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GEOTHERMAL EXPLORATION PROJECT
LAKES DISTRICT

DRILLING OF WELL LA-8

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ABSTRACT

LA-8 is the last and the deepest exploratory well in the Aluto-Langano Geothermal field, drilled to a total depth of 2500m. The well was drilled with different sizes of bits and hole openers telescopically narrowing to the bottom. After the completion of every stage of hole making process in this well, API K55 of different sizes and grades, buttress thread casings were run in various hole diameter and depth.

This well was drilled using different kinds of drilling fluids namely mud, aerated foam, aerated water and water. Separated water from well LA-4 steam water was used intensively for this well drilling operation; water had been the priority unless otherwise there was a dictating factor. When ever there were caving and cutting lift problems change of drilling fluid from water to one of the rest would be foreseen. Blow-out that encountered in this well was small in magnitude and it was controlled with in a short period of time. The time spent on blow-out controlling and fishing in this well was very little to be mentioned.

Well LA-8 is the first well to be drilled by the national drilling crew under the supervision of Geothermal Energy New-zealand limited (UNDP) - Consultant)and MOWLEM Int. limited (contractor). The supervision work required one drilling engineer and tool pusher from MOWLEM and one drilling superintendent from GENZL. Drilling of LA-8 by the national drilling crew enabled the Project to reduce its cost to a considerable amount. The drilling progress didn't show any decline in efficiency and no failure was also reported due to incompetence.
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1. INTRODUCTION

LA-8 was drilled on top of Aluto Volcanic complex and is located at a grid reference of E476946.4m, N862374.5m and Z1895.75m (see fig. 1.10).

The drilling activity of well LA-8 was started on October 20, 1985 and was completed on March 14, 1985. This was the time interval from the rigging up to the rigging down operation. Prior to the spudding, civil works such as site preparation, access road construction and work on the drilling water supply were completed. Like the first five drill sites, this site was not subjected to consolidation grouting; it was not either compacted by vibrating roller. However an attempt was made to compact the site using 50 tonne weighing oil field truck. As can be seen later in this report the top formation was a total loss of circulation zone. According to kebede the unconsolidated top formation was composed of alluvium and pumice (kebede, 1985). Due to the low strength of this formation the drilling mud came out to the surface through fissural pattern cracks In order to seal of the cracks and for a better cutting lift, stiff drilling mud was used in this hole and in the other problem areas; otherwise the preferential drilling fluid was water. Air drilling techniques such as aerated water and foam were also applied wherever there was cuttings lifting problem and it was effective in the lost circulation zone where the formation was competent. On the other hand, drilling both with aerated water and foam exhibited severe problems in the soft formation. Prior to the cementing of the casing the following API, K-55 buttress thread casings had been landed to the respective depths. The 20".94lb/ft casing in the 24" hole to a depth of 39.65m; the 13 ³/₈" 48lb/ft casing in the 17 ¹/₂" hole to depth of 294.20m; the 9 ⁵/₈" 40 lb/ft casing in the 12" hole to a depth of 708m; the 7" 26lb/ft liner landed between 666.98m and 2463.86m.
The first two casing namely the 20" and the 13 3/8" casings were cemented with locally available portland cement; where as the 9 5/8" casing was cemented with high temperature cement.
Apart from these in all the holes, total losses of circulation were observed during drilling. i.e before casing running and cementing operations begun. The occurrence of heavy losses made impossible to get returns of cement slurry during casing cementing operations. Hence operators were obliged to pump a large volume of slurry through the annulus. The 20" casing cementing work required 19.8m$^3$ of slurry; out of this 27.72% was pumped through the annulus. The 13 3/8" casing was cemented with 68.5m of cement slurry, out of this 52.2% was pumped through the annulus. The 9 5/8" casing required 58m$^3$ of cement slurry; out of this 48.81% was pumped through the annulus.

The drilling of this well was completed having a little fishing problems compared to LA-3 and LA-6. On the other hand the down time was on the highest record next to LA-1 and LA-2. The total down time of this well was 756 hr. Unlike the other seven wells 80.7% of the down time had been caused by waiting on material supply (wom), otherwise this well could have been completed in a shorter time than shown in this report.

As it is mentioned above, caving and cuttings lifting were the major drilling problems reported during the drilling operation of this well.

These phenomena retarded the well completion time and forced to consume a considerable amount of cement. Cement consumption in this well was 272tonne which is by 94.1tonne excess of the average value of the Langano wells. On the contrary bentonite and mud additives consumption in LA-8 was minimal. For instance 29.8tonne of bentonite and 0.42tonne of caustic soda were consumed in LA-8. But bentonite consumed in the other seven wells was between 219 tonne and 52.6 tonne.
2. DRILLING WATER SUPPLY

The first four wells (LA-3-LA-6) which are drilled on the top of Aluto volcanic complex were drilled by using Lake Zeway water. In order to meet the pumping head requirement which was 300m static head and distance ranging from 10km to 12km, three to four multistage pumps were operated in series. On the other hand, drilling water for well LA-7 and LA-8 was pumped from LA-4's waste disposal pond requiring only one multistage pump as proposed in one of the project monthly meeting (GEP, 1984). The water was obtained by separating from steam water of well LA-4 using atmospheric separator. The change of drilling water source from Lake Zeway to LA-4 enabled the project to reduce its fuel expenditure by 75%. However there was doubt about the effect of chemicals such as silica on the drilling equipment. Deposition of silica in significant quantity only occurs if the geothermal water is cooled sufficiently to become supersaturated with amorphous silica (Arnorsson, 1979). After the completion of drilling of these two wells (LA-7 and LA-8) silica deposition was observed only in places where fluid was not subjected to a dynamic condition. LA-4's water consists several salts such as calcium chloride and sodium chloride (Mekuria, 1984). Calcium chloride and sodium chloride could decrease the cement thickening time and other chemicals such as sulfate also affect the cement strength. Cement is susceptible to sulfate attack if the mixing water consists considerable amount or if the cement is exposed to the sulfate environment (Halliburton. 1972). The effect of the former one could be compensated by cement retarder where as the latter one needs a detailed study. In LA-8, 0.4% of HR-12 cement retarder was used with G class cement while cementing the 9 5/8" casing.
3. DRILLING

3.1 Drilling of the 24" Hole

Drilling of the first hole started on October 28, 1984 with 12 1/2" tricone bit to 49.29m. This hole was opened with 24" hole opener using 12 1/2" bit as pilot down to 45m. The average penetration rate and the average hole opening rate were 3.24m/hr. and 6.20m/hr. respectively. As can be seen from the lithology of well LA-8, loose formations which are alluvium and pumice and lithic breccia consisting of predominantly coarse angular pumice and some rhyolite and obsidian fragments extend down to 63.5m (Kebede, 1985).

In order to prevent caving or hole enlargement due to this soft formation and for an easy cuttings lift in such a big hole, it is recommended to apply mud drilling technique. Hence stiff drilling mud was used throughout the drilling operation of this hole and a good return of circulation was also obtained. However total loosens of circulation were encountered all the way down to the bottom during the hole opening operation. It was also observed that the circulating mud was coming out to the surface under the rig wooden pads.

To continue pumping mud in this condition was found uneconomical and due to this the operator was forced to used mud and water alternatively down to 45m.

3.1.1. Cementing of the 20" Surface Casing

It is customary in a cementing operation such as this to calculate the required amount of cement, water and other consumable prior to the casing running. Slurry pumping time is also predetermined.
3.1.1.1 Cement consumption Estimate

The expected volume of slurry to be used is calculated as follows using Fig. 3:10.

1. Volume capacity of 20", casing
   \[ 185.28 \text{ lit/m} \times 10\text{m} = 1852.80 \text{ lit.} \]

2. Annular volume capacity between the 20" casing and the 24" open hole:
   \[ 88.90 \text{ lit/m} \times 39.65\text{m} = 3,524.88 \text{ lit.} \]

3. Volume capacity of the 24" hole:
   \[ 291.90 \text{ lit/m} \times 5.35\text{m} = 1,561.67 \text{ lit.} \]

4. The 121/2" pilot hole was filled with cuttings during the hole opening operation. Hence there will not be considerable amount of cement slurry wastage.

The sum of items 1-4 is 6,939.35 lit. Due to the irregularity of the hole, 100% excess of the calculated amount of slurry is assumed to be used.

Thus the total slurry requirement would be 13,878.1 lit. This amount of slurry at a specific gravity of 1.8 yields 16.21 tonne of cement. Water requirement of the given specific gravity of slurry was 53.71 lit. per 100kg of cement.
20" Davis Type 600
Cement guide shoe

K55 20" 94 lb/ft Casing

Total Loss

39.65 m
45.00 m
49.28 m

Fig. 3-10  Cementing of the 20" casing
For a good cementing job, pumping of slurry must be finished within a short time and this can be done only with an efficient cementing equipment. The total pumping time calculated for this job is 33 minute, assuming that the mud pump is operated at a discharge rate of 500 lit/min. What matters most when a pump is run at high pumping rate is the competence of the formation. otherwise the calculated pumping time is much below the setting time of portland cement slurry at 30°C stable down hole temperature.

3.1.1.2. Placement of Slurry

Pumping of slurry was started after making the necessary equipment arrangement. To start with 15.3m³ of portland cement slurry at a specific gravity of 1.8 had been pumped through the 20" casing. At the beginning there was a reasonable amount of return, but latter on as the slurry column got heavier, loss of circulation was encountered and it was not possible to get return of circulation. The first pumping was carried on for 40 minute. Finally the cement slurry in the casing was displaced by 6.8m³ of water. After 7 hr. waiting on cement (WOC) the uncemented column in the annulus was measured to be 6m. This uncemented annular space between the 20" casing and the 24" open hole should require 0.53m³ of slurry at a specific gravity of 1.8, however 4.5m³ of slurry at a specific gravity of 1.8 had been pumped down through the annulus. The total amount of cement consumed for 20" casing cementing work was 23.13 tonne; which is 243% excess of the calculated amount.

In order to avoid the possible blow-out risk, 21 ¼" Shaffer annular blow-out preventor which has a pressure rating of 2000 PSI at the top and 20" ANSI 300 series master valve at the bottom were fitted on the 20" casing.
3.2 Drilling of the 17 1/2" Hole

After 36 hr. WOC, drilling on the cement (DOC) began starting from 31.4m and rock cuttings were also coming to the surface with the circulating drilling water. The reason why rock cuttings were obtained instead of cement cuttings was that pumice which has low density might have ascent and floated on the top of the slurry as pumping ceased. The absence of non-return valve of the 20" casing guide shoe had a big contribution to this phenomenon. Doc was carried out for 3hr. and cuttings which accumulated below the casing shoe where also cleared by circulation water.

Drilling on the formation continued with mud starting from 49.29m using 12 1/4" tricone bit. Total circulation losses were observed between 86.90m and 99m. Due to this and for an economic reason change of drilling fluid from mud to water was also made. But the change didn't give a better solution. It is known that one of the objectives of a geothermal exploration drilling is to get representative cutting and core samples for scientific studies. In addition to this, it was also essential to get rid of cuttings out of the hole for a better drilling progress. For these reasons an attempt was made to clean the hole by applying aerated fluid technique. Hence drilling continued with foam and aerated water alternatively from 99m down to 129.60m with a good return of circulation. At this depth a drastic penetration rate drop was encountered due to bit worn out and was replaced by a new one. While tripping in with a new bit to the bottom of the previous depth, an obstruction was encountered at 96.5m. The obstruction was cleared by circulating water and by rotating the drill stem simultaneously. This technique enabled the driller to free the
string and to drill down to 144.7m. The same as before drilling below this depth was not possible due to bit stuck and bit blockage. It was suspected that the stuck was caused by hole caving. After the bit being freed from cutting, and attempt was made to lower it down to the bottom. This time also like the other two cases, an obstruction was encountered at a depth of 88.80m. The obstruction was cleared by using circulating water and this gave one more chance to the driller to drill down to 162.7m with aerated water. However drilling with aerated fluid caused a caving problem. Then the bit was lifted back to the casing shoe to see how fast cuttings was accumulating. The rate of cuttings accumulation in the hole was between 2m/min and 4m/min. Since this problem didn't come to an end, to continue drilling in such condition was not advisable. Hence five hole groutings had been conducted starting from 85m. See table 3.1 for the detail.

<table>
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<th>It No</th>
<th>Cement - class</th>
<th>Volume m</th>
<th>Sp.gr.</th>
<th>Hesitation time (hr.)</th>
<th>Cement Level (m)</th>
</tr>
</thead>
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<tr>
<td>2</td>
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<td>11.2</td>
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<td>&quot;</td>
<td>5.6</td>
<td>1.87</td>
<td>10:00</td>
<td>28.3</td>
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</table>

Table 3.1 Hesitation grouting of the 17 1/2" hole.

After the hole was grouted as indicated in the above table, drilling on the cement and on the formation became an easy task. The penetration rate between 275.3m and 308.89 was fast compared to the previous depths. (see fig. 4.20). Drilling both on the cement and on the formation was carried out using water. The total drilled depth was 308.87m and complete circulation losses
were also encountered starting from 226m down to the bottom. Due to the total circulation losses that encountered below 226m it was hardly possible to get a representative cutting samples for this part of the hole. For this reason core sample was taken prior to the 13 3/8" casing running. However an obstruction was encountered at 269.71m while tripping in the hole for coring. The obstruction was cleared by circulating water at a flow rate of 1250 lit/min which resulted in a good return of circulation. As the hole washing process continued the travelling block was broken and a repair work was carried out for 20min. While conducting the repair work, the bit was standing in the bottom with no room left for the suspended cuttings in the annulus to settle. This means cuttings were settled around the string when the drilling fluid lost in to the thief zone. As a result of this the bit was packing by cuttings and it was not possible to move it either in the upward or downward directions. The over pull load recorded during this incident was 70 tonne. Since the pull load could exceed the mast capacity, Jarring was carried out for several hours by connecting 5 3/4" over-shot and hydraulic jar on the first pipe next to the kelly. Part of the fish was retrieved after making several jarring and the remaining fish was also recovered by using 9 5/8" over-shot in the bottom and hydraulic Jar on the top.

Before Jarring took place the top of the fish was located at 231m and the over pull load recorded was 50 tonne.

After the fishing operation was completed the hole was opened with 17 1/2" hole opener, using 12 1/4" bit as a pilot to a depth of 308.22m. There was a total loss of circulation all the way down to the bottom during the hole opening operation (See fig.4.30). The rate of hole opening was fairly good in the first 51.27m, whereas the progress was unpleasant down to 308.22m.
3.2.1 Cementing of the 13 3/8" casing

Prior to the casing running operation the 17 1/2" hole was reamed and washed for several hours, with no return of circulation. Right after the hole washing job completed, API, K-55, 13 3/8" 48lb/ft buttress thread casing was run to 294.20m.

3.2.1.1 Cement Consumption Estimate

Cement slurry is calculated using Fig. 3.20.

1. Annular volume capacity between the 20" and 13 3/8" casings.
   94.48 lit/m x 39.60m = 3,741.41 lit.

2. Volume capacity of the 13 3/8" casing.
   81.89 lit/m x 20m = 1,637.80 lit.

3. Annular volume capacity between the 13 3/8", casing and the 17 1/2" open hole.
   64.40 lit/m x 254.6m = 16,396.24 lit.

4. Volume capacity of the 17 1/2" hole.
   155.20 lit/m x 14m = 2,172.80 lit.

5. Volume capacity of the 12 1/4" hole.
   This space is considered filled in by cuttings.

Sum of Item 1-5 is 23,948.25 lit. Due to the irregularity of the hole, 100% excess of the calculated amount of cement slurry was estimated to be used.
Hence the total cement slurry requirement was 47,869.50 lit. For a specific gravity of cement slurry 1.80, the above figure yields 55.95 tonne of cement and 30.05 m$^3$ of water. The pumping time calculated for 600 lit/min. pump discharge rate is 1:20 hr.
3.2.1.2 Placement of Slurry

Cementing of the 13 3/8" casing was conducted in two steps. The first cementing job was conducted by pumping 33m³ of portland cement at a specific gravity of 1.80 using conventional cementing method.

After 45 minutes of pumping there was no return of circulation and pumping continued for another half an hour with no return of circulation. Hence the first cementing work was terminated by displacing cement slurry in the casing with 22.5m³ of water. The 2nd cementing job was carried out by three hesitation cementing through the annulus (see table 3.20)

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Cement class</th>
<th>Volume (m³)</th>
<th>Sp.Gr.</th>
<th>Hesitation time (hr)</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.80</td>
<td>5.00</td>
<td>Nil</td>
</tr>
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<tr>
<td>3*</td>
<td>&quot;</td>
<td>9.50</td>
<td>1.80</td>
<td>23.00</td>
<td>Obtained</td>
</tr>
</tbody>
</table>

* Squeezed at 5 kg of /cm²

Table 3.20 2nd hesitation cementing job of the 13 3/8" casing

The total cement consumption of 13 3/8" casing cementing job was 80.02tonne. This amount is by 243% in excess of the calculated amount. As can be seen from the above discussions, 51.82% of the total amount of cement consumed by this hole was pumped through the annulus.
After 12hr. WOC, 10" 3000 PSI capacity double ram hydraulically operated shaffer b.o.p and the same size and capacity of annular b.o.p were installed on the 13 3/8" casing.

3.3 Drilling of the 12 1/4" hole

DOC in the 13 3/8" casing was carried out between 260.77m and the casing shoe. Having finished DOC the new hole was deepen down to 310m using 12 1/4" bit. Core sample was also taken between 310m and 316m and the recovery rate was only 7.94%. Due to the soft formation, the core recovery was low. The formation encountered at this depth was a highly indurated volcanic ash. (Kebede, 1985). Drilling on the formation continued to 618m with a fairly good penetration rate. At 617m the formation became harder than the previous depth (below the 13 3/8" casing shoe) and total circulation losses were also encountered. For this reason a core sample was taken between 618m and 620.80m. The recovery rate was 43% and the average rate of coring was 0.5m/hr.

The main factor which retarded the coring rate was not only the formation hardness, but it was as well due to accumulated cuttings in the bottom of the hole. Like the previous two holes, cuttings accumulation in this hole was caused by losses of circulation. When the drilling fluid was lost in to the formation, cuttings would be suspended in the annulus till the dynamic force of the fluid could not lift them any more. On the other hand the end result would be the same when circulation ceased. As a result of these two cases cuttings would settle in the bottom and the drilling progress was affected. In order to get rid of cuttings
in the hole, air drilling technique such as aerated water was applied. Due to the injected air, light hole column was crated which allowed the formation fluid to escape in to the hole. As a result of this, the hole started to below-out (kick). The kick occurred between 617m and 626m and was made under control by pumping cold water at a high flow rate through the drill string. The well head pressure recorded during the kick was 15kgf/cm². Due to the same reason mentioned before to make a good drilling progress with water or aerated fluid was not possible. When ever the drilling fluid was changed from water to aerated water the hole would start to kick. An attempt was also made to drill with water at a flow rates between 1400 lit/min and 1680 lit/min. This time, it was possible to deepen the hole to 664.5m. The penetration rate between 620m and 664.65m was good compared to the previous depths, where as the drilling progress was poor, (see fig. 4.10 and fig 4.20). However it was hardly possible to drill down below this depth (664.65m) either with water or with aerated water. Hence the hole was grouted using 9m³ or 10.51 tonne of portland cement slurry from the bottom up to 565.87m. After 8hr. WOC drilling both on the cement and on the formation was carried out with water at a flow rate ranging from 1250 lit/min to 2500 lit/min. Drilling of this well terminated at a depth of 783.57m.

3.3.1 Cementing of the 9 5/8" Casing

Before running the casing, an attempt was made to clean the hole. However there was no return of circulation and 37.25m of cuttings were accumulated in the bottom at the end of the hole washing. After the reaming and the washing works completed, API K-55, 9 5/8", 40lb/ft buttress thread casing was run to 708m.
3.3.1.1. Cement Consumption Estimate

Using Fig. 3.30 cement consumption is calculated as follows.

1. Annular volume between the 9 5/8" and 13 3/8" casings:
   34.79 lit/m x 294.20m = 10,235.22 lit.

2. Annular volume between the 9 5/8" casing and 12 1/2" open hole:
   28.94 lit/m x 426.68m = 12,384.12 lit.

3. Volume capacity of the 9 5/8" casing:
   39.55 lit/m x 20m = 791 lit.

4. Volume capacity of the 12 1/4" open hole: no need to calculate because the part of the hole is filled by cuttings.
   Sum of time 1-4 is 23,374.34 lit; 100% excess of the calculated amount of cement slurry at a specific gravity of 1.80 yields
   54.61 tonne of dry cement and 29,326.1 lit. of water. If the mud pump is operated at 600 lit/min this amount of slurry can be pumped in 1:30hr.
3.3.1.2. Placement of Slurry

To start with, 30m of G class cement slurry at a specific gravity of 1.80 was pumped together with 0.4% by weight of HR-12 Halliburation cement retarder through the 9 5/8" casing.
As return of circulating was not obtained the slurry was displaced using 27m of water. The slurry and the water were isolated by top plug. The 2nd cementing job was carried out with 28.6m of G class cement at a specific gravity of 1.8 through the annulus. This work required 68.45 tonne of G class cement which is by 250.7% excess of the calculated amount.

3.4 Drilling of the 8 1/2" Hole

After 16hr. WOC from the primary cementing job, the landing length was removed and drilling on the cement commenced using 8 1/2" bit starting from 709.50m. Drilling on the formation was carried out from the bottom of the 12 1/4" hole down to 784.53m. Core sample had been also taken between 784.53 and 787.53m and the recovery was 35%. Drilling continued down to 1050m with a good penetration rate and partial loss of circulation was detected all the way down to 1050m. Drilling below this depth could not be continued due to the non availability of competent stabilizers and reamers; an adequate stabilizer and reamer which do not permit bit walk will provide stiffness to the down hole assembly. Starting from December 12, 1984 to January 16, 1985 the drilling progress was nil and the time elapsed is categorized as a down time due to waiting on material (WOM). In the mean time water was circulated to keep the hole from collapse and to maintain low down hole temperature. On January 16, 1985 after 36 days without progress in drilling, the roller reamers were received on site. On the same day the mid-night shift made an attempt to ream the hole and drilling below 722.5m was found difficult. The main problem was that, every time after making up a new pipe joint, it was not an easy task to lower the bit down to the bottom. This was caused by an obstruction that encountered at several depths. Hence hole
cleaning and reaming was carried out for several times. Normally after circulating water with good returns of circulation for some time, the bit would be lifted back to the casing shoe to see the stability of the formation; however, the end result would be either bit stuck or an obstruction. In one of this kind of trials made on January 21st 1985 the bit was stuck at 823m and an over pull load developed was 50 tonne. As described before, the same problem of obstruction was encountered for every kelly move and it was suspected that could happen due to hole collapse. It is also believed that this problem was caused by the collapse of soft ashy formation which stay under water for a long time during waiting on roller reamer. This statement is confirmed by geological results; the formations from 723.50m to 1037m are compact tuff, thin breccia layers with during waiting on roller reamer. This statement is confirmed geological results; the formations from 723.50m to 1037m are compact tuff, thin breccia layers with rhyolite and tufaceous fragments, rhyolitic tuff and volcanic ash (Kebede, 1985).

The occurrence of soft formation and man-made underground environment created this phenomenon. Hence a big hole diameter was created which intern created a drastic annular fluid velocity reduction. As a result of this, cuttings could not reach the One can understand from the above statements that the problem could not be overcome either by reaming or cleaning the obstruction. Hence several hole groutings had been conducted which contributed a great deal to the achievement in this hole. The first grouting work was conducted at 772m with 14m$^3$ or 16.36 tones of portland cement slurry. After 7 hr. WOC the top of cement was at 756.03m. The 2nd grouting job was conducted using 7m$^3$ or 8.18 tonne of portland cement slurry and the top of cement was at 728.53m, after 8hr. WOC. DOC continued with fast penetration rate down to 761.2m
and cuttings were also lifted to the surface at well. But there was no success in drilling down below this depth. This time also the hole was grouted using 8m$^3$ or 9.4 tonne and 5m$^3$ or 5.84 tonne of portland cement slurry at an interval of 8hr. The top of cement was encountered at 703m, after 15hr. WOC from the first grouting job. One can tell from the above slurry consumptions that the hole was enlarged at several places. The enlargements of the hole could have been better determined by caliper log.

Since such logging facility was not available in Ethiopia a rough average enlarged hole diameter was calculated from different batches of cement slurry, which were used for hole grouting. Assuming no losses of circulation, the hole diameter between 756.03m and 772m was enlarged to 41 1/2"; the hole diameter between 728.53 and 756.03 was enlarged to 22". From the last grouting work the hole diameter between 703m and 761.20 was enlarged to 19 1/4". These calculations proved that, hole collapse occurred at several places below the casing shoe and drastic velocity reductions were also created which intern prevented cutting lift to the surface, though there were good return of circulation (see fig.4.30 and fig.4.40).

After completing DOC and clearing of cuttings and core sample were taken between 1050.8m and 1052.8m, where the coHaving finished coring, it was tripped down with 8 1/2 bit to drill on the formation, however, obstructions were encountered at several places almost for every kelly move and the hole was filled fastwith suspended cuttings even for a short circulation interruption time. Due to this reason bits were stucked at several depths and moving down with a bit was the main problem. As a final solution, the hole above 756m was grouted with 8m or 9.35 tonne of portland cement slurry. After 16hr. WOC drilling on the cement commenced starting
from 713.6m. From the above shown cement slurry consumption the hole enlargement is calculated to be 19 3/10". Drilling below the cemented zone was difficult and the same problem of the previous nature was created.

In order to increase the annular velocity of the drilling fluid, water was circulated through the 7 7/8" washover pipes down to 903m and the wash pipe got stocked as it was moved up to the surface. While tripping out the wash pipe an over pull of 55 tonne was recorded. The fishing operation was conducted as follows. Having disconnected the joint on the string, it was tripped down with an over-shot, jarring tool and with two 8" drill collars. The top of the fish was found at 675.20m and jarring carried out for hours; at last the fish was freed and circulation continued, but cuttings couldn't be lifted to the surface. At last 6m$^3$ or 7 tones of light slurry cement was circulated through the wash pipe and finally the hole was filled with 26m$^3$ or 30.37 tonne of portland cement slurry. After 8hr. WOC drilling on the cement was carried out from 707.6m to 964m and clearing of cuttings was also done successfully down to 1052m. Finally drilling on the formation continued to the well target depth which was 2500m. Four core samples were also taken as drilling was progressing. The status of the core samples taken are listed below:-

1. Cored between 1496.20m - 1496.20m and the core recovery was 11%.
2. Cored between 1830.50m - 1832.80m and the core recovery was 2%
3. Cored between 1965.20m - 1966.50m and the core recovery was 26%.
4. Cored between 2500.00 - 2501.00m and the core recovery was 30%.

Having finished drilling API K-55, 7" 26lb/ft buttress thread liner was landed between 666.98m. and 2463.86. The original plan was to land the liner between 703.12m and 2500m. However because of cuttings that accumulated in the bottom of the well. The operator was obliged to land the liner to a shorter depth than indicated in the plan. Assuming that the best producing zone would be at the well bottom, slotted liner which has a total length of 596.81m was landed to the bottom and the rest 1200.07m blind liner was connected at the top. Having completed liner running, the well completion test had been conducted prior to the rigging down. Drilling of well LA-8 completed on the 14th of March 1985.

4. DRILLING PROGRESS AND TIME ANALYSIS

The time elapsed from the rigging up to the rigging down operation is taken as a total drilling time of a well. In the case of LA-8 the drilling time covers the time elapsed from October 20, 1984 to March 14, 1985. The drilling progress and the time breakdown are analyzed as shown in fig.4.10 and table 4.10 respectively. Drilling particulars such as weight on the bit (WOB), bit speed or rotary table speed, drilling fluid physical characteristics and types of formations are the main factors for a good or poor penetration rate (see fig. 4.20, 4.30 and Fig. 4.40).

An appropriate bit is also one of the main factors for a good penetration rate and use of a wrong bit can result in a poor penetration rate or a poor drilling progress rate and can affect the well economy. In this case well LA-8 required 18 bit runs. (see bits record analysis in table 4.20).
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BOB = Bit on the bottom, DOC = Drilling on cement, WOW = Waiting, on water, WOM = Waiting on material,
Figure 4.20 Drilling Particulars
Symbol for Lithostratigraphy distribution
Shown on Figure 420 (after Kebede)

Recent Alto Phyroclastics.

Upper Pleistocene - Resent Aluto - rhyolites

Late Pleistocene - Upper Pleistocene Silicic Tuffs and Breccias.

Late Pleistocene Sediments.

Early Pleistocene - Late Pleistocene Silicic Tuffs and Breccias.

Upper Pliocene - Early Pleistocene Basalt.

Upper Miocene - Upper Pliocene Ignimbrites.
Figure 4-30 Drilling fluid in and out at various depths.
Figure 4.40 Annular Velocity of Drilling Fluids.
Table 4.20 Bits record for well LA-8
Geothermal Field:- Aluto-Langano
Type of drilling:- exploratory
Well No:- LA-8
Reg name:- K600T
Drilling Fluid:- Mud (0-49m), water and areated water
Date:- 28/10/84 - 6/3/85

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F= Finished, RR = Re-run
RT = Rotary table
5. THE RIG AND THE DOWN HOLE ASSEMBLY

5.1 Drilling Rig

LA-8 was drilled using one oil field rig which consists of the followings as the main parts:
K600 trailer mounted rig equipped with hydraulically actuated telescopimg mast.
- The rig engine: - 12V-71T detroit diesel
- Mast capacity: - 133.64 tones (minimum rated static hook load).
- Mast weight: - 12247kg.
- Racking capacity 2 double: - 250 pipes
- Engine capacity: - 525 BHP at 2100 rpm
- Two mud tanks and two triplex single acting mud pumps.
- Cement storing and pumping units.
- Blow outs preventing unit.
- Power generation unit. (376 KW).
- Air drilling equipment

5.2 Down hole Assembly

- Drilling pipes: - 4" 0.D, 2 13/16" I.D, 14 lb/ft, E.grade Connection = NC 40 box & pin, 5 1/4" tool joint
  Total length = 2359.58m.
  Used between = 0 - 2500m.
- Drill collar: - 8"0.D,
  Total length = 93.94m.
  Used between = 0-783.57m.
- Drill collar: - 61 1/2" O.D.
  Connection = NC 46 box and pin
  Total length = 75.59m.

- Drill collar: - 5 3/4" O.D.,
  Connection = NC 40 box and pin
  Total length 38.25m.
  Used between 783.57m - 2500m

Subs

- NC 40 box up and 6 5/8" Reg. Pin down cross over sub.
- 65/8" Reg. box up and 6 5/8" Reg. box down near bit sub
- NC 40 box up and 46 pin down cross over sub.
- NC 46 box up and 4 1/2" I.F box down near bit sub.
- NC 50 box up and NC 40 pin down kelly saver sub.

Reamer and Stabilizers

One near bit reamer and a maximum of three stabilizers were used between 753m and 2500m.

5.3 CONSUMPTIONS

5.3.1 Cement and drilling fluid Additives

Portland cement = 262.90 tonne
G class cement = 68.50 "
Bentonite = 29.80 "
Caustic Soda = 0.42 "
Liquid soap = 4.00 "
Ampli-Foam = 0.42 "
5.3.2 Fuel Consumption

Total Diesel = 256,682 lit.
Rig Site = 169,623 lit.
Water Pump = 60,884 lit.
Camp electric generators = 26,175 lit.
Petrol consumption for drilling and related activities = 19,894 lit.
6.0 CONCLUSIONS AND RECOMMENDATIONS

1. The use of a geothermal water for drilling is appreciated; down time due to waiting water that had been a big problems in the other wells was not seen during the drilling of this well. However there is a need to study the effect of a geothermal water on cement.

2. All the holes namely the 24", the 17 1/2" and the 12 1/4" holes were not grouted prior to the casings running operation. And this resulted in a poor casings cementing job. This practice needs to be avoided in a future drilling operation.

3. Well LA-8 was drilled to a total depth of 2500 m. using K.600T rig. drilling in excess of 2000m using this rig is not advisable.
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References

- Geothermal Exploration project (Ethiopia-Lakes district rift); 1984: minutes of project monthly meeting.


- Geothermal exploration project (Ethiopia-Lakes district rift); March, 1984: minutes of project monthly meeting.

- Stefin Arno'rsson: 1979: Hydrochemistry in geothermal investigations in Iceland.


- Halliburton services: March, 1972: oil well cements and cement additives.