Preliminary Results and Interpretations of a High-Resolution Aeromagnetic Survey and Drilling Program to Investigate Buried Volcanic Features near Yucca Mountain

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Introduction

Seven drill holes have been completed in Crater Flat, Jackass Flats and the Amargosa Desert to investigate the extent and age of buried basaltic volcanic features in the Yucca Mountain region (Figure 1). Combined with interpretation of aeromagnetic data and other geologic information, these drill holes allow a comprehensive interpretation of the volcanic history of Crater Flat and Jackass Flats, and too a lesser extent, the volcanic history of Amargosa Desert. By design, not all the drill holes targeted basalt. Several targeted Miocene tuff, both to aid in the ability to interpret different sources of aeromagnetic anomalies (basalt versus tuff), and to provide definitive evidence that not all alignments or groupings of aeromagnetic anomalies are due to buried basaltic features (Perry et al. 2005). The results and interpretations presented here are preliminary as we await final analysis of thin sections, final core descriptions, final age-dating and geochemical analyses and further interpretation of drilling and aeromagnetic data. To date, only one *preliminary* age determination has been completed (basalt of anomaly Q, 10.2 Ma). Age determinations for all drilled basalts are expected mid-2006.

Summary information for the seven drill holes is presented in Table 1. Four of the seven drill holes encountered basaltic volcanic features (anomalies Q, A, JF-5 and G), two encountered tuff bedrock (anomalies O and I), and one finished in alluvium (anomaly JF-6), although as discussed below, the causative magnetic body below the drill hole is interpreted as Miocene tuff. Locations of the drill holes relative to the targeted aeromagnetic anomaly are shown in Figure 2.

Drilling Results

Anomaly Q (Drill Hole USW VA-4a, Total Depth = 163.3 meters)

Anomaly Q was drilled to investigate the origin of four adjoining negative magnetic anomalies in northern Crater Flat (Figure 1). O'Leary et al. (2002) suggested that these anomalies represent buried Miocene basalt related to anomaly T to the south (Figure 1). Based on the 2004 aeromagnetic survey, we interpreted anomaly Q as representing tuff based largely on the presence of a NNW-trending fault apparent on the east side of the anomaly that appeared to be an extension of faulted tuff terrain to the east (Figures 1 and 4b).

Table 1. Summary information for completed drill holes

Anomaly	Drill hole	Location	Magnetic Source	Predicted Source	Depth to basalt (m)	Basalt thickness (m)	Comments
A	USW VA-1	Crater Flat	Basalt	Basalt	147.8	62	
Q	USW VA-4a	Crater Flat	Basalt	Tuff	140.8	>22.5[a]	Interpreted as possible Miocene basalt by Connor et al. (2000) and O'Leary et al. (2002)
JF-5	UE-25 VA-10	Jackass Flats	Basalt	Basalt	77.1	>17.2[b]	Correlates with two other drilled basalts in Jackass Flats
JF-6	UE-25 VA-11	Jackass Flats	Likely tuff	Unknown	n/a	n/a	See discussion in text
I	USW VA-5	Amargosa Desert	Tuff	Tuff	n/a	n/a	Modeled as basalt by O'Leary et al. (2002)
O	USW VA-3	Amargosa Desert	Tuff	Tuff	n/a	n/a	Modeled as basalt by O'Leary et al. (2002)
G	USW VA-2	Amargosa Desert	Basalt	Basalt	118.9	31	Thickness determined from adjacent Nye Country drill hole (April 2006)

[a]30 meters of correlative basalt encountered in VH-2 (entire basalt thickness penetrated)
[b]38 meters of correlative basalt encountered in J-11 (entire basalt thickness penetrated)

At anomaly Q, basalt was encountered at a depth of 141 meters beneath avalanche deposits of Paleozoic quartzite and dolomite (Appendix 1). A total of 22.5 meters of basalt was penetrated at anomaly Q before drilling was stopped before reaching the bottom of the basalt because of drilling problems. Examination of the core indicates that the basalt consists of four thin lava flows (1-4 meters thick) of olivine and plagioclase-phyric basalt separated by zones of scoria and oxidized flow breccia. Vesicle size and frequency increase near the top of each flow. The major-element composition of the basalt at anomaly Q is typical of alkali basalts in the region (Table 2).

Drill hole VH-2, about 5 km south of anomaly Q (Figure 1), encountered a similar sequence of slide blocks of Paleozoic rocks on top of a 30-m-thick sequence of olivine and plagioclase-phyric basalt flows at a depth of 330 meters (Carr and Parrish, 1985). This basalt was dated at 11.3 Ma by K/Ar. At the southern end of Crater Flat, on the ridge southeast of Steve's Pass, a 20-30 meter-thick sequence of flows is exposed beneath avalanche deposits of Paleozoic carbonates (Map unit Trx of Potter et al. 2002). Ages of 11.2 and 11.3 Ma obtained by Ar/Ar are reported for this basalt (Reamer, 1999). Based on the similarity of the three sequences (avalanche deposits above several stacked basalt flows), the age of the basalt encountered at anomaly Q is interpreted to be 11.3 Ma. A preliminary K-Ar determination indicates an age of about 10.2 Ma. By extrapolation, we interpret adjacent aeromagnetic anomalies P, R and 4, with similar magnetic characteristics (Figure 1 and 4b), as representing the same basalt sequence.

Table 2. Major-element compositions of basalts of anomalies Q and A

Oxide (wt%)	Anomaly Q Basalt	Anomaly A Basanite
SiO_2	47.40	42.00
TiO_2	1.92	2.76
Al_2O_3	16.70	12.40
FeO	4.17	3.07
Fe_2O_3	6.27	10.19
MgO	6.47	9.34
CaO	8.99	12.10
Na_2O	3.06	2.85
K_2O	1.25	0.54
P_2O_5	0.72	1.12
MnO	0.15	0.18
$C0_2$	0.48	0.77
H_2O-	0.40	0.70
H2O+	1.30	2.70
Total	99.28	100.72

The results of drilling at anomaly Q support the conclusion that much of the western half of Crater Flat is floored by multiple flows of Miocene basalt. Assuming a constant thickness of 30 meters and an area of between 70 and 100 km^2, the volume of this basalt is estimated at 2-3 km^3.

Anomaly A (Drill Hole USW VA-1, Total depth= 210.6 meters)

Anomaly A was drilled to investigate the origin of a positive magnetic anomaly south of Little Cones in southern Crater Flat. At anomaly A, a 62-m-thick massive basalt unit was encountered beneath alluvium at a depth of 148 meters (Appendix 1). In contrast to the basalt at anomaly Q, there is no evidence to indicate multiple flows or lava flow contacts (basal flow breccia or scoria), or internal flow features such as parallel flow partings or vesicles. The basalt is fractured at multiple (random?) angles. The fractures are one to several millimeters in width and filled with white calcite.

Two results of drilling the basalt of anomaly A were unanticipated. The first is that the "basalt" of anomaly A is not basalt, but basanite, as indicated by the major-element analysis in Table 2. The main characteristic distinguishing the basanite of anomaly A from the typical alkali basalt of the region is a very low SiO_2 content of 42 weight percent, below the range for basalt (Table 2; compare to composition of basalt of anomaly Q). Mafic rock of this composition has not previously been recognized in the Yucca Mountain region. The SiO_2 values are unusually low compared to a typical basanite (44-46 wt% SiO_2), but lava flows of similar composition (termed "low-silica basanites") have been reported from the Hurricane volcanic field of southwestern Utah (Smith et al. 1999).

The basanite contains sparse phenocrysts of olivine and clinopyroxene in a fine-grained groundmass of clinopyroxene, plagioclase, olivine, and magnetite. The groundmass includes patchy areas of heavily altered groundmass where analcime (?) is present. Several veins of coarser-grained, differentiated basanite are present, which range in width from a few millimeters to 10 or 20 centimeters. These veins comprise no more than 1% of the total core length. The mineralogy of the veins includes coarse crystals of feldspar, olivine, clinopyroxene, amphibole, magnetite and apatite These differentiated veins are similar in mineralogy and texture to differentiated veins and pods observed within sills at Paiute Ridge, 70 kilometers to the NE of anomaly A, at the northeastern edge of the Nevada Test Site. Based on analogy with Paiute Ridge, the differentiated veins probably represent residual, vapor-rich magma that injected the surrounding crystal mush during the late stages of crystallization.

The second unanticipated result at anomaly A is that the basanite body may represent a sill (or other sill-like intrusion, such as a laccolith or lopolith). Alternatively, it may represent an exceptionally thick lava flow or a ponded lava flow. Currently, no evidence has been observed that conclusively allows a definitive interpretation. Understanding of the geologic context of the basanite is difficult because drilling was stopped at 1 foot below the apparent base of the basanite due to lost circulation of drilling fluid and related safety issues. Core was not being collected at this point. When drilling stopped, the drill hole had entered sediment with a clay-rich matrix, supporting clasts of tuff. It is not clear whether this sediment represents alluvium underneath the base of the basanite or material filling a large fracture within the interior of the basanite.

Two preliminary observations are also problematic. First, cuttings from both the bottom and top of the basanite are well crystallized and appear no different than basanite within the interior of the basanite body. There is no evidence of oxidation, vesiculation, brecciation, or chilling. These observations are problematic for either a flow or a sill. Second, there is no evidence recognized in alluvium either immediately above or below the basanite of thermal effects from a cooling basanite body.

The interpretation of a lava flow or ponded lava flow has several problems. Except for the basalt of anomaly B (and assuming it is a single lava flow), no single flow has been observed in the Yucca Mountain region with a thickness approaching 60 meters. If a flow were this thick, its original lateral extent would logically be much more than the 1-km distance indicated by anomaly A. Thinner Miocene basalt units have lateral extents of several kilometers or more. It is unlikely that a ponded flow would be limited to such a small area, without other (non-ponded) parts of the flow being evident. In addition, no flow-base breccia is recognized from the cuttings.

The lack of flow features, total thickness, and evidence of internal differentiation leads to a conclusion that the basanite of anomaly A may be a sill. Sills of similar circular shape and scale are observed at Paiute Ridge (Figure 5). The thickness of the largest sill (diameter of ~1 km) at Paiute Ridge is estimated to be in excess of 100 meters (Byers and Barnes, 1967). A problem with this conclusion is the apparent lack of thermal effects on the overlying and underlying sediments and the apparent lack of chill textures in the basanite at the contacts.

Assuming a diameter of 1 km and a constant thickness of 60 meters, the volume of the basalt at anomaly A is about 0.05 km^3.

Anomaly O (Drill Hole USW VA-3, Total depth =188.1 meters)

Anomaly O was drilled to investigate the origin of four aligned anomalies (L, M, N and O) with similar magnetic properties in northern Amargosa Desert south of Steve's Pass (Figure 1). O'Leary et al. (2002) modeled anomalies L, M, N, and O as basalt bodies at depths of 50 to 220 meters. We interpreted these anomalies as representing buried and faulted tuff, because they are part of a larger positive anomaly to the northwest that contains apparent fault offsets that mimic patterns seen within the Yucca Mountain block. A sequence of nonwelded tuff (at 163 meters) on top of moderately welded tuff (188 meters) was encountered in the drill hole beneath alluvium and alternating sequences of pyroclastic material and sediment (Appendix 1). The preliminary interpretation, based on drill cuttings, is that the tuff represents nonwelded and welded units of the Bullfrog Tuff. Bath and Jahren (1984) report that the Bullfrog Tuff is normally polarized with a relatively high magnetization, consistent with the magnetic characteristics of anomaly O. Based on the results of drilling at anomaly O, and the similar magnetic characteristics of anomalies L, M, N and O (Figure 1), we interpret all four anomalies in this alignment as representing buried tuff.

Anomaly I (Drill hole USW VA-5, Total Depth = 200.3 meters)

Anomaly I was drilled to investigate the origin of an isolated positive anomaly to the southeast of the Lathrop Wells cone. O'Leary et al. (2002) modeled anomaly I as a basalt at a depth of 250 meters. Based on the 2004 aeromagnetic survey, we interpreted anomaly I as a buried and faulted tuff body. This interpretation was based on the anomaly's relationship with positively magnetized tuff outcrops to the northeast and an apparent northwest-trending fault on the southwest edge of the anomaly that parallels other northwest-trending faults mapped in tuff bedrock to the north (Figure 1). Tuff bedrock was encountered in the drill hole at a depth of 163.1 meters (Appendix 1).

The fault interpreted from the aeromagnetic data on the SW edge of anomaly I (Figures 1 and 4a) is significant because it projects to the northwest beneath the Lathrop Wells cone along a trend that includes other positive (tuff) anomalies and an outcrop of tuff at the southern end of the Lathrop wells lava flows. North of the cone, the fault trend continues, merging with mapped NW-trending faults in tuff bedrock. The location of the Lathrop Wells cone is coincident with the intersection of this fault and a northeast-trending fault that may be part of the Stagecoach Road fault zone (Figure 4a).

Anomaly JF-5 (Drill hole UE-25 VA-10, Total depth = 94.3 meters)

Anomaly JF-5 is part of a broad positive anomaly in Jackass Flats (anomaly U in Figure 1) that was interpreted as buried Miocene basalt by O'Leary et al. (2002). Anomaly JF-5 was drilled to test whether the positive anomaly represents down-faulted basalt that correlates with Miocene basalt outcrops in central Jackass Flats (Figure 1). Perry et al. (2005) interpreted anomaly U as a single basalt unit down-faulted to successively deeper levels of the basin to the south (Figure 1). The evidence for this includes a date of 9.6 Ma for a basalt outcrop at the northern end of anomaly U and a date of 9.5 Ma for basalt encountered at a depth of 400 meters in drill hole 23P at the southern end of the anomaly.

At anomaly JF-5, basalt was encountered at a depth of 77 meters (Appendix 1). This basalt has a distinct texture consisting of glomeroporphyritic clots of olivine phenocrysts in a groundmass that is coarsely intergranular (dominated by plagioclase). This distinct texture is also seen in the 9.6 Ma basalt that crops out to the east of Anomaly JF-5, indicating that the basalt of JF-5 represents correlative basalt on the downthrown western side of a north-trending fault (Figure 1). Basalt with the same distinct texture is observed in cuttings from drill hole J-11 (Figure 5) and in cuttings from drill hole 23P, indicating that Anomaly U of Perry et al. (2005) represents an extensive Miocene basalt that underlies much of Jackass Flats to the east of Forty Mile Wash. This basalt is geochemically and petrographically distinct from Miocene basalts on the boundaries of Jackass Flats on Kiwi Mesa, Little Skull Mountain and Skull Mountain (Tft in Figure 5). The relative ages of these basalts will be determined by Ar/Ar dating.

The occurrence of the basalt of Anomaly U in three drill holes leads to the conclusion that other positive anomalies identified in Jackass Flats and associated with anomaly U (JF-1, JF-2, JF-3, JF-4, W) represent 9.5 Ma basalt. Alternatively, anomalies JF-4 and W, lying on the eastern side of a NE-trending fault (Figure 5) may represent Topopah Spring Tuff, as suggested by an outcrop of Topopah Spring Tuff that lies along the same NE-trending anomaly alignment and immediately to the southwest of the 9.6 Ma basalt outcrop (Figures 1 and 5).

Assuming anomaly U covers an area of about 100 km^2 and has an average thickness of 30 meters (Table 1), the volume of the basalt of Anomaly U is about 3 km^3.

Anomaly JF-6 (Drill hole UE-25 VA-11, Total depth = 195.6 meters)

Anomaly JF-6 was drilled to investigate the origin a well-defined negative anomaly in Jackass Flats. Only alluvium was encountered before drilling was terminated at a depth of 196 meters (Appendix 1). This is the only drill hole that did not penetrate either basalt or tuff bedrock. The rational to terminate drilling was based the depth of the drill hole (i.e., basalt encountered below this burial depth would likely be Miocene age) and the relationship of the results of this drill hole to results in nearby drill holes. Five other drill holes in western Jackass Flats drilled to depths of at least 360 meters encountered either tuff bedrock or tuff colluvium, but no basalt (Figure 1). Drill hole JF-3, (not shown in Figure 1) is about 1.3 km west of drill hole JF-6 and encountered tuff bedrock at 146 m.

Anomaly G (Drill hole USW VA-2, Total depth = 144.9 meters)

Anomaly G was drilled to investigate the origin of three aligned negative aeromagnetic anomalies in the northern Amargosa Desert. Basalt was encountered beneath alluvium at a depth of 118.9 meters and the hole was stopped in basalt at a depth of 144.9 meters

(Appendix 1). Scoria in cuttings near the top of the basalt unit indicates the basalt of anomaly G is a lava flow. A Nye Country drill hole completed adjacent to this drill hole in April 2006 encountered basalt at a depth of 120.4 meters and the base of the basalt between 150.9 and 152.4 meters, demonstrating that the flow is about 31 meters thick.

The basalt of anomaly G has 5-10% phenocrysts of amphibole and 2-3% phenocrysts of olivine (Figure 6). The phenocryst assemblage of amphibole + olivine is observed at Little Cones and Red Cone, but amphibole is not a major phenocryst but rather rare and difficult to find, unlike the basalt of anomaly G. The identification of amphibole in the basalt of anomaly G has been confirmed by X-ray diffraction analysis. Nicholas and Rutherford (2004) demonstrated experimentally that amphibole + olivine is a stable high-pressure assemblage at temperatures of <975° C with > 3 wt% water dissolved in the melt.

Based on the similar magnetic characteristics of the aligned anomalies G, F, and H, and the results of drilling anomaly G, we conclude that all the anomalies likely represent basalt of similar age. Depth of burial indicates that the basalt of anomaly G may be older than the basalt of anomaly B to the east (3.8 Ma), but the age can only be ascertained by K-Ar dating.

Other Buried Basalts in Amargosa Desert

Basalt of Anomaly B

Anomaly B was penetrated by two exploration (oil and gas) drill holes completed in 1991 (Figure 5, drill holes FF25-1, FF5-1). Basalt was encountered in both holes at a depth of approximately 100 meters and a thickness of approximately 50-60 meters. With an area of about 12.5 km^2, the volume is about 0.7 km^3. The basalt of anomaly B has been dated at 3.85 Ma by Ar/Ar (Perry et al. 1998), which is within analytical error of ages determined for the Pliocene basalts in southeast Crater Flat.

Basalt of drill hole MSH-C

Drill hole MSH-C is located within a positive aeromagnetic anomaly about 15 km to the southeast of anomaly B (Figure 5). As reported in Reamer (1999), 8 meters of basalt was encountered at a depth of 149 meters. The basalt has a K-Ar date of 9.6±0.1 Ma (R. Fleck, USGS, unpublished), the same age as reported for the basalt of Anomaly U in Jackass Flats, indicating they are both are part of a widespread eruptive episode in Jackass Flats and the eastern Amargosa Desert.

Basalt of Anomalies C and D

Anomalies C and D have opposing magnetic polarities and are modeled at depths of 200 and 180 meters, respectively (Langenheim, 1995). Basalt was encountered in a pre-1963 water well at a depth of 178 meters immediately to the west of anomaly D (Figure 5). No age information is available for this basalt, but the depth of burial compared to basalts of anomaly B and drill hole MSH-C suggests a late Miocene age.

Synthesis

Drilling of Aeromagnetic Anomalies and the Extent and Age of Buried Basalt

Drilling results indicate that Miocene basalt is present as the early eruptive phase in both Crater Flat and Jackass Flats. While Pliocene and Quaternary basalt erupted in Crater Flat, there is no evidence of post-Miocene basaltic volcanism in Jackass Flats. Six deep drill holes in western Jackass Flats (J-12, J-13, JF-3, 10S, 22S, and JF-6), did not encounter basalt. Three drill holes farther east and south (JF-5, J-11 and 23P) in Jackass Flats encountered an extensive Miocene basalt unit (Figure 1 and 5). Based on the drilling results, in combination with interpretation of the aeromagnetic data, we conclude that no post-Miocene basalt has erupted in Jackass Flats.

With drill holes at anomalies B, I, O, and G, the extent of buried basalt in the northern Amargosa Desert is reasonably well constrained. Drilling of anomalies O and I demonstrate that some anomalies previously modeled as basalt are Miocene tuff. Most significantly, the proposed volcanic alignment represented by anomalies L, M, N, and O, which was modeled as an alignment of basalt bodies, represents faulted and buried tuff. The southern Amargosa Valley is less well characterized, but basalt of unknown age is known to be present at anomalies C/D, and Miocene basalt was encountered at drill hole MSH-C within a positive aeromagnetic anomaly in southeastern Amargosa Desert (Figure 5).

Currently, the only known buried post-Miocene basalt (ignoring partially buried basalts in Crater Flat) is at Anomaly B in northern Amargosa Desert (Figure 1). Of the four drill holes completed in the current program that encountered basalt, only the basalts at anomalies A and G have the potential to be of post-Miocene age. The simplest interpretation of anomalies F and H, aligned with anomaly G, is that these anomalies represent basalt of the same age as the basalt of anomaly G (age yet to be determined), based on similar magnetic characteristics (Figure 1). Ages of other anomalies (e.g., C and D) will be estimated based on new depth-of-burial models, ranges of sedimentation rates derived from ages of basalts of anomaly B, drill hole MSH-C, and anomaly G, and magnetic polarity.

Association between Faulting, Volcano Location, and Fault/Fissure Orientation

A primary observation from the 2004 aeromagnetic survey is the close association between Quaternary volcanoes and faults interpreted from the aeromagnetic data. This association was also interpreted from earlier high-resolution ground magnetic surveys (Connor et al. 2000). Analog field studies at eroded centers have also demonstrated that nearly all dikes occupy normal faults, indicating capture of dikes by faults in the shallow crust.

Although vent alignments in the Yucca Mountain region are commonly oriented to the northeast, fissures systems or faults that underlie several volcanic vents are oriented N-S or to the NNW. The fissure system (dikes and vents) of the 3.7 Ma basalts in southeastern Crater Flat is oriented slightly northwest. Lathrop Wells Cone lies at the intersection of NNW-trending and NE-trending faults (Figure 4a). While it is a reasonable interpretation that the feeder dike filled a fault plane, it is uncertain whether it filled a NNW or NE-trending fault plane. Elongation direction of the cone and the oxidation pattern within the cone have been cited as evidence of a NNW-trending feeder dike (Perry et al. 1998). Makani Cone and Black Cone are associated with N-S trending and NNW-trending faults, respectively, apparent in the aeromagnetic data (Figure 4b). At Makani Cone, a N-S fissure on the eastern half of the volcanic edifice provides evidence of the coincidence of the underlying fault and the fissure. The Sleeping Butte cones, which consist of two cones forming a NE-trending alignment, lie partly on Miocene tuff bedrock, and tuff bedrock is present between the cones. Faulting near and between these cones has a predominantly N-S orientation with no evidence of a connecting NE-trending structure.

If dikes are captured by faults in the shallow crust, what is the origin of N to NW-trending faults in the Yucca Mountain region? Ferrill et al. (1999) interpret NW-trending faults (excluding strike-slip faults) in Yucca Mountain as connecting faults that represent breaches in relay ramps connecting larger en-echelon NE-trending normal faults. The connecting faults strike obliquely to the major fault orientations and provide a mechanism for dike orientations that are oblique to the regional stress field, if these faults capture dikes in the shallow crust. Thus, dikes could have NW, N, or NE orientations depending on whether they are captured by major bounding faults or connecting faults, irrespective of the regional stress field (cf. Connor et al. 2000). The Solitario Canyon dike set is an example of a dike set that simultaneously filled fault planes of two orientations, N and NW. Thus it appears that local availability of fault planes in the shallow crust determined the final dike orientations instead of the regional stress field.

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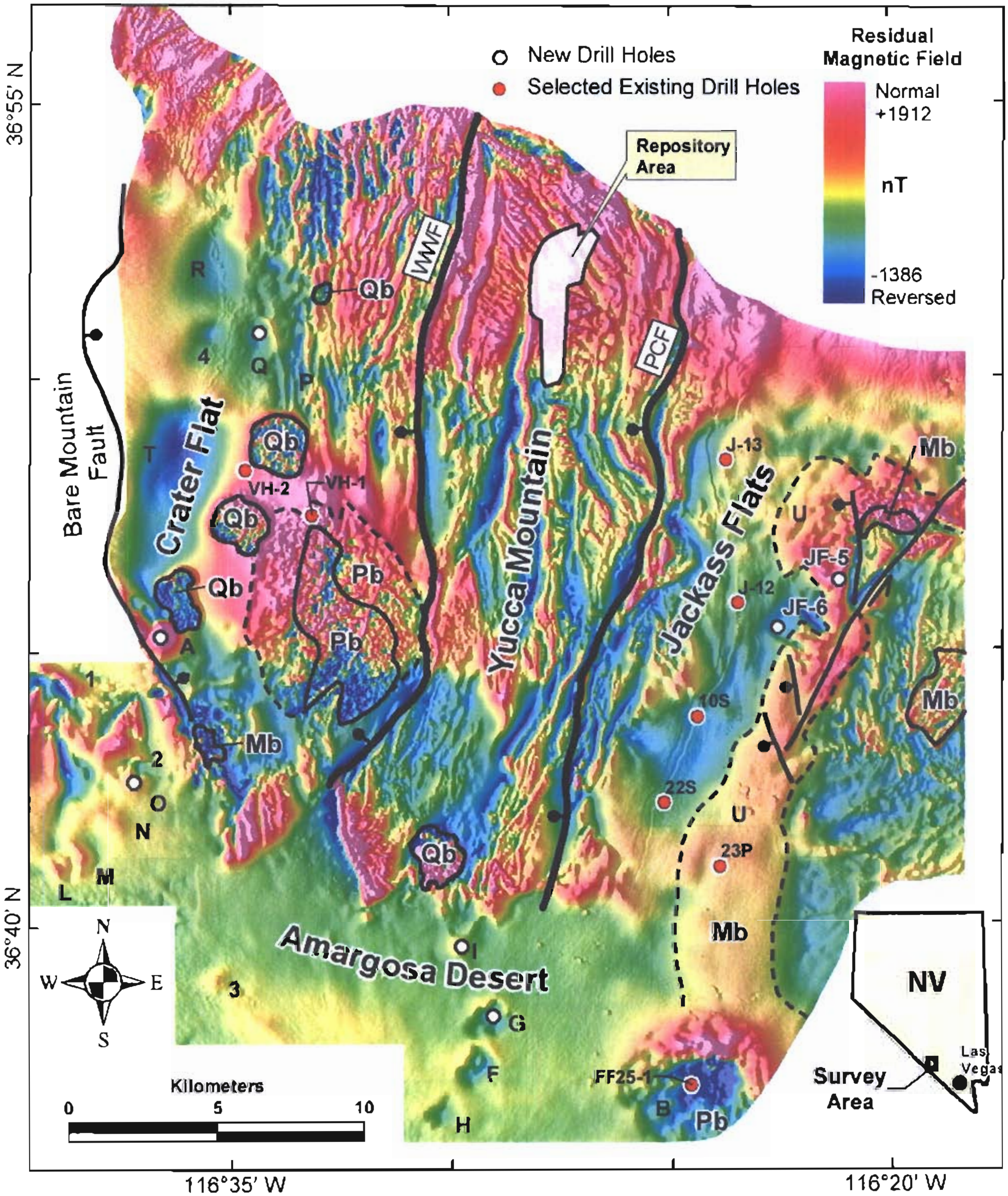


Figure 1. High-resolution aeromagnetic survey and locations of new drill holes near Yucca Mountain. Solid white circles indicate seven drill holes completed for the current drilling program. Solid red circles indicate selected pre-existing drill holes that provide key constraints on the location of buried basalt near Yucca Mountain. Qb=Quaternary Basalt, Pb=Pliocene basalt, Mb=Miocene basalt. Figure modified from Perry et al. (2005).

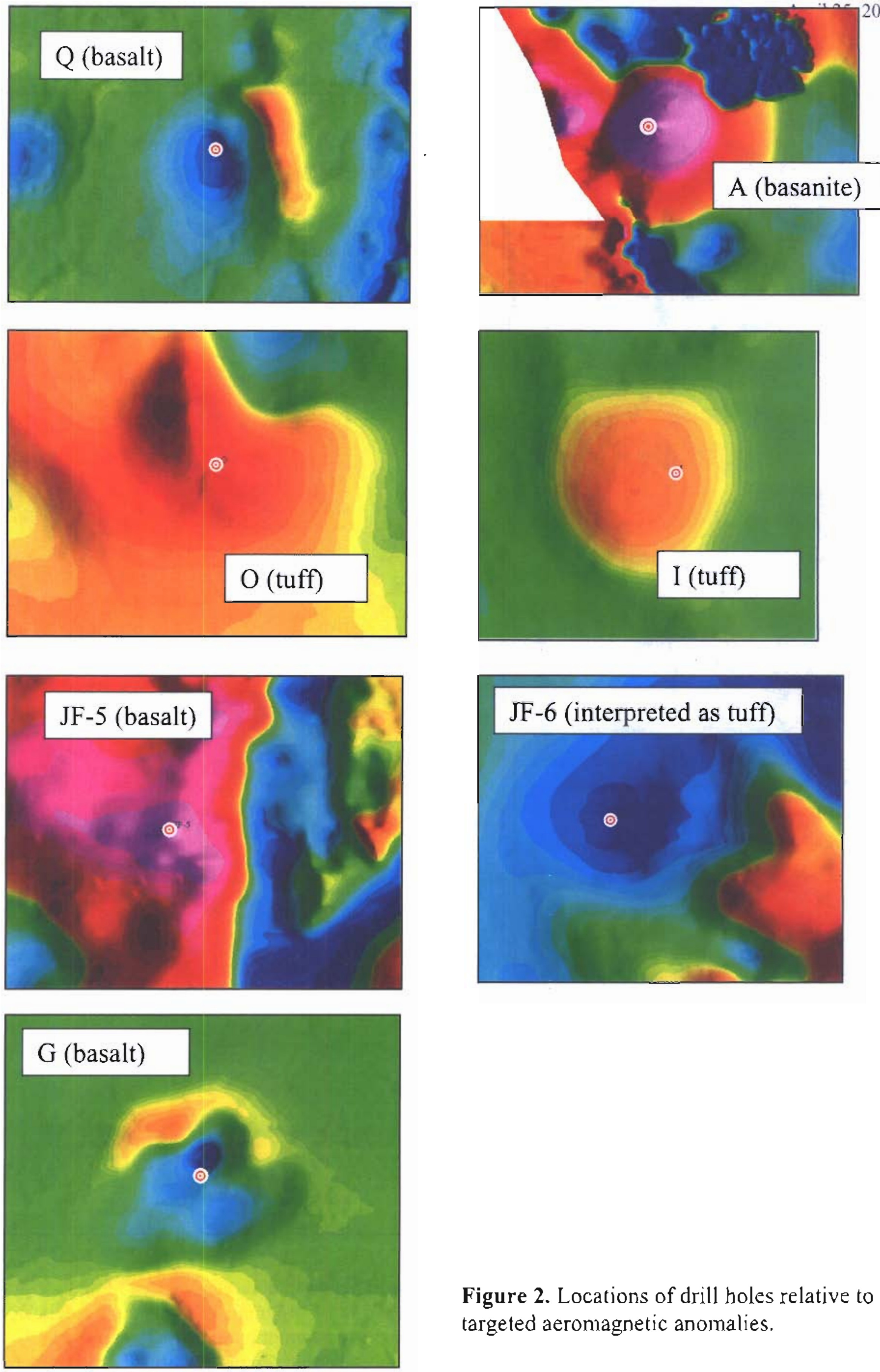


Figure 2. Locations of drill holes relative to targeted aeromagnetic anomalies.

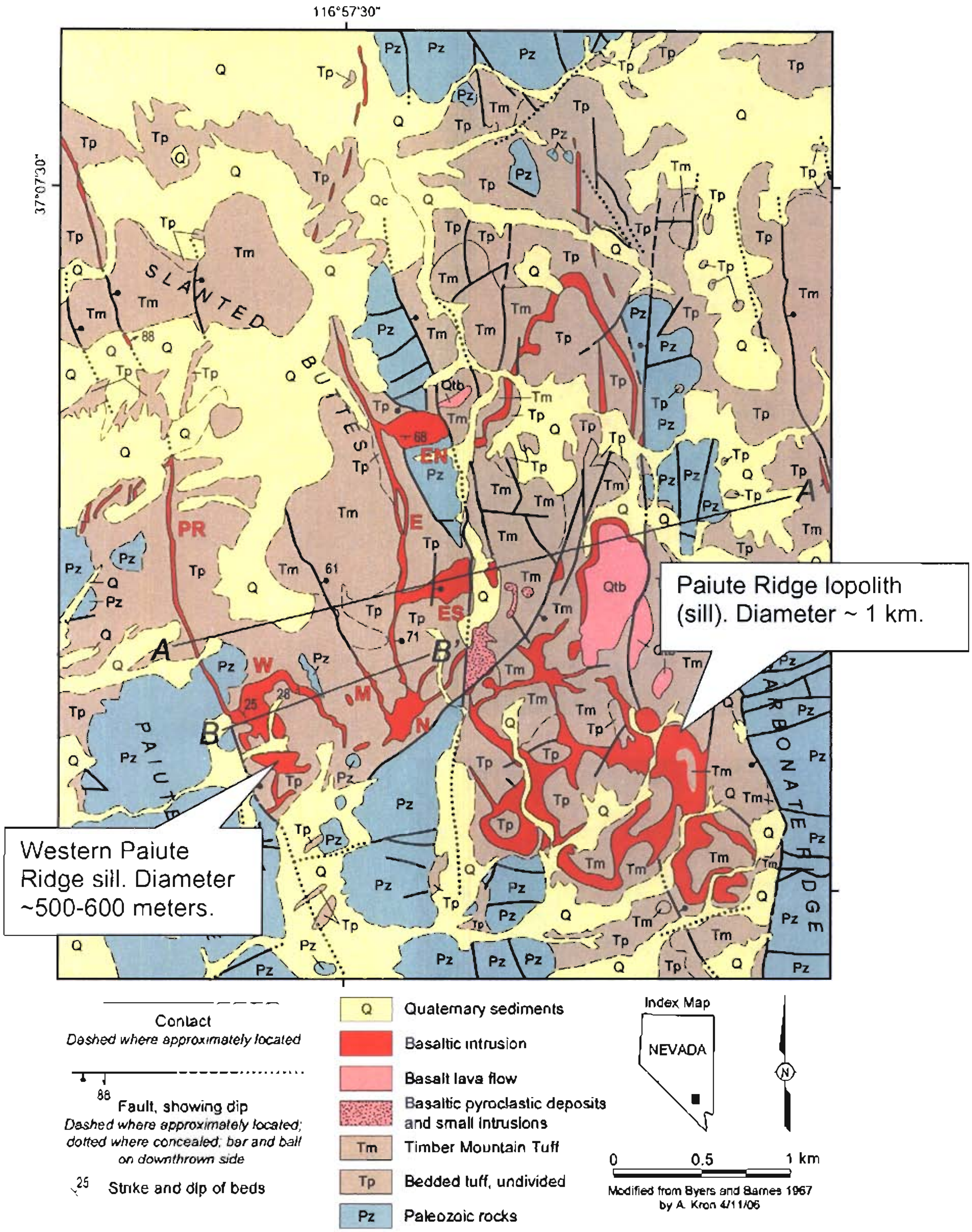
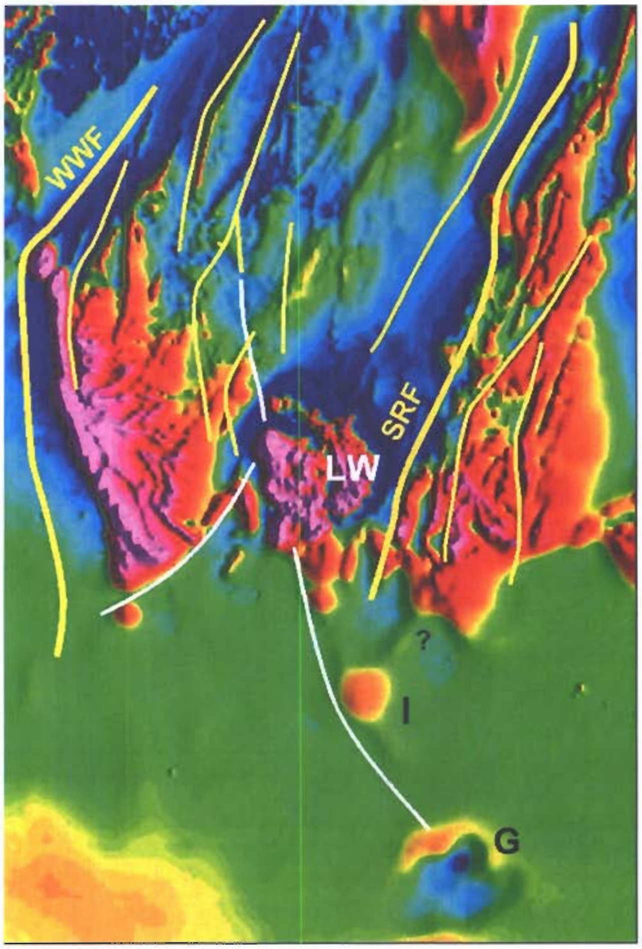
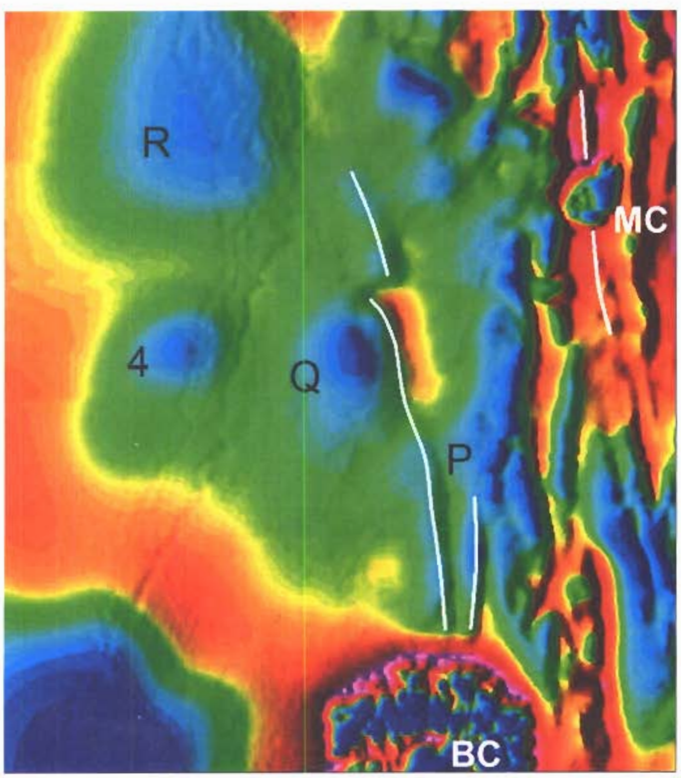


Figure 3. Paiute Ridge intrusive and eruptive complex, from a portion of the map of Byers and Barnes (1967). Red-shaded units within the Paiute Ridge lopolith are pods of coarse grained, differentiated basalts.



a)



b)

Figure 4. Fault relationships at Quaternary volcanoes. a). Black Cone and Makani Cone (white fault traces inferred from aeromagnetic data), b) Lathrop Wells cone (yellow fault traces generalized from Potter et al. (2002), white fault traces inferred from aeromagnetic data). LW=Lathrop Wells, BC=Black Cone, MC=Making Cone. Taken from presentation given by Frank Perry in Workshop 2 of the PVHA-U.

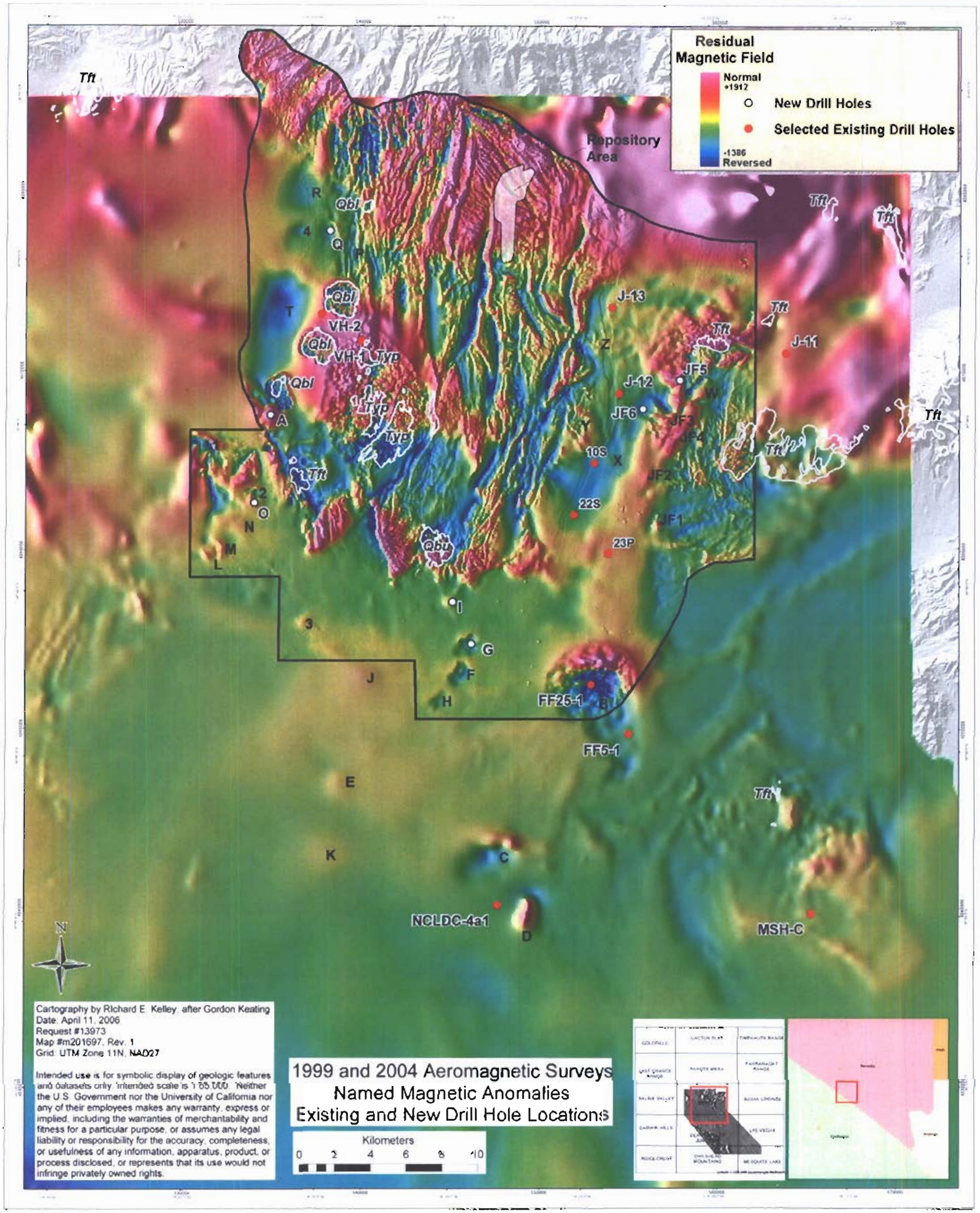
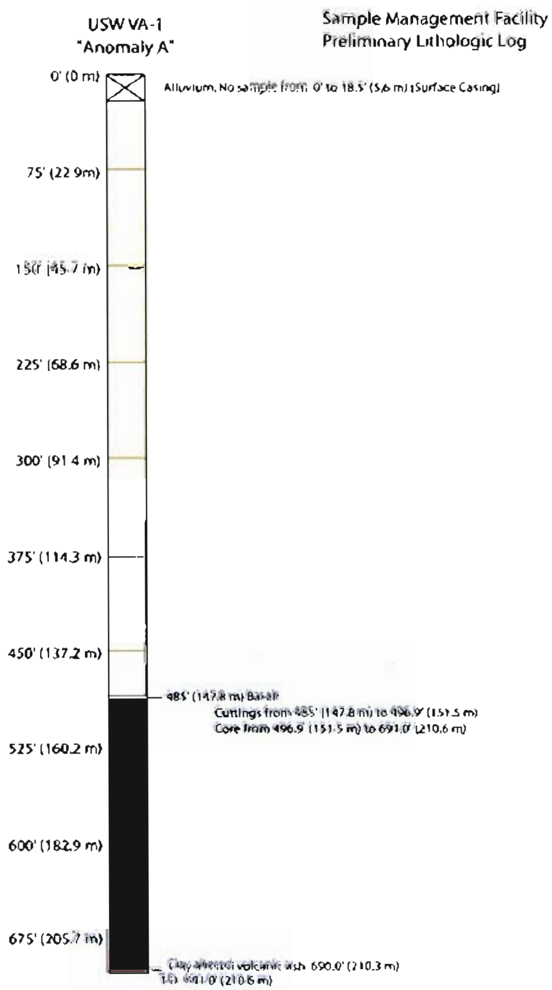
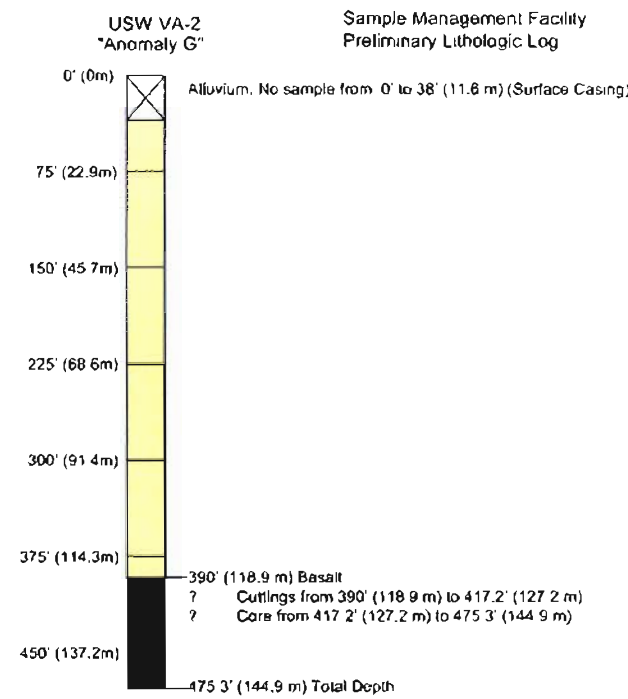


Figure 5. Combined 2004 and portion of 1999 aeromagnetic survey showing anomalies and drill holes in Crater Flat, Jackass Flats and Amargosa Desert. Qbu and Qbl = Quaternary basalt, Typ = Pliocene basalt, Tft = Miocene basalt.

Figure 6. Photograph of core of hornblende-olivine basalt of anomaly G. Diameter of core is 2.25 inches. Dark gray crystals are amphibole, rust-colored crystals are altered olivine.

Appendix 1: Preliminary Lithologic Contact Logs





Note: basalt in USW VA-1 is now classified as a basanite

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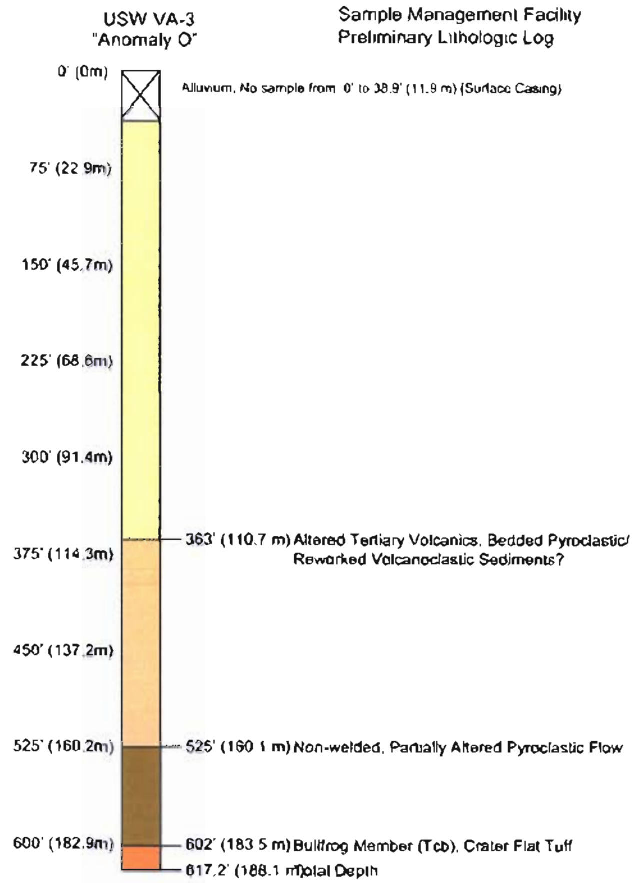

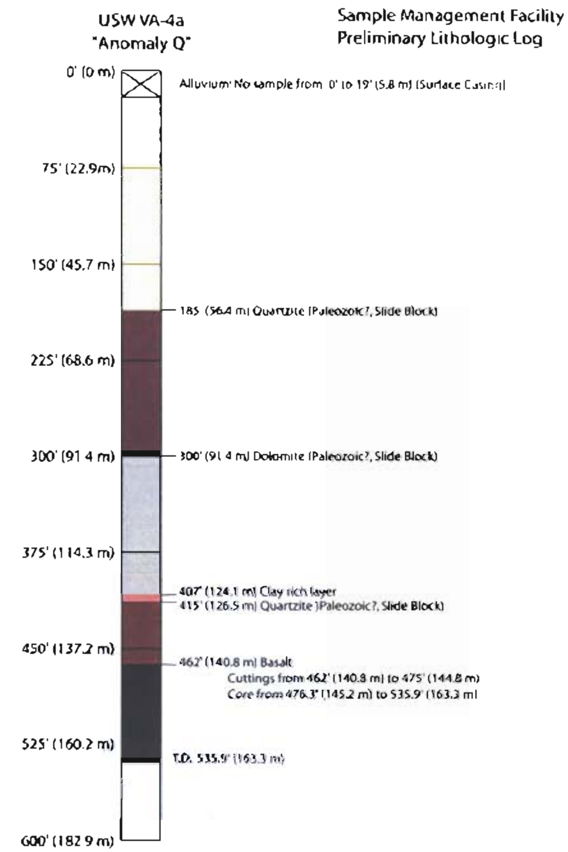

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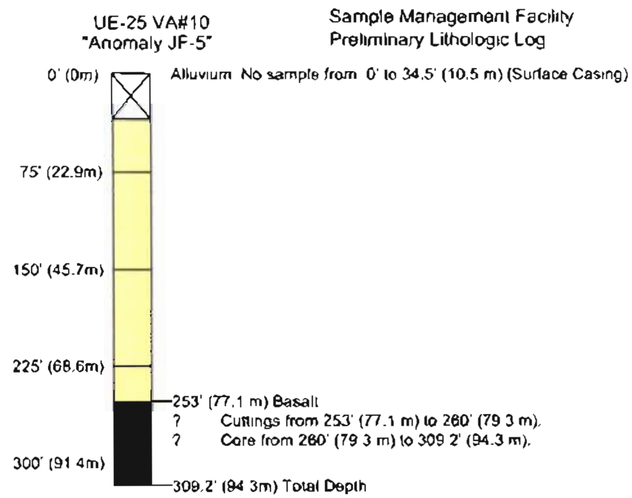

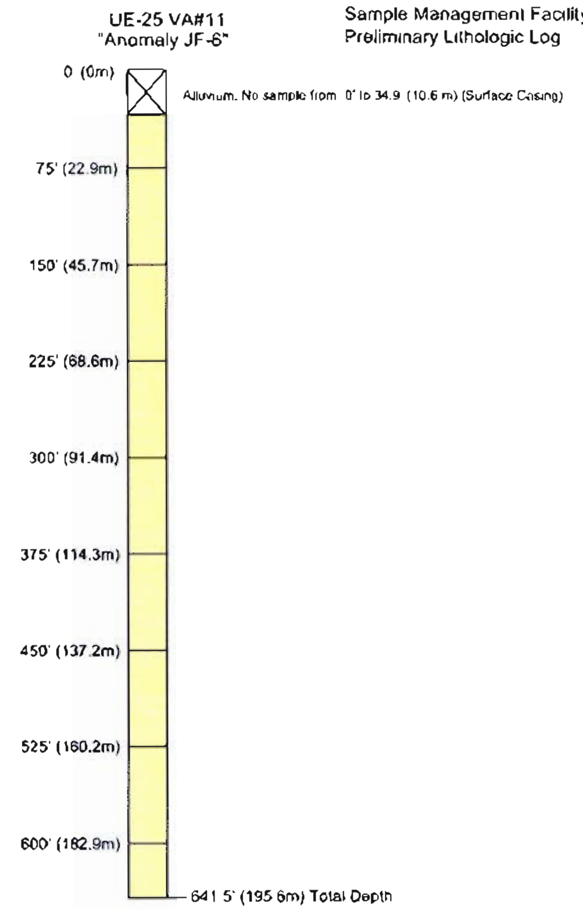

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