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# Department of the Navy Geothermal Exploration on Naval Air Station Fallon (NASF) Managed Lands in Dixie Valley, Nevada

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## ABSTRACT

The Department of the Navy Geothermal Program Office (DON GPO) is currently engaged in geothermal exploration on Naval Air Station Fallon (NASF) Training Ranges (Fallon, NV) with a focus on discovering a geothermal resource is Southern Dixie and Fairview Valley's. Results of the drilling of 20 ( 500-foot deep) temperature gradient holes, and 125 2-meter (2M) temperature probes have validated data from exploration activities in these valleys from the 1970's and 1980's, and have also identified previously unknown geothermal anomalies (Skord et. al, 2011).

2M temperature probes, LiDAR, and hyperspectral data were acquired and analyzed in partnership with SEI Group, Inc. and the University of Nevada-Reno Great Basin Center for Geothermal Energy (UNR-GBCGE). A primary goal of this work is to understand the nature of the left-stepping oblique to vertical slip transition zone between the Dixie Valley Structural Basin and the Fairview Valley Structural Basin. Previous geophysical studies in Dixie Valley (Mankhemthong 2008) suggest this transition zone to be the structural control of the geothermal anomalies at Eleven Mile Canyon and Pirouette Mountain. Additional geophysical surveys are currently being pursued to better define this apparent transition zone at depth. Those geophysical surveys include gravity, magnetic, and magneto-telluric (MT). The synthesis of these data will be used to generate several intermediate to deep slim-hole drilling targets to test our exploration model and further delineate potential geothermal resources at NASF.

## Introduction

The Navy GPO is actively exploring for geothermal resources at a number of military bases throughout the world utilizing contractor support in conducting exploration /drilling to meet the renewable energy goals of the Department of Defense. The goal is to complete these exploration campaigns in a 2-year period, ultimately, trying to identify the presence of a geothermal resource that industry can develop and garner the DOD revenue and/or energy assurance.

Through American Reinvestment and Recovery Act (ARRA) funding, the Department of the Navy Geothermal Program has acquired LiDAR and Hyperspectral Imagery, acquired shallow

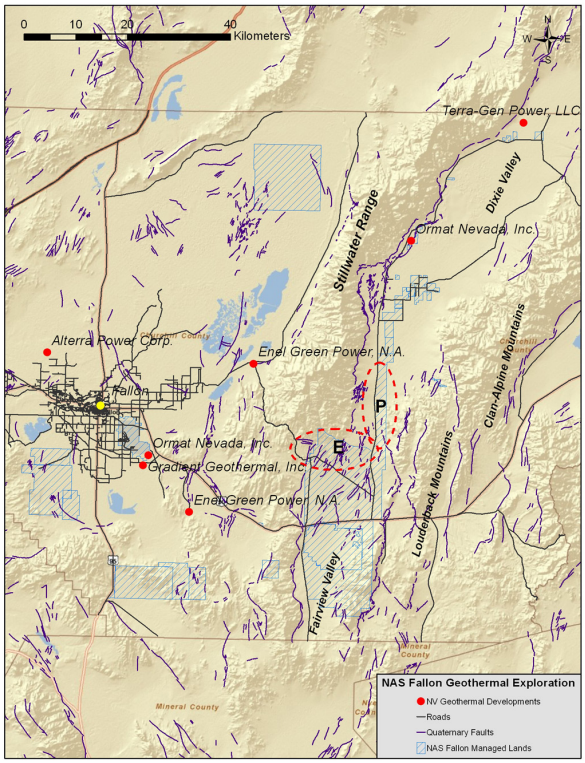


**Figure 1.** Map illustrating the location of NAS Fallon Managed lands (241,000 acres), in proximity to both current and pending geothermal developments. The (P) represents the Pirouette Mountain Geothermal Anomaly, while the (E) represents the location of the Eleven-Mile Canyon Geothermal Anomaly.

probe temperature surveys, conducted fault mapping, and drilled twenty-four, five-hundred foot temperature gradient holes on NAS Fallon Managed lands; sixteen of those temperature gradient holes were drilled in Fairview Valley, and Southern Dixie Valley. This paper will discuss the preliminary results from the surveys acquired, and the shallow temperature gradient drilling initiated in August 2010; it will also explain the exploration approach and methods the Navy GPO has engaged in and is currently pursuing at NAS Fallon through contractor support.

## Study Areas

Naval Air Station (NAS) Fallon is located in the Lahontan Valley of west-central Nevada, approximately 70 miles east of Reno and six miles southeast of the city of Fallon. Geothermal exploration on NAS Fallon lands isn't a new concept; NAS Fallon main base, located approximately 10 miles southeast of Fallon, in the Carson Sink, has seen its share of geothermal exploration as in 2005 when a geothermal development contract with Ormat, Nevada Inc. was struck (Figure 1).

There are many support functions NAS Fallon provides to the Navy, however, NAS Fallon's primary mission is to support the Naval Strike and Air Warfare Center's (NSAWC) Navy Fighter Weapons School, Top Gun flight; The training ranges in Dixie and Fairview Valley's make for great flight simulation of forward deployed areas.

Naval Air Station Fallon Training Ranges cover an area of approximately 241,000 acres, and are in proximity to three current operating geothermal power plants (Figure 1), one being the hottest geothermal system in Nevada, Terra-Gen's Dixie Valley plant (Blackwell et. al., 2009). With two previously identified geothermal anomalies, Eleven-Mile Canyon, and Pirouette Mountain (Figure 1), and with a land position in proximity to known developments in Northern Dixie Valley (Terra-Gen), and pending developments in the central part of the valley at Dixie Meadows (Ormat Nevada Inc.) (Figure 1), the DON GPO suspects that NAS Fallon managed lands in Dixie Valley may yield a geothermal resource.

## Geologic Setting

Southern Dixie Valley is bounded to the east by the NNE trending Stillwater Range and to the west by the north trending Louderback Mountains and the NNE trending Clan Alpine Range (Figure 1). The valley was formed as a result of late Miocene to Holocene E-W extension that exposed the Stillwater Caldera Complex and large sections of Pre-Cenozoic upper crustal material (John, 1993).

The navy property in Southern Dixie Valley is situated in the structural termination and transition of two major fault systems (Figure 1) associated with known geothermal occurrences. Our position at Eleven Mile Canyon and South to Hwy 50 (Figure 2) covers the southern termination of the Dixie Valley Fault, well known for the 1954 rupture and the highest temperature of produced geothermal fluid in the state of Nevada at the Terra-Gen facility ub Dixie Valley. This range bounding east dipping normal fault is the dominant structure controlling motion along the eastern front of the Stillwater Range.

The Pirouette Mountain (Figure 2) property is directly adjacent to the northern termination of the Gold King and Louderback Mountains faults. These are both west dipping normal faults that were recently active as part of the 1954 Fairview Peak rupture event that triggered the Dixie Valley Event. Analysis of static stress changes by Caskey and Wesnousky (1997) showed that the northward propagation of slip along four distinct faults in the Fairview Peak event, based on the stress changes modeled, were a driver in the Dixie Valley event. A 3.2 magnitude seismic event was recorded in this area as recently as April 22, 2011(NSL, 2011). This is one of the only parts of Dixie Valley with significant east-dipping neotectonic activity in the western part of the valley. The origin of geothermal fluids recognized in the Hunt Exploration data is thought to have a relationship with the confluence at depth of these east-dipping structures with the west dipping Dixie Valley Fault.

## Geophysical Setting

Previous geophysical work has been limited in the southern Dixie Valley. Most recently, Mankhemthong (2008) performed a gravity study in Southern Dixie Valley and Northern Fairview Valley. This work directly overlay the Navy GPO project area at Pirouette Mountain and Eleven-Mile Canyon (Figure 1). The results show evidence to an inter-basin transition zone that has defined areas of compressional stresses and tensional stresses that correlate to shallow temperature anomalies. North of the project area in the greater Dixie Valley, numerous geophysical surveys have proven to show insight to geology at depth. Numerous gravity surveys (Schaefer, 1983; Blackwell et al., 1999; Abbott and Louie 2001) have modeled faulting, basin depths, and geologic units, whereas aeromagnetic surveys have delineated previously unknown faulting (Grauch, 2002; Smith et al., 2002) and the locations of magnetic bedrock. These surveys have supplemented three seismic studies (Herring, 1967; Okaya and Thompson, 1985; Abbott and Louie, 2001). MT and other electrical methods have also been used for understanding the geothermal potential in Dixie Valley geothermal field with good success (i.e.: Wannamaker, 2005). While these surveys do not directly overlay our focus areas, they are very close in proximity and will be used to correlate with planned acquisition of geophysical data for this project.

## Exploration Methods and Preliminary Results

Given the nature of pursuing geothermal exploration on military bases and training ranges, a number of factors come into play when considering exploration: prospect identification/potential, access to training ranges, and; mission compatibility. Also, prior to any exploration activities, the necessary environmental clearances must be obtained to ensure NEPA requirements, and tribal consultations are addressed. Like any good exploration strategy/plan, delays are expected and worked into the exploration timelines. Since the Navy GPO works at the pleasure of the commands we are servicing, planning the work around the training missions requires flexible contractor support and strong relationships with base personnel.

The Navy GPO scheduled a number of exploration endeavors (with contractor support from SEI Group, Inc.) in the summer of

2010; that work included: shallow temperature probe surveys, LiDAR and Hyper spectral acquisition/analysis, and temperature gradient drilling. The Navy GPO is also mining both existing geophysical and drilling data that was collected in Dixie Valley as part of previous research studies or exploration efforts. The following is a description of the ongoing exploration on NAS Fallon lands in Dixie Valley:

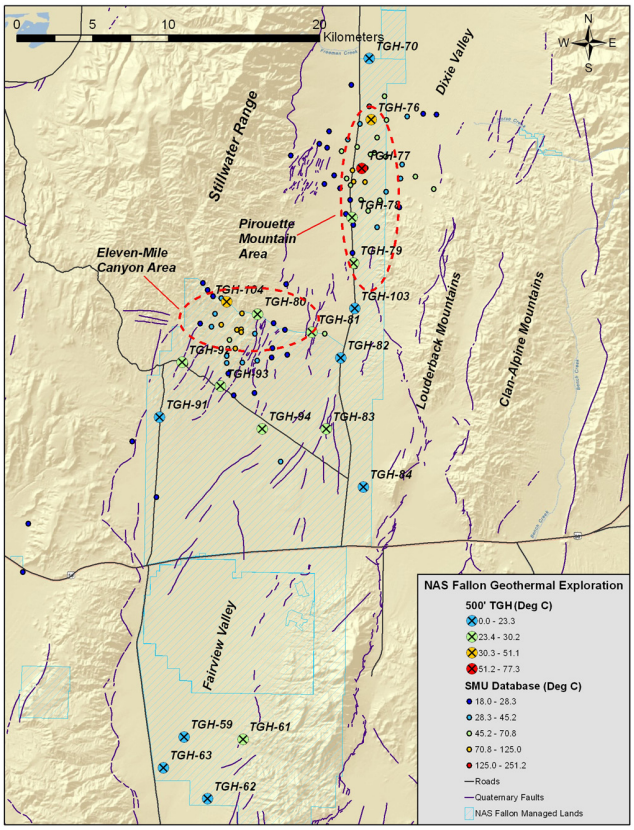


**Figure 2.** Location of twenty, shallow temperature gradient holes, drilled in Fairview and Southern Dixie Valley. The shallow gradients correlate with previous Hunt exploration drilling from the 1970's (courtesy of SMU database).

## *Temperature Gradient Drilling*

The Navy GPO (with contract support from Dan's Water Well and Pump Service- Tracy, CA), drilled 24-500' Temperature Gradient Holes (TGH's) on NAS Fallon lands from August – November 2010 using ARRA funding. Twenty of those holes were drilled in Fairview and Southern Dixie Valley (Figure 2). Two of those twenty had temperatures > 50ºC, with the hottest of those holes being TGH-77 (77.3°C), followed by TGH-104 (51.1°C) (Figure 3).

The temperatures encountered at the Pirouette Mountain and Eleven-Mile Canyon areas validate Hunt Exploration data the Navy GPO has been pursuing (Bowers, 2010-11). Hunt Energy drilled multiple 500', 2000', and even a 7300' hole at the Pirouette Mt area (Figure 2); the Navy GPO is currently pursuing both geophysical and geological logs that may exist from Hunt Energy's files. This data is currently being stored at Southern Methodist University and the Navy GPO is currently working with SMU faculty and staff to acquire this data.

## *LiDAR Analysis*

High resolution LiDAR was collected over NAS Fallon Managed lands with a vertical accuracy < 13 cm in the fall of 2010 (Figure 4). LiDAR permits the imaging of very small irregularities in the surface of the earth that generally go undetected by conventional field mapping. In particular, this technology can be extremely helpful in identifying fault scarps that are present in unconsolidated sediments that are indicative of Holocene tectonic activity (Monastero and Coolbaugh, 2007). Mapping young active faults that could be potential conduits for fluid flow is a common exploration approach for any geothermal exploration campaign; active faults are a common occurrence in geothermal systems (Sabin et. al, 2004, Bell and Ramelli, 2009). NAS Fallon lands cover more than 241,000 acres and by acquiring LiDAR data, the Dept. of the Navy and its sub-contractors are able to focus their efforts and field observations on areas where fault's are detected (Figure 4. overleaf).

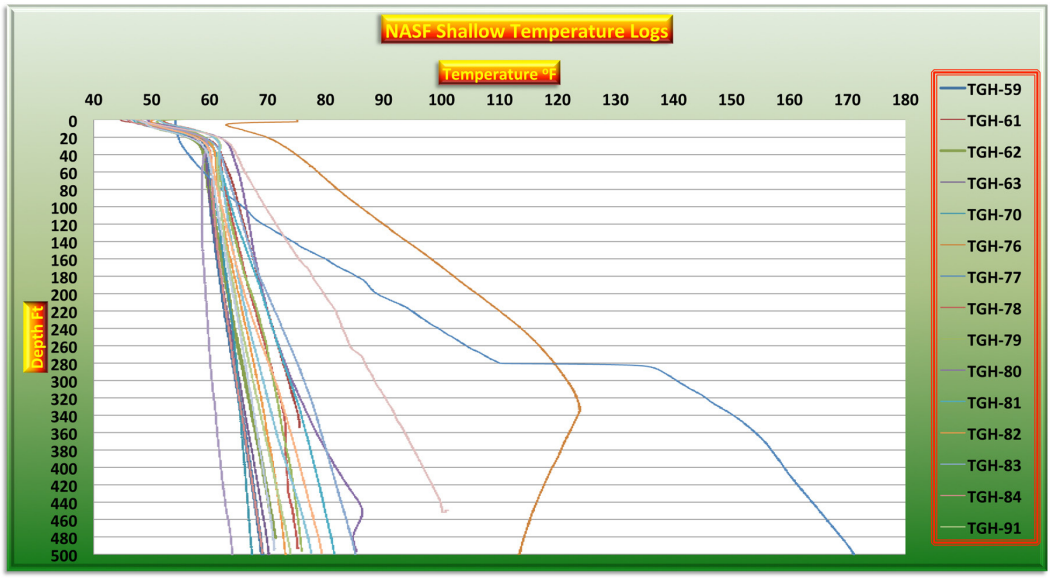


**Figure 3.** Graph of Temperature profiles for the 20-500' Temperature Gradient Holes drilled in Fairview Valley and Dixie Valley in the Fall of 2010. TGH-77 reached a maximum temperature of 171°F (77°C) at a depth of 500' (150m).

## *Shallow Temperature Probe Surveys*

The most significant shallow temperature anomaly was found at the Pirouette Mountain area (Figure 5). This area was previously identified from drilling back in the late 1970's by Hunt Exploration. A more recent gradient hole (TGH-77), drilled by the Navy Geothermal Program, found a temperature of 171°F (77°C) at a depth of 500' (150m). No shal-

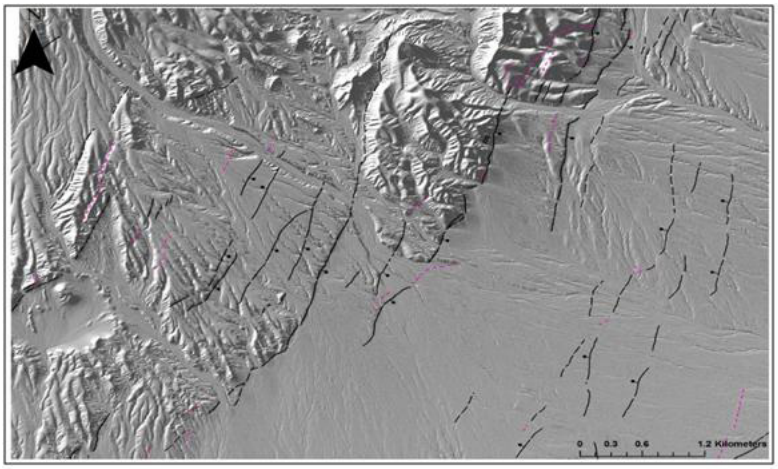

**Figure 4.** Map illustrating LiDAR imagery and NNE trending faults in LaPlata Canyon. Lines highlighted in red are faults that experienced 1954 rupture. (Figure courtesy of Helton et. al, 2011).

low temperature surveys have previously been conducted in the Pirouette Mountain area. The two-meter anomaly found here is characterized by temperatures 3-4 °C above background, and covers a north-south trending area 3-5km long (Skord et. al, 2011).

## *Additional Geophysical Exploration*

Based on the previous geophysical work in and around the project area, we have begun to implement an exploration strategy of collecting higher density gravity stations, an aeromagnetic survey, as well as ground MT work (Figures 6). The Navy is pursuing efforts to piggyback an existing Department of Energy funded EGS methodology project (DE-EE0002778). In 2010, the Department of Energy awarded a cost-share grant to AltaRock Energy, Inc.; AltaRock is conducting an Engineered Geothermal System (EGS) Exploration Methodology project in the northern portion of Dixie Valley approximately centered on the existing geothermal electrical production field (Figure 6).

A necessary consequence of this endeavor is also the definition of the geological exploration characteristics of the Dixie Valley hydrothermal system(s) (i.e., hot, high permeability, essentially fractured rocks, conducting fluid). As part of this proposal, various geophysics will be acquired such as MT, Gravity, and Aeromagnetics (Figure 6).

Existing gravity and magnetic data will be collated for Dixie Valley and joint magnetic/gravity inversion models will be created for these data, with a focus on improving site selection for hydrothermal geothermal resources.

In the efforts of progressing new technology to the geothermal industry, we are acquiring a small ZTEM spec survey through Geotech LTD. Geotech LTD. , coordinating flight acquisition through NAS Fallon Range Operations, is scheduled to acquire, process, and interpreting Z-TEM (Z-Axis Tipper Electromagnetic). The

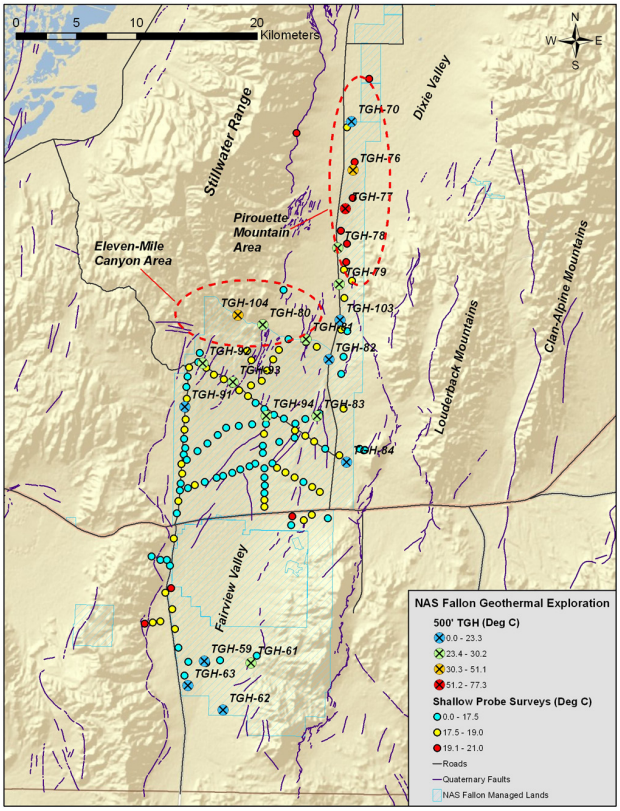


**Figure 5.** Map illustrating shallow probe survey results for Fairview Valley and Southern Dixie Valley.

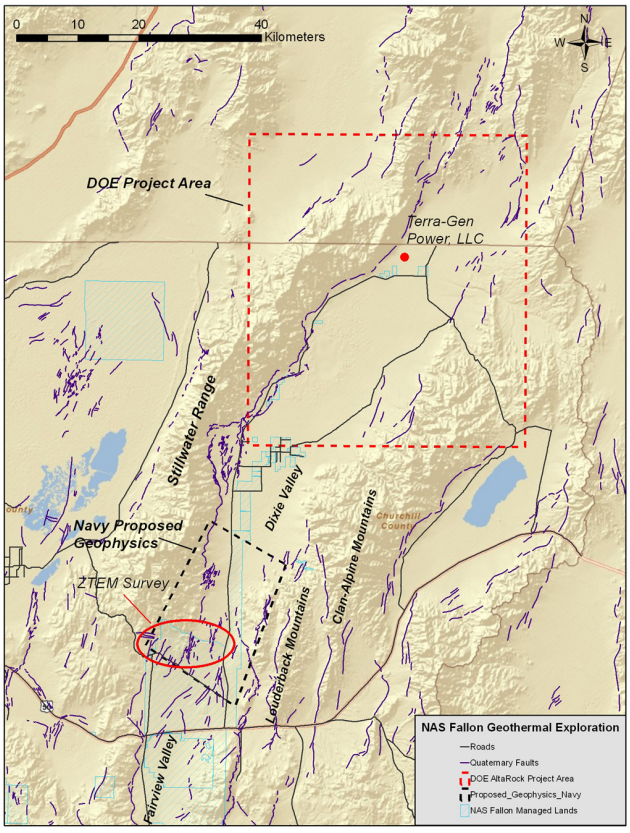


**Figure 6.** Map illustrating the location of geophysical surveys being pursued by the Navy GPO to further define the subsurface structure influencing shallow temperatures at the Eleven Mile Canyon and Pirouette Mountain Areas. The Navy GPO is pursuing detailed gravity, aeromagnetics, and MT surveys through DOE project (DE-EE-0002778).

area of acquisition is the Eleven-Mile Canyon Area (Figure 6) This system is an innovative airborne EM system which uses the natural or passive fields of the Earth as the source of transmitted energy. GPO will use new inversion techniques and compare with MT results when acquired. With these datasets, as well as results from shallow drilling and previous geologic work, the Navy GPO will have a very good understanding of the density, susceptibility, and conductive properties of the subsurface in southern Dixie Valley.

## Conclusions

Preliminary results indicate elevated shallow temperatures at depth in the Pirouette Mountain and Eleven Mile Canyon areas, verified by shallow probe surveys and shallow temperature gradient holes drilled. These elevated drilling temperatures validate previous drilling data that is currently being mined for geophysical and geologic data; also, to reduce redundant exploration and drilling efforts. As many as a dozen additional shallow temperature gradient holes will be drilled in Southern Dixie Valley to further determine the extent of the anomalies at Eleven-Mile Canyon and Pirouette Mountain as well as explore prospects from the ongoing data mining endeavor. LiDAR and Low-Sun Angle Photography have exposed previously unidentified faults in Dixie Valley and have validated the presence of fault terminations believed to be contributing to the Eleven-Mile Canyon and Pirouette Mountain geothermal anomalies (Mankemthong, 2008; Helton et. al, 2011). Additionally, the GPO is also pursuing several geophysical surveys that will yield detailed subsurface information, much needed to determine subsurface structures and conductivity of the Eleven-Mile Canyon and Pirouette Mountain areas. The synthesis of all these data will be tested with the drilling of two or three intermediate/deep slim holes, scheduled for calendar year, 2012.

## Acknowledgements

The Department of the Navy Geothermal Program Office would like to recognize the NAS Fallon NSAWC Range Operations, NAS Fallon Range Scheduling, Public Works, and Environmental offices. These offices were responsible for coordinating access for drilling, assisting in the flight scheduling for acquiring LiDAR, Hyper spectral, LSA, and providing environmental oversight and guidance to ensure all NEPA requirements were met.

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