

## CHAPTER X

# LOCATING BURIED CONDUCTIVE MATERIAL ALONG THE GETCHELL TREND, OSGOOD MOUNTAINS, NEVADA: IMPLICATIONS FOR GOLD EXPLORATION AND THE CARBON-GOLD ASSOCIATION(?)

By V.J.S. GRAUCH<sup>1</sup> and DONALD B. HOOVER<sup>1</sup>

## INTRODUCTION

The Getchell trend is an alignment of six sedimentary-hosted, disseminated gold deposits along the eastern side of the Osgood Mountains in north-central Nevada (fig. 1). In 1988, the U.S. Geological Survey conducted a multi-sensor airborne geophysical program in this area in order to demonstrate the utility of integrated airborne geophysical surveying for exploration or mineral assessment in covered terranes. The surveys included an airborne electromagnetic (EM) survey, flown using three different frequencies. Apparent resistivity maps were constructed for each frequency; these maps are standardly used to interpret lateral variations in subsurface resistivities. (The word "apparent" is used because there are some simplifying assumptions made about the Earth in order to make the resistivity computation from measured EM parameters.) In a preliminary assessment of the apparent resistivity maps for the Getchell-trend area, Hoover and others (1991) observed that all the exposed gold deposits are associated with linear conductive zones. Because EM surveys can map subsurface resistivities, apparent resistivity maps, thus, can be an important guide to locating buried conductive zones, which in turn may be associated with buried gold deposits.

Unfortunately, the geophysical signature of buried conductive material is commonly masked by the effect of overlying or neighboring rocks, making identification on

apparent resistivity maps difficult. A step toward isolating this signature is to take the ratio of apparent resistivities calculated for two different frequencies (Pierce and Hoover, 1991). Analogous to a derivative, the ratio of apparent resistivity at a higher frequency divided by that for a lower frequency is a measure of how fast resistivity is changing with depth. Buried conductive material, which we define as rocks with very low resistivity underlying rocks with moderate to high resistivity, will then be represented by areas where resistivity is decreasing with depth. However, areas where highly resistive rocks overlie moderately resistive rocks also express decreasing resistivity and, yet, are areas of no interest. Thus, a better approach enhances areas where resistivity is decreasing with depth *and* the apparent resistivity is low. We call such an operation a buried-conductor enhancement.

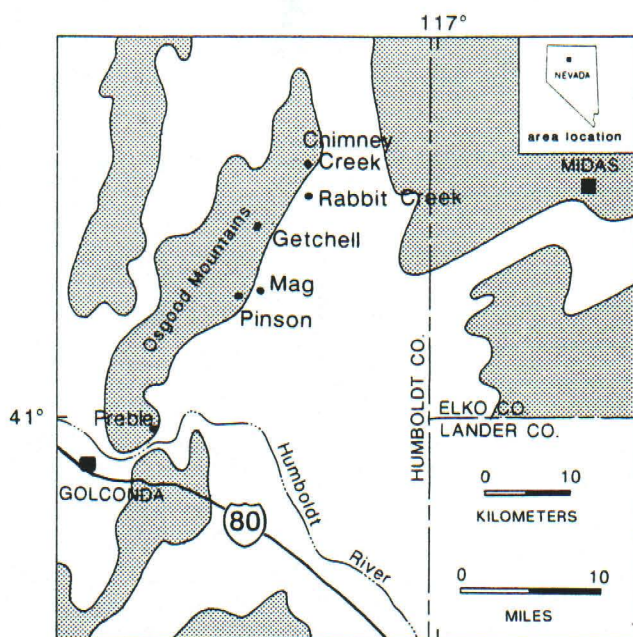
The purpose of this report is two-fold: (1) to introduce a buried-conductor enhancement of resistivity data that pinpoints buried conductive material and thus can better isolate subsurface areas of interest; and (2) to argue that the primary conductive material reflected in the enhanced map is the carbonaceous matter that has a common association with deposits of this type. In addition, perhaps the conductive properties of the carbonaceous matter have some sort of indirect or direct, but as yet unknown, relationship to the gold mineralization.

## GEOLOGIC SETTING

The Getchell trend lies along the eastern side of the Osgood Mountains, a structurally complicated range

<sup>1</sup>U.S. Geological Survey, Mail Stop 964, P.O. Box 25046, Denver Federal Center, Denver, CO 80225.





**Figure 1.** Location of the six sedimentary-hosted gold deposits that make up the Getchell trend along the east side of the Osgood Mountains. Stippling represents topographic ranges.

composed of Paleozoic sedimentary rocks, Cretaceous granodiorite, and Tertiary extrusive rocks (fig. 2). The Osgood Mountains host deposits of silver, tungsten, barite, and manganese as well as gold. The gold deposits are similar to the well-known Carlin deposit; disseminated, invisible gold is hosted in Paleozoic, thin-bedded, carbonaceous, calcareous siltstones and silty carbonates. Mineralization is controlled locally by the Getchell fault system at the Getchell, Pinson, and possibly Preble deposits (Bagby and Berger, 1985). Similar range-front faulting controls mineralization at the Chimney Creek (Osterberg and Guilbert, 1991) and Mag (Foster and Kretschmer, 1991) deposits. The Rabbit Creek deposit is more strati-form than fault controlled (Bloomstein and others, 1991).

Carbonaceous matter is abundant at all the Getchell-trend gold deposits; this association is typical of sediment-hosted, disseminated gold deposits in general, although no direct correlation between gold and organic carbon has been documented within the deposits themselves (Percival and others, 1988; Bagby and Berger, 1985). The carbonaceous matter may have originated as hydrocarbons that were partially remobilized by hydrothermal fluids along fractures and fault zones (Hausen and Park, 1986; Broili and others, 1988) and then heated to anthracite (Hausen and Park, 1986) or higher (Leventhal and Hofstra, 1990) coal rank. Studies at the Jerritt Canyon deposit in north-eastern Nevada demonstrate that graphitization of the carbonaceous matter occurred prior to gold mineralization so that carbon was unavailable for gold transport (Leventhal

and others, 1987). Only a few gold grains are spatially related to carbonaceous matter (Leventhal and others, 1987; Hausen and Park, 1986). In any case, the genetic relationship between the carbonaceous matter and gold mineralization, if any, remains unclear.

## APPARENT RESISTIVITY DATA

Resistivity (or conductivity, its inverse) is primarily a function of the interconnected porosity of the rock, the amount and quality of contained water, and degree of saturation (Keller and Frischknecht, 1966). Concentrations of electronically conductive minerals, such as metallic sulfides and graphite, can significantly lower resistivities locally but generally contribute little to bulk resistivities of rock units. Thus, bulk-earth resistivity is normally determined by ionic conduction through fluids contained in the pore spaces of rocks. As a rule of thumb, rocks with low porosity, such as igneous rocks, will have higher resistivities than rocks with high porosity, such as some clastic sedimentary rocks. On the other hand, a rock unit with moderate porosity in which the pores are filled with saline water instead of fresh water has an extremely low resistivity. In addition, large amounts of clay minerals decrease resistivities dramatically because of their ability to absorb water (Palacky, 1986).

The depth of exploration of an EM survey is dependent on the frequency of the EM measurements and the resistivity of the subsurface. Low-frequency measurements have greater exploration depths than high-frequency measurements, and the depth of exploration is greater in resistive terranes than in conductive ones. For example, at a given location, depth of exploration using 900 Hz is greater than for 7,200 or 56,000 Hz. Between locations, the 900-Hz depth of exploration is greater where subsurface resistivities are higher.

Apparent resistivity data for the Getchell-trend area were computed from data collected during an airborne EM survey flown in 1988 using a DIGHEM IV system. The

**Figure 2 (facing page).** Generalized geology of the Osgood Mountains and location of precious metal occurrences. Rock units adapted primarily from Willden (1964). Additional geologic names from Hotz and Willden (1964); ages from Erickson and Marsh (1974) and Silberman and others (1974). CC, Chimney Creek central pit; CN, Chimney Creek north pit; CS, Chimney Creek south pit; GC, Getchell central pit; GN, Getchell north pit; GS, Getchell south pit; HC, Hansen Creek mine; MA, Mag mine; PI, Pinson mine; PR, Preble mine; RC, Rabbit Creek pit (future outline); SCA, Summer Camp gold mine; SCO, Silver Coin silver mine; TR, Turquoise Ridge gold mineralization; 13, section 13 gold mineralization.



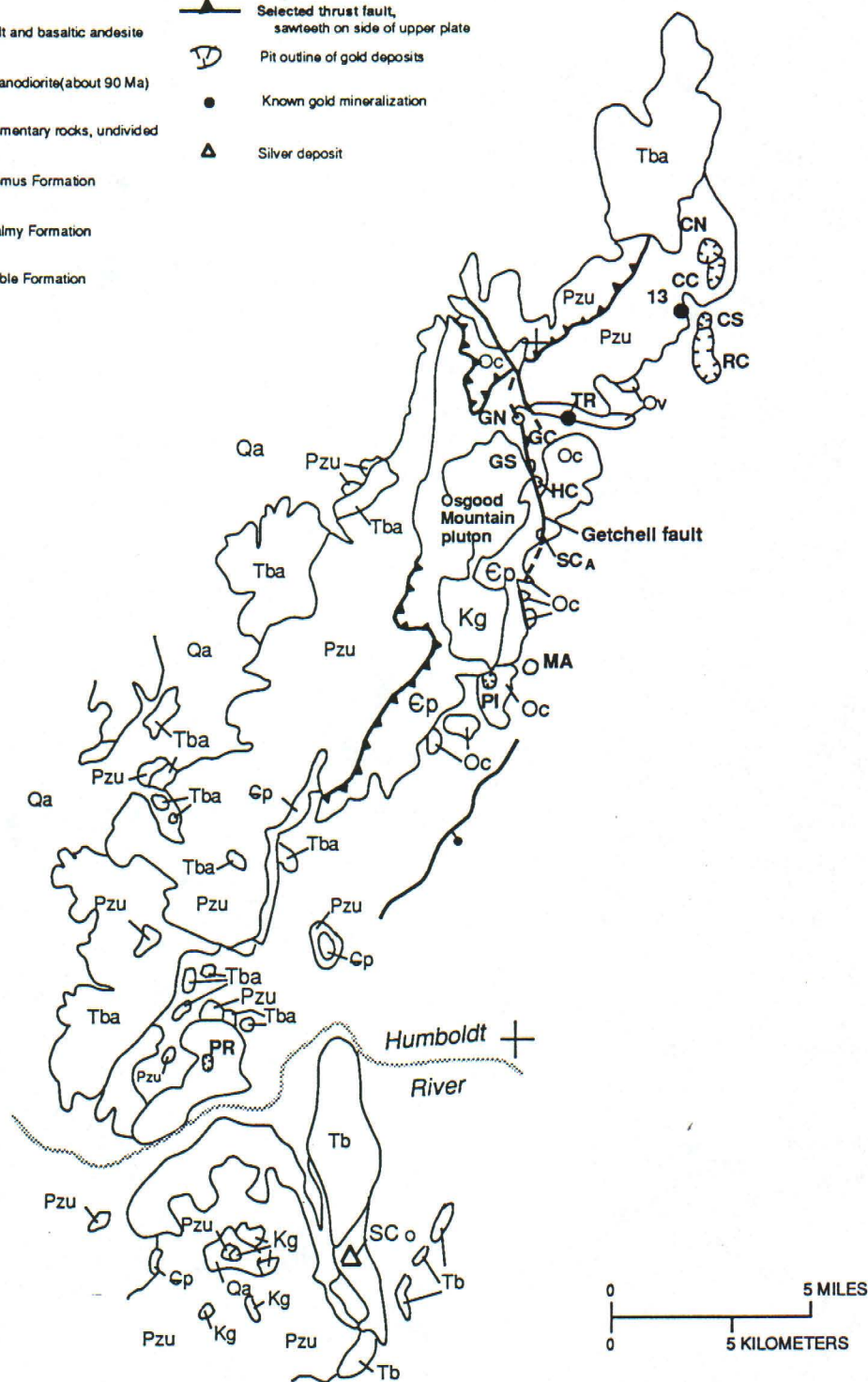
117° 15'

## EXPLANATION

<b>Qa</b>	Quaternary alluvium		Contact
<b>Tb</b>	Pliocene basalt		Selected normal fault, ball on down-thrown side
<b>Tba</b>	Miocene basalt and basaltic andesite		Selected thrust fault, sawtooth on side of upper plate
<b>Kg</b>	Cretaceous granodiorite (about 90 Ma)		Pit outline of gold deposits
<b>Pzu</b>	Paleozoic sedimentary rocks, undivided		Known gold mineralization
<b>Oc</b>	Ordovician Comus Formation		Silver deposit
<b>Ov</b>	Ordovician Valmy Formation		
<b>Ep</b>	Cambrian Preble Formation		

41° 15'

41° 00'





survey was flown 30 m (100 ft) above ground along north-west- and southeast-trending lines spaced 402 m (1/4 mile) apart (except over the gold deposits, where they were spaced 201 m (1/8 mile) apart). Data were acquired using frequencies of 56,000, 7,200, and 900 Hz, and apparent resistivities were calculated for each of these frequencies. Details of the data-acquisition system and the computation of apparent resistivity are described in Pierce and Hoover (1991).

The alluvial cover in the Getchell-trend area is typically fairly conductive, so that the depth of exploration using 900 Hz in those areas ranges from about 10 m (33 ft) to 100 m (330 ft). In areas of exposed rock, exploration depths are generally greater and, for most lithologies, range from about 100 m (330 ft) to 1,000 m (3,300 ft). Pierce and Hoover (1991) discuss the apparent resistivity results for the Getchell-trend area.

### BURIED-CONDUCTOR ENHANCEMENT

As shown by Pierce and Hoover (1991), the logarithm of the ratio between apparent resistivities calculated for 7,200-Hz and 900-Hz frequencies, respectively, gives information about how resistivity changes with depth. Roughly speaking, where the ratio is greater than one (the logarithm is positive), resistivity is decreasing with depth. Where it is less than one (the logarithm is negative), resistivity is increasing with depth. For the buried-conductor enhancement, this ratio is then multiplied by the logarithm of the 900-Hz apparent conductivity (the inverse of apparent resistivity) after adding a constant to ensure only positive logarithms for the conductivity. The conductivity for the 900-Hz frequency is used because it represents the deepest looking frequency. In equation form, the results of the enhancement ( $E$ ) can be written for each grid point as:

$$E = \left\{ \log \left( \frac{1}{\rho_{900}} \right) + k \right\} \log \left( \frac{\rho_{7,200}}{\rho_{900}} \right) \quad (1)$$

where

$\rho_{900}$  is the 900-Hz apparent resistivity (ohm-meters),

$\rho_{7,200}$  is the 7,200-Hz apparent resistivity (ohm-meters), and

$k$  is a constant that ensures the left-hand side of the product will be positive for all grid points.

Note that  $k$  is usually chosen by inspection of the minimum value of  $\log \left( \frac{1}{\rho_{900}} \right)$  for all grid points.

Because the negative values of  $E$  represent the uninteresting case where the resistivities are increasing with depth, these values are neglected. Thus, the final plot of  $E$  has high values where the product of the 900-Hz apparent

conductivity and the amount of decrease in resistivity with depth is great. The highest  $E$  values represent places where there is a large, probably abrupt, decrease in resistivity at depth. Moreover, the change in resistivity must occur at fairly shallow depths because the depth of exploration is diminished by the presence of the low resistivities in the subsurface.

### RESULTS FOR THE GETCHELL-TREND AREA

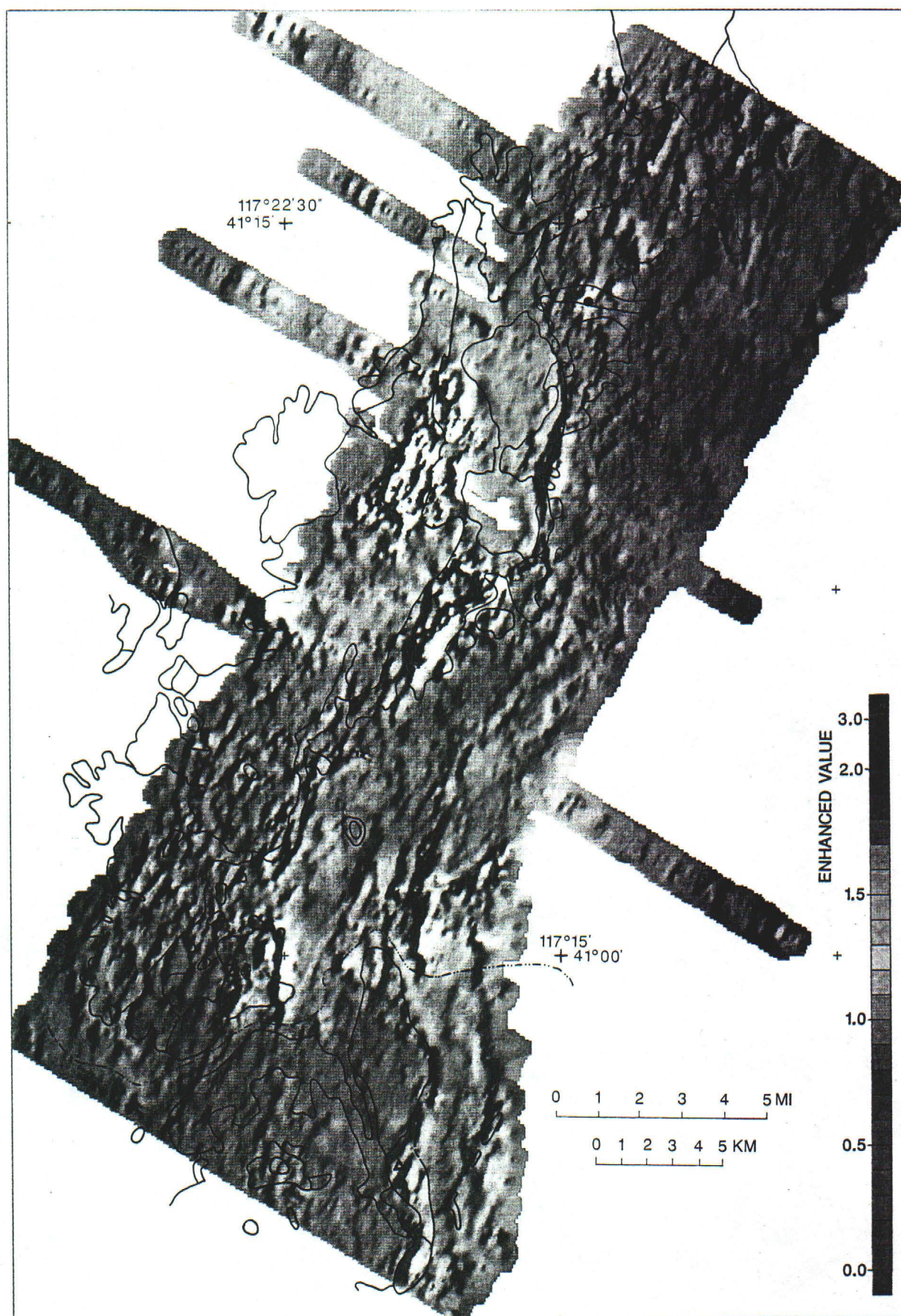
The result of applying the above buried-conductor enhancement to apparent resistivity data for the Getchell trend area is shown on figure 3. The highlighted features of the enhanced map are present on both the 900-Hz apparent resistivity and ratio maps of Pierce and Hoover (1991) as expected from equation (1), but there are many fewer targets on the enhanced map. The smaller number greatly facilitates follow-up investigations.

### NATURE OF THE CONDUCTIVE MATERIAL

We surmise that the broad regions of slightly higher values on figure 3 are due to buried lithologies that are less resistive than the overlying lithology, whereas the high enhanced values that occur as spots, lines, or stringers are due to local concentrations of buried conductive material. In the case of the spot of high enhanced values near lat 41°02'N., long 117°17'W., the conductive material likely is a buried warm spring. In most other cases, we deduce that graphite primarily comprises the conductive material from the following observations: (1) Most of the highest enhanced spots where subsurface information is available correlate with rocks that contain large concentrations of carbonaceous matter, moderate to large amounts of clay or other argillaceous rock, and small amounts of

**Figure 3 (facing page).** Results of the buried-conductor enhancement applied to apparent resistivity data from an airborne survey over the Getchell-trend area. The dimensionless values increase as a function of the product of the decrease in resistivity with depth and the 900-Hz apparent conductivity (the inverse of resistivity). The enhancement is presented in color shaded relief, with false illumination from the east. Negative values represent the uninteresting case where resistivity increases with depth. Broad regions of slightly higher values are probably due to buried lithologies that are less resistive than the overlying lithology, whereas the high values that occur as spots, lines, or stringers are most likely caused by concentrations of buried conductive material that is composed partially or wholly of graphitized carbonaceous matter. Geologic contacts, pit outlines, and occurrence locations are from figure 2. Faults are not shown for clarity. Refer to figure 2 for names.







sulfides; (2) occurrences of argillaceous rock without carbonaceous matter do not correspond to low resistivities on the apparent resistivity maps; (3) the amount of sulfides is not sufficient to produce the low resistivities measured; and (4) graphite can lower resistivities of rocks quite dramatically, even when present in small quantities (Nelson and others, 1982; Grant and West, 1965). Moreover, laboratory analyses of carbonaceous matter sampled from sedimentary-hosted disseminated gold deposits elsewhere in northern Nevada indicate cryptocrystalline graphite (Leventhal and Hofstra, 1990) with an anthracite or higher coal rank (Leventhal and Hofstra, 1990; Hausen and Park, 1986). Both anthracite coal and graphite are excellent electrical conductors. Moreover, if the cryptocrystalline graphite is localized along bedding or fault planes, as is carbonaceous matter at the Carlin deposit (Hausen and Park, 1986), the interconnectivity of the crystals would further increase conduction.

From these observations we infer that many, if not most, of the moderate to high values on the enhanced map reflect carbonaceous matter that is at least partially graphitized. Thus, the enhanced map can help determine the location and nature of buried carbonaceous matter in the Getchell-trend area.

Where known, the areas of highest enhanced values have no associated gold mineralization, although they commonly occur near or on line with precious-metal deposits (the two known silver deposits included). The high values to the west of the Osgood Mountains pluton are exceptions: no known gold mineralization occurs nearby. On the other hand, all but two of the gold occurrences that were detectable by the EM survey correspond to moderately enhanced values, which generally occur as lines or stringers. The two exceptions are at the central and south pits of the Getchell deposit, where the lack of enhancement may be explained by resistivities that increase rather than decrease with depth (Pierce and Hoover, 1991). Here, the deposit and its associated conductive material are entirely exposed at the surface. The gold mineralization in section 13, the Chimney Creek south pit, and the Rabbit Creek deposit are deeper than the EM depths of exploration. The inadequate depth of exploration near the Rabbit Creek deposit implies that the large enhanced area to the south must reflect widespread, buried conductive material within the overburden, which may or may not be related to the deposit below (Pierce and Hoover, 1991).

## STRUCTURE

Many faults are manifested on the enhanced map (fig. 3), either as lines or stringers, or as abrupt changes in value. For example, the northeasterly trending enhanced line about 3 km west of the central Chimney Creek pit

coincides with part of a mapped thrust fault (Willden, 1964); carbonaceous rocks and some sulfide mineralization are present at depth (B. Berger, written commun., 1977). At the Pinson and Mag deposits, linear enhanced areas trend north and northeast, corresponding to Tertiary structure (E. Kretschmer, written commun., 1991). The north-south-trending linear enhanced area east of the Preble deposit is associated with the west edge of a graben-like feature that is interpreted from geophysical data (Hoover and others, 1991; Grauch and others, 1991) and corroborated by drilling (E. Kretschmer, oral commun., 1990). To the east, a more subtle linear area of low values on the enhanced map that trends northeast may represent the east edge of the graben. A northeasterly trend is suggested by connecting linear enhanced areas to the northeast and southwest of the Preble deposit. The trend may be a major fault related to the northerly trending fault mapped in the pit (Kretschmer, 1984).

Faults are also expressed by abrupt changes in character on the enhanced map, such as the two northeast-trending faults along the southeastern and northeastern edges of the study area. These faults are corroborated by other geophysical evidence (Hoover and others, 1991).

## CONCLUSIONS

The buried-conductor enhancement applied to apparent resistivity maps can be a valuable tool for gold exploration in the Getchell-trend area. The high enhanced values are most likely explained by subsurface concentrations of graphite. Precious-metal mineralization may occur adjacent to areas that have the highest enhanced values, but it does not occur directly over these areas. Mineralized areas correspond better to low and moderately enhanced values that commonly follow faults. Possible explanations for these observations are: (1) Carbonaceous matter is moderately but not highly conductive in association with gold mineralization, implying that highly conductive carbonaceous matter and gold mineralization are mutually exclusive for a given area; (2) conductive carbonaceous matter is present in association with gold mineralization, but rocks overlying mineralized areas are less resistive than in nonmineralized areas; or (3) conductive carbonaceous matter is present in association with gold mineralization, but the resistive cover has been stripped off during mining. The last possibility does not explain the moderately enhanced values that occur near mines in areas where the cover has not been stripped off. The remaining two explanations both suggest that the resistivities of the rocks are somehow related to gold mineralization. Perhaps the gold mineralization event destroyed some of the conductive properties of the carbonaceous matter or increased the porosity of the overlying rocks. In situ electrical measurements near the Pinson mine suggest that carbonaceous



ore exhibits higher resistivities compared to carbonaceous non-ore (Hoover and others, 1987). This observation also suggests an interrelation between the conductive properties of carbonaceous matter and associated gold mineralization.

We predict that abundant carbonaceous material (partially or wholly graphitized) will be found at depth at the spots of highly enhanced values under the basalt south of the Silver Coin mine (fig. 2); under Paleozoic sedimentary rocks just to the northeast of Turquoise Ridge mineralization and near lat 41°7'30"N., long 117°22'30"W.; and under alluvium near the northern tip of the study area. In addition, faults containing conductive material that may have controlled hydrothermal fluid flow in the past occur along the southeastern edge of basalt northeast of the Silver Coin mine, along the contact between Preble Formation and alluvium 2 km west of Lone Butte, under alluvium about 1 and 2 km southeast of the Pinson mine, and possibly within the Paleozoic rocks west of the section 13 mineralization. Even if no gold is found in these areas, the buried-conductor enhancement does well in isolating conductive fault zones that may be related to mineralization. This technique may become extremely useful in studying the role of carbonaceous matter in sedimentary-hosted, disseminated gold deposits.

## REFERENCES CITED

- Bagby, W.C. and Berger, B.R., 1985, Geologic characteristics of sediment-hosted disseminated precious-metal deposits in the Western United States, in Berger, B.R., and Bethke, P.M., eds., *Reviews in Economic Geology, Volume 2—Geology and Geochemistry of Epithermal Systems*: El Paso, Society of Economic Geologists, p. 169–232.
- Bloomstein, E.I., Massingill, G.L., Parratt, R.L., and Peltonen, D.R., 1991, Discovery, geology, and mineralization of the Rabbit Creek gold deposit, Humboldt County, Nevada, in Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and Ore Deposits of the Great Basin, Symposium Proceedings*: Reno, Geological Society of Nevada, p. 821–845.
- Broili, C., French, G. McN., Saddrick, D.R., and Weaver, R.R., 1988, Geology and gold mineralization of the Gold Bar deposit, Eureka County, Nevada, in Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., *Bulk Mineable Precious Metal Deposits of the Western United States Symposium Proceedings*: Reno, Geological Society of Nevada, p. 57–72.
- Erickson, R.L., and Marsh, S.P., 1974, Geologic map of the Golconda quadrangle, Humboldt County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1174, scale 1:24,000.
- Foster, J.M., and Kretschmer, E.L., 1991, Geology of the Mag deposit, Pinson mine, Humboldt County, Nevada, in Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and Ore Deposits of the Great Basin, Symposium Proceedings*: Reno, Geological Society of Nevada, p. 845–856.
- Grant, F.S., and West, G.F., 1965, *Interpretation theory in applied geophysics*: New York, McGraw-Hill, 584 p.
- Grauch, V.J.S., Hoover, D.B., and Wojniak, W.S., 1991, Subsurface structure and lithology near the Getchell gold trend, Osgood Mountains, Nevada—Geophysical insights: U.S. Geological Survey Circular 1062, 34 p.
- Hausen, D.M. and Park, W.C., 1986, Observations on the association of gold mineralization with organic matter in Carlin-type ores, in Dean, W.C., ed., *Proceedings of the Denver Region Exploration Geologists Society Symposium on Organics and Ore Deposits*: Denver Region Exploration Geologists Society, p. 119–136.
- Hoover, D.B., Grauch, V.J.S., Pitkin, J.A., Krohn, M.D., and Pierce, H.A., 1991, An integrated airborne geophysical study along the Getchell trend of gold deposits, north-central Nevada, in Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and Ore Deposits of the Great Basin, Symposium Proceedings*: Reno, Geological Society of Nevada, p. 739–758.
- Hoover, D.B., Smith, B.D., Grauch, V.J.S., and Podwysocki, M.H., 1987, Geophysical studies in the vicinity of the Getchell fault system, Humboldt County, Nevada: U.S. Geological Survey Circular 995, p. 31–32.
- Hotz, P.E., and Willden, Ronald, 1964, *Geology and mineral deposits of the Osgood Mountains quadrangle, Humboldt County, Nevada*: U.S. Geological Survey Professional Paper 431, 128 p.
- Keller, G.V., and Frischknecht, F.C., 1966, *Electrical methods in geophysical prospecting*: New York, Pergamon Press, 523 p.
- Kretschmer, E.L., 1984, *Geology of the Pinson and Preble gold deposits, Humboldt County, Nevada*: Arizona Geological Society Digest, v. 15, p. 59–66.
- Leventhal, Joel, and Hofstra, Albert, 1990, Characterization of carbon in sediment-hosted disseminated gold deposits, north central Nevada, in Hausen, D.M., Petersen, E.U., and Tafuri, W.J., eds., *Gold '90, Symposium Proceedings*: Littleton, Colorado, Society for Mining, Metallurgy, and Exploration, p. 365–368.
- Leventhal, J.S., Hofstra, A.H., Vuletich, A.K., and Mancuso, T.B., 1987, Sediment-hosted disseminated gold mineralization at Jerritt Canyon, Nevada. III—Role of organic carbon [abs.]: *Geological Society of America, Abstracts with Programs*, v. 19, no. 7, p. 745.
- Nelson, P.H., Hansen, W.H., and Sweeney, M.J., 1982, Induced-polarization response of zeolitic conglomerate and carbonaceous siltstone: *Geophysics*, v. 47, no. 1, p. 71–88.
- Osterberg, M.W., and Guilbert, J.M., 1991, Geology, wall-rock alteration, and new exploration techniques at the Chimney Creek sediment-hosted gold deposit, Humboldt County, Nevada, in Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and Ore Deposits of the Great Basin, Symposium Proceedings*: Reno, Geological Society of Nevada, p. 805–820.
- Palacky, G.J., 1986, Geological background to resistivity mapping: *Geological Survey of Canada Paper* 86-22, p. 19–27.
- Percival, T.J., Bagby, W.C., and Radtke, A.S., 1988, Physical and chemical features of precious metal deposits hosted by sedimentary rocks in the Western United States, in Schafer, R.W., Cooper, J.J., and Vikre, P.G., eds., *Bulk Mineable Precious*



- Metal Deposits of the Western United States Symposium Proceedings: Reno, Geological Society of Nevada, p. 11-34.
- Pierce, H.A., and Hoover, D.B., 1991, Airborne electromagnetic applications—Mapping structure and electrical boundaries beneath cover along the Getchell trend, Nevada, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., eds., *Geology and Ore Deposits of the Great Basin*, Symposium Proceedings: Reno, Geological Society of Nevada, p. 771-780.
- Silberman, M.L., Berger, B.R., and Koski, R.A., 1974, K-Ar age relations of granodiorite emplacement and tungsten and gold mineralization near the Getchell mine, Humboldt County, Nevada: *Economic Geology*, v. 69, p. 646-656.
- Willden, Ronald, 1964, *Geology and mineral deposits of Humboldt County, Nevada*: Nevada Bureau of Mines and Geology Bulletin 59, 154 p.



# Advances Related to United States and International Mineral Resources: Developing Frameworks and Exploration Technologies

*Edited by* RICHARD W. SCOTT, JR., PAMELA S. DETRA, *and* BYRON R. BERGER

---

U.S. GEOLOGICAL SURVEY BULLETIN 2039

*The Bulletin reports some accomplishments of the  
U.S. Geological Survey in research on  
mineral resources in 1992*



UNITED STATES GOVERNMENT PRINTING OFFICE WASHINGTON : 1993

*Complete volume in USGS Pubs drawers.*