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Repeat logging in Well LL-03 at Laugaland í Holtum in August 2000

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On 3 August 2000, the temperature, resistivity and neutron-neutron response were logged in well LL-03 at Laugaland í Holtum by Orkustofnun at the request of Dr. Frank Roth, Geoforschungszentrum Potsdam (GFZ) in order to to ascertain whether any changes had occurred in these physical properties in connection with the recent earthquake activity in the region.

The logs acquired after the earthquakes are listed in Table 1, whereas a selection of reference logs acquired prior to the earthquakes are listed in Table 2.

Table 1. Logs acquired in August 2000 (after the earthquakes)

Log type	Date	Filename	Depth interval (m)	Comments
Temperature log	03-08-2000	T03082000	0-1087	
16" normal resistivity log	03-08-2000	S03082000.orig	27-1087	As measured
16" normal resistivity log	03-08-2000	S03082000.adj	27-1087	Calibrated, depth adjusted
64" normal resistivity log	03-08-2000	L03082000.orig	27-1087	As measured
64" normal resistivity log	03-08-2000	L03082000.adj	27-1087	Calibrated, depth adjusted
Neutron-neutron log	03-08-2000	N03082000.orig	7-1087	As measured

Table 2. Logs for comparison (acquired prior to earthquakes)

Log type	Date	Filename	Depth interval (m)	Comments
Temperature log	07-07-1977	T07071977	0-920	
Temperature log	18-10-1977	T18101977	0-1100	
Temperature log	17-09-1980	T17091980	0-1060	
Temperature log	25-06-1992	T25061992	0-1106	
Temperature log	23-04-1999	T23041999	3.5-1080	
16" normal resistivity log	27-10-1999	S27101999.orig	25-1080	As measured
16" normal resistivity log	27-10-1999	S27101999.adj	25-1080	Calibrated, depth adjusted
64" normal resistivity log	27-10-1999	L27101999.orig	25-1080	As measured
64" normal resistivity log	27-10-1999	L27101999.adj	25-1080	Calibrated, depth adjusted
Neutron-neutron log	27-10-1999	N27101999.orig	7-1087	As measured
Neutron-neutron log	27-10-1999	N27101999.adj	7-1087	Depth adjusted

Temperature logs

Water started to flow from well LL-03 on 20-22 July after a rapid rise in the water table since the earthquakes from a depth of several meters. This was probably caused by changes in crustal stress resulting from the earthquakes, although reinjection into the Laugaland geothermal field, which was initiated recently, may also have played some role. On 3 August, the flowrate was 0.5 l/s.

The temperature logs are plotted together in Enclosure 1. The most recent of the logs predating the earthquakes show a regime of inflow into the well at several feedpoints and downward flow of this fluid to a depth of 830 m where it reenters the formation. The new log can be interpreted in two different ways: (1) The fracture at 830 m now feeds water into the well in addition to the other feedpoints and above this depth water everywhere flows upwards; (2) Water now flows upwards above the feedpoint at 120 m, whereas below this depth water continues to flow down the well to a depth of 830 m as before. In either case, it is evident that water entering the well at feedpoints in the 200-250 m depth range is warmer than before. Temperature differences between the feedpoints in this depth range also seem to have increased. At present it is unclear whether this is caused by changes in the fracture network feeding this interval or by the reinjection.

In conclusion, a comparison of the August 2000 temperature log with the earlier ones does not reveal any new water-conducting fractures (feedpoints), but does shows changes in the temperature anf flowrate of the water flowing through previously existing fractures. These changes may probably be explained by a combination of stress change (general increase in formation pressure) associated with the earthquakes and reinjection, but do not rule out movements on some of the fractures feeding the well.

Resistivity logs

The resistivity logs are plotted together in Enclosure 2. Two kinds of adjustments were made to the final logs (marked .adj in Tables 1 and 2) before they were plotted. Firstly, a correction was applied to the logs based on a calibration carried out at the surface with a set of known resistances. Secondly, the origin of the August 2000 neutron-neutron log was taken as a common depth reference and the logs shifted to this datum.

The new logs agree remarkably well with those obtained in 1999. The main change observed is a decrease in the 16" resistivity log above 110 m. This can probably be explained by the increased temperature (and salinity ?) in this depth range caused by the newly established upflow. Too much should not be read from the differences between the 16" logs in the 400-700 Ohmm range, because of the large correction that was applied to the 1999 log as a result of the surface calibration. The differences may simply reflect the inaccuracy of the correction. Keeping this in mind, the only significant difference between the 16" resistivity logs that may require other explanations seems to be a decrease in resistivity in the 465-470 m depth interval.

The main change in the 64" resistivity log is a decrease in resistivity from 150-155 m. This may or may not be associated with the upflow. We also note a slight decrease in the 465-470 m range which correlates spatially with the main anomaly in the 16" log.

Neutron logs

The neutron logs are plotted together in Enclosure 3. Both were measured with a log speed of 6 m/min. The August 2000 log was measured at 0.5 m a depth interval and is plotted as measured. The 1999 log was measured at a depth interval of 0.1 m. In the plot only every 5 th point has been retained and the depth scale shifted as described in the previous section.

The match between the two logs is remarkably good. All of the observed differences can probably be attributed to statistical fluctuation.