Geophysical Interpretation of the Verdi/Mogul Basin Geology, Washoe County, Nevada

INTRODUCTION

The Washoe County Department of Water Resources is currently conducting water resources investigations in the Verdi/Mogul basin (see Figure 1). This investigation will result in the development of a groundwater numerical model. This model will provide a conceptual understanding of the occurrence and movement of groundwater primarily in the volcanic and sedimentary aquifers. Therefore it is important that the subsurface alluvium-bedrock configuration of these valleys is understood and delineated- the primary focus of this report.

Geophysical methods can provide a useful image of subsurface geologic structure. These methods include seismic reflection and refraction, electromagnetic and resistivity methods, magnetic surveys, and gravity surveys. Gravity and magnetic surveys were chosen for this investigation because of the relative ease in collecting the data as well as the reasonable cost of acquiring the data. The interpretation of the total magnetic field and the gravitational field (sometimes referred to as potential fields modeling) can be used to locate the subsurface alluvium-bedrock interface and its high angle contacts. This is done through a forward modeling process that involves constructing geologic cross sections, evaluation of their calculated magnetic and gravity responses, and comparison to the actual measured data. The modeling of magnetic and gravity responses is however, non-unique as two or more differing geologic models can describe the measured potential fields data.

Washoe County contracted an airborne geophysical survey (Dighem, 1995, 1996) to map the total magnetic field and electrical resistivity response of this basin. Washoe County also contracted land based gravity surveys (Carpenter, 2000 and 2005). In order to constrain the geologic models, surface data from geologic maps and subsurface data from water well drilling logs is used to guide the potential fields modeling. The Nevada Bureau of Mines and Geology published regional geological mapping of these areas that provides surface geologic constraint on the potential fields modeling.

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GEOLOGIC SUMMARY

The location map (Figure 1) is a color shaded, digital elevation model (DEM) of the study area. The most prominent topographic features are the Verdi Range to the west, Peavine Mountain on the north, and the Carson Range on the south. Elevations range from 1,433 meters (4,700 feet) at the Truckee River near Mogul to 2,574 meters (8,444 feet) in the Verdi Range, 2,520 meters (8,266 feet) on Peavine Mountain, and 2,701 meters (8,860 feet) in the Carson Range. The Truckee River enters the study area from the south, flowing to Verdi and then flows east to Mogul and Reno on its course to Pyramid Lake. The Truckee River generally cuts Tertiary sedimentary rock and is confined to its incised channel with minimal flood plain areas. Alluvial fans are minimally developed such that the sedimentary units are predominately pediments to the flanks of the three mountain ranges. Most of the flat lying valley area is covered with a thin veneer (<30m) of Quaternary Truckee River deposits. Two perennial creeks, Dog and Roberts, and several ephemeral (unnamed) are tributary to the Truckee River.

There are few published reports on detailed geology of this specific area. The University of Nevada and the Nevada Bureau of Mines and Geology are currently working in the area and have geologic publications and maps (Henry and Perkins, 2001; Trexler et al., 2000; Bell and Garside, 1987). Figure 2 represents a generalized geologic map, enhanced with shaded topography, from Dr. Chris Henry (2000, with permission), Nevada Bureau of Mines and Geology. Generally the study area can be described with five geologic units (Table 1), Cretaceous granodiorite, Mesozoic metavolcanics and metasediments, Tertiary volcanics, Tertiary sediments, and Quaternary alluvium.

Table 1.
Generalized geologic units.

Qal	Quaternary Alluvium
Ts	Tertiary Sediments
Tv	Tertiary Volcanics
Mzv	Mesozoic Metavolcanics
Kgr	Cretaceous Granodiorite

The oldest rocks are the Cretaceous granodiorite and Mesozoic metamorphic rocks primarily exposed in the Verdi Range, Peavine Mountain and at the community of Mogul. The metamorphic rocks are associated with the Peavine sequence. These rocks are primarily intermediate volcanic extrusives and detritus. They have been intruded by granodiorite associated with the Sierra Nevada batholiths, dated at 97.1±0.5 Ma (Henry, 2007). These uplifted rocks occurred approximately 3 Ma (Henry and Perkins, 2001).

Mid- to late Tertiary (Miocene age) volcanics are comprised of andesite and dacite flows, intrusives, and ash flow tuffs that are associated with the Alta and Kate Peak Formation also mapped in other areas of Washoe and Storey Counties. These comprise much of the underlying or outcropping rocks of Peavine and the Carson Range. The sedimentary rocks of late Miocene to Pliocene have been named the sandstone of Hunter Creek by Bell and Garside (1987). These rocks have also been associated with the Truckee Formation and the Coal Valley Sequence. For this report, these rocks are termed the "Verdi Basin sediments" (Trexler, personal communication).

The Verdi Basin sediments largely form uplifted and tilted pediments on the flanks of the three ranges. They have been extensively mapped and consist of variations of, from oldest to youngest, conglomerate, sandstone, silt and mudstone, and relatively thick diatomite. From this coarse-to-fine grain depositional character the environment can be inferred as fluvial to deltaic to lacustrine deposition. This sequence spans approximately 12-10.4 Ma until approximately 3 Ma (Henry and Perkins, 2001).

The generalized geologic map of Henry (2000) is well suited to orient the reader to the geologic structure. As shown in Figure 2, the Verdi Basin is an east-west elongated basin whereby the north and south slopes dip toward the basin axis following topography. The west slope has steep, Cretaceous (K) rock forming the topography of the Verdi Range whereby the Verdi Basin sediments (Ts), oddly, generally dip to the west. At the eastern hydrographic boundary of the Basin, Cretaceous granodiorite (K) crops out.

The southern Verdi Basin sediments form large bluffs that dominate the landscape along the northern extent of the Carson Range. These sediments also form the southern slope of Peavine Mountain, but are not as thick and contain outcrops of the olivine basalt. It is not uncommon for the sediments to lie directly upon Cretaceous granodiorite. The Quaternary sediments, mostly glacial outwash and Truckee River deposits, are probably less than 30m (100 feet) thick based upon lithologic drill logs.

Little is known of the geologic structure prior to Basin and Range tectonic events or the Sierra Nevada orogeny that occurred 3 Ma (Henry and Perkins, 2001). In northwestern Nevada, normal faulting during the formation of the Basin and Range created north-south trending mountain ranges comprised of granodiorite and volcanic rocks with volcanic and alluvial filled basins. The Verdi Basin was probably influenced by this and captured within the Sierra Nevada uplift.

The unique character of the Verdi Basin shows fault structures trending north-south, east-west, and northwest-southeast. The north-south and east-west trending faults are probably mostly dip-slip whereas the northwest striking faults are probably oblique, dextral, strike slip faults (Cashman, 2007). Immediately to the east of the Verdi Basin are northeast, sinistral faults (Cashman, 2007). The basin has been described as a doubly plunging syncline (Trexler, et al, 2000).

GEOPHYSICAL DATA SETS

Gravity information was compiled from several surveys contracted to Tom Carpenter, consulting geophysicist. Surveys were conducted from 2000 through 2005 during which over 200 gravity stations were measured within the hydrographic basin (Carpenter, 2000 and 2005). Hundreds of other regional gravity stations have been collected by Carpenter under other Washoe County contracts whereby the compilation has been singly processed. The data were collected using a LaCoste and Romberg Model G-230 gravimeter with a precision of 0.01 mGal. Positions were located by rapid static GPS survey methods using a WILD GPS – System 300 manufactured by Leica. The elevation accuracy is believed to be better than ±20cm. The 1971 International Gravity Reference Network base at the James G. Scrugham Engineering Mines Building at the University of Nevada, Reno served as the local reference gravity value. The measured data were reduced to Complete Bouguer values using 2.50 g/cm^3 as the bouguer density.

Dighem, Inc. was contracted by Washoe County to conduct the airborne geophysical surveys (Dighem, 1996). The DIGHEM system utilizes the principle of frequency domain electromagnetic induction to measure shallow profiles of the electrical resistivity of the earth beneath its helicopter towed transmitter-receiver boom. The term frequency domain refers to the system's continuous transmission and reception of oscillating magnetic signals at fixed frequencies, in this case 900 Hz, 7200 Hz and 56,000 Hz. Its basic principal of operation is related to inductive metal detectors but more sophisticated in is details. Continuous oscillating magnetic signals are generated at the system's operation frequencies by controlled currents in separate tuned transmitter coils located in the towed boom's front-end. The generated magnetic field lines have the geometry of the fields of a dipolar bar magnet centered on the transmitter coil which extend through the air and into the earth. The maximum effective penetration is about 100 meters with the actual usable depth determined by earth resistivity and transmitted frequency through the skin-depth formula as well as the strength of the transmitter and its height above the earth. Through the principle of Faraday's law of magnetic induction, the transmitter's oscillating, earth penetrating magnetic field lines induce weak but measurable oscillating secondary eddy currents in the earth whereby the lower the earth's resistivity, the stronger the secondary eddy current signal. Through Ampere's law, the earth eddy currents produce associated oscillating magnetic fields (secondary magnetic fields) which extend out of the earth into the air where they can be detected. The amplitude and phase of these secondary signals are measured by tuned receiver coils in the rear of the towed boom. The DIGHEM data used in this study was processed by the contractor to provide estimates of the earth's electrical resistively at each of the three frequencies. This report largely uses the 900 Hz earth resistivity estimate, which is the deepest probing and most geologically useful of the three frequencies for the Verdi/Mogul basin.

Gravity Data

Figure 3a displays the gravity dataset as Complete Bouguer Anomalies (density slab=2.50g/cc), gridded (150m) and contoured (1.0 mGals contour interval), overlain on the topographically shaded Henry geologic map. Also included are the gravity station locations (red dots). For illustrative purposes, Figure 3b displays the contoured gravity data (0.5 mGals contour interval) as a color shaded relief map. In comparing the two Figures (and the Bell and Garside, 1987 geologic map not shown) many features can be delineated. Theses features are numbered (1-10) on Figure 3b and discussed below.

1. The highest valued gravity anomalies are correlated to granodiorite and in particular the highest of the anomalies to the metamorphic rocks in the Verdi Range and Peavine Mountain. The boundaries of these two range blocks define the basin margins on the west and north particularly where the higher gradients and high angle faults are mapped (Verdi Range) or inferred (Peavine Mountain).

2. At the southern edge of the basin a moderately high gravity anomaly is found that trends, from left to right, southeast to east. Interestingly this anomaly plots on Tertiary volcanics that have been hydrothermally altered (labeled "bleached" on the Thompson and White geologic map, 1964). This is inferred to represent an intrusive body, perhaps a laccolith. More importantly for this report though, is that it represents the southern boundary of the basin where Cretaceous outcrop can also be found along the high angle, gravity gradient.

3. Another relatively high-valued gravity anomaly is located to the east of the Verdi basin over what is mapped as granodiorite, termed in this report the Mogul granodiorite. The eastern and southwestern boundaries of the outcrop are associated with strong gravity gradients (closely packed contours) and define the eastern boundary of the Verdi/Mogul basin.

4. The lowest value gravity anomalies correspond to the mapped Tertiary sediments termed the "Verdi Basin sediments". These are effectively delineated in the central portion of the basin with low gravity anomaly of –179.5 mGals. These sediments form the pediments (or bluffs) along the north face of the Carson Range as shown on the Henry geologic map in Figure 3. The basin deposits can also be somewhat delineated immediately north of the west-east low anomaly just discussed and a smaller (6 km^2 or 2.5 mi^2) pocket of sediments north of the Mogul granodiorite. As will be discuss later, these sediments range in thickness from 100-400m and are inferred to overlie Tertiary volcanics, in most cases.

5. Here, moderate valued anomalies correlate to Tertiary volcanic rocks, but elsewhere do not typically delineate olivine basaltic rocks found in the Tertiary sediments.

6. Moderate anomalies also correlate to granodiorite (K) rocks that are inferred to be near the surface in several areas of the southern portion of the mapped area where small outcrops appear beneath the Tertiary volcanic rocks.

7. Strong gravity anomaly gradients, expressed as closely spaced contours, indicate high angle faults or contacts. The largest valued gradient is located atop the normal fault trace of the Henry map, oriented north-south in the western portion

of the map. Other gradients of note are two parallel northwest-southeast oriented structures that trace the outcropping granodiorite and mapped olivine basalt (Bell and Garside, 1987) found in the central portion of the Figures. Other lesser gradients probably represent the gradual change in thickness of the volcanic and sedimentary rocks towards the center of the basin. Also, see Figure 6c1 fro gravity gradient mapping. The gradient fabric shows three pattern orientations of west-east, north-south and northwest-southeast corresponding to the major mapped geologic fault systems.

Magnetic Data

Figure 4a displays the east-west flight line paths of the Dighem survey, overlain on the Henry geologic map. Flight line spacing is typically 600m (2000 ft). Figure 4b displays the contoured magnetic data overlain on the Henry geologic map and Figure 4c displays a color-shaded relief map of the total field magnetic data. The total magnetic intensity values observed along the light lines were interpolated to a 100-meter grid, upward continue filtered 100 meters. This was done to reduce expressions of shallow magnetic sources and the reduced-to-pole corrected better-centered anomalies over their geologic sources.. The contour interval is 50 nano-Teslas (nT).

The most obvious anomalies are the north-south oriented feature at the west end of the figures and the conical feature at the near center of the map (Figures 4b and 4c). Both of these anomalies are inferred to represent the expression of the olivine basalt (Bell and Garside, 1987). However, these basalts are not distinctly mapped throughout the area by the airborne survey. This is due to the relatively wide, survey flight line spacing and to the "fickle" magnetic nature of volcanic extrusive rocks. The conical feature has the appearance of a volcanic cone and is mapped over olivine basalt outcrop. The north-south oriented feature may represent a dike swarm, a structure that lies between two normal faults on the Henry geologic map. It may also represent Mesozoic metamorphic rock of the Peavine Sequence. The low magnetic anomalous areas correspond closely to the Verdi Basin Sediments in the southern portion of the Figures. The granodiorite is outlined by its moderately magnetic expression (see Figure 3b).

Resistivity Data

Figure 5a and 5b displays the 900 Hz resistivity data on the Henry geologic map and as a color-shaded relief map, respectively. The gridded data (100m) was also upward continued 100m. This was done to smooth out the near surface conductive units. Because the data is contoured logarithmically (base 10), each 0.25 unit contour represents a 78% increase in the change of apparent resistivity.

The more resistive units map the Mogul granodiorite and the granodiorite and/or metamorphic rocks along the base of the Verdi Range. The olivine basalts centrally mapped (along US 40) are shown as moderately conductive. The magnetic unit inferred as a dike swarm discussed above is shown as moderately to highly resistive and therefore may not be olivine basalts, (if the two units are to have the same signature resistance). Very low resistive units of note are located adjacent to the Mogul granodiorite. These units of low resistance are not well mapped, but have the signature of geothermal discharge based upon similar anomalies located over the Steamboat Springs Geothermal Area (Widmer, 2007). The low anomaly located at the extreme east of edge of the map is located over a commercial hot springs spa.

Potential Fields Analysis

One method of analysis compares data sets by overlaying contours of one set upon another data set imaged as a color-shaded relief map. Another method takes the horizontal derivative of potential fields to delineate regions of where the strongest gradients exist. This "total horizontal gradient" processing technique applied to gravity, magnetic and resistivity data often delineate the boundaries of lithologic units. Fault structures can also be modeled using gravity data based upon the vertical offset and consequent density contrast.

<u>Gravity-Magnetic-Resistivity comparisons</u>

Figure 6a displays color-shaded relief map of the reduced-to-pole, upward continued (100m) total field magnetic data, with contoured (0.5mGals interval) with the Complete Bouguer Anomaly gravity data. The gravity high anomalies plot over the obvious magnetic highs. These are the olivine basalt outcrop in the center of the map and the north-south structure on the east face of the Verdi Range. Low gravity anomalies (low density units) plot over low magnetic units especially where the Verdi Basin sediments are found south of I-80. Mogul granodiorite is subtly mapped where high-density contours map on low magnetic material. Also, where this granodiorite is inferred from the gravity, the magnetization increases at the boundaries and might indicate a thin volcanic cover beneath thin Verdi Basin Sediments.

Figure 6b displays the contours (1 mGal interval) of the gravity data upon the color-shaded relief map of the upward continued (100m) $\log_{10}$ 900 Hz resistivity data. Overall the two data sets are complimentary. Once again, the high gravity anomalies are depicted with the high resistivity along the east face of the Verdi Range and the Mogul granodiorite. And the gravity lows are supported by the low resistivity south of I-80 where the Verdi Basin sediments are the thickest. Other subtle features can also be seen north of Verdi proper, inferred to be thinner deposits of these Tertiary sediments.

<u>Lineament Analysis</u>

Figure 6c1 displays a color-shaded relief map of the total horizontal gradient (THG) of the gravity data (original grid was upward continued 100m). The stronger gradient trends are demarked with a lineament (yellow line segment) where the greatest contrast in density occurs, typically representing high angle contacts. Figure 6c2 plots these lineaments on the Henry geologic map showing the Complete Bouguer Anomaly gravity contours. Several important contacts are delineated. At the southwestern portion of the Figure, contacts of the Verdi Basin sediments (Ts) are approximately delineated west and south of I-80, where the largest gradient mapped falls along a fault depicted on the Henry geologic map. In the northwest portion of the Figure a southeast projecting gravity high lobe is delineated by two lineaments mapped under Quaternary deposits. In the center of the Figure, a northwest trending gradient occurs along US Highway 40 (road not shown) that parallels the olivine basalt. Finally, the lateral subsurface extent of the Mogul granodiorite appears to be partially delineated by three lineaments. In general, the lineaments appear to correlate to geologic structure and should assist in defining the boundaries of these units.

Figure 6d1 is a color-shaded relief map of the total horizontal gradient (THG) of the total field magnetic data (upward continued 100m, reduced-to-pole). Here the THG process shows where the greatest lateral change in magnetism occurs, often delineating the edges of magnetic bodies. Lineaments were drawn where the gradients were greatest and where the trend was supported by at least two flights lines. That is to say that gradients from the gridding process were discounted if not supported by more than one flight line. These lineaments are displayed on the Henry geologic map (Figure 6d2), contoured with the total field magnetic data (100nT contour). In Figure 6d2, a pair of magnetic THG lineaments (peach colored lines) corresponds to the western and eastern boundaries of the Verdi Range magnetic anomaly (also see Figure 4b). The eastern lineament overlies a mapped fault on the Henry geologic map. The western lineament occurs in an area of undifferentiated **Ts**. Magnetic THG lineaments were also identified on the southwestern and northeastern edges of a circular magnetic anomaly associated with a mapped olivine basalt. The Mogul granodiorite has weak to zero magnetic expression and consequently is poorly outlined by magnetic gradients.

Overall, the magnetic THG lineaments are more difficult to relate to mapped geologic features than the gravity THG lineaments in the study area. This is a result of the large range of magnetization strengths within the individual geologic units which causes local subunits, such as the olivine basalt, to dominate the magnetic map.

Figure 6e1 shows the total horizontal gradients of the $\log_{10}$ 900 Hz resistivity data, portrayed as a color-shaded relief map. Lineaments drawn are plotted on the Henry geologic map (Figure 6e2) and define the edges of resistive units on the Verdi Range and the Mogul granodiorite. The Mogul granodiorite is poorly defined by these lineaments, probably due to the wide flight line spacing and resultant gridding process.

Figure 6f displays all three lineament sets derived from the total horizontal gradient process, overlain on the Henry geologic map. The magnetic and resistivity lineaments support the normal fault structure at the base of the Verdi Range. The gravity and magnetic lineaments support the delineation of the olivine basalt along US Highway 40 in the center of the Figure. The gravity and resistivity lineament sets delineate, to some degree, the Mogul granodiorite outcrop. Also shown are mapped Quaternary faults (blue).

Potential Fields Discussion

As can be seen in Figure 3b, the gravity data has utility in directly delineating the geometries of the various sub-basins in the Verdi-Mogul area. This study interprets local gravity highs as representing shallow or outcropping basement rock of lower porosity (with high density); and local gravity lows as representing thicker sequences of potential aquifers consisting of alluvium or fractured volcanics with lower densities. It is particularly useful in delineating the Verdi Basin sediments. The fabric of apparent fault structure is delineated as noted in Figure 3b (features delineated with a 7). Additional work in the southwest portion of the basin (or this Figure) would help to define metamorphic units and the very low gravity anomaly in this area.

The magnetic data was useful in defining the volcanic nature of the olivine basalt in the central portion of the area. The magnetic high found at the western boundary begs the question as to whether it is basalt as well, but current field mapping does not lend any support to this. However, volcanics do exist to the north of this anomaly. This data set also shows the non-magnetic nature of the Verdi Basin sediments and of the Mesozoic metavolcanics and Cretaceous granodiorite. The magnetic lineaments also help to define basin structure.

The resistivity displayed in logarithm units is very helpful in defining the geothermal system and granodiorite at Mogul. It also supports the anomaly found at the base of the Verdi Range. At these sites the gradient is rather steep, producing sharp, linear features at the Mogul granodiorite.

The "wide" spacing of the airborne magnetic and resistivity flight lines probably only generally outline other features besides those noted. There is common identification of features when two data sets are compared as discussed above. This helps to reduce the uncertainty of geologic features such as shown in Figure 6a where both data sets' anomalies appear coincident.

The lineament analysis using total horizontal gradient techniques is useful with individual data sets. As displayed in Figure 6f, however, few lineaments are coincident. Where they are coincident, structure is more certain. This is apparent where mapped faults exist (at the base of the Verdi Range), an inferred fault along the centrally located olivine basalt (along US 40), and the Mogul granodiorite. These lineaments are useful when constructing the geologic cross sections, lending support to inferred structure.

GEOLOGIC MODELS

Figure 7 shows the location of eight geologic cross sections that were developed using the gravity data sets, mapped geology and borehole lithologic descriptions. These sections were chosen primarily based upon their perpendicular alignment to gravity gradient contours and secondarily to the availability of borehole data along that section. While the sections were modeled beyond the length sections shown, only the portions within the scope of the study are displayed. These same section portions are better detailed in the appendix with borehole depths and locations, gravity profiles and other data of interest. Note that the scale of the west to east sections is 1:35,000 whereas the north to south sections are 1:25,000 scale. All sections have no vertical exaggeration.

Each section is conformable to the other sections. Care was taken to model each section consistent with the geology and geophysical evidence throughout the study area. Where sections crossed one another, each lithologic thickness of the coincident sections were modeled to within ~20% (mostly to 10%) and without compromising the gravity data or other geologic evidence. Care was also taken to refrain from inserting inferred faults as a way of explaining lithologic anomalies. Finally, the Tertiary volcanic unit was usually included as a laterally continuous unit unless direct evidence proved otherwise. It is recognized that this may not be physically true throughout the study area, but it is a reasonable assumption as the unit is widespread in outcrop throughout the area.

Figure 7 displays the common lineaments derived from the geophysical and topographical data sets. These lineaments are inferred as faults in the cross sections and some may be coincident with mapped faults. Lithologic data derived from boreholes were important factors in determining the location and existence of the structural inferences.

At the western edge of the map, two faults are drawn that are coincident with those shown on the Henry map. These were independently drawn based upon the gravity gradients. At the northwest, lineaments are drawn on the boundaries of the high-density, subsurface, lobe like unit emanating from the Dog Creek drainage. To the east, a northwest-southeast striking normal fault is drawn. This lineament is coincident with volcanic and granodiorite outcrop boundaries, both mapped or understood from borehole lithologic logging. Topography was also useful in determining this lineament. For the purposes of this report, it will be referred to as the "River Bend fault" as its discovery was found where the Truckee River bends from eastward to southward and Verdi locals use this name (i.e. River Bend Trailer Park). Further to the east, another normal fault is drawn that is derived from the mapped granodiorite and the three geophysical data sets. Two west-east trending lineaments are drawn at the bottom of the Figure and are drawn largely due to topographic breaks, mapped lithologic changes and gravity gradients. All of these features, as well as their uncertainty, are discussed below.

The inferred faults all depict a sense of dip slip motion. The lineaments can be grouped in three sets of two based upon their strike and close proximity. The inner lineaments indicate a slip direction towards the Verdi basin creating a "dropped-down or pull-apart". It is interesting to note that the geologic modeling, based upon the gravity, supports this as does field mapping of the Tertiary sediments that are contained within this interpreted feature. Whether or not this is structurally feasible is not understood at this time, but will be investigated. However, explanations could be related to 1) the Sierra Nevada Batholith moving to the northwest relative to the North American craton (citation), 2) isostatic rebound in the Carson, Verdi and/or Peavine ranges, and/or 3) movement relative to the Walker Lane strike slip fault zone.

Figures 8a and 8b each lay out the cross sections discussed below. Figure 8a shows the four west-to-east cross sections with the top section the most northern. Figure 8b shows the four north-to-south cross sections with the most eastern section as the top section. These two Figures do not display the geologic evidence used in their construct, but these same sections can be viewed in the Appendix where borehole lithology is noted, coincident gravity profiles, and with markers that indicate where cross sections intersect with their lithologic contacts. All faults shown are inferred and a sense of motion is provided. There is no vertical exaggeration and the scales are 1:35,000 and 1:25,000, respectively. The distances scale is in meters and provides a means of locating features on the sections discussed below.

Section A-A'

This section shows very little lithologic change from the underlying granodiorite. At the left of the section, inferred metamorphic rock underlies a small thickness of volcanic rock with minor sedimentary rock (Verdi Basin sediments). At the west is an inferred contact bounding the gravity anomaly identified as 6 in Figure 3b. It is not understood if this is a fault that also may have created the Dog Creek Canyon, trending north-northwest. The metamorphic unit is shown to underlie the volcanic unit because it is mapped in the area consistent with Sections BB' to DD', and explains the gravity anomaly. However, this unit could also be dense volcanic rock that is mapped in the area as well, but would require hundreds of meters of thickness.

At the eastern end of the section, the sedimentary unit is mapped and the depth is estimated from gravity modeling. Note that volcanics or metamorphic rocks do not underlie this unit as modeled because there are sedimentary units on top of granodiorite near Mogul. However, there are volcanic units also mapped in the area and in Mogul so that this problem is not worked out, but is minor with respect to the ground water flow model objectives.

Section B-B'

This section was difficult to model. Fortunately, there were boreholes drilled to depths of 150 meters (500 feet) that helped to constrain the model. This section displays several faults that indicate fault block structure. The most western fault is shown on the Henry geologic map and supported by gravity gradients. The second inferred fault is aligned with the gravity anomaly demarked in Figure 7 that continues to the northwest and shown in Section A-A' as a bounding lineament. An inferred, west-tilted fault block results eastward (6,000m distance tick) and is well documented by borehole data (see detailed cross section in Appendix A).

The graben at distance 6000m to 7000m is documented from recent exploratory drilling (TMWA, 2007). This area also proved difficult to model, but the lithologic results from the recent drilling did not provide any other structural explanation in the context of the gravity modeling. At the 7000m distance the inferred fault is aligned with that shown in Figure 7 and satisfactorily explains topographic relief. This is the "River Bend" fault discussed above. It is assumed that the vertical representation indicates dip slip, but perhaps strike slip motion has occurred on this inferred fault. The discolored volcanic unit at the vertical fault is noted as basalt. The inferred fault at the 9000m distance could easily be a representation of paleo-topography, but is supported by all three geophysical data sets in terms of physical parameter contrasts.

Section C-C'

This west-east section traces along the core of the sedimentary "bluffs" (Ts) that parallel the I-80 and Truckee River corridor. This section depicts sedimentary thickness of 200-400m in the western portion of the section and lesser thickness to the east. This section highlights where the thickest sequence of the Verdi Basin Sediments (Ts) are located.

An assumption was made that the Tertiary volcanic unit underlies these sediments. This is based upon the mapping of the volcanics to the south (upslope of these sediments) and to the north where many water wells were drilled into volcanic rock. Where the volcanic grade is sloping, faults could have been used to models these as offsets, but no evidence could support there usage.

Section D-D'

This section was modeled to better understand the thickness of the mapped volcanic unit and to try to work out the mapped metamorphic unit at the western end of the section, located at the mouth of the Truckee Canyon. This section represents a relatively thin volcanic thickness and where Mesozoic metavolcanic rock is near surface. Further to the south (south of the study area and not shown), the volcanic sequence is relatively thick and may represent a prehistoric volcanic center. To the far right of the section, gravity modeling was difficult and most likely the result of the mapped "bleached" volcanic unit found in the Hunter Creek canyon where rock density has not been measured.

At the 5000m to 5500m distance a unit of metamorphic rock (K) is shown as in Figure 7 on the Henry map, largely based upon the Thompson and White geologic map (1964) in this area. The western fault in the section is mapped on the Henry map, but the inferred fault at the east is not. Further to the east the granodiorite is exposed (K) and so the contact between the two units is not known. This high angle, normal fault may explain this contact. The thickness of the metamorphic unit became problematic as this "wedge" extended to a modeled depth of hundreds of meters. This was necessary because this unit has the highest density of all lithologic units and was needed to satisfy the gravity gradient. The density of gravity measurements in this area should be sufficient to explain this anomaly. But the topography of the canyon and juxtaposed geology is enough to confuse interpretation.

Section H-H'

The north (left) end of the section begins in Tertiary sediments that are elevated above the valley floor by granodiorite. Although not shown, the thickness to the north is estimated at 300m. This is supported by the gravity low anomaly seen in Figure 3b, symbol 4. Southward the granodiorite clearly dominates this section before a "wedge" of Tertiary sediments and volcanics is interpreted. The most southern inferred fault is shown in Figure 7 as the most southern lineament. The other fault shown is inferred and does not coincide with a mapped fault on the Henry map to the east. Both of these inferred faults bound an apparent uplifted section of volcanics that are also "bleached" as discussed by Thompson and White (1964). This part of the section was difficult to interpret. It is apparent from the Henry map and from Cashman (2007) that fault structure is difficult to ascertain in this portion of the Hunter Creek canyon. Note that strike slip faulting is inferred on the Henry map. This section represents only one incomplete interpretation.

Section G-G'
This section was rather straightforward to model. The basalt unit, also shown in Section BB', is verified by borehole lithology (see same section in Appendix A). The fault shown is the River Bend fault as shown in Figure 7 that crosses the basin from southeast to northwest and that shown in section BB". The dip on this inferred fault could be modified from its present slope to one less steep. But the dip on this inferred fault in Section BB' could not be changed from its vertical sense.

The thickness of the volcanic unit below the Tertiary sediments could be manipulated. What is shown, though, is consistent with the thickness where this section crosses section CC'. The thickness is also consistent with sections HH' and GG' as is the uniformity of the Tertiary sedimentary thickness. The inferred fault to the right of the section is approximately located where the fault on the Henry map (Figure 7) is drawn. Again, this portion of the section was difficult to model because of the outcropping granodiorite and the apparent geometry and thickness of the volcanic unit.

Section F-F'
As in Section GG", this section was straightforward to interpret as the apparent geometry of the lithologic units is simply viewed. The interpretation was greatly assisted by borehole lithologies obtained from water well drilling. The 300m thickness of the Tertiary sediments is partially verified by water well drilling (Promax exploratory well) located at 11,600m distance, drilled to a depth of 150m.

The fault structure shown, that represents a horst block (Verdi Bluffs), is inferred from topography, borehole lithology and the gravity data. No other fault structures were needed to model this section. On Figure 7, the River Bend fault is shown to cross this section at the 9,400m distance. There is some discrepancy as to where the continuation of this fault lies relative to the section. It is probable that the fault crosses this section line further north where the Tertiary volcanics outcrop. However, the gravity modeling does not require an offset of lithology. Likewise at the south end of this section, the interpretation does not require denser metamorphic rock as did section DD', a problematic area to interpret.

Section E-E'
This section was also relatively straightforward to model, based upon the gravity data. The Tertiary sediments are interpreted as being 300m thick, partially based upon the Gold Ranch well penetrating 180m of this sedimentary rock (see Appendix for section detail). From the 8000m to the 9,500m distances there is a metamorphic unit that was required due to its density. This coincides with that unit as shown in Section AA'. If the Tertiary volcanics were substituted for the metamorphic unit, an abnormally thick unit would be required. Recall that this unit correlates to the subsurface lobe-like feature identified with

the gravity and magnetic data. Also, at the south end of the section, the metamorphic unit shown was more easily modeled to the gravity data than in section DD'.

MODEL DISCUSSION AND CONCLUSIONS

Previous geologic work did not provide much insight into the geologic structure of the Verdi Mogul basin or regionally. It appears to be mostly limited to surface mapping of lithology with some mapping of obvious faults. Therefore the structure proposed herein cannot be compared to previous work, either locally or regionally. Lithologic structure within the southern Washoe County is currently being studied by Widmer and Oppliger (in progress), Widmer and Cashman (in progress), and others conducted by the Nevada Bureau of Mines and Geology.

Quaternary sediments, largely deposited by the Truckee River, are rarely found beyond the river corridor. Where found, it is apparent from drill logs that the thickness of this unit is a few tens of feet. This would suggest that the Truckee River has mostly been an erosive force, at least during the last few millennia. It is suggested that the Truckee River, or its predecessor, has eroded the Tertiary sediments to the present topography.

Most of the relatively flat lying topography of the basin is dominated by the Verdi Basin Sediments of Tertiary age (Ts). This unit is thickest (300m) at the southern portion of the basin and composes the bluffs that parallel the Truckee River on the south side, particularly where the Truckee River emerges from the canyon. Thin deposits can also be found on the lower slopes of the Verdi Range and northeast of the River Bend Fault, perhaps in an uplifted section (?). The River Bend fault may be a northern boundary for the Verdi Basin Sediments. Thick deposits of this sediment are also found north and east of the Mogul granodiorite noted in Figure 3b and 7.

The extent of the subsurface Tertiary volcanics (lumped as the Kate Peak formation) is poorly understood. As previously discussed, in outcrop they lie atop the Cretaceous granodiorite and metamorphic rocks, but not continuously. Henry and Perkins (2001) discuss that Verdi Range tectonic activity might have begun in 12Ma. Perhaps the Tertiary volcanic unit was mostly eroded from this activity and therefore explain its absence from the Verdi Range. This hypothesized process might also have occurred in Mogul. Paleo-topography is certainly an explanation for where and how thick the Tertiary volcanics are today.

Likewise, the extent of metamorphic units, particularly at the base of the Verdi Range, is unknown. This unit was not considered as a widespread and continuous unit in the modeling. This is because very little evidence for its occurrence could be found. And, from a ground water modeling perspective, this unit is considered to be comparable to the granodiorite, i.e. having the same hydrogeologic properties.

The fault structures were proposed in order to explain lithologic offsets needed in the modeling or to explain unconformities between nearby drill logs. Exploratory drilling for production wells yielded surprising results in terms of the lithology encountered. As discussed above in the Section BB', the proposed River Bend Fault was necessary in this modeling effort and was useful to explain other topographic and geophysical anomalies. Obviously, more detailed geologic work is required to verify this structural feature.

Most of the modeling effort yielded satisfactory results. This is from the perspective of lithologic modeling to the gravity data set. The magnetic data set proved to be not very useful overall for the modeling effort. This was due to its magnetic variability within the diverse volcanic unit, i.e. andesite, basalt, ash-flow tuff, and lahar deposits. It was useful in identifying, in particular, the extent of the basalt unit in the center of the study area- at the "River Bend" (see Figure 3b, number 7). Also, magnetic anomalies were noted along the base of the Verdi Range, however no lithologic conclusions were reached.

The structural or lithologic problem areas that could not be satisfactorily modeled are:

1. the metavolcanic areas on the valley floor,
2. volcanic configurations in the Hunter Creek canyon,
3. Cretaceous rock outcrop on north slope of Carson Range,
4. the extent of volcanic rock on the valley floor, and
5. if the inferred faults are real or the result of paleo-topography.

These problems are reserved for future work by interested parties. Ground water modeling may provide some insight into their solutions. This present investigation may be revised after the ground water modeling is complete or as other geologic evidence is brought forward.

REFERENCES

Bell, John W. and Garside, Larry J., 1987. Geologic Map of the Verdi quadrangle. Nevada Bureau of Mines and Geology. Map number 4Gg.

Carpenter, Thomas., 2005, 2000. Gravity data acquisition and processing, Verdi/Mogul Area Project, Washoe County, Nevada. Consultant report prepared for Washoe County Department of Water Resources, Nevada.

Cashman, Patricia. 2007. personal communication. University of Nevada, Reno.

DIGHEM^{V}, 1995, 1996. Airborne geophysical survey of the Verdi Area. Consultant report prepared for Washoe County Department of Water Resources, Nevada. Dighem, Inc., Mississauga, Ontario, Canada.

Geosoft, Inc. 2000. Oasis Montaj, data processing and analysis system for earth science applications, Version 5.1.8, Geosoft, Inc. Toronto, Ontario.

Henry, Chris. 2007, personal communication. Nevada Bureau of Mines and Geology, Reno, NV

Henry, Chris and Perkins, Michael. 2001. Sierra Nevada-Basin and Range transition near Reno, Nevada: Two-stage development at 12 and 3 Ma. Geology; vol. 29, no. 8, p. 719-722.

Henry, Chris., 2000. Simplified geologic map of the Truckee Meadows. Unpublished

field notes and mapping.. Printed with permission.
Northwest Geophysical Associates, 1996. GM-SYS, Gravity and Magnetics Modeling for Windows. Version 4.9.56. Northwest Geophysical Associates, Corvallis, Oregon.
Skalbeck, John D., 1998. Measurement of Physical and Paleomagnetic Properties from Rocks in the Steamboat Hills and Carson Range, Washoe County, Nevada. Unpublished report prepared for Washoe County Department of Water Resources.
Thompson, G.A., and White, D. E. 1964. Regional Geology of the Steamboat Springs Area, Washoe County, Nevada. USGS Professional Paper 458-A
Trexler, Jim and Cashman, Patricia. 2005. personal communications, unpublished field notes and mapping. University of Nevada, Reno.
Trexler, Jim., Cashman, Pat., Henry, C., Muntean, T., Schwartz, K., TenBrink, A., Faulds, J., Perkins, M., and Kelly, T. 2000. Neogene basins in western Nevada document the tectonic history of the Sierra Nevada-Basin and Range transition zone for the last 12 Ma. in Lageson, D., Peters, S., and Lahren, M., eds., Great Basin and Sierra Nevada: Boulder Colorado, Geological Society of America Field Guide 2, p. 97-116.
Widmer, Michael C. and Cashman, Patricia., 2007. Gravity-based geologic model of the Central Truckee Meadows, Washoe County, Nevada (in progress). Washoe County Department of Water Resources, Reno, Nevada.
Widmer, Michael C., 2007. Preliminary geophysical interpretation of the South Truckee Meadows, Washoe County, Nevada (in progress). Washoe County Department of Water Resources, Reno, Nevada.
Widmer, Michael C. and Oppliger, Gary L., 2007. A Gravity Based Structural Analysis of Southern Washoe County, Nevada (in progress). Washoe County Department of Water Resources, Reno, Nevada.

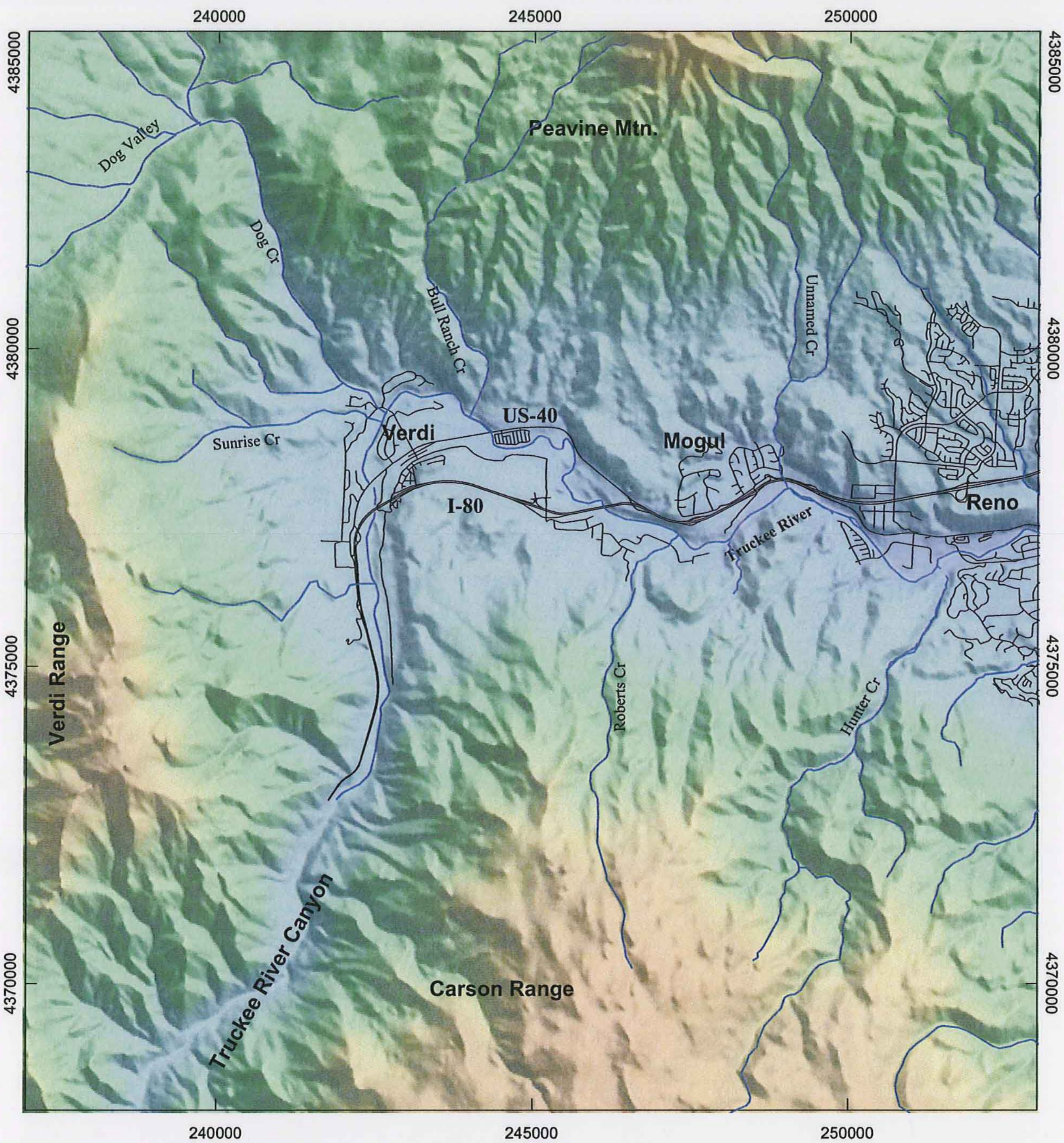

Figure 1. Location map of the Verdi-Mogul basin, west of Reno, Nevada shown as topographic color shaded relief. Roads for California are not shown.

Scale 1:120000
2500 0
metres

Verdi-Mogul Water Resource Investigation
Washoe County Department of Water Resources
mcw

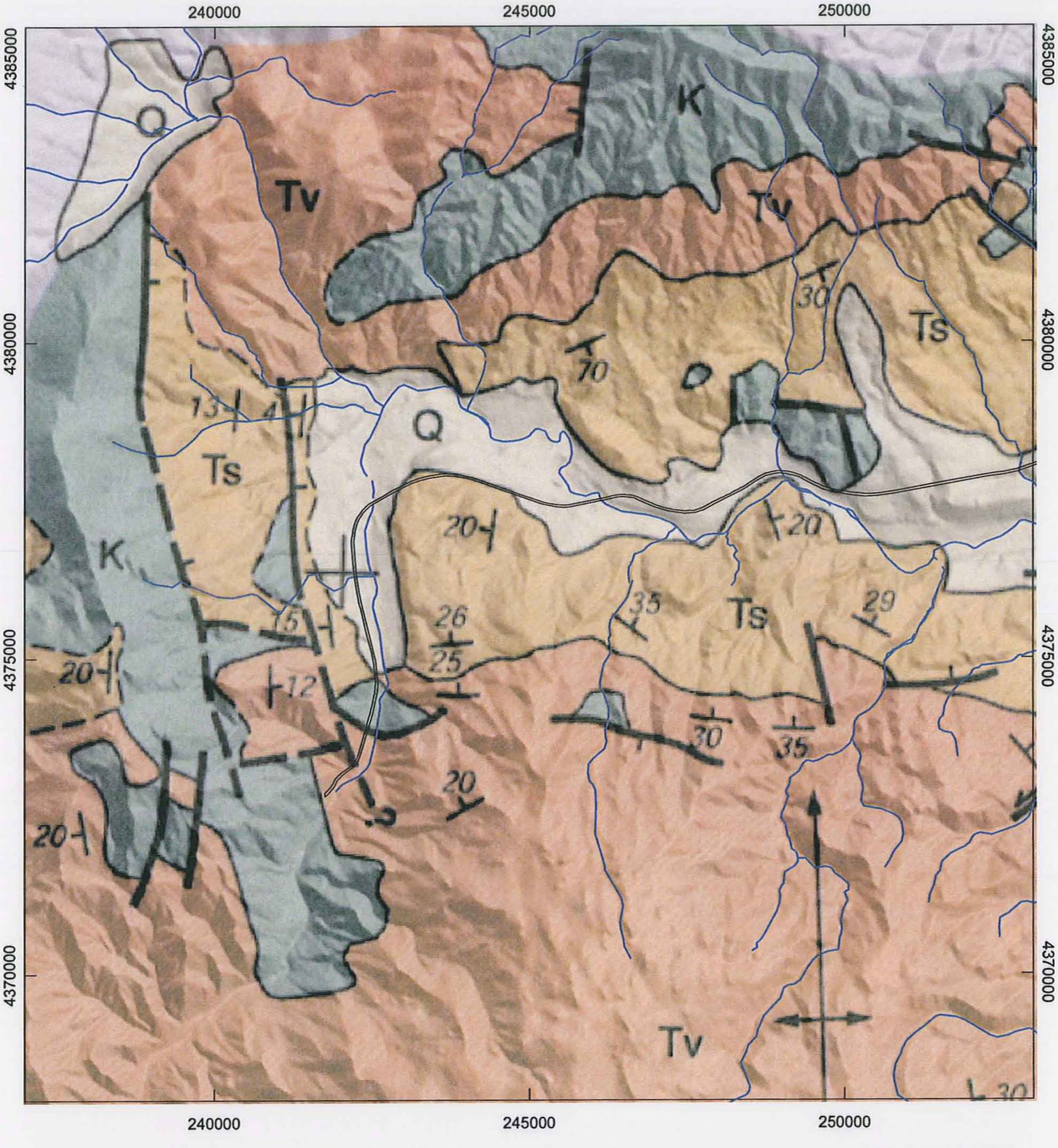

Figure 2. Simplified geologic map from Henry (2000). See text for description of units. Streams and I-80 freeway are shown.

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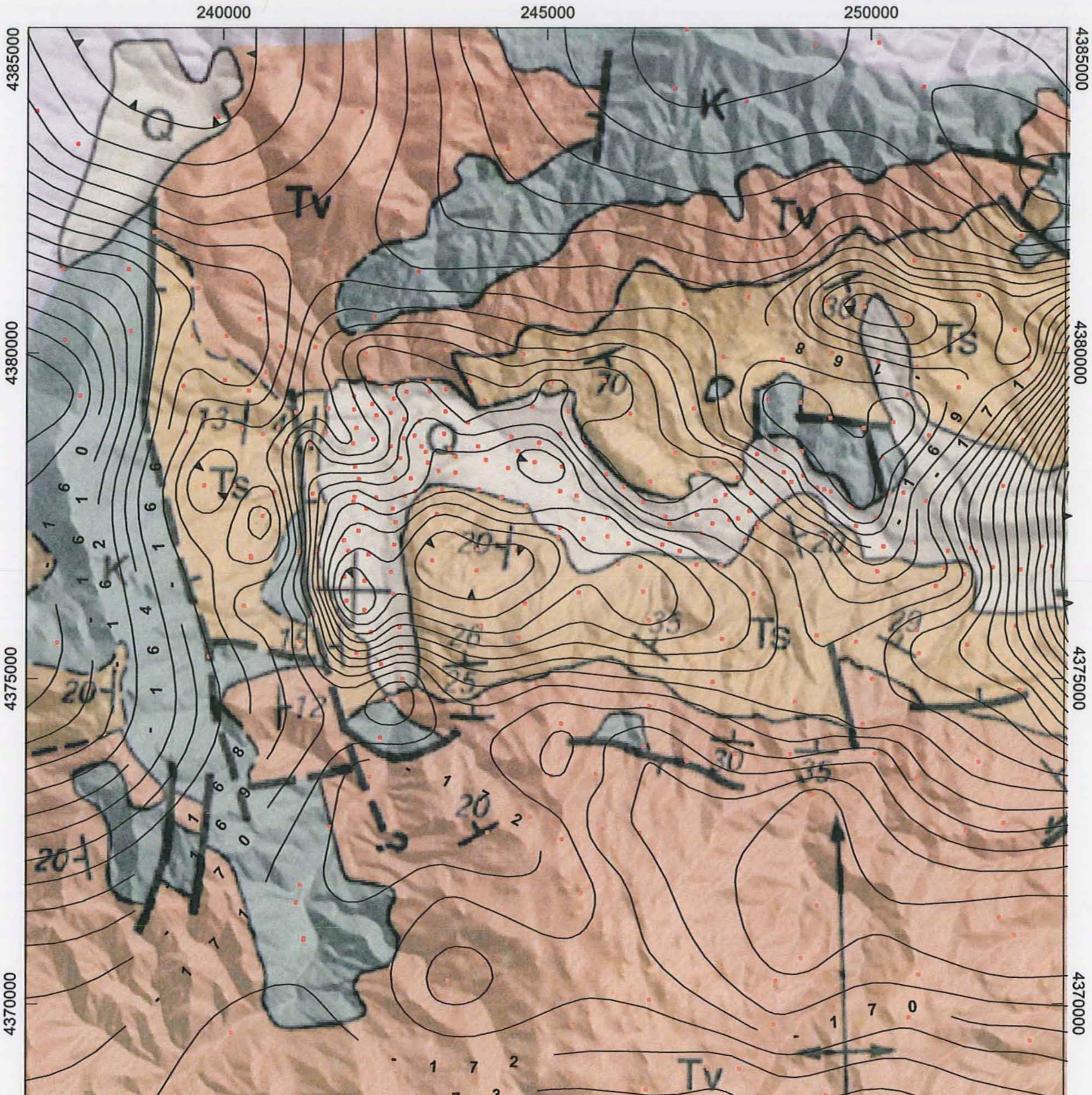

Figure 3a. Complete Bouguer Anomaly gravity map. Density calculated at 2.50 g/cc. Contour interval is 1.0 mGal. Dots indicate data points used in gridding.

Scale 1:120000

2500 0

metres

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Washoe County Department of Water Resources

mcw

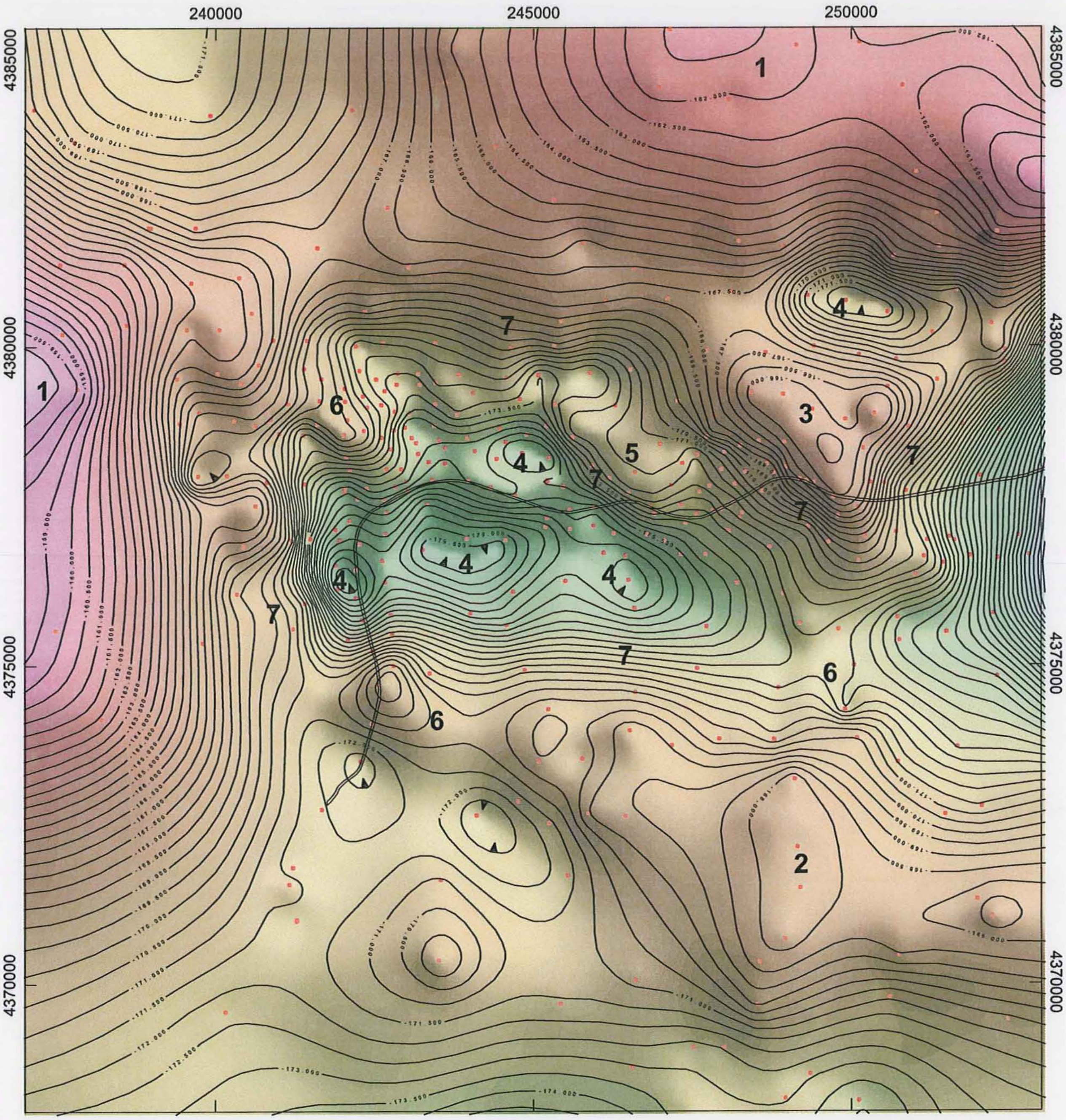

Figure 3b. Color shaded relief of CBA gravity map (density=2.50g/cc). Contour interval is 0.5 mGals. Dots indicate data points used in gridding. Nevada portion of I-80 freeway is shown for reference. Numbers indicate gravity anomalies discussed in text.

Scale 1:120000

2500 0

metres

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Figure 4a. Path of flight lines flown for electrical resistivity and total field magnetics. Flight lines numbers are shown at ends of flight lines (Dighem, 1995).

Scale 1:100000

1000 0 1000 2000

metres

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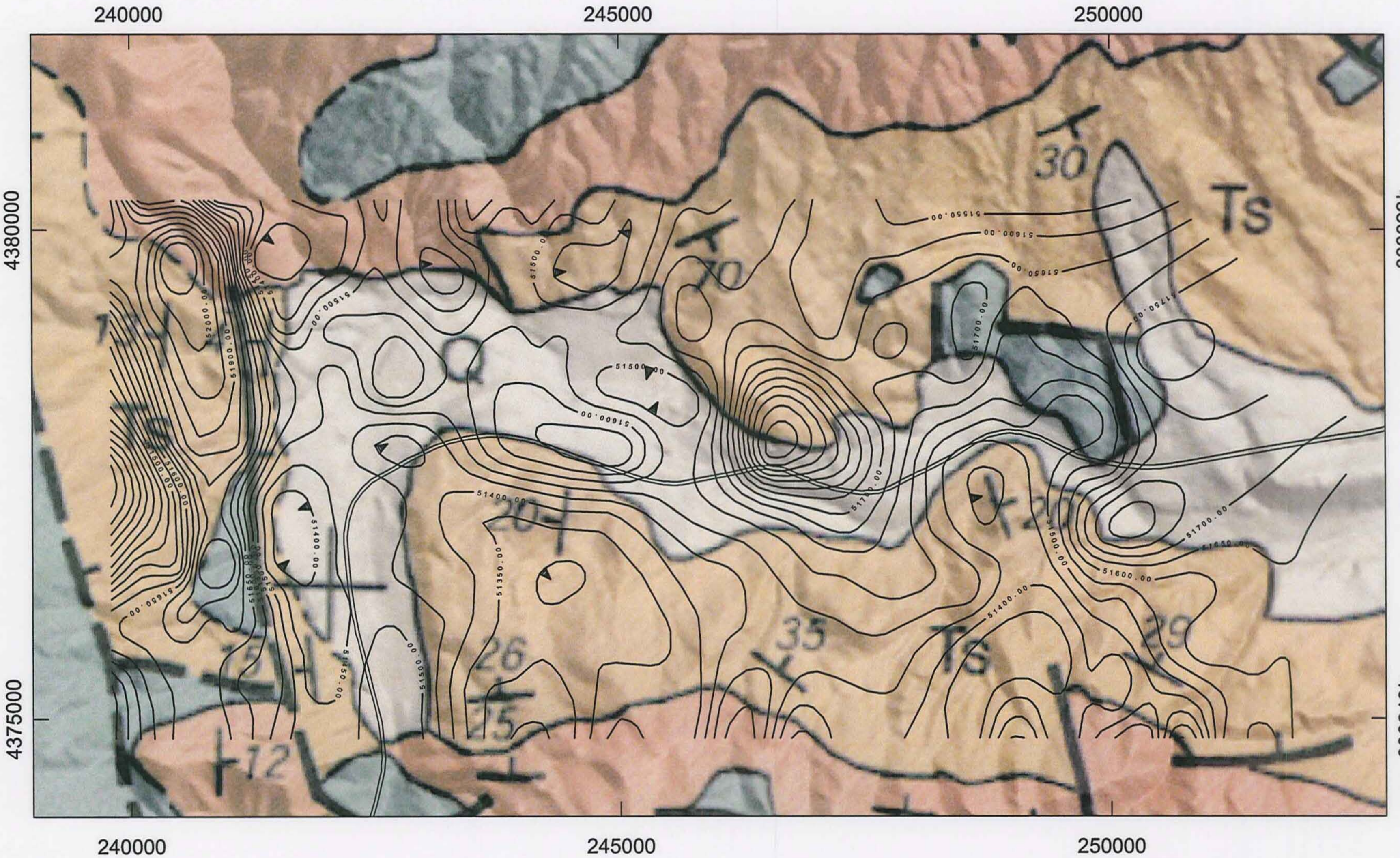

Figure 4b. Contoured total field magnetic data, reduced to pole, upward continued 100m overlain on the Henry geologic map. Contour interval is 50 nTs. I-80 freeway is shown for reference.

Scale 1:100000

1000 0 1000 2000

metres

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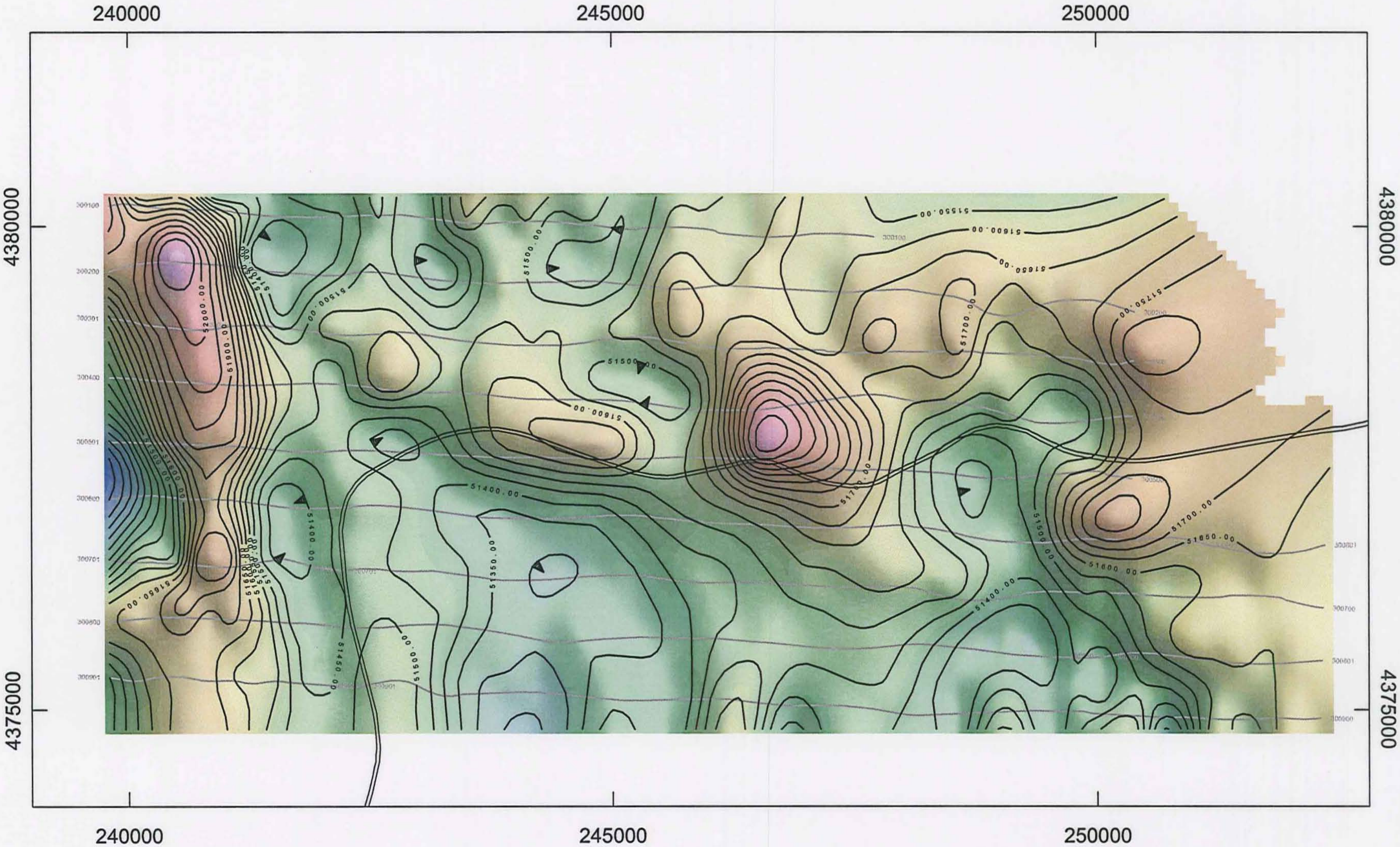

Figure 4c. Contoured total field magnetic data, reduced to pole, upward continued 100m as colored shaded relief map. Contour interval is 50 nTs. I-80 freeway is shown for reference. Flight lines are also plotted.

Scale 1:100000

1000 0 1000 2000

metres

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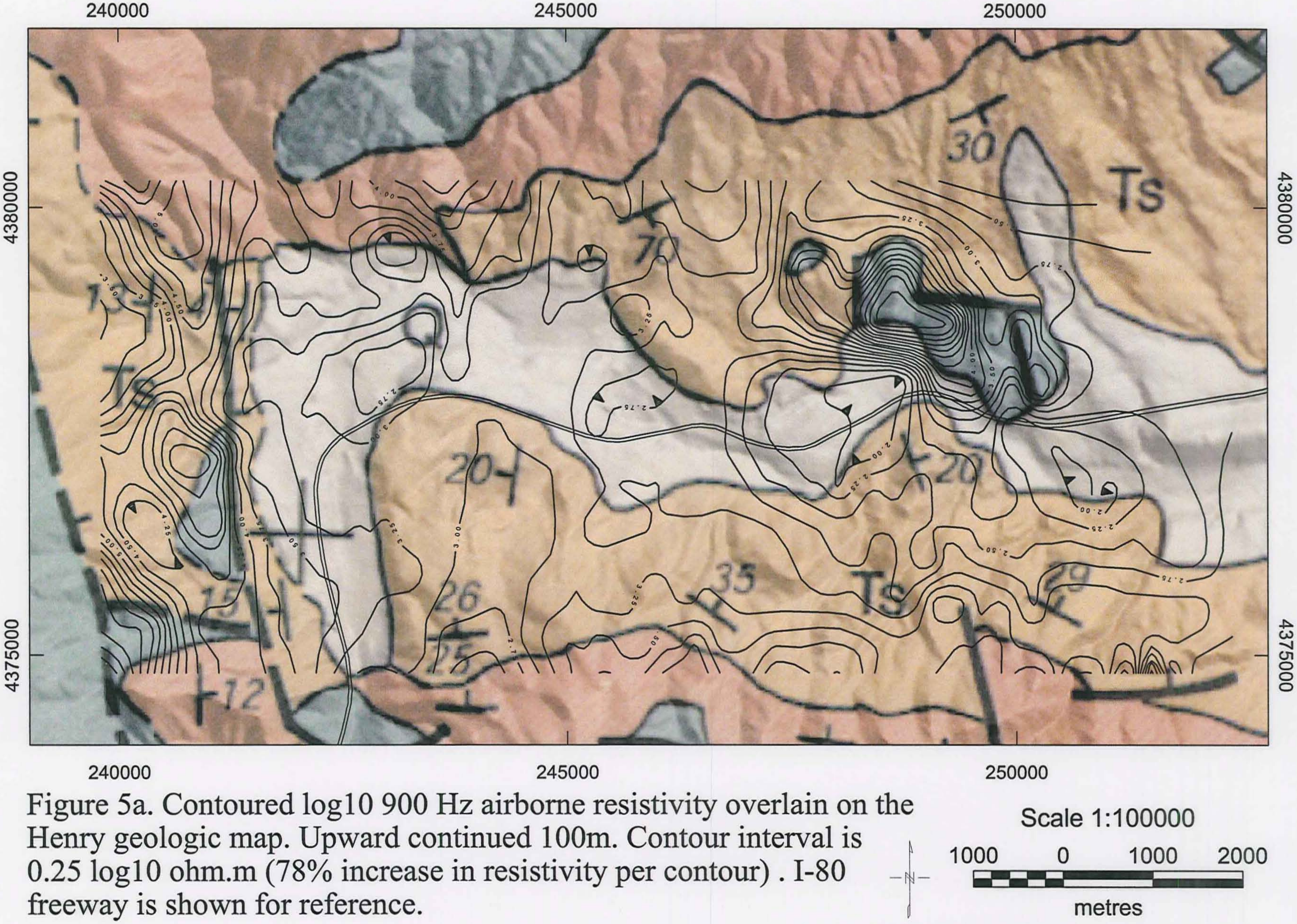

Figure 5a. Contoured log10 900 Hz airborne resistivity overlain on the Henry geologic map. Upward continued 100m. Contour interval is 0.25 log10 ohm.m (78% increase in resistivity per contour) . I-80 freeway is shown for reference.

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mcw

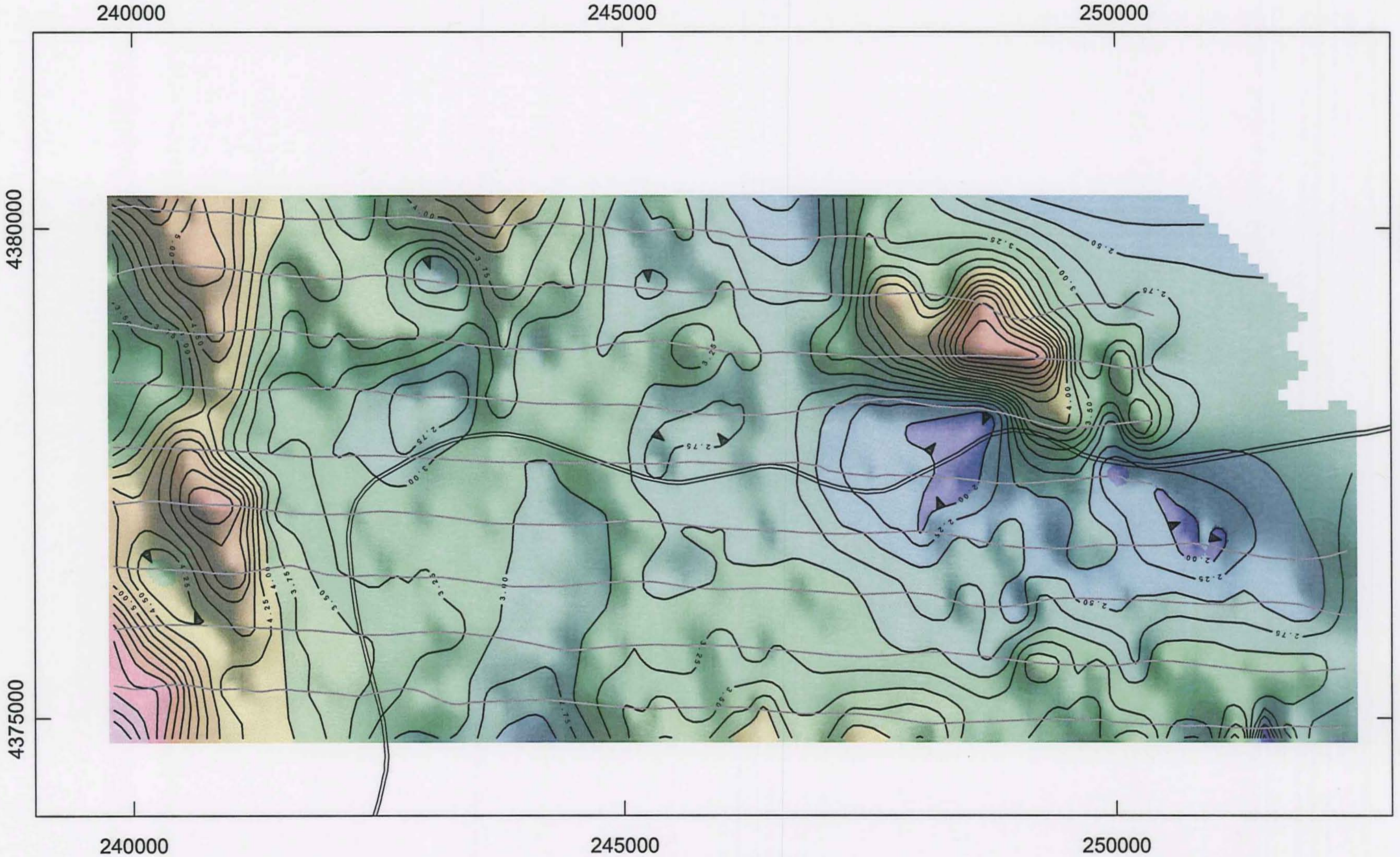

Figure 5b. Color shaded relief map of the log 900 Hz airborne resistivity. Contour interval is 0.25 log10 ohm.m (78% increase in resistivity per contour). Also, upward continued 100m. I-80 freeway is shown for reference. Flight line locations are also shown.

Scale 1:100000

1000 0 1000 2000

metres

Verdi-Mogul Water Resource Investigation Washoe County Department of Water Resources
mcw

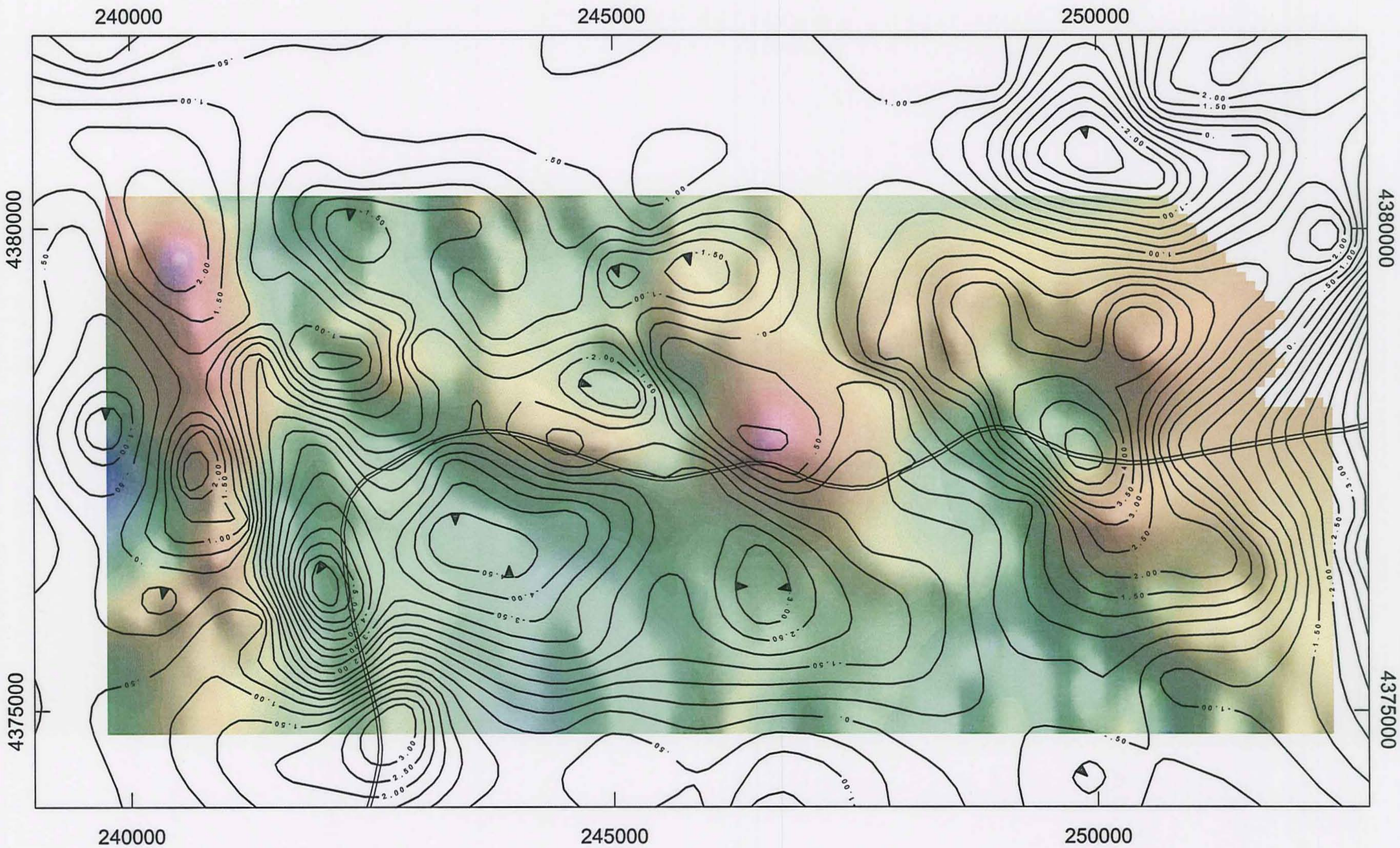

Figure 6a. Color shaded relief map of total field magnetic data, reduced to pole,upward continued 100m. Contour data is CBA gravity, (0.5 mGal interval) I-80 freeway is shown for reference.

Scale 1:100000

1000 0 1000 2000

metres

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Washoe County Department of Water Resources
mcw

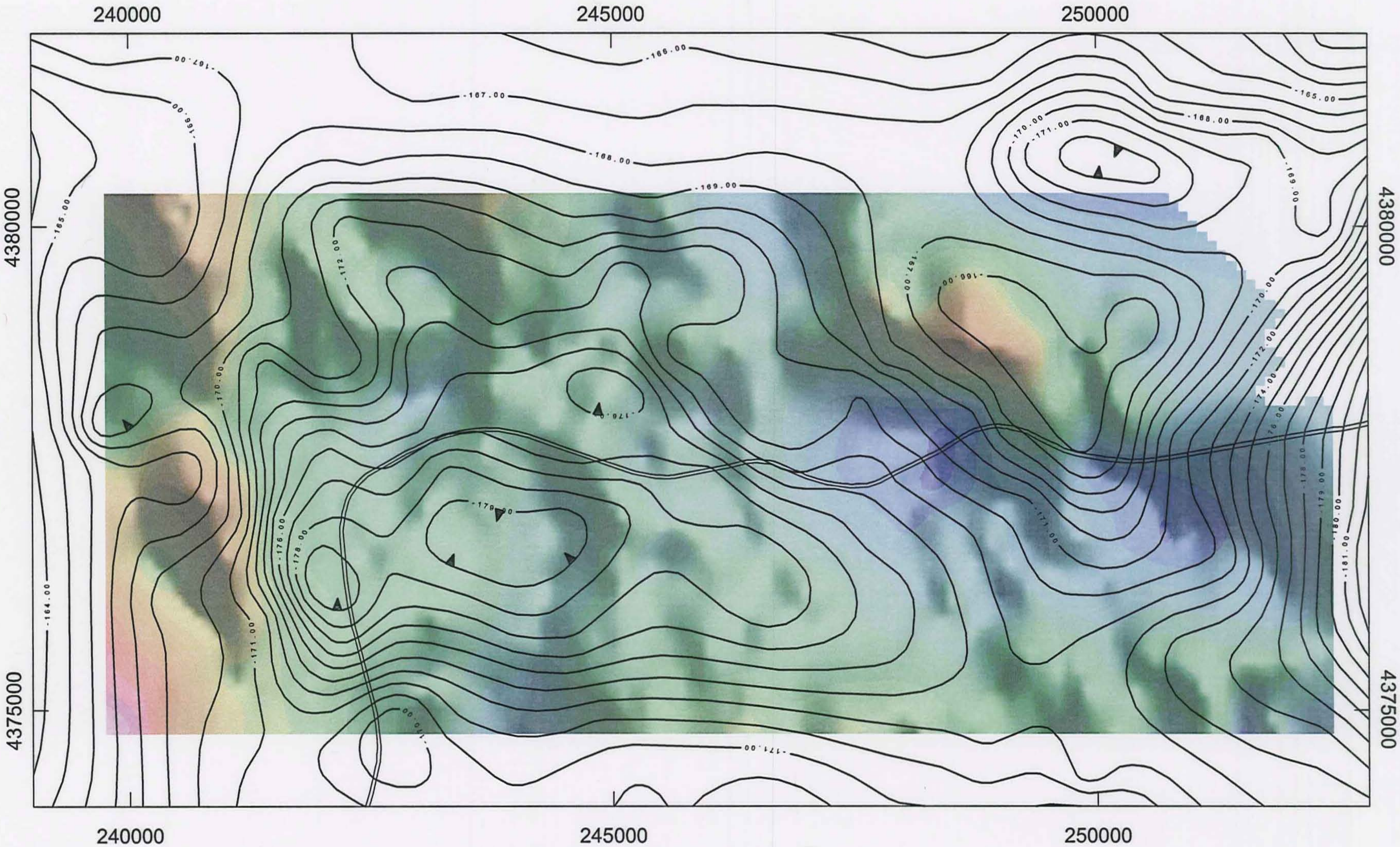

Figure 6b. Color shaded relief map of log 900 Hz resistivity, upward continued 100m (0.25 Log10 ohm m. interval). Contour data is of gravity data (1 mGal interval). I-80 freeway is shown for reference.

Scale 1:100000

1000 0 1000 2000

metres

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mcw

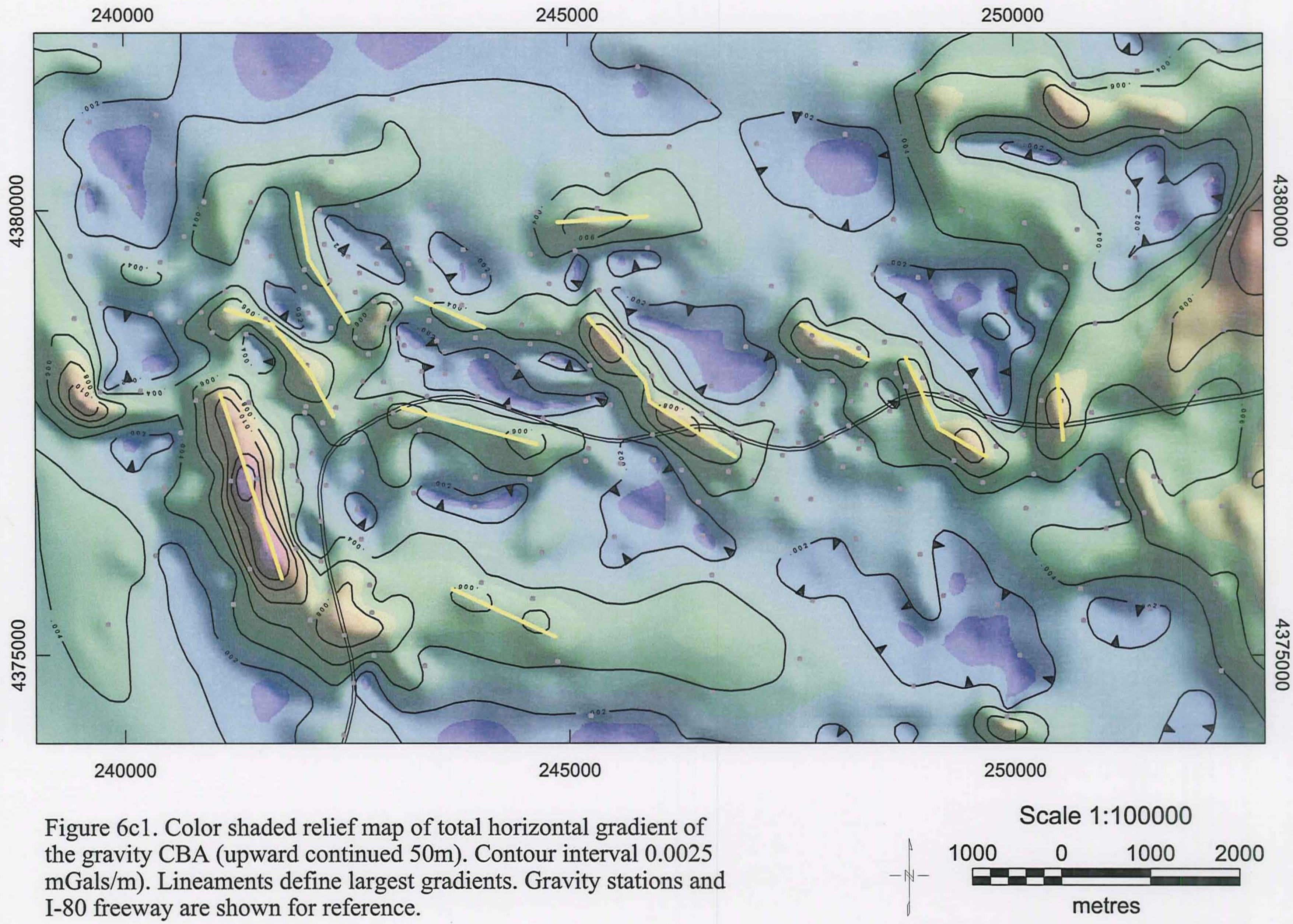

Figure 6c1. Color shaded relief map of total horizontal gradient of the gravity CBA (upward continued 50m). Contour interval 0.0025 mGals/m). Lineaments define largest gradients. Gravity stations and I-80 freeway are shown for reference.

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Washoe County Department of Water Resources
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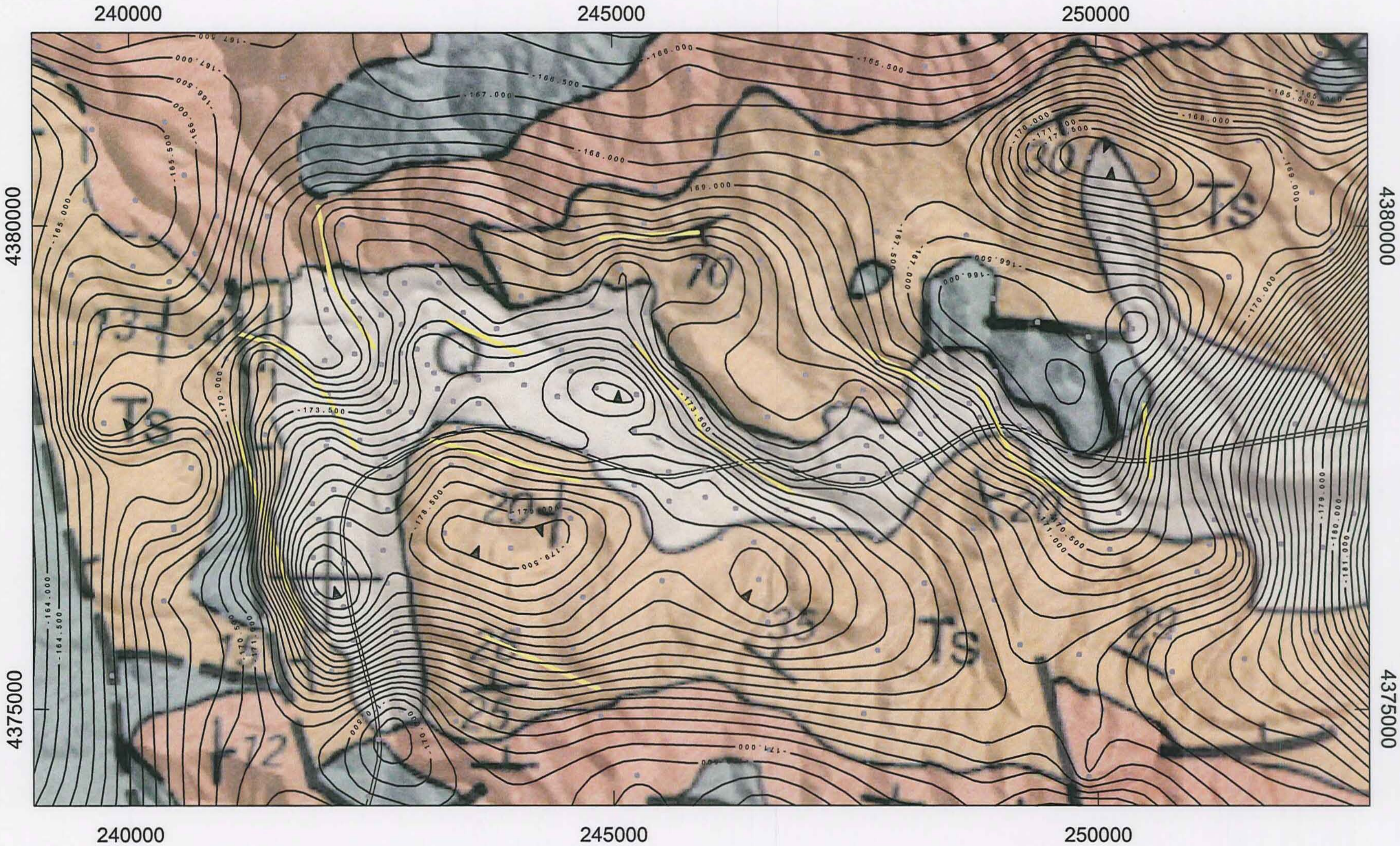

Figure 6c2. Complete Bouguer Anomaly contours (0.5 mGals interval) overlain onto Henry geologic map. Yellow lineaments are from Figure 6c1. Dots indicate data points used in gridding.

Scale 1:100000

1000 0 1000 2000

metres

Verdi-Mogul Water Resource Investigation Washoe County Department of Water Resources
mcw

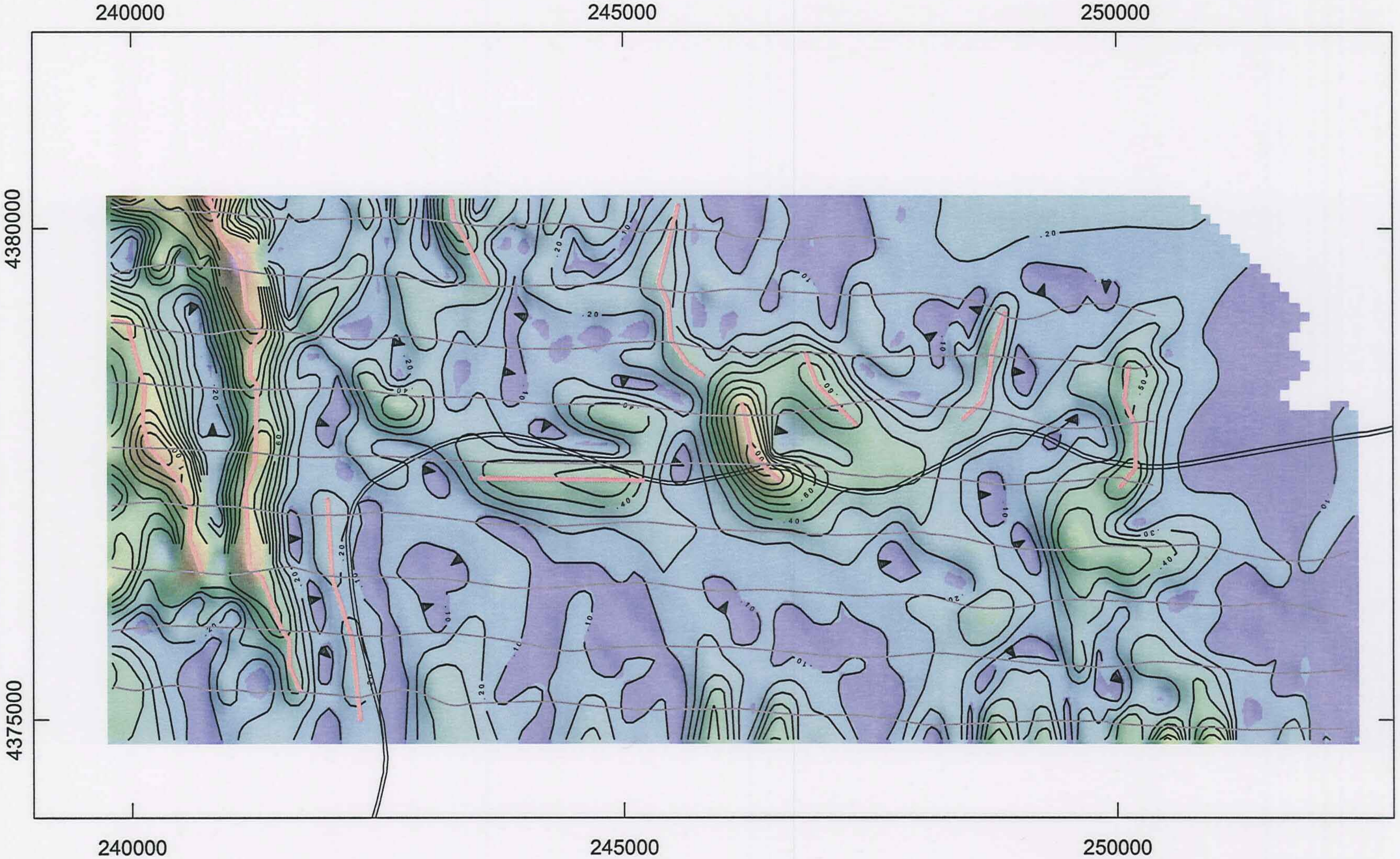

Figure 6d1. Color shaded relief map of magnetic (upward continued 100m, rtp) total horizontal gradient, contour interval 0.1 nT/m. Lineaments are shown as peach colored lines delineating large gradient slopes. I-80 freeway is shown for reference.

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mcw

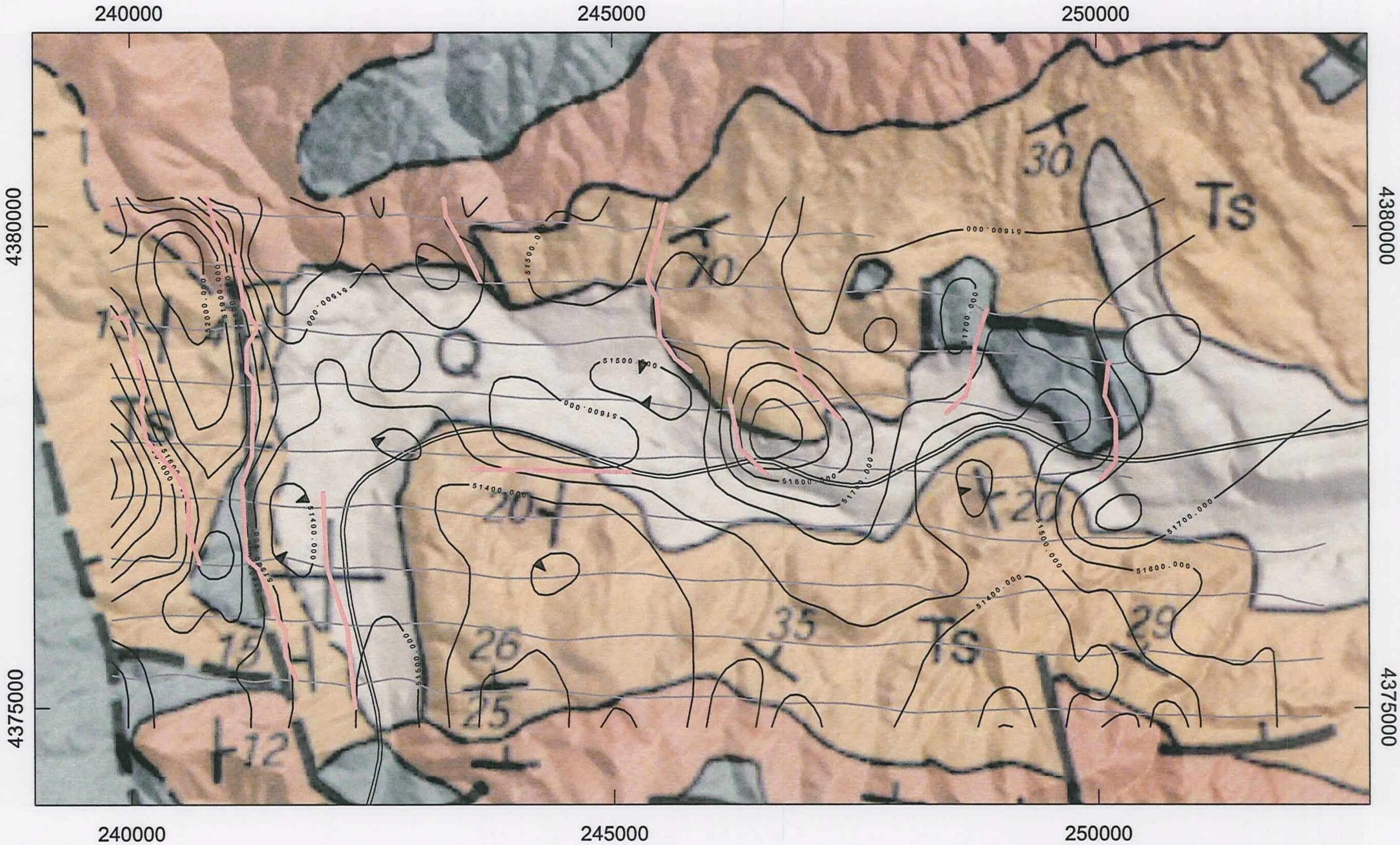

Figure 6d2. Color shaded relief map of total field magnetic (upward continued 100m, rtp) data at a contour interval of 100 nT. Lineaments (peach colored lines) delineating large gradient slopes as shown in Figure 6d1. I-80 freeway is shown for reference.

Scale 1:100000

1000 0 1000 2000

metres

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mcw

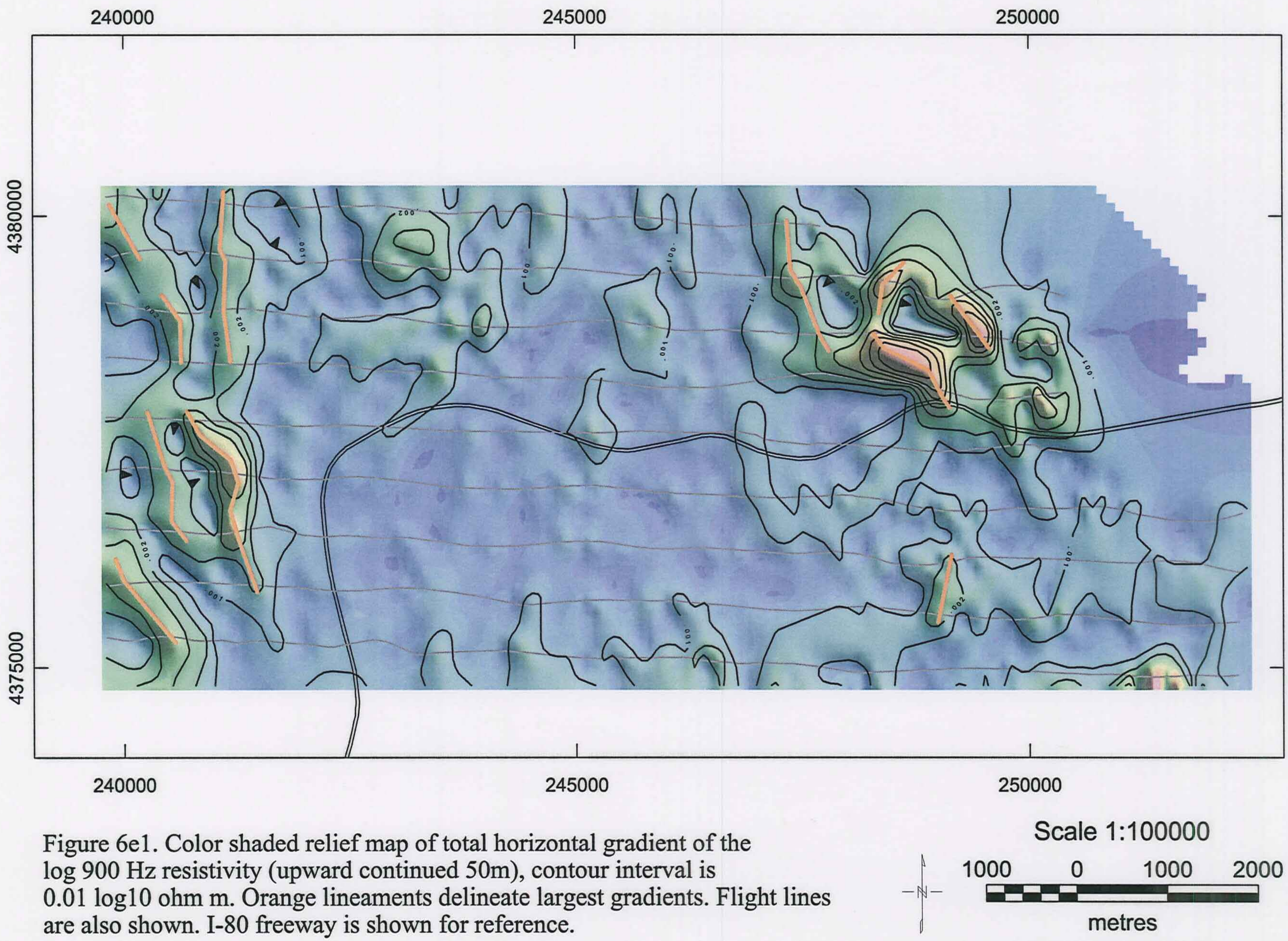

Figure 6e1. Color shaded relief map of total horizontal gradient of the log 900 Hz resistivity (upward continued 50m), contour interval is 0.01 log10 ohm m. Orange lineaments delineate largest gradients. Flight lines are also shown. I-80 freeway is shown for reference.

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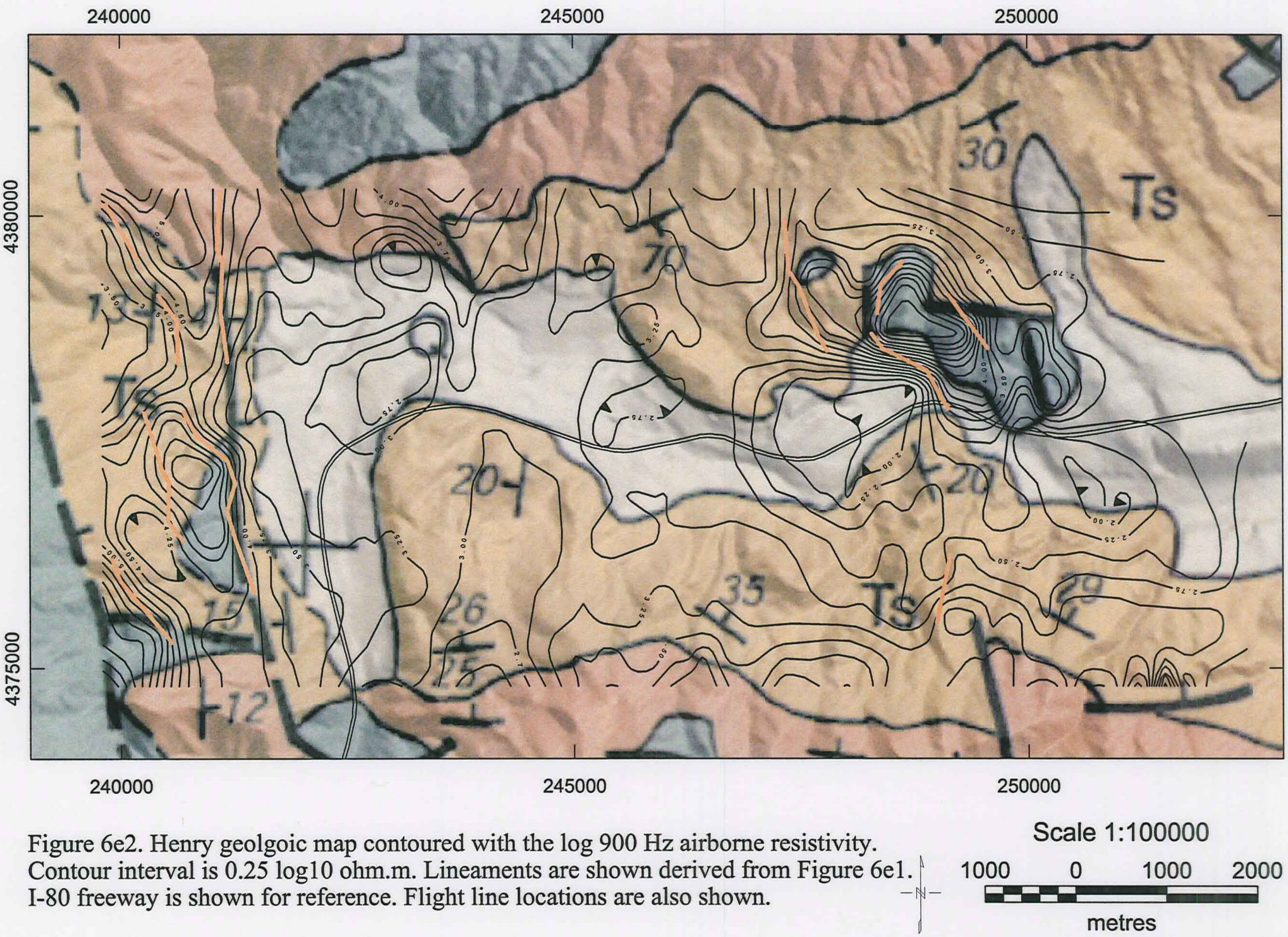

Figure 6e2. Henry geolgoic map contoured with the log 900 Hz airborne resistivity. Contour interval is 0.25 log10 ohm.m. Lineaments are shown derived from Figure 6e1. I-80 freeway is shown for reference. Flight line locations are also shown.

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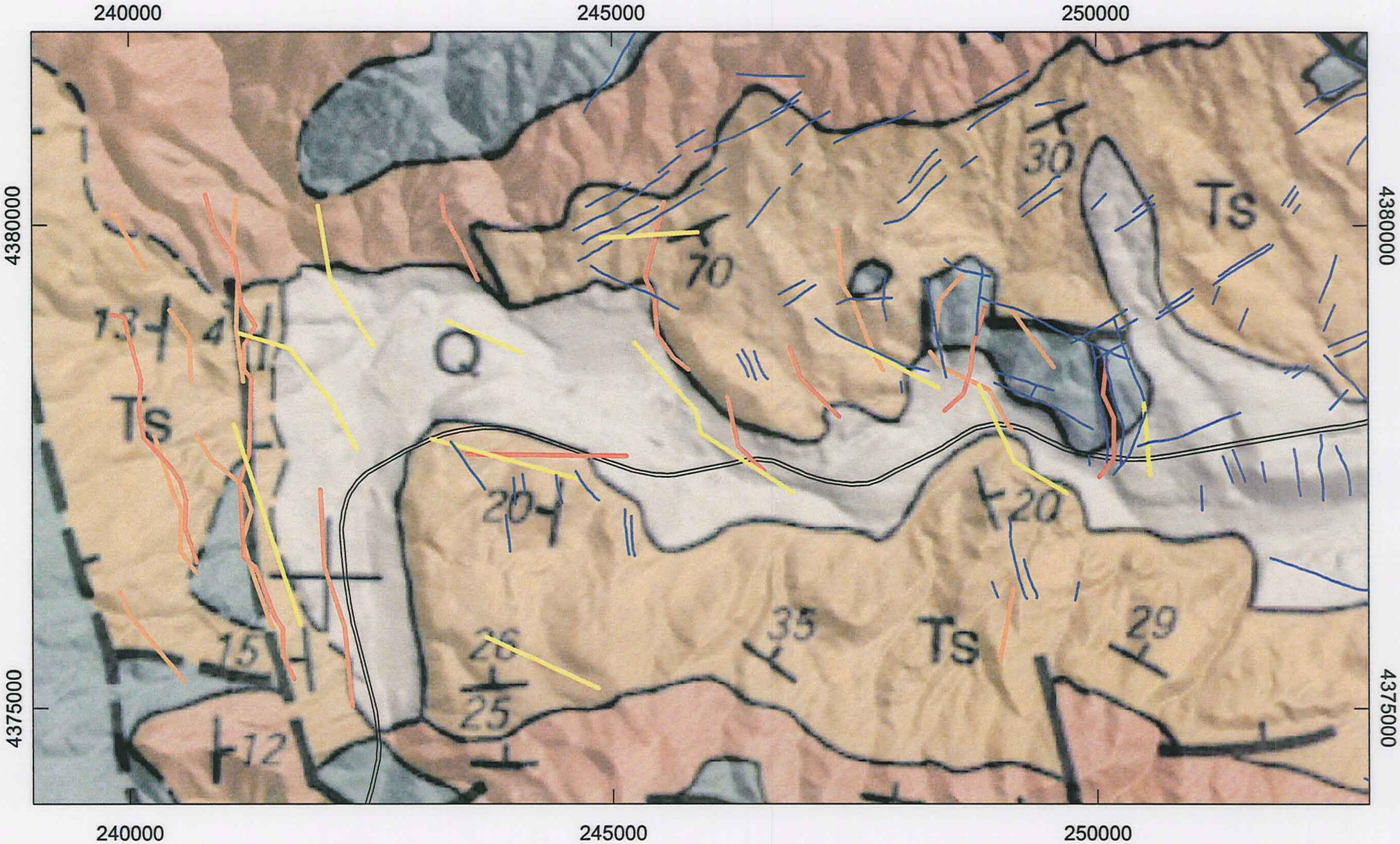

Figure 6f. Henry geologic map with lineaments derived from gravity (yellow), magnetic (in red), and log 900Hz resistivity (in orange) total horizontal gradient processing. I-80 freeway is shown for reference. Mapped faults and lineaments (blue) are also shown (Bell and Garside, 1987).

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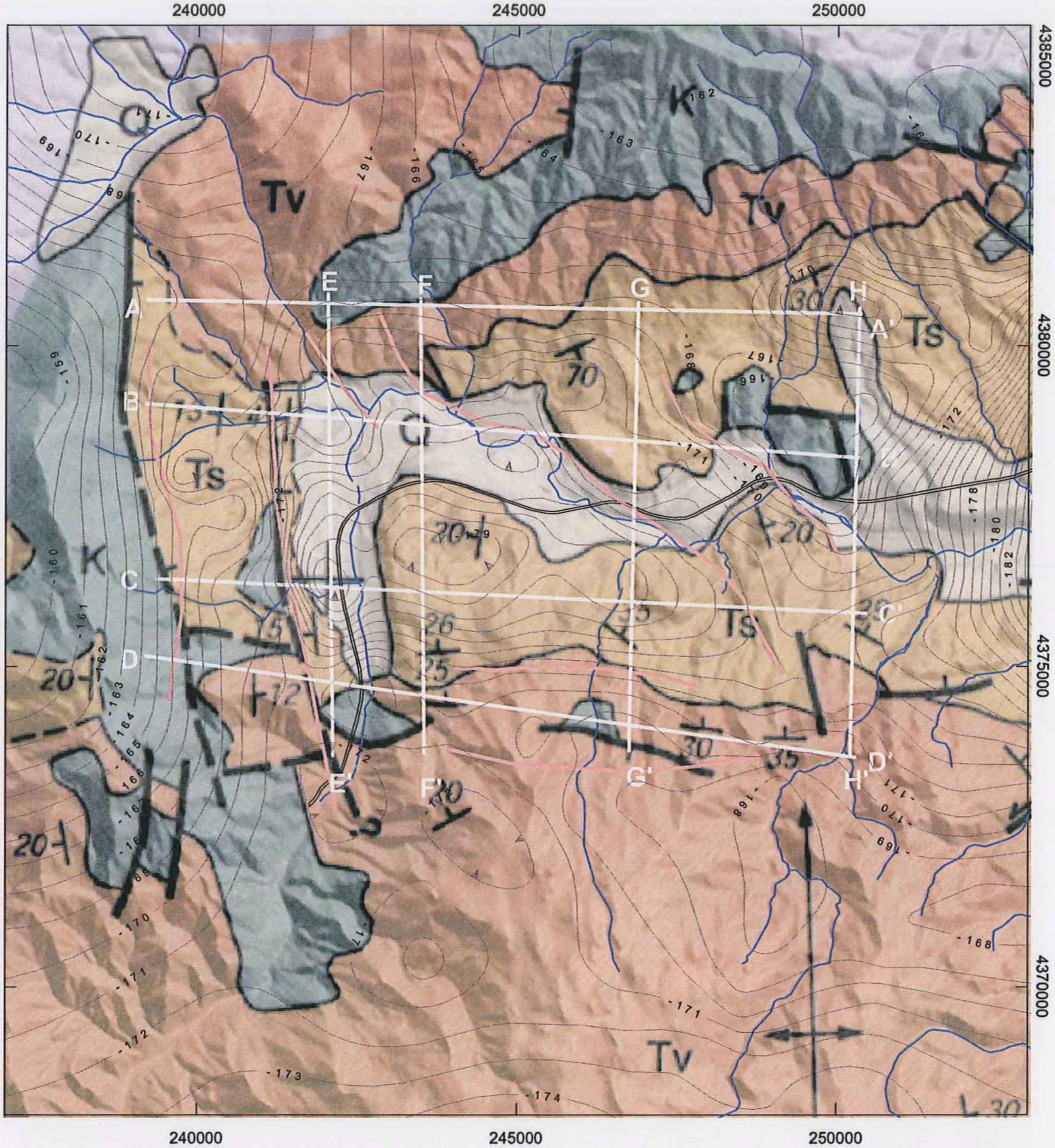


Figure 7. Geologic map from Henry (2000) showing the location of the geologic cross sections and generalized lineaments (see text). Gravity gradients, streams and I-80 freeway are also shown.

Scale 1:120000

2500 0

metres

Verdi-Mogul Water Resource Investigation
Washoe County Department of Water Resources

mcw

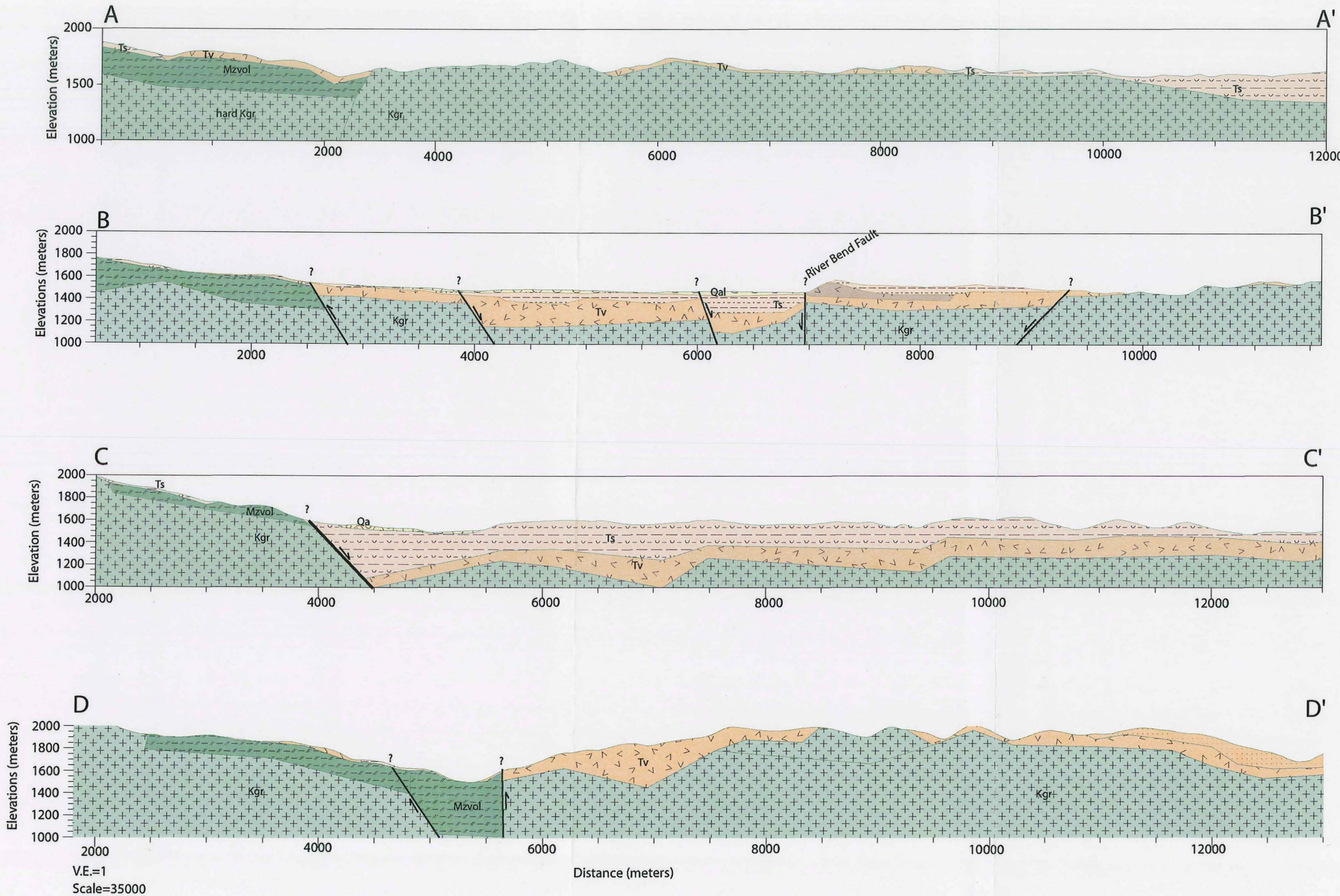


Figure 8a. Geologic cross sections based upon gravity, borehole lithology and surface mapping. Sections are from west to east (left to right) and stacked from north to south (top to bottom). See Figure 7 and text for discussion and legend explanation.

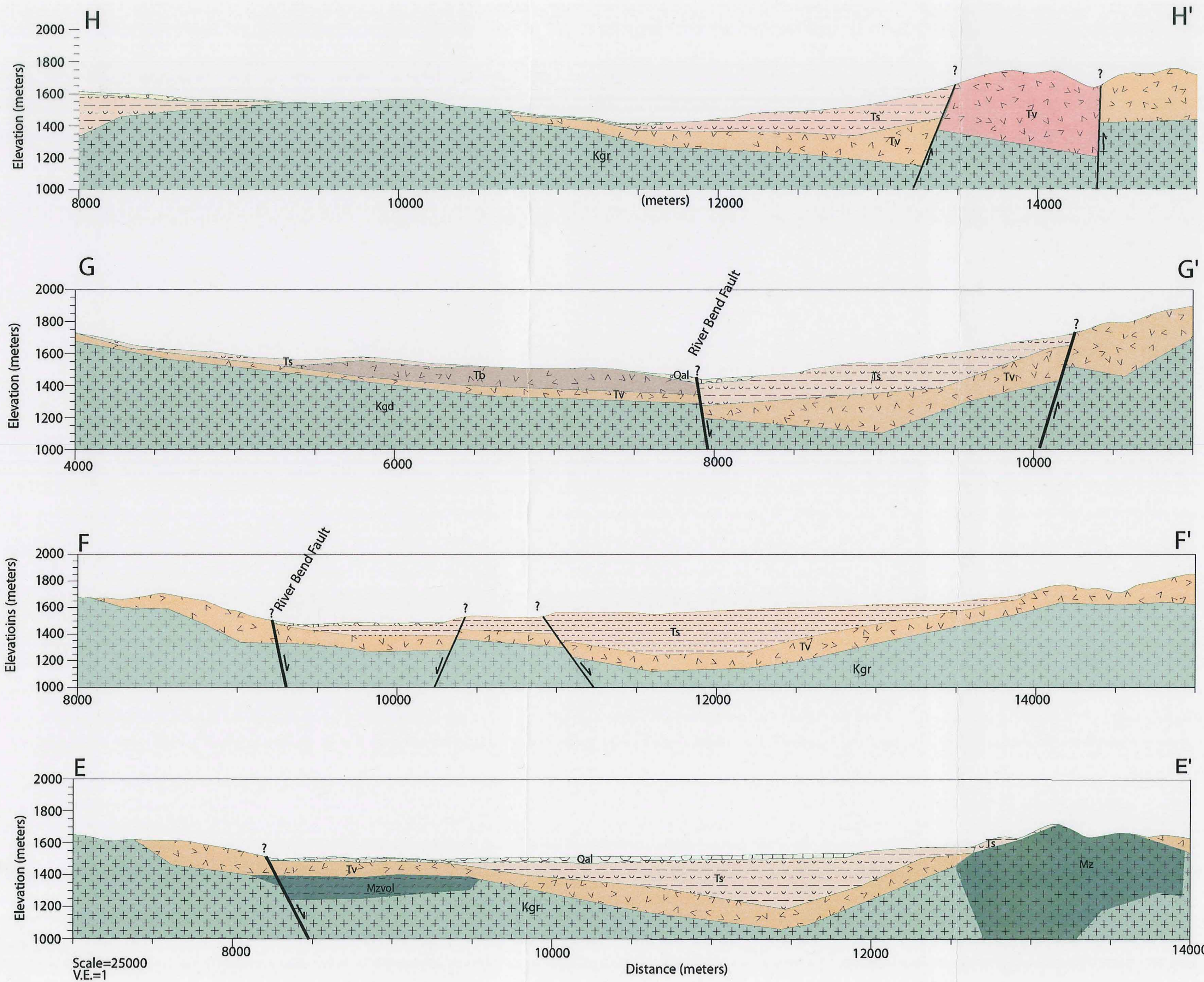


Figure 8b. Geologic cross sections based upon gravity, borehole lithology and surface mapping. Sections are from north to south (left to right) and stacked from east to west (top to bottom). See Figure 7 and text for discussion and legend explanation.

Appendix A Detailed geologic cross sections

The cross sections portrayed have two plots. The top being the gravity curves based upon the observed data (dots) and the calculated curve (black line) based upon the geologic model found in the lower section. Also shown is the error (red line) between the measured and calculated gravity response. A distance scale relative to the beginning of the cross section (not all shown) is at the bottom and is referred to in the text. The derricks refer to 1) geophysical anomalies, lineaments and faults and 2) borehole data. The circle with vertical line represents where cross sections intersect. The markers show lithologic contacts noted on the well log or on the other cross sections and constrain the model. Note that inferred faults were not included on these detailed , vertically exaggerated (x2) sections. Please also note scale differences.

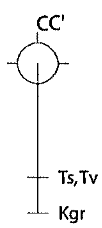
Geologic Legend

Qal= Quaternary alluvium   Ts= Tertiary sediments (incl Verdi Basin Sediments)   Tv=Tertiary volcanics
Mzvol= Mesozoic metavolcanics and sediments   Kgr= Cretaceous granodiorite

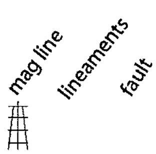
Gravity Legend

● =Observed,   —— =Calculated,   ------ =Error

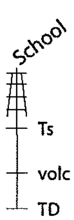
Cross section symbols



Location of intersecting cross section with its modeled depth of lithologic contacts

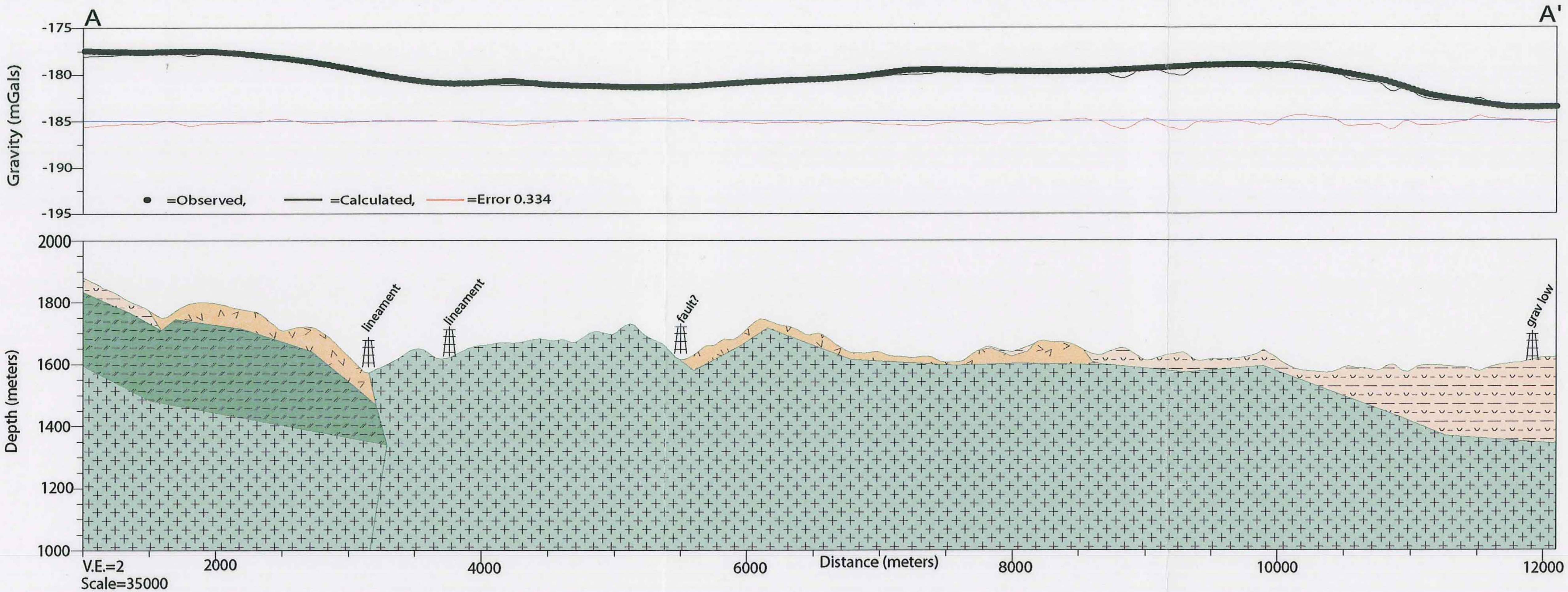


Geophysical anomaly or mapped fault

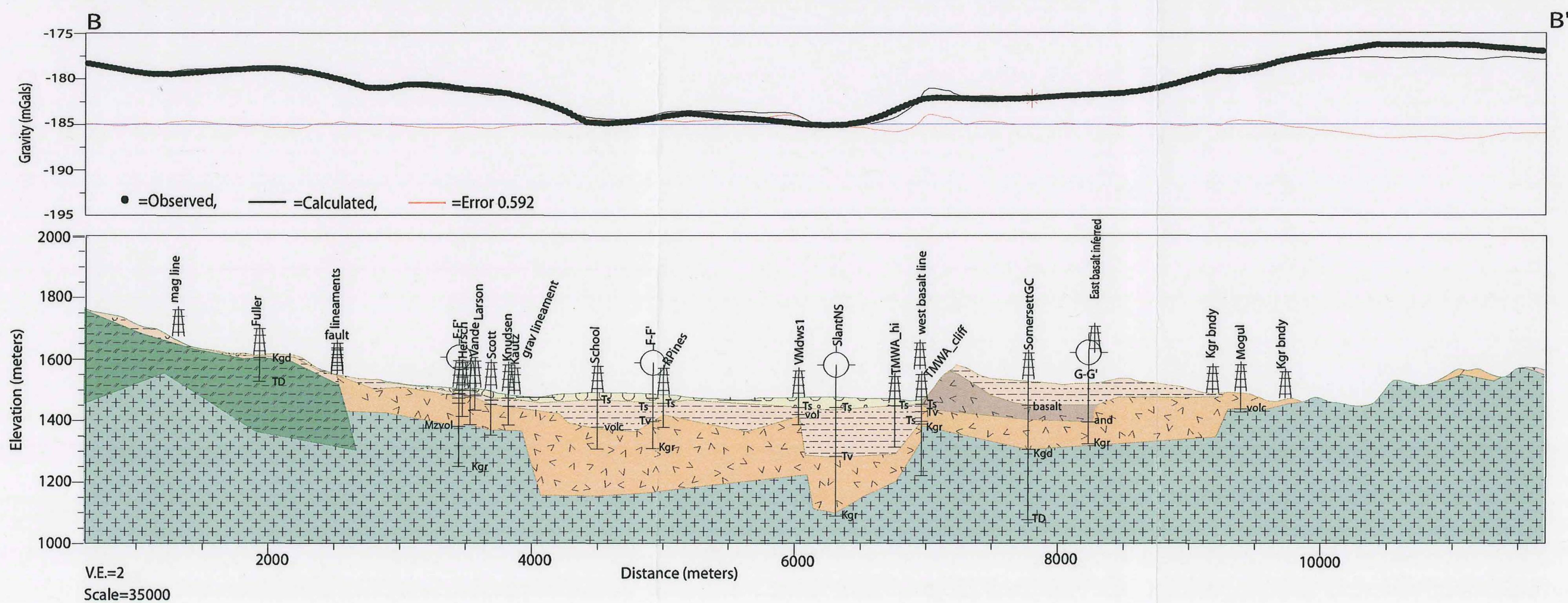


Location of well, name, and lithologic contacts w/ at depths found on log

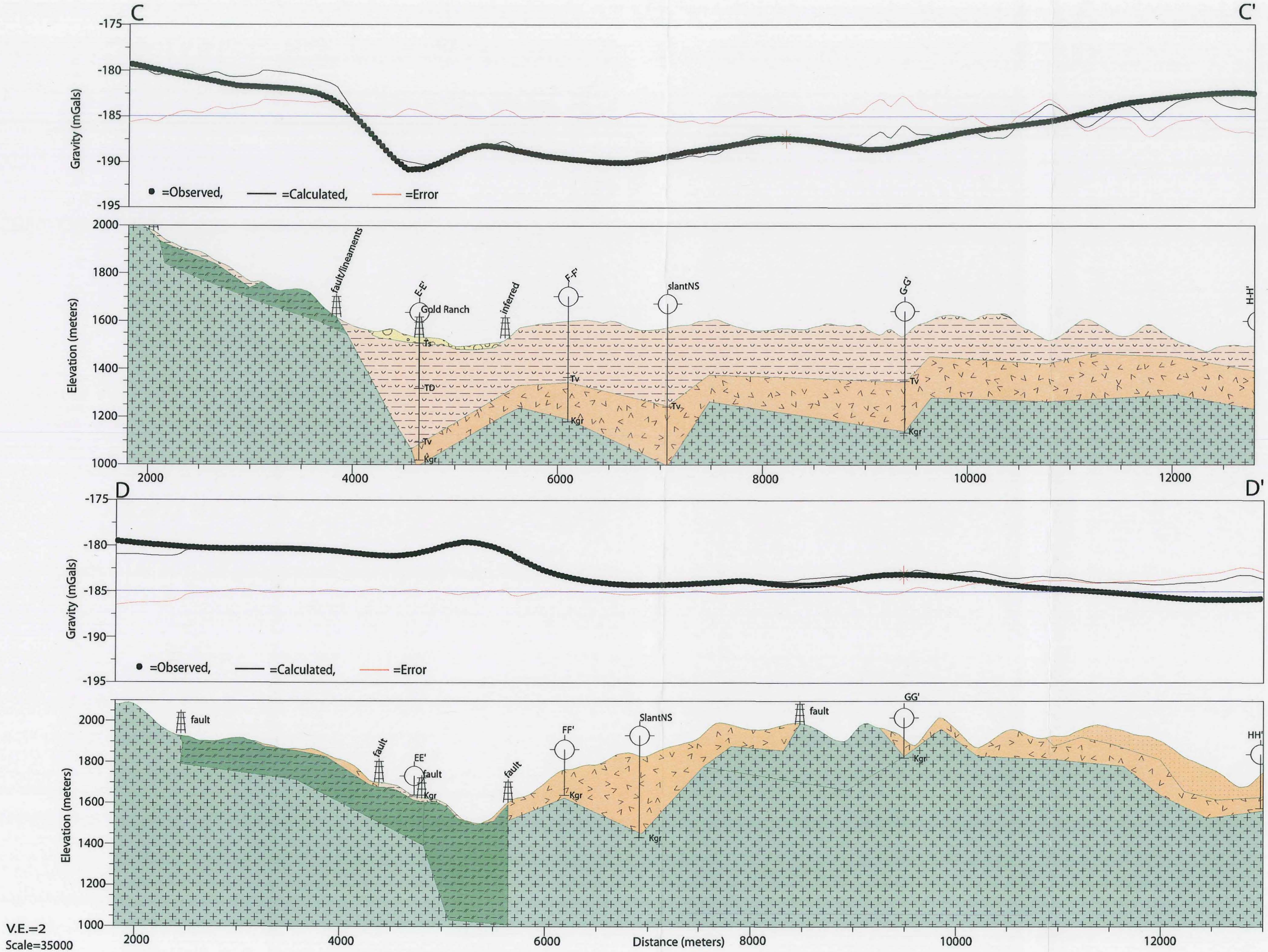
6000   Distance (meters)   measured from beginning of cross section

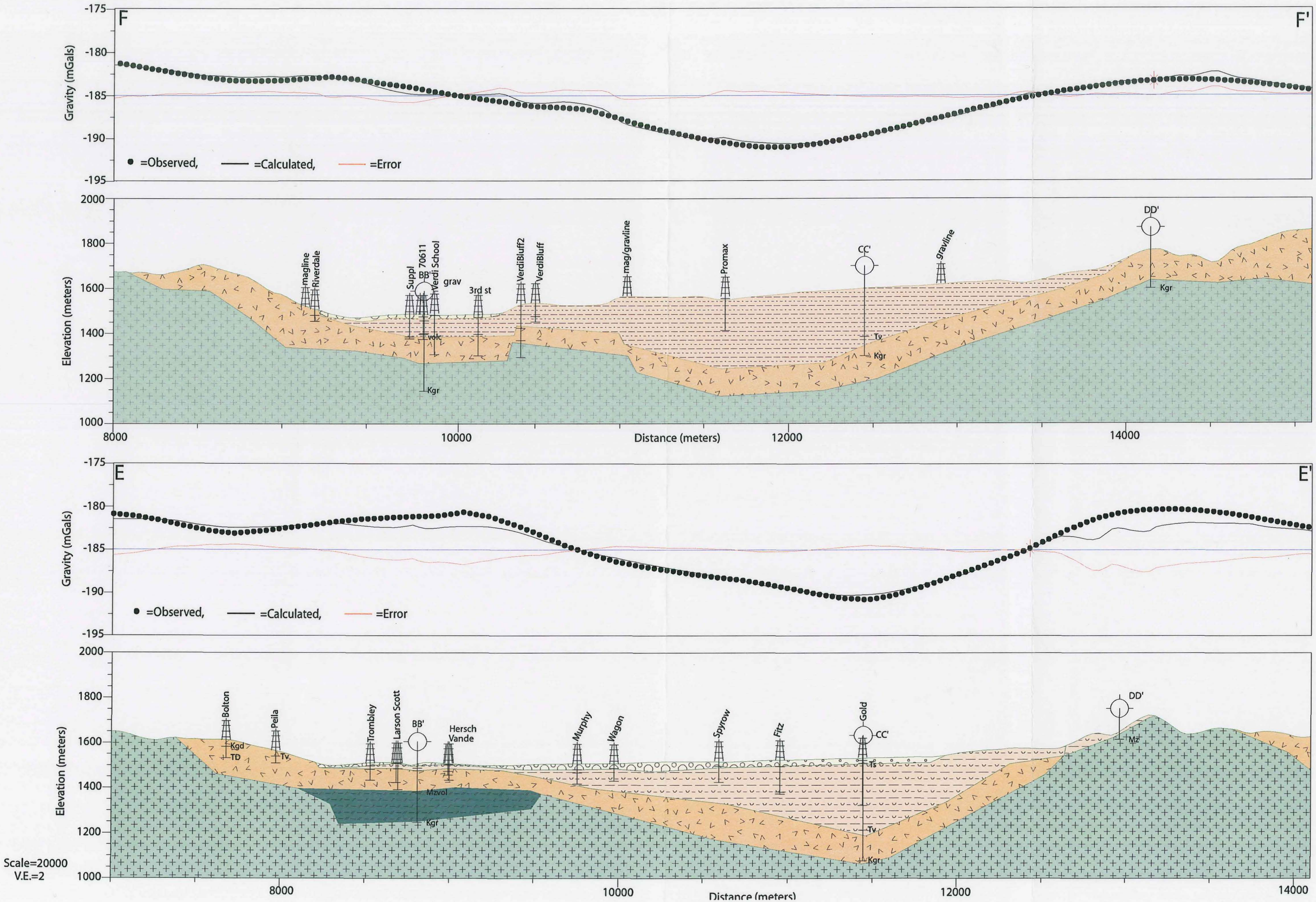


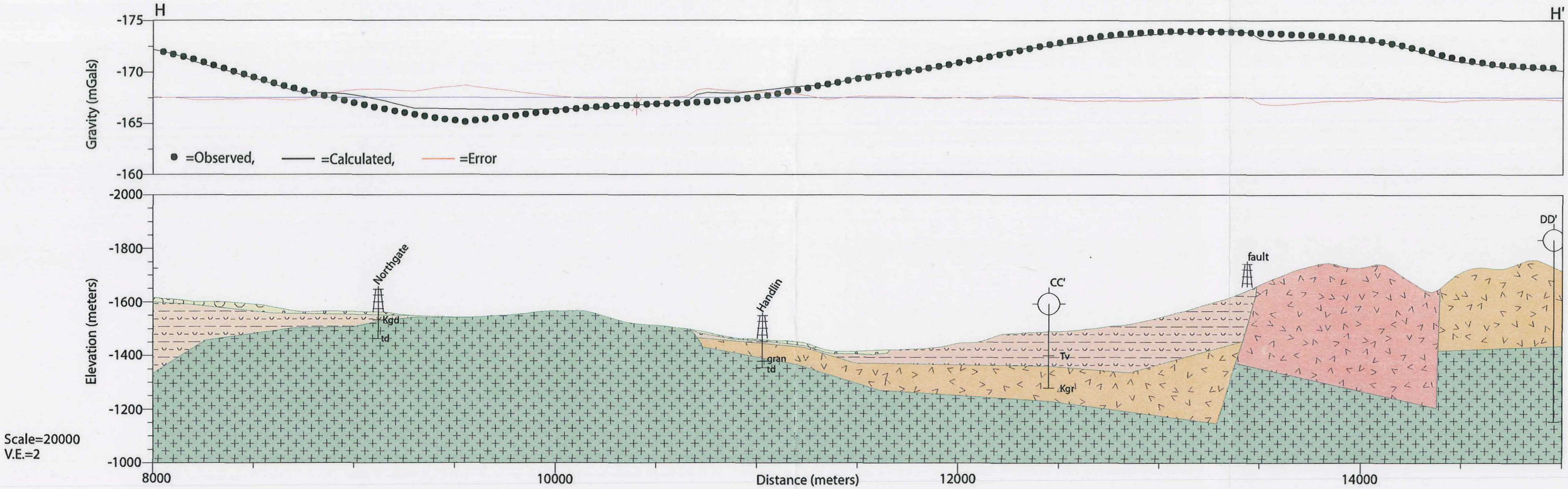
A
A'
Gravity (mGals)
-175
-180
-185
-190
-195
● =Observed,
=Calculated,
=Error 0.334
Depth (meters)
2000
1800
1600
1400
1200
1000
lineament
lineament
fault?
grav low
V.E.=2
Scale=35000
2000
4000
6000
Distance (meters)
8000
10000
12000

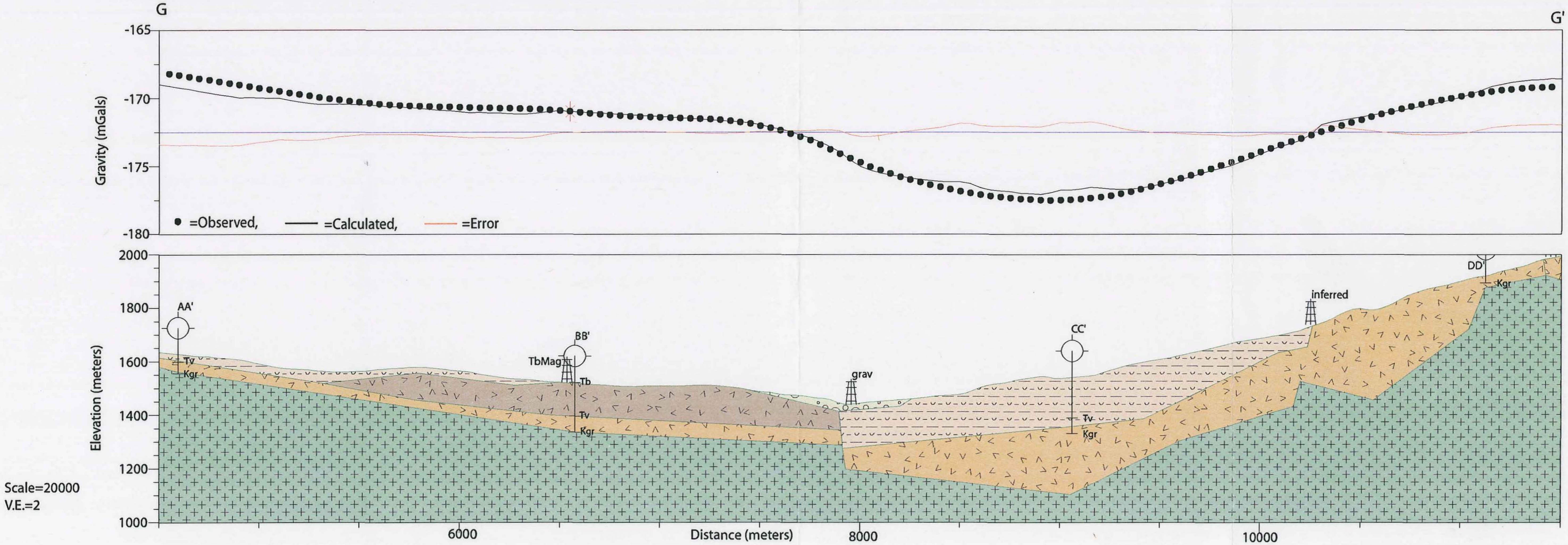


B
B'
Gravity (mGals)
-175
-180
-185
-190
-195
● =Observed,
=Calculated,
=Error 0.592
Elevation (meters)
2000
1800
1600
1400
1200
1000
mag line
Fuller
lineaments
fault
E-E'
Hersch
Vande
Larson
Scott
Knudsen
Kautz
grav lineament
School
F-F'
RPines
VMdws1
SlantNS
TMWA_hi
west basalt line
TMWA_cliff
SomersettGC
East basalt inferred
G-G'
Kgr bndy
Mogul
Kgr bndy
Kgd
TD
Mzvol
Kgr
Ts
volc
Tv
vol
basalt
and
Kgd
TD
volc
V.E.=2
Scale=35000
2000
4000
Distance (meters)
6000
8000
10000


C
C'
Gravity (mGals)
-175
-180
-185
-190
-195
=Observed,
=Calculated,
=Error
Elevation (meters)
2000
1800
1600
1400
1200
1000
fault/lineaments
E-E'
Gold Ranch
inferred
F-F'
slantNS
G-G'
H-H'
Ts
TD
Tv
Kgr
2000
4000
6000
8000
10000
12000
D
D'
fault
EE'
FF'
SlantNS
GG'
HH'
V.E.=2
Scale=35000
Distance (meters)


F
F'
Gravity (mGals)
-175
-180
-185
-190
-195
=Observed,
=Calculated,
=Error
Elevation (meters)
2000
1800
1600
1400
1200
1000
magline
Riverdale
Suppl
BB'
70611
Verdi School
grav
3rd st
VerdiBluff2
VerdiBluff
mag/gravline
Promax
CC'
gravline
DD'
volc
Kgr
Tv
Kgr
Kgr
8000
10000
Distance (meters)
12000
14000
E
E'
Gravity (mGals)
-175
-180
-185
-190
-195
=Observed,
=Calculated,
=Error
Elevation (meters)
2000
1800
1600
1400
1200
1000
Bolton
Peila
Trombley
Larson Scott
BB'
Hersch
Vande
Murphy
Wagon
Spyrow
Fitz
Gold
CC'
DD'
Kgd
TD
Tv
Mzvol
Kgr
Ts
Tv
Kgr
Mz
Scale=20000
V.E.=2
8000
10000
Distance (meters)
12000
14000


H
H'
Gravity (mGals)
-175
-170
-165
-160
=Observed,
=Calculated,
=Error
Elevation (meters)
-2000
-1800
-1600
-1400
-1200
-1000
Northgate
Kgd
td
Handlin
gran
td
CC'
Tv
Kgr
fault
DD'
Scale=20000
V.E.=2
8000
10000
Distance (meters)
12000
14000


G
G'
Gravity (mGals)
-165
-170
-175
-180
=Observed,
=Calculated,
=Error
Elevation (meters)
2000
1800
1600
1400
1200
1000
AA'
Tv
Kgr
BB'
TbMag
Tb
Tv
Kgr
grav
CC'
Tv
Kgr
inferred
DD'
Kgr
Scale=20000
V.E.=2
6000
Distance (meters)
8000
10000