International
Progress Report

IPR-04-21

Äspö Hard Rock Laboratory

Prototype Repository

Preparation of deposition holes prior to emplacement of buffer and canisters in Section II

D13

Roland Pusch
Geodevelopment AB

Christer Andersson
Svensk Kärnbränslehantering AB

May 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

Report no.	No.
IPR-04-21	F63K
Author	Date
Roland Pusch Christer Andersson	2004-05-14
Checked by	Date
Christer Svemar	2004-06-18
Approved	Date
Christer Svemar	2004-09-02

Äspö Hard Rock Laboratory

Prototype Repository

Preparation of deposition holes prior to emplacement of buffer and canisters in Section II

D13

Roland Pusch
Geodevelopment AB

Christer Andersson
Svensk Kärnbränslehantering AB

May 2004

Keywords: Prototype Repository, deposition holes, boring, rock stress, water flow

PROTOTYPE REPOSITORY

Deliverable D13

Preparation of deposition holes prior to emplacement of buffer and canisters in Section II

Roland Pusch

Geodevelopment AB

Christer Andersson

SKB

May 2004

EC Contract FIKW-2000-00055

EC-5th EURATOM Framework programme 1998-2002

Key Action: Nuclear Fission

Abstract

The deposition holes were bored by use of a Robbins SBM 1.8 TBM machine equipped with a vacuum system for removal of the muck. The average boring rate was 0.45 m per hour. During boring the torque, pressure in the thrust cylinders, rate of rotation, and rate of penetration were recorded. In adjacent boreholes gauges for rock stress/strain and temperature measurements were installed and an AE, Acoustic Emission, system was implemented before the boring of the deposition holes.

The average diameter of the six deposition holes varied between 1760 and 1762 mm. The requirements concerning straightness and orientation specified by SKB were achieved.

Geological mapping of the walls and bottom of the six holes as well as mapping of water inflow spots have been made. Measurement of the inflow rates has been made as well. These measurements demonstrate that the majority of the water inflow is at the bottom of the holes and that very few fractures in the walls contribute to the inflow.

Rock stress measurements have given the average primary stresses and calculation of the stress conditions in the near-field based on these stresses has yielded data of the maximum stresses caused by the excavation. These calculations indicate that the maximum compressive stress is generated at the uppermost part of the deposition holes and that it should not yield failure, which was also confirmed by the observations.

Sammanfattning

Deponeringshålen borrades med en vertikal tunnelborrmaskin tillverkad av Robbins med beteckningen SBM 1.8 TBM. Ett vakuumsystem användes för att transportera bort borrkaxet från borrhålsbottnen under borrning. Den genomsnittliga borrsjunkningen vid borrning var 0,45 m per timme. Under borrningen registrerades kontinuerligt bland annat vridmomentet, kraften i cylindrarna som pressar borrhuvudet mot berget, rotationshastigheten och borrsjunkningen. Vid borrningen av de två sista hålen var spännings-/töjningsgivare tillsammans med givare för temperaturmätning installerade i näraliggande kärnborrhål. Även ett system för registrering av akustisk emission användes vid borrningen.

Deponeringshålens genomsnittliga diameter varierade mellan 1760 och 1762 mm. De av SKB uppställda toleranskraven uppfylldes. Toleranser var givna på bland annat hålens rakhet och deras start- och slutkoordinater.

Deponeringshålens väggar och bottnar har karterats med avseende på geologi och inflödespunkter för vatten. Inflödet från de enskilda inflödespunkterna såväl som det totalt inflödet har mätts. Inflödesmätningarna visar att majoriteten av vatteninflödena i deponeringshålen härrör från hålbotten och endast en liten andel härrör från sprickor i hålväggarna.

Bergspänningsmätningar har genomförts i närområdet av Prototypförvaret och resultaten därifrån har använts för att beräkna lasten på deponeringehålens närområde. Beräkningarna påvisar att den största påkänningen erhålles i den övre delen av deponeringshålen men att brottlast ej uppnås. Dessa resultat stämmer väl med gjorda observationer.

Contents

1 Drilling of deposition holes

1.1 Background

The requirements with respect to the geometry of the deposition holes were defined by SKB to be as follows:

The nominal diameter of the hole shall be 1750 mm –5 and +50 mm.

The starting centre point of the hole shall divert no more than 25 mm from the theoretical starting point measured perpendicular to the tunnel axis. The deviation parallel to the tunnel axis may be no more than 50 mm.

Hole alignment. The measured centre point in the bottom of the hole shall not divert more than 25 mm from a vertical projection of the starting centre point.

Straightness. A measured centre point of the bore hole at any depth shall not divert more than 16 mm from a theoretical line drawn between the starting and bottom centre point. This criterion includes deviation due to re-gripping.

Re-gripping or any other operational activity may not result in an instant horizontal displacement of the centre point that is more than 10 mm.

The hole wall surface should not have larger irregularities than 10 mm.

No criteria have been defined for the bottom shape of the hole.

Several bids for the boring were considered but the company Drillcon AB was contracted for making the drillings by use of a TBM-type boring with vacuum extraction of the debris. The six holes in the test area were drilled between June and September 1999.

1.2 Drilling process

The drilling operations were performed successfully by use of a Robbins SBM 1.8 TBM machine with a drilling head illustrated by Figure 1-1. The average drilling rate was 0.45 m per hour. Cutters were not changed in the course of the drilling of the respective holes. During drilling of all the holes the rig was instrumented so that the turning momentum, pressure in the thrust cylinders, rate of rotation, rate of penetration among other things were recorded. These data were used to evaluate this new shaft-drilling technique. In boreholes adjacent to deposition holes No. 5 and 6 gauges for rock stress/strain and temperature measurements were fixed by cementation. The readings taken were used to study the rock mechanical response close to the deposition holes due to excavation. Around the same deposition holes an AE, Acoustic Emission, system was implemented. Two rock stress measurements in the vicinity of the Prototype Repository area had given rather different results regarding the direction of the major principal stress. When monitoring the volume around a deposition hole during boring with an AE-system most events will occur in the hole walls that are perpendicular to the direction of the major principal stress.

After analyse of the AE-information the far field stress orientation could be assessed. This assessment agreed very well with one of the rock stress measurements made and the stress field orientation could be determined. After a later recalculation of the rock stress measurement that did not agree with the AE-measurement it was found that the consultant had used a wrong co-ordinate set for the calculations. The new results now agreed with the orientation derived from the AE-measurements.

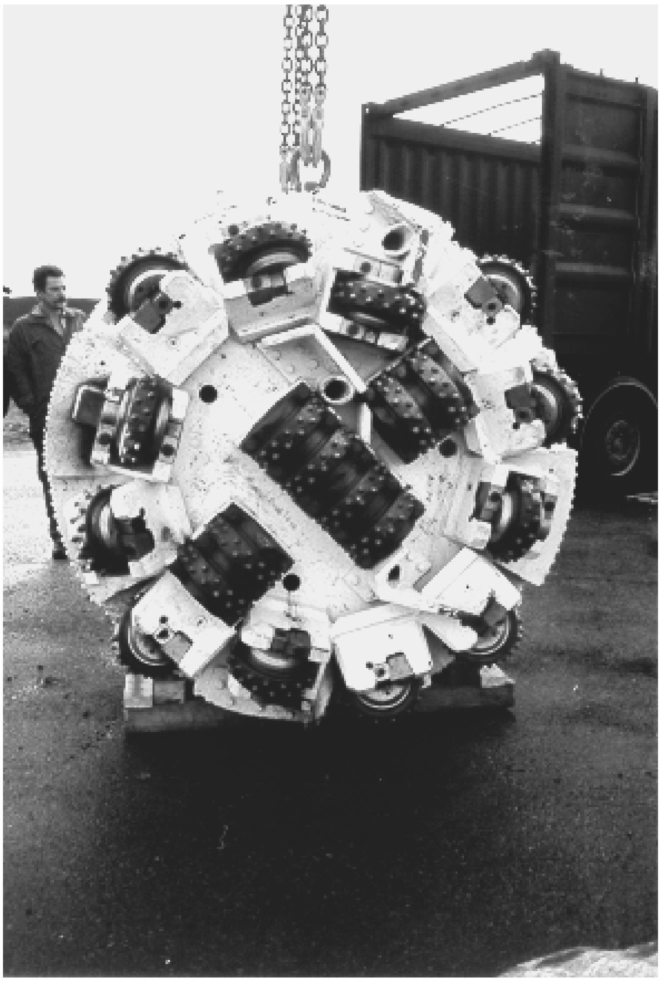

Figure 1-1. *Head of the drilling machine showing carbide cutters. Note some of the carbide cutters were replaced with disc cutters.*

The cuttings produced during boring had a sieved d_{50} value of 2.8 mm. The larger chips had an average size of approximately 28/18/7 mm (length/width/thickness). It was removed from the borehole during boring by a vacuum system (Andersson et al, 2002).

2 Properties of the deposition holes

2.1 Geological structure

The geological structure and the rock mass properties determine the hydraulic performance of the rock and its mechanical behaviour. An example of discontinuities that characterize the rock mass in which the Prototype Repository test drift is located is illustrated in the series of models shown in Figure 2-1.

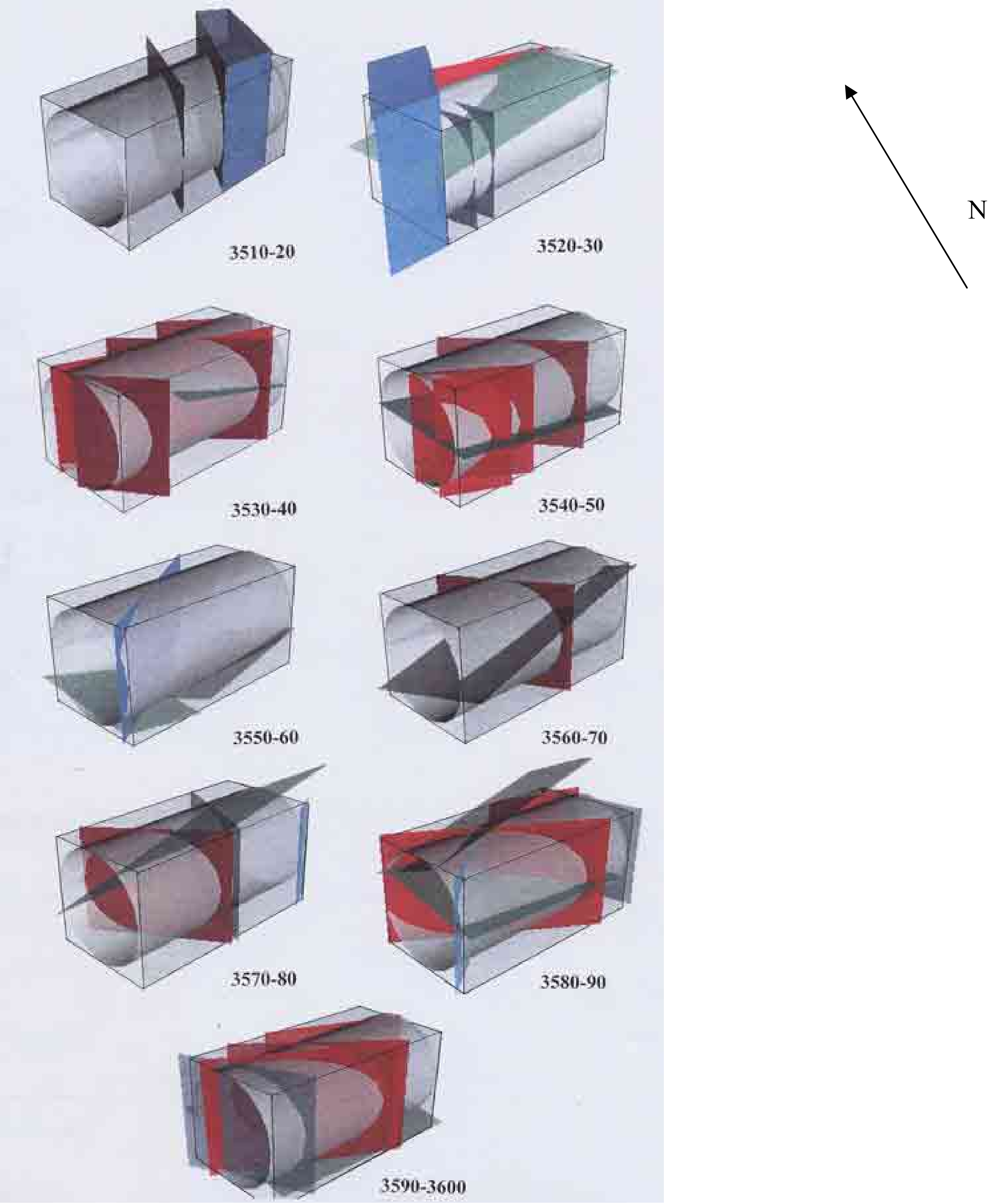

Figure 2-1. *Visualisation of discontinuities in the Prototype Repository test drift.*

2.2 Deposition hole geometry

Surveying of the deposition holes gave the data in Table 2-1, which certifies that the criteria specified in Section 1.2 were fulfilled. A special observation was that a block with a volume of a few cubic decimeters fell from the wall in hole 2 approximately 1.5 meters down the hole. This piece of rock was located in a part of the hole where modelling indicate increased compressive stress due to the excavation. The main reason for it's expulsion was the existence of unfavourably oriented pre-existing fractures.

Table 2-1. Geometry of deposition holes.

Section	Deposition hole	Maximum deviation from centre line [mm]	Offset between start and end point [mm]	Averaged diameter [mm]
1	Hole 1 DA3587G01	6	5.4	1760
1	Hole 2 DA3581G01	5	7.8	1760
1	Hole 3 DA3575G01	5	1	1761
1	Hole 4 DA3569G01	4	4	1761
2	Hole 5 DA3551G01	6	4	1762
2	Hole 6 DA3545G01	8	1.4	1760

2.3 Discontinuities in walls and bases of the deposition holes

Geological mapping of the wall and base of the six deposition holes with indication of where inflow has been spotted is presented in Figures 2-2 to 2-7 [1].

These data have been reported earlier in D12 but are shown also in the present document for possible use in forthcoming analyses of flow and stress. Comparison with Figure 2-1 indicates that a number of fractures in adjacent deposition holes may interact.

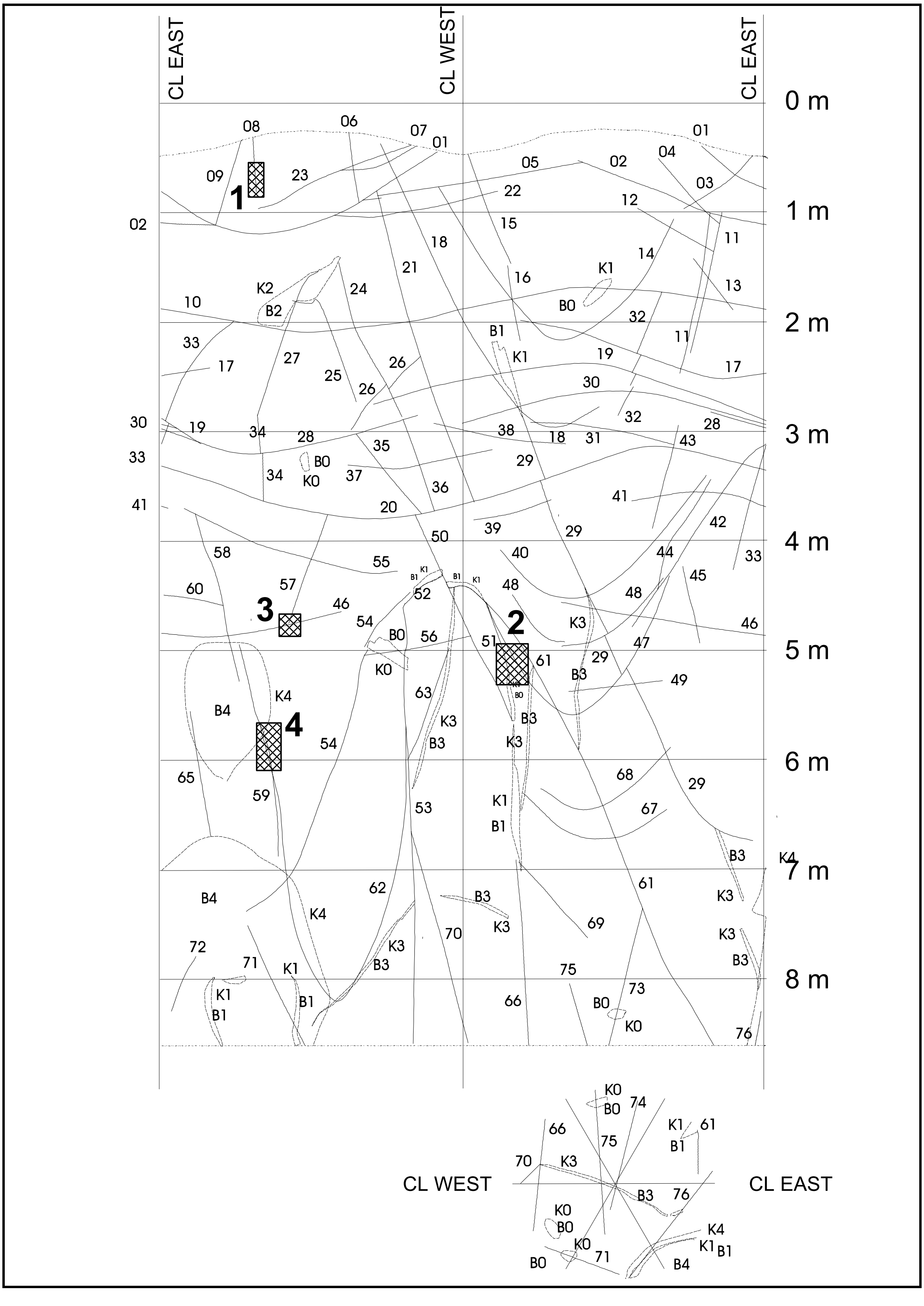

Figure 2-2. *Deposition hole mapping in DA3587G01. Mapped water-bearing features are marked with shaded areas.*

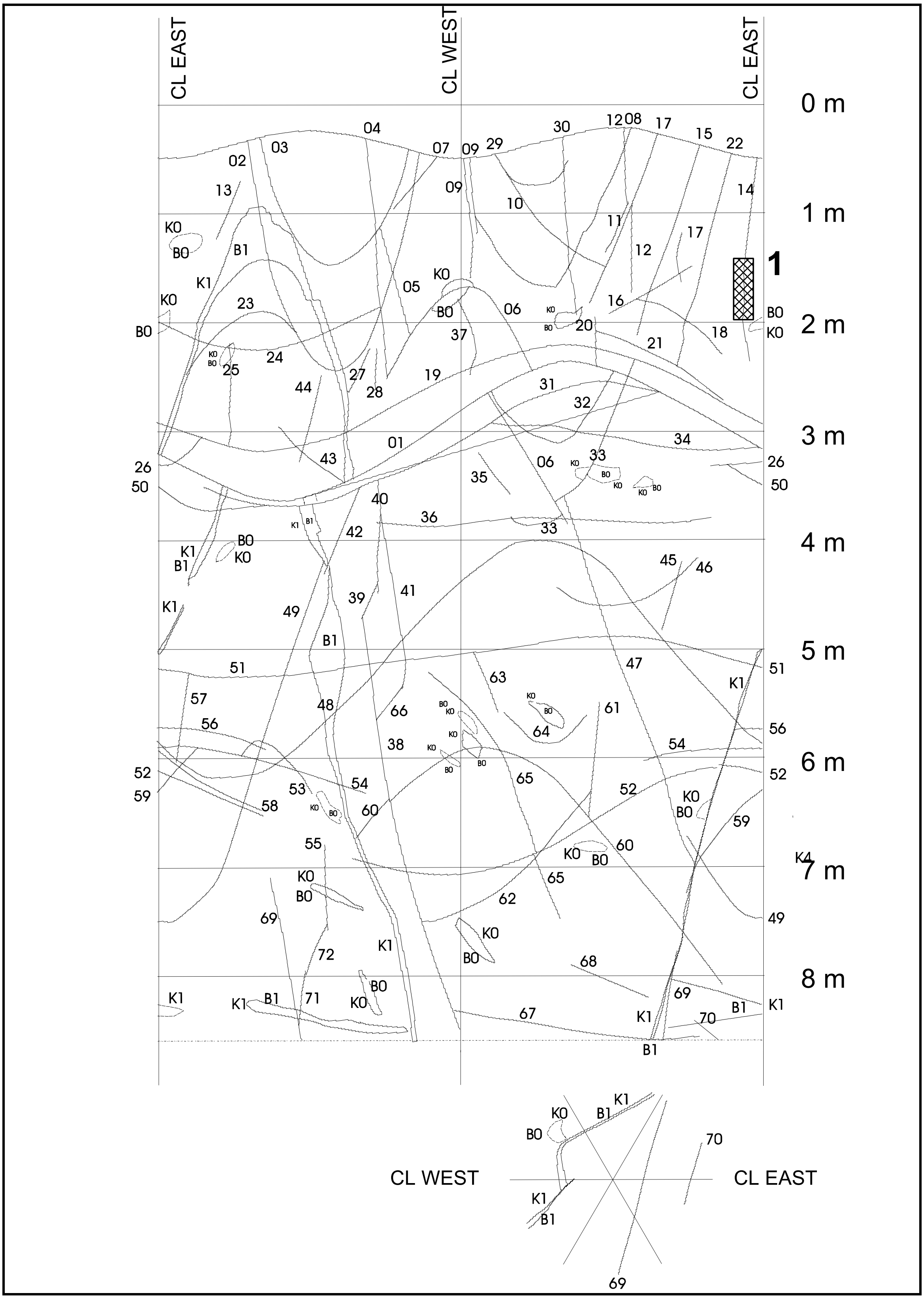

Figure 2-3. Deposition hole mapping in DA3581G01. Mapped water-bearing features are marked with shaded areas.

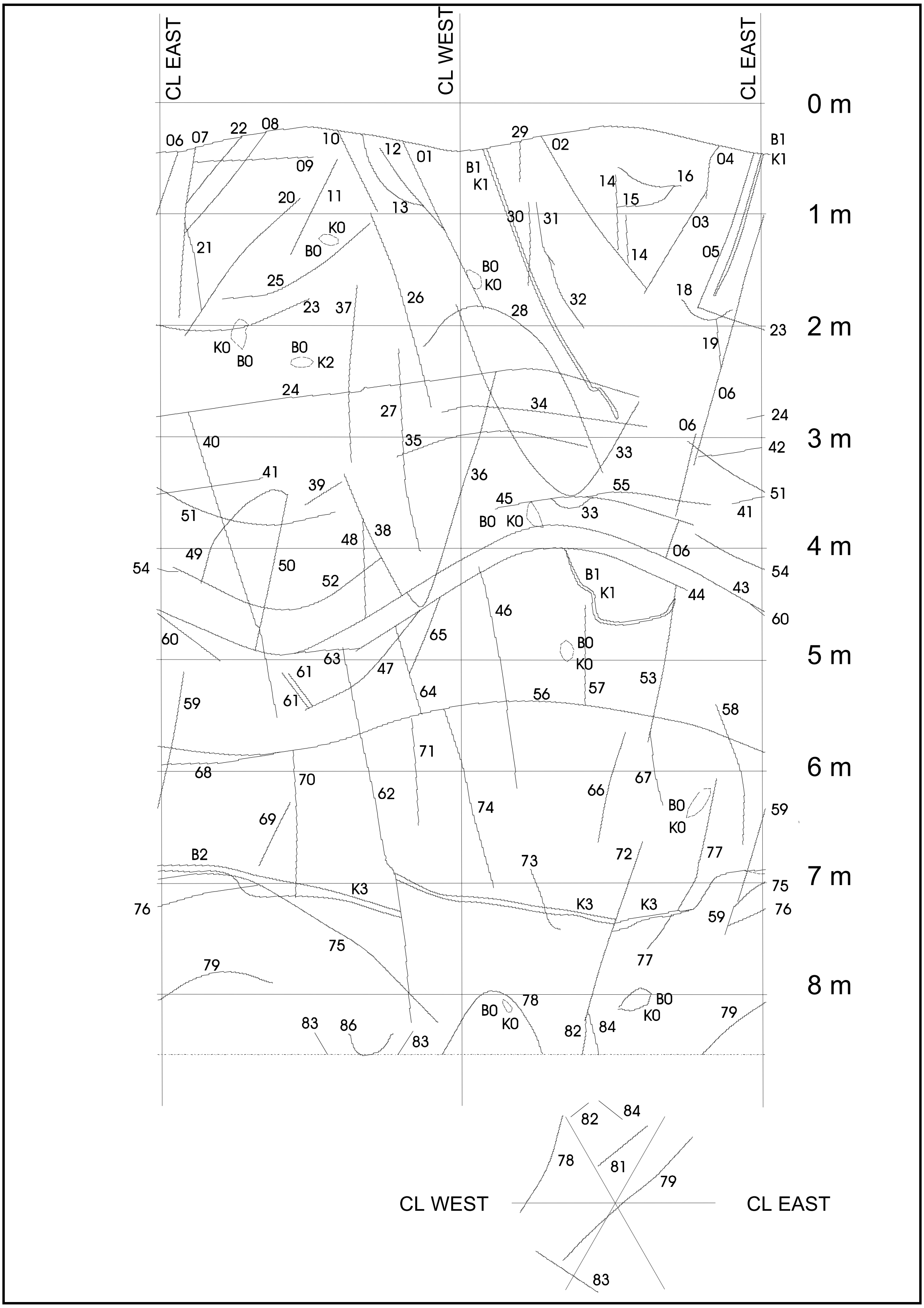

Figure 2-4. *Deposition hole mapping in DA3575G01. No water-bearing features were observed.*

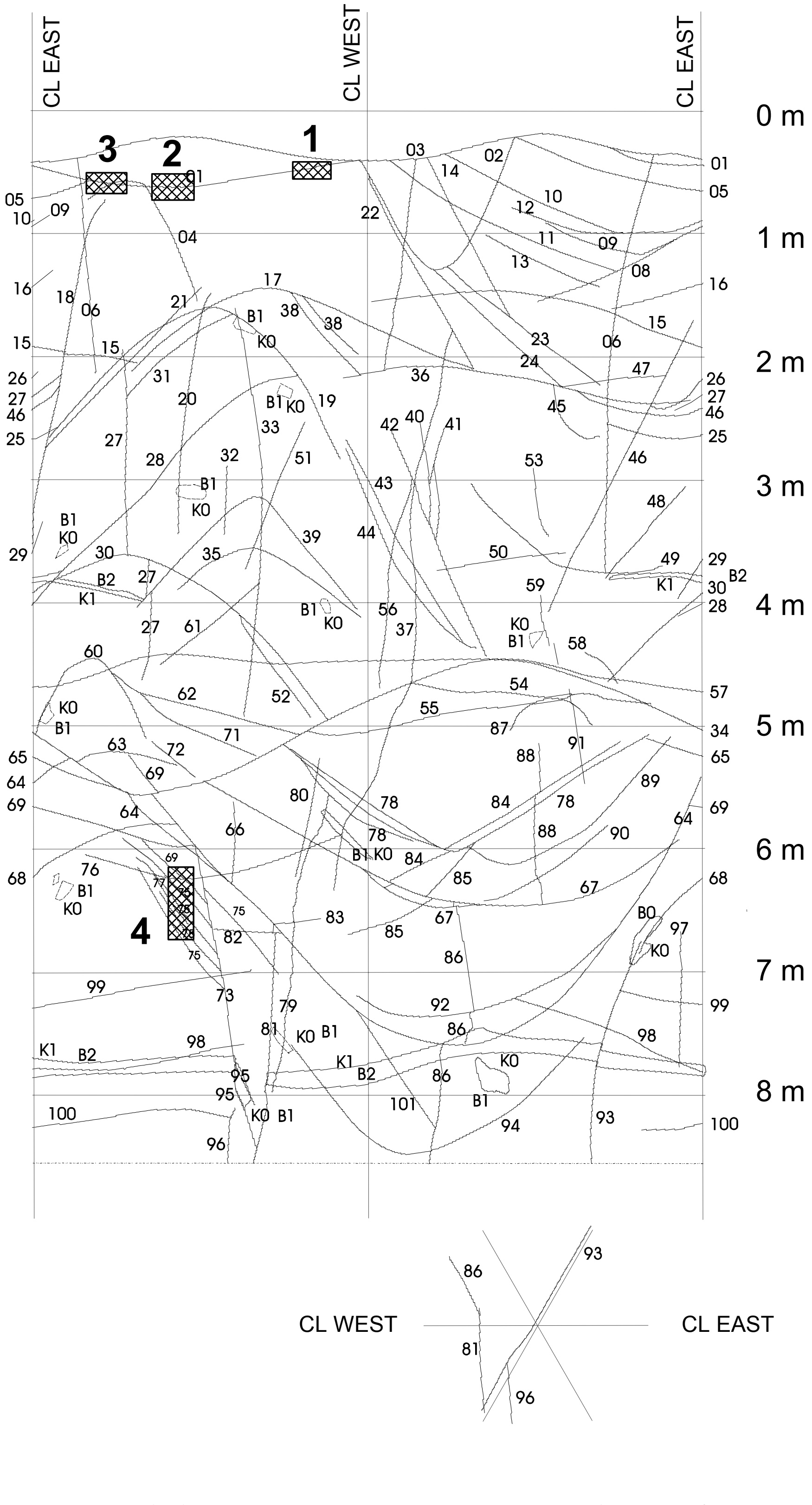

Figure 2-5. *Deposition hole mapping in DA3569G01. Water-bearing features are marked with shaded areas.*

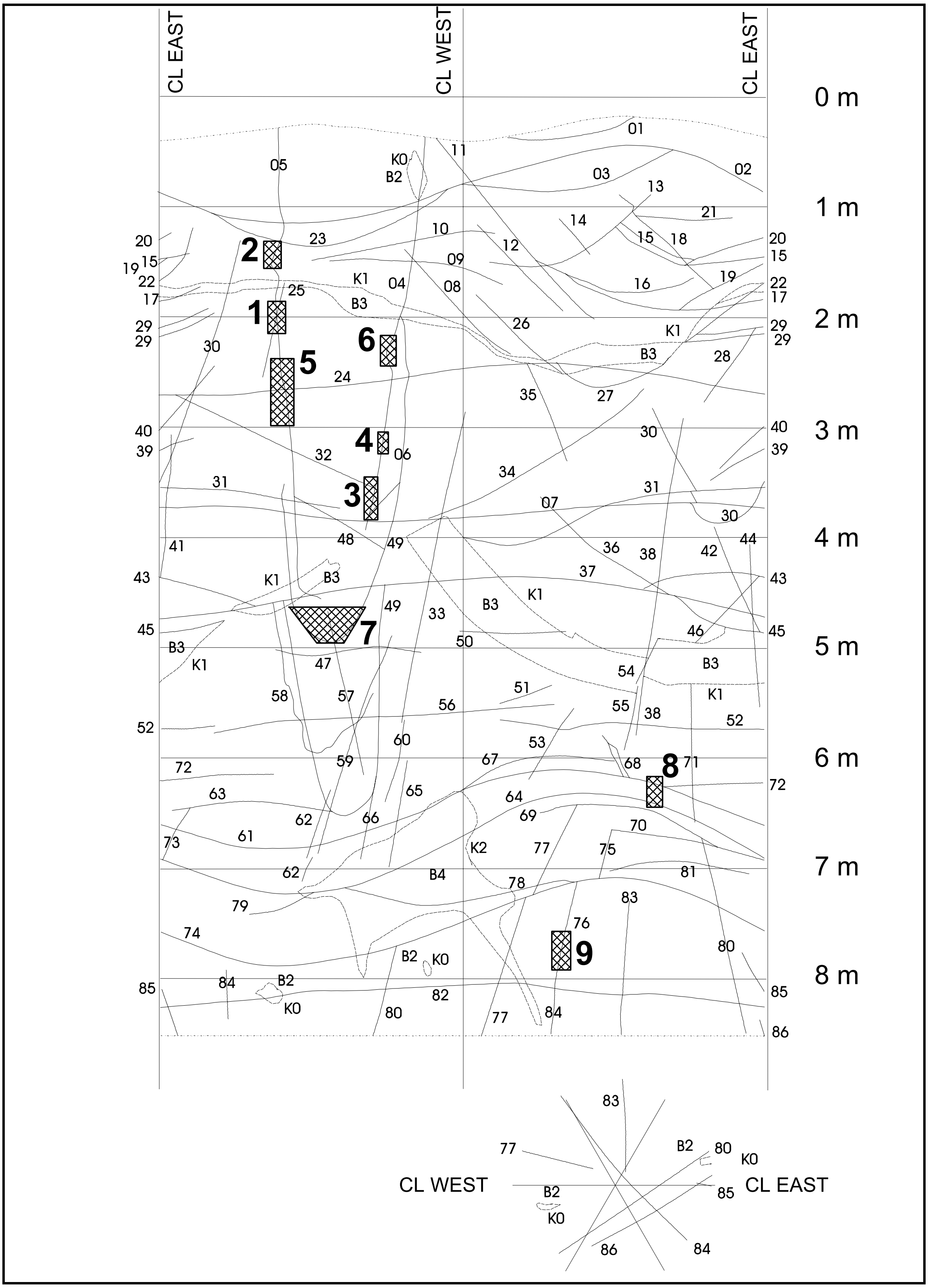

Figure 2-6. Deposition hole mapping in DA3551G01. Water-bearing features are marked with shaded areas.

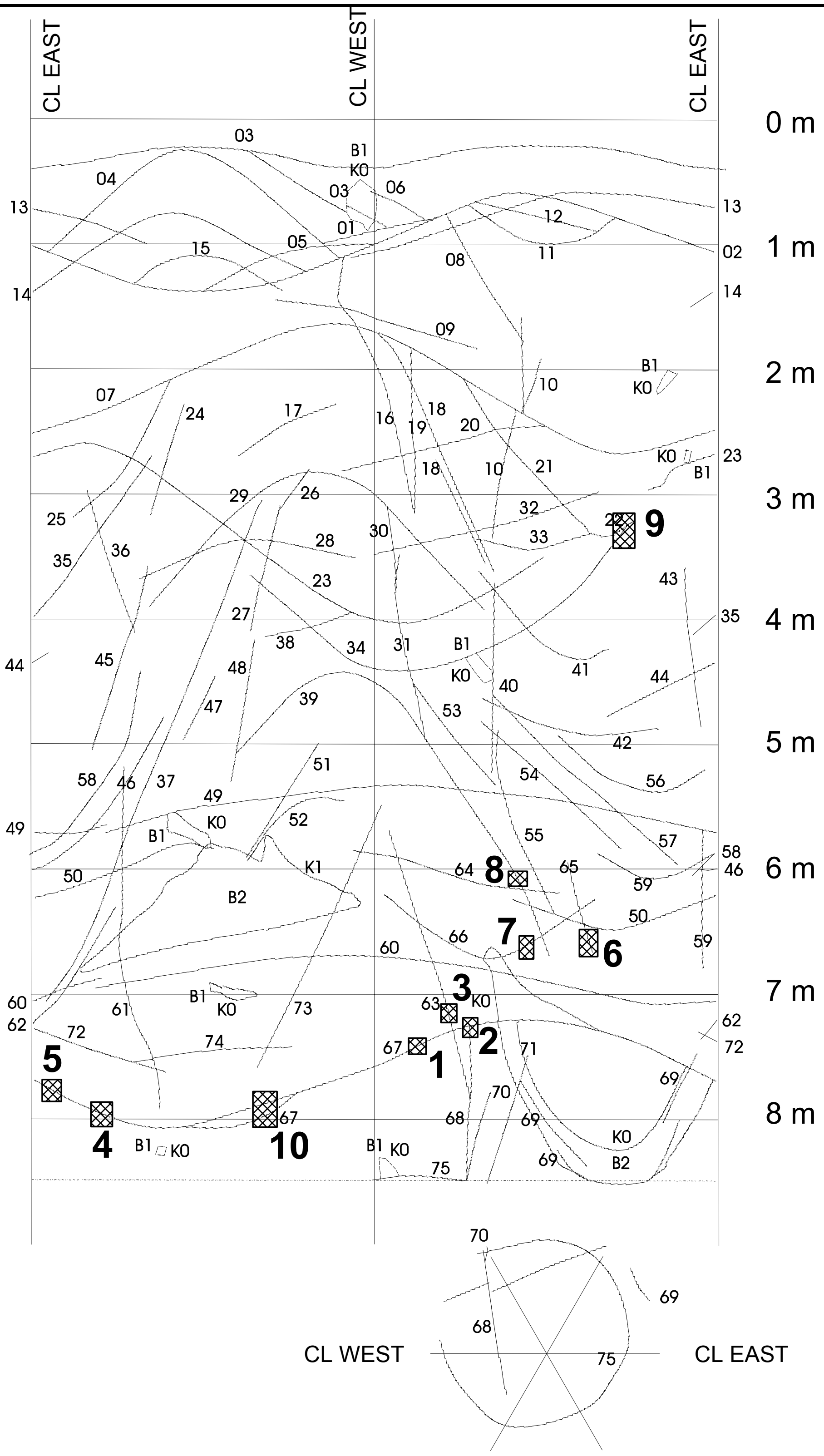

Figure 2-7. Deposition hole mapping in DA3545G01. Water-bearing features are marked with shaded areas.

2.4 Preparation of deposition holes

2.4.1 General

For preparing the activities in Section II, i.e. application of the buffer, canisters and backfill, water sampling and piezometric and stress measurements in the rock, the following steps were taken:

1. Cutting grooves in the walls of the deposition holes for instrument cables.
2. Core-drilling of holes for installation of packers and sensors.
3. Cleaning
4. Casting cement for creating a plane, horizontal base for the canisters

5. Application of plastic sheets for controlled application of pellet fill

Figure 2-8 shows a longitudinal section through the test drift.

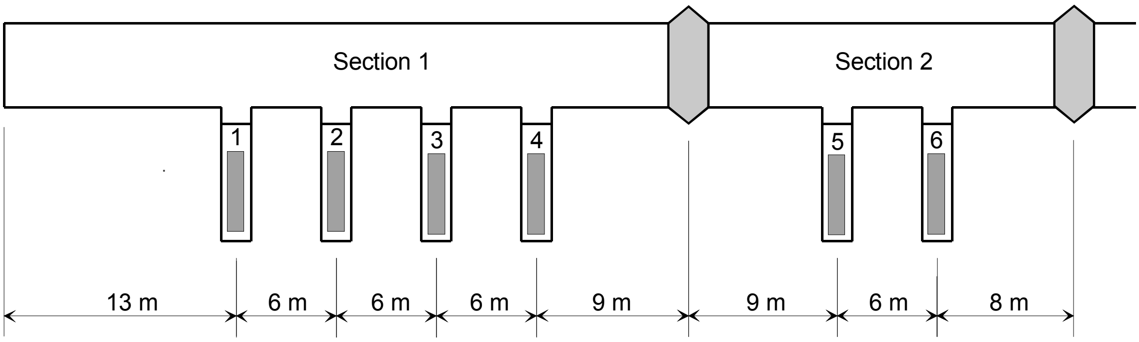

Figure 2-8. *The Prototype Repository.*

2.4.2 Grooves

Grooves in the walls of the deposition holes were sawed, the depth being a few centimetres. After emplacement of the cables the grooves were sealed with cement grout IC30, with a water/cement ratio of 0.6 with 0.5% superplasticizer.

2.4.3 Core-drilling of holes for installation of packers and sensors

The rock mass in Section II contains a significant number of boreholes for hydraulic testing, sampling, stress and vibratory measurements. Figures 2-9 is a general perspective over the test area and Figure 2-10 an overview of the system of longer boreholes in Section II.

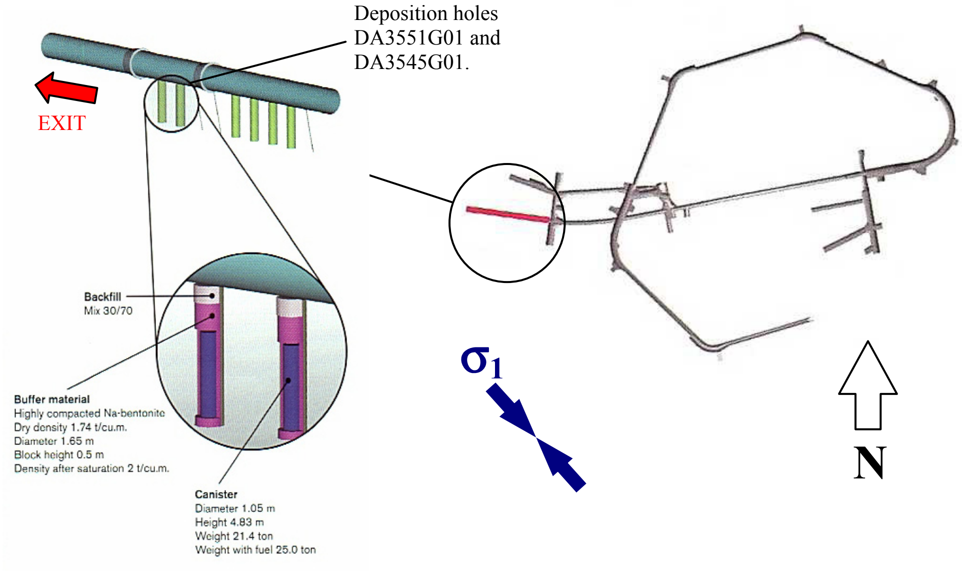

***Figure 2-9**. The Äspö test area with Section II marked.*

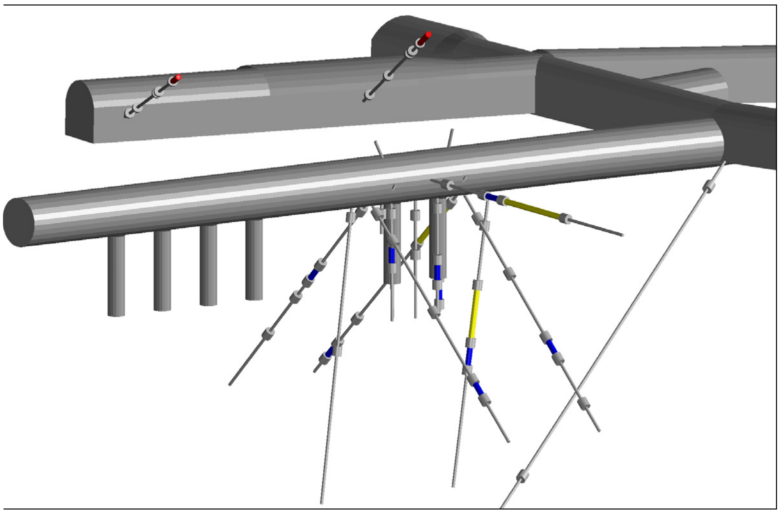

***Figure 2-10.** Boreholes with hydro monitoring sections in Section II. Packers (grey), Hydrochemistry (red), Hydraulics (yellow), Circulation (green), hydromechanlical (blue).*

Boreholes for testing and instrumentation drilled from deposition holes (DA 3551G01 and DA3445G01)

Drilling machines of type COP 1238 and Onram 100 with core-drilling bits were used to drill holes for hydraulic testing and installation of gouges. For securing stability and exactness a movable stand was bolted to the periphery. Water flushing with 1 l/min.was made in the drilling process. Nine holes with a minimum diameter of 28 mm were drilled in each of the two deposition holes. Three holes were about 2 m deep, three about 5 m deep and three holes at around 8 m deep. Of the three holes at each level two were bored parallel to each other at opposite sides of the deposition hole, while the third was drilled perpendicular to the other two. This implies that two holes were bored almost parallel to the tunnel axis and one hole almost perpendicular to the tunnel axis at each level.

Temperature measurements in rock

The thermocouples in Section II are placed on 3 levels in each of the deposition holes, at the base, and 3 and 6 m up. Level (Figure 2-11). At the latter levels thermocouples are placed in two boreholes drilled perpendicular to each other. In the lowest holes four thermocouples are placed 0, 0.2, 0.5 and 1.0 m from the rock surface. In each of the other boreholes, five thermocouples are placed 0, 0.2, 0.6, 1.1 and 2.2 m from the perimeter of the holes. .

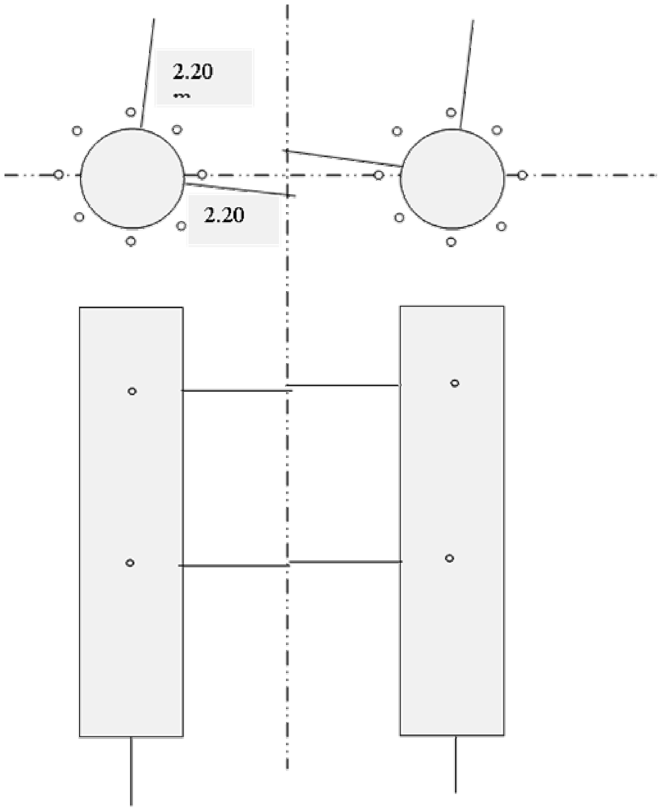

Figure 2-11. *Overview of the thermocouples in Section II. The deposition hole to the left is No 5 and the one to the right No 6.*

Stress measurements in rock

Deposition holes No. 5 and 6 have been instrumented for monitoring stress and strain changes of the host rock. Eight biaxial stress meters were placed in 76 mm boreholes at approximately 1, 3, 4 and 7 m depths. The positions of these short holes are shown in Figure 2-12. The diameter of the holes is 32 mm.

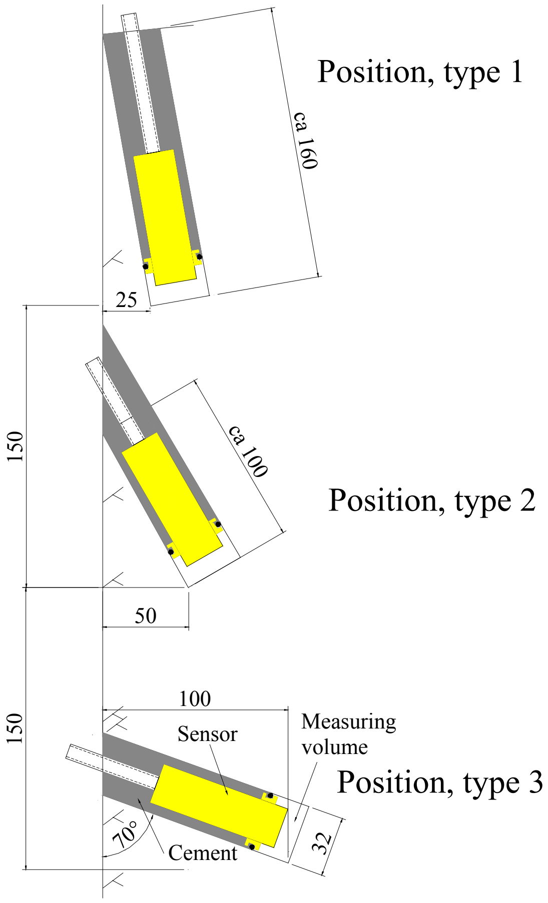

Figure 2-12. *Figure showing the different types of orientation of the sensors.*

Complementary measurements

Ten boreholes with 76 mm diameter were cored from the inside of the two deposition boreholes for displacement sensors and thermocouples (Figures 2-13 to 2-15). Figure 2-16 is a view of the orientation of the boreholes.

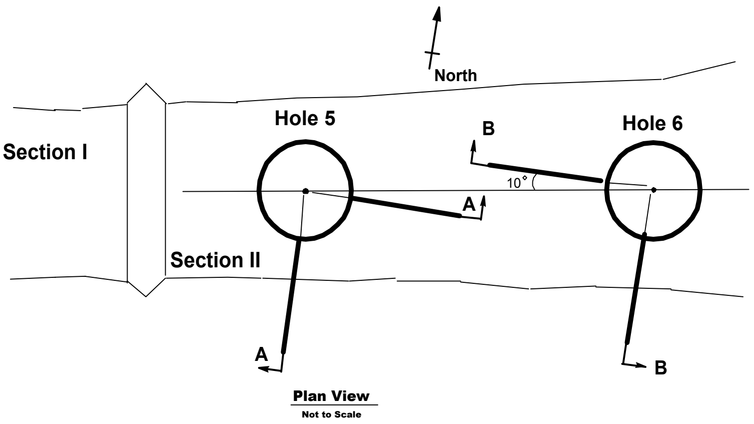

Figure 2-13. Plan view of complementary boreholes.

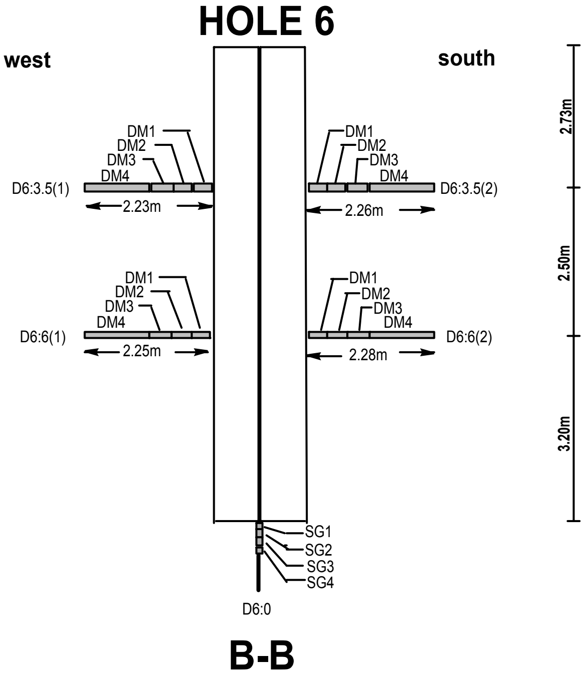

Figure 2-14. Elevation view of complementary instruments in deposition Hole 6.

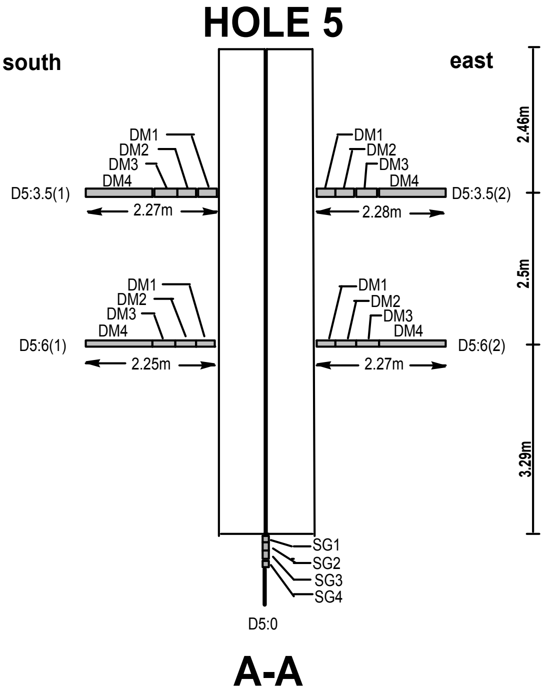

Figure 2-15. *Elevation view of complementary instruments in deposition Hole 5.*

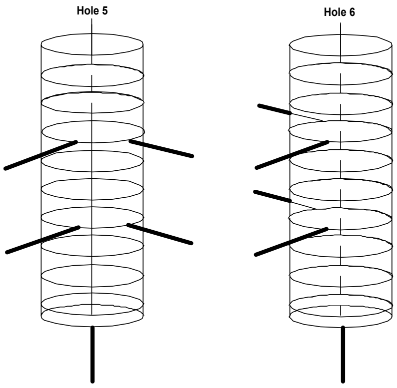

Figure 2-16. *Schematic view of complementary boreholes.*

Boreholes close to the deposition holes

Three 7 m deep and three 3 m deep vertical holes with 56 mm diameter were drilled close to deposition holes No 5 and 6 for resistivity measurements. Such data are used for estimation of the degree of saturation in the rock. The distance between the deposition hole walls and the 56 mm holes is approximately 200 mm.

2.4.4 Foundation of canisters

The base of the deposition holes was evened out and a concrete cast using Portland cement with w/c 0.46 and 0.5 % superplastizer. The semiliquid cement gave a perfectly horizontal base for the canisters which were placed on copper plates covering the cement.

2.4.5 Cleaning of the deposition holes

The deposition holes were cleaned by vacuum-cleaning before the installation of the buffer.

2.4.6 Installation of water protection sheets in the deposition holes

A plastic sheet formed as a large tube with a diameter of 1910 mm was attached to the rock surface of the deposition hole in order to prevent wetting of the bentonite buffer during the installation phase. The sheet was attached to the concrete foundation slab by an O-ring, which was removed after the installation of the buffer and the canister by pulling it up before the gap between the bentonite blocks and the rock wall was filled with bentonite pellets.

2.5 Stress situation in the rock around the deposition holes

An average stress tensor for the area has been compiled from more than 20 triaxial overcore measurements. The primary stresses in the rock have been determined and the stress changes that will result from construction and operation stages have been predicted. The major principle stress is about 25 MPa at 310^o bearing with subhorizontal plunge. The uniaxial compressive strength of the host rock is approximately 210 MPa and the uniaxial crack-initiation stress about 120 MPa.

Stresses generated during drilling of the deposition holes and during heating have been predicted by numerical methods and in-situ rock stress measurements. These analyses have shown that high stresses, up to 120 MPa, may be developed around the deposition holes before the Prototype Repository tests start.

3 References

Svemar C, Pusch R, 2000. Prototype Reporsitory, Project description FIKW-CT-2000-00055. Int. Progress Report IPR-00-30, SKB, Stockholm.

Forsmark T., Rhén I., Andersson C., 2000 Prototype Repository: Hydrogeology - Deposition- and lead-through boreholes: Inflow measurements, hydraulic responses and hydraulic tests. SKB IPR-00-33.

Andersson C., Johansson Å., 2002 Boring of full scale deposition holes at the Äspö Hard Rock Laboratory. Operational experiences including boring performance and work time analysis. SKB TR-02-26