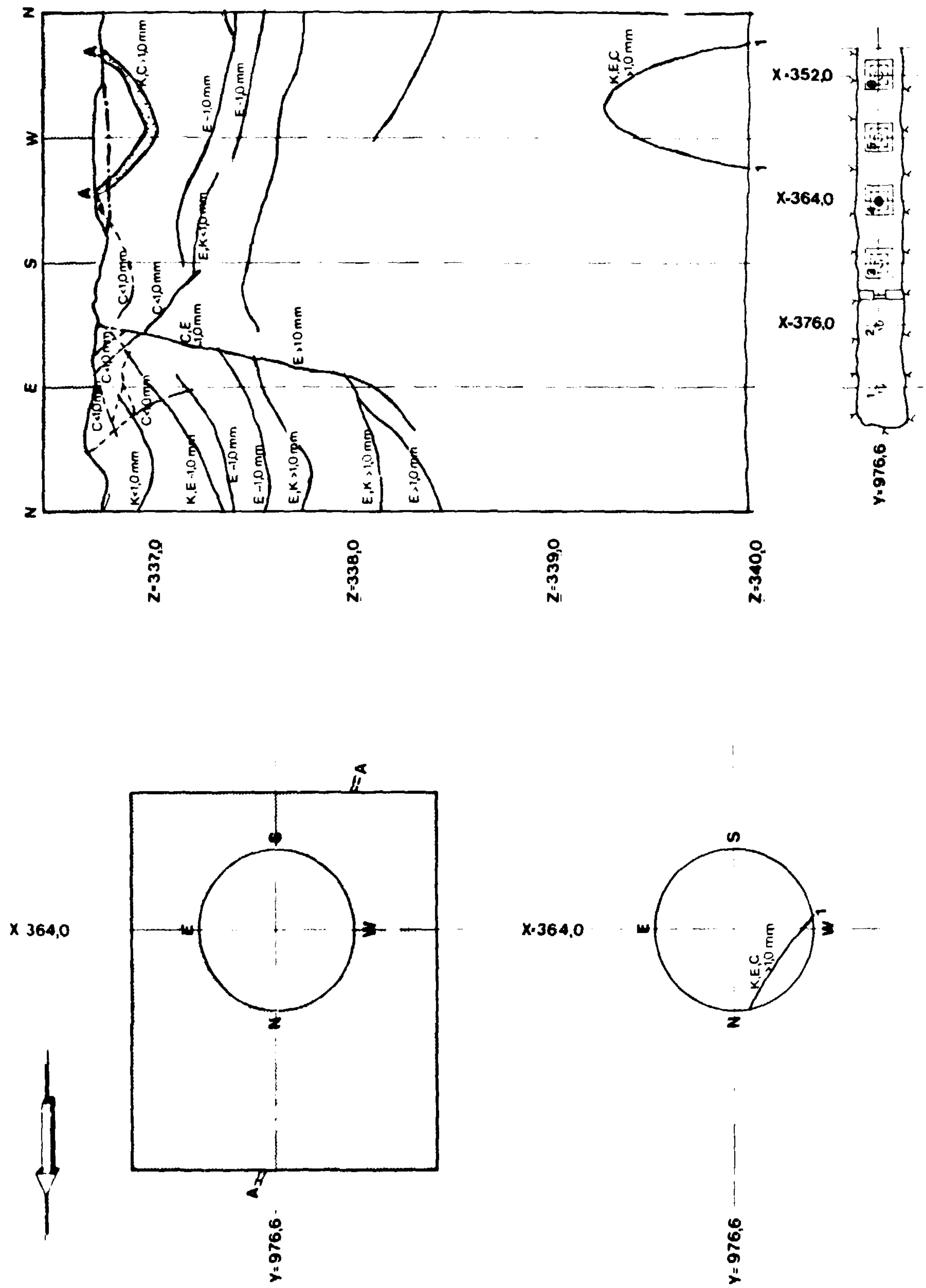


Fig.11. Major discontinuities in hole no 4.

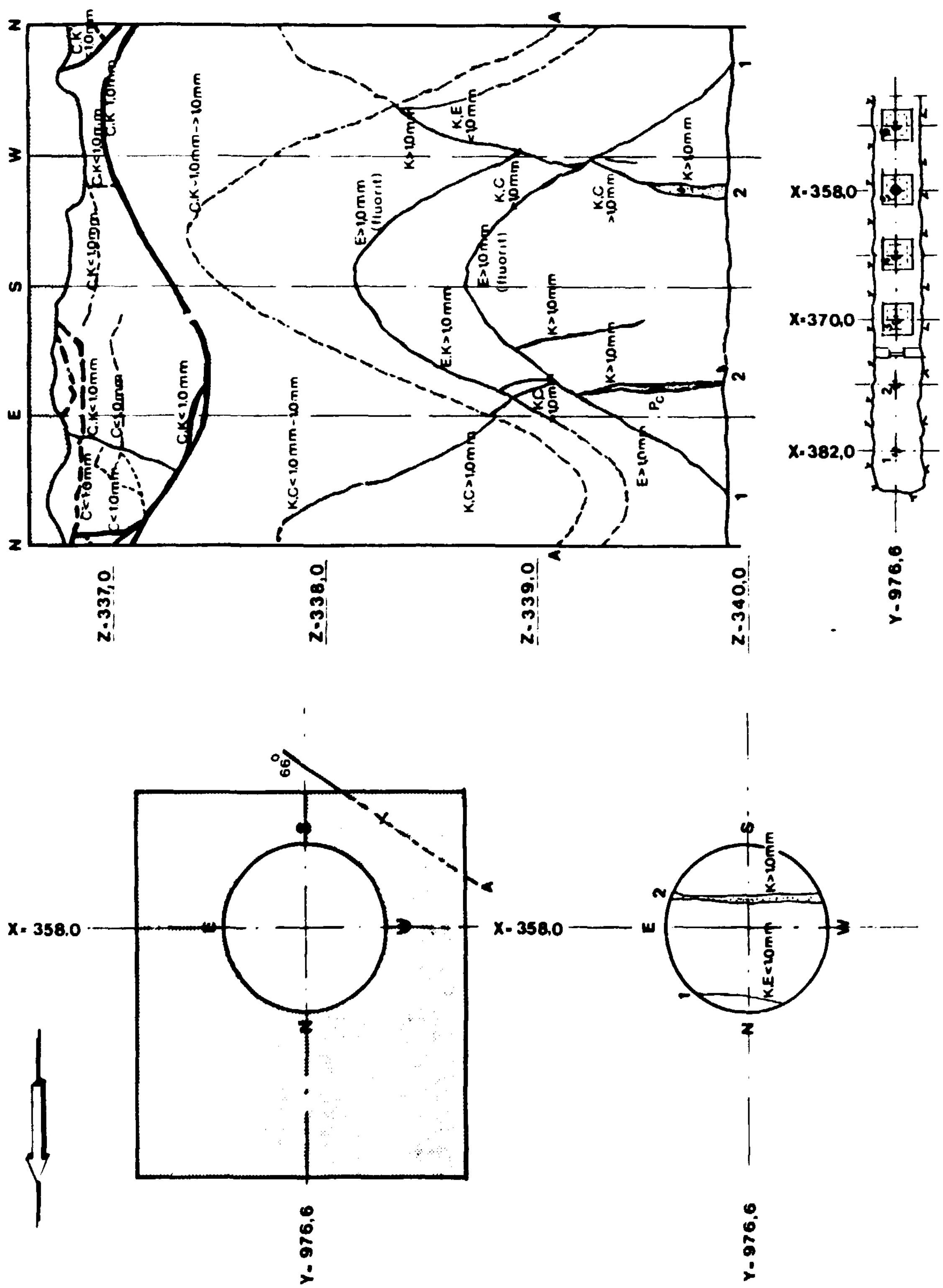


Fig.12. Major discontinuities in hole no 5.

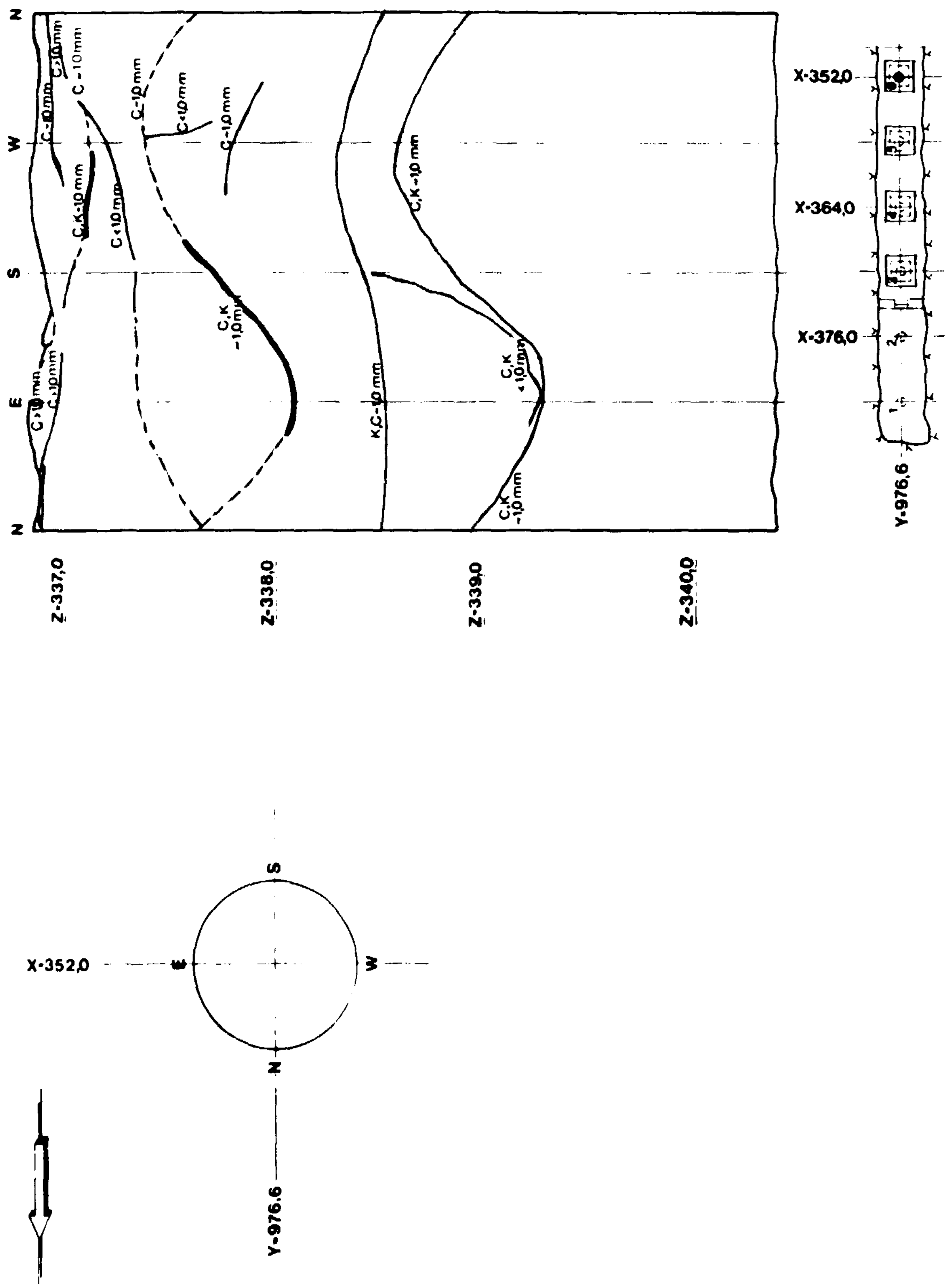


Fig.13. Major discontinuities in hole no 6.

4.3 Rock stress state

The in-situ stresses have not been measured in the BMT area but the general stress field is expected to be about the same as in the relatively closely located "Pilot Heater Test" and "Full-scale Heater Test" areas (Fig.14). Here, the Division of Rock Mechanics, University of Luleå, has determined the rock stresses by applying *Leeman 3D overcoring* technique /3/. It is concluded from these investigations* that:

1. The major principle stress is about 20 MPa. It is horizontal and almost perpendicular to the BMT tunnel

2. The intermediate principle stress is about 10 Mpa. It is horizontal and almost parallel to the BMT tunnel

3. The minor principle stress is about 4 MPa. It is practically vertical

The tangential stresses are zero at the tunnel periphery in a cross section through the tunnel. The horizontal rock stress is probably up to 30 MPa one or two meters above the crown and below the floor of the tunnel, respectively. Superposition of induced stresses on the general stress field yields a maximum tangential stress at the periphery of the heater holes of 5 to 55 MPa.

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* Bengt Leijon, Div. Rock Mech., Univ. of Luleå, pers. comm.

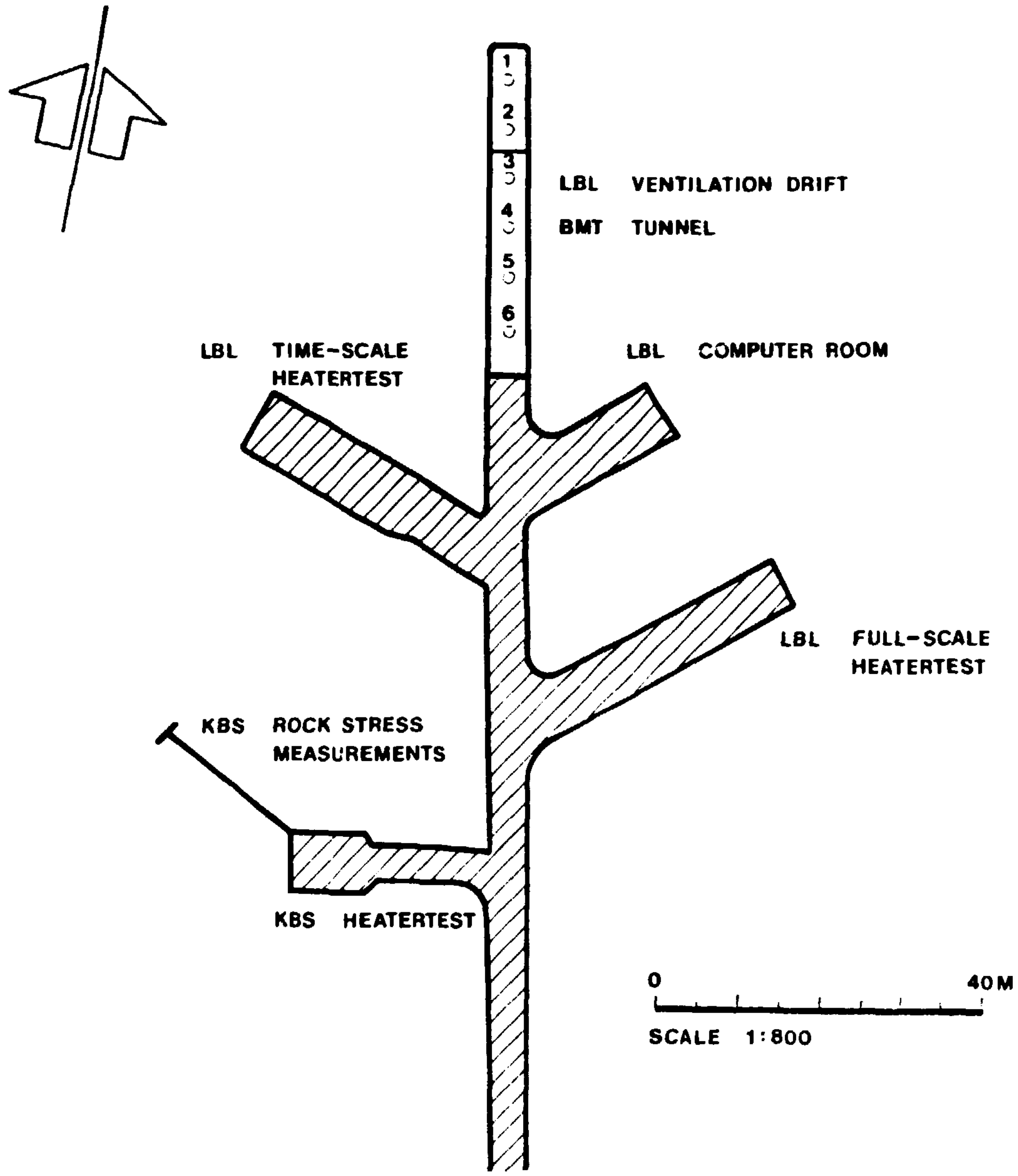

Fig.14. Location of sites for rock stress measurements.

5. HYDROLOGY

5.1 General

The average hydraulic conductivity of the Stripa rock mass is known to be low as can be inferred from the very moderate pumping that is required to drain the mine. Actual evaluation from various tests has yielded a range of the hydraulic conductivity of 10^{-12} to 10^{-10} m/s for most of the rock mass. Attempts have also been made to determine the hydraulic conductivity in the local BMT area. Thus, the LBL Macropermeability Test offers very valuable information on the water inflow characteristics, and additional tests of similar type that were performed later have also contributed to the understanding of the rather complex hydrologic conditions in the test area.

Careful petrologic studies by LBL /4/have shown that the granite, termed quartz monzonite by the investigators, is medium grained with very obvious microfracturing in the natural state of the rock. Although many of the very narrow discontinuities are closed, a fraction of them stay open and contribute to the hydraulic conductivity and to the migration of dissolved species. The rock matrix can therefore be regarded as a porous medium with a very low, but still practically important permeability. Laboratory experiments on block samples free from visible fractures, have yielded an average hydraulic conductivity of the crystal matrix of $5 \cdot 10^{-13}$ m/s /5/.

5.2 Tunnel

5.2.1 The Macropermeability Test

The macropermeability test was an attempt by LBL to determine the hydraulic conductivity of a large volume, i.e. about 200 000 m^3, of rock /6/. It was evaluated on the basis of measured water inflow into the sealed, 33 m long inner part of the tunnel, and recorded water pressures at various distances from the tunnel periphery. Since the flow rate into the tunnel was so low and the surface area so large that a significant fraction of the inflow would be lost to evaporation and the remainder impossible to collect, it was decided to evaporate all inflowing water and determine the seepage rates by measuring the net moisture pickup in the heated air of a closed ventilation system. Tests were run at air temperatures of about 20, 30, and 45 °C followed by a cool-down test back to 20 °C.

The average "radial" hydraulic gradient, which had to be known for the evaluation of the gross hydraulic conductivity, was determined by measuring the water pressure in 90 isolated intervals in Ø 76 mm boreholes (Fig.15 - 17). Each packer-confined interval was about 5 m long, i.e. a length intended to include 15 to 20 water-bearing fractures.

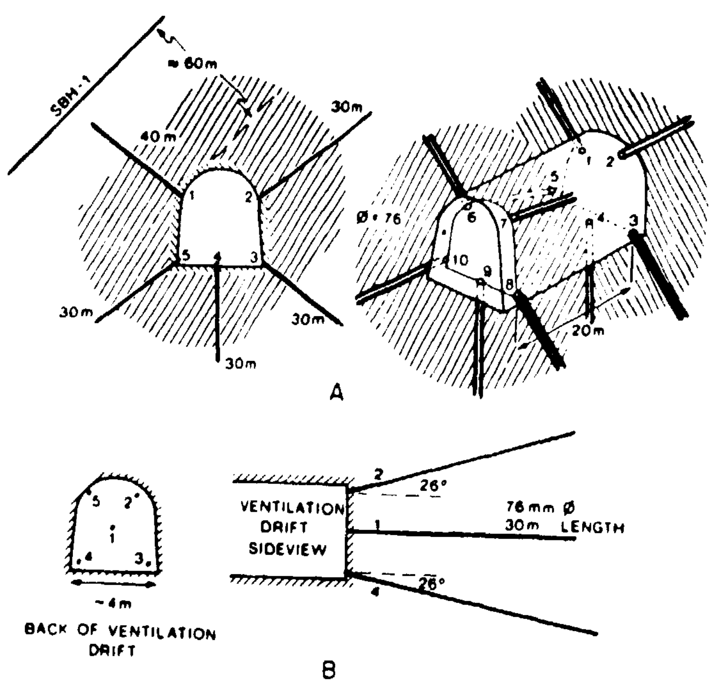

Fig.15. LBL boreholes used for the macroperm. test.

XBL 7811-13108

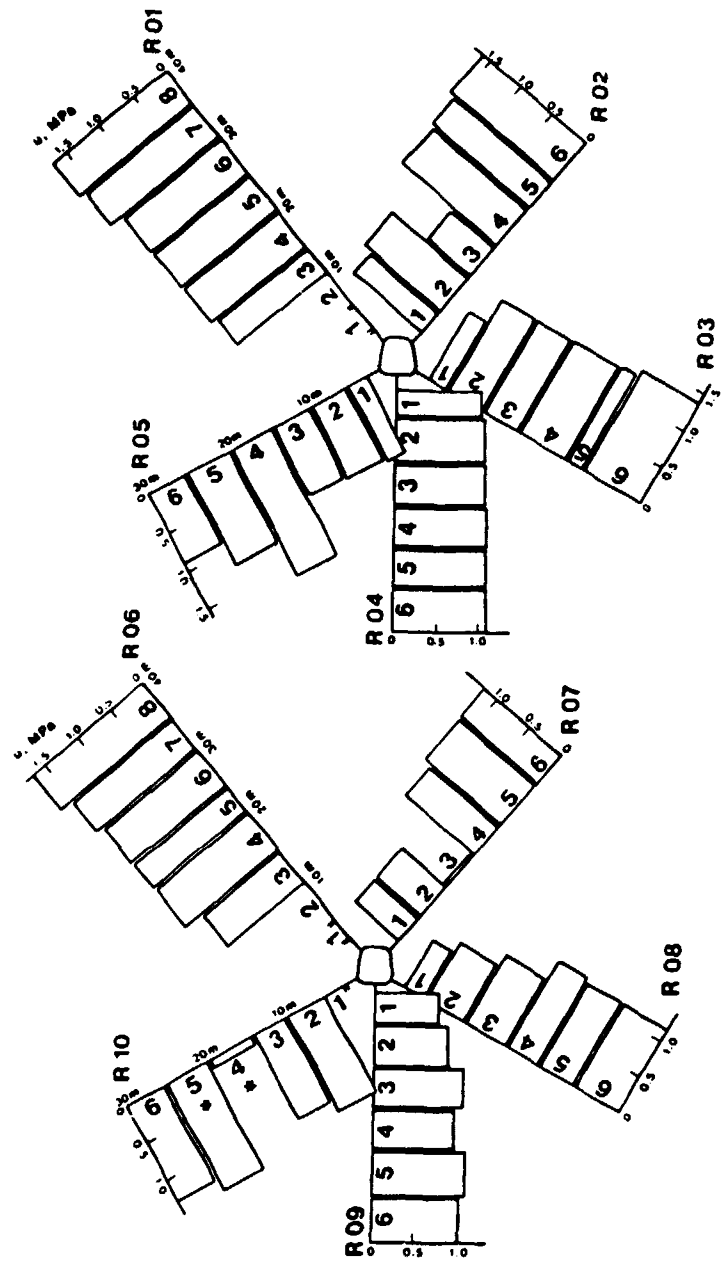

Fig.16. Pressure diagrams representing the water pressure distribution in the final phase of the LBL test. R 01 is equivalent to the radially oriented no 1 in Fig.15, R 02 to radial no 2 etc.

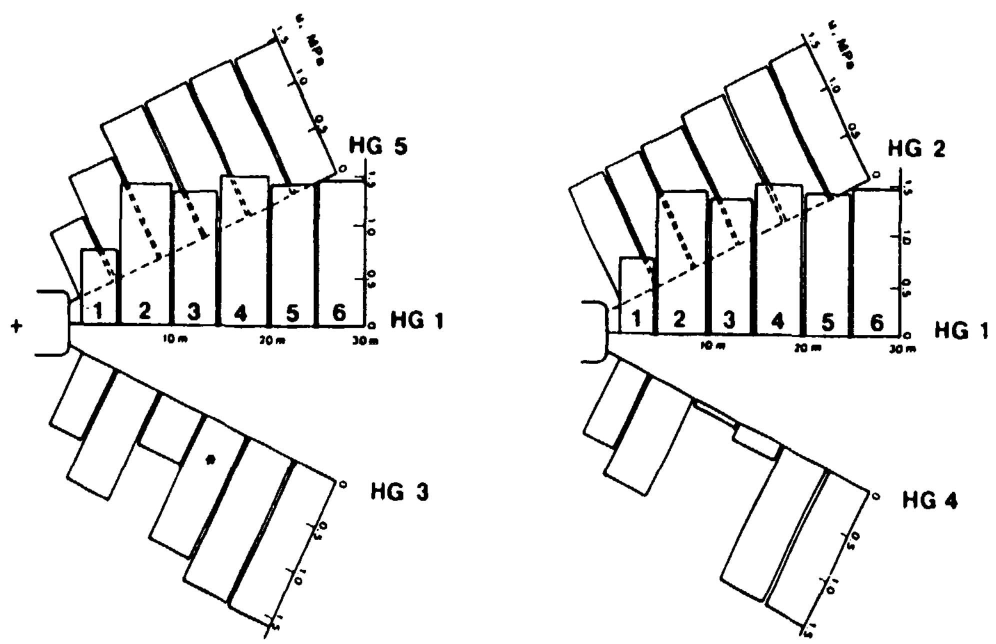

Fig.17. Pressure diagrams representing the water pressure distribution in the final phase of the LBL test. HG 1 is equivalent to the front face hole no 1 in Fig.15 etc.

The outer end of the sealed tunnel in LBL:s experiment was situated approximately where heater hole no 6 is located in the Buffer Mass Test, so the inflow characteristics determined by LBL are of profound interest to the latter test. The average inflow under reasonably steady flow conditions in LBL:s tests with different temperatures are summarized in Table 4.

Table 4. Results of the Macropermeability Test /7/.

Test no	Nominal temp. °C	Average flow ml/min	Gross hydraulic conductivity, m/s
1	20	50	$1.0 \cdot 10^{-10}$
2	30	42	$9.4 \cdot 10^{-11}$
3	45	43	$1.0 \cdot 10^{-10}$
4	20	47	$9.8 \cdot 10^{-11}$

The evaluated gross hydraulic conductivity was derived by application of the Thiem equation for steady radial flow to a long cylindrical opening in a homogeneous isotropic porous medium:

$$k = \frac{q \ln(r_2/r_1)}{2\pi b(h_2-h_1)} \qquad (1)$$

where k= coefficient of hydraulic conductivity

q= volumetric water flow rate into the opening

r_1 and r_2 = radial distances from the tunnel axis to the first and second water head measuring points

h_1 and h_2 = water head at radial distances r_1 and r_2

b= length along axis of cylindrical opening over which seepage takes place

The water heads were derived from the pressures recorded in the boreholes. These pressures came on a straight line with a slope proportional to k when plotted against the radius of the measurement points (Fig.18).

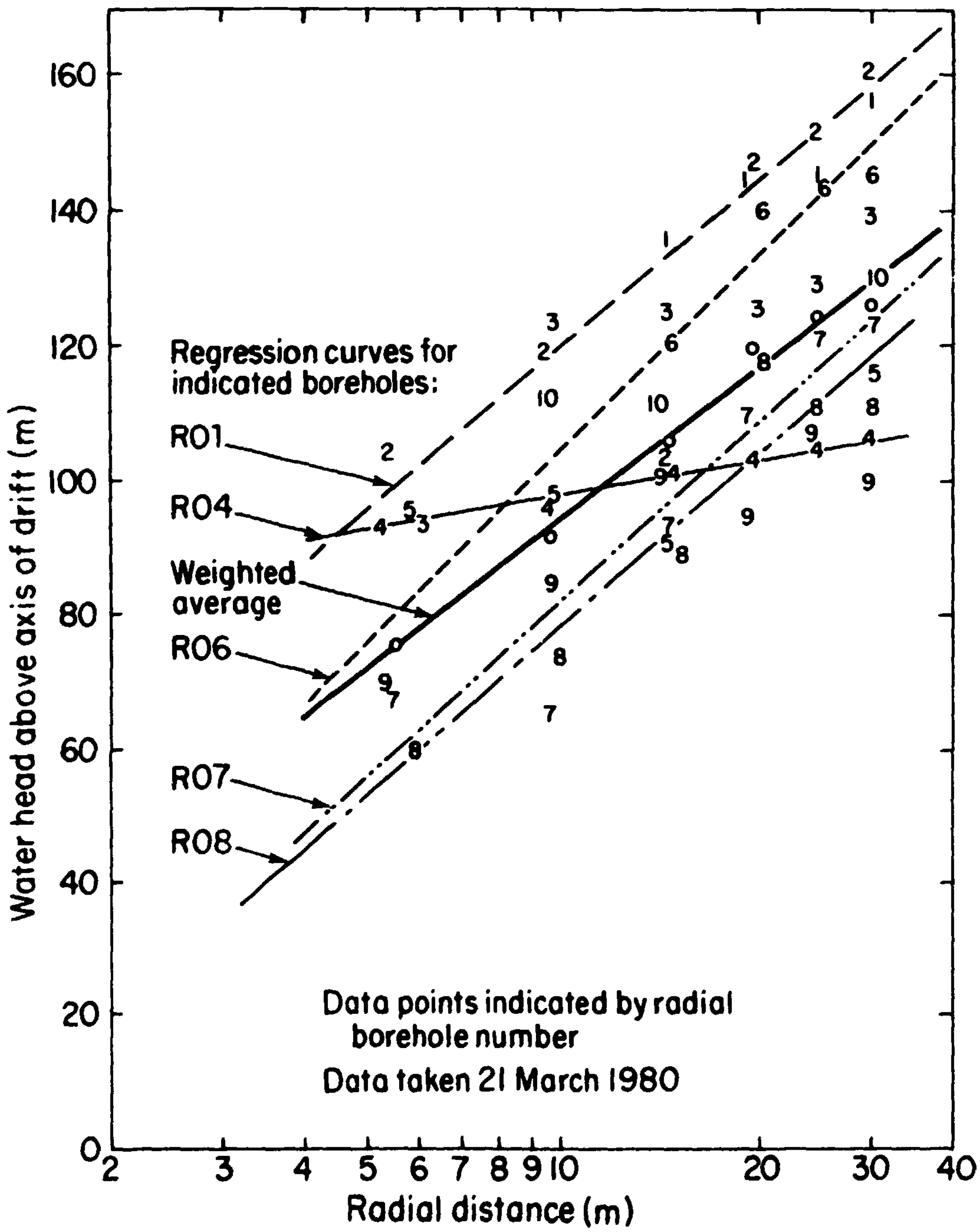

Fig.18. Distance/pressure plot of first 20°C test /7/.

5.2.2 The "drying" procedure

In conjunction with the preparation of the bulwark for the buffer mass test it was suggested* that a simple version of the macro-permeability test be run to estimate the inflow into the inner part of the BMT tunnel. The suggested technique was to use large standard air-drying units which are ordinarily installed for removing moisture from buildings. Two devices of this sort, which were set to keep the relative humidity constant at about 70 %, were in operation for a few weeks (Fig.19). This was sufficient to yield approximate equilibrium between water inflow and condensation, the evaluated inflow being estimated at about 13 ml/min into the 13 m long tunnel. This quantity corresponds to 1/3 to 1/4 of the inflow in the entire 33 m long tunnel, which suggests that water enters it rather uniformly. However, the accuracy of the "drying" procedure is not sufficient to allow for such a conclusion.

Fig.19. Air-drying unit with condensate collector.

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* Anders Bergström, KBS

5.2.3 Ocular inspection

The distribution of the inflow of water into the BMT tunnel was also estimated by identifying the successive moistening of the roof and walls after stopping the ordinary ventilation during one weekend. The evaluation of these observations* was rather subjective and uncertain because of the difficulty of deciding whether the appearing moistening originated from areas with many narrow fractures or from water flowing from individual large discontinuities. Fig.20 - 23 show the interpretation of the study, which can only be taken as a rough illustration of where water preferably enters the roof and walls. The floor could not be mapped in this way.

It is obvious from the plottings that the eastern wall has the largest extension of water-bearing zones, while the tunnel front is the driest wall. The water inflow into the western wall is largely dominated by a few discontinuities which are strongly or moderately water-bearing. The roof shows an inflow pattern that is similar to that of the western wall. Most water seems to enter the central part of the roof, i.e. between heater holes no 1 and 2.

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* Observations by Hans Carlsson, KBS, and Lennart Börgesson, LuH.

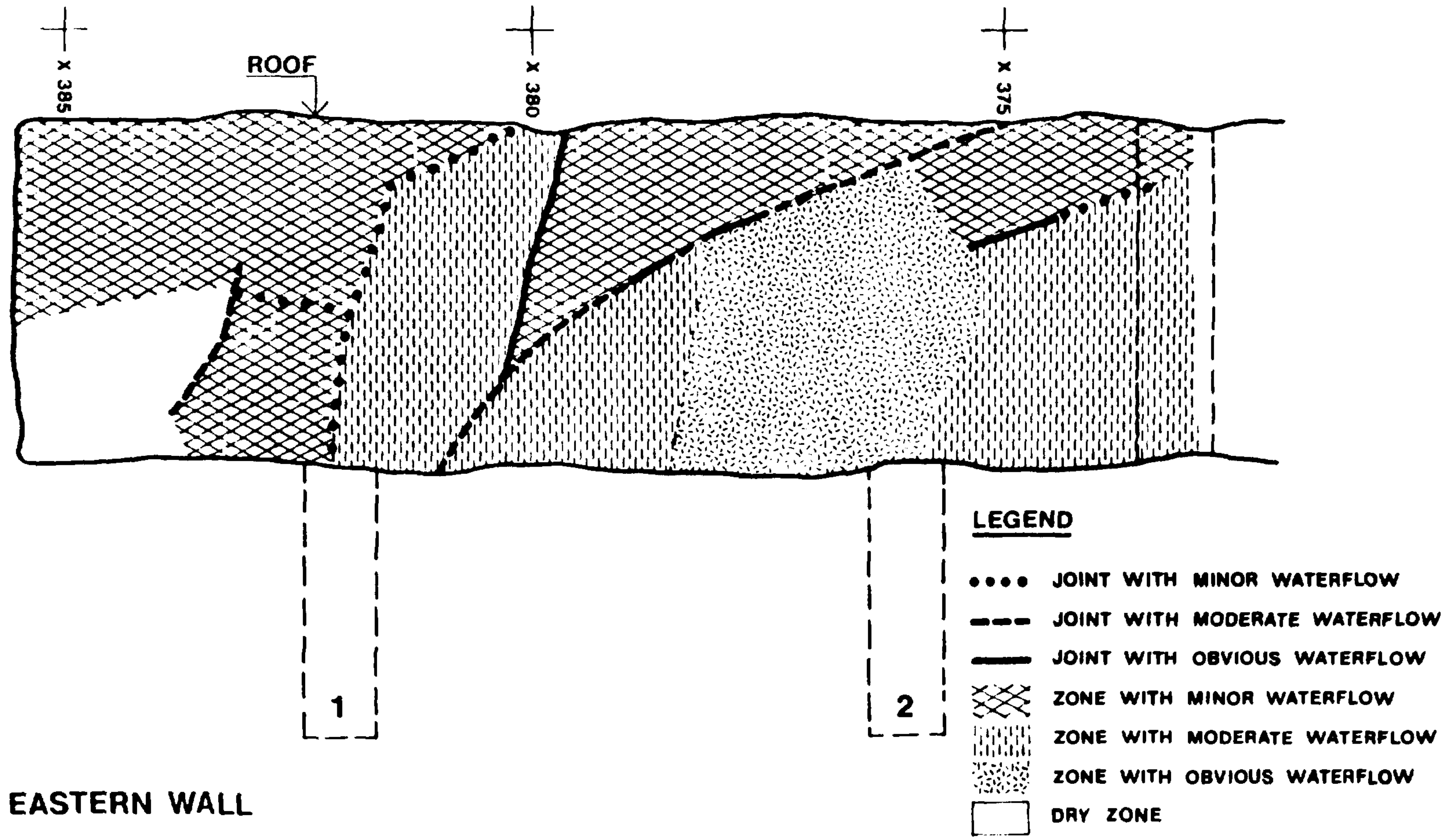

Fig.20. Generalized water inflow pattern in the BMT tunnel, eastern wall.

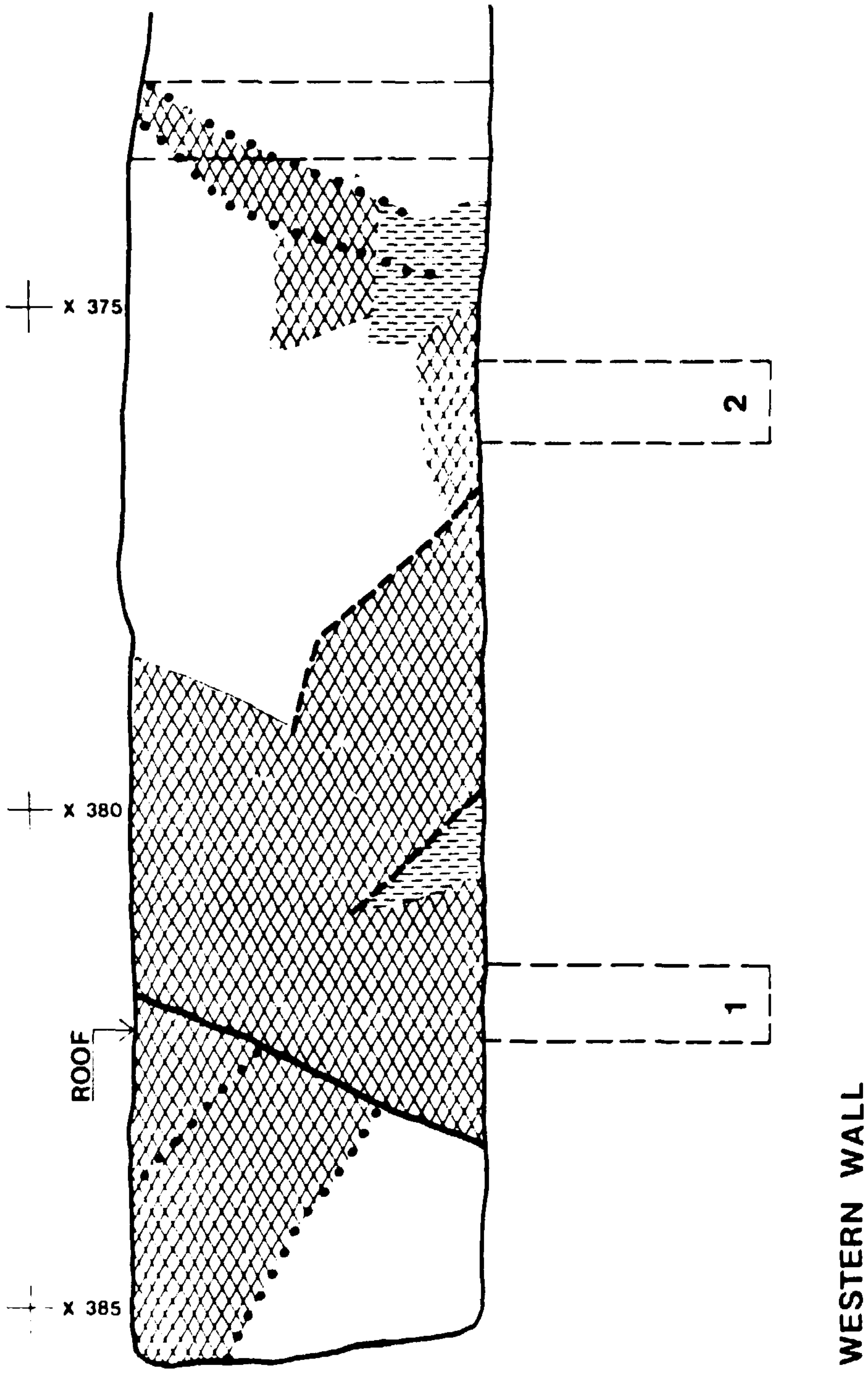

Fig.21. Generalized water inflow pattern in the BMT tunnel, western wall.

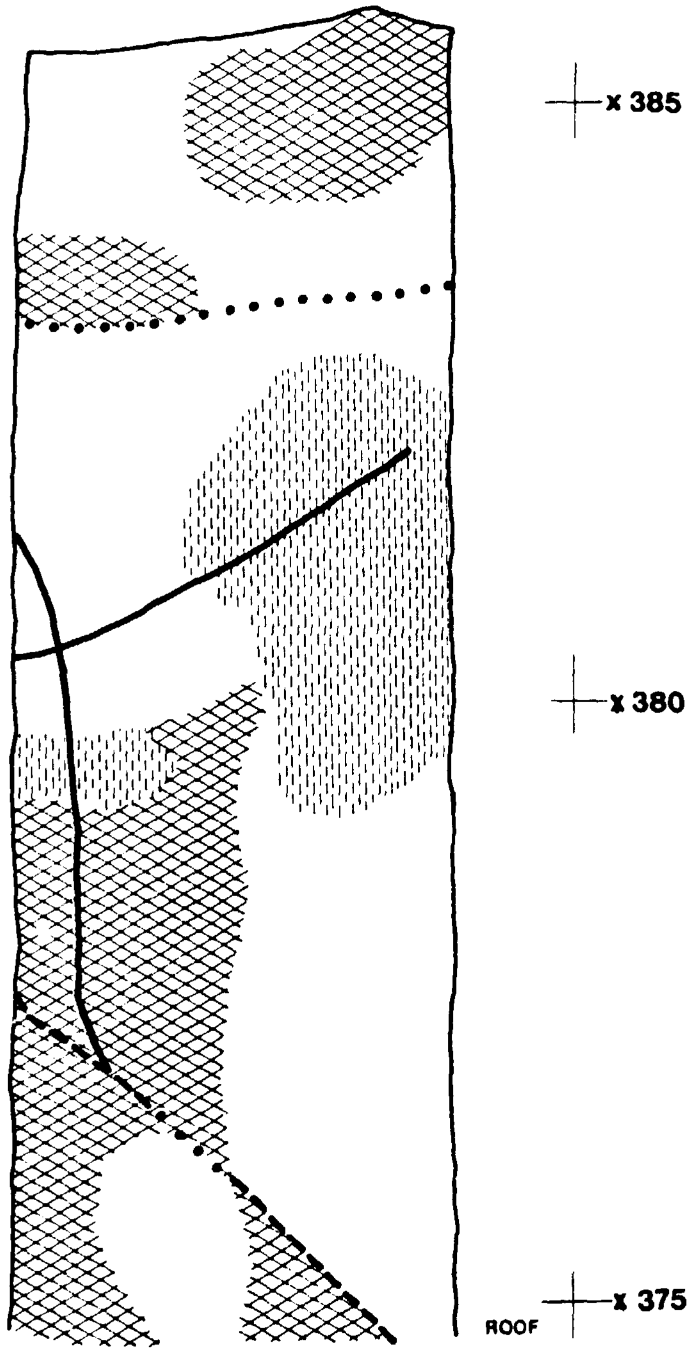

Fig.22. Generalized water inflow pattern in the BMT tunnel, roof.

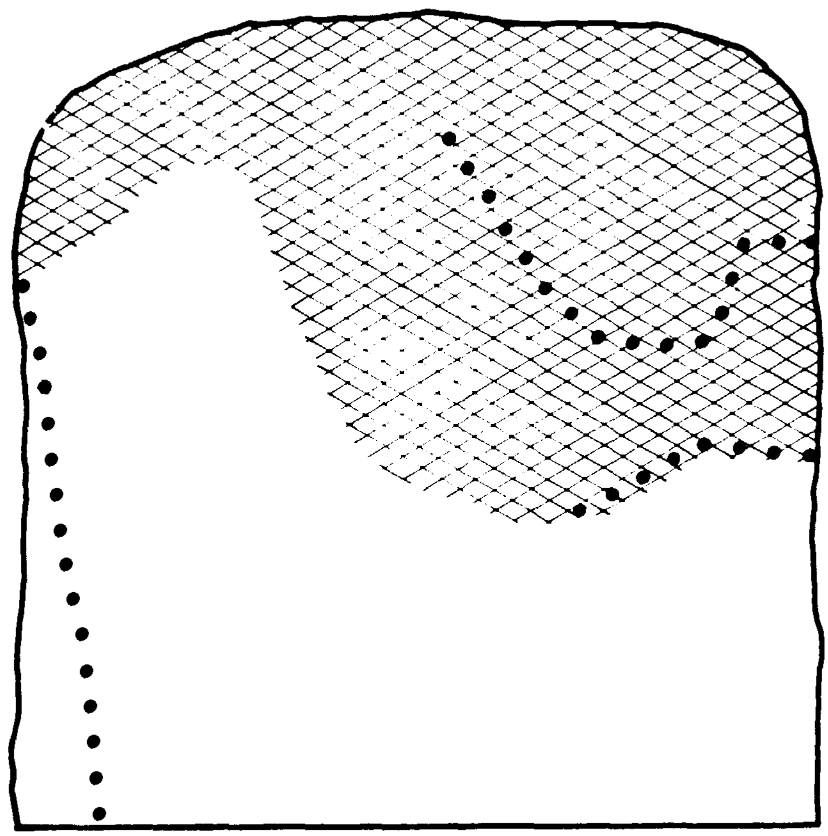

Fig.23. Generalized water inflow pattern in the BMT tunnel, front.

5.3 Heater holes

5.3.1 Pilot holes

Twelve Ø 56 mm holes were drilled in the tunnel floor as a preparation of the drilling of the six large heater holes /1/. Six of the pilot holes (1A - 6A) indicated suitable conditions for the subsequently drilled heater holes, and these pilot holes were core-mapped and used for water inflow tests. The location of open, natural joints or fractures in the cores is summarized in Table 5.

Table 5. Fracture mapping of pilot holes. Figures denote the number of natural discontinuities in each core length interval (L.Jacobsson & H.Norlander).

Depth below tunnel floor m	Hole number					
	1A	2A	3A	4A	5A	6A
0 - 0.25	1	2	RF*	2	0	2
0.25 - 0.50	2	2	RF	1	0	1
0.50 - 0.75	1	0	3	2	2	0
0.75 - 1.00	2	1	4	1	RF	0
1.00 - 1.25	3	1	3	1	2	0
1.25 - 1.50	1	1	2	0	2	2
1.50 - 1.75	0	1	0	0	1	0
1.75 - 2.00	2	1	2	0	2	0
2.00 - 2.25	0	0	1	1	0	0
2.25 - 2.50	2	3	1	1	1	1
2.50 - 2.75	RF	3	1	0	0	1
2.75 - 3.00	1	1	2	4	1	0
3.00 - 3.25	3	0	1	1	3	0

* RF stands for richly fractured rock

The mapping shows that while holes no 1A, 3A and 5A are rich in joints and fractures, 4A and particularly 6A contain few discontinuities. Hole no 2 is intermediate in this respect. Holes no

4A and 6A are fracture-free over a considerable axial length, while the discontinuities are fairly uniformly distributed in the other holes.

Simple inflow tests were run in the holes to get a rough measure of the water-bearing capacity of the intersecting joints and fractures. For this purpose, the holes were first completely drained and then allowed to be filled by inflowing groundwater, which was pumped out after 1 day. The inflow capacity is given in Table 6.

Table 6. Inflow rate in pilot holes; average over 4 days.

Hole no	Water inflow l/day
1A	6.2
2A	5.6
3A	3.0
4A	0.2
5A	1.9
6A	0.2

It is concluded that the water inflow is roughly in accordance with the fracture frequency. Thus, holes no 1A, 3A and 5A carry much water, while holes no 4A and 6A are fairly dry. The considerable inflow in hole no 2 suggests that the relatively few discontinuities are rather wide and carry much water. It is also reasonable to believe that the moderate inflow in the fracture-rich hole no 3A is due to rather small apertures.

5.3.2 Full-size heater holes

Ocular inspection was made to identify water-bearing parts of the holes in connection with the detailed fracture mapping which was described on page 15 - 22. This inspection was difficult because surface water flowing from the tunnel walls and floor drained into the holes and masked the inflow regions deeper down in the holes. A qualitative determination was made by use of a simple movable packer for the collection of inflowing water on various levels (Fig.25). Unforeseen practical difficulties and extreme time shortage appeared at the recording of hole no 3, while the other holes could be investigated reasonably well. However, the inflow data, which are given in Table 7, can only be taken as a rough, relative measure of the water-bearing capacity since surface water emanating from ongoing drilling operations nearby in the tunnel probably affected the measurements.

Table 7. Inflow rate in heater holes.

Hole no	Water inflow, l/day			
	Upper half	Lower half exc. lowest 20 cm	Lowest 20 cm	Total
1	3.7	1.1	0.7	5.5
2	8.0	1.2	1.6	10.8
3	-	-	-	-
4	2.7	3.2	-*	5.9
5	-	-	-	6.7
6	Upper and lower halves = 0.8		0.2	1.0

* Water flowed richly from a deep preexisting LBL hole (R9)

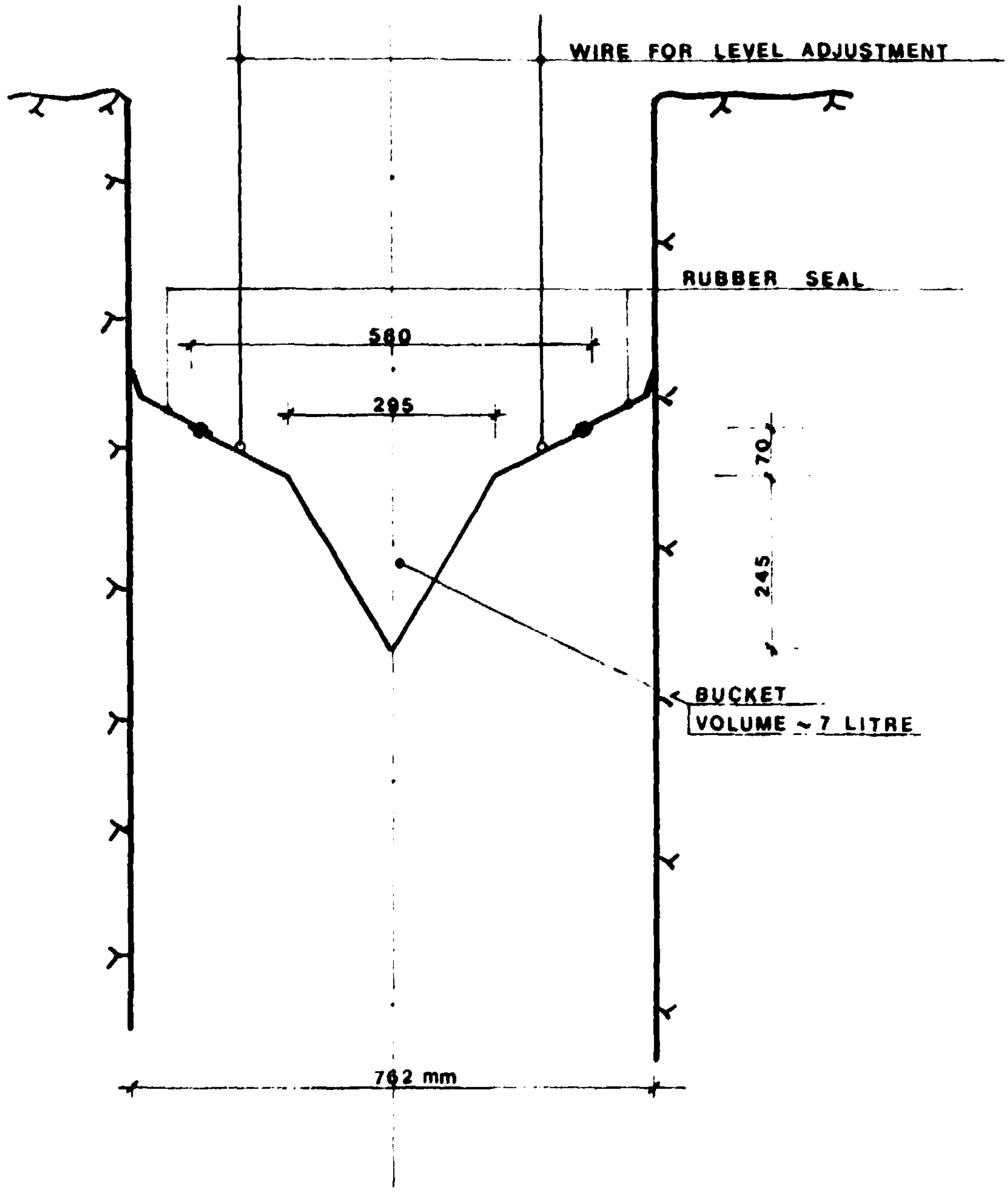

Fig.25. Device for collecting inflowing water in the heater holes.

This investigation indicates that the general conclusions from the pilot hole study hold also for the large concentric heater holes, except for no 4 which has an inflow comparable to that of hole no 1. The fact that not a single open, clearly water-bearing discontinuity could be identified in the fracture mapping operation (cf. Fig.11) suggests that the inflow measurement in this hole is not relevant. A critical analysis of the results of all the inflow recordings for the heater holes actually shows that no direct comparison can be made between the pilot holes and the full-size heater holes because the hydrologic conditions were so different when the respective tests were run. The major reason for this is that the inflow into all the holes was dominated by the fracture-rich tunnel floor which was exposed to quite different amounts of water at different occasions. The most reliable inflow characteristics are probably offered by the pilot holes.

5.4 Groundwater chemistry

For certain BMT purposes, such as the choice of sufficiently corrosion-resistive steel qualities for various gauges, and for the prediction of possible mineral transformations, certain groundwater chemical data need to be known. In this respect, the conditions in the BMT area are assumed to be similar to those in the rest of the mine, which are summarized in Table 8 and Fig.26. The data are based on various tests by LBL and by the Swedish Geological Survey.

Table 8. Chemical analyses of Stripa groundwater. Sample no 6 represents water from the DbH2 hole, which is very close to the BMT tunnel.

Analysis	Water sample						
	1	2	3	4	5	6	7
pH field	6.7	6.5	7.3	7.0	8.7	9.1	8.9
Ca ppm			21	24	14	19	17
Mg ppm			5.7	4.7	0.3	0.5	0.3
Na ppm			4.0	4.5	51	37	61
K ppm			2.0	1.0	0.2	0.4	0.2
Cl ppm			1.5	4.0	49	44	85
SO_4 ppm			2.0	10.0	1.4	2.4	2.4
HCO_3 ppm	1	5	93	82	73	79	52
SiO_2 ppm			13.6	9.9	12.0	12.0	12.1
Fe ppm						0.06	
NO_2 ppm						<0.01	
NO_3 ppm						0.12	
PO_4 ppm						<0.01	
NH_4 ppm						0.14	

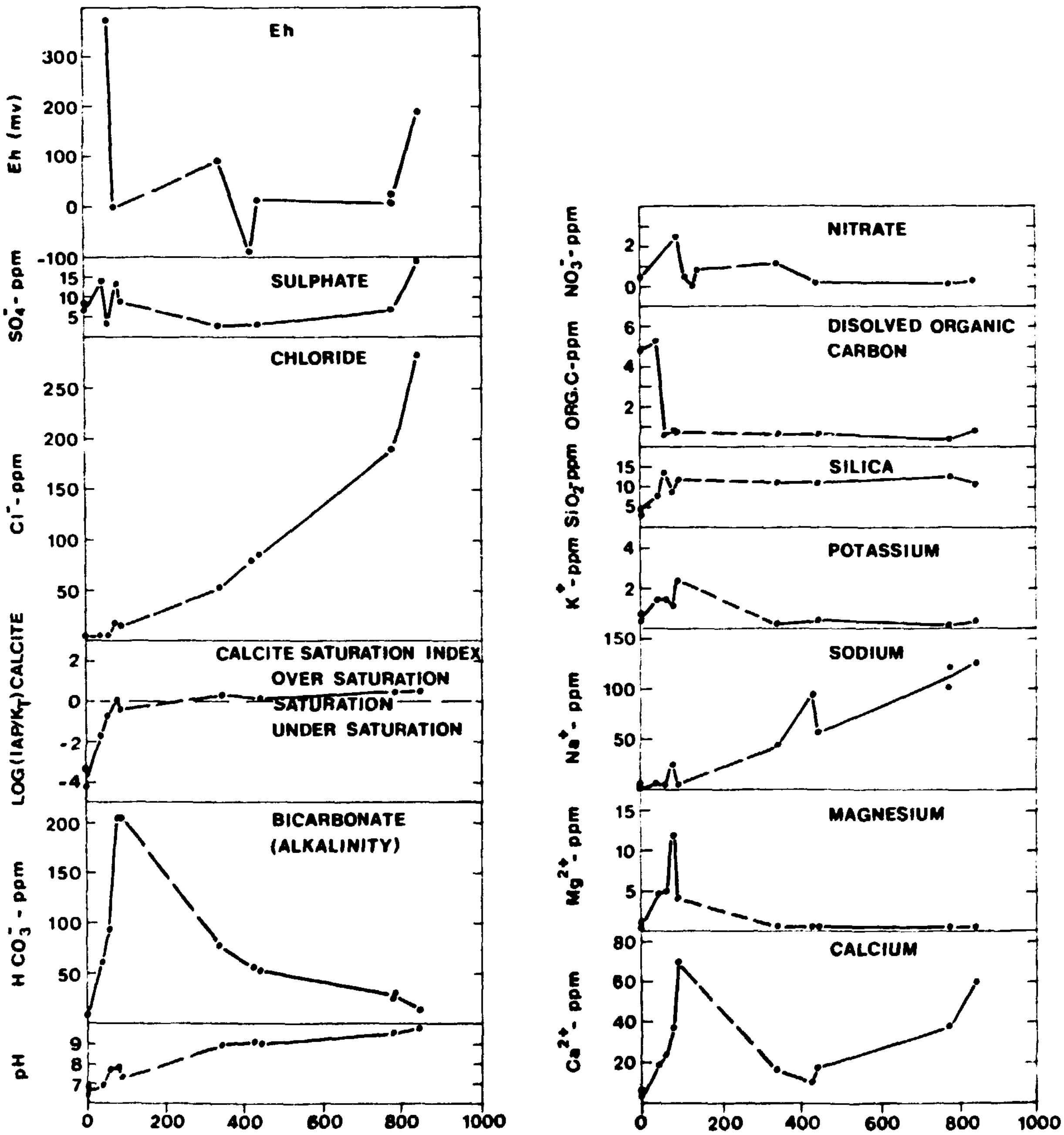

Fig.26. Average geochemical variation with depth of groundwaters in the Stripa mine /8/. Depth in meters on the horizontal axis.

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