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Akutan Well AK-3

Drilling Site Selection Document

Prepared for the City of Akutan

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Summary

A well location has been selected for a resource confirmation well to be drilled at the Akutan geothermal area located in Hot Springs Bay Valley (HSBV). A small diameter well will be drilled into the conceptualized resource outflow of the Akutan geothermal system. The drilling project is funded by the City of Akutan, with grants supplied by AEA (a continuation of a previous grant) and the U.S. Department of Energy (DOE). As described in the Statement of Project Objectives (SOPO) developed for the DOE, the goals of the project are:

- Identify a drilling target and well site within the hot springs area of HSBV
- Construct drilling site improvements and establish a base camp
- Drill and test a resource confirmation well at the approved target location
- Assess the probability of producing commercial quality geothermal resources from production wells
- Prepare a bankable feasibility study to support development investment/financing

To achieve these goals, the well must be designed and drilled to intersect the resource at a depth that a flow test and/or injection test is possible for resource characterization. Economic limitations of the total funding available require that the well be drilled similar to the 2010 operation, in which all equipment and personnel are transported by helicopter, limiting the rig size and, therefore, capability. Depending on the selected rig and the well design, the likely maximum borehole size is 4”, drilled vertically to a depth of 1500 ft.

Site selection for the new well is based on data collected since 2009, including the data from the 2010 drilling campaign. Through reexamination of the data and reports, including reprocessing of the 2012 gravity survey data and building a 3D visualization in GOCAD software, the target sites were focused on the area close to the hot springs in lower HSBV and narrowed to several sites with generally equal merit. Site 1 is located 520 ft southwest of TG-2, Site 2 approximately 1200 ft northwest and upslope of TG-2 (Figure 1), and Site 3 about 2900 ft southwest of TG-2 in HSBV.

These sites were chosen based on the proximity to TG-2 and the known conditions there, logistical ease, intersection with the northwest striking faults that seem to concentrate the fluids in the hot spring area, thickness and character of the low resistivity cap in the area, and the northwest striking density change that implies geologic structure. During the process of site selection, many possible locations were considered and eliminated based on logistical considerations, technical constraints, or scientific unknowns that would increase the risk of not achieving the goals of the project.

A successful project would be an exploration well drilled into a permeable structure in the HSBV area that would sustain flow and meet or exceed the estimates made from TG-2 flow characteristics. The estimated liquid flow from TG-2 was 50 gpm, but the steam flow could not be estimated and the test duration was only a few hours. Using these rudimentary measurements from TG-2, a pumped production well at the same location might produce 465 to 820 gallons per minute, implying a potential of **between 1.3 and 2.3 MW_g of power generation.**

Introduction

Previous exploration summary

The current exploration of the HSBV geothermal resource began in 2009 with preliminary geological, geochemical and geophysical surveys of the project area. These data were used to create an initial conceptual model for the HSBV system that described upflow located beneath the fumarole field west and above the HSBV, and a shallow tabular outflow that comes to surface at the hot springs area in the lower valley (Figure 3). This conceptual model was used to inform site selection for the second stage, which included thermal gradient well drilling. Initially, four drill sites were targeted, two of which were drilled in 2010. These wells were intended to measure the thermal and geologic structure of the shallow tabular outflow depicted in the conceptual model in two different locations: where the outflow reaches the surface at the lower HSBV hot springs (TG-2) and the southwest lateral margin of the outflow sheet (TG-4).

TG-2 revealed high temperatures and shallow permeability, but was determined to be insufficient for development of 10 MW net power generation considered at the time to be required for viable project economics. Thus, attention was turned to the potential of the hypothesized upflow area, and additional exploration was conducted to cover the western part of the field and the fumarole area.

In 2012, new structural and alteration mapping was conducted, as were an extended magnetotelluric (MT) study and a gravity survey. No additional chemical sampling was done by the City team, but a USGS group sampled the hot springs in 2012 and a publication of their findings was released early in 2014 (Bergfeld et al., 2014). Following these studies, extensive research and planning was conducted for potential drilling from a site above the fumarole area to target the upflow of the resource. Late in 2013, it was determined that any near term potential development of geothermal resources on Akutan would have to come from the valley area because the price per unit of power for development in the fumarole area was much too high to attract the private investment needed to continue the project.

The City team believes that the valley area surrounding TG-2 could have the potential to sustain 2 to 5 MW, and intends to confirm this with a third exploration well drilled in that area. The DOE grant, combined with the remaining funds supplied by the AEA, will allow for the drilling of this additional well.

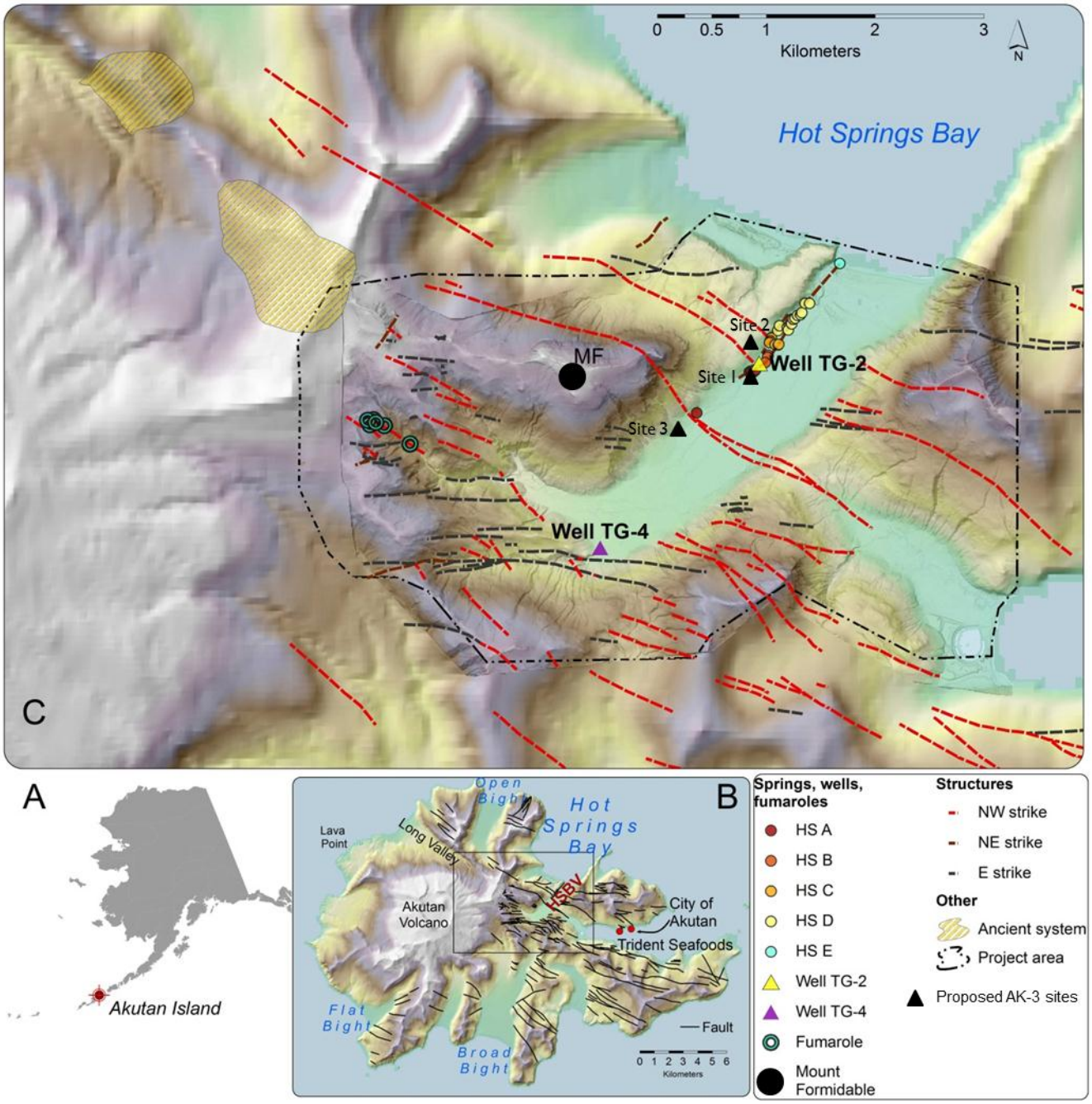

Figure 1: Location map of Akutan Island, Alaska, showing the locations of HSBV, previous thermal gradient drilling, and surface features of the geothermal system. Hot springs locations in HSBV are color coded according to the groups established by Motyka (1981) and affirmed by Bergfeld (2014). (A) Location of Akutan within Alaska. (B) Akutan Island, with the City of Akutan and Trident Seafoods fish processing facility, Hot Springs Bay Valley (HSBV) and Long Valley identified as well as island-wide structures (black lines = fault traces). Black rectangle indicates extent of HSBV focus map (C). (C) Geothermal surface features and structures of HSBV (see legend). MF refers to Mount Formidable; structures are symbolized by dominant strike orientation. This is Figure 1 from *Exploration of the Hot Springs Bay Valley (HSBV) Geothermal Resource Area, Akutan, Alaska* by Stelling et al. (submitted to Geothermics, 2014).

TG-2 Drilling Results

Two thermal gradient holes were cored in 2010 (Figure 1). TG-2 was drilled to 833 ft (254 m) near the hot springs, and TG-4 was drilled to 1500 ft (457 m) in the upper part of the HSBV. Both were abandoned in 2013. TG-4 showed no signs of permeability and, though it had a maximum static temperature of 327°F (164°C), appears to be outside of the shallow reservoir area[1]. TG-2, on the other hand, was hot at a very shallow depth, and encountered a flow zone at about 590 ft (180 m) that hampered drilling until the well was terminated at 833 ft (254 m).

Temperature profiles were collected from TG-2 immediately after drilling, and an thermally equilibrated survey was done nine months after drilling was completed. The temperature profiles for TG-2 are shown in Figure 2, along with the lithology and occurrence of alteration minerals. The maximum measured flowing temperature in TG-2 was 359.6°F (182°C) at 585 ft (178 m). The flowing temperature measured was much hotter than the equilibrium temperature at that same depth of (338 °F (170 °C)), indicating that the hotter water was being drawn in from a nearby source. A new well in this area will target the source of these fluids, presumably fluid running along a structure. One theory is that the flow zone encountered in in TG-2 at 590 ft is lithologically controlled, perhaps a sub-horizontal contact between volcanic lithologies. It is likely that, somewhere near TG-2, this horizon intersects a westward dipping structure carrying the hot fluid. When the well was flowing, the hotter fluids carried in the structure came along the lithologic boundary into the well (Kolker, 2012)[2]. Subsequent to drilling, the existence of the westward dipping structures in the area of the hot springs has been substantiated by field mapping and structural analysis[3].

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[1] The reader is advised to review the published paper that discusses the drilling results: Kolker, A., Bailey, A., Howard, W., 2011. *The 2010 Akutan Exploratory Drilling Program: Preliminary Findings*. Geothermal Resource Council Transactions Vol. 35, 6pp.

[2] This is further explained in Kolker, A., P. Stelling, W. Cumming, and D. Rohrs (2012). *Exploration of the Akutan Geothermal Resource Area*. Proceedings, Thirty-Seventh Workshop on Geothermal Reservoir Engineering. Stanford, CA: Stanford University, 2012. p. 1234-1243.

[3] The report by Hinz and Dering (2012), gives an excellent review of Akutan geology, regional and island geologic structure and the tectonics that effect the geothermal system.

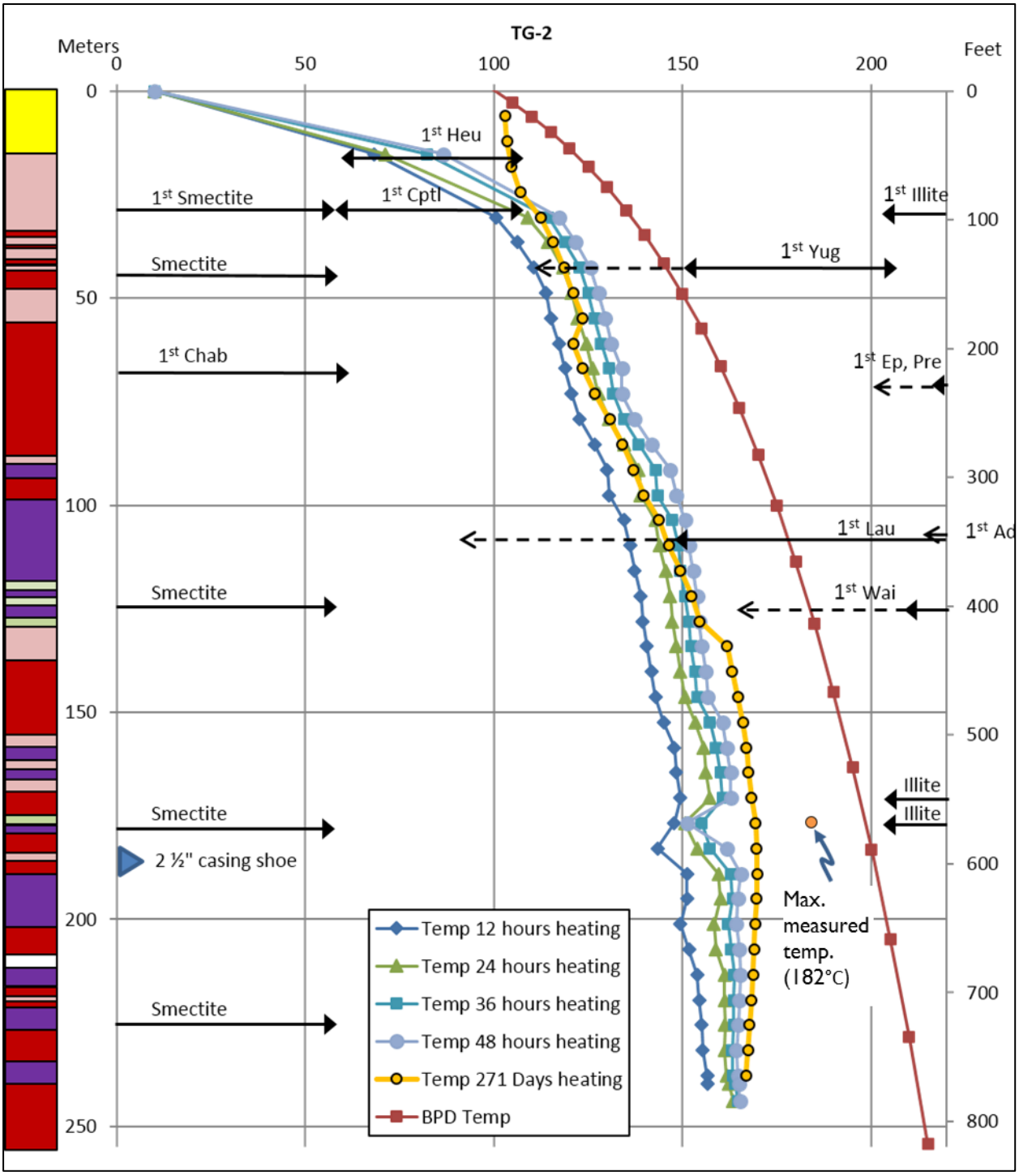

Figure 2: Well profile data from thermal TG-2, including end-of-drilling temperatures, equilibrated temperatures, lithologic column, occurrences of smectite clay identified during core analysis, and shallowest occurrence of important secondary minerals. Figure from Kolker et al. (2012).

Conceptual Model of the Akutan Geothermal Resource

The original conceptual model for the HSBV system included upflow located near the fumarole region at the head of the valley, and a shallow tabular lateral outflow following either the main valley trend of HSBV or the area underlying Mount Formidable, that ultimately reaches the surface at the lower hot springs area (Kolker, 2012[4]). Additional geologic and geophysical investigations in 2012 support and refine this model, favoring the outflow path generally parallel to the main valley trend, based on the patterns seen in MT modeling and further modeling of the gravity data collected in 2012[5]. The heat source for the system is associated with a resistive body revealed in the 2012 MT modeling effort underneath the fumarole area[6]. In the resistivity pattern the upflow appears to split at depth, with a portion of the geothermal fluid discharging sub-vertically to the fumarole field in upper HSBV, and another portion flowing laterally beneath the surface, with the outflow path likely structurally controlled based on the resistivity patterns (Figure 3). The deep movement of the flow would explain the lack of surface alteration observed in the region between the fumaroles and the hot springs.

In both the fumarole field and hot springs region, near-surface permeability appears to be largely controlled by the intersection of tectonic fabrics. In the hot springs area, resistivity patterns show conductive layers parallel to the trend of lower HSBV, with the greatest conductivity occurring downstream of the intersection of the northwest wall of HSBV and the NW-trending cross-valley fault.

The upflow region (beneath the fumaroles) is more likely to have higher temperatures (as high as 527°F or >275°C) and to have greater near-surface permeability than the hot springs area, but physical access to the upflow region with drilling and other equipment is substantially more challenging. The lower hot springs region is likely to contain a high temperature (around 320-356°F or 160-180°C) resource hosted by localized fracture flow that ultimately feeds the hot springs. A study of changes in heat flow from the hot springs region between 1981 and 2012 indicates that the lower HSBV hot springs have nearly doubled and heat flow has increased by an order of magnitude during this period, suggesting that the lower HSBV geothermal system is in a waxing phase (Bergfeld et al., 2014[7]).

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[4] This paper also reviews the two original scenarios (CM1 and CM2) of the flow path from the fumarole area to the hot springs. This part of the model has been refined with additional data and reviewed for selection of valley drill targets.

[5] Please review Mira Geoscience, 2014. *Rock Density and Gravity Data Analysis, 3D Geoscience Data Integration, and Interpretation at the Akutan Island Geothermal Project, Alaska*. Unpublished report to Geothermal Resource Group pages 17-28 for further explanation.

[6] This is discussed further in Ohren, M., Bailey, A., Hinz, N., Oppliger, G., Hernandez, J., Rickard, W., Dering, G., 2013. *Akutan Geothermal Area Exploration Results and Pre-Drilling Resource Model*, Geothermal Resource Council Transactions Vol. 37, 7pp.

[7] Though this paper does not review the chemical data gathered by the City project (Bergfeld et al., 2014), it is a succinct review of the fumarole and hot spring chemistry data that characterizes the geothermal resource chemistry.

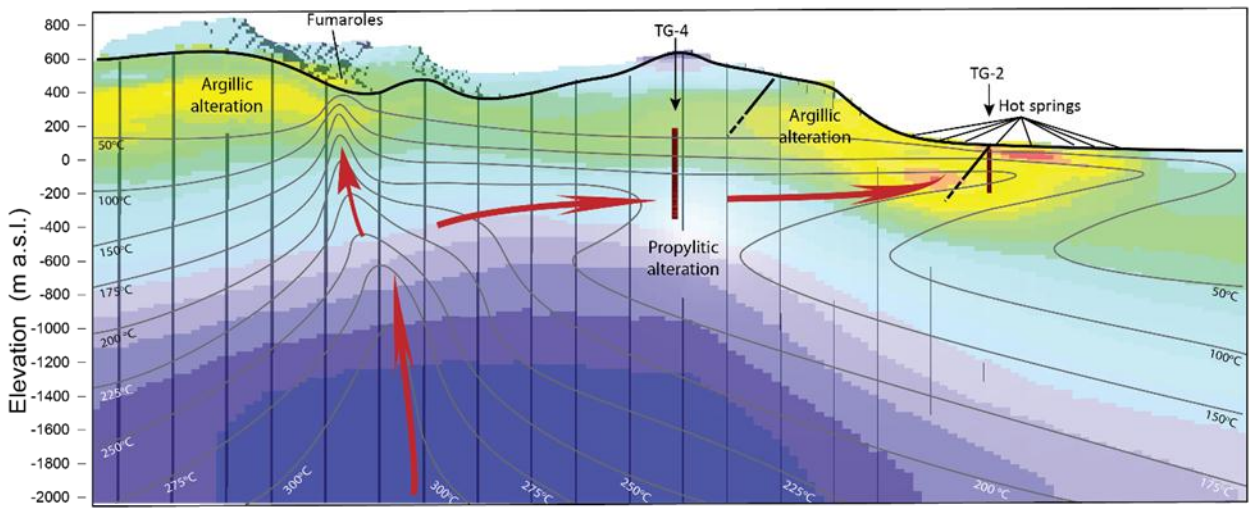

Figure 3: Southwest-northeast cross section view across a profile line connecting the fumaroles and hot springs. Isotherm contours (black lines) based on downhole temperature data, chemical geothermometry, hot springs and fumarole locations, and MT resistivity data. This is Figure 9C from *Exploration of the Hot Springs Bay Valley (HSBV) Geothermal Resource Area, Akutan, Alaska* by Stelling et al. (submitted to Geothermics, 2014).

Fluid and Gas Geochemistry of the Akutan Geothermal Area

Previously published chemical data from hot springs, meteoric water and fumarole gases has been combined by Dr. Pete Stelling of Western Washington University with data from three water samples collected from TG-2 and TG-4. For reference, the results of the chemical analyses and the Powell and Cumming geothermometry calculations for those samples are shown in Tables 3 and 4 respectively at the end of this document. Two samples were collected at TG-2 when it was flowing from approximately 585 ft (178 m) depth and one from the bottom of the well at 833 ft (254 m). TG-4 was airlifted to bring the sample to surface, and it was contaminated with drilling fluids. The shallower TG-2 sample was the least contaminated of the three well samples. Dr. Stelling has submitted his observations as a part of a publication in Geothermics, which is currently under review. Some of that analysis is presented below.

All of the chemical data shows that the hot springs area hosts neutral-chloride brine. The dominant anion in the Akutan waters is Cl^-, which suggests a relatively well-developed geothermal system. The samples from the wells and hot springs are slightly elevated in HCO_3^- and SO_4^{2-}, indicating either equilibration at moderate reservoir temperatures or dilution through mixing with near-surface waters enriched in HCO_3^- and SO_4^{2-}. Chloride concentrations are significantly lower in hot springs samples than in the TG-2 well discharge sample, indicating strong near-surface dilution by meteoric water.

Cation concentrations in Akutan liquids show a linear trend between the sample from TG-2 and snow/meteoric water, further supporting significant near-surface mixing of hydrothermal and meteoric water. As seen in Figure 4, the water sampled in the A springs[8] appear to be more mature than the B or

[8] The spring locations appear to migrate over time, as they are seeps into cold streams, for the most part. The springs are therefore grouped and assigned a GPS location that may or may not change upon the return of an investigator. Bergfeld (2014) and Motyka (1988) combat this by dividing the springs into general groupings by

C springs, lending more weight to selection of a drilling target near TG-2 (Site 1 in Figure 5). Although the deeper sample from TG-2 (254 m) is somewhat contaminated from drilling fluids, the very low Mg^{2+} concentration in that sample, potentially indicative of geothermal fluids, suggests that even the uncontaminated sample from TG-2 (178 m) may be partially mixed with meteoric water. This interpretation suggests that the actual reservoir conditions are likely to be more equilibrated than any sample collected to date, and that the reservoir is relatively mature (Stelling et al., 2014). New fumarole gas and condensate data collected in 2010 and presented by Bergfeld, support the initial chemical interpretation of a hotter, neutral-chloride upflow that possibly feeds a shallow, cooler, neutral outflow at the hot springs.

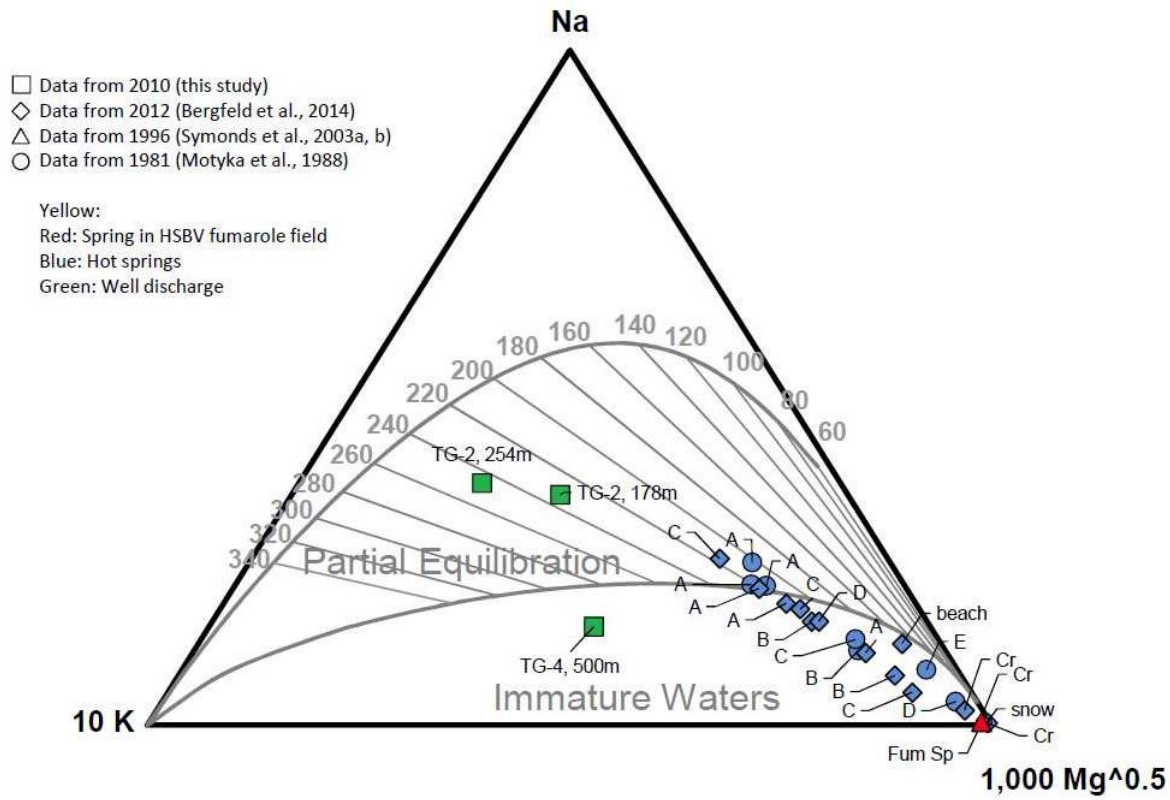

Figure 4: Na-K-Mg plot for Akutan hot springs and well discharge samples. Letters A-E refer to hot spring groups (see Figure 1); Fum Sp=spring in HSBV fumarole field; Cr=creek above hot springs. Varying extent of partial equilibration for all samples suggests dilution along the flow path. Extrapolation from hot springs lineaments and the discharge from TG-2: 178m indicate deep reservoir temperatures of at least 220-240 °C. Geothermometry of the deeper sample from TG-2 and the sample from TG-4 should be discounted due to contamination with drilling fluids. Plot made using program from Powell and Cumming, 2010. This is Figure 4 from *Exploration of the Hot Springs Bay Valley (HSBV) Geothermal Resource Area, Akutan, Alaska* by Stelling et al. (submitted to Geothermics, 2014).

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locations along the stream, from upstream A to downstream E. These are color-coded in Figure 1 and labeled with letters A-D in Figure 5. TG-2 sits at about the division line between the A grouping and the B grouping.

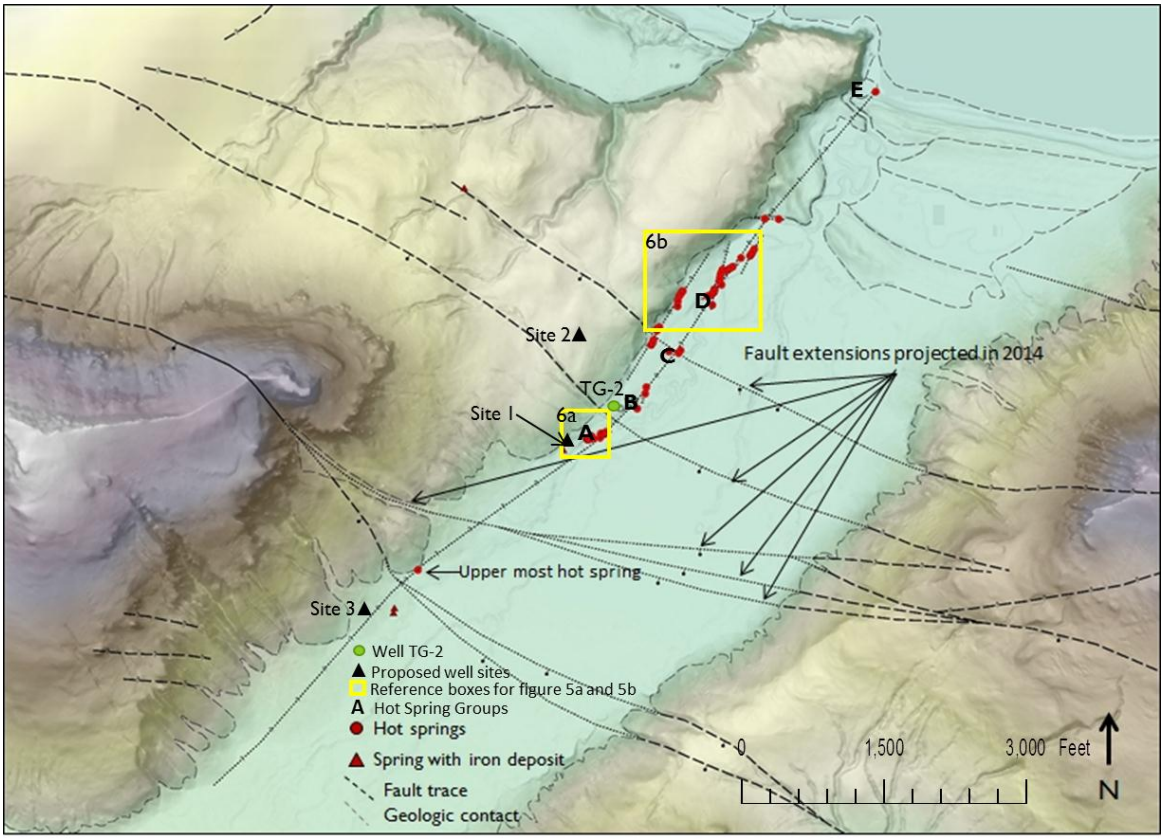

Figure 5: Lower Hot Springs Bay Valley, showing the three proposed drilling sites, and mapped faults. Topography background from USGS DEM. Faults and spring sites mapped by Hinz and Dering 2012, updated 2014.

Fault Targeting

The flow path of fluids from the upflow zone under the fumarole area, above HSBV, to the outflow area at the hot springs is not well understood. However, evidence from the geophysical model, and the occurrence of surface manifestations, suggests that it does not follow along the valley from head to toe along a stratigraphic unit but, instead, is structurally controlled. In a recent modification to the 2012 geologic map completed by Hinz et al. for the City of Akutan, the probably northwest-southeast trending fault splays across the main southwest-northeast trending fault are projected to connect with fault exposures on the south side of the valley (Figure 5). Recently, with the renewed focus on the lower HSBV, Hinz reviewed and reevaluated the 2012 work and provided additional findings regarding the lower part of the valley.

The hot springs in lower HSBV align with multiple structures and structural intersections. The location of these spring clusters may represent the most pervasive near-surface fracture systems in the area that allow fluid to escape through the reservoir cap to the surface. In selecting a target for drilling, the most important aspect will be to intersect the permeable faults and fractures at depth beneath the reservoir cap. The surface features help to determine the orientations of the minimum and maximum stress in the tectonic regime and the sense of movement on faults. Figures 6a and 6b show views of the hot spring area and the intersecting features described by Hinz (2014).

Two trends can be seen in the gravity data, which was collected in 2012 and reinterpreted in 2014[9]. Figure 7 shows the first vertical derivative of the complete Bouguer gravity map, with interpretive traces showing where density changes occur. The traces show a northwest trend and an intersecting southwest trend, as suggested by Hinz. The northwest striking faults mapped by Hinz et al. (2012) and confirmed by the gravity data are interpreted to focus the flow of fluid into the valley where there is a pathway to the surface, leading to the occurrence of the hot springs.

The dip on the northwest striking faults is thought to be between 60° and 70°, based on a parallel fault located southwest of the hot spring area. Figure 8 shows this cross-valley fault exposed on the southeast side of the valley with a measured dip of 62° to the southwest. The dip on normal faults often changes along strike, so 60° is a valid assumption, though it likely varies from 58° to 70°.

The United States Geological Survey (USGS) and the Alaska Volcano Observatory (AVO) maintain a seismic network on Akutan Island that was supplemented in the summer of 2012 with an array of 16 additional seismometers in the vicinity of HSBV, with a goal of collecting seismic data that could be used in the future to compare with data collected after geothermal production begins. Microseismic data has proven valuable for locating faults, determining fault orientations, and stress state for many applications, including geothermal exploration. Active seismicity on one of the mapped northwest striking faults that cross HSBV would be a good indicator of an open fracture, which would be an attractive drilling target. The existing array is too widely spaced to be of use for targeting particular faults. The additional 16 stations collected in the valley area may contain useful data, but the 2012 data is unreleased and unprocessed at this time.

[9] For a full description of the reinterpretation of the gravity data please see Mira Geoscience , Rock Density and Gravity Data Analysis, 3D Geoscience Data Integration, and Interpretation at the Akutan Island Geothermal Project, Alaska (2014).

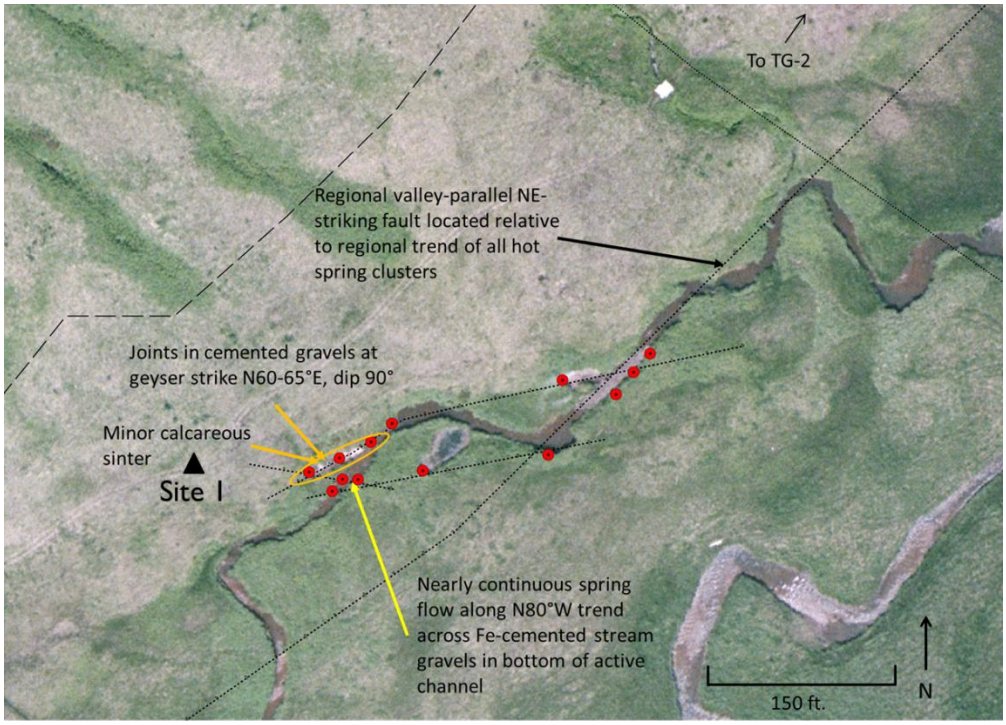

Figure 6a: Structural features revealed in the upper hot spring area (A springs). Figure courtesy Nick Hinz, 2014. Image contracted by City of Akutan, 2010.

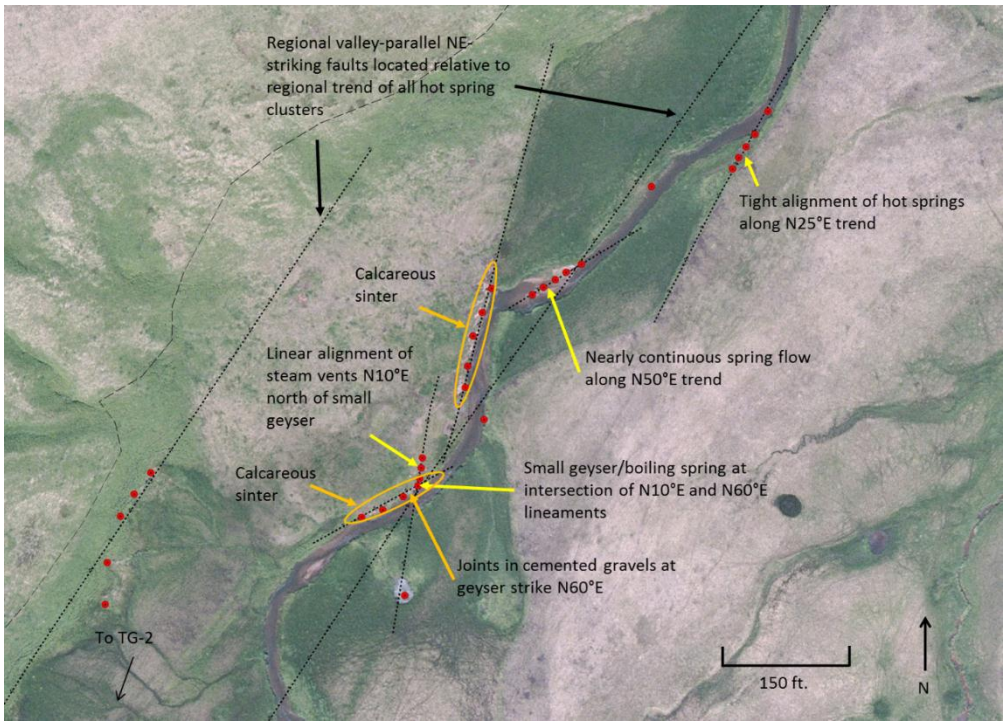

Figure 6b: Structural features revealed in the lower hot spring area (B and C springs). Figure courtesy Nick Hinz, 2014. Image contracted by City of Akutan, 2010.

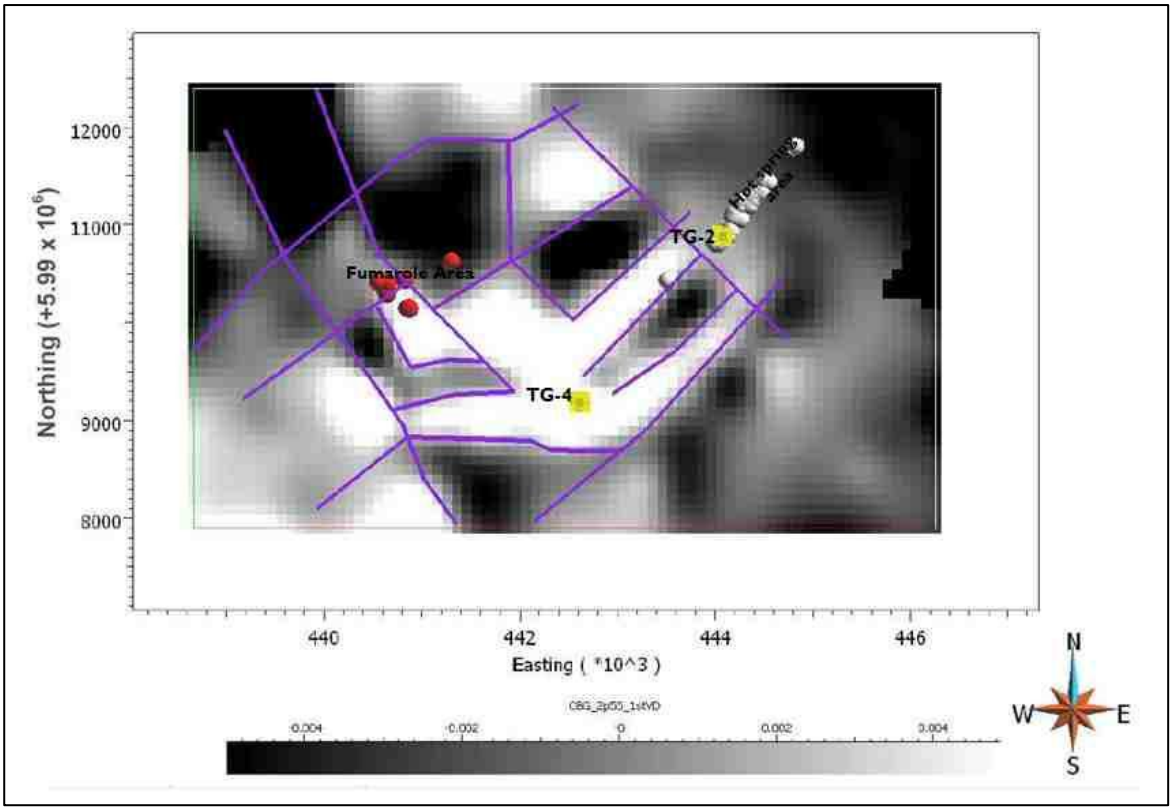

Figure 7: First vertical derivative of the complete Bouguer gravity map referenced to a terrain correction density of 2.55 g/cm^3 with overlain interpretation lines (purple). Units on the grey scale are mGal/m. Fumaroles (red spheres), hot springs (white spheres), and the two TG wells (yellow symbols) are also shown. Gravity map and interpretation by Mira Geoscience.

Figure 8: Fault trace of mapped cross-valley fault, vantage from northwest along strike. Measured strike and dip on fault splays is 62°SE.

Resistivity Model

A resistivity model of the HSBV extending west under the fumarole area was created in 2009 and revised with new data in 2012. Based on this model, resistivity values have been assigned to characterize different levels of the geothermal resource. Table 1 identifies these layers and their interpretation.

Table 1: Resistivity layers in model created from MT data collected in 2010 and 2012.

Layer Name	Resistivity Value	Interpretation
Conductive	<30 ohm-m	Clay cap/altered rock
Intermediate resistivity	40<100 ohm-m	Potential reservoir
High resistivity	>160 ohm-m	Basement rock

The conductive layer (defined here as resistivity values ≤30 ohm-m) varies in thickness, averaging 820 ft, with a maximum thickness of about 1640 feet. This layer extends to encompass the majority of the highlands portion of the field area. The top of this conductive layer reaches the surface in the area surrounding the fumaroles, which would be expected given the intensity of alteration in the exposed rock. The low resistivity layer is also exposed in the northeastern part of the field, and in the hot springs area toward the mouth of HSBV. The conductive layer is likely indicative of a shallow aquifer circulating close to the surface, as evidenced by the presence of the hot springs. The potential well targets intersect the mid-range resistivity layer, which is expected to be the host of the geothermal reservoir.

Potential Drill Site 1

The potential Site 1 (Figure 9) is considered based on the proximity to TG-2 and the known conditions there, logistical ease, intersection with the northwest striking faults that may transmit the fluids to the hot spring area, thickness and character of the low resistivity cap in the area, and the northwest striking density change that implies attractive geologic structures.

Based on an assumed dip of between 60° and 70°, a surface location offset 300 ft to 500 ft from the surface trace of the fault would allow intersection with the fault at the desired depth, greater than 600 ft and less than 1500 ft. Table 2 shows the approximate depth to the fault at depth and measured distances from the fault trace, using the assumed dips to the southwest. The proposed site is 450 ft northwest of the closest northwest-trending fault trace. The well would intersect the fault between 700 ft and 1100 ft. Figures 10a and 10b show a cross section perpendicular to the trace of the faults, with the fault projected with a 60° dip down to 1500 ft, which is the maximum depth of the planned well.

Site 1 is located on dry ground at the edge of HSBV. Operationally, it will be very similar to the drilling of TG-2. The surrounding wetland areas will require that the site be restricted as to where equipment and personnel are set down, but there is enough dry area to perform all the necessary operations. Water can be easily obtained for the drilling operation from the creeks of HSBV.

Table 2: Examples of depth to fault from map distances spread from surface location.

Dip (degrees)	Distance (ft)	Depth to Fault (ft)
60	400	693
60	500	866
60	600	1039
70	400	1099
70	500	1374
70	600	1648

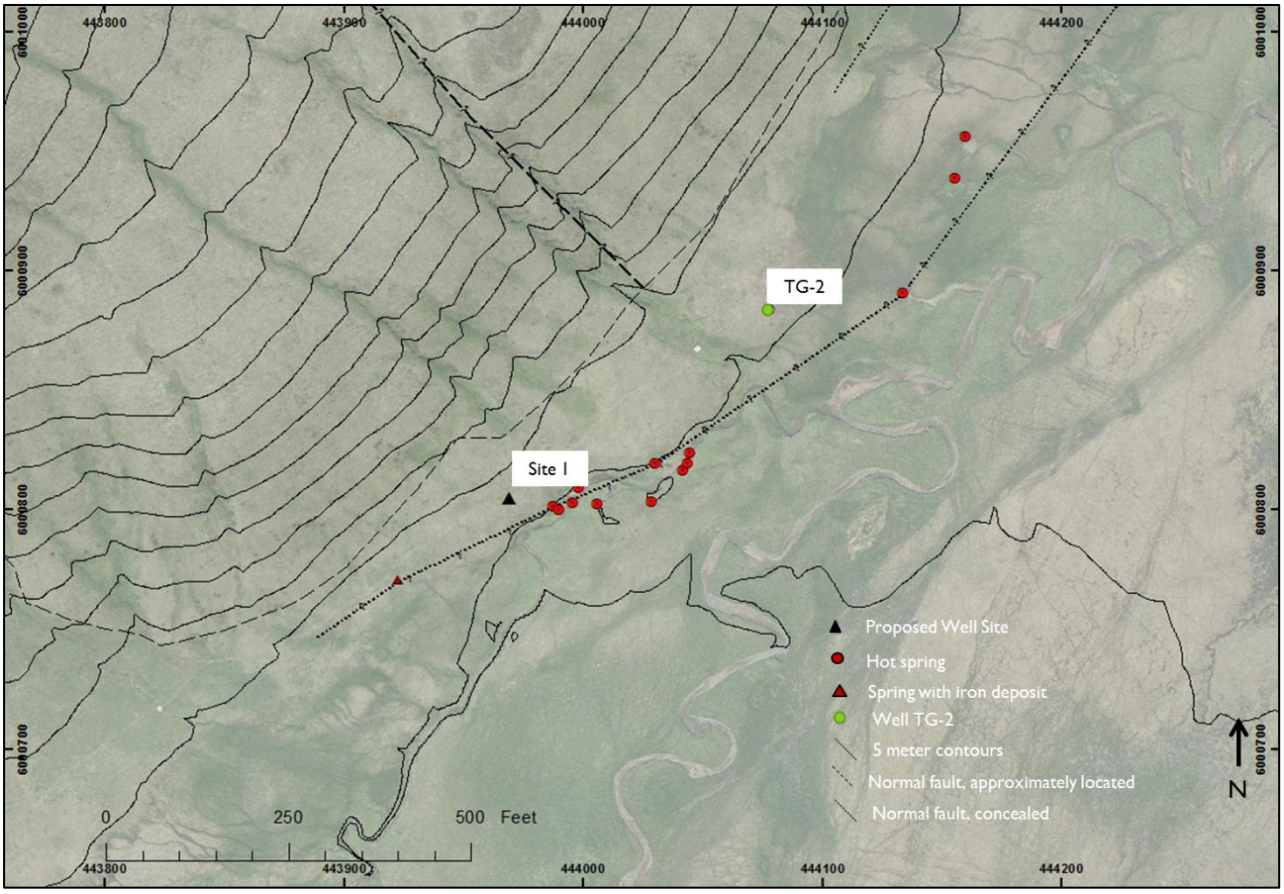

Figure 9: Potential Site 1, approximate UTMm WGS84 Zone 3 coordinates: 443969 E 6000805 N.

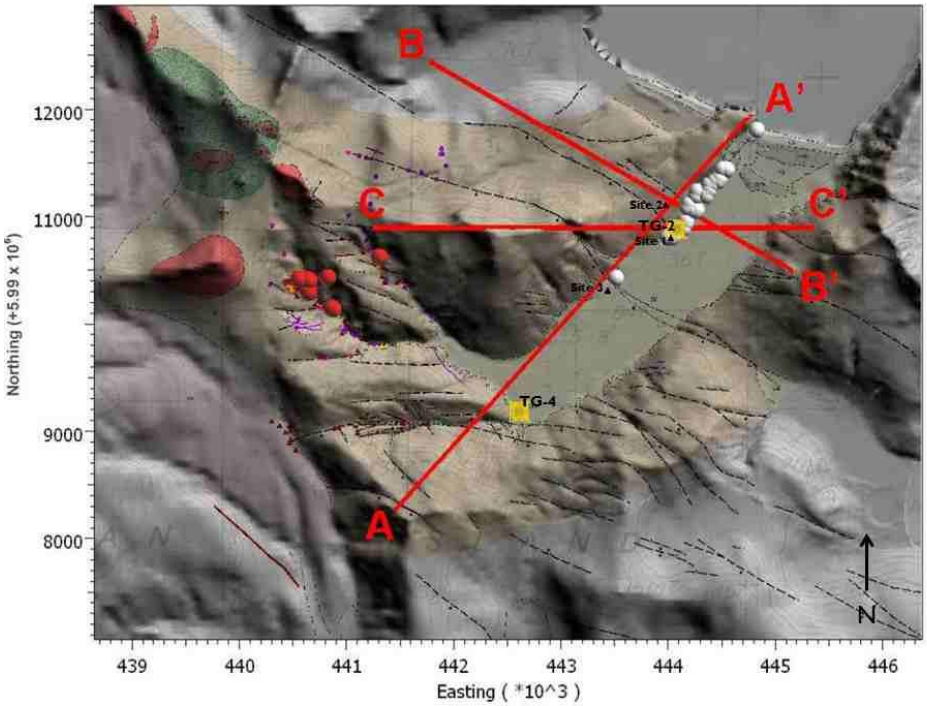

Figure 10a: Geologic map of project area (Hinz and Dering, 2012) showing location of cross section A-A' displayed in Figure 10b. Fumaroles are red spheres, hot springs are white spheres, TG wells are yellow squares, and proposed sites are black triangles.

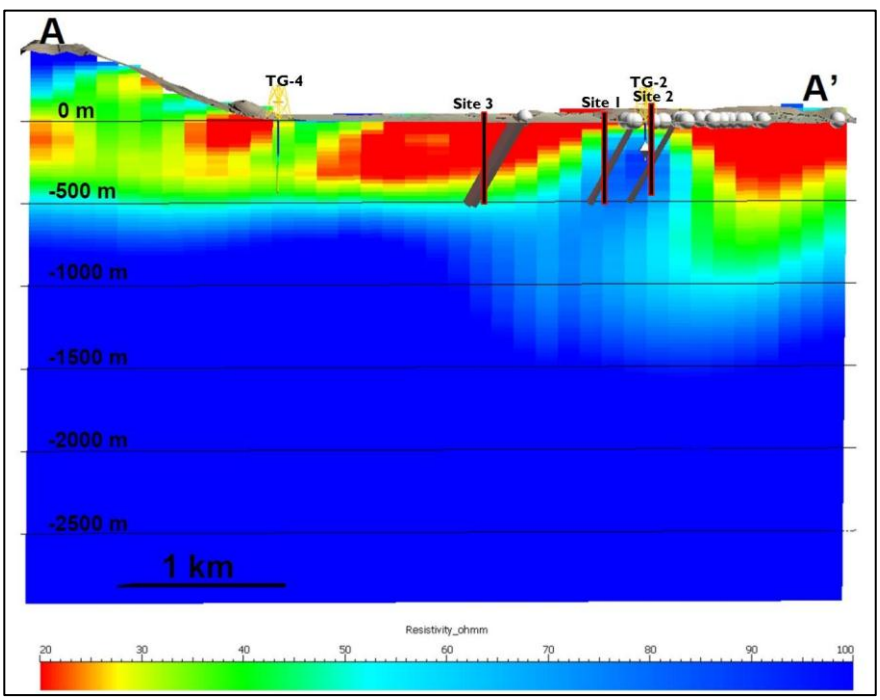

Figure 10b: Cross section A-A' showing mapped faults with 60° dip projected to depth of 1500 ft into resistivity model as grey surfaces. The color bar displays resistivity in ohm-m. Thin horizontal black lines represent depth below sea level. Bottom of the resistivity model is 2925 m below sea level. Total width of resistivity model shown here is 5 km. TG-2 was drilled into

zone of moderate (~70 ohm-m) resistivity; the three suggested well sites will also penetrate this area and are shown as black bars projected onto the section.

Potential Drill Site 2

Potential Site 2 (Figure 11) is considered due to the proximity to TG-2 and the known conditions there, the northwest striking fault set, and the character of the resistivity signature at an accessible depth. Site 2 is offset from the mapped fault about 450 ft at the surface and would be expected to penetrate the fault between 700 ft and 1100 ft depth. The site is located about 175 ft above the valley floor on a relatively flat bench and, therefore, would not be subject to the marshy conditions found in the valley and thus is more attractive for setting up a drilling operation. The supporting helicopter would have plenty of dry ground to lay down equipment and deliver personnel. Site 2 may be somewhat more susceptible to wind than a valley location, and water would have to be brought uphill to the site.

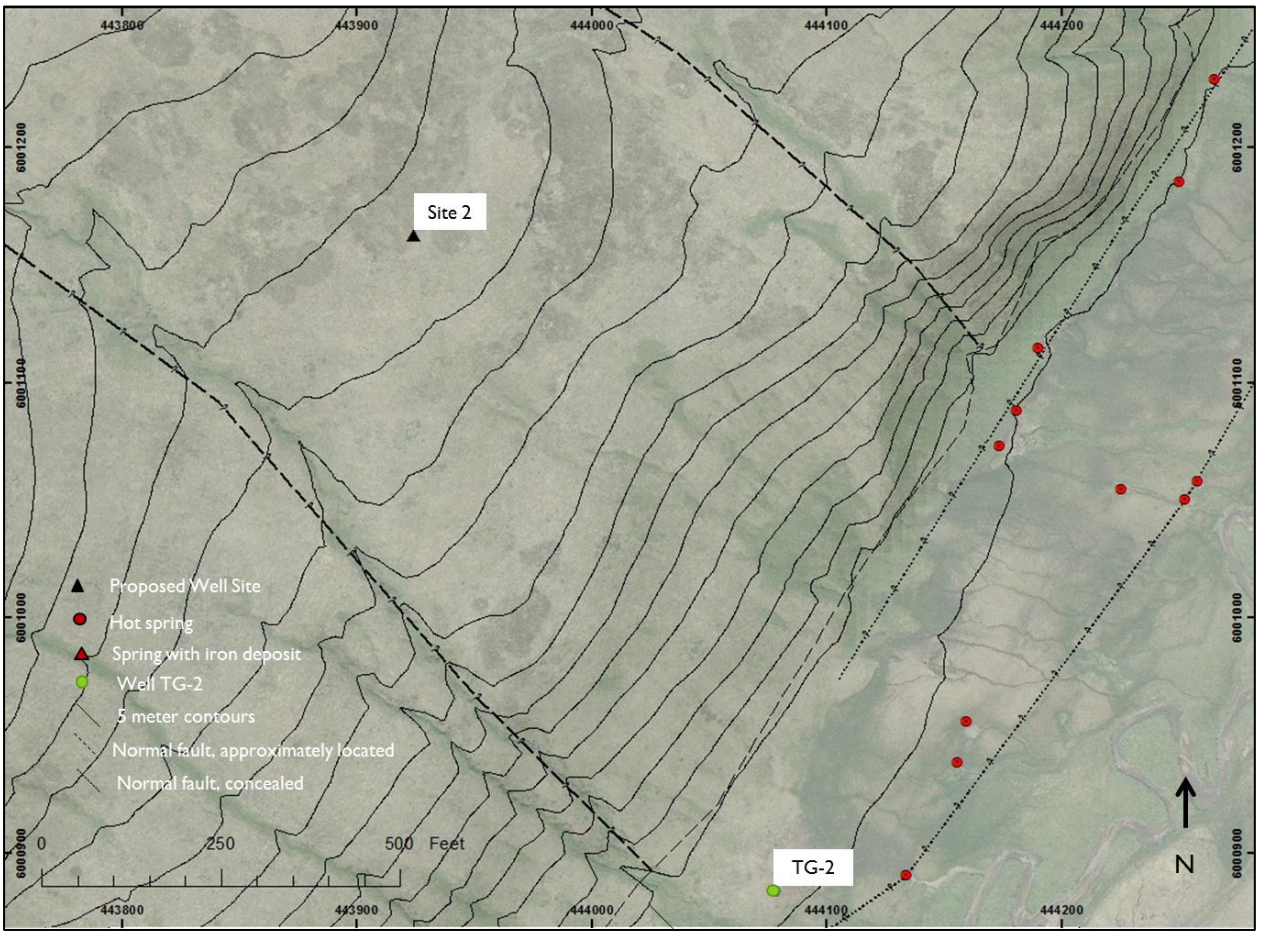

Figure 11: Potential Site 2, approximate UTMm WGS84 Zone 3 coordinates: 443926 E, 6001160 N.

Potential Drill Site 3

The potential Site 3 (Figure 12) is suggested based on its proximity to the prominent cross-valley fault, the character of the resistivity signature at an accessible depth, and the lateral distance from TG-2.

Site 3 is offset from the cross-valley fault approximately 450 ft. The target fault is a prominent feature, but it is unknown whether it is a fluid conductor or a barrier to flow. The uppermost hot spring and deposition of iron from nearby springs are the only indicators at the surface of geothermal circulation in the area.

Site 3 is located in the valley in an area on dry ground where drilling operations can be carried out. Water for drilling operations would be easily brought to the site from the nearby creek. The current data does not fully characterize Site 3, which was initially an attractive target because of the location of the NW dipping cross-valley fault. But further review of the other data was not able to substantiate the viability of Site 3 as a target. The uppermost hot spring is located close, but is up-dip, to the most prominent fault mapped near HSBV. This fault has been identified as likely playing a part in the flow of geothermal fluids, but it may be acting as a flow barrier. As soon as possible, a sample from this spring will be collected and analyzed. If the analytical results suggest these fluids are produced from a more chemically mature, hotter reservoir, then Site 3 would become a more viable drilling target for an exploratory hole as the project continues. The low-resistivity, clay cap/altered rock is thicker at Site 3 than at Site 1 or Site 2. The MT models indicate that a 1500' drill hole may not get through this altered zone into the resistivity layer that is more indicative of a geothermal reservoir.

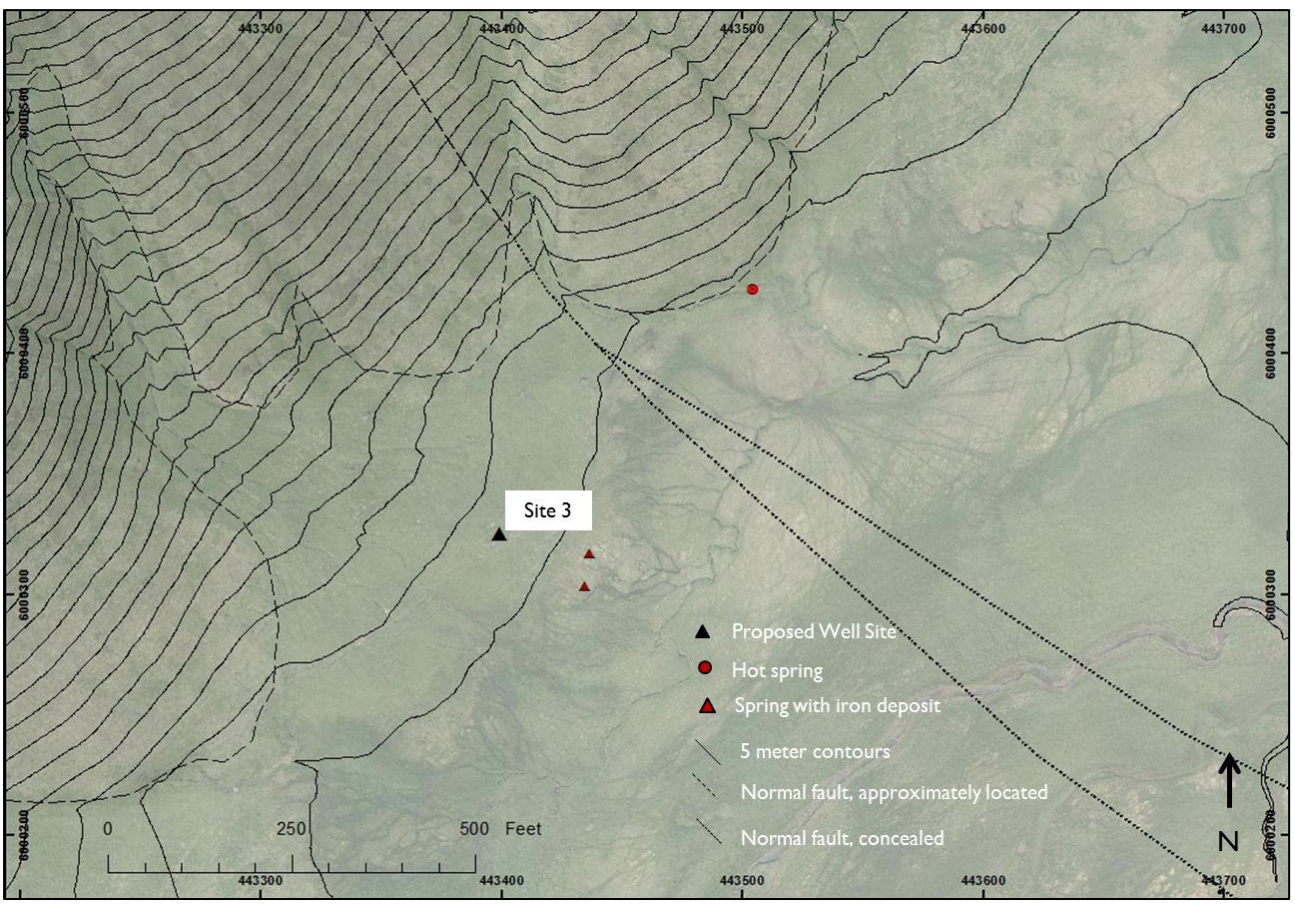

Figure 12: Potential Site 3, approximate UTM WGS84 Zone 3 coordinates: 443399 E, 6000325 N.

Conclusion

A well, tentatively designated AK-3, will be drilled to a maximum of depth 1500 ft in the area of HSBV to confirm an exploitable geothermal resource. The importance of the selected location of this well cannot be understated. The results of this well may be the last opportunity for the project to move forward by proving the existence of the resource. After an initial data review eliminated many drilling targets, three sites were given further consideration based on the existing data.

Site 3 is eliminated because there is not enough definitive information to determine if the well is likely to be successful. The MT signature in this area is attractive, but the 2009 and the 2012 MT models indicate that a 1500' drill hole may not penetrate the reservoir at this location. It is also possible that the MT signature is not related to the current geothermal system, and there is not enough additional data available to indicate that the cross-valley fault is a permeable feature that would be a viable target for drilling. Depending on the results of any additional data gathered, Site 3 will remain as a target for future drilling after the completion of AK-3.

The two remaining sites have nearly equal scientific merit, and both could be expected to yield results that are equal or better than that of TG-2. However, Site 2 is eliminated due to more difficult water access. It would likely be more expensive to drill on the hillside and water pumping for drilling could become a problem. In addition, all other things being equal, the lower elevation of Site 1 would mean that due to hydraulic principles the reservoir level would be closer to the surface and would likely flow more easily than from Site 2.

Site 1, therefore, is selected as the preferred site for exploration well AK-3. A drill hole at Site 1 has a good likelihood of providing the information needed to make a decision to either move the geothermal development project forward or suspend the project. The depth at which permeable and productive structures will be encountered cannot be predicted with certainty due to the relatively young volcanic overburden and vegetation, but the approximate location of the underlying structures is identified with significantly greater confidence by examination of geologic and geophysical evidence at a slightly larger scale.

The 2012 geologic mapping confirmed that the HSBV geothermal area is located where three distinct structural grains come together, yielding E-W, WNW, and NE-striking faults as can be seen in the 2012 geologic map. Fault slip data indicate N-S to NE-SW modern day extension direction which favors dilation on either the E-W or WNW-striking faults[10]. The NW trend and the lower valley NW striking faults that are the target of AK-3 is in evidence in the gravity data, in matching lineaments on the opposite side of the valley, and in the subtle topography and drainage pattern in that part of the valley and valley walls.

The likelihood is high that the well will confirm the presence of a developable resource. The project team has extensive experience on Akutan Island and understands the logistical, social, and economic drivers and limitations. The technical team consisting of Geothermal Resource Group and subcontractors has decades of experience in geothermal drilling and exploration, and has been involved

[10] This is further explained in pages 23-25 of Hinz and Dering, 2012.

in the Akutan project since 2009. Drilling a resource confirmation well is the next step in exploration and a key step in bringing the project to development.

Site 1 is likely to have similar characteristics to the drilling of TG-2[11]. Preparations for this drilling campaign will include planning for a shallow flow zone that needs to be sealed off in order to penetrate the reservoir at the predicted fault intersection depth. The proposed Site 1 also provides lateral separation from TG-2 and is a good location from which to test the reliability of the existing resistivity model and the characteristics of the northwest trending faults. Site 1 is located in an area mapped as "upland" by a wetland specialist in 2014, out of the marshy part of the valley on dry land. Another advantage to Site 1 is that if the reservoir level is at the same depth or deeper under the valley as it is under the upslope Site 2 topographic bench, well productivity would likely be higher at the Site 1 because there will be less head to overcome in order to flow to surface.

Upon approval of Site 1 as the preferred well location, a well prognosis, well design, and detailed drilling program will be prepared in order to secure a drilling permit. Preparation for drilling in HSBV will take many months of planning and it is vital that these plans are allowed to continue without delay if drilling is to take place in summer 2015. If further data becomes available prior to drilling, it will be analyzed and appropriate steps will be taken to ensure that the planned Site 1 well (AK-3) is as successful as possible.

[11] In preparation for drilling AK-3 and in light of the difficulties encountered in drilling TG-2, a series of observations ('lessons learned') about the drilling have been made so that problems can be avoided in the next well. The main way we are going to avoid drilling problems while drilling the slim hole is to use a more capable drilling rig, and equipment with better pumps and more water storage to control the well better. We are also taking a very close look at the casing setting depths and will most probably set both the surface and production casing a little deeper now that we have some accurate temperature information to use in the well design.

Table 3: Geochemical analyses of Akutan waters. Hot spring data are from Motyka and Nye (1988); well discharge and steam condensate samples were analyzed by Thermochem, Inc.

Sample Name	Type	Date	Classification	Temp °C	pH	Li	Na	K	Ca	Mg	SiO_2	B	Cl	F	SO_4	HCO_3
HS A3	Spring fluid	8/7/1980	Neutral Cl Brine	84	7	1.3	323	28	12	0.9	145	11	420	1.1	43	172
HS A3	Spring fluid	7/10/1981	Neutral Cl Brine	84	n.d.	1.2	328	26	12	1.0	135	12	410	0.9	41	nd
HS B1	Spring fluid	7/9/1981	Neutral Cl Brine	47.4	6.4	0.61	172	16	15	1.5	103	5.9	220	0.6	22	116
HS C4	Spring fluid	7/9/1981	Neutral Cl Brine	73.4	6.5	0.61	207	16	18	1.6	133	7	280	1.0	43	118
HS D2	Spring fluid	8/8/1980	Neutral Cl Brine	58.8	6.8	0.34	128	9.3	11	12	91	3.4	140	0.9	26	128
HS E	Spring fluid	7/12/1981	Neutral Cl Brine	67	7.3	1.1	1660	74	130	320	121	4.5	3440	0.5	495	161
Fum Sp	Spring fluid	7/9/1981	Acid Sulfate	92.3	2.6	0.01	17	3.5	32	13	220	-0.5	5.2	-0.1	1300	0
Fum Cond	Fumarole condensate	10/26/2010	Steam Condensate	100	6.79	nd	17	nd	nd	nd	nd	<.05	4.18	0.31	nd	nd
Fum Cond	Fumarole condensate	10/26/2010	Steam Condensate	99	3.07	nd	<.02	nd	nd	nd	nd	<.05	1.30	0.36	nd	nd
Fum Cond	Fumarole condensate	10/26/2010	Steam Condensate	99	2.92	nd	<.02	nd	nd	nd	nd	<.05	0.36	<.02	nd	nd
TG-2, 178m	Well discharge	8/2/2012	Neutral Cl Brine	182	6.72	1.7	693	69.1	15	0.4	219	50.4	1048	1.16	55	152
TG-2, 254m	Well discharge	8/8/2012	Neutral Cl Brine	171	7.95	2.0	876	103.8	292	0.3	314	26.6	1872	0.99	70	26
TG-4, 500m	Well discharge	8/24/2012	Neutral Cl Brine	163	8.11	0.7	420	114.9	2751	1.7	37	6.0	5745	0.70	32	22

nd = not determined

Table 4: Geothermometry results (°C) for Akutan hot springs and discharge waters. Calculations from spreadsheets by Powell and Cumming (2010).

Sample	Chalcedony (conductive)	Quartz (conductive)	Na-K-Ca	Na-K-Ca Mg corr	Na/K Fournier	Na/K Truesdell	Na/K Giggenbach	K/Mg Giggenbach
HS A3	135	159	189	148	205	173	221	127
HS A3	130	155	185	136	198	164	214	123
HS A3*	133	157	178	140	186	149	203	125
HS B1	112	139	179	97	211	180	227	103
HS C4	129	154	171	99	196	161	213	102
HS D2	105	132	164	-245	191	156	208	64
HS E	123	148	162	-349	156	114	175	74
Fum Sp	166	187	40	-103	288	281	297	42
TG-2-178	166	187	211	211	217	187	232	173
TG-2-254	197	214	196	196	232	207	246	198
TG-4-500	58	89	87	87	322	329	328	165
unreliable								

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