Characterizing Structure and Geology with Potential Field Geophysics to Assess Geothermal Resource Potential near Battle Mountain, NV

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ABSTRACT

The northeastern extent of the Reese River Valley near the town of Battle Mountain, NV, is the focus of new geothermal characterization efforts under the INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems (INGENIOUS) project, which aims to accelerate discoveries of new, commercially viable hidden geothermal systems while reducing exploration and development risks. The study area, referred to as Argenta Rise, is a candidate for hosting a hidden geothermal system as it occupies a favorable structural setting thought to be conducive to hydrothermal upwelling. The absence of surface thermal features (hot springs, fumaroles, or paleo-geothermal deposits) at Argenta Rise makes it challenging to locate potential geothermal resources and necessitates a detailed geophysical investigation. New gravity and ground based magnetic data were acquired to help resolve subsurface geology and intra-basinal structures that may be locally influencing any potential hydrothermal fluid flow. The gravity data delineate at least three structurally controlled basins, as well as a broad intra-basinal gravity high which may reflect structural relief in the basement surface. Anomalies in the ground based magnetic data coincide with the traces of numerous mapped faults within the basin, and in some cases suggest that the faults extend well beyond their mapped traces. Additionally, some anomalies do not appear to be associated with any currently mapped structural features and may represent previously unknown, concealed faults or contacts. The magnetic data also reveal an extensive network of small, shallow dikes along the western flank of the northern Shoshone Range, likely related to the emplacement of the mid-Miocene Northern Nevada Rift (NNR). Additional data and modeling will continue to further define the basin geometry, constrain geophysically inferred contacts, and delineate concealed faults and fault offsets. Ultimately, these results will help guide future geothermal characterization efforts in this region.

REGIONAL GEOLOGIC SETTING

Argenta Rise is located ~15km southeast of the town of Battle Mountain along the western flank of the northern Shoshone Range within the north-central Basin and Range Province (Figure 1). Local stratigraphy consists of highly deformed and thrusted Paleozoic siliciclastic (purple) and carbonate (gray) rocks that are locally intruded by Jurassic-Tertiary granitoids (red-pink). Overlying these units are voluminous packages of Cenozoic volcanics (orange) and sediments (tan). The two predominant fault orientations observed within the study area trend NNW and ENE and record the transition from middle Miocene ENE-WSW rift-related extension to the NW-SE directed extension characteristic of the modern day Basin and Range, respectively. Interactions between these two fault sets create numerous potentially favorable zones for promoting hydrothermal fluid flow within the study area.

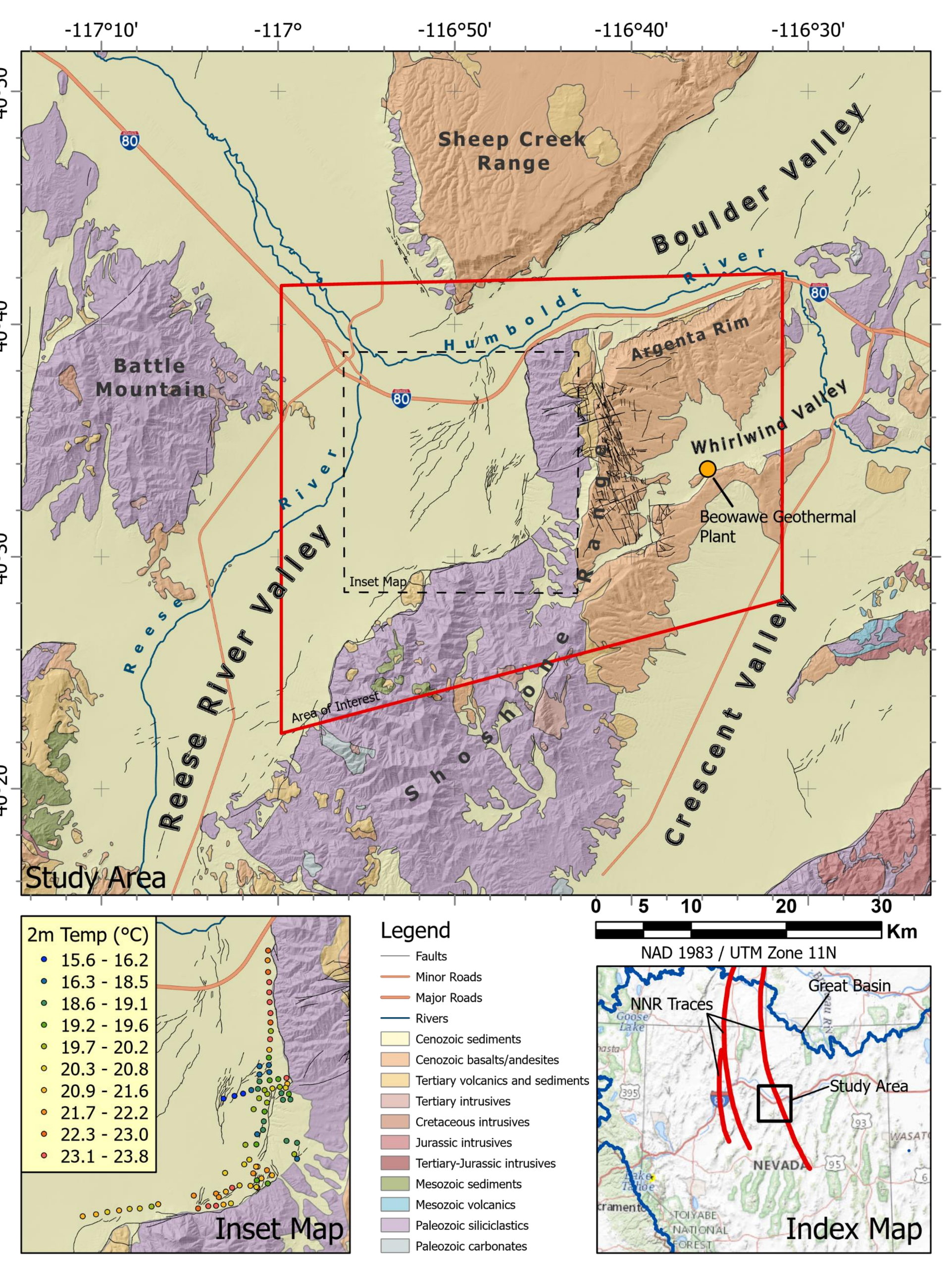


Figure 1: Topographic hillshade (USGS, 2013, 2018) overlain by regional geologic map (adapted from Crafford, 2007) in the vicinity of Argenta Rise (top), results of a 2-meter temperature probe survey conducted by the University of Nevada Reno (UNR) on the west flank of the northern Shoshone Range (inset map, bottom left), and index map (bottom right) displaying the location of the study area, hydrologic boundary of the Great Basin and traces of the NNR (NNR traces obtained from Glen and Ponce, 2002).

METHODOLOGY

Potential field methods (gravity and magnetic) are a low cost, non-invasive means of geothermal exploration that facilitates imaging of subsurface basin geometry, faults, contacts, fractures zones, and alteration zones, which may inhibit or promote hydrothermal fluid flow. To date, we have collected a total of 1,207 new gravity stations (Figure 3) and ~71.6km of ground based magnetic data along 13 individual profiles (Figure 5). Ongoing aeromagnetic and aeroradiometric data collection will significantly improve upon the resolution of existing datasets and allow for much more detailed structural mapping at a regional level than is currently possible (Figure 7).

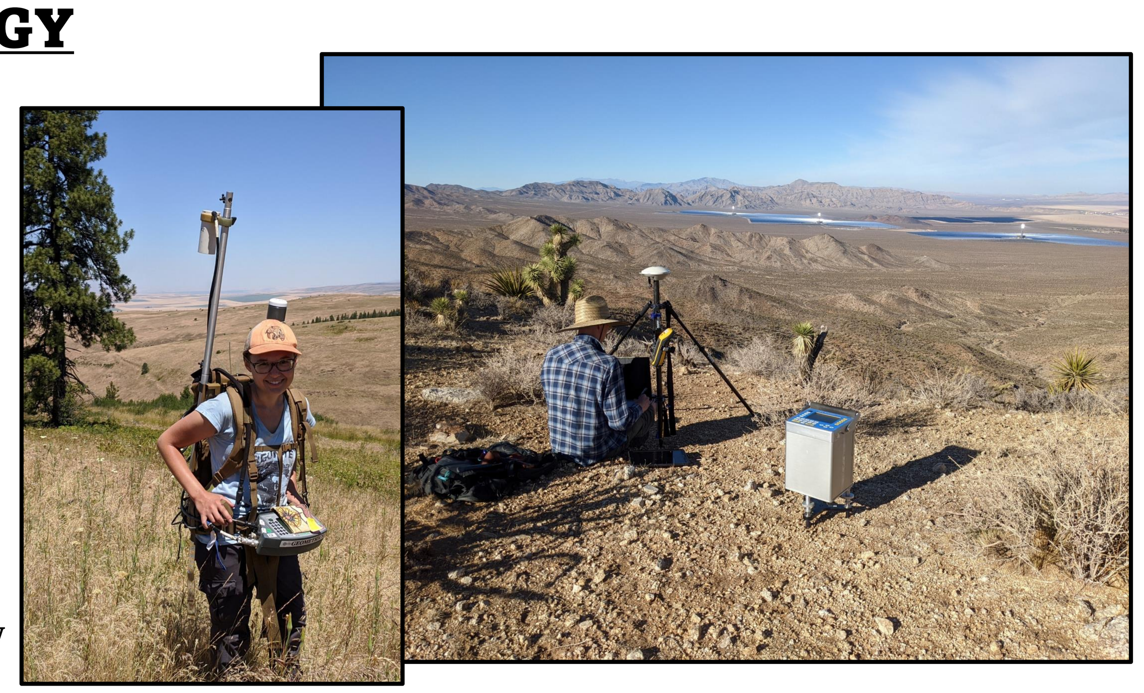
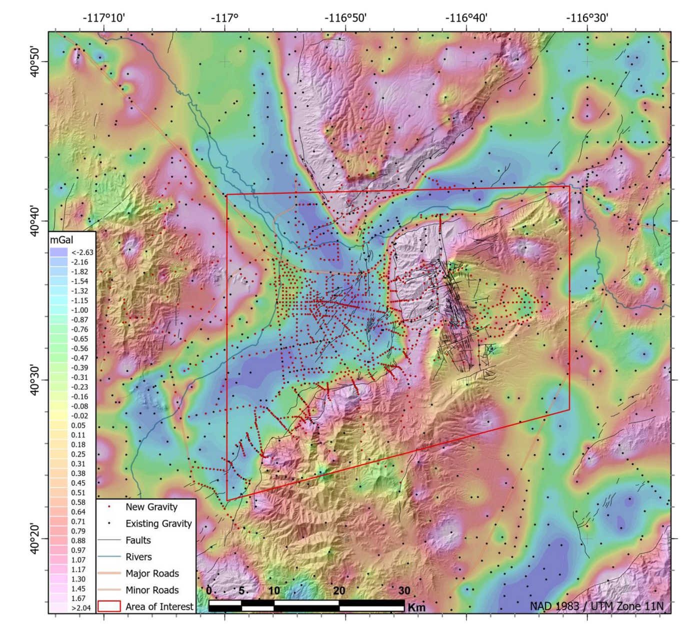


Figure 2: The image on the left shows Laurie Zielinski near Pendleton, OR, with a backpack mounted magnetometer and GPS similar to the ones used in this study. The image on the right shows William Schermerhorn collecting a gravity measurement near Mountain Pass, CA.

GEOPHYSICAL MAPPING

Gravity



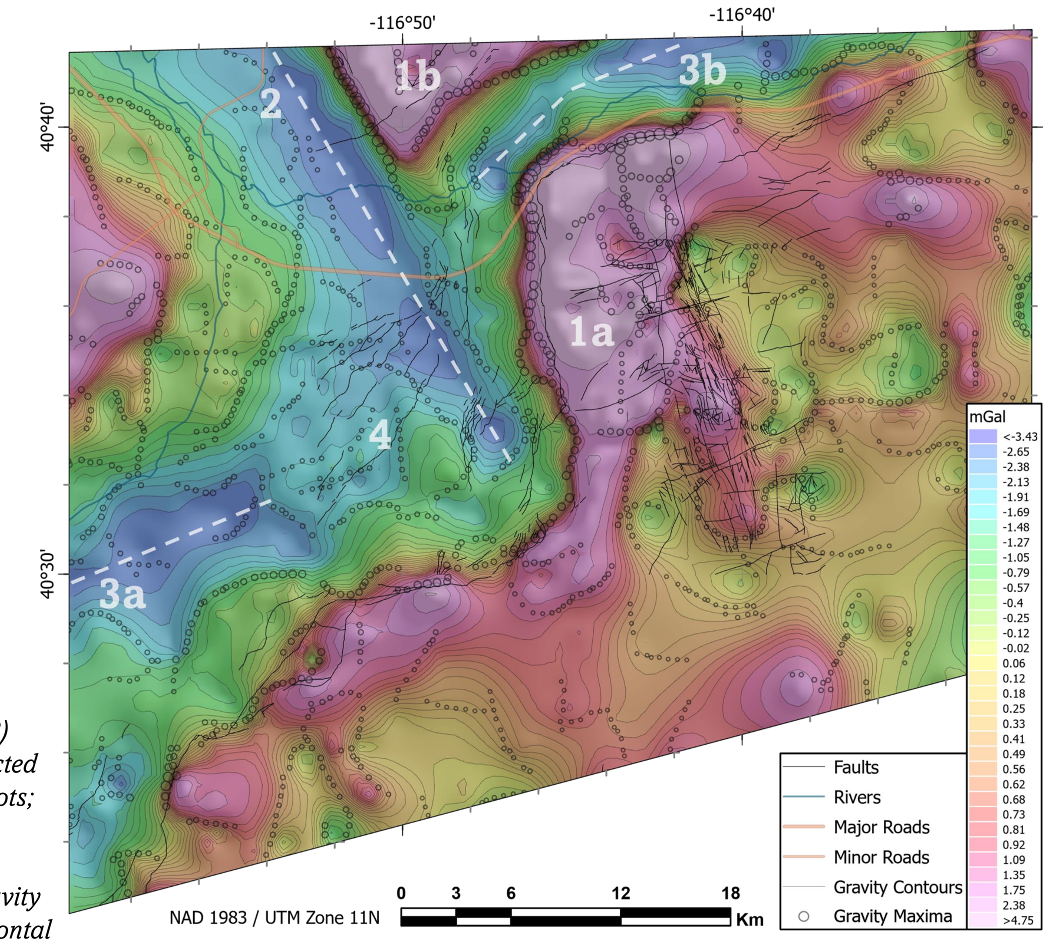


Figure 3 (above left): Topographic hillshade (USGS, 2013, 2018) overlain by residual isostatic gravity anomaly grid, newly collected gravity stations (red dots) and existing gravity stations (black dots; Hildenbrand et al., 2002).

Figure 4 (above right): Shaded relief of the residual isostatic gravity anomaly in the area of interest (red polygon in Figure 3). Horizontal gradient maxima (HGM) of the residual isostatic gravity anomaly (open black circles) are proportionately sized relative to the magnitude of the gradient and highlight shallow crustal structure that is obscured by basin fill sediments. Interpretation of the numbered features are discussed in the conclusions.

Magnetics

Figure 5 (right): Topographic hillshade (USGS, 2013, 2018) overlain by aerial imagery showing ground magnetic profile locations, and locations of interpreted structural features (reference Figure 6 below).

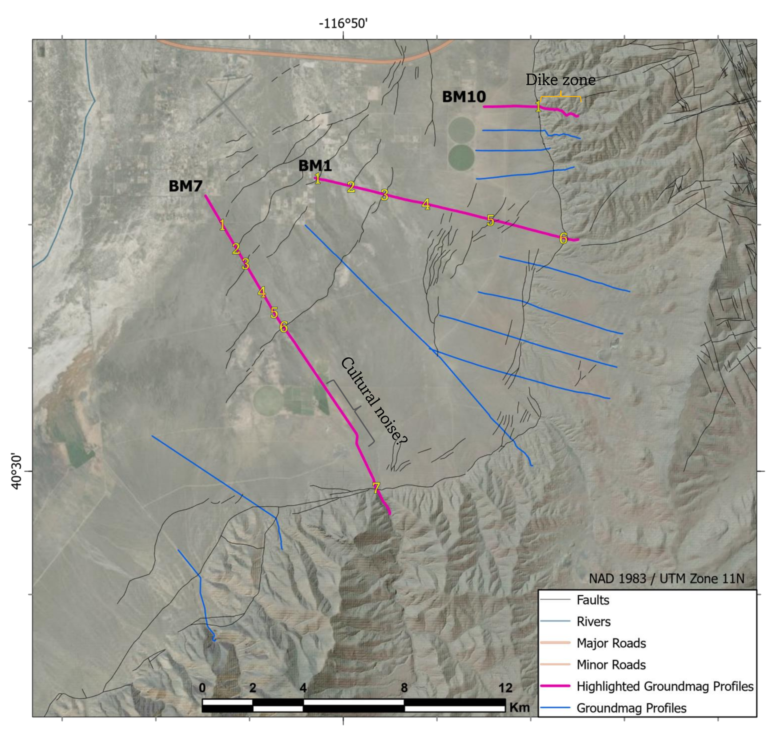
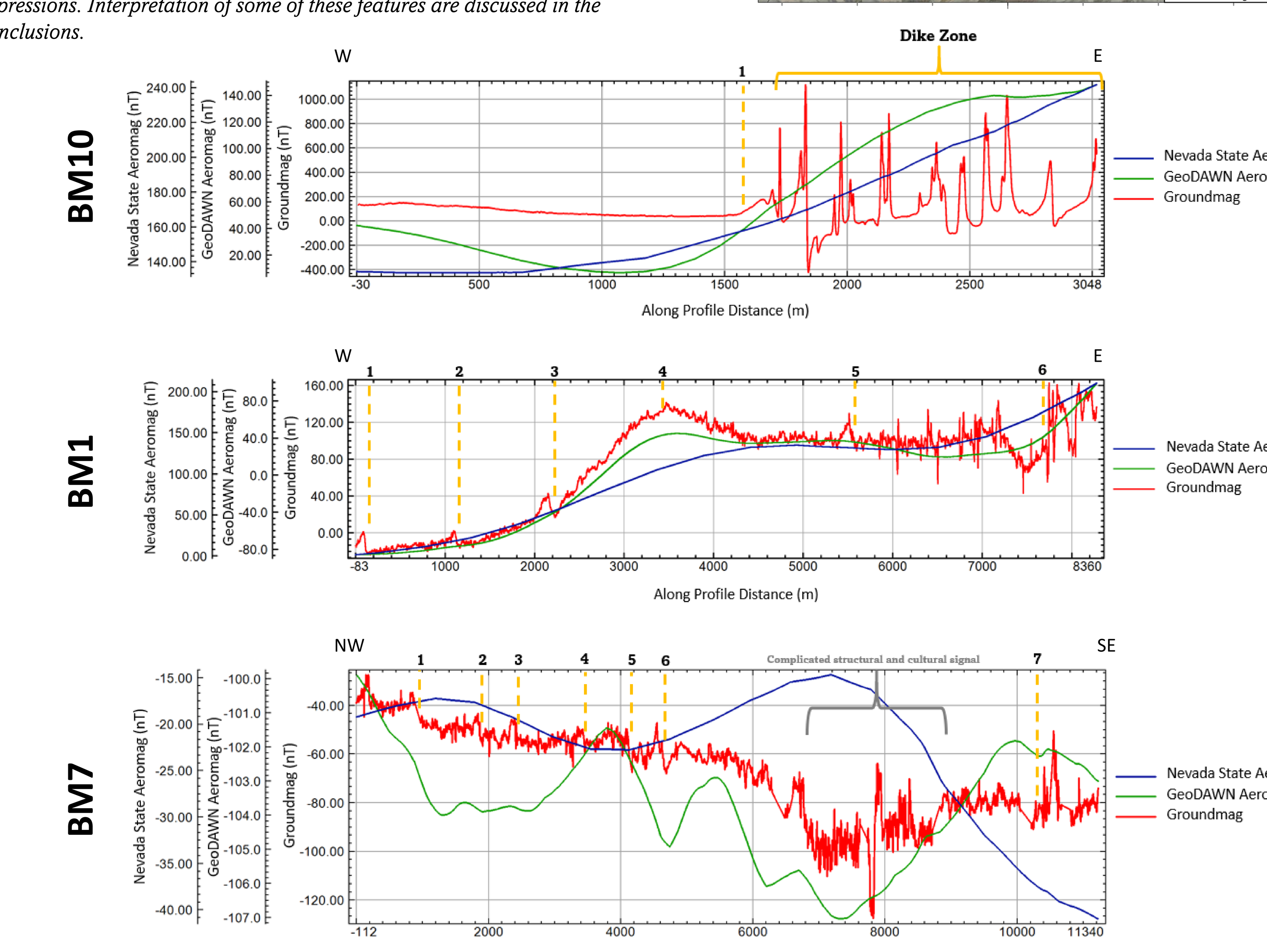


Figure 6 (below): These three panels show magnetic anomalies along the profiles as observed in the hiked traverses (red line), ongoing high-resolution aeromag survey (green line; in progress, Glen and Earney, 2022), and existing Nevada state magnetic map compilation (blue line; Kucks et al., 2006). Interpreted structural features are indicated by the numbered dashed yellow lines (reference Figure 5 to the right). This figure illustrates the value in high resolution ground-based and airborne surveys for identifying concealed structures with subtle geophysical expressions. Interpretation of some of these features are discussed in the conclusions.



Airborne Geophysics (GeoDAWN surveys)

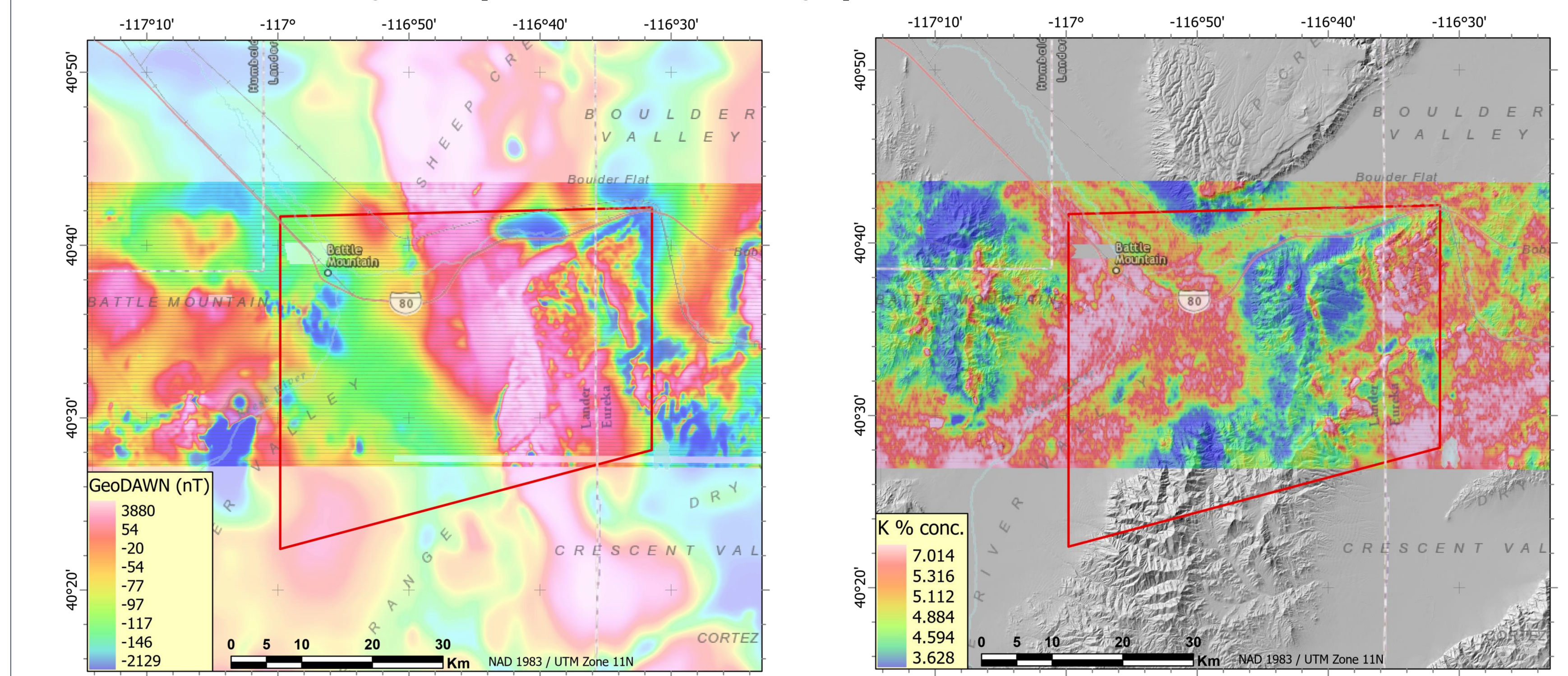


Figure 7: The left image shows the existing aeromagnetic map (Kucks et al., 2006) overlain by the new high-resolution aeromagnetic data (still in progress). The specifications of this survey are a substantial improvement over the existing aeromagnetic survey data (new survey flight lines shown in light gray). Radiometric data is being collected concurrently with the magnetic data. The right image shows a topographic hillshade (USGS, 2013, 2018) overlain by a map of Potassium concentrations. This type of radiometric measurement is limited to the upper few centimeters of regolith, but can be very useful for mapping out bedrock geology. The GeoDAWN surveys are still in progress (Glen and Earney, 2022).

CONCLUSIONS

- The new high resolution geophysical data collected thus far reveals that Argenta Rise is situated in a very structurally complex region of the north-central Great Basin.
- Gravity data reveal that there are at least 3 structurally controlled basins present in the study area:
  - The most prominent basin (feature 2 in Figure 4) abuts the western flank of the northern Shoshone Range at a step-over between ENE-trending faults and NS-trending faults and continues along a northwestern trend between the southern Sheep Creek Range on the east and Battle Mountain on the west. This basin is asymmetric and deepest in the east.
  - Another basin (feature 3b in Figure 4) trends ENE between the narrow valley separating the southern Sheep Creek Range and Argenta Rim. This basin is truncated on the west by NNW-trending structures.
  - The third basin (feature 3a in Figure 4) is located between Battle Mountain and the Shoshone Range and also trends ENE. This basin is truncated along its eastern extent by an approximately 10km wide series of subtle intra-basinal gravity highs (feature 4 in Figure 4; discussed more below) that separate it from the NW-trending basin.
- The subtle intra-basinal gravity highs (feature 4 in Figure 4) form a subsurface ridge-like feature across the Reese River Valley and may be indicative of structural relief in the basement surface resulting from localized uplift along ENE and NNW trending structures indicated by the mapped faults and gravity HGM. These features may have an important effect on hydrothermal circulation in the basin, but this remains unclear.
- The gravity map is otherwise dominated by large regional highs (features 1a and 1b in Figure 4) that correspond to outcrops and near surface bodies of Paleozoic basement lithologies, as well as mid-Miocene NNR related intrusives.
- The ground based magnetic profiles map subtle anomalies (on the order of several nT) which are interpreted to reflect concealed faults within the basin. Although the fault map presented here was established prior to this study, our work suggests that some of the mapped fault traces should be extended, and in some cases we found evidence for previously unmapped structures.
- The ground based magnetic data also reveals an extensive network of small, shallow dikes along the western flank of the northern Shoshone Range (see Profile BM10 in Figure 6), several of which appear to be previously unrecognized and unmapped. Dikes often take advantage of pre-existing structures and zones of weakness in the crust (i.e. faults, contacts, etc.) as they intrude into the shallow subsurface and may impact local hydrothermal processes.
- Ongoing airborne geophysical surveys (magnetic and radiometric) will offer a significant improvement over existing datasets with respect to the resolution at which subsurface structures and geology can be delineated. When these surveys are concluded, they will prove to be extremely valuable for any future geothermal or mineral resource studies in this region.

The Nevada state aeromagnetic and the Nevada gravity data are available at https://pubs.usgs.gov/ds/2006/234/nevada.htm. New data from this study are not currently publicly available. Contact the primary author of this poster for more information (tearney@usgs.gov).

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