IS Kawerau – Minerals Background Study

1. Background

The Kawerau region has been subject to limited mineral exploration, with initial mining beginning in 1886 when an Auckland company began to investigate the sulphur fields found near Onepu. These fields were reported to have certain properties that were not found in the sulphur at White Island, off the coast from Whakatane. In peak production the company was shipping 30 tons a week down the Tarawera River to Tauranga, but in June 1889, it was discovered the company only had a prospecting licence and was therefore mining the sulphur illegally. In 1894 all leases were allowed to lapse, ending sulphur mining at Kawerau [1].

Approximately 100 years later, in the late 1980s, further mineral exploration began to take place, however this related to the extraction of minerals from the geothermal brine used for electricity production and in the Tasman Pulp and Paper Company's (Tasman) industrial processes. Primary focus was on silica extraction.

Fletcher Challenge Limited (FCL) in conjunction with Tasman (a wholly owned subsidiary) successfully developed a silica extraction technology which was tested at Kawerau and Wairakei geothermal fields. Tasman's interest in silica extraction arose from a need to improve future newsprint quality. Commonly used fillers such as calcined clay and synthetic precipitated silica were not produced locally, leaving Tasman to face the expensive prospect of having to import them [2]. FCL and Tasman developed a process to manufacture specialty geothermal silicas which were deemed to have value in newsprint and other industries [2].

Historically, the risk of silica deposition in geothermal systems has been a constraint in maximising the energy potential of high temperature geothermal resources. Geothermal brine has needed to be re-injected at high temperature to avoid this deposition. This significantly undervalues the amount of energy brought to the surface, as it limits the temperature range that can be used for energy production [2].

The recent rejuvenation of geothermal energy development globally, combined with a greater range of commercial applications for high quality silica, has renewed interest in the extraction of silica (and other minerals and metals) from geothermal brine. The composition and volume of geothermal brine at Kawerau may offer considerable potential for the extraction of various minerals; however the commercial viability of such activities is further dependent on mineral concentrations, mining technology implemented, recovery rates and the quality of recovered minerals.

2. Mineral resources and volumes

Geothermal fluids, heated as they travel through hot rock bodies, interact with the rocks becoming increasingly saturated with various minerals. Typically, the higher the temperature of the geothermal brine the greater its chemical content [3].

Many of the chemical constituents in geothermal fluids are a potential source of valuable minerals and metals. The first application of such mining techniques took place at Larderello, Italy, as early as the turn of the last century where boric acid was extracted from geothermal steam [3].

2.1 Silica

Of primary focus is the extraction of precipitated amorphous silica from geothermal brine. This is due to the potential value to be created through additional geothermal energy generation, the production of silica as a marketable commodity in its own right, and the removal of environmentally sensitive constituents providing for the disposal of low temperature desilicified water [4].

In 1990 Tasman built a pilot plant at Kawerau to produce silica from separated geothermal water for paper machine trials. The plant processed over 30 million litres of separated geothermal water, producing 30 tonnes of geothermal silica. The technology was able to integrate the extraction process with upstream power generation, direct use of heat and the subsequent reinjection of geothermal brine [2]. For unknown reasons this technology was not taken to commercial scale by FCL and Tasman, but when in production the pilot plant had a proven production output of 500kg of precipitated silica per day. The process was continuous and the plant achieved a commercial number of hours, with important information regarding the reticulation of atmospherically separated water and precipitated silica slurry having been obtained [4].

A 1992 study investigated the potential extraction volumes and values for high quality precipitated silica from a range of geothermal fields in New Zealand. Potential extraction volumes at Kawerau were based on a geothermal brine flow of 7 million tonnes per annum, at a concentration of 750mg/kg. The initial estimated recoverable volume of 4,500 tonnes per annum [4] was further revised in a later study to an estimated 3,000 tonnes [2]. Providing this end figure is based on the same brine flow and concentration, it indicates a recovery rate of approximately 57%.

Now 20 years later and with considerable subsequent geothermal development, total consents for the extraction of geothermal brine from the Kawerau field stand at approximately 95,000 tonnes per day, or around 35 million tonnes per year. A further resource consent for the extraction of 45,000 tonnes per day is currently being sought by Ngati Tuwharetoa Geothermal Assets (NTGA). If granted this would bring an additional 16 million tonnes of geothermal brine to the earth's surface each year.

It is estimated that if there was a low risk of silica deposition in re-injecting geothermal brine at low temperatures, then 10-20% more power could be generated per unit of mass withdrawn for the same capital invested. In additional to this, existing methods for inhibiting silica deposition represent a direct cost to the asset owner for the additional energy generated at lower temperatures [2]. For these reasons geothermal energy developers and asset owners may well have an interest in the successful extraction of silica from within geothermal systems.

The concentration of minerals within the geothermal brine at Kawerau varies widely from mineral to mineral, with brine composition also varying depending on the point of extraction - i.e. well to well. Over the years there have been a range of studies testing mineral content within the Kawerau geothermal field, with results from 2004 providing the latest relevant data from a range of wells. This data relates to production well chemistry which, importantly for potential mineral extraction, means the brine is brought to the earth's surface. Brine composition (mg/kg) for the following minerals has been averaged over the five production wells where monitoring took place [5].

- Lithium – 4.72
- Sodium – 601
- Potassium – 93.6
- Calcium – 1.3
- Magnesium – <0.01
- Rubidium – 0.58
- Caesium – 0.45
- Chlorine – 875
- Boron – 38
- Silica – 658

Under the assumption that geothermal brines from all production wells at Kawerau share the same mineral composition and concentration as above, we can broadly estimate that the total amount of silica brought to the earth's surface could be up to 22,000 tonnes annually.

35 million tonne brine flow x concentration 658 ppm x 95% plant uptime

At a recovery rate of 57%, combined silica recovery from all wells at Kawerau could be as high as 12,000 tonnes annually. These estimates are drawn from work completed approximately 20 years ago, therefore potential recovery volumes and silica quality as they stand today would require further investigation by qualified persons. Successful commercialisation will depend heavily on access to the brine, along with the extraction technology deployed, market value of the end product, and capital and operational expenditures.

Further to this, if undertaken by the geothermal generation asset owner, silica extraction provides an additional revenue source, therefore lowering the cost of geothermal power production. Extraction from geothermal brine could also offset or eliminate the need to source applicable resources from energy intensive and environmentally damaging mining technologies.

2.2 Other minerals

While further minerals in geothermal brine may have potential value [2], the removal of silica scale within the geothermal system is the necessary catalyst for the extraction of these minerals. Once the silica has been removed to the point where precipitation is no longer a problem, further technologies can then be deployed to extract other minerals and metals [3]. To date global interest has been concentrated on the recovery of zinc, manganese, lithium and a number of rare earths [3].

Available quantities for other minerals contained within the geothermal brine can be estimated by running the same calculation as used for silica. Potential recovery rates, however, will vary upon the type of technology implemented and the success of this.

Further to the minerals above, some geothermal brine may contain significantly high concentrations of precious metals such as silver, gold, palladium and platinum [3]. Areas of potential interest for gold and silver include parts of the Taupo Volcanic Zone (TVZ) displaying high prospectivity for epithermal gold mineralisation. Geothermal fields of interest are mainly confined to the active eastern side of the TVZ [6], with small quantities of ore-grade silver and gold having been deposited by geothermal fluids in several fields of the TVZ, including Kawerau. Deposits have also previously been found in pipes, weir boxes, and drill hole discharges associated with geothermal exploration and development [7].

In order for a geothermal system to produce an economic precious metal deposit within the typical lifetime of a geothermal system, the deposition process must be efficient, and the gold and silver concentrations in the geothermal fluid must be sufficient [8].

A study completed at Kawerau circa 2002 found that samples obtained from wells at ≥1000m depth and temperatures of between 260 and 295°C contained gold, silver and thallium at parts per billion (ppb) levels, while arsenic, antimony and copper ranged from hundreds to thousands of ppb. Results from the study suggested deep water wells at Kawerau are under-saturated in gold but close to saturation in silver [8].

Further to this, silver and gold mineralisation is also present in geothermal systems at Puhipuhi or Goldmine Hill, 14km southwest of Kawerau. However, more recent reconnaissance exploration in the 1980s and 1990s didn't prove any commercially viable deposits [6].

As with silica, the commercial viability, market demand and prices for any mentioned minerals would require further investigation.

3. Mineral uses and applications

There is an increasing worldwide interest in silica production from geothermal brines to meet the demand for over 2.7 million kilograms of commercial grade silica per day. Silica is used in a range of applications including the following: [3]

- Rubber
- Plastics
- Paint
- Paper
- Ceramics
- Pharmaceuticals

- Pesticides
- Chemical and odour absorbents
- Fibre optics
- Adhesives

The value and price for silica varies widely and is very dependent upon purity, physical properties and the value to the particular application. Figures from a 2006 study in the USA suggested that while silica used in the production of rubber for tires, dental products and pesticides may be worth US$1/kg, silica used in paint could approach US$2 to US$4/kg. Further to this it stated that chromatographic grade silica may justify a price as high as US$6/kg or even higher depending on the end use [3].

The same study examined potential revenues from silica extraction at several geothermal fields in the USA, using a recovery rate 60% (similar to the earlier indicated rate), a selling price of US$2,200 per metric tonne and a plant capacity factor of 95% [3].

4. Mining regulations in New Zealand

Mining activity in New Zealand is directly managed by New Zealand Petroleum & Minerals (NZPAM), a business unit within the New Zealand Government's Ministry of Economic Development (MED). NZPAM manages the Government's oil, gas, coal, and other mineral resources, with the overall aim of maximising the Crown mineral estate's contribution to the economy, in line with the Government's objectives for energy security and economic growth [9].

New Zealand Petroleum & Minerals' work includes: [9]

- Administering the Crown Minerals Act 1991
- Allocating prospecting, exploration and mining permits and licences
- Management of technical data and reports from petroleum and mineral exploration and development activity
- Provision of advice to the Government
- Monitoring permit holders' work programme obligations
- Promoting investment in the Crown mineral estate
- Collecting royalties, fees and levies.

Crown-owned minerals are those minerals that are owned and administered by the Crown, as set out in the Crown Minerals Act 1991. Crown-owned minerals include all gold, silver and petroleum (oil and gas) in New Zealand's territory (being onshore and offshore to 12 nautical miles), and about half of the in-ground coal, metallic and non-metallic minerals, industrial rocks and building stones. These resources are referred to as the 'Crown mineral estate'. The Crown also has sovereign rights over, and manages petroleum and mineral resources in the Exclusive Economic Zone (being offshore between 12 and 200 nautical miles) and the Extended Continental Shelf [9].

Minerals that are not Crown-owned are owned privately. Privately-owned minerals are, in most cases, owned by the land owner, but determining mineral ownership in any particular title or land holding is often not an easy task. It will, in many cases, be necessary to search back to the first alienation of the land from the Crown to establish whether or not the minerals continue to be held with the fee simple title, or had been reserved by the Crown, or had been excluded as a result of any subsequent transaction (such as a transfer or a Public Works Act acquisition) [9].

Ownership or rights to the minerals within the geothermal brine at Kawerau is not clear cut and further investigations have been undertaken.

5. Mineral extraction outcomes and technologies

Geothermal brines can be considered as low grade ores, with the ore already liberated and at elevated temperature and pressure. By understanding the make-up of the brine and using a comprehensive extraction methodology, it should be possible to: [10]

- Recover the mineral value in the dissolved salts
- Recover additional thermal energy from the brine
- Eliminate scaling problems

In order to do this it is necessary to determine the potential value in the brine and establish the preferred extraction method/s, while taking advantage of the temperature and pressure of the brine. Emphasis should be placed on the highest value added product, but not always exclusively on this product alone [10].

It is thought that the technology exists to allow improved treatment of brines in a commercially viable manner, but further development is required to put this technology in place [10].

Further parties have developed technologies to extract silica from geothermal brine. They include:

- Lawrence Livermore National Laboratory in the USA. A study from 2006 at Mammoth Lakes, California demonstrated that both precipitated and colloidal silica could be produced from the geothermal fluids by first concentrating the silica to over 600 parts per million (PPM) using reverse osmosis. The co-produced silica was said to be of very high purity, and therefore potentially useful in markets where high purity is necessary, such as colloidal silica for silicon chip polishing, precision casting, paper coatings, and raw silica for solar photovoltaics [11]. It is also thought the technology allows plants to work more efficiently while producing silica as a marketable by-product. The production of freshwater has been deemed a further benefit of silica extraction, as it can be used as a heat exchanger coolant to further increase power production [12].

- The U.S. Department of Energy's Brookhaven National Laboratory, in collaboration with Caithness Operating Company of Reno, Nevada, USA. These parties won a 2001 R&D 100 Award for developing a technology to recover commercial-quality silica from geothermal brine. The Brookhaven/Caithness technology recovers silica from low-salinity brines that contain very few impurities, rather than high salinity brines with greater impurities. Recovered silica using this process is reported to be 99.9% pure, offering a wide range of commercial applications if commercially viable [13].

None of the technologies for silica extraction as mentioned have been examined for past or likely future commercial viability. Technology studies would need to be part of a comprehensive feasibility study into the likely commercial success of mineral extraction from geothermal brines.

References

[1] Moore, Kenneth W, 1990. Kawerau, Its History and Background.

[2] Harper, Thain and Johnston. An integrated approach to realise greater value from high temperature geothermal resources: A New Zealand example.

[3] Bloomquist, 2006. Economic Benefits of mineral extraction from Geothermal Brines, Washington State University, USA.

[4] Harper and Thain, 1992. Towards the efficient utilisation of geothermal resources.

[5] Bignall and Harvey, 2005. Geoscientific Review of the Kawerau Geothermal Field. Institute of Geological and Nuclear Sciences, New Zealand.

[6] Healey, 2005. Minerals in the Bay of Plenty Region. Environment Bay of Plenty, Tauranga.

[7] Christie and Brathwaite. Mineral Commodity Report 13 — Silver. Institute of Geological and Nuclear Sciences Limited.

[8] Brown and Simmons. Precious Metals in High Temperature Geothermal Systems. Geothermal Institute, Auckland University, New Zealand.

[9] New Zealand Petroleum and Minerals. New Zealand Mineral Estate brochure. See www.nzpam.govt.nz/cms/pdf-library/folder.2007-05-17.4547411750/NZP-M%20Minerals%20Estate%20web%20version.pdf

[10] Patterson, 2006. Geothermal Brines – Problem or Resource? Advanced Ceramics Research, USA.

[11] Bourcier, Ralph, Johnson, Bruton & Gutierrez, 2006. Silica Extraction at Mammoth Lakes, California.

[12] Bourcier, 2005. Mining Geothermal Resources. Lawrence Livermore National Laboratory.

[13] Article - Brookhaven National Laboratory, USA. 2001. Brookhaven Lab and Caithness Operating Company Win R&D 100 Award For a Technology to Recover Silica from Geothermal Brine. See www.bnl.gov/bnlweb/pubaf/pr/2001/bnlpr072601b.htm

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