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EXTRACTION OF GOLD AND SILVER FROM GEOTHERMAL FLUID

K.L. Brown and P.J.C. Roberts

Geothermal Research Centre, DSIR, Wairakei, New Zealand
Spectrum Resources Ltd, P.O. Box 17036, Auckland 5, New Zealand

ABSTRACT

This paper describes five separate experiments conducted at KA35 well at the Kawerau geothermal field. The experiments were designed to try to recover the gold and silver which was initially dissolved in the geothermal water. The fluid from the well was depressurised and fed through a mild steel collection vessel. The vessel contained a series of collection devices which were analysed after each experiment for gold and silver recovery. A wide variety of materials were tested in a number of difference physical environments.

The gold recoveries varied from 0.007 to 0.24 mg per tonne of geothermal fluid. Silver recoveries were 0.096 to 0.84 mg per tonne of geothermal fluid. The maximum recoveries were obtained in the first experiments using mild steel collection plates, and subsequent changes to physical parameters and collection materials only reduced the gold and silver recovery. A surprising discovery was that activated charcoal is useless as a collection medium and actually seems to redissolve depositing gold.

The experiments concluded when the well became blocked by calcite deposition. It is thought that the characteristics and chemical composition of the fluid discharged by the well was changing towards the end of the experiments.

INTRODUCTION

Gold and silver scaling deposits were discovered in the surface pipework from New Zealand geothermal fields (Brown, 1986). Approximate calculations for the well BR22 at Broadlands/Ohaaki showed that the deep aquifers contained about 1.5 mg/tonne of gold and 8.0 mg/tonne of silver. With these concentrations, it was felt worthwhile to investigate the possibility of commercial extraction of gold and silver from those geothermal fields which had been developed. At the Kawerau geothermal field, the surface concentrations of gold and silver are found to be higher than at Broadlands, consequently it was decided to construct a small pilot plant at Kawerau. The key element in the commercial recovery of the available gold and silver is the ease of extraction from the geothermal fluid. Because the concentrations are so low, the extraction must be very cheap and efficient. At BR22, it was observed that the gold and silver was very efficiently deposited as a result of a large pressure drop. This paper describes five experimental runs in the Kawerau pilot plant.

EXPERIMENTAL

The vessel used for the pilot plant experiments is shown schematically in Figure 1. It was designed to allow for a large pressure drop through an orifice plate. The fluid then entered an expansion chamber which was packed with various collection media. The apparatus was set up at KA35 well at the Kawerau geothermal field. A special tapping enabled two phase fluid at the wellhead pressure to be supplied to the orifice plate. Normal measurements included the pressure drop on entering the chamber, the exhaust pressure and the flow rate. Observations at BR22 had shown that the gold and silver, in a chalcopyrite matrix, deposited onto mild steel. For the first two experiments, a mild steel mesh filling was used. The mesh enabled a large surface area to be presented to the fluid. The mesh was cut into circular plates and these were identified with a numbered tag. Each plate was weighed before placing it into the vessel. At the conclusion of each experiment, the plates were removed, dried and weighed. The amount of gold and silver collected was analysed by either (a) sampling the deposit from the plates and analysing this deposit, or (b) dissolving the plates completely followed by chemical analysis. Due to the time and cost of method (b), method (a) was preferred. Thus the total amount of gold and silver deposited onto each plate could be calculated. In those experiments where activated charcoal was used, a chemical analysis of the whole sample was performed. The results of these analyses enabled a total recovery rate to be calculated. This is expressed in terms of mg of gold or silver per tonne of geothermal fluid. (This is equivalent to the parts per billion (ppb) concentration extracted from the fluid.)

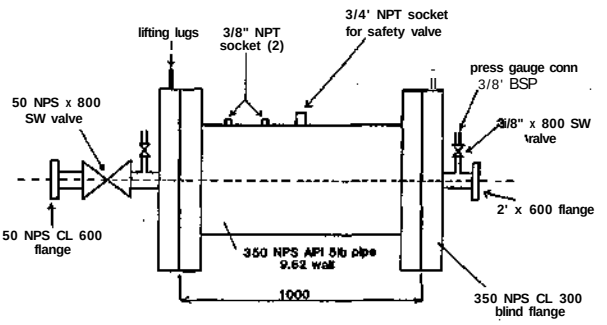

Figure 1: A schematic of the collection vessel.

EXPERIMENT 1

For this experiment, 45 plates were placed in the vessel together with a packer to prevent movement. The experiment was run for 26 days with a 1 inch orifice plate. The inlet pressure was 26 Bg and this was reduced by the orifice plate to 15.8 Bg inside the vessel. The exhaust pressure was 15.0 Bg. With these conditions the total flowrate was -19.0 tonnes/hour. When the vessel was opened, all

of the plates had a friable black coating. The coating was thickest at the bottom where liquid water, as opposed to steam, was present. The black deposit was highly magnetic. Unfortunately, the force of the water had punctured holes into the first 22 plates, so it was pointless measuring weight increases for these plates. Analysis of the plate deposits showed that gold concentrations varied from 0.5 wt% to 6.57 wt%. Silver concentrations in the precipitated deposit varied from 3.4 to 20.3 wt%. The average weight increase per plate was around 2.0 gm. It was impossible to calculate the amount of gold recovered due to the puncturing of the initial plates, however an estimate was made by extrapolating the weight gains using a least squares line. This is shown in Figure 2, together with the gold concentrations as a function of the position in the vessel. Using this data, it was estimated that 2.86 g of gold was deposited during the experiment. With a total flow of 11747 tonnes, this infers a recovery rate of 0.24 mg gold per tonne of geothermal fluid. A similar calculation for silver gave a recovery rate of 0.84 mg silver per tonne. Other recovery rates were Copper 0.16, Lead 0.04, Zinc 0.09, Antimony 0.07, Arsenic 0.13. A SEM investigation showed that the deposit was thickest nearest the edges of each of the mesh pores. This is probably a flow-related phenomenon.

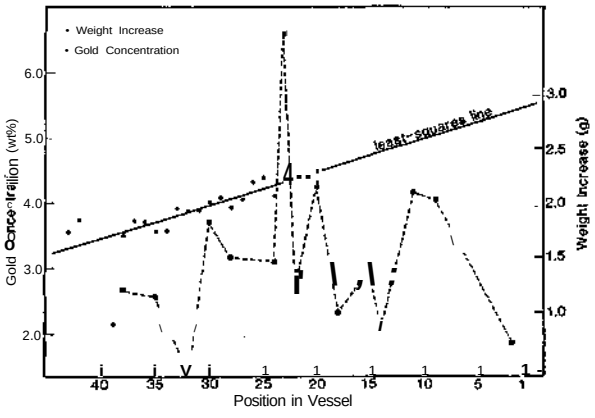

Figure 2: Gold concentrations and weight increases of plates in Experiment 1.

EXPERIMENT 2

Inspection of Figure 2 shows that gold is still precipitating on the final plates during Experiment 1. This indicates that the flowrate is too high, and the residence time in the vessel is too short. Consequently, for experiment 2, a 0.75 inch orifice plate was used. This was designed to reduce the flow by half. As well, a total of 98 plates were installed for this experiment in an endeavour to collect all of the available gold and silver. A flow spoiler was used to prevent damage to the initial collection plates. The inlet pressure was 24.9 Bg and the reduced orifice lowered the pressure inside the vessel to 13.2 Bg. Because of the large number of collection plates installed, the exhaust pressure was 12.3 Bg. The flowrate was 11.2 tonne/hour, and the experiment ran for 34 days. When extracted, the plates showed changes in colour depending on the position within the vessel. Generally, plates nearer to the inlet were darker coloured than plates nearer to the exhaust. The flow spoiler had functioned correctly and no plates were damaged. Samples for analysis were collected by brushing the plates, and these deposits were analysed for gold, silver, copper, and iron. The results for gold and silver are shown in Figure 3.

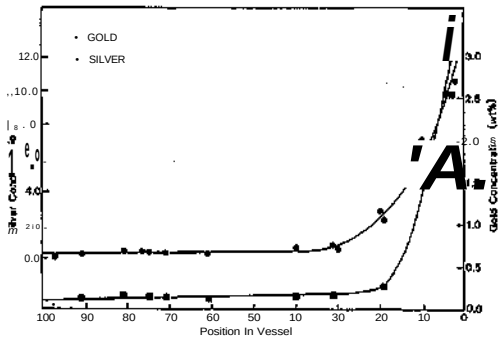

Figure 3: Gold and silver concentrations on plate deposits Experiment 2.

Copper concentrations ranged from 0.4 wt% to 6.4 wt%, iron concentrations varied from 26 wt% to 57 wt%. The individual plate metal recoveries were interpolated and integrated to give a recovery rate of 0.21 ppb for gold and 0.88 ppb for silver. These results are almost identical to Experiment 1. The reduction in flowrate had the desired effect of depositing all of the available gold in the vessel. Figure 3 shows that most of the gold and silver is deposited by plate number 30. This corresponds to an elapsed time since depressurisation of only about 0.3 seconds. The gold is deposited faster than silver, and the silver is deposited faster than copper. This is the order that would be expected from the electrochemical series.

EXPERIMENT 3

A number of different packing materials were used for this short experiment. These were designed mainly to test the deposition mechanism and to investigate whether the composition of the packing material was important. Consequently, a number of different materials were used. These were inert materials - titanium and platinum - and the very reactive metals aluminum and copper. The aluminum, titanium and platinum-coated titanium plates were attached to the normal mild steel plates by stainless steel wire. The copper was present as a large ball which fitted snugly into the vessel. The flow conditions etc. were the same as Experiment 2. When the vessel was opened, it was found that the copper had all been converted to copper sulphide and had deposited a dull green coating downstream of the copper ball. It was estimated that about 30% of the copper had been lost. The platinum covered titanium plate had much less deposit than the steel plate to which it was fixed. The aluminium had a clean surface with no deposit and close examination showed pitting on the surface indicating that the aluminium had been dissolving. There was, however, elevated silver concentrations on the plate upstream of the aluminium, indicating that an electrolytic cell had probably been set up. (No gold was detected here.) We concluded that mild steel seemed to be the best material for the collection plates. Copper and aluminium are not satisfactory materials.

EXPERIMENT 4

As shown from inspection of Figure 3, there is still a small amount of gold and silver depositing onto the very last plates. This suggests that some gold and silver may be lost from the exhaust of the vessel. It was decided to try to find a method for collecting these residual lower levels of gold and silver. As activated charcoal is used to quantitatively adsorb gold in a variety of situations, it was decided to test its effectiveness

in geothermal fluid. A stainless steel holder was fabricated to contain the 9.3 kg of activated charcoal which was in the form of ~7 mm chips. The holder has stainless steel mesh at either end to contain the charcoal. For this experiment, the level of the exhaust tube was altered to try to raise the water level inside the vessel. The vessel was packed with 10 steel mesh plates, followed by the activated charcoal, followed by a further 25 plates. The flow rates etc. were the same as Experiment 2. This experiment lasted 13.5 days.

When the vessel was opened after this experiment, it was noted that the activated charcoal was very green coloured at the front and much less so at the rear end of the holder. Pyrite crystals were observed within the charcoal collector. Because of the range of colour within the charcoal, separate samples were taken from the front, middle, and rear of the collector. An average representative sample was also taken. The deposits on the plates were analysed as before. The deposit on the plates upstream of the charcoal showed somewhat less than normal concentrations of gold (about 0.5 wt% average), although the silver concentrations were higher (1-2 wt%). The deposits on the plates downstream of the activated charcoal showed very low concentrations of gold and silver (gold = 54 ppm, silver = 330 ppm). Gold was only detected in the front sample of activated charcoal (14.5 ppm) and it was less than 1 ppm in all other charcoal samples. Silver was detected in the charcoal at an average level of 22 ppm. The activated charcoal analyses are shown in Figure 4. The total amount of gold recovered amounted to about 0.01 ppb and silver recovery was 0.08 ppb. It appears that copper is well scavenged by the charcoal, but silver and gold are not extracted by the charcoal. The very low gold and silver concentrations downstream of the charcoal seem to indicate that the charcoal is redissolving any available gold. The total amount of gold and silver recovered is lower than previous experiments which possibly pointed to a change in conditions of the well.

EXPERIMENT 5

A 0.5 inch orifice plate was installed for this experiment. This lowered the flow rate and increased the pressure drop. The inlet pressure was 24.0 Bg and the exhaust pressure was 10.9 Bg. The collector containing the activated charcoal was placed after only one plate at the very front of the vessel for this experiment. Following this were a number of mild steel mesh plates as before. The initial plate upstream of the charcoal formed a deposit which contained 1.48 wt% of gold and 11.88 wt% of silver. Gold was not detected in the activated charcoal and very reduced concentrations were found in the deposits of the plates following the charcoal collector. These results confirm the findings of the previous experiment.

DISCUSSION

A summary of the gold and silver recovery rates for the five experiments is:

Recovery (ppb)	Expt 1	Expt 2	Expt 4	Expt 5
Gold	0.24	0.21	0.011	0.007
Silver	0.84	0.88	0.081	0.096

The first two experiments were the most successful at collecting the gold and silver, but the amount is less than the 1.5 ppb of gold theoretically available at BR22. The low concentrations of recovered gold probably indicate that this collection method is not economically viable. It must be realised however that these experiments were not able to be run in a manner which maximises the amount of gold and silver depositing. The well was on production and as such had a low well-head pressure. This means that there is a large pressure drop within the well casing and gold could very well have been deposited within the casing, reducing the amount available at the surface. Figure 3 suggests that the gold that is available is deposited very efficienty on the steel mesh plates.

REFERENCES

Brown, K.L. 1986. Gold Deposition From Geothermal Discharges in New Zealand. Economic Geology 81, 979-983.

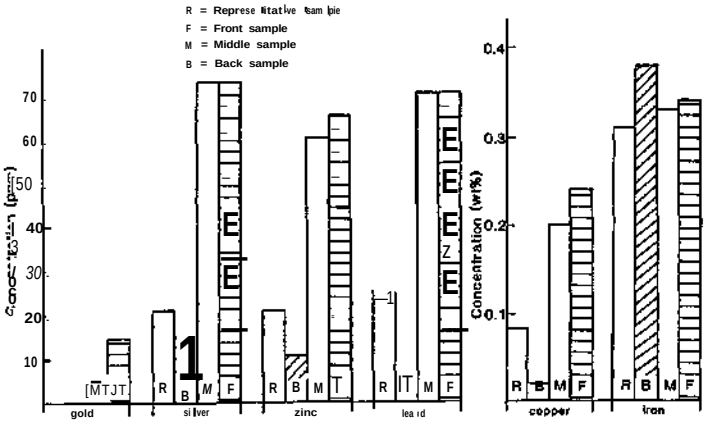

Figure 4: Concentrations of elements from charcoal from Experiment 4.