

GEOCHEMISTRY OF A HAWAII GEOTHERMAL WELL: HGP-A

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Extensive sampling and analysis have been carried out on the Hawaii Geothermal Project well-A (HGP-A) over a period of 12 months beginning in July 1976. Samples of the following types have been taken: downhole samples taken with a Klyne thief sampler, steam-condensate samples taken at the well head with a double cyclone separator and effluent water samples taken at the outlet of the steam silencer. Water quality analyses have included the following: Na⁺, K⁺, Ca⁺⁺, Mg⁺⁺, Cl⁻, S⁼, SiO₂, alkalinity and pH. Age dating of the well waters was done by ³H analysis and ¹⁴C analysis of CO₂ in the discharge gases.

Results. The results of the water quality analysis made on downhole water samples are summarized in Table 1; included in Table 1 is also the statistical profile of the data. The salient features of the data obtained are as follows:

Salinity and Chloride. Values for both parameters were low (Table 1) in comparison with those for open ocean water (33.4‰ and 17,000 mg/l respectively) and were relatively free of variation with depth as illustrated by the chloride profile (Fig. 1).

pH. Downhole pH varied between 3 and 5 for the 6 sets of samples tested. The Feb. 14, 1977 depth profile obtained shortly after the well was quenched represented the only set of samples with significantly higher pH values.

Silica. All measurements indicated abnormally high silica levels in HGP-A well water when compared with normal Hawaiian ground water (<80 mg/l). Silica profiles showed little variation with depth but large variations were observed between sampling periods.

Major Cations Na, K, Ca, Mg. Cation concentrations show a moderate variation with depth and conditions of the well prior to sampling (Fig. 2). The observed increase in potassium concentrations taken at shallow depths on Feb. 14, 1977 is thought to be a real perturbation in that it was observed for all ions for which determinations were made.

Tritium. Three samples were collected for tritium analysis (weir box, 690m and 1575m). All showed < 0.2 tritium units of radioactivity thus the mean age of the water is in excess of approximately 30 years.

Continuous Flow Series HGP-A. Samples of well fluid were collected both at the well head through a cyclone separator and condenser, and at the steam silencer outlet. In order to compare these numbers with the downhole results they must be multiplied by the factor 1/f where f is the steam fraction (generally 0.70 for HGP-A).

Table 2 presents a summary of both downhole and steady state discharge water chemistry data. The Cl⁻, SiO₂ and major ion concentrations all have a similar concentration vs. time profile (Figs. 3 and 4). Initial ion concentrations are seen to change abruptly after approximately 4 hours of flow which corresponds to the time necessary to clear one well bore volume of liquid. After the initial change a steady state ion concentration is approached after 2-4 days. Each successive flow of the well resulted in slightly higher concentrations of chloride and major cations (Fig. 5).

The present interpretation of the data obtained to the present is that there are several sources of water in the well: ocean water at shallow depth, 5-10%; meteoric water at deeper levels, 65%; hydrothermal fluids, 25%. The mixing of seawater and coal meteoric waters makes a geochemical estimate of downhole temperatures rather difficult but work is presently underway to resolve these problems.

TABLE 1. Summary of downhole chemical parameters

Parameter	Mean	Median	Standard deviation	Coefficient of variance
Conductivity	3670 μmhos/cm 3500	3100 μmhos/cm	2270 μmhos/cm 1360	62% 39
Salinity	2.8 ‰ 2.6	2.3 ‰	1.4 ‰ 1.0	51% 39
Chloride	1160 mg/l 1040	925 mg/l	810 mg/l 465	69% 45
Silica	440 mg/l	420 mg/l	230 mg/l	52%
Sulfide	135 mg/l	100 mg/l	96.4 mg/l	71%
Sodium	830 mg/l 730	600 mg/l	460 mg/l 270	55% 37
Potassium	135 mg/l 123	123 mg/l	56.0 mg/l 46.4	42% 38
Calcium	84.2 mg/l 53.8	40 mg/l	120 mg/l 49.5	142% 92
Magnesium	2.1 mg/l 1.0	1.0 mg/l	3.8 mg/l 0.7	62% 69

Where two values appear, the upper value includes all samples while the lower values excludes February 1977 depth samples at 692 m (2270 ft).

TABLE 2
HGP-A geochemical summary
(Concentrations in mg/l of total discharge)

	Cl	Na	K	Ca	Hg	SiO ₂	S ²⁻	pH	Trit.	t* qtz	t** Na/K	t*** Na/K/Ca
DOWNHOLE												
Non-flowing (ave. of 5 profiles): mean	1040	730	123	53.8	1.0	440	135	3	<.1	240°C	250(WE)	231
σ	+465	+270	+46	+49.5	±.7	+230	+96				252(FT)	
2270' (02/14/77)	4720	2008	245	445	14.0	432	.66	3	-	240°C	211(WE)	210
											210	
Low flow (average) of 4 samples	1040	480	103	22.6	.25	710	-	2.5	-	286°C	287(WE)	248
											294(FT)	
WEIR BOX												
approximate steady-state (01/30/77)	780	390	68	24	.11	41	-	8.5	-	93°C	256(WE)	229
											259(FT)	

*Fournier and Rowe (1966): $t = 1311/[5.196 - \log(SiO_2)] - 273$; SiO₂ in ppm.

**White (1968), Ellis (1969): $t = 855.6/[.6269 + \log(Na/K)] - 273$; Na and K in moles.

Fournier and Truesdell (1973):
 $t = 777/[.4693 + \log(Na/K)] - 273$; Na and K in moles.

***Fournier and Truesdell (1973):
 $t = 1647/[\log(Na/K) + \frac{1}{3}\log(\sqrt{Ca}/Na) + 2.24] - 273$; Na, K, and Ca in moles.

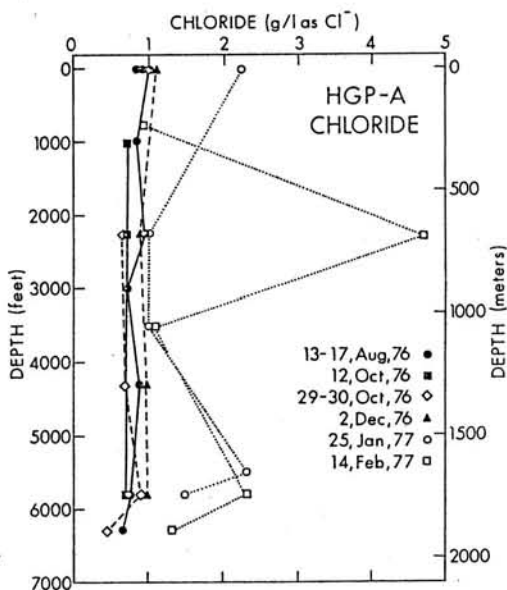


Figure 1. Downhole distribution of chloride for HGP-A.

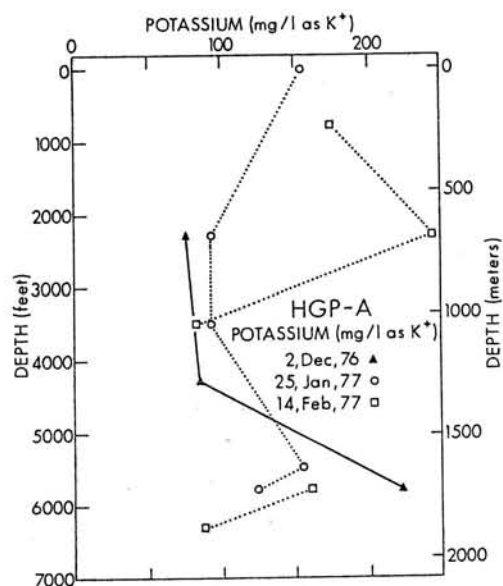


Figure 2. Downhole distribution of potassium for HGP-A.

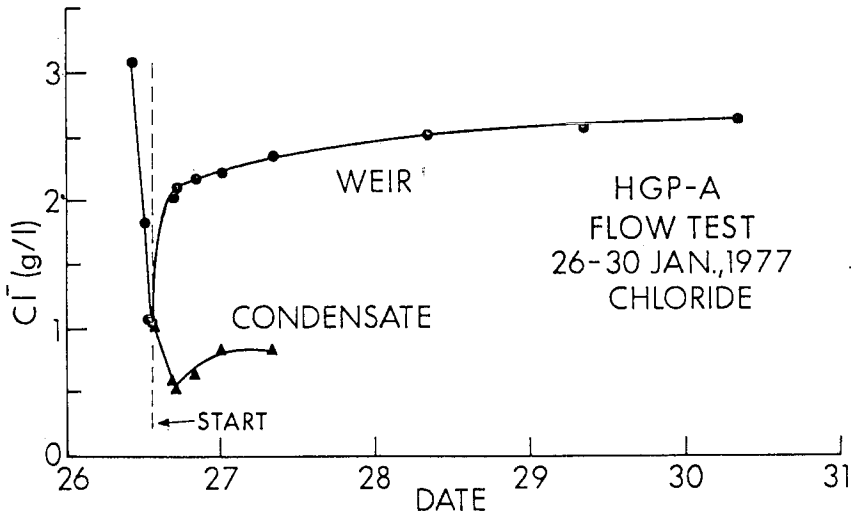


Figure 3. The approach of chloride to steady state for water samples collected at the weir and from the condenser.

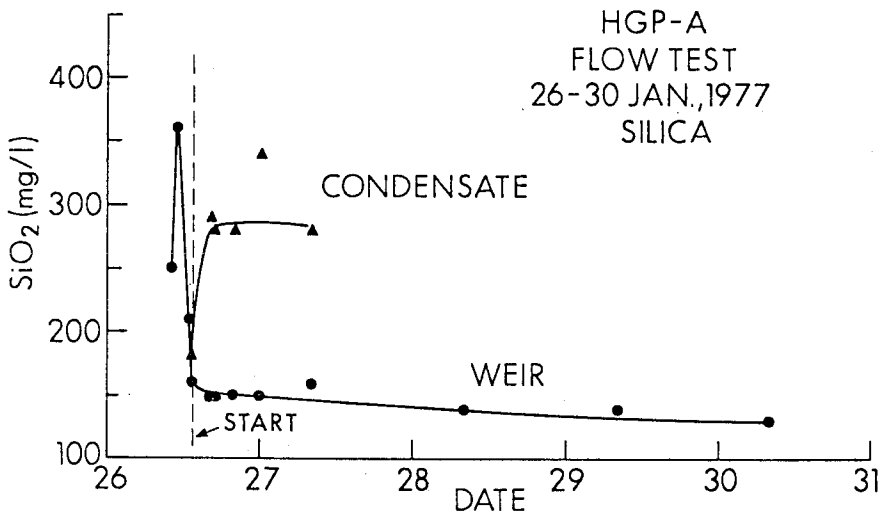


Figure 4. The approach of silica to steady state for water samples collected at the weir and from the condenser.

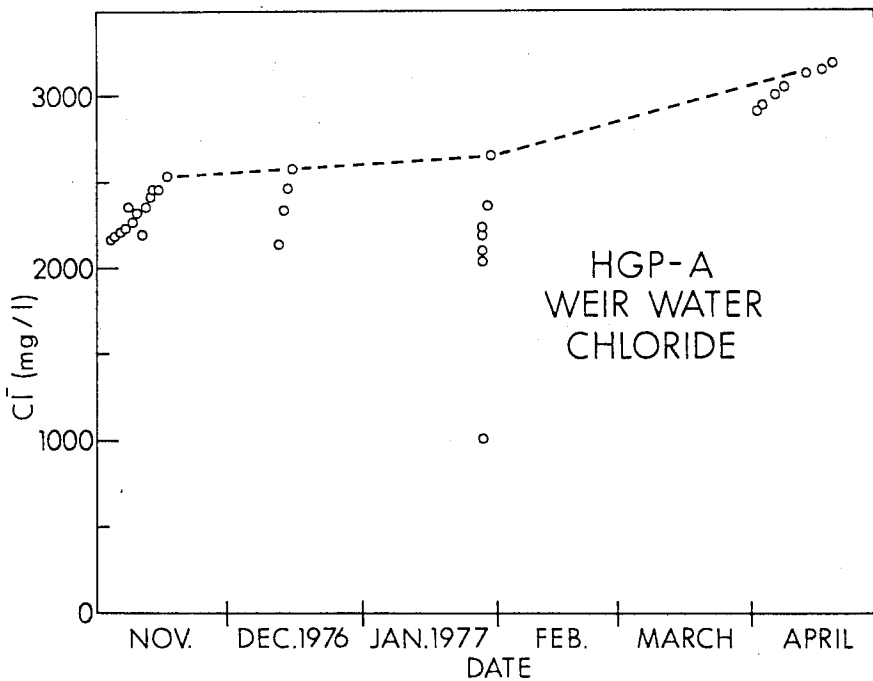


Figure 5. Chloride concentrations of samples collected from the weir and plotted versus the date of sampling. The steady rise after each well test suggests that the well has not reached equilibrium with the surrounding waters. To compare these results the reader must multiply them by $(1-f)$ where f is the steam fraction of the discharge.