GP21A-0124

Magnetic Modeling of Buried Basalt Near the Potential Repository at Yucca Mountain, Nevada, Constrained by New Paleomagnetic, Rock Magnetic, and Petrographic Studies

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Background

1) Uncertainties in igneous activity probability affect risk calculations linearly.

2) The U.S. Department of Energy (DOE) sponsored a high-resolution aeromagnetic survey of the Yucca Mountain region in 2004 to support the expert elicitation on the number and age of basaltic intrusions in the area, and identify and characterize potential sites of buried basaltic intrusions.

◆ The survey was conducted using a helicopter with an average sensor elevation of 40–50 m [131–164 ft] above terrain.

3) Based on the aeromagnetic survey, DOE selected seven magnetic anomalies (A, G, I, JF5, JF6, O, and Q; Figure 1) to be drilled and cored. The drilling program was completed in 2006. Of the seven anomalies drilled, four encountered basalt (A, G, JF5, and Q; Table 1 and Figure 2).

Objective

● Perform an independent analysis (Stamatakos, et al., 2007) of the new aeromagnetic and drilling data to constrain the geometry of subsurface sources of the magnetic anomalies.

◆ Conduct rock magnetic and paleomagnetic studies of core samples (Figures 3 - 5), petrographic analyses of thin sections of the basalt samples (Figure 6), and detailed 2D forward modeling (Table 2 and Figures 7 - 14).

Location

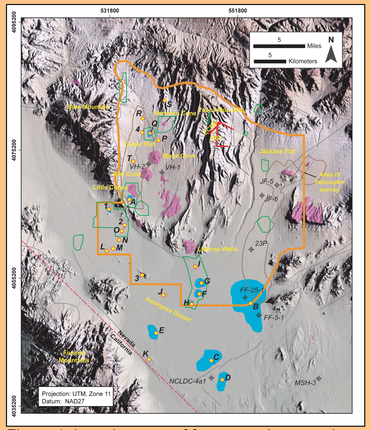

Figure 1. Location map of features relevant to igneous activity studies. Base map is a colorized shaded relief digital elevation model based on 1 m [3.3 ft] digital elevation data. Orange outline delineates the DOE aeromagnetic survey area. Green outlines show location of Center for Nuclear Waste Regulatory Analyses ground magnetic surveys (Magsino, et al., 1998). Purple shading shows exposures of basalt. Blue shading shows location of buried basalt based on aeromagnetic data or drilling information.

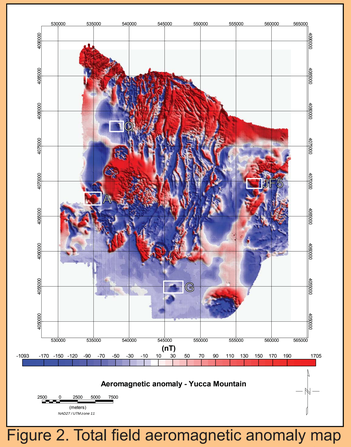

Figure 2. Total field aeromagnetic anomaly map around Yucca Mountain, Nevada, gridded at approximately 40–50 m [131–164 ft] above ground surface based on data from DOE aeromagnetic survey. The white rectangles show anomalies A, G, JF5, and Q.

Rock Magnetic and Paleomagnetic Studies

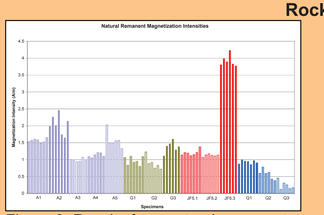

Figure 3. Results from natural remanent magnetization (NRM) measurements for basalt specimens from anomalies A, G, JF5, and Q.

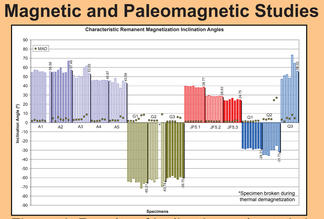

Figure 4. Results of inclination-only statistics of characteristic remanent magnetization for basalt specimens after demagnetization from anomalies A, G, JF5, and Q. Bars with shadows denote the estimated characteristic inclination angles for the anomalies. MAD - Mean angular deviation

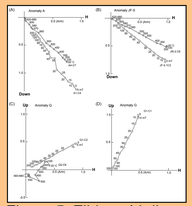

Figure 5. Zijderveld diagrams showing thermal (grey circles) and alternating field (white circles) demagnetization of basalt samples.

Results: Anomaly A and 2D Model

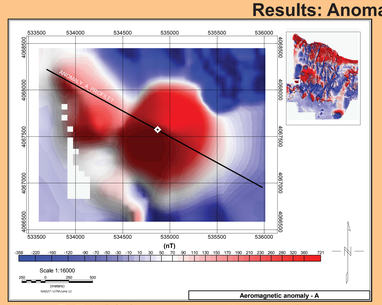

Figure 7. Total field aeromagnetic anomaly A showing borehole location and profile location for two-dimensional (2D) modeling.

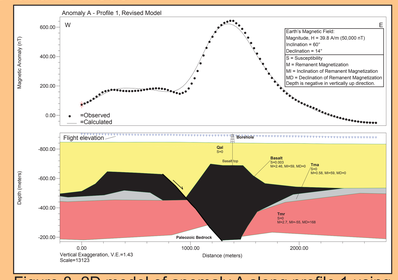

Figure 8. 2D model of anomaly A along profile 1 using measured values (Table 2). Qal - Quaternary alluvium, Tma - Ammonia Tanks Tuff, Tmr - Rainier Mesa Tuff.

Results: Anomaly G and 2D Model

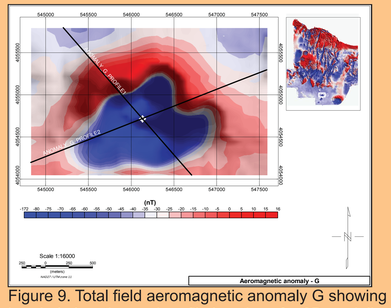

Figure 9. Total field aeromagnetic anomaly G showing borehole location and profile locations for 2D modeling.

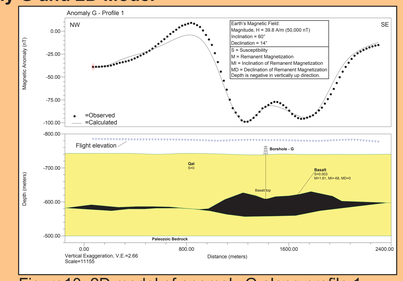

Figure10. 2D model of anomaly G along profile 1. Qal - Quaternary alluvium.

Results: Anomaly JF5 and 2D Model

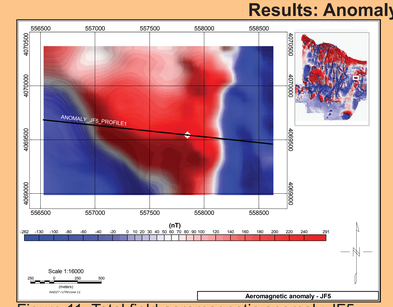

Figure 11. Total field aeromagnetic anomaly JF5 showing borehole location and profile location for 2D modeling.

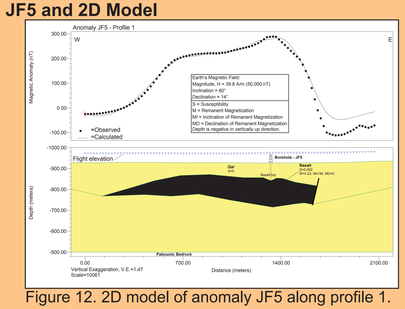

Figure 12. 2D model of anomaly JF5 along profile 1. Qal - Quaternary alluvium.

Results: Anomaly Q and 2D Model

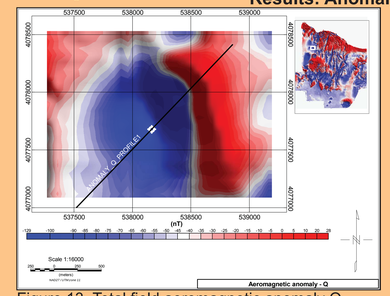

Figure 13. Total field aeromagnetic anomaly Q showing borehole location and profile location for 2D modeling.

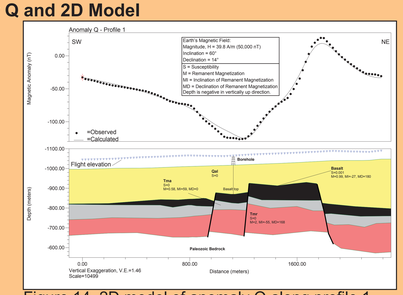

Figure 14. 2D model of anomaly Q along profile 1. Qal - Quaternary alluvium, Tma - Ammonia Tanks Tuff, and Tmr - Rainier Mesa Tuff.

Table 1. DOE Data From Boreholes*

Anomaly	Depth	Interpreted Anomaly Source	Ages (Ma)†	Notes
A	148–211 m [586–692 ft]	Basalt	10.08 ± 0.02 10.04 ± 0.02	Lack of flow features and thickness suggest the body may be a sill
Q	140–163 m [459–535 ft]	Basalt	11.07 ± 0.2 10.80 ± 0.5	Four lava flows separated by breccia and scoria
G	119–145 m [390–476 ft]	Basalt	3.74 ± 0.21 3.99 ± 0.22	Scoria at top and bottom of flow
JF5	77–94 m [253–308 ft]	Basalt	9.4 ± 0.2	Correlates with J-11 and 23P
I	163–200 m [535–656 ft]	Tuff	not dated	Faulted tuff consistent with fissure at Lathrop Wells cone
O	163–188 m [535–617 ft]	Faulted tuff	not dated	Bullfrog tuff at base
JF6	196 m [643 ft]	Faulted tuff	not dated	Basalt may be deeper, but DOE concluded that basalt encountered below 200 m [656 ft] would be older than 5.3 Ma

*Perry, F., A. Cogbill, R. Kelly, M. Cline, C. Lewis, and R. Fleck. "Status and Interpretation of Aeromagnetic Survey and Drilling Program to Support Probabilistic Volcanic Hazard Analysis–Update." Transcripts of the 172ND Advisory Committee on Nuclear Waste Meeting, Rockville, Maryland, July 17, 2006. ML062090096. pp. 1–164. 2006.
†Ma is million of years before present.

Table 2. Source Parameters for Magnetic Anomaly Models

Anomaly	Unit	χ* (SI)	Inc† (°)	Dec‡ (°)	M§ (A/m)
A	Quaternary Alluvium (Qal)	0	–	–	0
	Basalt	0.003	59°	0°	2.46
	Ammonia Tanks Tuff (Tma)	0	59°	0°	0.58
	Rainier Mesa Tuff (Tmr)	0	−55°	168°	2.7
G	Quaternary Alluvium (Qal)	0	–	–	0
	Basalt	0.003	−68°	0°	1.61
JF5	Quaternary Alluvium (Qal)	0	–	–	0
	Basalt	0.002	38°	0°	4.23
Q	Quaternary Alluvium (Qal)	0	–	–	0
	Basalt	0.001	−27°	180°	0.99
	Ammonia Tanks Tuff (Tma)	0	59°	0°	0.58
	Rainier Mesa Tuff (Tmr)	0	−55°	168°	2

χ* is the volume susceptibility.
† Inc is the inclination angle of the remanent magnetization vector.
‡ Dec is the declination angle of the remanent magnetization vector with respect to north. Note that in the absence of measured declinations, declinations were assumed to be north for normal-polarity inclinations and south for reversed-polarity inclinations.
§ M is intensity of the remanent magnetization.

Petrographic Thin Sections

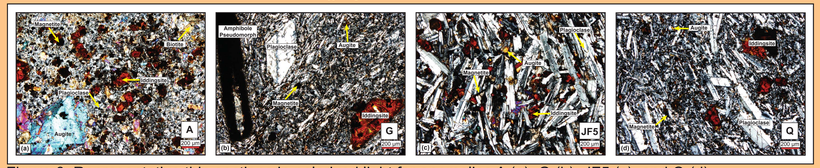

Figure 6. Representative thin sections in polarized light for anomalies A (a), G (b), JF5 (c), and Q (d).

Conclusions

1) The subsurface geometry of aeromagnetic anomaly A appears consistent with a basaltic sill or large eroded conduit, which are basalt features not exposed in the surrounding area.

◆ Basalt of anomaly A has smaller groundmass crystals than basalt from other anomalies.

◆ Biotite phenocrysts in anomaly A basalt support the interpretation of an intrusion.

2) Subsurface geometries consistent with nearby basaltic lava exposures can be modeled for aeromagnetic anomalies G, JF5, and Q using measured magnetic characteristics.

◆ Fault offsets in models for anomalies JF5 and Q appear consistent with 9–11Ma dates.

3) Abundant relict amphibole phenocrysts in anomaly G Basalt are not observed in contemporaneous surface exposures in nearby Crater Flat, indicating at least 2 distinct magma types were erupted at approximately 3.8 Ma.

4) The basalt samples carry a strong remanent magnetization that dominates over susceptibility.

◆ Demagnetization of the samples shows little evidence for thermo-chemical or viscous remanent magnetization overprints.

◆ Hysteresis experiments results (Stamatakos, et al., 2007) indicate pseudo-single domain field for magnetite.

References

Magsino, S.L., C.B. Connor, B.E. Hill, J.A. Stamatakos, P.C. La Femina, D.A. Sims, and R.H. Martin. "CNWRA Ground Magnetic Surveys in the Yucca Mountain Region, Nevada (1996-1997)." CNWRA 98-001. San Antonio, Texas: CNWRA. 1998.

Stamatakos, J. A., S. Biswas, M. Silver. "Supplemental Evaluation of Geophysical Information Used to Detect and Characterize Buried Volcanic Features in the Yucca Mountain Region." CNWRA 02-012. San Antonio, Texas: CNWRA. 2007.

Acknowledgments

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Backup Figures

Location

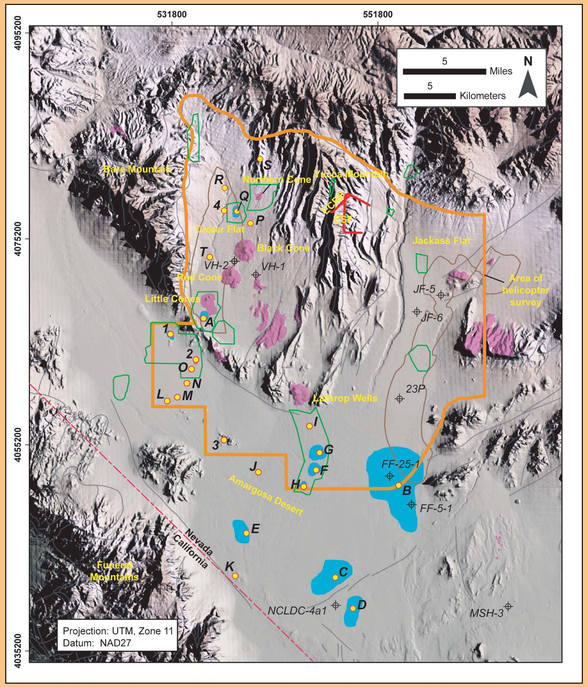

Figure A-1. Location map of features relevant to igneous activity studies. Base map is a colorized shaded relief digital elevation model based on 1 m [3.3 ft] digital elevation data. Orange outline delineates the DOE aeromagnetic survey area. Green outlines show location of Center for Nuclear Waste Regulatory Analyses ground magnetic surveys (Magsino, et al., 1998). Purple shading shows exposures of basalt. Blue shading shows location of buried basalt based on aeromagnetic data or drilling information.

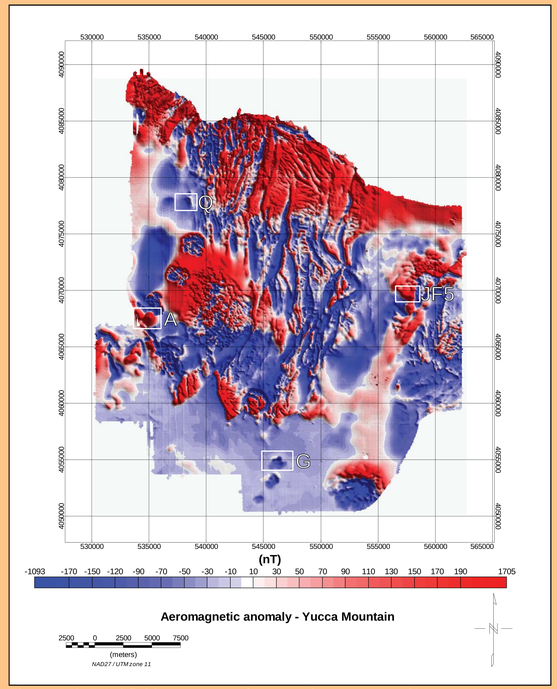

Figure A-2. Total field aeromagnetic anomaly map around Yucca Mountain, Nevada, gridded at approximately 40–50 m [131–164 ft] above ground surface based on data from DOE aeromagnetic survey. The white rectangles show anomalies A, G, JF5, and Q.

Results: Anomaly A and 2D Models

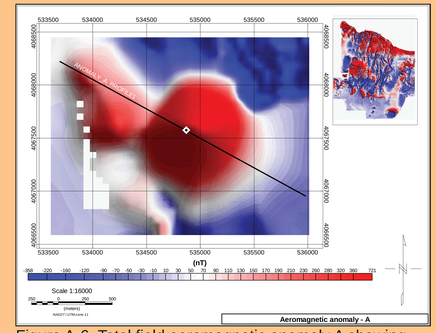

Figure A-6. Total field aeromagnetic anomaly A showing borehole location and profile location for two-dimensional (2D) modeling.

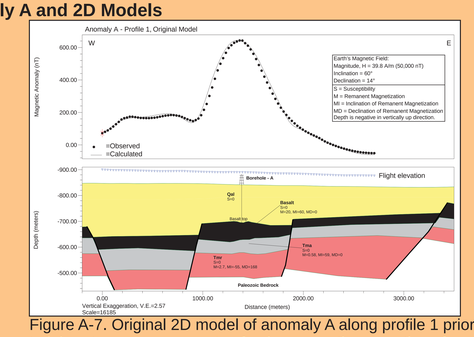

Figure A-7. Original 2D model of anomaly A along profile 1 prior to laboratory measurements of paleomagnetic properties of basalt samples from anomaly A borehole. Qal - Quaternary alluvium, Tma - Ammonia Tanks Tuff, Tmr - Rainier Mesa Tuff.

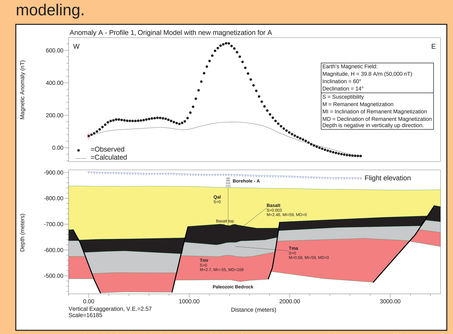

Figure A-8. Original 2D model of anomaly A along profile 1 with new intensity of basalt showing the misfit between observed and calculated anomaly. Qal - Quaternary alluvium, Tma - Ammonia Tanks Tuff, Tmr - Rainier Mesa Tuff.

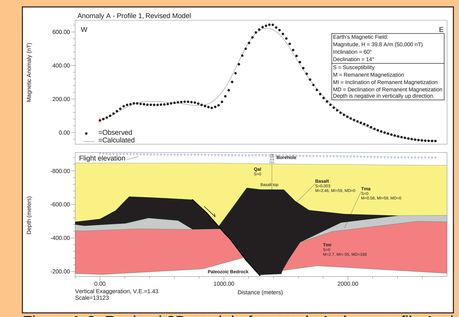

Figure A-9. Revised 2D model of anomaly A along profile 1 with new intensity of basalt. Qal - Quaternary alluvium, Tma - Ammonia Tanks Tuff, Tmr - Rainier Mesa Tuff.

Results: Anomaly G and 2D Model

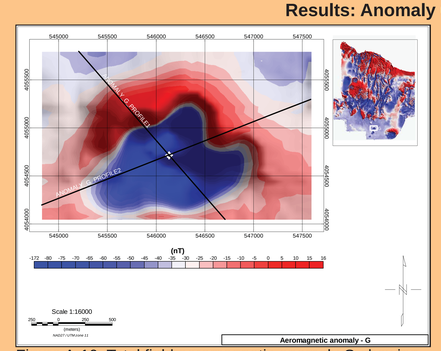

Figure A-10. Total field aeromagnetic anomaly G showing borehole location and profile locations for 2D modeling.

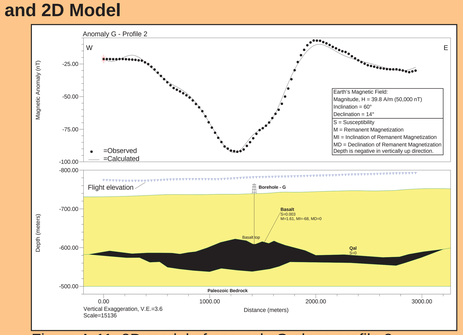

Figure A-11. 2D model of anomaly G along profile 2. Qal - Quaternary alluvium.

Rock Magnetic and Paleomagnetic Studies

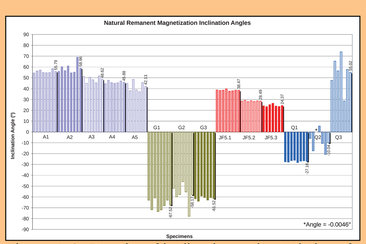

Figure A-3. Results of inclination-only statistics of NRM for basalt specimens from anomalies A, G, JF5, and Q. Bars with shadows denote the estimated inclination angles for the anomalies.

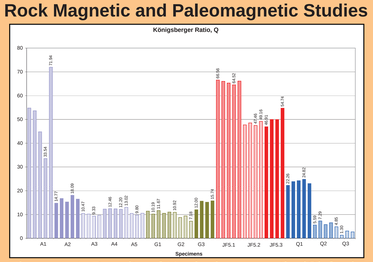

Figure A-4. Results of Königsberger ratio (Q) for basalt specimens from anomalies A, G, JF5, and Q.

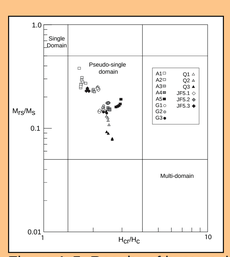

Figure A-5. Results of hysteresis experiments on a Day plot.