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Hydrological monitoring stations in boreholes near the Húsavík-Flatey fault zone. Installment and November to December 2000 performances

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HYDROLOGICAL MONITORING STATIONS IN BOREHOLES NEAR THE HUSAVIK-FLATEY FAULT ZONE

Installment and November to December 2000 performance

Introduction

This short report describes an automated data logging system, which monitors hydrological parameters in wells near the Husavik-Flatey fault zone. In February 2000, the Geophysical Division of the Icelandic Meteorological Office subcontracted Orkustofnun-GeoSciences, to install and operate this system for three years time. Five wells in total are to be monitored by 4 logging stations. All the necessary equipment was purchased and ready for assembly in our electrical lab in May to June 2000, to be installed and field-tested while still summer in Iceland. But due to the two large seismic events, which struck the S-Iceland seismic zone in June 2000, this plan changed and was delayed until November 2000. Meanwhile, valuable experience was achieved by installing and operating similar logging stations in the earthquake hazard zone.

The report is structured as follows. First comes a description and location information for the wells selected for monitoring. Secondly the design of the automated logging system is described. Finally the two months of field operation are discussed and the collected data presented in graphs.

Well selection strategy and locations

Table 1 shows the wells selected for the hydrological monitoring and Figure 1 shows their locations. In general the monitoring wells should have the following properties:

1. To be either non-artesian or fully closed and with pressure on the wellhead.
2. Water temperature must be lower than 30-40°C at the depth of a submerged pressure sensor.
3. Wells must be cased through free-surface groundwater systems, in order to minimize meteorological disturbance.
4. Located on both sides of the Husavik-Flatey fault zone.

Two of the logging stations comply with all the above (Flatey and Husavik), whereas in the case of Arnes and Storu-Tjarnir a compromise had to be made. At Storu-Tjarnir we choose to log two artesian wells. One is periphery to the local, fracture hosted geothermal system and flows 0.1 l/s, while the other is drilled directly into it. That one remains fully closed most of the year. In Arnes, a mild artesian flow of a few liters/minute resides. Instead of measuring directly the flowrates of the free flow wells, we simply monitor the temperature of the discharged fluid. This way the logging stations show indirectly if the flowrate increases, due to the sensitivity of the discharge temperature to the flowrate.

Table 1: *Wells near the Husavik-Flatey fault zone selected for hydrological monitoring.*

Well name	Well ID	Logger name	Site name	Depth (m)	Location Hjörsey datum	Well status
FE-01	56811	S-8	Flatey	555	66.163476 N 17.841316 W	Non-artesian Waterlevel at 16.5 m
AA-01	59701	S-9	Arnes	1250	65.875338 N 17.405956 W	Artesian flow of a few liters/minute
ST-06	57226	S-10	Storu-Tjarnir	595	65.709058 N 17.738454 W	Artesian flow of a few liters/minute
ST-07	57227	S-10	Storu-Tjarnir	452	50 m to the south of ST-06	Closed most of the time and with pressure
HU-04	51031	S-11	Husavik	504	66.055088 N 17.347046 W	Non-artesian Waterlevel at 15.75 m

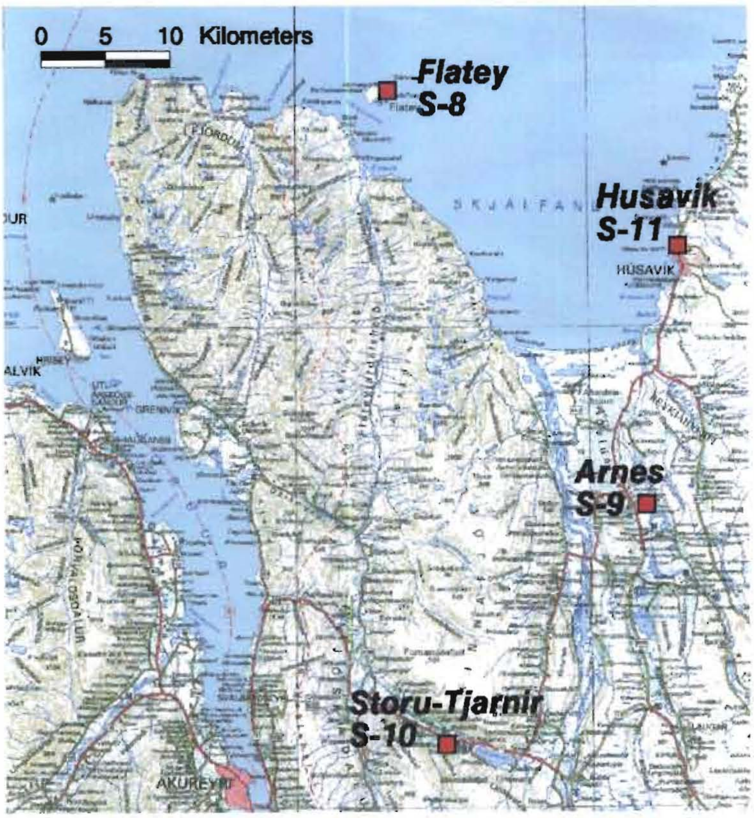

Figure 1: *Location of the hydrological monitoring stations.*

Configuration of the data loggers

The data logging system now operating in the Husavik-Flatey fault zone is using, in our view, the most modern way of logging, retrieving, storing and presenting remote field data. In the field we stack: A Campbell CR-10-X logger, a GSM cell phone, power supply, internal battery and the necessary connecting cables into the same watertight box. On the outside are cables to well sensors and external power (220 Volts from national grid or a combination of 12V batteries and solar cells). The loggers are programmed to record all connected sensors every minute to store in their own memories, plus the loggers internal temperatures and battery voltages. Every 24 hours the loggers are called upon by an inhouse, PC-Windows computer at Orkustofnun. It retrieves the newly collected data and stores as files on a Unix operated and frequently backed-up computer system. About 1 hour after new information is downloaded, a special shell script will automatically update GIF images, showing status of each hydrological station for the last 2 days, last week, last month and finally last year. At the time of writing this report, in January 2001, this part is also near completed and should be visible on the web in late February. The web page www.os.is/ros/eftirlit/forbodiskjalfta/s8/ is showing the basic structure of the upcoming web pages. Note that this way the system generates and updates its own hydrological report near automatically.

Field data collected in November to December 2000.

The following figures present the field data collected since commissioning of the logging stations in early November 2000. The graphics are made in two parts. The upper half shows the status of well sensors, whereas the lower half is showing logger voltage and temperature. These data are important in order to judge the data quality.

Figure 2 shows the pressure at 50 m depth in well FE-01 in Flatey. No abnormal pressure signals are recorded during these two months. Tidal fluctuations are, on the other hand, dominating the pressure signal. The higher frequency signal is simply the daily tides, whereas the lower frequency correlates with the 28 days lunar circle. In total the tidal amplitude is in the order of 0.15 bars, and much lower if only the daily tides are considered. This logger should therefore clearly show stress related pressure changes, if similar to those now observed in the S-Iceland seismic zone. Despite a 100% uptime, some loss of data appears to happen between December 17 and 24. The loss is due to lack of sunlight and, therefore, to low datalogger voltage for providing reliable pressure data.

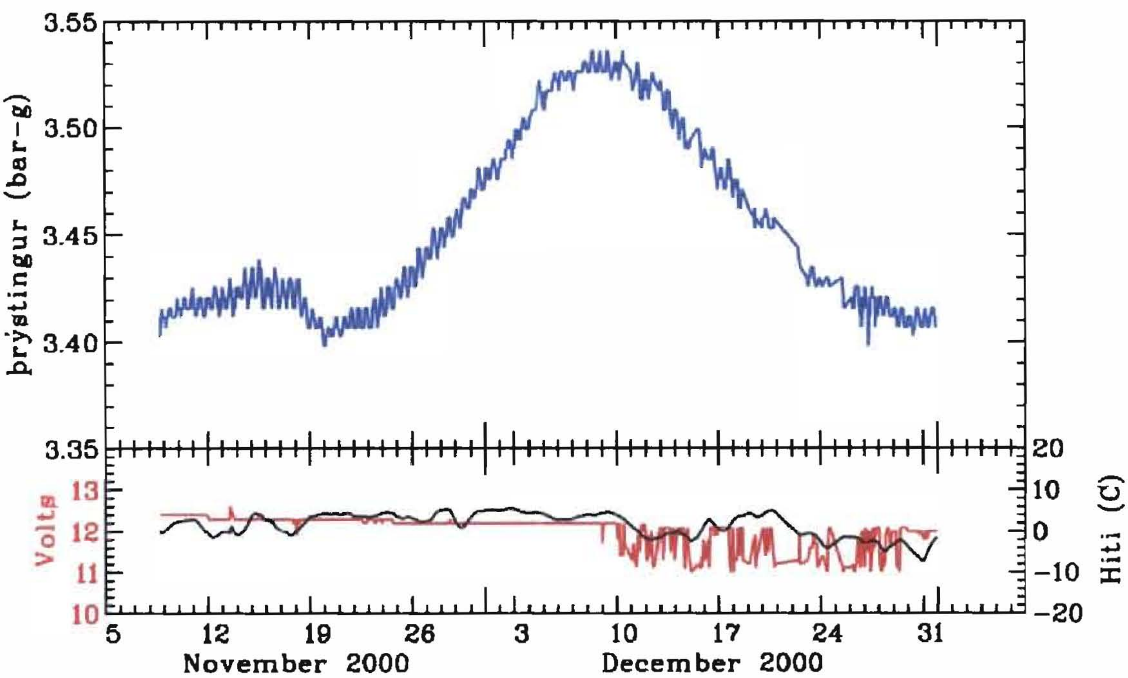

Figure 2: *Pressure at 50 m depth (upper half), and logger temperature and voltage (lower half) for station S-8, monitoring well FE-01 in Flatey. Þrystingur is Icelandic for pressure (bars-g) and hiti is temperature (°C).*

Figure 3 shows data collected in the Arnes (S-9) monitoring station. The well is artesian with a pressure sensor at 80 m depth. A pressure rise equivalent to 30 cm of water is measured during these first two months of logging. The rise is most likely only due to the pressure sensor installment, i.e. when removing the leaking wellhead we temporarily disturbed the well. A constant state is then achieved in a week. We also monitor the discharge temperature of the well (not plotted yet). The average temperature is 7.75°C and its standard deviation is 0.14°C. Overall this means that the well is mostly stable during the logging period. This logger is supplied with 220V grid power and has 100% uptime.

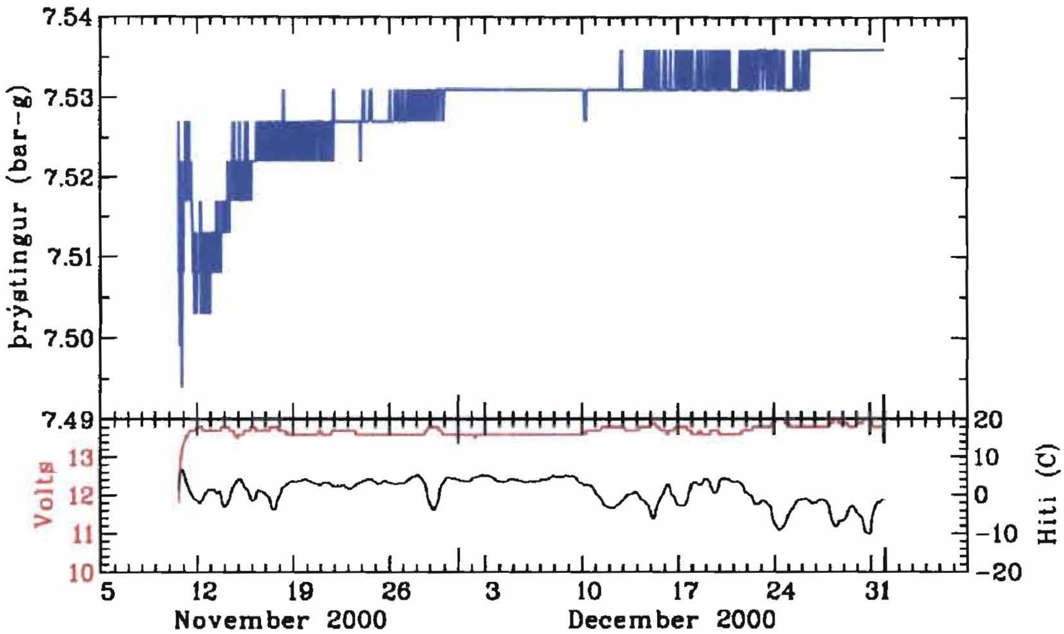

Figure 3: *Pressure at 70 m depth (upper half), and logger temperature and voltage (lower half) for station S-9, monitoring well AA-01 in Arnes. Þrystingur is Icelandic for pressure and hiti is temperature (°C).*

Figure 4 shows discharge temperature and pressure of well ST-06 at Storu-Tjarnir, and wellhead pressure of well ST-07 also at Storu-Tjarnir. Both are connected to logging station S-10. Like in the case of well AA-01, this field remains practically stead-state during November and December 2000. But some problems are, however, encountered. Firstly that the logger is not responding after December 25 due to low voltage on its single, 12 V external battery. The station is located in deep valley and enjoys therefore practically no sunshine at this time of the year. Secondly it is clear that the pressure sensor of well 6 is defective. This is concluded from the very stable discharge temperature of the well and from the unrealisticly high-pressure value recorded. Thirdly it appears that the GSM conditions in the area are weak, leading to some data losses between November 13 and 17. Finally, it should be mentioned that the second well, number 7, is not fully closed all year round. The well must produce if pressure of the local heating pipe network falls below a certain minimum. The spikes in its pressure history are, therefore, coherent with temporary discharge from this well.

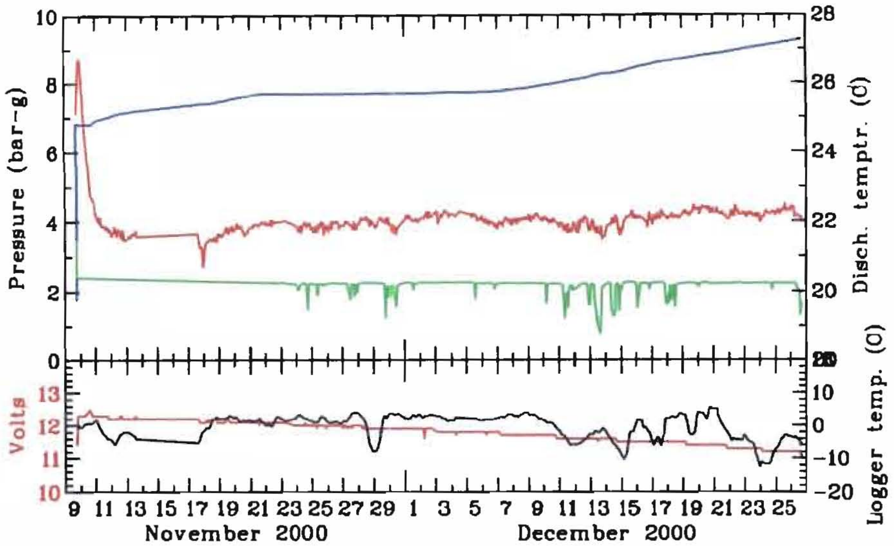

Figure 4: *Well data (upper half), and logger temperature and voltage (lower half) for station S-10, monitoring wells ST-06 and 07 in Storu-Tjarnir. In the upper graph, the top curve is the defective pressure sensor of well 6. The sagged center curve is its discharge temperature. The lowest curve in the upper portion shows the wellhead pressure of well 7.*

Figure 5 finally shows pressure data collected in well HU-4 in Husavik, monitored by logging station S-11. Due to its location inside town, a concern arose for the safety of the logger. Therefore a subsurface cable was specifically plowed from well 4 to well 1, near 400 m distance. In this location the logger is comfortably stored inside a cottage at near tropical temperature, due to inside pipe and pumps used for hot water production out of well 1. The pressure sensor in well 4 is placed at 80 m depth. Waterlevel at the time of installation was found at 15.75 m depth. Like in Storu-Tjarnir it appears that the pressure sensor failed after 1 month of operation. During this period a daily tidal fluctuation is observed and also the 28 days lunar circle. The logger performs therefore almost identically to the one in Flatey. But in early December some type of a sensor problem arises, resulting in substantial fluctuation of the pressure signal.

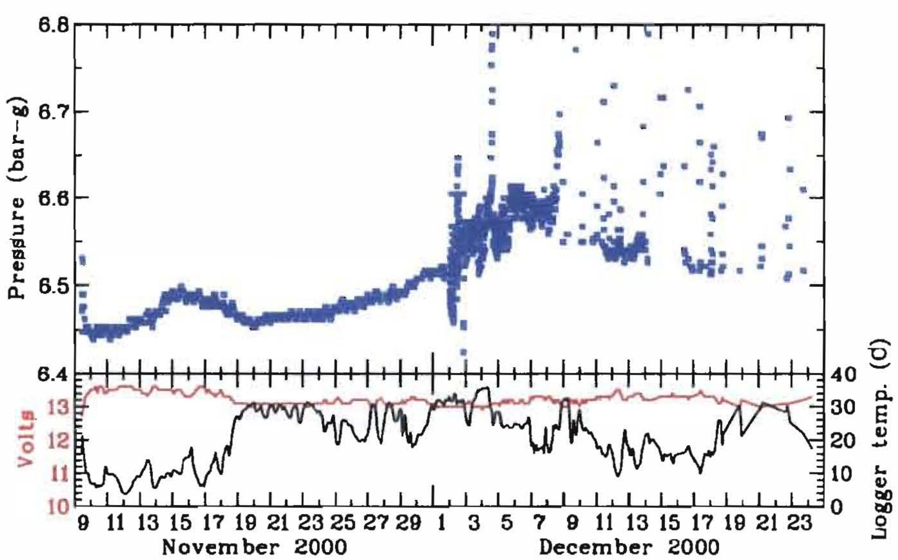

Figure 3: *Pressure at 80 m depth (upper half), and logger temperature and voltage (lower half) for station S-11, monitoring well HU-04 in Husavik.*

Conclusions

The main conclusions drawn from the installment and two-month operation of automated hydrological logging stations near the Husavik-Flatey fault zone are as follows:

1. Five wells are presently connected to 4 automated logging stations near the fault zone.
2. The data loggers themselves are performing very well and with only minor losses of data.
3. Some battery voltage problems are, however, faced by solar powered stations in December to January, due to the limited sunlight available this close to the Artic Circle.
4. High quality pressure sensors are performing poorly in two wells. Possibly they are too sensitive for gases and other chemicals, which are observed at low concentrations in these wells.
5. Automated shell scripts, which daily update web pages showing well status in the monitored wells, are nearly completed.

Orkustofnun, Reykjavik on January the 17th, 2001

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