ORKUSTOFNUN

# Static temperature and pressure profiles in Boullante wells 2, 4, 5, 6 and 7

**Ómar Sigurðsson**

**Greinargerð Ómar-2002-04**

# Static Temperature and Pressure Profiles in Bouillante Wells 2, 4, 5, 6 and 7

## INTRODUCTION

The geothermal field at Bouillante is located in the town of Bouillante on the western coast on Basse Terra, Guadeloupe. Guadeloupe is an island belonging to the islands on the Antilles arc in the Caribbean Sea. Géothermie Bouillante SA., which also operates a small power plant there, operates the geothermal field. In the 1970's four geothermal wells were drilled in the field by EURAFREP, but only well BO-2 turned out to be economically productive. It has now, with some interruptions, supplied the power plant with steam for over a decade. In 1998 well BO-4 was stimulated and is now considered economically productive. As a result of that and due to limited access to land for locating boreholes, new wells BO-5, BO-6 and BO-7 were drilled from the BO-4 platform. During the period from December 2000 to May 2001 COFOR directionally drilled the three new wells in the geothermal field at Bouillante.

Compagnie Francaise de Geothermie (CFG) has been responsible for the scientific work for the drilling and utilization of the new wells. It subcontracted Orkustofnun GeoScience Division (ROS) to give consultancy and assist in measurements on both the new and the older wells. This report describes the activity that the representative Omar Sigurdsson participated in during his stay in Guadeloupe in March 2002. During that time static temperature and pressure profiles were measured in wells BO-2, BO-4, BO-5, BO-6 and BO-7. Well BO-2 had been shut-in for about two weeks prior to the measurements, but the other wells had been standing idle at least since June 2001. The data for the temperature and pressure profiles is reported and some discussion provided with the data for each of the wells. The author thanks the help and support he received from Mr. Jean-Marc Cheradame in performing the measurements.

## MAIN ACTIVITY IN MARCH 2002

*March 11th:* Traveled from Iceland to Paris, France and continued to Guadeloupe. Arrived in Guadeloupe at around 19:00 local time. Met there with Mr. Jean-Marc Cheradame and went with him to Bouillante. Arrived at the hotel at 21:30 after nearly 20 hours of travel.
*March 12th:* Woke up late due to mistake in changing the clock. Jean-Marc and me went to the BO-4 platform to check the conditions there and then to the power plant. Started looking for the necessary tools and equipment to put the counter and steering arm on the winch unit. Lubricator pipe changed. Collected the gauges, clocks and reader together. After battery and petrol had been bought for the winch, the unit was transported to the BO-4 site late in the afternoon. Well BO-7 was made ready for measurements by transferring the top plate from well BO-6 to the wellhead of BO-7.
*March 13th:* Early in the morning a temperature survey was made in well BO-7. The temperature gauge encountered some obstacle at 1019 m depth. Not much attempt was made to get by it, as it was known that some mud could be in the well. The sequential pressure survey got past that obstacle but was feeling some others now and then down to the bottom at 1095 m. Blind plate was put near the wellhead of BO-5 to block the well from the discharge pipe line and a moveable work platform build around the wellhead. In the afternoon a temperature run was made in well BO-5.

When pulling out of the well, the gauge was pulled to the top with 161 m remaining on the depth counter. The gauge was recovered unharmed and the rest of the day spent on overhauling the counter.
*March 14th:* Started early on a pressure survey in well BO-5, which was finished in the morning. Well BO-6 made ready for measurements by moving back the top plate with the reduction to 2" from well BO-7 and the moveable work platform from well BO-5. Blind plates were put near the wellheads of BO-4 and BO-6 to block the wells from the discharge pipe line. In the afternoon a temperature run was made. However, when we were ready to pull out of the well the winch could not be started. Mechanics were called on site to look at the motor for the winch, but they could not do anything. About 100 m were pulled up by hand, but rest of day spent in an attempt to fix the winch. Under the evening the winch unit was fixed temporary so that the gauge could be pulled out of the well.
*March 15th:* A pressure run was made in well BO-6 in the morning and the work platform moved to well BO-4. In the afternoon temperature and pressure runs were made in well BO-4 down to 1100 m which was considered as a safe measuring depth. The winch unit was transported down to the power plant and set near well BO-2.
*March 16th:* Charts from the measurements in wells BO-4, BO-5, BO-6 and BO-7 read in the morning. Then the gauges were prepared for measurements in the afternoon. When we had the temperature gauge in and opened the wellhead valves on BO-2 a large leakage was observed at the blind plate. Well closed and bolts tighten on the flanges holding the blind plate. Reopened the well with similar leakage as before so the well was closed again. Loosened the upper bolts on the flanges while tightening the lower bolts. When the well was opened again only a small leakage was observed so both the temperature and pressure runs were completed under those conditions. Charts from BO-2 read.
*March 17th:* Worked on the data in the morning and met with Mr. Bernard Herbrich and Mr. Brian Carline from Kinley. In the afternoon Jean-Marc and me went to the airport and traveled to Paris.
*March 18th:* Arrived in Paris and continued traveling to Iceland.

## WELL BO-2

Well BO-2 was drilled in the 1970's to a depth of 338 m and cased with 7" casing to 288 m depth. A long-term discharge test was carried out between November 1970 and July 1971 resulting in total flow rate about 150 t/hr (41.7 kg/s) with about 20% steam fraction for separation pressure in the range 6-8 bar-a. Some further testing were done in 1982/1983. The well was produced in the years 1987 to 1992. The well was closed in 1993 and 1994, but some discharge tests were made during that time and other measurements performed in the well. In a discharge test in 1994 total flow rate of 165-180 t/hr (45.8-50.0 kg/s) was obtained with similar steam fraction as before (22%) for separation pressure between 6-7 bar-a. Wellhead pressure for those flow rates was about 11 bar-a. In 1993 static temperature and pressure profiles were measured and a multifinger caliper log carried out. The caliper log indicated corrosion in the upper most two casing joints and minor scaling in the casing. Since July 1996 the well has been in production with only minor stops during maintenance at the power plant.

In 1999 dynamic temperature and pressure profiles were measured in well BO-2 as well as static profiles after a pressure buildup for three days. In May 2000 a multifinger caliper log was repeated in the well down to 75 m depth. At that depth the caliper tool encountered reduction in the diameter of the well to less than 5.6", which was the diameter of the tool. Scaling in the well had therefore increased during the past 4 years of production. This was followed by an acid wash of the well in 2001.

Figures 1 and 2 show the measured static temperature and pressure profiles in well BO-2 along with the older profiles for comparison. The temperature profiles from 1993 and 2002 are similar,

but in 1999 the well is warmer because it had only been shut-in for three days when the profile was measured. The bottom hole temperature was measured in 1993 at 248.6 °C, in 1999 at 251.6 °C and now at 246.7 °C. The difference is near the calibration accuracy of the gauges used, but the same gauge was used in 1993 and in 1999 and a different gauge in the current measurement. The gauge that was used now was calibrated in 2001. Similar conditions prevailed in the current measurement as in 1993 and one would conclude that temperature has not changed in the vicinity of the well during these years.

The available static pressure profiles are more or less identical as can be seen on figure 2. The bottom hole pressure was said to be 45.3 kg/cm$^2$ (44.4 bar-g) in 1970, measured 43.0 kg/cm$^2$ (42.2 bar-g) in 1993, and 43.5 kg/cm$^2$ (42.7 bar-g) in 1999 and currently 43.5 kg/cm$^2$ (42.7 bar-g). These numbers could indicate a small drawdown between 1970 and 1993 (~2 bar), but some calibration error could also be involved in the bottom hole pressure value from 1970. **No drawdown** is observed in the reservoir near well BO-2 from 1993 and to 2002.

## WELL BO-4

Well BO-4 was drilled in the 1970's in two stages to a total depth of 2505 m. The well was completed with a 9 5/8" casing to 558 m depth, a slotted 7" liner from 541 m to 1199 m and 4 ½" slotted liner from 1184 m to 2504 m. The main circulation losses during drilling were attributed to the interval 560 m to 1050 m. Discharge testing performed between July 1978 and June 1979 yielded about 60 t/hr (16.7 kg/s) total flow rate at about 4 bar-g wellhead pressure and with about 17% steam fraction at that pressure. Due to this poor performance the well was not considered economical for utilization at that time. In 1998 the well was stimulated by altering between injection of inhibited seawater and warm-up periods. A short discharge test in 1999 confirmed the success of the stimulation as a total flow rate of over 130 t/hr (36 kg/s) was obtained at 14 bar-g wellhead pressure. Furthermore, logging the width of the well showed that the well was clean and free from obstruction down to 1100 m depth and that obstacles encountered before the stimulation job had completely vanished. Basically no scaling was found in the casing. A long-term discharge test was performed from January to May in the year 2000, but at a relatively small rate around 22.5 t/hr (6.2 kg/s) that supported earlier findings.

Well BO-4 has been closed since May 2000. The figures 3 and 4 show the static temperature and pressure profiles from the well along with some older profiles for comparison. The older temperature profiles show higher temperatures especially in the upper cased part of the well. At the production depth the current profile is similar to the one from 1996, but no indication of temperature inversion is observed as in the 1996 profile. The temperature gauge used now was calibrated in 2001 and it gives a reservoir temperature about 246 °C around well BO-4. The discharge enthalpy in the discharge tests from recent years corresponded to about 250 °C reservoir temperature or about 4 °C higher than currently measured. This difference is within the error limits of the method used for determine the enthalpy (Russell James method), but if true that could indicated that portion of the discharge is coming from depths greater than 1100 m in BO-4. Extrapolating the temperature gradient that would correspond to 1500-1600 m depth so depth to temperature inversion should be greater than that.

Looking at the pressure profiles in figure 4, it can be seen that the static profile from 1996 is in error below 500 m depth. It appears that there has been a shift in the base-line when the gauge hit the liner hanger at 543 m depth. If that were the case the 1996 profile would follow the profile from 1998 and be about 1.5 kg/cm$^2$ higher than the 1999 and 2002 profiles. The current profile falls on to the static profile from 1999 and will be taken as representative for the reservoir pressure around the well.

## WELL BO-5

Well BO-5 was drilled in two stages. It is directionally drilled with kick off point (KOP) at 225 m and with an inclination buildup to about 32° in the direction of N45°E. In the first stage the well was drilled to 610 m (MD) in January 2001. The well was deepen in the second stage to 1198 m (MD) in May 2001. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to 500 m and completed with 7" perforated liner from about 460 m to bottom (1197 m). Not all of the pipes in the liner are perforated. A short discharge test in June 2001 gave total flow rate over 220 t/hr (61 kg/s) at 24.5 bar-g wellhead pressure. At 6 bar-a separation pressure the steam fraction was about 24%. The estimated discharge enthalpy corresponded to an inflow temperature of 265-270 °C. Since that test the well has been closed.

Figures 5 and 6 show the measured static temperature and pressure profiles in well BO-5. The same gauges have been used in most of the measurements and they turn out to be more or less identical. Highest temperature measured in the well is 250.5 °C in the depth interval 900-1000 m. All the measurements indicate that temperature decreases below 1000 m so there is a temperature inversion in the well. It is thought that the well intersects the productive "Faille de Cocagne" fault zone in the depth range 900-1000 m. The temperature appears to have a maximum in the permeable fault, but as the well stretches further away from the fault the temperature decreases. The measured static temperature is about 10-20 °C lower than indicated by the discharge enthalpy. That could be an indication of either boiling into the reservoir (excess steam) or that during discharge a warmer fluid is drawn to the well (see discussion for BO-6). It is not considered likely here that possible calibration problem with the Kuster gauges could explain that difference.

The pressure profiles in figure 6 basically coincide with each other. Therefore, it is difficult to determine a pivot point in the profiles, but it appears to be in the interval 935-1145 m suggesting the main feed zone to be in this interval. That corresponds to the depth interval with the maximum temperature were the well is thought to have intersected the "Faille de Cocagne" fault.

## WELL BO-6

Well BO-6 was drilled in February 2001 to 1248 m (MD). It is directionally drilled with kick off point (KOP) at 230 m and with an inclination buildup to about 36° in the direction of N20°W. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to 498 m and completed with 7" perforated liner from 462 m to bottom. The well was discharged briefly in early March 2001 and again for three weeks in late March and April 2001. A total discharge rate of 255 t/hr (71 kg/s) was achieved at 25.5 bar-g wellhead pressure. At 6 bar-a separation pressure the steam fraction was about 26%. The estimated discharge enthalpy corresponded to an inflow temperature of 265-275 °C. The well has been closed since April 2001.

The measured static temperature and pressure profiles from well BO-6 are shown in figures 7 and 8. Different gauges were used in the measurements in 2001, but even if there could be some calibration problem involved in those temperature measurements the character in the static temperature profile is different in the current measurement. The sharp maxima around 900 m depth is not observed now even though it was confirmed by two measurements in 2001. The current static temperature profile reaches a maximum around 1000 m and below that depth a small decrease in temperature is observed indicating a possible inversion in the formation temperature. The highest temperature recorded now is 251.5 °C, which is 15-25 °C lower than indicated by the discharge enthalpy. Furthermore, indications were that both total flow rate and estimated discharge enthalpy had increased slightly during the extended discharge test of the well. The increased flow rate could have been a result of further cleaning of mud and drill cuttings from the

production fractures and part of those cuttings could now have reduced the depth of the well from 1242 m to 1228 m. The increase in discharge enthalpy indicates heating possibly due to boiling into the formation (excess steam). It could also be a result of warmer fluid being drawn to the well during discharge as can be speculated from the characteristics of the temperature profiles in March 2001.

The pressure profiles after the well warmed up are basically identical between the years and it is difficult to determine a pivot point in the profiles. It was thought that the well had intersected the "Faille de Cocagne" fault at 900 m depth as indicated by the sharp temperature maxima, but the current temperature maximum is at 1000 m depth and the pivot point appears to be below 900 m.

## WELL BO-7

Well BO-7 was drilled in April 2001 to 1400 m (MD). It is directionally drilled with kick off point (KOP) at 230 m and with an inclination buildup to about 37° in the direction N130°W. The inclination drops off below 1000 m and is 23° at 1300 m. All depth numbers refer to measured depth unless other is indicated. The well is cased with 9 5/8" casing to about 500 m and completed with 7" perforated liner from 463 m and to 1100 m. The liner shoe is supposedly closed, hindering possible flow from deeper parts of the well. The well was only discharged for few hours in June 2001 with total discharge rate around 50 t/hr (14 kg/s) and wellhead pressure less than 5 bar-g. The well has been closed since then.

Figures 9 and 10 show the measured static temperature and pressure profiles from well BO-7. The well should by now be fully warmed up as is inferred by the temperature profiles. Some obstacles were encountered in the deepest part of the liner, which could be mud that has build-up to some mud cakes. One such obstacle caused the temperature gauge to sit at 1019 m, while the pressure gauge got past it to the bottom of the liner. The current temperature profile shows a possible indication of a temperature inversion below 1000 m depth or in the deepest part of the liner. However, as the difference in the readings is small as well as the depth interval below 1000 m this can not be confirmed by this measurement.

The pressure profile shows an intersection point near 600 m depth with the profile measured after stimulation attempts at end of the drilling operation. At that depth the main active feed point was in the well during the short discharge in June 2001. However, the pivot point could be located below the liner, which is only down to 1100 m of the 1400 m drilled.

## FIELD DISCUSSIONS

The static temperature profiles from all the wells are shown in figure 11. The profiles from the wells on the BO-4 platform are similar, but with some definite features. No temperature inversion is observed in well BO-4 while the other wells at that platform show indication of a small inversion. The temperature is highest in well BO-6, with a slightly lower temperature in well BO-5, then well BO-4 and well BO-7 has the lowest temperature of them. The temperature inversion is slightly more pronounced in well BO-5 than in well BO-6. At shallower levels well BO-5 is slightly warmer than the other wells on the BO-4 platform. Well BO-2 is geographically about 90 m lower than the BO-4 platform so for comparison its profiles should be shifted at least 90 m downwards. Nevertheless is the temperature highest at shallow depths at well BO-2. Visualizing the temperature profiles on a map of the wells (figure 12) could give the following picture. Temperature maximum is around the fault zone "Faille de Cocagne" with a possible small decrease in temperature towards north to the fault zone "Faille de la Baie". North of that fault zone the temperature could decrease more. South of the "Faille de Cocagne" the temperature

decreases slowly or by few degrees as is seen in well BO-4 and then in well BO-7. South of the fault "Faille de Descoudes" which well BO-7 intersects the temperature could decrease more rapidly. The faults "Faille de la Baie" and "Faille de Descoudes" could delineate this part of the Bouillante geothermal field to the north and to the south, respectively. As well BO-6 appears to have the maximum temperature the inflow to this part of the geothermal field could be from the west from a source under the Bouillante Bay.

Figure 13 shows the static pressure profiles as measured in the wells. When compared to the profile from well BO-4 the inclination of the other wells is most noticeable. In figure 14 the static pressure profiles have been corrected to true vertical depth for the directionally drilled wells BO-5, BO-6 and BO-7. Furthermore, the depth reference for well BO-2 has been changed by 90 m to compensate for the geographical height difference between well BO-2 and the BO-4 platform. Then it can be seen that the wells have a similar pressure potential except well BO-7 where the pressure potential is about 4 bar lower than at the other wells. That could indicate that the controlling feed zone in well BO-7 is below 1100 m depth and is outside the geothermal reservoir then delineated by the "Faille de Descoudes" fault in the south. The pressure potential appears to be about 0.5 bar higher in wells BO-5 and BO-6 than in well BO-4. The potential is just a little higher in well BO-6 than in BO-5, but the difference of 0.1-0.2 bar is within the error limit of the pressure gauge so it is not confirmative.

## CONCLUSIONS AND RECOMMENDATION

Same temperature and pressure conditions prevail in the reservoir around well BO-2 as did for nearly a decade ago. **No pressure drawdown** is observed in the reservoir despite the well has been the sole supplier of steam to the geothermal power plant since 1996.

Reservoir temperature and pressure conditions around well BO-4 appear to have remained stable for the past years. No temperature inversion is observed down to the measured depth of 1100 m, but indication of inversion was in older measurements. It is speculated that the depth to such inversion could be greater than 1600 m.

A small temperature inversion is observed in the formation temperature around the new directionally drilled wells BO-5 and BO-6 after they have intersected the fault zone "Faille de Cocagne" to the north of the BO-4 platform. A weak indication is of similar formation temperature inversion in the directionally drilled well BO-7 after it intersects the fault "Faille de Descoudes" to the south of the BO-4 platform.

Highest temperatures are observed in the wells BO-5 and BO-6 where it is assumed that they intersect the highly permeable fault zone "Faille de Cocagne". The temperature is slightly higher in well BO-6 than in well BO-5. The fault zone is therefore the main fluid conduct in this part of the Bouillante geothermal reservoir, which could be delineated in the north by the fault "Faille de la Baie" and in the south by the fault "Faille de Descoudes".

The pressure potential is similar in wells BO-2, BO-4, BO-5 and BO-6. The pressure potential could though be just over 0.5 bar higher in wells BO-5 and BO-6 than in well BO-4. The potential appears to be highest in well BO-6, but the difference of about 0.2 bar between wells BO-6 and BO-5 is well within the error limit of the pressure gauge. The pressure potential is about 4 bar lower at well BO-7 than at the other wells indicating that well BO-7 is a peripheral well or even outside the main reservoir.

Based on the new measurements for static temperature and pressure profiles in all of accessible wells drilled into the Bouillante geothermal reservoir it is concluded that well BO-6 is nearest to

the main upflow in the reservoir. That would indicate that the hottest part of the geothermal reservoir would be to the west or under the Bouillante Bay.

Obstacles were observed in the deepest 80 m of the liner in well BO-7, which are most likely made from buildup of mud cakes. After the drilling operation in 2001 the well was only discharged for few hours and had not cleaned itself of drilling mud and cuttings. It is recommended that further discharge testing will be carried out for well BO-7 with the purpose of cleaning the well. It should be considered if the well can be discharged through the 2" warm-up pipe system, which will be permanently installed at the site for the main production wells.

Reykjavik 27 March 2002

Omar Sigurdsson
Geothermal Reservoir Engineer

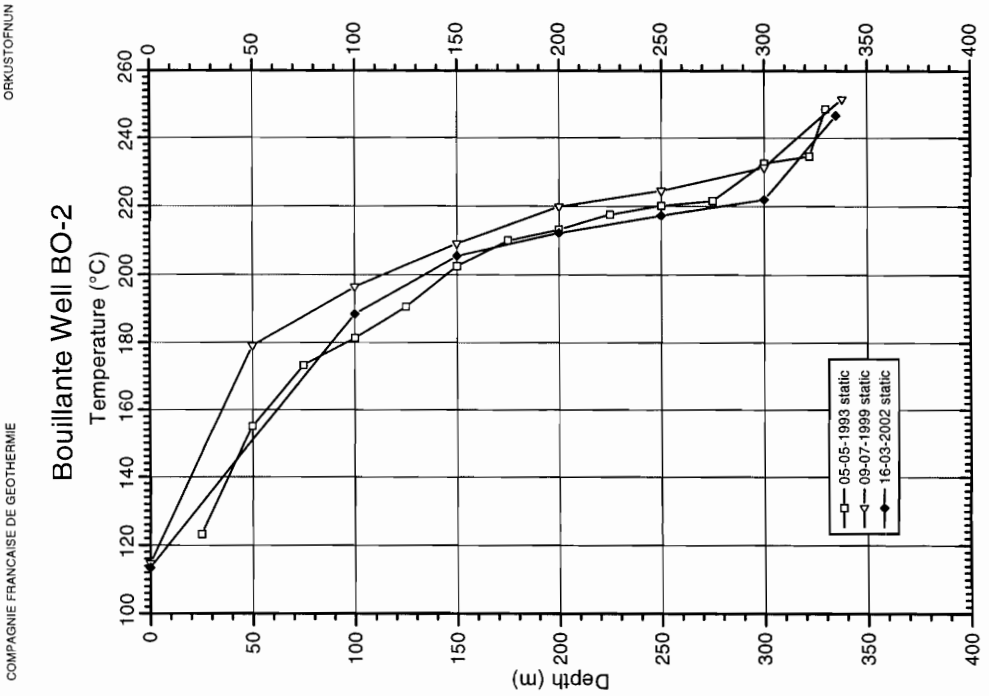


**Figure 1.** Static temperature profiles measured in well BO-2.

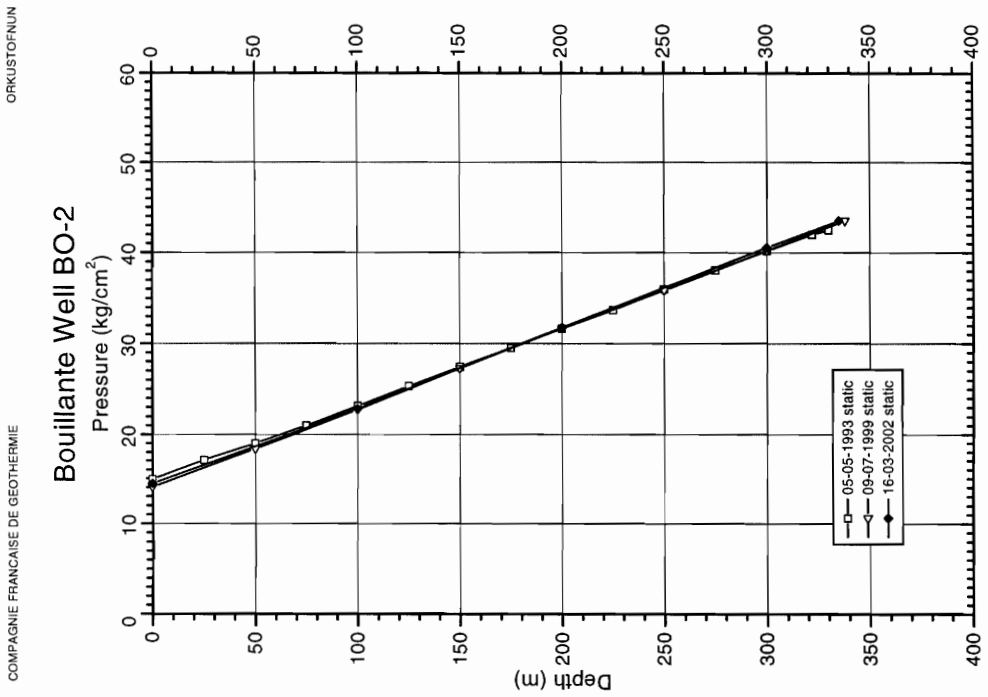


**Figure 2.** Static pressure profiles measured in well BO-2.

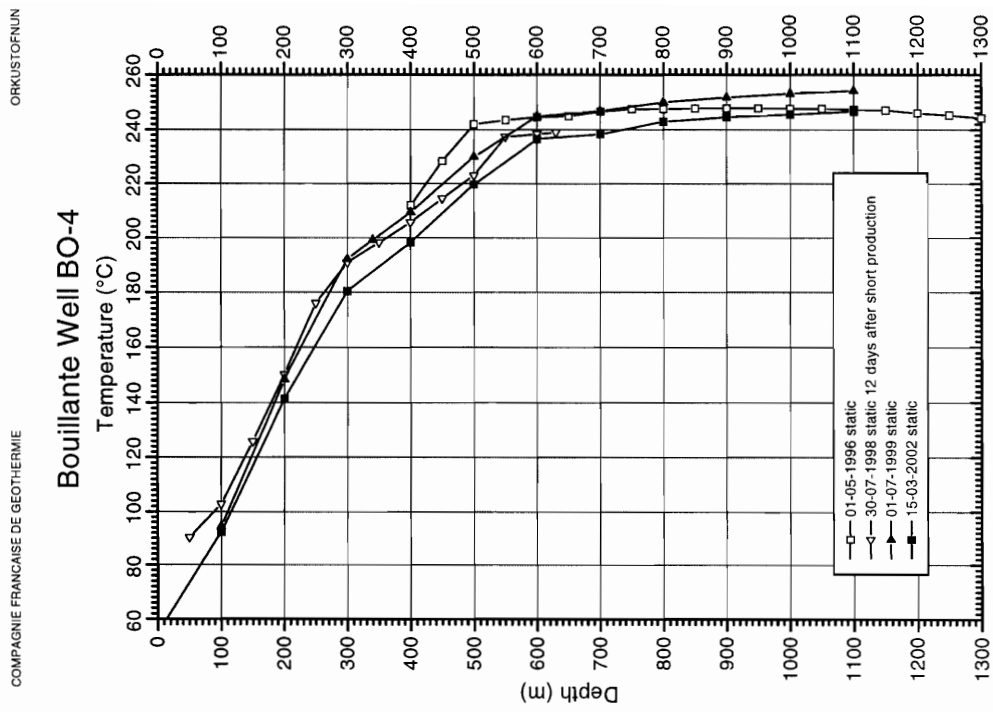


**Figure 3.** Static temperature profiles measured in well BO-4.

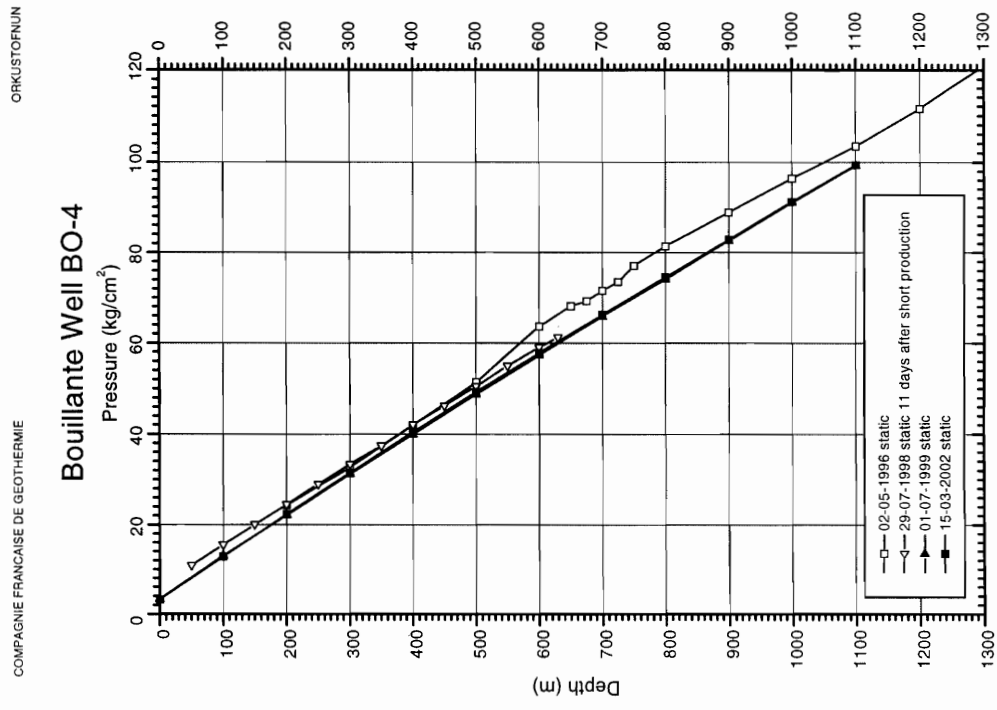


**Figure 4.** Static pressure profiles measured in well BO-4.

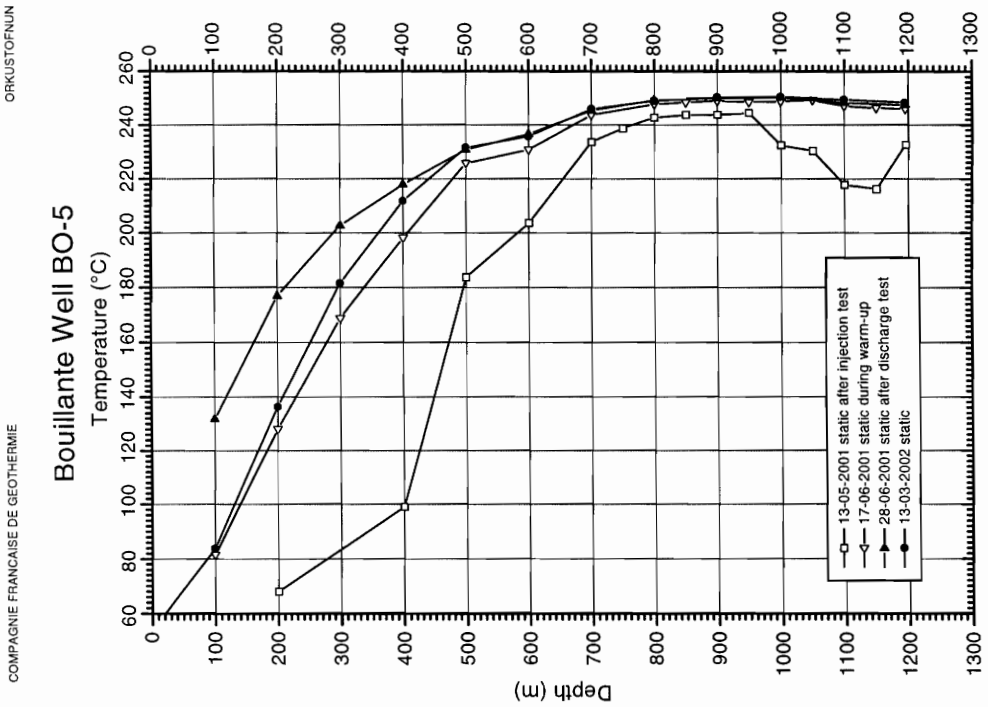


**Figure 5.** Static temperature profiles measured in well BO-5.

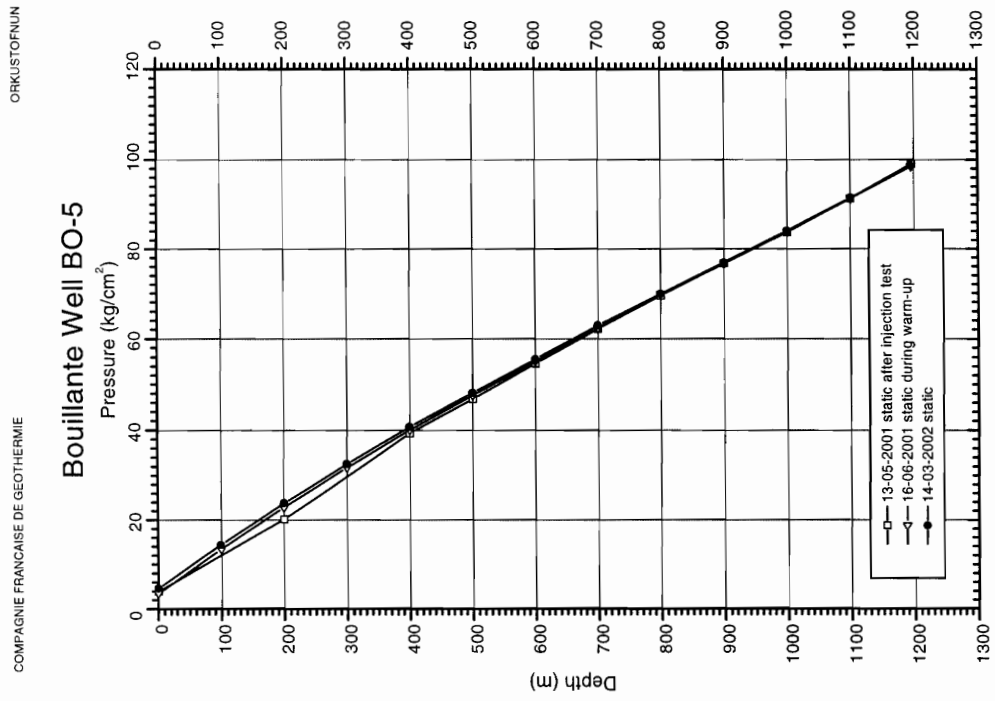


**Figure 6.** Static pressure profiles measured in well BO-5.

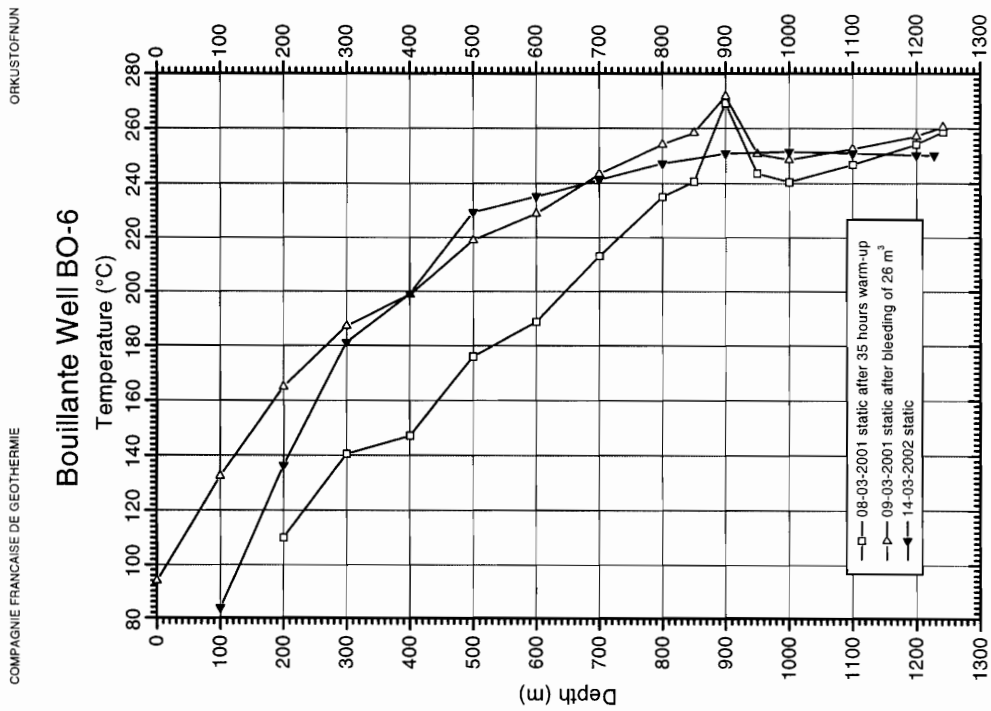


**Figure 7.** Static temperature profiles measured in well BO-6.

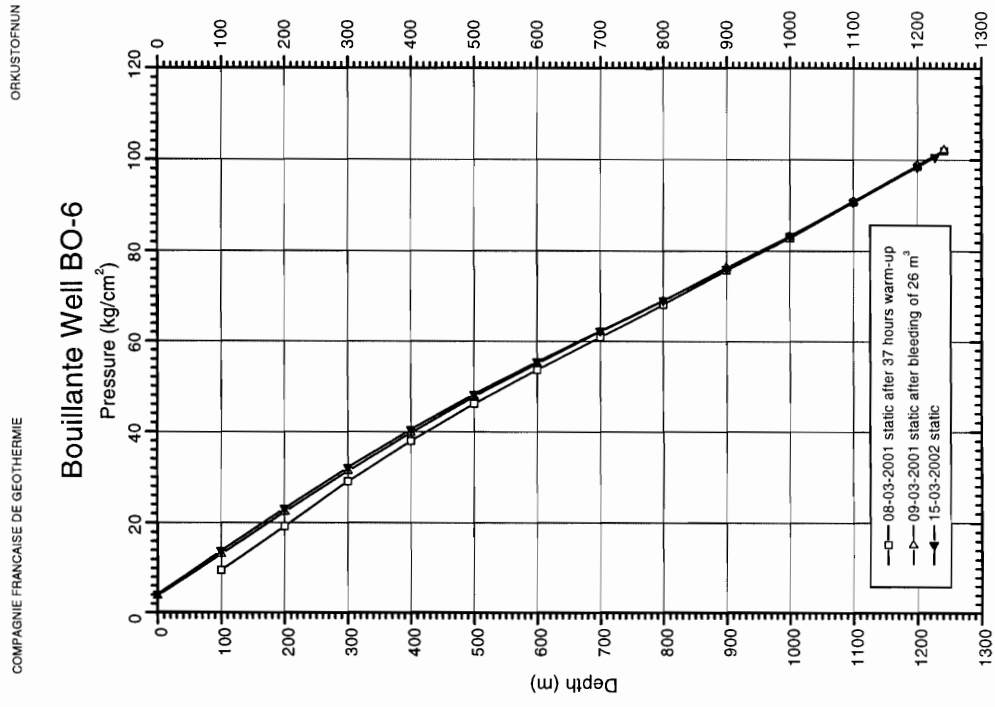


**Figure 8.** Static pressure profiles measured in well BO-6.

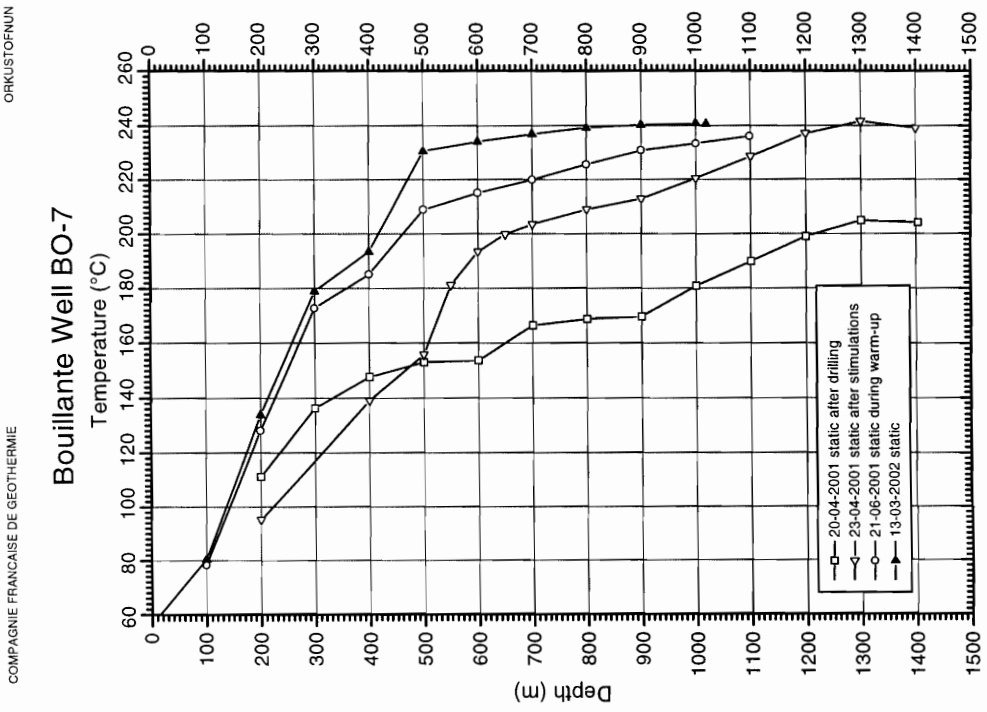


**Figure 9.** Static temperature profiles measured in well BO-7.

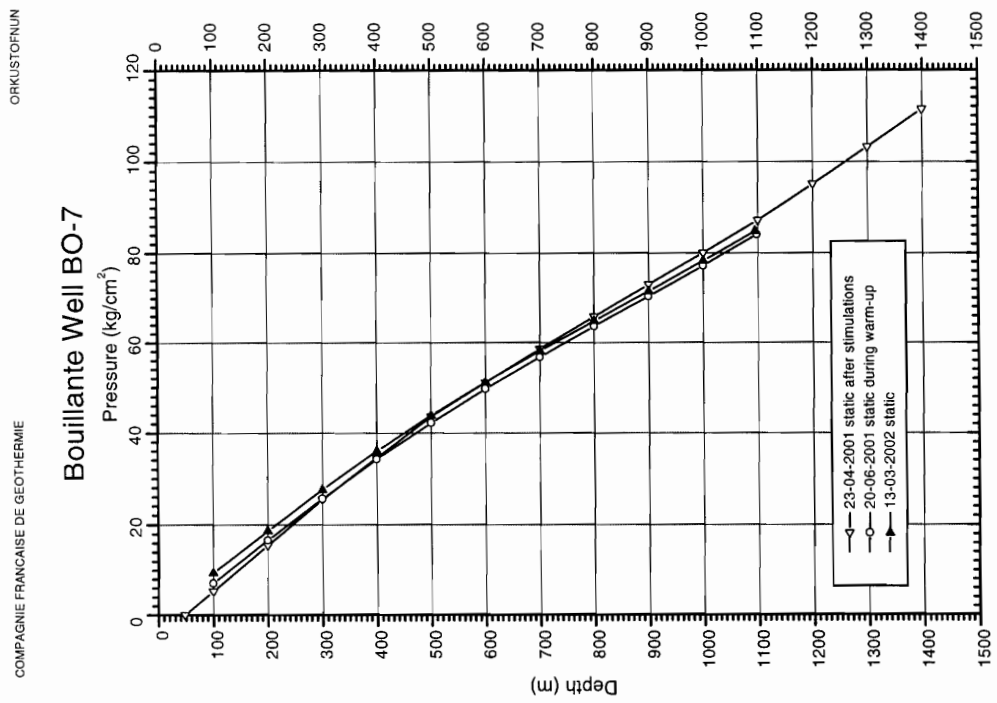


**Figure 10.** Static pressure profiles measured in well BO-7.

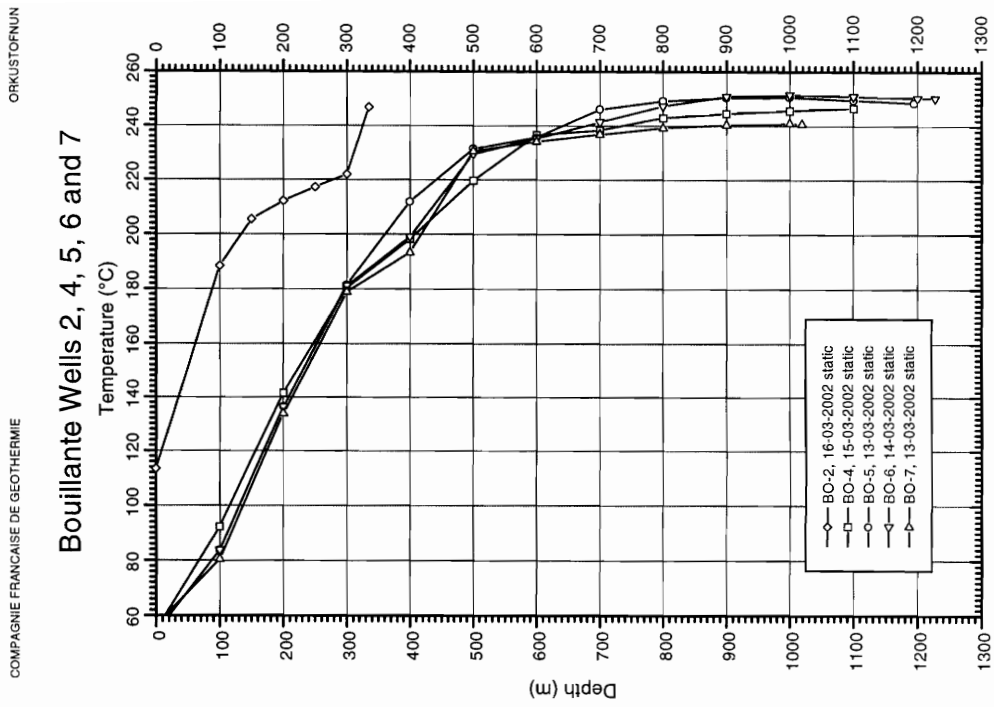


**Figure 11.** Static temperature profiles measured in wells BO-2, BO-4, BO-5, BO-6 and BO-7. The depth is as measured in the wells (MD).

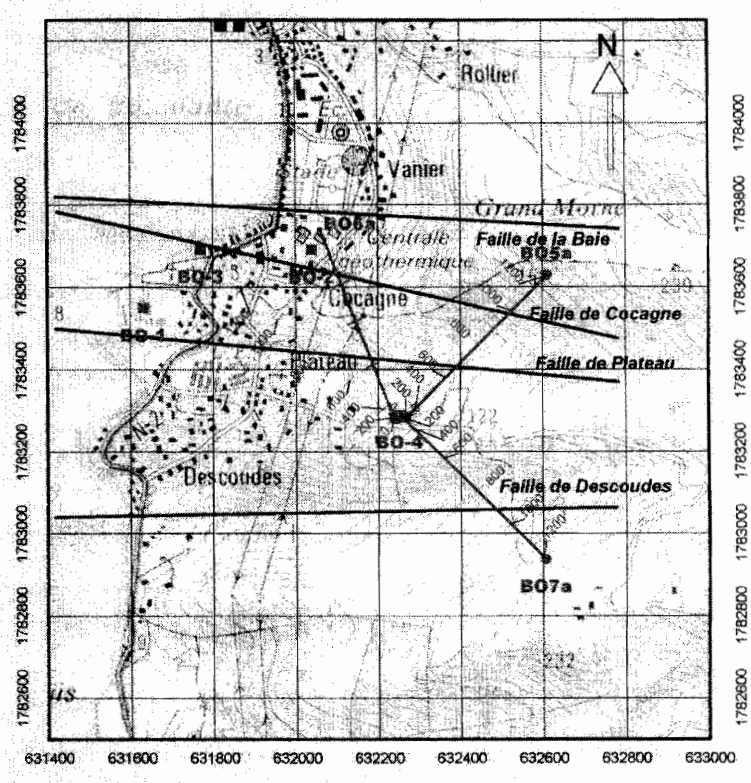


**Figure 12.** A map of the Bouillante area showing the location of the geothermal wells, the surface projection of the new directional wells and the major fault zones. (Figure obtained from CFG).

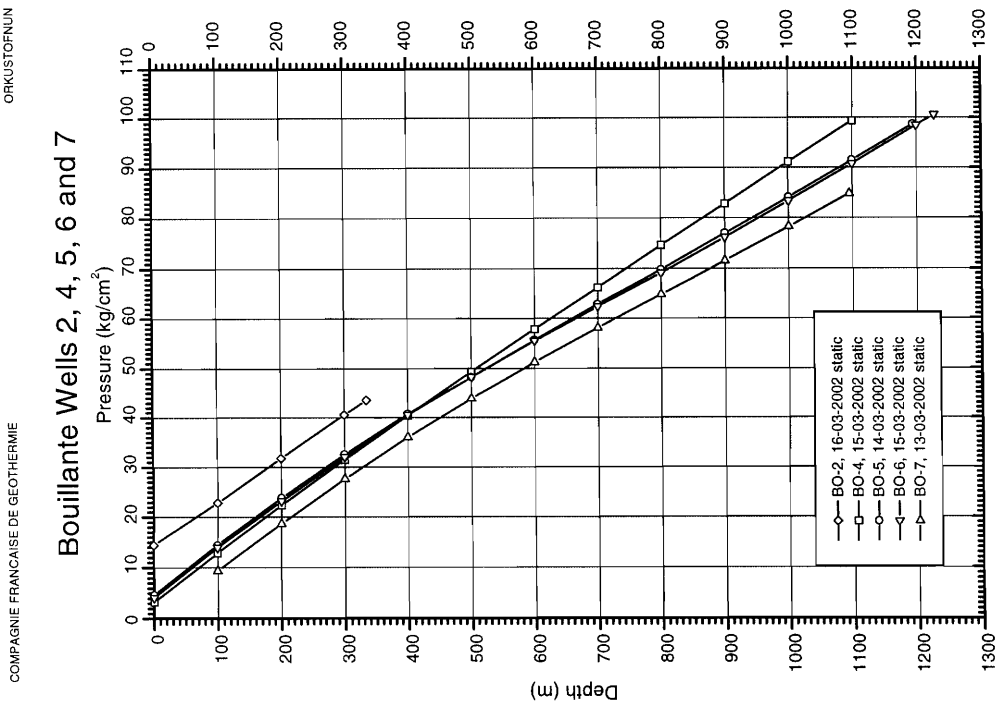


**Figure 13.** Static pressure profiles measured in wells BO-2, BO-4, BO-5, BO-6 and BO-7. The depth is as measured in the wells (MD).

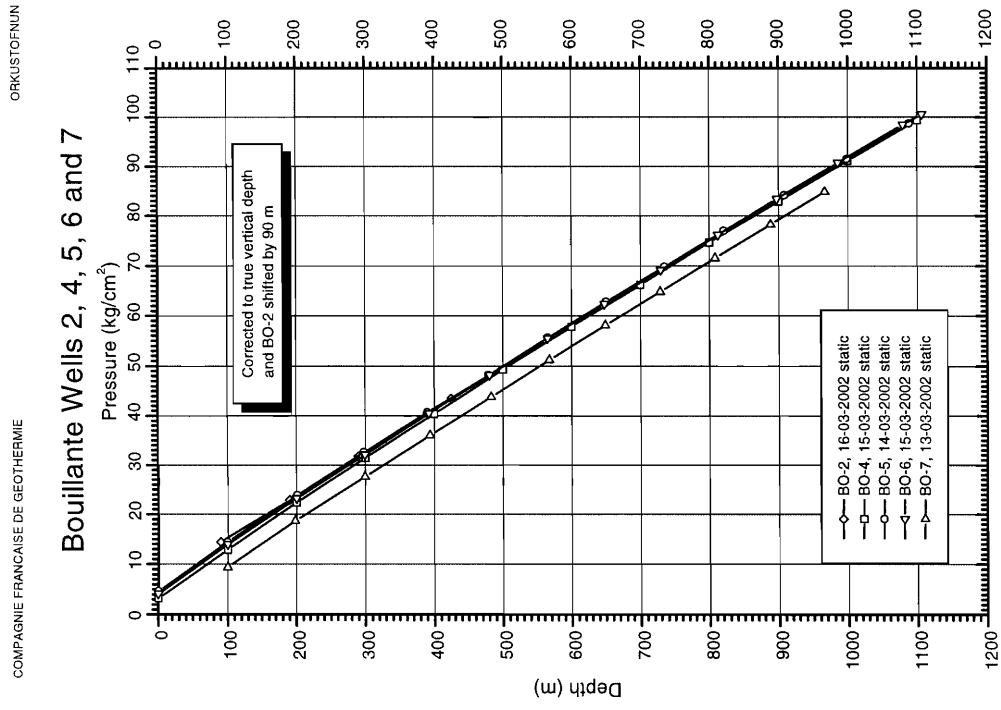


**Figure 14.** Static pressure profiles measured in wells BO-2, BO-4, BO-5, BO-6 and BO-7. The profiles for the directionally drilled wells BO-5, BO-6 and BO-7 are corrected to true vertical depth (TVD). The profile for well BO-2 has been shifted by 90 m, which is about the height difference between the BO-2 site and the BO-4 platform.

## APPENDIX

Static temperature and pressure logging in well BO-2

Static temperature and pressure logging in well BO-4

Static temperature and pressure logging in well BO-5

Static temperature and pressure logging in well BO-6

Static temperature and pressure logging in well BO-7

# STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-2

Date: 16-3-2002

Temperature gauge KT-10073; Clock 3h, serial no. V4304; Time 14:20-16:35
Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 16:50-17:40
Zero reference 1m above wellhead valves, which is about 3m above cellar.

| TEMPERATURE | | | | PRESSURE | | | |
|---|---|---|---|---|---|---|---|
| Depth (m) | Deflection (cm) | Temperature (°C) | Observations (Temp. Logging) | Deflection (cm) | Pressure (bar) | Pressure ($kg/cm^2$) | Observations (Press. Logging) |
| | | | | | | | |
| 0 | 0.488 | 81.7 | Small bleeding from stuffing | | | | Small bleeding from stuffing |
| 0 | 0.796 | 100.4 | box and at blind plate | | | | box and at blind plate |
| 0 | 1.012 | 113.4 | | 0.539 | 14.14 | 14.42 | |
| 100 | 2.250 | 188.5 | Temp still slightly rising | 0.870 | 22.40 | 22.84 | |
| 150 | 2.527 | 205.5 | | | | | |
| 200 | 2.636 | 212.2 | | 1.204 | 31.17 | 31.78 | |
| 250 | 2.719 | 217.3 | | | | | |
| 300 | 2.796 | 222.0 | | 1.529 | 39.77 | 40.55 | |
| 335 | 3.192 | 246.7 | | 1.646 | 42.70 | 43.54 | |
| 0 | 0.789 | 99.9 | | 0.559 | 14.72 | 15.01 | |
| | | | | | | | |

**Remarks:** Leakage at blind plate so well was opened and closed two times before measurements started.

# STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-4

Date: 15-3-2002

Temperature gauge KT-10073; Clock 3h, serial no. V4304; Time 13:30-15:30
Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 15:50-17:30
Zero reference about 3m above cellar.

| TEMPERATURE | | | | PRESSURE | | | |
|---|---|---|---|---|---|---|---|
| Depth (m) | Deflection (cm) | Temperature (°C) | Observations (Temp. Logging) | Deflection (cm) | Pressure (bar) | Pressure ($kg/cm^2$) | Observations (Press. Logging) |
| 0 | | | Small gas pocket bled off | 0.119 | 3.17 | 3.23 | Small bleeding from stuffing box |
| 100 | 0.662 | 92.3 | Small bleeding from stuffing box | 0.477 | 12.59 | 12.84 | |
| 200 | 1.476 | 141.5 | | 0.841 | 21.92 | 22.35 | |
| 300 | 2.117 | 180.4 | | 1.183 | 30.82 | 31.43 | |
| 400 | 2.410 | 198.3 | | 1.517 | 39.62 | 40.40 | |
| 500 | 2.759 | 219.7 | | 1.850 | 48.35 | 49.30 | |
| 600 | 3.030 | 236.6 | | 2.167 | 56.67 | 57.79 | |
| 700 | 3.060 | 238.4 | | 2.477 | 64.93 | 66.21 | |
| 800 | 3.133 | 242.9 | | 2.787 | 73.15 | 74.59 | |
| 900 | 3.158 | 244.5 | | 3.090 | 81.22 | 82.82 | |
| 1000 | 3.175 | 245.5 | | 3.397 | 89.40 | 91.16 | |
| 1100 | 3.190 | 246.5 | | 3.699 | 97.45 | 99.37 | |
| 0 | 0.045 | 54.8 | | 0.132 | 3.52 | 3.59 | |

**Remarks:** Only measured to 1100 m depth, which was has been determined as safe depth.

# STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-5

Dates:

13-3-2002 Temperature gauge KT-10073; Clock 3h, serial no. V4304; Time 15:30-17:30
14-3-2002 Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 9:00-10:50
Zero reference about 2m above cellar.

| TEMPERATURE | | | | PRESSURE | | | |
|---|---|---|---|---|---|---|---|
| Depth (m) | Deflection (cm) | Temperature (°C) | Observations (Temp. Logging) | Deflection (cm) | Pressure (bar) | Pressure ($kg/cm^2$) | Observations (Press. Logging) |
| | | | | | | | |
| 0 | | | WHP 4.8 bar-g | 0.170 | 4.53 | 4.62 | WHP 4.8 bar-g |
| 100 | 0.523 | 83.8 | Small gas pocket | 0.535 | 14.15 | 14.43 | Small gas pocket |
| 200 | 1.391 | 136.3 | Temp still slightly rising | 0.893 | 23.35 | 23.81 | |
| 300 | 2.137 | 181.6 | | 1.224 | 31.91 | 32.54 | |
| 400 | 2.632 | 211.9 | | 1.532 | 39.92 | 40.71 | |
| 500 | 2.948 | 231.5 | | 1.812 | 47.24 | 48.17 | |
| 600 | 3.016 | 235.7 | | 2.086 | 54.52 | 55.59 | |
| 700 | 3.182 | 246.0 | | 2.357 | 61.66 | 62.87 | |
| 800 | 3.231 | 249.1 | | 2.613 | 68.46 | 69.81 | WHP 4.7 bar-g |
| 900 | 3.252 | 250.4 | | 2.875 | 75.43 | 76.91 | |
| 1000 | 3.253 | 250.5 | | 3.139 | 82.47 | 84.09 | |
| 1100 | 3.237 | 249.5 | | 3.410 | 89.71 | 91.48 | |
| 1195 | 3.220 | 248.4 | | 3.675 | 96.79 | 98.69 | |
| 0 | 0.028 | 53.8 | Counter stuck (161m) | 0.195 | 5.20 | 5.30 | |
| | | | | | | | |

**Remarks:** Counter on winch wrong when pulling out of the well after temperature measurement due to friction with steering arm.

# STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-6

Dates:

14-3-2002 Temperature gauge KT-10073; Clock 3h, serial no. V4304; Time 12:45-18:20
15-3-2002 Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 9:10-11:00
Zero reference about 2m above cellar.

| TEMPERATURE | | | | PRESSURE | | | |
|---|---|---|---|---|---|---|---|
| Depth (m) | Deflection (cm) | Temperature (°C) | Observations (Temp. Logging) | Deflection (cm) | Pressure (bar) | Pressure ($kg/cm^2$) | Observations (Press. Logging) |
| 0 | | | WHP 3.6 bar-g | 0.152 | 4.05 | 4.13 | WHP 3.8 bar-g |
| 100 | 0.520 | 83.7 | Small bleeding from stuffing box | 0.517 | 13.68 | 13.95 | Small bleeding from stuffing box |
| 200 | 1.390 | 136.3 | Temp still slightly rising | 0.870 | 22.73 | 23.18 | |
| 300 | 2.129 | 181.1 | | 1.206 | 31.43 | 32.05 | |
| 400 | 2.423 | 199.1 | | 1.520 | 39.69 | 40.47 | |
| 500 | 2.917 | 229.5 | | 1.813 | 47.29 | 48.22 | |
| 600 | 3.010 | 235.3 | | 2.080 | 54.36 | 55.43 | |
| 700 | 3.107 | 241.3 | | 2.336 | 61.14 | 62.34 | |
| 800 | 3.201 | 247.2 | | 2.588 | 67.81 | 69.14 | |
| 900 | 3.259 | 250.8 | | 2.846 | 74.66 | 76.13 | |
| 1000 | 3.269 | 251.5 | | 3.112 | 81.75 | 83.36 | |
| 1100 | 3.260 | 250.9 | | 3.384 | 89.01 | 90.76 | |
| 1200 | 3.250 | 250.3 | WHP 3.7 bar-g | 3.666 | 96.54 | 98.44 | |
| 1228 | 3.249 | 250.2 | | 3.745 | 98.64 | 100.58 | WHP 3.8 bar-g |
| 0 | | | WHP 3.8 bar-g | 0.185 | 4.93 | 5.03 | |

**Remarks:** Winch did not start at end of temperature measurement at 14:40 so gauge was not on surface until 18:20

COMPAGNIE FRANCAISE DE GEOTHERMIE ORKUSTOFNUN

# STATIC TEMPERATURE AND PRESSURE PROFILES IN WELL BO-7

Date: 13-03-2002

Temperature gauge KT-10073; Clock 3h, serial no. V4304; Time 9:00-10:50
Pressure gauge KP-K8238; Clock 3h, serial no. V4304; Time 11:15-12:40
Zero reference about at top of cellar.

| TEMPERATURE | | | | PRESSURE | | | |
|---|---|---|---|---|---|---|---|
| Depth (m) | Deflection (cm) | Temperature (°C) | Observations (Temp. Logging) | Deflection (cm) | Pressure (bar) | Pressure ($kg/cm^2$) | Observations (Press. Logging) |
| | | | | | | | |
| 0 | | | | | | | |
| 100 | 0.466 | 80.4 | | 0.348 | 9.21 | 9.39 | |
| 200 | 1.350 | 133.8 | | 0.702 | 18.31 | 18.67 | |
| 300 | 2.092 | 178.9 | | 1.041 | 27.04 | 27.57 | |
| 400 | 2.331 | 193.4 | | 1.354 | 35.30 | 35.99 | |
| 500 | 2.935 | 230.6 | | 1.652 | 42.98 | 43.83 | |
| 600 | 2.991 | 234.1 | | 1.924 | 50.21 | 51.20 | |
| 700 | 3.036 | 236.9 | | 2.178 | 56.96 | 58.08 | |
| 800 | 3.072 | 239.2 | | 2.426 | 63.56 | 64.81 | |
| 900 | 3.090 | 240.3 | | 2.674 | 70.16 | 71.54 | |
| 1000 | 3.100 | 240.9 | | 2.920 | 76.72 | 78.23 | |
| 1019 | 3.095 | 240.6 | Gauge siting | | | | |
| 1095 | | | | 3.161 | 83.15 | 84.79 | |
| 0 | 0.072 | 56.5 | | | | | |
| | | | | | | | |