2 OVERVIEW OF SHALLOW BOREHOLE INVESTIGATIONS

Preparation for MSB-2 started in April 2002. Drilling and planned field work in both MSB-2 and 4 were carried out at the same time. After completion of the field work in MSB-2 and 4, drilling and planned field work in both MSB-1 and 3 were carried out. All field work and site restorations were finished on schedule by the end of October 2002. Four sets of the MP System^{TM} were installed in all boreholes by December 2002. In each borehole, the entire drilled sections include the sedimentary rocks of the Mizunami Group and the upper part of the Toki Granite. Geological, hydrogeological and geochemical investigations were carried out according to the Working Programme [2], as shown in Figures 1 to 6.

The following subsections (**2.1** to **2.7**) provide an overview of the Shallow Borehole Investigations in each field.

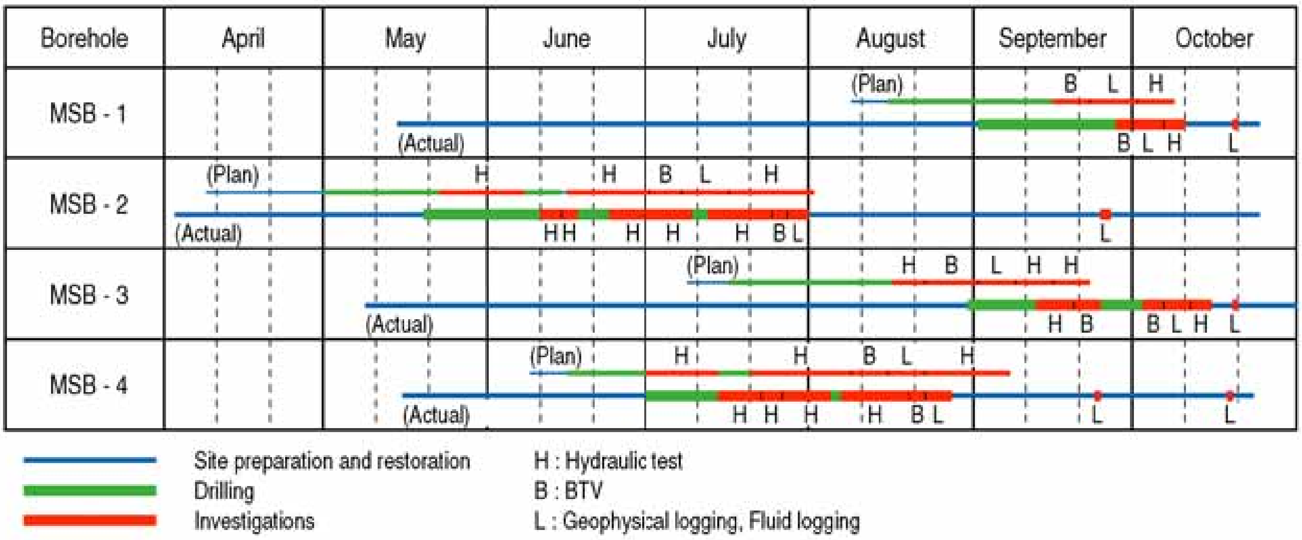


Figure 1 Timetable of planned/actual investigations in MSB boreholes

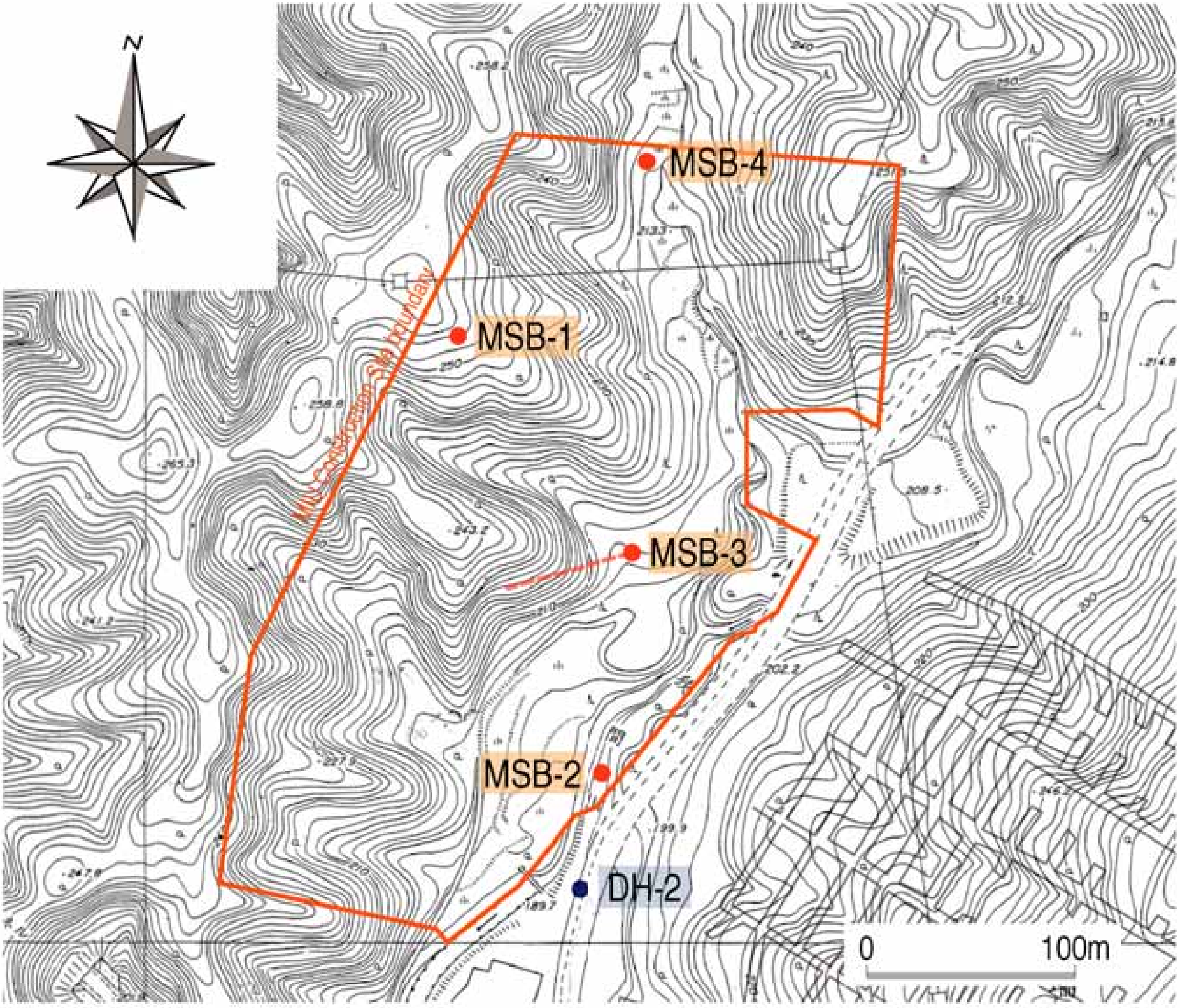


Figure 2 Location of MSB boreholes

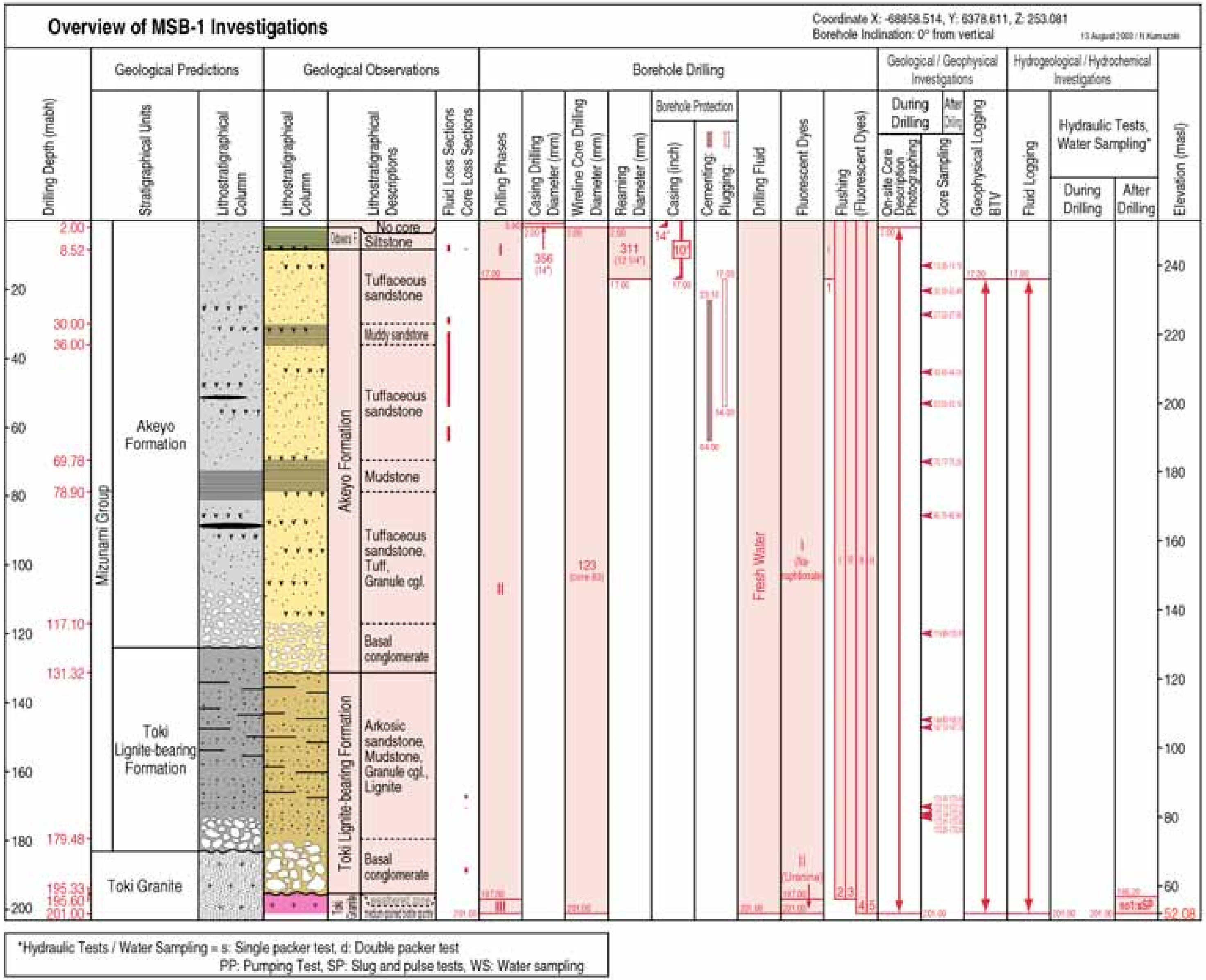
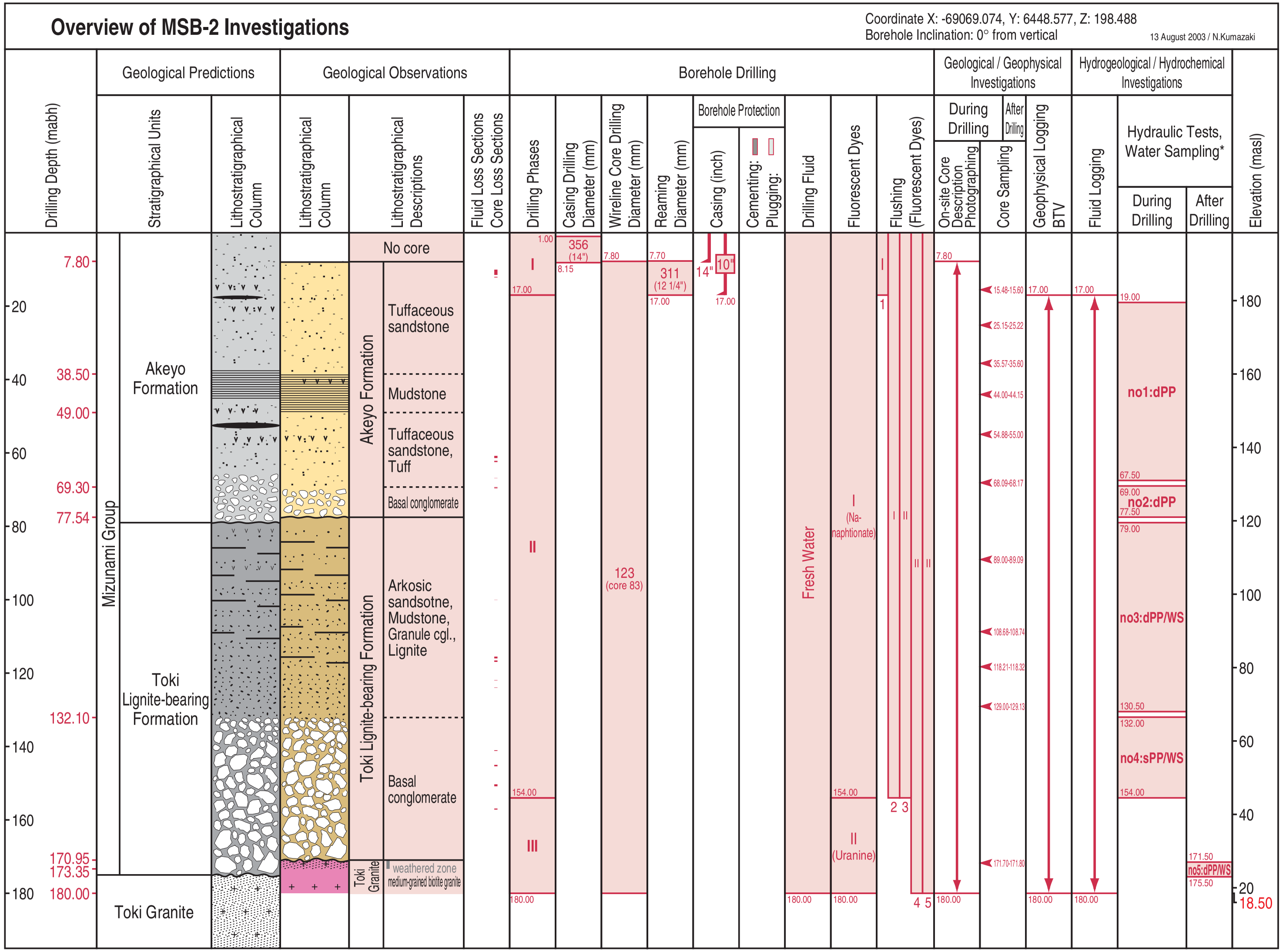


Figure 3 Overview of MSB-1 Investigations



*Hydraulic Tests / Water Sampling = s: Single packer test, d: Double packer test
PP: Pumping Test, SP: Slug and pulse tests, WS: Water sampling

Figure 4 Overview of MSB-2 Investigations

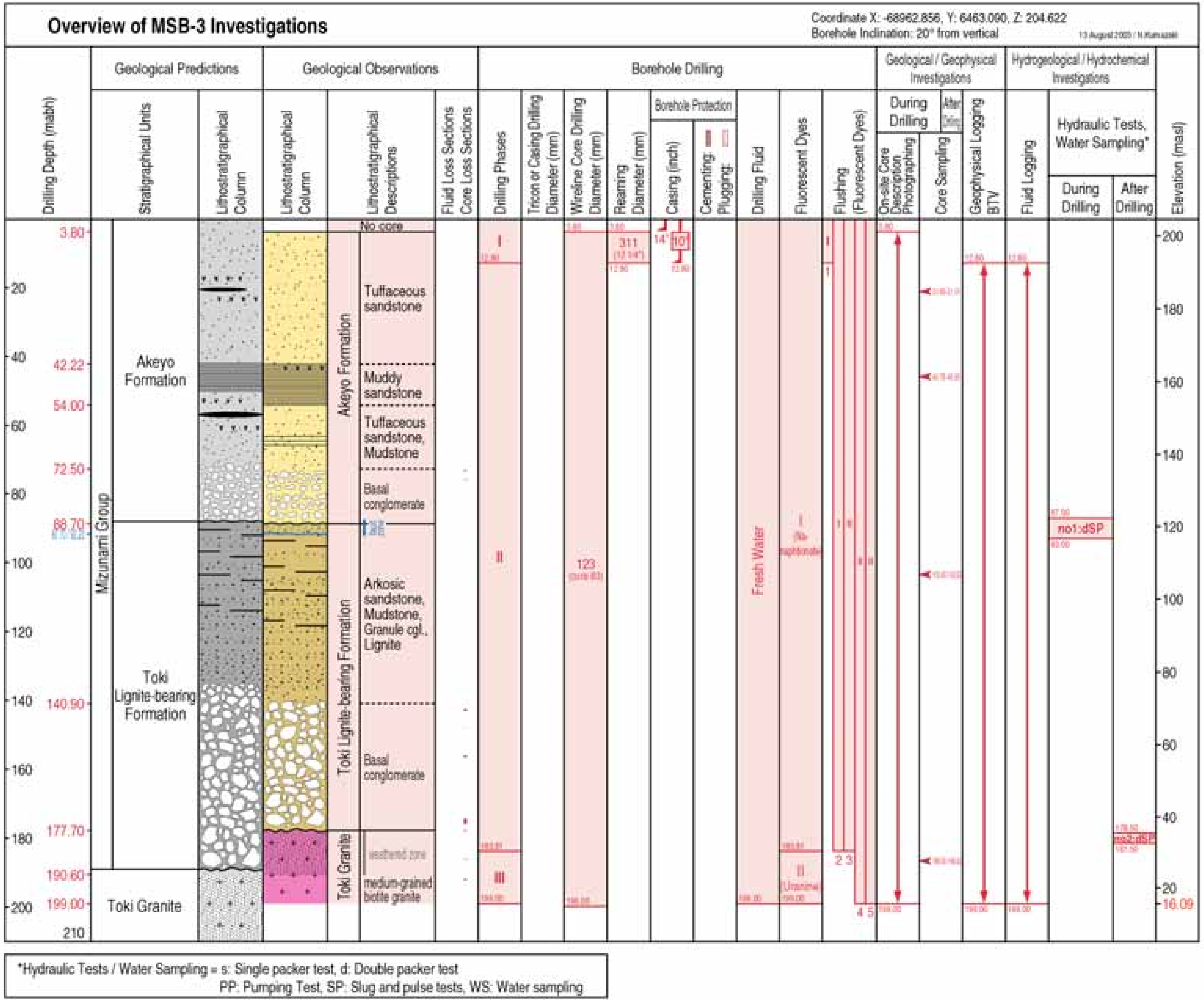


Figure 5 Overview of MSB-3 Investigations

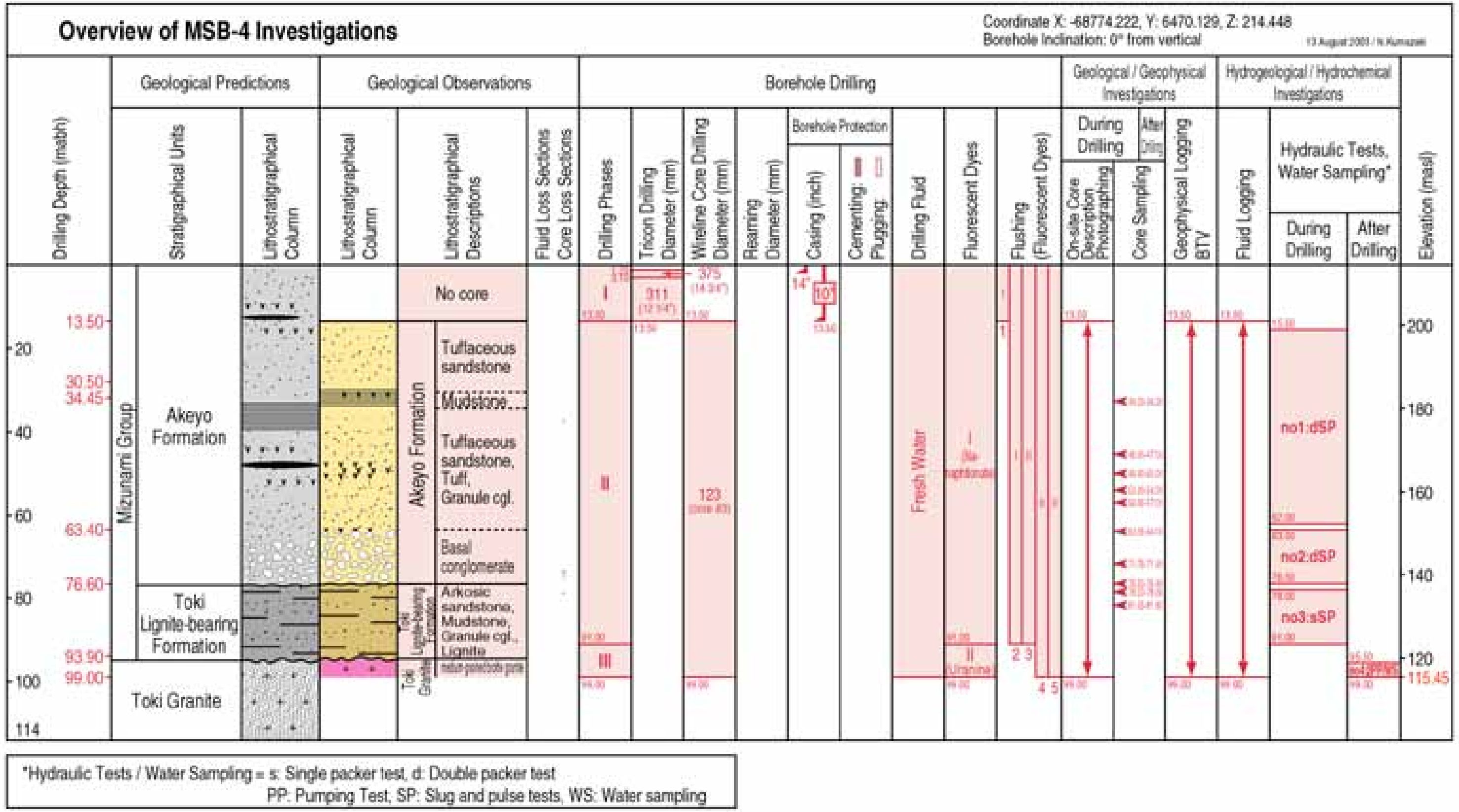


Fig. 6 Overview of MSB-4 Investigations

2.1 Borehole Drilling

2.1.1 Aims

- Full core recovery for geological, hydrogeological, hydrochemical and geochemical investigations.
- To provide suitable locations for downhole investigations such as hydraulic tests, groundwater sampling and borehole logging.

2.1.2 Work performed

The four MSB boreholes were drilled with two rigs. Initially, MSB-2 and 4 were drilled simultaneously, and then MSB-1 and 3 were drilled. As planned the original working programme, each borehole was drilled in three phases, phase I from surficial material to bedrock, phase II to above or immediately below the unconformity between sedimentary rocks and granite, and phase III to below the bottom of the weathered granite (Figures 3, 4, 5 and 6).

Casing and cementing: After the soil and friable top of the Mizunami Group were drilled with either tricone bit or casing drilling from the surface to depths ranging from 2.00 to 8.15 mabh (metres along borehole), 14 inch (355 mm) casing pipes were installed and fixed by full hole cementing. PQ wireline core drilling was then performed from the bottom of the 14 inch casing to a depth of 12.80 to 17.00 mabh. In MSB-4, tricone bit drilling was used because the need for core was low. After the boreholes were reamed to a diameter of 12 1/4 inch (311 mm), 10 inch (254 mm) casing pipes were installed and fixed by full hole cementing. Summary of drilling and casing installations in each borehole is shown in Table 1.

Table 1 Summary of drilling and casing installations

Borehole		MSB-1	MSB-2	MSB-3	MSB-4
Coordinates*	X	-68858.514 m	-69069.074 m	-68962.856 m	-68774.222 m
	Y	6378.611 m	6448.577 m	6463.090 m	6470.129 m
	Z	253.081 m	198.488 m	204.622 m	214.448 m
Drilling length		201.0 m	180.0 m	199.0 m	99.0 m
Core recovery		98.6 %	96.8 %	97.3 %	99.4 %
Casing	14”-STPG**	2.00 mabh	8.15 mabh	3.41 mabh	3.10 mabh
	10”-SUS***	17.00 mabh	17.00 mabh	12.80 mabh	13.50 mabh
	Temporary 5”-SUS***	-	-	12.57 mabh	-
Water level after drilling		64.27 mabh	13.75 mabh	14.8 mabh	8.1 mabh

*Coordinates: World Geodetic System
**STPG: carbon-steel casing
***SUS: stainless-steel casing

Coring: PQ wireline core drilling was performed from the bottom of the 14 inch casing to the final depth in each borehole. A triple-barrel corer with an acrylic innermost tube was employed to ensure full core recovery. For all PQ drilling, the borehole diameter was 123 mm and the core diameter was 83 mm. MSB-1, 2 and 4 are vertical, while MSB-3 is an inclined hole, about 20 degrees from vertical, oriented to intersect the NNW fault in the sedimentary rocks.

Drilling/flushing fluid: Fresh water was used for all drilling and flushing operations. The fresh water was tagged with different fluorescent dyes, depending on the rock being drilled, to allow identification of drilling fluid during the hydrochemical investigations. Drilling fluid (I), fresh water tagged with Na-naphtionate, was used only in the sedimentary rocks and drilling fluid (II), fresh water tagged with uranine, was used in the final drilling phase into the upper part of the granite. The concentration of fluorescent dyes was kept as constant as possible during drilling.

Monitoring: Drilling data such as drilling rate, bit revolution, bit load, torque, pumping pressure, rate of water supply and return and any fluid volumes lost or gained were continuously monitored to complement the geological and hydrogeological investigations. A single shot hole deviation survey and calliper logging were performed after every 30 m of drilling and/or at geological boundaries because borehole enlargement due to circulation fluid erosion was expected in the sedimentary rocks based on prior experience in drilling other boreholes. The principal drilling parameters monitored and the result of borehole deviation in each borehole are presented in Figures 7 to 14.

Borehole protection: The occurrence of fluid loss and/or borehole collapse and the remedial action taken in each borehole is presented in Table 2. In MSB-1, 100 % drilling fluid loss occurred in the interval from 28 to 64 mabh. It was decided that plugging by cementing as well as with cellulose (LCM) was needed in this interval because hydraulic testing and long term monitoring would be difficult to perform because of the low hydraulic head. Although 100 % fluid loss occurred again below 67 mabh in MSB-1, drilling continued without borehole protection because there was insufficient time to identify the outflow point(s) and perform hydraulic tests. In MSB-3, borehole collapse occurred at the bottom of the basal conglomerate of the Akeyo Formation and at the NNW fault. Dredging and flushing by reverse circulation (from outside to inside of PQ rods) during drilling was performed often to prevent sludge accumulation and borehole collapse.

Table 2 Occurrence of fluid loss and borehole collapse and the remedial action in each borehole

Borehole	MSB-1	MSB-2	MSB-3	MSB-4
Loss of drilling fluid	i) 100 % loss (28~64 mabh) ii) 100 % loss (67~199 mabh)	Several percent loss (between top of basal conglomerate layer in Akeyo F. and bottom of borehole)	Several percent loss (in granite)	None.
Remedial action for loss of drilling fluid	Fluid loss section filled with LCM and cemented. Drilling continued.	Drilling and investigation continued.	Drilling and investigation continued.	None.
Borehole collapse	None.	None.	91~102 mabh	None.
Remedial action for borehole collapse	None.	None.	Dredging and flushing carried out.	None.

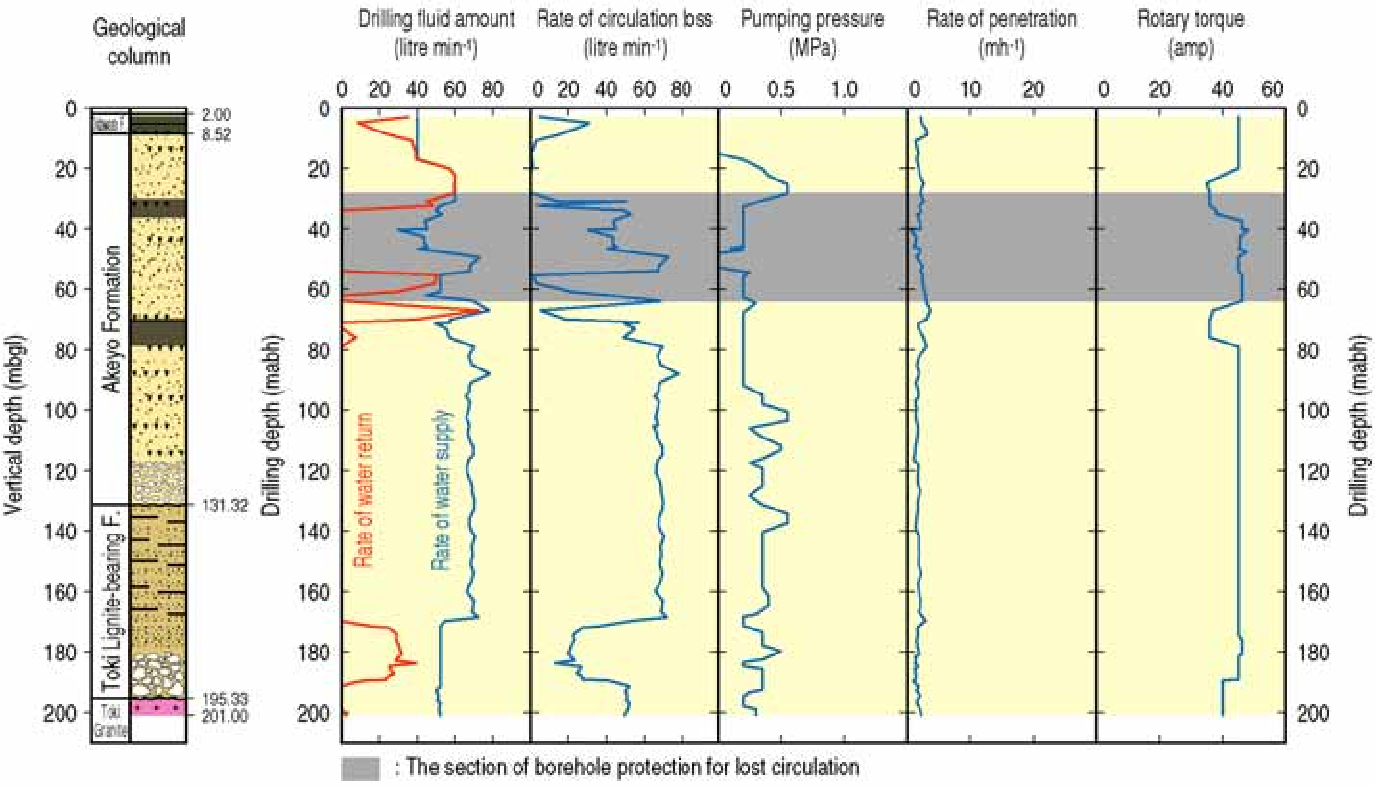


Figure 7 Monitoring of major parameters during drilling (MSB-1)

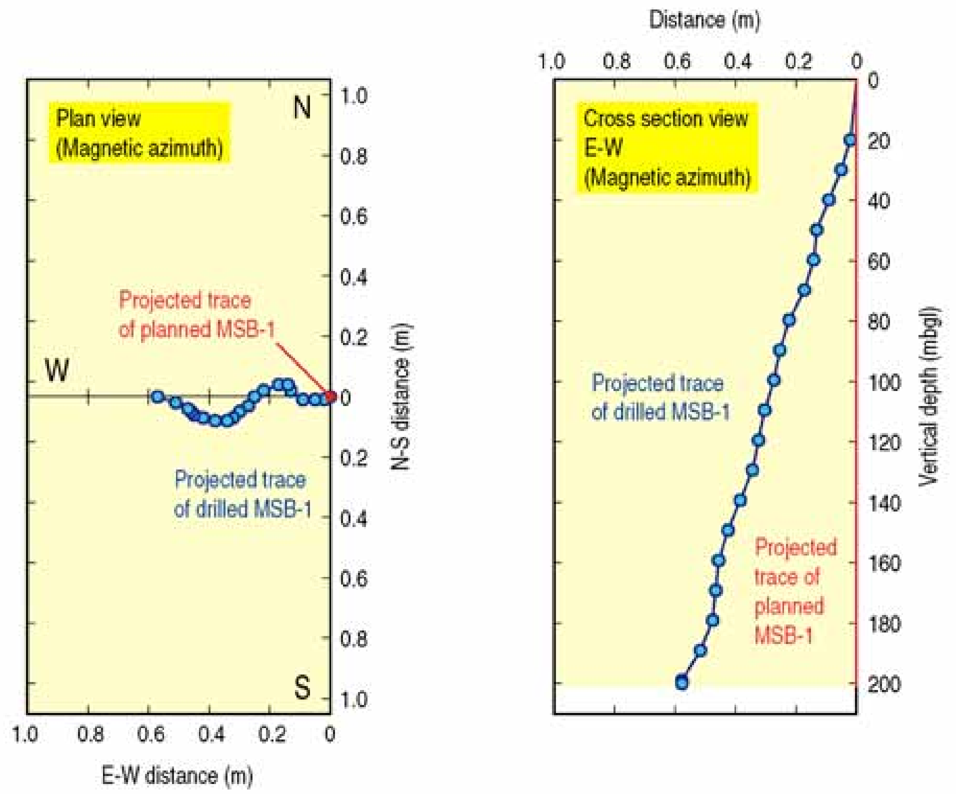


Figure 8 Borehole deviation from 0.00 - 201.00 mabh (MSB-1)

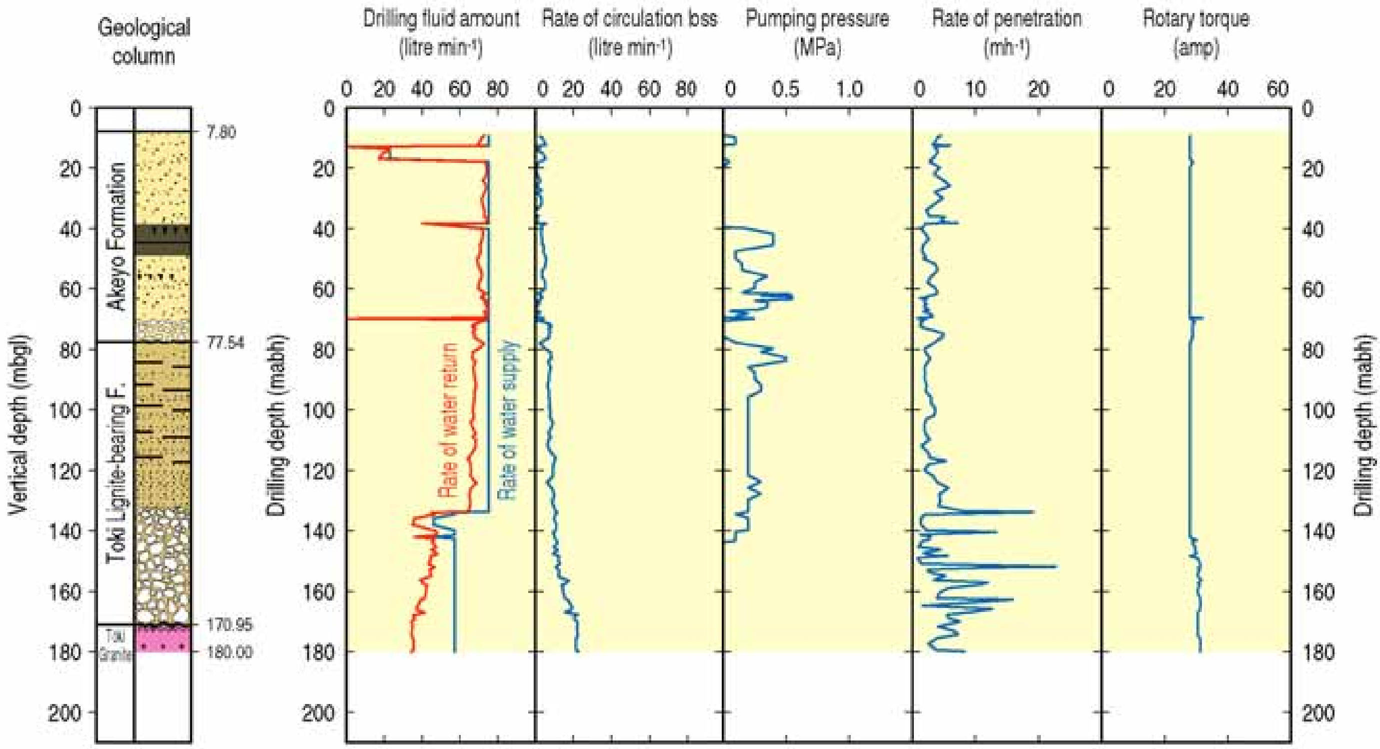


Figure 9 Monitoring of major parameters during drilling (MSB-2)

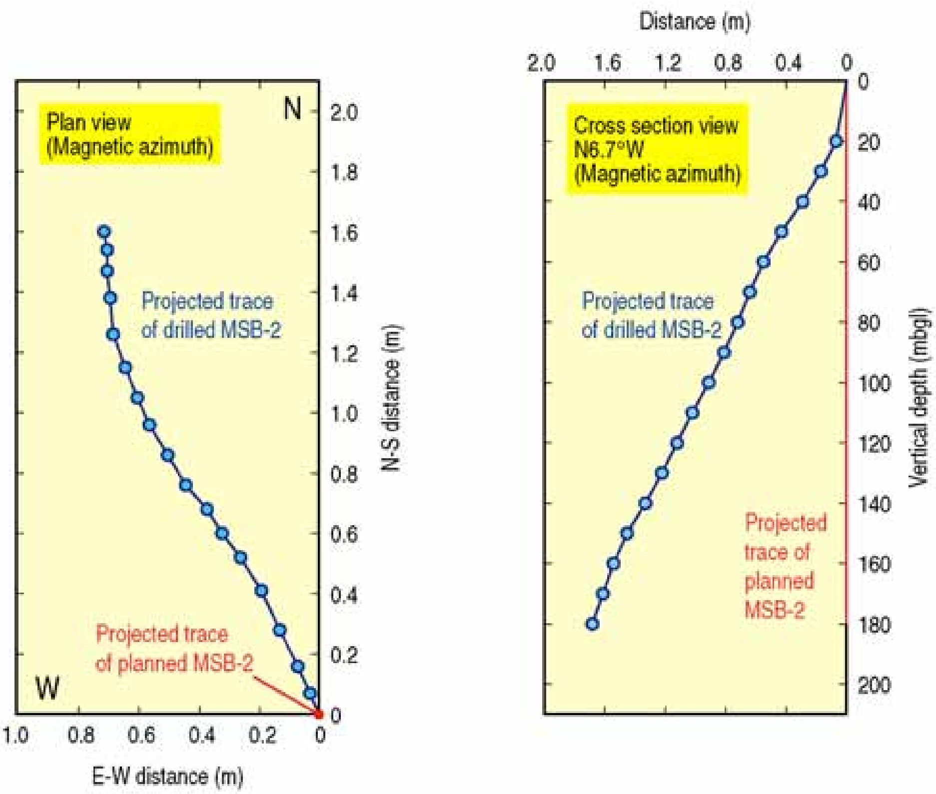


Figure 10 Borehole deviation from 0.00 - 180.00 mabh (MSB-2)

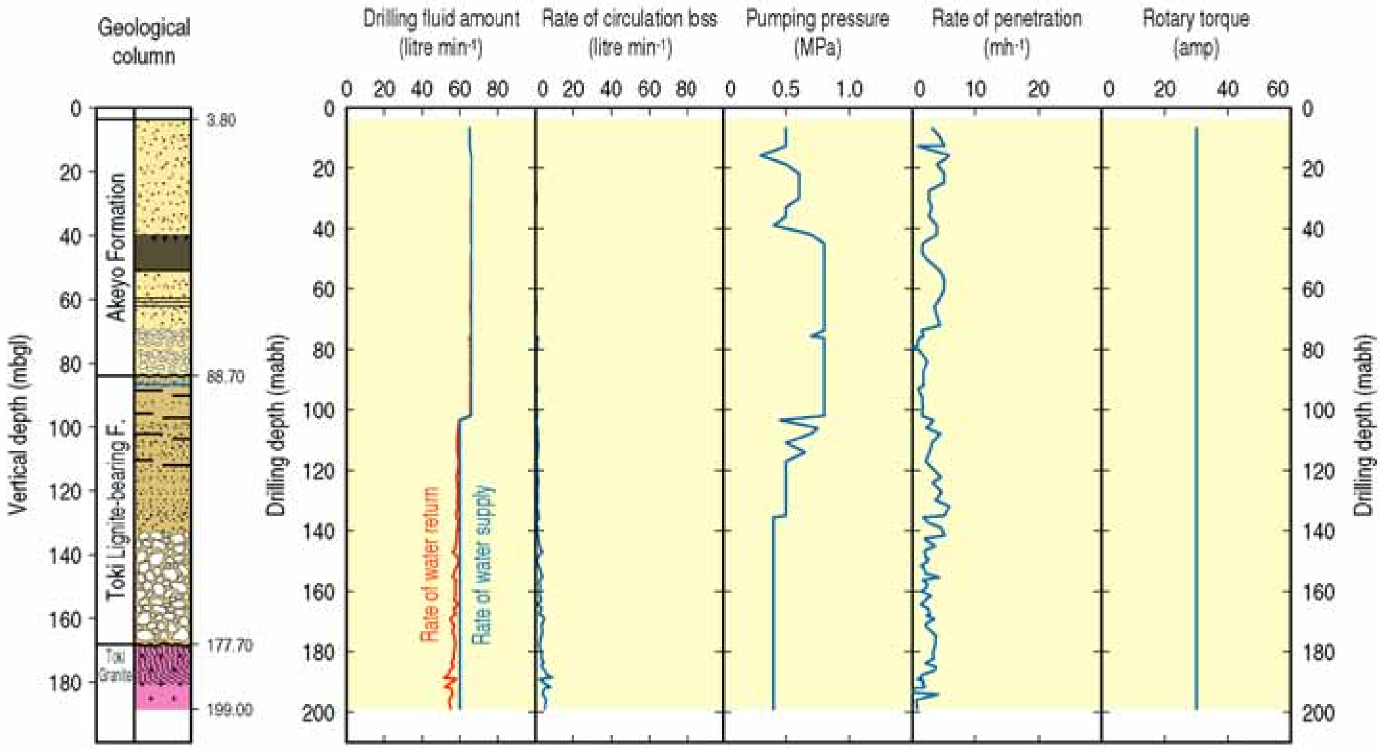


Figure 11 Monitoring of major parameters during drilling (MSB-3)

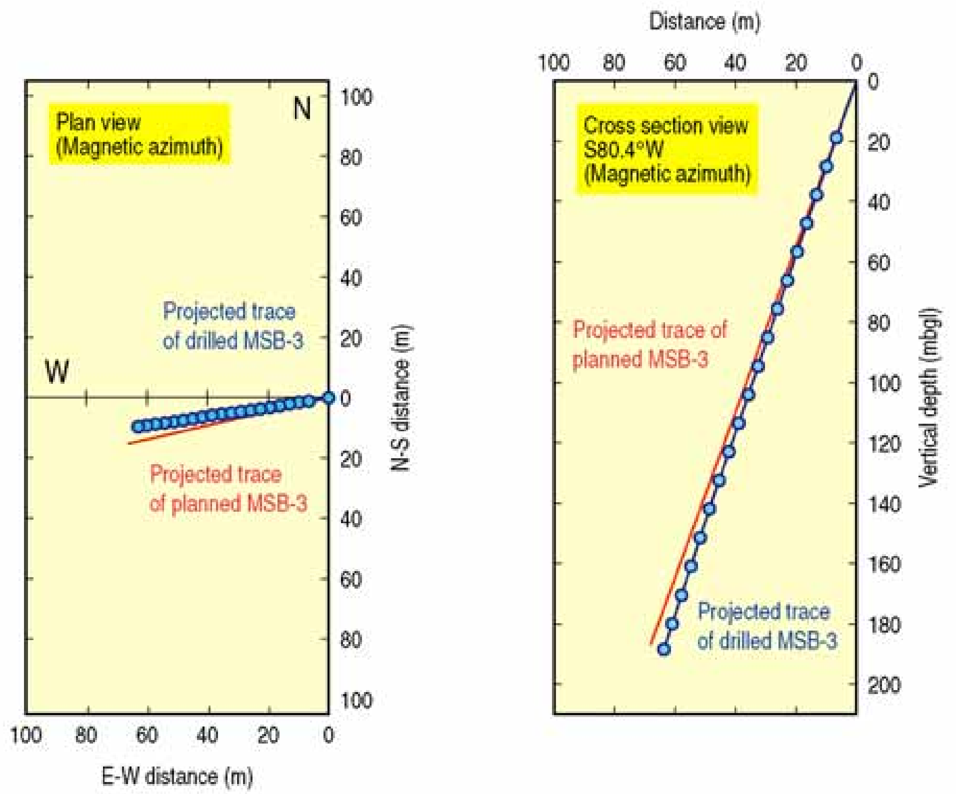


Figure 12 Borehole deviation from 0.00 - 199.00 mabh (MSB-3)

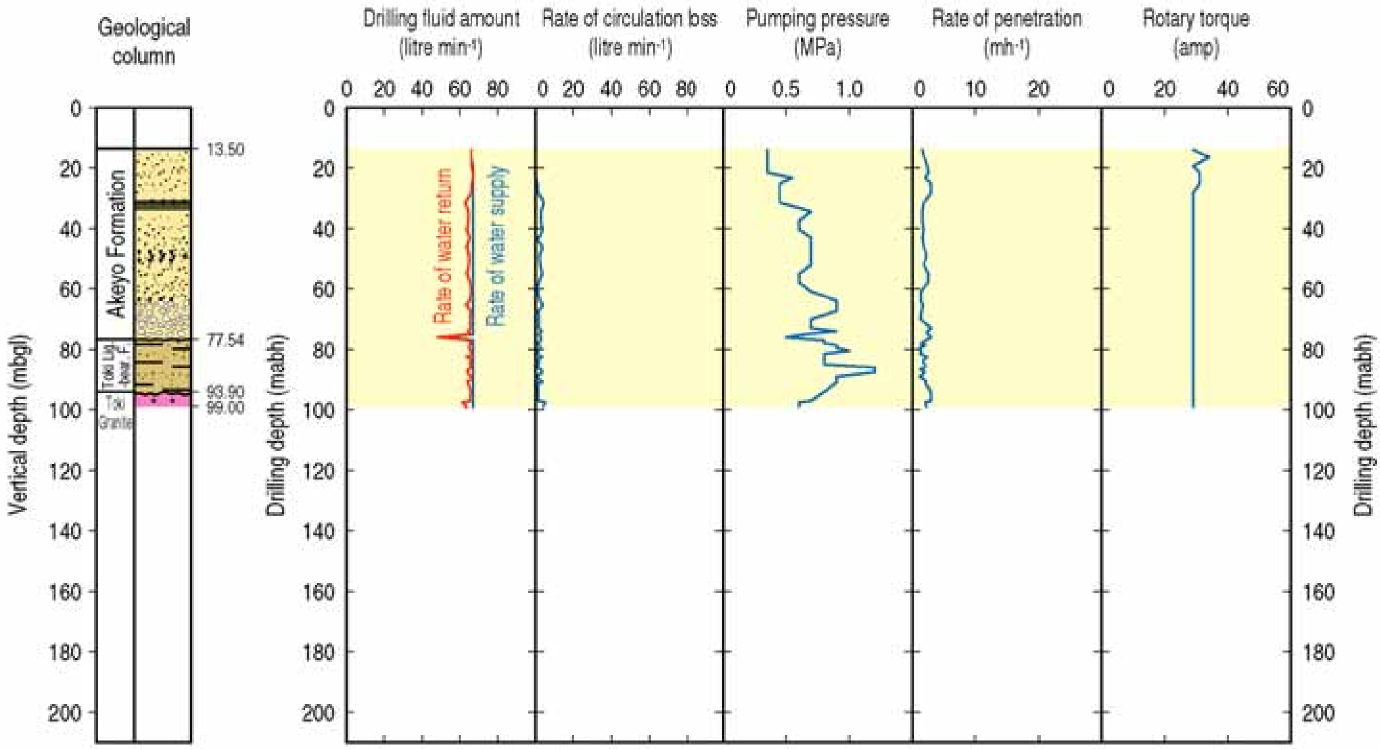


Figure 13 Monitoring of major parameters during drilling (MSB-4)

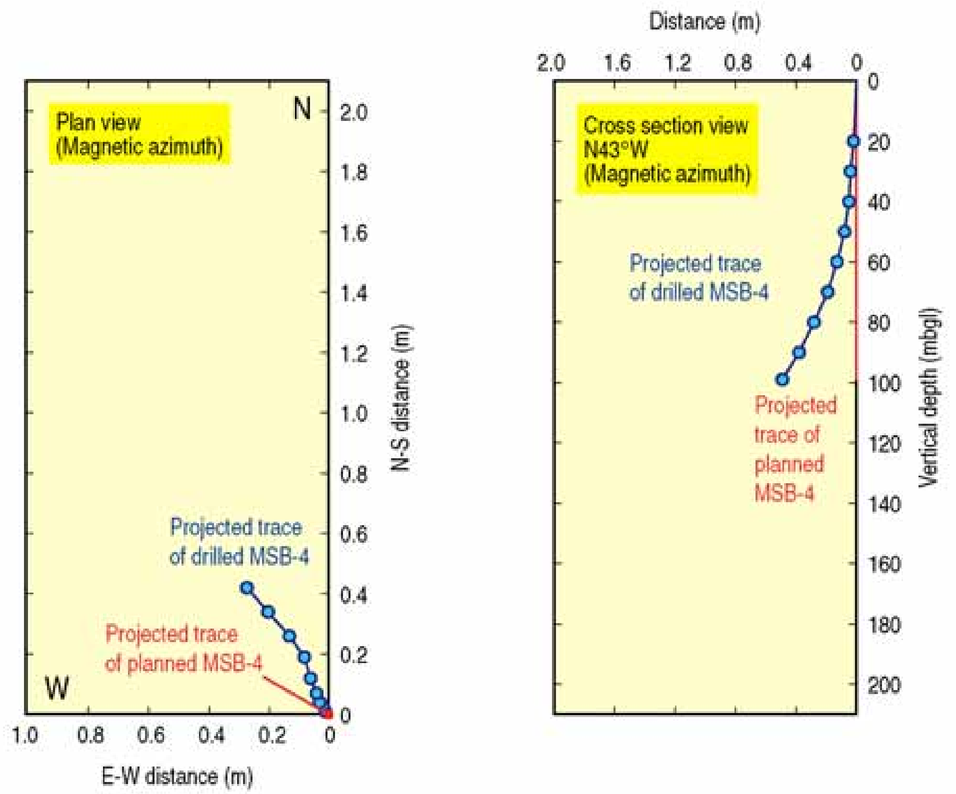


Figure 14 Borehole deviation from 0.00 - 99.00 mabh (MSB-4)

2.1.3 Results

- Drilling was successfully performed through the weathered granite in all boreholes, as planned in the original working programme.
- In MSB-1, 100 % drilling fluid loss occurred in the interval from 28 to 64 mabh. Plugging with both cellulose (LCM) and cementing was carried out seven times in the interval. Although 100 % fluid loss occurred below 67 mabh, drilling continued to the bottom of the weathered granite without any plugging work.
- The average rates of core recovery through the sedimentary rocks and the granite were 98.6 %, 96.8 %, 97.3 % and 99.4 % in MSB-1, 2, 3 and 4, respectively. Also, 100 % core recovery was achieved in the fault zone (87.7 to 92.2 mabh) in MSB-3. However, some cases of reduced core recovery occurred. For example, in the two intervals a few meters thick in the basal conglomerate layer of the Toki Lignite-bearing Formation in MSB-1 and 3, core recovery dropped to 55.3 % and 54.0 %, respectively. This is presumed to be because drilling fluid flushed out unconsolidated matrix in the conglomerate.

2.1.4 Evaluations

- The use of a triple-barrel coring technique with an acrylic innermost tube as in the previous MIU-4 investigation resulted in both excellent core recovery and high quality core for geological, hydrogeological, hydrochemical and geochemical investigations.
- The monitoring of drilling data, keeping fluorescent dye concentrations constant in the drilling fluid, periodic calliper logging during drilling and the appropriate borehole protection measures provided suitable locations for both installation of long term monitoring equipment and the downhole investigations such as hydraulic testing, and groundwater sampling.

2.1.5 Lessons learned

- Periodic calliper logging during drilling should be carried out in soft sedimentary rocks such as the Mizunami Group, because fluid circulation may easily enlarge borehole diameter; this knowledge is important for follow up testing and surveys.
- If necessary, PQ rods can be used as casing to the depth of significant borehole collapse in order to continue with a downsized drilling specification using, for example, HQ drilling. This will allow completion of any downhole investigations such as BTV and hydraulic tests.
- Employment of a solids control system should be considered in future investigations to prevent sludge formation on borehole walls and its accumulation at the bottom of a borehole.
- Further modification of drilling methods, such as using a percussion coring method without drilling fluid, to achieve full core recovery in the conglomerate layers and the weathered granite, in which lower core recovery occurred.