Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 251

A Survey of Trace Metals and Microbiota in Geothermal Fluids and Sinter from the Taupo Volcanic Zone, New Zealand

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Arsenic, antimony, boron, mercury and thallium can occur in silica sinter that is actively depositing from geothermal systems. These elements are the principal pollutants contained in waste geothermal brine from geothermal power stations, In order to assess the role of the microbiota in the immobilisation of these constituents into the silica sinter, the inorganic geochemistry of the fluids and sinter has been characterised, and the microbiota have been investigated using high resolution field-emission SEM.

Sampling sites were natural hot springs from the Waikite geothermal area, and geothermal well discharges from the Tokaanu, Ohaaki, and Wairakei geothermal fields. Water and sinter samples were analysed for all sites. Sequential extraction was used to determine whether the trace metals deposited in the sinter were exchangeable, or bound to oxides, carbonates, organics or incorporated into the silicate lattice. Samples for SEM analysis were collected under sterile conditions, fixed with gluteraldehyde and prepared for SEM by critical point drying.

Arsenic concentrations ranged from detection to 1650ppm in the sinters, for geothermal water concentrations of 0.5 to 6.3ppm. The sinter arsenic was primarily associated with the oxide and crystalline fractions of the sinter. The former probably occurs by absorption on to iron oxides formed as the reduced fluid is oxidised, and the latter by inclusion into the growing colloidal silica structure.

Antimony sinter concentrations ranged from detection to 500ppm, for geothermal water concentrations of 20ppb to 500ppb. There was an approximate linear correlation between water and sinter concentrations, and nearly all of the antimony was associated with the crystalline fraction of the sinter.

Boron sinter concentrations ranged from 65ppm to 1700ppm, although the water concentrations were confined to a narrow range from 25 to 75ppm. The boron was principally associated with the crystalline fraction, with two samples having appreciable exchangeable boron. There is no obvious relationship between sinter and water boron concentrations.

Thallium concentrations in the sinter ranged between 0.5 and 6.6ppm, for water concentrations between 0.1 to 11ppb. There is an approximate liner relationship between the water and sinter concentrations. In all cases, a substantial portion of the sinter concentration is associated with the organic fraction.

Mercury sinter concentrations varied from detection to 0.14ppm, for geothermal water concentrations of detection to 0.35ppb. In the sinters where mercury was detected, it was always associated with the organic fraction. There is no obvious relationship between the water and sinter concentrations.

Microorganisms observed from the different sites in this study showed different growth habits. Vent mound geyserite from Tokaanu is submerged in very high temperature (94°C) water, and has an epilithic, monomorphic biofilm of long, thin hyper-thermophiles. However, at the same temperature and pH conditions in weirboxes from Wairakei, hyper-thermophiles do not occur as a biofilm, but exist as widely dispersed individuals on the sinter surface. Silicified hyper-thermophiles from the weirbox of Bore 116 show a preferred orientation, indicating a significant hydrodynamic effect on the biota. Geyserite forming in the splash-zone of 94°C waters from the Tokaanu vent contains a viable, endolithic, photosynthesising microbiota. The presence of chloroplasts was established by DNA analysis, and ethanol leaching of the chlorophyll pigment was observed. A separate hypolithic community was discovered on the underside of geyserite projections, and showed increased morphological diversity, compared to both the endolithic and epilithic communities described above. At 74°C at Wairakei, a sparse population of morphologically similar individuals was observed. At 69°C at Ohaaki, a dimorphic population of coccoid and rod-shaped micro-organisms colonised an artificial substrate. At 61°C at Wairakei, pink microbial streamers were observed, comprising large (~150mm) epilithic algal filaments and numerous bacterial strands. Finally, silica oncoids in cooler 53°C pools have a diverse living epilithic community at the surface. Inter/intra cellular silica colloids were observed in one sample (Figure 1), occurring only in one morphotype. Artificial substrates showed that some bacteria became completely silicified within 14 days, and there is some evidence that the rate is dependent on the aqueous silica concentration. Of the elements investigated in this study, the sequential extraction indicates that only Hg and Tl have a likelihood of being associated with bacterial deposition. However, thriving microbial communities have been found in a wide range of thermal environments.

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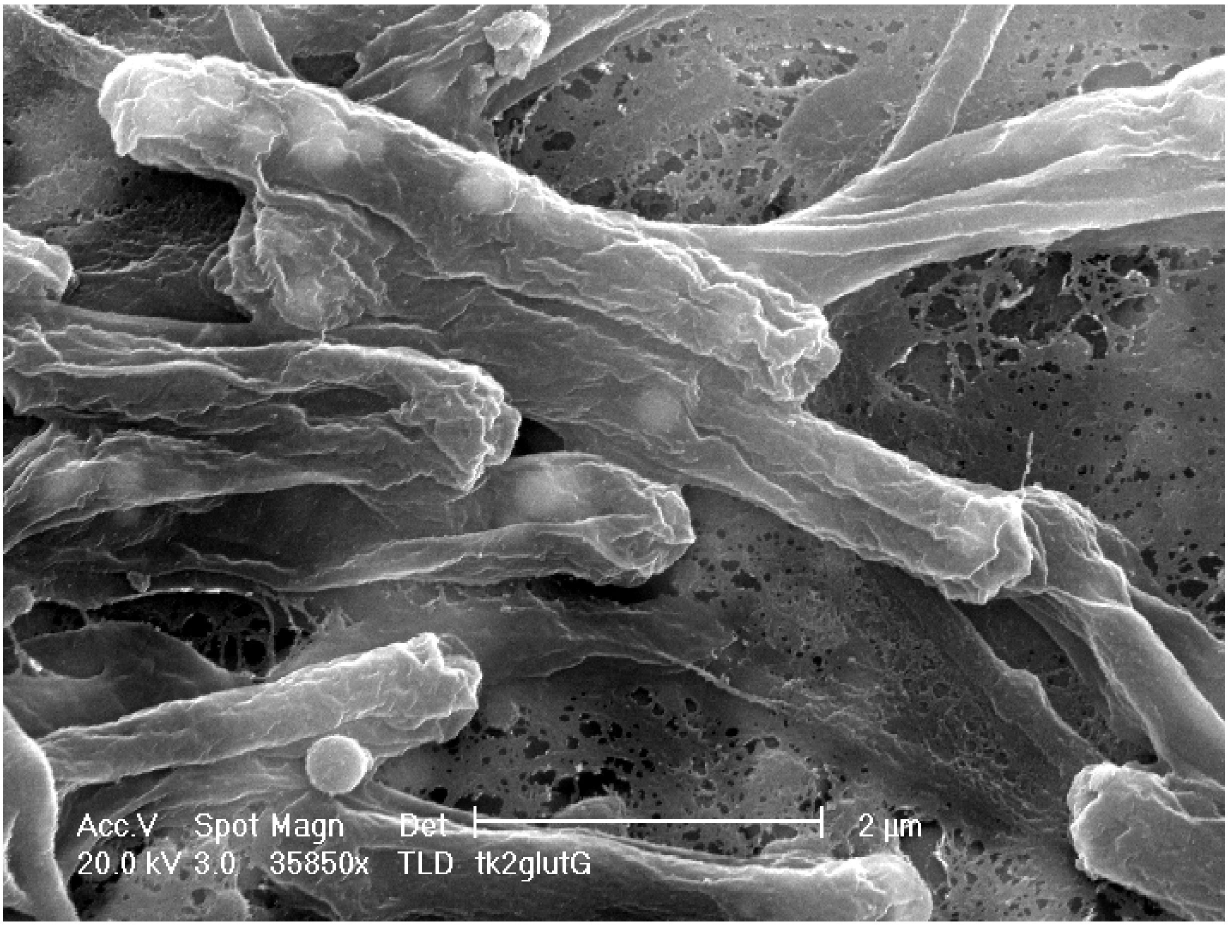

Figure 1: Microorganisms with silica colloids appearing within their sheaths or cellular membrane