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Geophysical Characterization of Mineral and Energy Resources at Yucca Mountain and Vicinity, Nevada

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INTRODUCTION

This report was prepared for the Yucca Mountain Project (Department of Energy) as part of the study of the mineral and energy resource potential of the site (Activity 8.3.1.9.2.1.5) under the Human Interference part of the program. Most of the 1991 geophysical scoping activities in the Mineral Resources Study were involved with the acquisition and evaluation of existing data. This report presents an overview of how geophysical data (existing and planned) will aid in the evaluation of the potential for mineral and energy resource potential at Yucca Mountain and vicinity.

In the assessment and the exploration for mineral resources, geophysics along with geology and geochemistry constitute a triumverate association required for the identification and classification of favorable areas for undiscovered mineral deposits. Geophysical methods play a particularly important role in current exploration and assessment of mineral resources because, short of drilling, they provide direct and indirect measurement of a wide range of physical properties or contrasts that are important for evaluation of mineral and energy potential. Geophysical data have relevance at all scales of investigation, ranging from the regional scale for identification of terranes and large structures that have a high potential for mineralization, to very local scales, borehole geophysics being one example. Although relatively few geophysical methods directly detect particular types of mineral deposits, geophysics can identify structures, lithologies, and alteration, which may then be used to infer potential mineralization. Geological, geochemical, and some geophysical methods are able to provide informaton at shallow depths through cover. These methods rely on extrapolation to infer conditions at depth. The deep-looking geophysical methods are especially important at Yucca Mountain because (1) they provide important constraints for extrapolation of geologic and geochemical data and (2) any potential significant mineralization is in the subsurface.

Modern assessment and exploration work is being aided by the codification of experience into discrete descriptions of mineral deposit models such as those presented by Cox and Singer (1986). These deposit models present what are believed to be the essential features of a particular class of deposits, and are descriptive in nature but due to our limited knowledge do not necessarily reflect the genetic parameters, due to our limited knowledge. These models will play an important role in the assessment work to be done. Unfortunately, models published to date have very limited information on geophysical attributes of the individual deposit models. This problem is being addressed, but these limitations of the existing deposit models need to be considered.

DESCRIPTION OF GEOPHYSICAL METHODS

One of the geophysical methods that can directly detect particular types of mineral deposits is gamma-ray spectrometry. Aerial and ground gamma-ray surveys measure the gamma radiation emitted by radioisotopes at and near the surface of the ground. These measurements are sensitive to naturally-occurring radioisotopes, particularly the members of the uranium-238 decay series, thorium-232 decay series, and potassium-40. Gamma-ray spectrometry is thus capable of locating uranium deposits if the deposit is near the surface or intercepted by a borehole. This method is also capable of detecting artificial isotopes such as cesium-137 and cobalt-60 that result from human activities.

Another geophysical method capable of directly detecting a particular type of mineral deposit is induced polarization (IP). The method measures the extra voltage (overvoltage) needed to drive an electric current through materials containing metallic minerals. The ratio between the amplitude of the overvoltage before and after the moment the current is stopped gives a measure of the concentration of metallic minerals in the material through which the current flows. Thus, induced polarization can detect sulfide deposits and has been extensively used in the search for disseminated sulfide ores by mining companies since the 1960's (Dobrin and Savit, 1988).

Most geophysical methods, however, provide only indirect evidence for the presence of mineral and energy deposits, which when combined with necessary geologic and geochemical information, can identify terrains or regions where the probability of mineral occurrence is likely. For example, mineralization often occurs in fault zones. Gravity and magnetic methods can often detect subsurface faults because the faults have juxtaposed rocks of different densities or magnetic susceptibilities. The resulting gradients in the gravity and magnetic fields indicate possible targets for mineral deposits. Faults may also be imaged with seismic methods. Seismic reflection and refraction methods are useful in determining the subsurface geometry under Yucca Mountain and vicinity. Seismic reflection has shown the existence of faulted blocks mostly buried by alluvium under Amargosa Valley (Oliver and others, 1990, p. 72). The integrated use of the seismic and potential field methods can pinpoint buried fault systems that may have associated mineralization.

Geophysical methods are important in defining the extent of buried intrusives which may be the source of mineralization, or constitute a heat source for a hydrothermal system to transport and deposit minerals in favorable host rocks. Paleozoic calcareous rocks present below the volcanic rocks at Yucca Mountain could host a variety of deposit types, as could various lithologies along detachment and related listric faults in the region. Certain mineral deposits, such as porphyry copper, molybdenum, gold, and skarn deposits, are often spatially associated with felsic intrusives. These plutons tend to be fairly magnetic, but not very dense. Thus, the combination of a gravity low and magnetic high may delineate possible buried plutons, which then may be associated with mineral deposits.

PREVIOUS WORK

A large body of geophysical literature is available for Yucca Mountain and vicinity, but little of it has been obtained for the express purpose of mineral assessment. This large amount of data constitutes an important resource for assessment investigations, but it needs to be evaluated in terms of its significance to potential mineralization with close coordination with relevant geologic and geochemical data.

Mineralization in the vicinity of Yucca Mountain has been known and described for many years (Ball, 1906; 1907; Cornwall, 1972), but this early literature does not include references to geophysical studies if any were made. The recent literature, while not directly addressing mineralization, does make reference to indications of potential mineralization in a few cases. Hoover and others (1982) and Ponce (1984) presented IP, gravity and magnetic studies in the Wahmonie area (Fig. 1). A strong IP response combined with evidence for extensive alteration in the surrounding volcanics suggests the likelihood of a porphyry system at depth below Wahmonie, the site of the Hornsilver Mine operating prior to World War II. One question that geophysics can help answer is whether this system extends westward along the axis of a mostly buried intrusive to Yucca Mountain in a manner analogous to the distribution of mineralization at the Twin Ridge pluton (Maldonado, 1981). A magnetic anomaly does trend from the Wahmonie-Calico Hills area west to Yucca Mountain. This anomaly has been interpreted both as a buried intrusive and as altered Eleana argillite metamorphosed by an intrusive body at greater depth (Kane and Bracken, 1983; Bath and Jahren, 1984; Baldwin and Jahren, 1982). Both interpretations indicate potential for mineralization below Yucca Mountain, though without additional data the significance for resource potential cannot be evaluated. On the basis of magnetic data, Kane and Webring (1981) have suggested that alteration may also be present in the central graben of Timber Mountain.

The possibility of past hydrothermal activity at Yucca Mountain is supported by existing drill core data. Maldonado and Koether (1983) note the presence of barite, fluorite, calcite, chlorite and pyrite in lavas in drill hole G-2, suggesting hydrothermal alteration. Fluorite and pyrite are also common in Paleozoic dolomites from drill hole UE25P#1 (Carr and others, 1986). Existing geophysical data in these drill holes need to be examined very closely to detemine whether geophysical evidence for the observed alteration exists and if so, what evidence there may be for its presence in other drill holes.

In-hole gamma-ray spectrometric data have been acquired in many of the drill holes but used only for correlation of lithologies. These data are invaluable in providing evidence for movement of potassium, uranium, and thorium either into or out of the rock units at Yucca Mountain. D. Muller (oral commun., 1988) has observed high potassium values at the top and bottom of the Bullfrog member of the Crater Flat Tuff in some areas, possibly indicating potassium-metasomatism.

Airborne gamma-ray data exist for the Yucca Mountain area and were obtained as part of the National Uranium Resource Evaluation (NURE) program at a 1- and 3-mile line spacing. These data have apparently not been considered in previous studies at Yucca Mountain. The area covered by the 1-mile spaced data include mineralized areas west of Yucca Mountain and the Calico Hills-Wahmonie region to the east, and warrant examination and analysis.

CONCLUSION

Geophysical methods, integrated with geologic and geochemical data, can help constrain the likelihood of mineralization in the vicinity of Yucca Mountain. Although most geophysical methods do not yield a direct measurement of mineralization, geophysics can define areas with higher potential for mineralization. Because geophysical methods can delineate the subsurface geometry of various physical properties, the assessment of mineral deposits within the Paleozoic section (below the potential repository depth) will rely heavily on the interpretation of borehole and geophysical data. Although geophysical methods may have difficulty in defining relatively small or localized structures at great depth, the maximum depth at which modeled structures can be defined can be calculated using estimates of physical property contrasts.

REFERENCES

Baldwin, M.J., and Jahren, C.E., 1982, Magnetic properties of drill core and surface samples from the Calico Hills area, Nye County, Nevada: U.S. Geological Survey Open-File Report 82-536, 27 p. (NNA.920219.0005)

Ball, S.H., 1906, Notes on ore deposits of southwestern Nevada and eastern California: U.S. Geological Survey Bulletin 285, p. 53-73. (NNA.920219.0006)

Ball, S.H., 1907, A geologic reconnaisance in southwestern Nevada and eastern California: U.S. Geological Survey Bulletin 308, 218 p. (NNA.920228.0002)

Bath, G.D., and Jahren, C.E., 1984, Investigations of an aeromagnetic anomaly on the west side of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-120, 40 p. text + 4 plates. (NNA.870323.0194)

Carr, M.D., Waddell, S.J., Vick, G.S., Stock, J.M., Monsen, S.A., Harris, A.G., Cork, B.W., Byers, F.M., Jr., 1986, Geology of drill hole UE25P#1: A test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada: U.S. Geological Survey Open-File Report 86-175, 87 p., 1 plate. (HQS.880517.2633)

Cornwall, H.R., 1972, Geology and mineral deposits of southern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 77, 49 p., 2 plates. (HQS.880517.1128)

Cox, D.P., and Singer, D.A., Editors, 1986, Mineral deposit models: U.S. Geological Survey Bulletin 1693, 379 p. (NNA.920219.0007)

Dobrin, Milton B., and Savit, Carl, H., 1988, Introduction to Geophysical Prospecting (4th ed.): McGraw-Hill, Inc., New York, New York, 867 p.

Hoover, D.B., Chornack, M.P., Nervick, K.H., and Broker, M.M., 1982, Electrical studies at the proposed Wahmonie and Calico Hills nuclear waste sites, Nevada Test Site, Nye County, Nevada: U.S. Geological Survey Open-File Report 82-466, 95 p. (NNA.890531.0060)

Kane, M.F., and Bracken, R.E., 1983, Aeromagnetic map of Yucca Mountain and surrounding regions, southwest Nevada: U.S. Geological Survey Open-File Report 83-616, scale 1:48,000, 20 p. (HQS.880517.1290)

Kane, M.F., and Webring, M.W., 1981, A preliminary analysis of gravity and aeromagnetic surveys of the Timber Mountain area, southern

Nevada: U.S. Geological Open-File Report 81-189, 40 p., 6 plates. (HQS.880517.2727)

Maldonado, Florian, 1981, Geology of the Twinridge pluton area, Nevada Test Site, Nevada: U.S. Geological Open-File Report 81-156, 33 p. (NNA.890511.0099)

Maldonado, Florian, and Koether, S.L., 1983, Stratigraphy, structure, and some petrographic features of Tertiary volcanic rocks at the USW G-2 drill hole, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 83-732, 93 p. (NNA.870506.0143)

Oliver, H.W., Hardin, E.L., and Nelson, P.H., 1990, Status of data, major results, and plans for geophysical activities, Yucca Mountain Project: U.S. Department of Energy Report YMP/90-38, 231 p. (NNA.900112.0097)

Ponce, D.A., 1984, Gravity and magnetic evidence for a granitic intrusion near Wahmonie site, Nevada Test Site, Nevada: Journal of Geophysical Research, v. 89, p. 9401-9413. (NNA.920219.0008)

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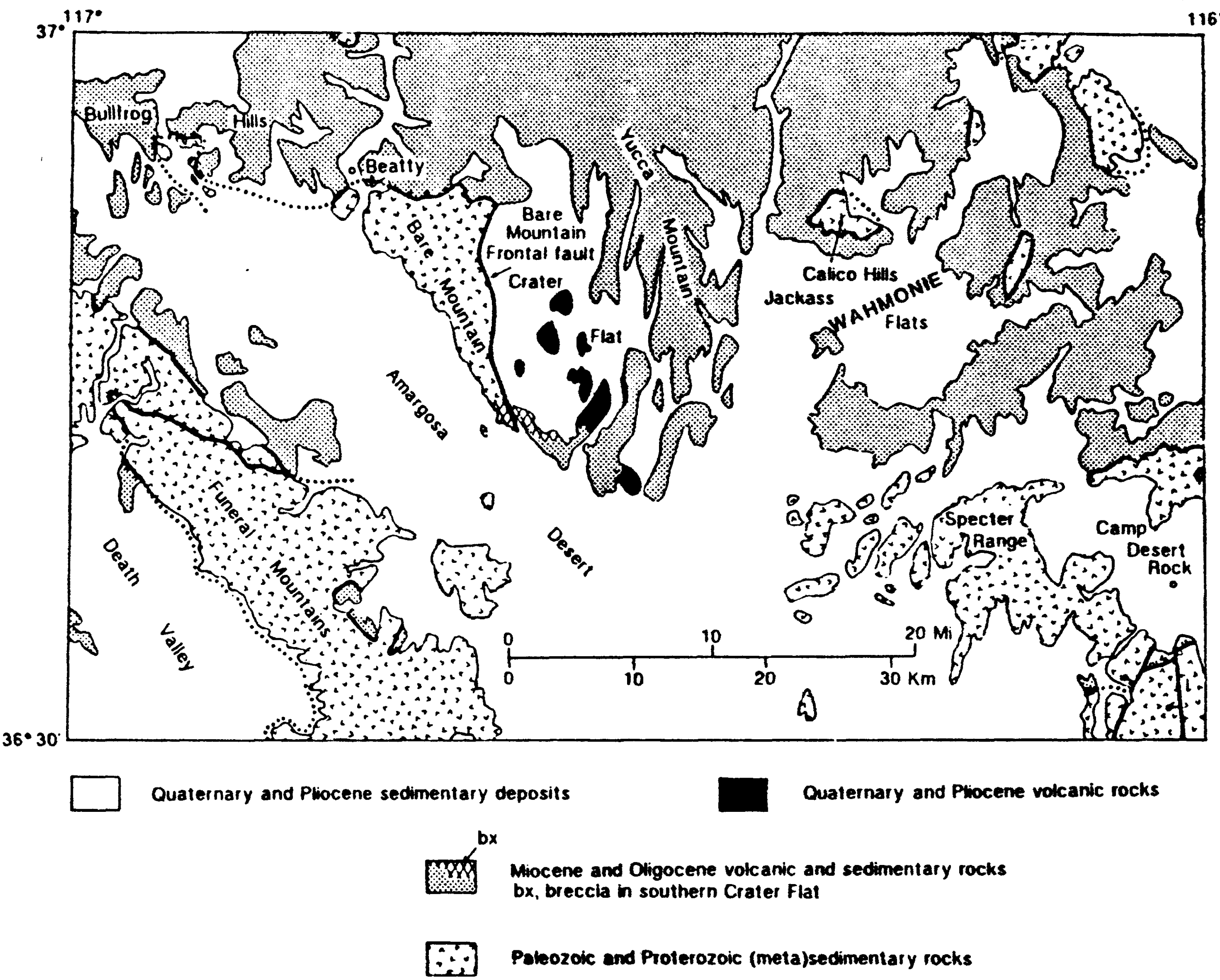

Figure 1. Simplified geologic map of the Beatty quadrangle, Nevada, showing location of Yucca Mountain, Calico Hills, and Wahmonie.