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Self-potential Observations and Techniques

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AMAX Exploration Inc. has been conducting self-potential surveys on virtually all of its geothermal properties since early 1977. Initially several contractors conducted the surveys, but during the past year we have fielded our own crew. Later I'll discuss the techniques that we have adopted, following examples of several of the more interesting surveys. All were performed using long dipoles (between 1.0 and 6.4km).

The Geysers, California:

The self-potential method came into prominence during later phases of our exploration on the Livermore Ranch north of Calistoga. An SP line was run along a road on the property crossing the Franciscan formation, which is the provenance for the Geysers steam to the northwest. A relatively negative response (-20mv) was observed over this unit, compared with the bounding serpentine and tuffs. A control line was then run along the Socrates Mine road right-of-way from Anderson Springs west to the Sonoma County line at the top of the Mayacmas Mtns crest, crossing the then-proven, but not yet producing, steam field. The region of steam production within the greywackes was generally negative (-25mv), and bounded on the west by a strong dipolar feature (250mv peak-to-peak) associated with a serpentine contact. The line could not be extended westward into the Big Sulphur Creek steam field at the time.

Animas (Lightning Dock, New Mexico):

Boiling water was discovered within 27m of the surface in wells drilled in the Animas Valley near Cotton City. Later geothermal investigations by AMAX and others have revealed a heatflow anomaly centered around the Hot Wells and extending more or less north-south. Geothermometers indicate a subsurface temperature of 160^{o} or higher. Gravity modelling along a line running roughly east-west through the wells, reveals a buried ridge of denser material than the surrounding valley fill, which extends to 1km depth on the west and 1/2km on the east. Cuttings from gradient holes reveal that rhyolite rises to within 30m of the surface in the vicinity of the wells.

The ridge has been deduced also from magnetics, and electrical surveys. Modelling of a telluric/MT profile over the wells, reveals buried aprons of conductive material, evidently associated with discharge of hot fluids along the slopes of the ridge. Heatflow holes drilled into the system intercept this aquifer of warm water at various depths below

30m. Wells penetrating deeper into the rhyolite encounter a zone of conductive heatflow beneath the aquifer. Seismic reflection profiles portray the structure of the ridge in considerable detail. In a profile 3.2km to the north of the hot wells, a considerable portion of the west limb of the ridge has been faulted. These faults are believed to provide the conduits for the ascending fluids.

A self-potential survey performed for AMAX by R. Corwin has mapped a number of near-surface dipolar features that appear to express loci of discharge. These fall on or near the crossover of a broader transition from negative on the east to positive on the west. The positive corresponds to the greater thickness of valley fill in that direction, so that the broad crossover may express the dipping west limb of the ridge.

McCoy, Nevada:

The McCoy geothermal prospect, 60km northwest of Austin, was discovered by logging of mineral holes in a Mercury district. It falls within the eastern edge of an incipient caldera at the juncture of three mountain ranges. A zone of negative SP values roughly outlines the thermal anomaly, which is in part the result of 100^{0} warm water aquifers at about 400-meter depth. A possible vertical conduit for this water is suggested in an east-west MT profile in the southern portion of the area (New Pass Range). Here a plume of electrically conductive material appears to issue from a larger conductive zone in a depth range of between 2 to 5km. In the first SP survey (by MGC) this "plume" appeared on the southernmost line as a 90mv negative anomaly. AMAX has subsequently extended this anomaly along 4 section lines to the south where the feature grew to -465mv. The locus of this maximum extends roughly parallel to the crest of the range and overlies an evident zone of P-wave delay and microearthquakes.

Profiles of the SP response and topography reveal a qualitative correlation that suggests that the latter plays a role in shaping the SP response. If the hydraulic gradient provides the generating mechanism, then we may look for similar correlations in nearby terrain of equal elevation. To the west, where SP lines cross over the spurs of McCoy Peak, the SP response actually turns positive with elevation; though the only evident geologic difference is an increased thickness of volcanics to the west.

The negative anomaly over the New Pass Range has not yet been tied to other properties. The several heatflow holes to the west reveal continuation of the thermal anomaly, and MT soundings indicate a conductive zone below several kilometers. The presence of high mercury values in the drill holes leads us to suspect that mineralization may be contributing to the self-potential response observed here.

Cove Fort, Utah:

The Cove Fort geothermal area is characterized by a relatively uniform SP response which we attribute to the presence of shallow conductive clays and hot water in the alluviated areas. An exception is the eminence known as Cinder Crater rising approximately 300m from the valley floor. A self-potential response of -70mv was observed during a survey by Terraphysics across the flanks of the basaltic cone; subsequently, AMAX ran a line over the summit, resulting in an anomaly of -170mv correlable with terrain ($\sim$-0.5mv/m).

Naturally the very porous nature of the material making up the crater leads one to deduce an electrokinetic origin for the observed effect. We have no knowledge of any successful heatflow holes drilled into the basalt that might confirm any thermoelectric component.

If, indeed, the hydraulic regime is the principal modus operandi, we would expect to measure a like relationship between terrain and SP response over a similar, though much older, vent such as Pavant Butte, 63km to the north. An SP line was run across its summit whose self-potential response was found to be only 5mv and positive relative to the base. At this point, I can only conclude that some property of Cinder Crater that differs dramatically from that of Pavant Butte is responsible for the SP negative response observed over the former.

Technique:

AMAX employs field techniques and equipment only slightly modified from recommendations by Corwin and Hoover. The basic equipment consists of Fluke and Data Precision 10MΩ meters, Tinker and Rasor sealed electrodes, and Sharpe reels and Mark Products 26 gauge cadmium-bronze wire. Primary reels are 3219m (or 2 miles) long, permitting one to tie to 3 section corners along the line. Secondary reels plug into the end of the primaries, provided tellurics and cattle permit. The wire changes color every hundred meters (10 colors per kilometer) according to the resistor color code, so that the operator can tell at a glance which centade he is in, eliminating the problem of station error due to sliding markers and peeling tape.

At a base, a flat-based electrode is implanted in a hole and covered by a reflecting board. Readings are taken after a 15-minute equilibration interval in three holes within a half-meter of the base-pot and at a common depth using a conical-base roving electrode, and averaged. If any reading exceeds the expected noise level of the line, the base is moved to a more uniform environment. Subsequent readings on the line are referred to these three satellites, rather than the base pot. Readings are made every 100 to 200 meters, or closer, depending on excursions of the data. At the end of the wire, a tripartite tie-point is read, to which the base electrode is later advanced for reading the next segment. While reeling in, even kilometer stations are reoccupied, and the tripartite base is reread to compute a drift correction. Lines are generally run on foot along section lines (1 mile apart) regardless of terrain. Landmarks are noted in the log and on the map. Roads are utilized as tie lines near the ends of cross-lines. The result is a uniformly profiled data set amenable to computer contouring and profiling.

Tellurics are monitored at a base location in the vicinity of the survey, using a custom designed Russtrak chart recorder.