Tracking the Archean-Proterozoic suture zone in the northeastern Great Basin, Nevada and Utah

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ABSTRACT

It is important to know whether major mining districts in north-central Nevada are underlain by crust of the Archean Wyoming craton, known to contain major orogenic gold deposits or, alternatively, by accreted crust of the Paleoproterozoic Mojave province. Determining the location and orientation of the Archean-Proterozoic suture zone between these provinces is also important because it may influence subsequent patterns of sedimentation, deformation, magmatism, and hydrothermal activity. The suture zone is exposed in northeastern Utah and southwestern Wyoming and exhibits a southwest strike. In the Great Basin, the suture zone strike is poorly constrained because it is largely concealed below a Neoproterozoic–Paleozoic miogeocline and Cenozoic basin fill. Two-dimensional resistivity modeling of the extent and orientation of the Archean-Proterozoic suture zone between these provinces will help constrain the location and orientation of the Archean-Proterozoic suture zone.

INTRODUCTION

The rifting of the craton margin in the Great Basin influenced many Phanerozoic events, including patterns of sedimentation, deformation, magmatism, and hydrothermal activity. The resistivity of rocks, in particular electrical resistivity or magnetotelluric sounding profiles in western Utah, north-central Nevada, and northeastern Nevada, reveals a deeply penetrating (>10 km depth), broad (tens of kilometers) conductor (1–20 ohm-meters) that may be the Archean-Proterozoic suture zone, which formed during Early Proterozoic rifting of the Craton. This major crustal conductor changes strike direction from southwest in Utah to northwest in eastern Nevada, where it broadens to ~100 km width that correlates with the Early Proterozoic rifting of the continent. Our results suggest that the major gold belts may be isolated blocks of Archean crust, so Phanerozoic mineral deposits in this region may be produced, at least in part, from recycled Archean gold. Future mineral exploration to the east may yield large gold tonnages.

Keywords: suture zone, Archean, Proterozoic, resistivity, gold, mining districts.

ELECTRICAL ROCK PROPERTIES

Electromagnetic (EM) geophysical methods detect variations in the electrical properties of rocks, in particular electrical resistivity or its inverse, electrical conductivity. The resistivity of geologic units in the upper crust is largely dependent upon their fluid content, pore-volume.
Figure 1. Magnetotelluric (MT) profile index map in northeastern Great Basin modified from John et al. (2003). A–A’ line is Utah MT profile, B–B’ line is eastern Nevada MT profile, C–C’ line is Elko MT profile, and D–D’ line is Wells MT profile. Double-sided red and black arrows are MT strike directions of two-dimensional conductors at ~10 km below the ground surface. MT strike resolution is ~±10°. SP, HP, and BM (green lines) are Secret Pass, Harrison Pass, and Bald Mountain MT profiles, respectively (Wannamaker and Doerner, 2002). Black dashed line is initial $^{87}$Sr/$^{86}$Sr = 0.706 isopleth ($Sr_i$) for the inferred edge of continental crust. Red dashed line is Archean crust edge of Reed (1993). Purple solid line is Archean crust edge of Link et al. (1993). Red solid line is Archean crust edge of Sims et al. (2005). Blue dashed lines show Archean crust south boundary and Proterozoic crust north boundary with mixed basement in between that of Tosdal et al. (2000). Green dashed line is Wells fault. Yellow rectangles are major mineral trends and lineaments. AR is Alligator Ridge district; BME is Battle Mountain–Eureka trend; CT is Carlin trend; GT is Getchell trend; JC is Jerritt Canyon district; jc (with X symbol) is Jerritt Canyon deposit; REH is Ruby–East Humboldt metamorphic core complex. Inset map shows the location of figure and the outline of the Great Basin (heavy black line).
porosity, interconnected fracture porosity, and conductive mineral content (Keller, 1989). Fluid content and conductive mineral content dominate the resistivity response within the upper to middle crust, and undersaturated melting conditions may be dominant near the base of the crust. Fluids within the pore spaces and fracture openings, especially if saline, can reduce resistivities in what would otherwise be a resistive rock matrix. Resistivity can also be lowered by the content of electrically conductive clay minerals, graphitic carbon, and metallic mineralization. It is common for altered volcanic rocks to contain replacement minerals that have resistivities 10 times lower than those of the surrounding rocks (Nelson and Anderson, 1992). Fine-grained sediments, such as clay-rich alluvium, marine shale, and other mudstones, are normally conductive from a few ohm-meters (ohm-m) to a few tens of ohm-meters (Keller, 1987; Palacky, 1987). Metamorphic rocks (nongraphitic) and unaltered, unfractured igneous rocks are normally moderately to highly resistive (a few hundreds to thousands of ohm-meters). Carbonate rocks can have similarly high resistivities depending on their fluid content, porosity, and impurities (Keller, 1987; Palacky, 1987). Fault zones may be moderately conductive (tens of ohm-m) when composed of rocks fractured enough to have hosted fluid transport and consequent mineralogical alteration (Eberhart-Phillips et al., 1995) or when composed of fractured rock that has graphic enrichment along former shear planes (Ritter et al., 2005). Higher subsurface temperatures cause higher ionic mobility that reduces rock resistivities (Keller, 1987; Palacky, 1987). Tables of electrical resistivity for a variety of rocks, minerals, and geologic environments may be found in Keller (1987) and Palacky (1987).

**MAGNETOTELLURIC SURVEY**

MT soundings (n = 12) were collected in July 2003 along a 112-km-long north-south profile (A–A'; Fig. 1) in east-central Tooele County, Utah (Williams and Rodriguez, 2003). MT (n = 25) soundings were collected in September 2003 along a 249-km-long north-south profile (B–B'; Fig. 1) in eastern Nevada (Williams and Rodriguez, 2004). Sounding locations for these two profiles were chosen to cross the suture zone hypothesized from regional interpretations of geologic mapping (Reed, 1993) and variations in Pb isotope data (Tosdal et al., 2000).

MT soundings (n = 19) were collected in September 2004 along a 160-km-long north-south profile (C–C'; Fig. 1) in northeastern Nevada (Williams and Rodriguez, 2005). MT soundings (n = 11) were collected in July 2005 along a 90-km-long east-west profile (D–D'; Fig. 1) in northeastern Nevada (Williams and Rodriguez, 2006). Sounding locations for these two profiles were chosen to cross the suture zone on the basis of hypothesized projections from MT data to the southeast (Williams and Rodriguez, 2004).

The MT data were rotated to perpendicular and parallel to the profile azimuth so that propagation modes for the signals were decoupled into transverse electric (TE) and transverse magnetic (TM) modes for subsequent two-dimensional (2-D) resistivity modeling (see Appendix).

**GEOLOGIC CORRELATIONS**

In Rodriguez and Williams (2001, 2002), crustal high resistivity (300–1000 ohm-m) was generally attributed to carbonates, intruded rock, plutonic rock, metamorphic rocks, or Precambrian basement. Moderately resistive (30–300 ohm-m) rocks were inferred to be volcanic and/or clastic sedimentary rocks. Evidence supporting these interpretations, such as exposures of Cretaceous quartz monzonite, Tertiary granite, diorite, widespread recrystallized carbonates, and broad magnetic highs supporting the presence of large, concealed, plutons near MT stations, was reported in Rodriguez and Williams (2001, 2002). Subvertical, 2-D, low-resistivity (1–30 ohm-m) conductors that penetrate to mid-crustal depths (5–15 km) may be explained by major crustal-scale fault or fracture zones, while broad, subvertical, low-resistivity (1–30 ohm-m) conductors that penetrate to lower-crustal depths (20 km) may be explained by major crustal-scale suture zones (Rodriguez et al., 2007). The low resistivities can be caused by material associated with faulting or fracture filling, such as mylonitic breccia, brine-filled fractures, argillaceous alteration from hydrothermal fluids, substantial graphitic carbon associated with shear zones, or fluid-deposited graphite derived from organic shales in the section (Wannamaker and Doerner, 2002), or possibly some combination of these (Eberhart-Phillips et al., 1995). The widths of the narrow, inferred crustal fault zones, in general, are not well constrained due to the combination of wide station spacing, the resolving power of diffusive EM, and the node spacing of the grid size used in the resistivity models (0.4–4 km). Shallown 3-D conductors in the upper few kilometers may be a combination of conductive (1–30 ohm-m) basin fill on shaly basement units, such as Devonian Pilot or early Mississippian Chainman Formations, with similar resistivities depending on their hydrocarbon maturity (Wannamaker and Doerner, 2002). Also, conductors that are 3-D in character may be due to termination, a change in conductor strike direction, or an intersection with another conductor with a different strike direction.

**RESULTS**

**Utah Profile**

Along the north-south Utah profile (A–A'; Fig. 1), the northern edge (between MT stations 3 and 4) of a broad (~20 km wide) conductive zone (10–200 ohm-m) trends south-southwest, penetrates to at least 20 km depth, and dips ~30° south-southeast (A–A'; Fig. 2). This conductive zone appears to be a major structural boundary because its great breadth and depth suggest a very broad and thick section of conductive crust that is juxtaposed between thick resistive crust north and south of it. This major structural boundary we interpret to be the suture zone because of its similar southwest strike and its proximity to the exposed suture zone (Reed, 1993) at the eastern Utah and southwestern Wyoming border (Cheyenne Belt; Fig. 1).

This major anomalous conductive zone greatly contrasts with the thick section of resistive (100–500 ohm-m) crust (below 3 km depth), north of MT station 4, that penetrates to the middle crust (at least 20 km depth), suggesting that this resistive crust is intact. We interpret this resistive section of crust to be Proterozoic because of its intact appearance and its proximity to exposed Archean rocks to the northeast near Salt Lake City, Utah (Fig. 1).

The thick section of resistive crust, south of MT station 8, that penetrates to the middle crust (at least 20 km depth), we interpret to be Proterozoic crust because its resistivity and thickness suggest that it is intact, and its position south of the inferred suture zone along this profile is consistent with where this relation is exposed to the east (Fig. 1). From the resistivity values alone, we cannot differentiate between the Proterozoic and Archean terranes, as both would appear as thick resistive crust, so our interpretation heavily relies upon its position south of the inferred suture zone.

Moderately conductive to resistive (20–1000 ohm-m) crust in the upper few kilometers correlates with Paleozoic rocks exposed at the surface (Moore and Sorensen, 1979). We infer shallower conductive (0.5–20 ohm-m) rocks in the upper 1–2 km to be Cenozoic basin fill (Saltus and Jachens, 1995).

**Eastern Nevada Profile**

Along the north-south eastern Nevada profile (B–B'; Fig. 1), the northern edge (between MT stations 3 and 4) of a very broad (~100 km wide) conductive zone (10–50 ohm-m; B–B'; Fig. 2) trends northwest with its northern edge adjacent to the Wells fault (Thorman et al., 1991) (Fig. 1), penetrates to at least 20 km depth, and...
Figure 2. Two-dimensional resistivity models. Numbered labels are magnetotelluric (MT) stations. A is Archean; P is Proterozoic; Pz is Paleozoic; SZ is suture zone; CFZ is crustal fault zone; pl is pluton; Oc is oceanic. Depths are from ground surface. Physiographic descriptions and acronyms are as in Figure 1. No vertical exaggeration. A–A' is Utah MT profile resistivity model. B–B' is eastern Nevada MT profile model. C–C' is Elko MT profile model. D–D' is Wells MT profile model.
dips ~55° southwest (B–B'; Fig. 2). We interpret this broad conductive zone to be related to the suture zone because of its large breadth and depth, although the northern edge of its trend is nearly perpendicular to the suture zone trend on the Utah profile (double-sided arrows on A–A’ and B–B'; Fig. 1). The EM response to the broad conductive zone also becomes predominantly 3-D, suggesting that it either terminates, takes a sharp turn, or an oblique off-profile conductive zone of similar size is nearby. Previous interpretations of MT profiles (Wannamaker and Doerner, 2002) near the Ruby Mountains (green lines, SP, HP, and BM; Fig. 1) west of our eastern Nevada profile (B–B'; Fig. 1) did not find any similarly broad, thick conductive zones, but did find broad, thick moderately conductive (40–100 ohm-m) zones that they inferred to be Paleozoic sedimentary rocks. Therefore, we interpret the eastern Nevada profile’s broad conductive zone to turn sharply to the north before it crosses Wannamaker and Doerner’s (2002) Ruby Mountain MT profiles, assuming that it continues to follow the same general trend of Reed’s (1993) approximate edge of Archean crust (Fig. 1). Also, we interpret this broad conductive zone to be the southwest corner of a rift boundary from the early Paleozoic rifted margin of western North America (Link et al., 1993), since the conductive zone strike direction is northwest and its much wider breadth suggests a rifted environment.

This major anomalous conductive zone also contrasts with the thick section of resistive (100–5000 ohm-m) crust (below 5 km depth), north of MT station 4, that penetrates to the middle crust (at least 20 km depth), suggesting that this resistive crust is intact. We infer this resistive section of crust to be Archean because of its intact appearance and because its position north of the suture zone is consistent with the suture zone model to the east (A–A'; Fig. 2). The thick section of resistive (500–5000 ohm-m) crust (from 1 to 6 km depth, north to south), south of MT station 22, that penetrates to the middle crust (at least 20 km depth), suggests that this crust is intact. We infer this resistive section of crust to be Proterozoic because of its intact appearance and its position south of the suture zone.

The thick sections of isolated resistive (100–500 ohm-m) crust, near MT stations 7 and 11, that penetrate to the middle crust (9–16 km depth) correlate with plutons (Grauch, 1996) beneath the profile. The thick isolated resistive (100–5000 ohm-m) block between MT stations 13 and 21 (below 5 km depth) may be an isolated block of Proterozoic or Archean basement in the suture zone (transition zone between Archean and Proterozoic crust; Tosdal et al., 2000) because of its depth extent, its position within the suture zone along this profile, and lack of correlation with any plutons.

Moderately conductive to resistive (20–2000 ohm-m) crust in the upper few kilometers correlates with Paleozoic rocks exposed at the surface (Coats, 1987; Grauch, 1996). Shallow, conductive (2–20 ohm-m) rocks in the upper 1 to 2 km we infer to be Cenozoic basin fill (Wallace et al., 2004).

**Elko Profile**

Along the north-south Elko profile (C–C'; Fig. 1), the northern edge (south of MT station 19) of a broad conductive zone (10–50 ohm-m, C–C'; Fig. 2) trends northeast with its northern edge adjacent to the initial 187Sr/86Sr = 0.706 isopleth (Sr) that separates oceanic crust from the north from continental crust to the south (Fig. 1). This conductive zone is ~50 km wide, penetrates to at least 20 km depth, and dips ~55° northwest (C–C'; Fig. 2). The southern half of the broad, conductive zone also becomes predominantly 3-D, suggesting that it either terminates, turns, or a large conductive zone is nearby. Previous interpretations of MT profiles (Wannamaker and Doerner, 2002) near the Ruby Mountains (green line, west end of SP; Fig. 1) east of our Elko profile (B–B'; Fig. 1) found broad, thick, moderately conductive (30–100 ohm-m) zones inferred to be Paleozoic sediments. We interpret the broad conductive zone along the Elko profile (C–C'; Fig. 2) to be part of the same rift zone inferred from the eastern Nevada profile because its wide breadth suggests a rifted environment. A narrower conductive zone near MT station 20 may be a separate crustal fault zone.

The thick section of resistive (100–1000 ohm-m) crust (below 5 km depth), north of MT station 20, that penetrates to the middle crust (at least 15 km depth), is north of the Sr line, suggesting that these resistive rocks are oceanic crust. The thick isolated resistive (100–200 ohm-m) block (below 5 km depth) between MT stations 21 and 22 may be an isolated block of Proterozoic or Archean basement in the inferred rift zone because of its depth extent and its position within the rift zone.

The thick section of resistive (100–200 ohm-m) crust (below 5 km depth) south of MT station 28 that penetrates to the middle crust (at least 20 km depth), suggests that this resistive crust is intact. We infer this resistive section of crust to be Proterozoic because of its intact appearance and its position south of the rift zone.

Moderately conductive to resistive (20–2000 ohm-m) crust in the upper few kilometers correlates with Paleozoic rocks exposed at the surface (Coats, 1987). However, resistive (100–500 ohm-m) rock near MT stations 14–16 that rises to the near surface may be plutonic rock because of its proximity to a large pluton (Coats, 1987; Grauch, 1996). Shallow, conductive (2–20 ohm-m) rocks in the upper 1 to 2 km we infer to be Cenozoic basin fill (Wallace et al., 2004).

**Wells Profile**

Along the east-west Wells profile (D–D'; Fig. 1), the eastern edge (between MT stations 28 and 29) of a broad conductive zone (5–50 ohm-m, D–D'; Fig. 2) trends northwest with its western edge north of Wells, Nevada (Fig. 1). This conductive zone is ~60 km wide, penetrates to at least 20 km depth, and dips ~70° southwest (D–D'; Fig. 2). The conductive zone also becomes predominantly 3-D, suggesting that it either terminates, turns, or a large conductive zone is nearby. We interpret this broad conductive zone to be related to the suture zone because of its breadth and depth, and (1) its proximity to, (2) similar electrical strike direction, and (3) position along strike with the suture zone on the eastern Nevada profile (Fig. 1). We also interpret this broad conductive zone to be partly a rift zone from east-west extension.

This major anomalous conductive zone also contrasts with a thick section of resistive (100–5000 ohm-m) crust (below 5 km depth), east of MT station 29, that penetrates to the middle crust (at least 20 km depth), suggesting that this resistive crust is intact. We also interpret this resistive section of crust to be Archean because of its intact appearance and its position adjacent to the inferred Archean crust on the eastern Nevada profile (B–B'; Fig. 2).

The thick section of isolated resistive (100–500 ohm-m) crust (below 5 km depth), between MT stations 30 and 32, that penetrates to the middle crust (15 to 20 km depth), could be an isolated block of Archean or Proterozoic basement because of its depth extent and its position west of the inferred rift boundary along this profile.

Moderately conductive to resistive (20–1000 ohm-m) crust in the upper few kilometers correlates with Paleozoic rocks exposed at the surface (Coats, 1987). We infer shallower conductive (1–20 ohm-m) rocks in the upper 1–2 km to be Cenozoic basin fill (Wallace et al., 2004).

**DISCUSSION**

Broad conductive zones, identified in our MT profiles, relate to geologic features evident at the surface. Along the Utah profile (A–A'; Fig. 1), the southwest strike of the broad conductive zone is oblique to the north-south orientation of adjacent Cedar Mountain to the west and Stansbury...
Mountain to the east. The strike is also oblique to the majority of the surface fault orientations and fold axes except immediately north of the conductive zone, where the strike is subparallel to the fold axes of Cambrian outcrop (Moore and Sorensen, 1979). Along the eastern Nevada profile (B–B'; Fig. 1), the northwest strike of the broad, conductive zone is also oblique to the north-south orientation of adjacent Pequop Mountains and Goshute Mountain, but is subparallel to the Wells fault (Fig. 1). The northern edge of the broad conductive zone trends directly adjacent to a new gold prospect in the Pequop Mountains. The broad conductive zones follow the general trend of the approximate edge of Archean crust (double-sided arrows on A–A', B–B', and D–D'; Fig. 1) proposed by Reed (1993). The broad conductive zones at depth apparently have little relation to most structural features found at the surface, but are subparallel to the Wells fault and the proposed approximate edge of Archean crust. We interpret the broad conductive zones along profiles A–A' and B–B' to be part of a major regional suture zone separating Archean terrane to the north from Proterozoic terrane to the south (Rodriguez et al., 2005). Along the Elko profile (C–C'; Fig. 1), the electrical strike direction of the narrow conductive zone near MT station 20 is subparallel to the shallow, ore-controlling faults near the Jerritt Canyon (jc, Fig. 1) deposit (Phinisey et al., 1995; Folger et al., 1995).

A comparison of the electrical strike directions of the broad conductive zones on the eastern Nevada, Elko, and Wells profiles, along with the electrical strike directions of narrow, deeply penetrating conductive zones reported in Rodriguez et al. (2007), on a map of anomalous gold in stream sediments (Fig. 3) of north-central Nevada (Emsbo et al., 2006) shows that the broad conductive zones generally occur within the anomalous gold distribution. These results reveal a possible link of the inferred deep crustal fault zones to gold distribution at the surface.

Our inferred suture zone follows the general trend of the approximate edge of Archean crust proposed by Reed (1993), although our interpretation would place the approximate edge of Archean crust north of Reed’s interpretation on the Utah and eastern Nevada MT profiles (gray swath; Fig. 4). Link et al. (1993) showed essentially the same extent for Archean crust in northeast Nevada (as part of the Wyoming Province), but interpreted Archean and Proterozoic basement to terminate at the early Paleozoic rifted margin in this region. Our interpreted results on MT profiles C–C' and D–D' (Fig. 2) show that Archean and/or Proterozoic basement may exist west of the rifted margin in the form of isolated rifted blocks at depth. This is an important distinction, because our results suggest that gold sources from potential Archean lode deposits may be closer to the mineral trends in north-central Nevada (Fig. 4) than might be surmised from Link et al. (1993).

Our proposed location for intact Archean is north of Tosdal et al.’s (2000) proposed location for Archean crust (north of the Ruby–East Humboldt metamorphic core complex, REH; Fig. 4) and east of the Sr line. Our resistivity models do not support intact Archean crust west and north of the Ruby–East Humboldt complex. Also, our proposed location for intact Proterozoic is south of Tosdal et al.’s (2000) proposed location along the eastern Nevada border. Intact Archean and

Figure 3. Anomalous gold in stream sediments (Au >30 ppb, peach color); map in northern Nevada is modified from Emsbo et al. (2006). Double-sided red and black arrows are magnetotelluric (MT) strike directions of two-dimensional conductors ~10 km below the ground surface. MT strike resolution is ±10°. Solid yellow rectangles are Battle Mountain–Eureka (BME), Getchell (GT), and Carlin (CT) trends, and Jerritt Canyon (JC) and Alligator Ridge (AR) districts. Physiographic descriptions and acronyms are as in Figure 1.
Proterozoic crust should appear as thick, broad resistive material. The interpretation of Tosdal et al. (2000), based on isotope data, places Archean crust adjacent to the Sr\text{i} line. Their interpretation might have been influenced by isolated blocks of rifted Archean crust that we infer could exist. Integrating our results with the isotope data suggests that isolated blocks of rifted Archean crust may exist adjacent to the Carlin trend and Jerritt Canyon district. This could have important implications for future mineral exploration in the area because it suggests that, in general, future mineral exploration to the east may yield large gold tonnages, as these exploration targets would be closer to potential Archean gold sources if ore-controlling faults and stratigraphy are favorable (Cline et al., 2005; Hofstra and Wallace, 2006). More specifically, exploration near edges of isolated blocks of inferred Archean crust, delineated with these MT surveys, may yield large tonnages in areas of favorable ore-controlling structure and stratigraphy.

A comparison of our inferred suture zone (gray swath; Fig. 4) with the projected Cheyenne belt from very deep (100 km depth) seismic velocity anomalies (Karlstrom et al., 2005) shows that our inferred suture zone generally follows the outer edge of a high-velocity anomalous zone in northern Utah and northeastern Nevada (Fig. 5) that is adjacent to the projected Cheyenne belt.

Sims et al. (2005) showed Archean basement extending into north-central Nevada west of the Battle Mountain–Eureka mineral trend (Fig. 4) based on geologic interpretations of magnetic data. Our resistivity models do not support intact Archean crust this far west and south, suggesting that the magnetic data may be reflecting other sources, although isolated blocks of rifted Archean crust may exist this far. Rodriguez et al. (2007) reported isolated blocks of thick (10–20 km) resistive (300–1000 ohm-m) crust beneath the Battle Mountain–Eureka, Carlin,
PROFILE RESISTIVITY MODELS. Resistivity models may have influenced subsequent patterns of sedimentation, deformation, magmatism, and hydrothermal activity. This geologic framework is the most compelling explanation for the Utah profile resistivity model. Resistivity modeling reveals thick (>10 km) conductive (2–20 ohm-m) zone wedged between resistive crust consistent with the suture zone exposed to the east that separates Archean terrane to the north from Proterozoic terrane to the south. An orthogonal deviation in the broad conductive zone electrical strike direction (from southeast in Utah to northwest in eastern and northeastern Nevada), significant widening (from 20 km to 100 km width), along with the appearance of isolated blocks of thick resistive basement within the conductive zone complicate the interpretation in northeastern Nevada. These results are best explained by early Paleozoic rift ing of the continent and Phanerozoic accretion, suggesting that the major gold belts may overlie isolated blocks of either Proterozoic or Archean crust, and where isotope data indicate Archean crust, Phanerozoic mineral deposits in this region may be produced, at least in part (Emsbo et al., 2006; Hofstra and Wallace, 2006), from recycled Archean gold. Isotope data (Tosdal et al., 2000) and magnetic data (Sims et al., 2005) suggest that the isolated blocks of resistive crust modeled along profiles MT1–MT9 may be either Archean, Proterozoic, or mixed basement.

SUMMARY AND CONCLUSIONS

The Archean-Proterozoic suture zone formed after Early Proterozoic rifting of the continental and subsequent Proterozoic accretion, and may have influenced subsequent patterns of sedimentation, deformation, magmatism, and hydrothermal activity. This geologic framework is the most compelling explanation for the Utah profile resistivity model. Resistivity modeling reveals thick (>10 km) resistive (100–5000 ohm-m) crust that we interpret as Precambrian crust, delineated with these deep resistivity surveys, may yield large tonnages in areas of favorable ore-controlling structure and stratigraphy.

ACKNOWLEDGMENTS

Data collection, processing, resistivity modeling, and preliminary interpretations in this study were supported by the U.S. Geological Survey Mineral Resources Program under the Metallogeny of the Great Basin project. We are grateful for access to survey sites by the Bureau of Land Management and the Humboldt National Forest Service. The manuscript was improved by helpful suggestions from A.R. Wallace and D.A. Ponce.

APPENDIX

Magnetotelluric Method

The magnetotelluric (MT) method is a passive surface electromagnetic (EM) geophysical technique that measures the Earth’s natural electric and magnetic field to investigate the electrical resistivity structure of the subsurface from depths of tens of meters to tens of kilometers (Vozoff, 1991). Worldwide lightning activity at frequencies of 10,000 Hz to 1 Hz and geomagnetic micropulsations at frequencies of 1 Hz to 0.001 Hz provide the majority of signal used by the MT method.

The natural electric and magnetic fields are recorded in two orthogonal, horizontal directions (the vertical magnetic field is also recorded). For a two-dimensional (2-D) Earth, the MT data can be decoupled into transverse-electric (TE) and transverse-magnetic (TM) modes; 2-D resistivity modeling is generally undertaken to fit both modes. When the geology satisfies the 2-D assumption, the MT data for the TE mode are assumed to represent the situation when the electric field is polarized along geologic strike, and the data for the TM mode are assumed to represent the situation when the electric field is oriented perpendicular to strike. The MT method is well suited for studying complicated geological environments because the electric and magnetic relations are sensitive to vertical and horizontal variations in resistivity. The method is capable of establishing whether the EM fields are responding to a 1-, 2-, or 3-D subsurface geometry. For an introduction to the MT method and references for a more advanced understanding, see Dobrin and Savit (1988) and Vozoff (1991).

Resistivity Models

The MT profile soundings were initially inverted with a 2-D resistivity inversion program, RL2D2I (Mackie et al., 1997), using only the TM mode data because significant portions of the observed data indicated a 3-D response (Wannamaker et al., 1984). We subsequently forward modeled using a 2-D finite-element integral solution program, PW2DIS (Wannamaker, 1989), to improve computed fits to the 2-D and 3-D MT data recorded along the profiles. Each 2-D resistivity model is constructed by adjusting the resistivity values beneath the profile of MT stations, so that for all stations the calculated 2-D response agrees with the measured data. Again, we primarily attempted to fit the TM mode data where the observed data indicated a 3-D response (Appendix Figs. 1–4). Resistivity boundaries in the models are only approximately located, because the MT station

Figure 5. Inferred Archean-Proterozoic suture zone (white swath) from magnetotelluric data and 100-km-depth tomographic image of seismic velocity and geologic elements modified from Karlstrom et al. (2005). Warm colors (red and yellow) are slow velocities relative to high velocities (cold colors, green and blue). Red lines are seismic line annotation from Karlstrom et al. (2005). Warm colors (red and yellow) are slow velocities relative to high velocities (cold colors, green and blue). Red lines are seismic line annotation from Karlstrom et al. (2005). Warm colors (red and yellow) are slow velocities relative to high velocities (cold colors, green and blue). Red lines are seismic line annotation from Karlstrom et al. (2005).
Appendix Figure 1. Magnetotelluric (MT) observed resistivity data (black circles and crosses are transverse electric [TE] and transverse magnetic [TM] modes, respectively) and calculated resistivity response (green circles and orange crosses are TE and TM modes, respectively) for profile A–A'.
Appendix Figure 2. Magnetotelluric (MT) observed resistivity data (black circles and crosses are transverse electric [TE] and transverse magnetic [TM] modes, respectively) and calculated resistivity response (green circles and orange crosses are TE and TM modes, respectively) for profile B–B’. 
Appendix Figure 3. Magnetotelluric (MT) observed resistivity data (black circles and crosses are transverse electric [TE] and transverse magnetic [TM] modes, respectively) and calculated resistivity response (green circles and orange crosses are TE and TM modes, respectively) for profile C–C'.

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Appendix Figure 4. Magnetotelluric (MT) observed resistivity data (black circles and crosses are transverse electric [TE] and transverse magnetic [TM] modes, respectively) and calculated resistivity response (green circles and orange crosses are TE and TM modes, respectively) for profile D–D'.

spacing is ~10 km for all profiles. It is possible that undetected rock units may exist between stations that are not interpreted in the resistivity model because of the wide station spacing. This is especially possible for resistive rocks, but also for narrow or thin conductive zones.

The Utah profile projection on the Utah resistivity model (B–B'); Fig. 2) passes through MT station 25 at a bearing of N13E (B–B'; Fig. 1). The profile resistivity model consisted of 136 × 64 variable dimension cells extending more than 300 km horizontally beyond the profile end points and more than 200 km vertically to minimize edge effects. In the finer part of the mesh, the horizontal element size varied between 8.5 km and 2.6 km, while the vertical element size varied from 10 m near the surface to 1000 m below 5 km depth.

The observed data and calculated response are in Appendix Figure 1.

The eastern Nevada profile projection on the eastern Nevada resistivity model (B–B'; Fig. 2) passes through MT station 25 at a bearing of N13E (B–B'; Fig. 1). The profile resistivity model consisted of 136 × 64 variable dimension cells extending more than 800 km horizontally beyond the profile end points and more than 500 km vertically to minimize edge effects. In the finer part of the mesh, the horizontal element size varied between 0.9 km and 4 km, while the vertical element sizes employed were the same as in the Utah profile model. The observed data and calculated response are in Appendix Figure 2.

The Elko profile projection on the Elko resistivity model (C–C; Fig. 2) passes through MT station 124 at a bearing of N21E (C–C; Fig. 1). The profile resistivity model consisted of 120 × 63 variable dimension cells extending more than 700 km horizontally beyond the profile end points and more than 180 km vertically to minimize edge effects. In the finer part of the mesh, the horizontal element size varied between 0.5 km and 2.5 km, while the vertical element sizes varied between 5 m near the surface to 1000 m below 5 km depth. The observed data and calculated response are in Appendix Figure 3.

The Wells profile projection on the Wells resistivity model (D–D; Fig. 2) passes through MT station 122 and bears east due east (D–D; Fig. 1). The profile resistivity model consisted of 93 × 64 variable dimension cells extending more than 500 km horizontally beyond the profile end points and more than 800 km vertically to minimize edge effects. In the finer part of the mesh, the horizontal element size varied between 0.4 km and 2.8 km, while the vertical element sizes employed were the same as in the Utah and eastern Nevada profile models. The observed data and calculated response are in Appendix Figure 4.


