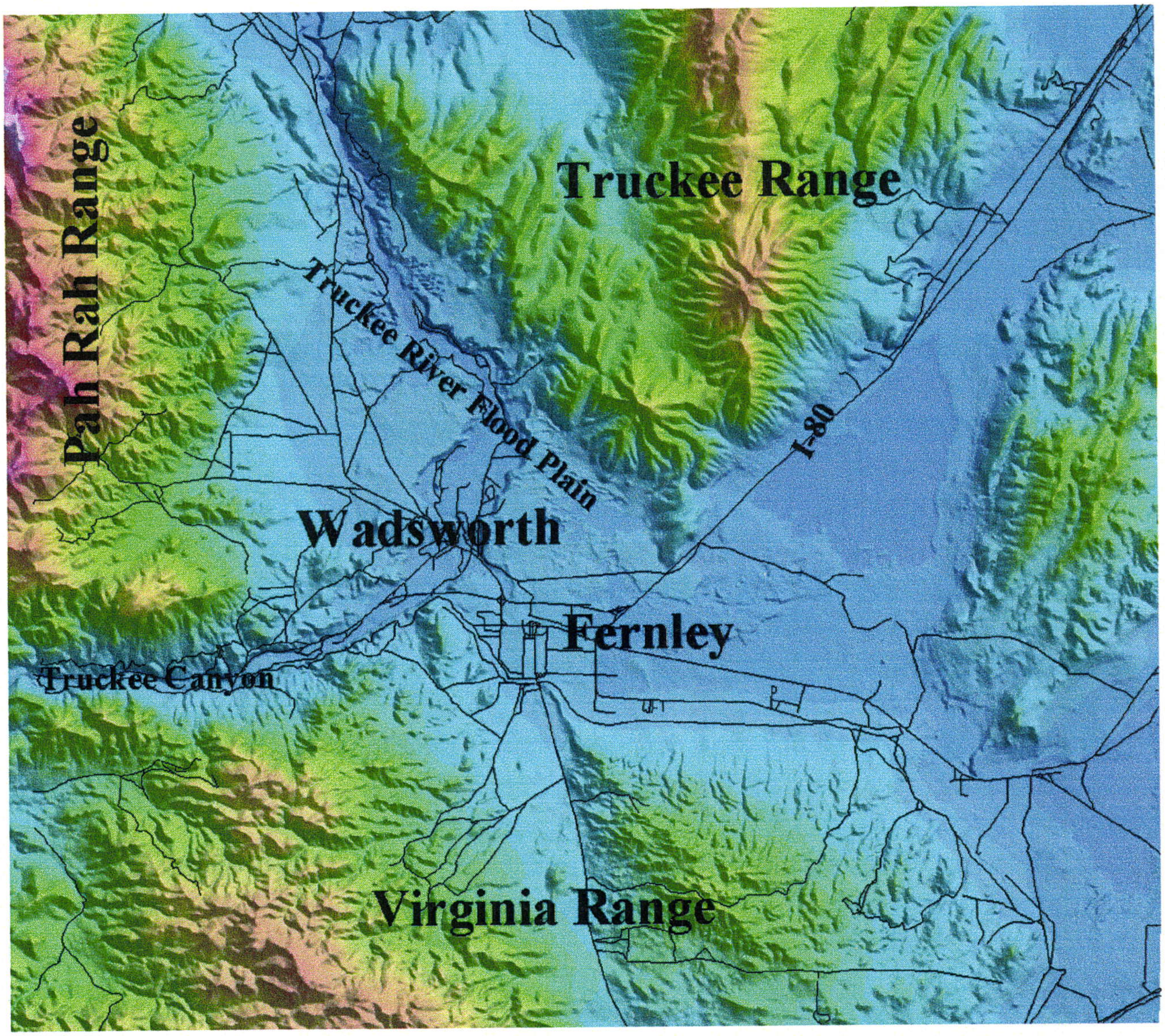
A GRAVITY AND MAGNETIC FIELDS DERIVED BEDROCK ELEVATION MODEL FOR THE FERNLEY/WADSWORTH BASIN, WASHOE AND LYON COUNTIES, NEVADA



Prepared for City of Fernley, Nevada
July 31, 2001

by
Michael C. Widmer
Washoe County Department of Water Resources

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

(Figures are located in the back of the text)

Figure

EXECUTIVE SUMMARY

Purpose

A groundwater flow and transport model of the Fernley-Wadsworth Hydrologic Basin is currently being constructed by the Desert Research Institute, University of Nevada, Reno under contract with Washoe County and the US Bureau of Reclamation. This model will be used to estimate the groundwater resources of the basin, delineate regional flow and solute characteristics and for use in future groundwater management activities. One component of the model construction is determining the bedrock surface elevation within the model domain. The use of potential fields (gravity and magnetic field measurements) modeling can provide a reasonable depiction of that surface. This report documents the development, by the Washoe County Department of Water Resources, of geologic models that are used to estimate the bedrock-alluvial contact, as a three-dimensional surface, within the 518km^2 (200mi^2) study area (Figure 1).

Geologic and Geophysical Data Sets

Geologic maps of the study area, prepared by the USGS and the Nevada Division of Mines and Geology (Green, et.al., 1991; Bonham and Papke, 1969), have been digitized (ADGIS, 2001) and are used in this modeling effort. Two gravity surveys have been conducted (Carpenter, 1998 and 2000) to provide a 214 station coverage of the area. Figure 3a shows these station locations and contours of the gridded data (0.5 mGals). Washoe County contracted an airborne geophysical survey of the area which yielded total field magnetic data and resistivity mapping (Dighem, 1996) along 345 flight line miles. Forty-four flight lines were flown at a spacing of 666 meters (2000 feet). Figure 6a shows the gridded results of the Total Field Magnetic data (100 nTeslas) and flight line locations.

Methodology

Potential fields modeling was accomplished using the software package GM-SYS™ (Northwest Geophysical Associates, 1996). The gravity and magnetic data were formatted for modeling using Oasis Montaj™ software (Geosoft, 1999). Data sets for magnetic, gravity, topographic elevation and magnetometer "bird" elevation were gridded. Nineteen profile lines were generated and modeled as shown in Figure 8. Mapped surface geology was strictly honored as control for each model cross section. Where possible, lithologic data from water well drilling was also used in constraining the modeling effort. The observed and modeled gravity data were fit as closely as possible whereas the magnetic data was fit to a lesser degree. The results should be considered "best-fit" models for the purpose of determining the bedrock elevation (see Figures 9-11).

Assumptions and Model Accuracy

Locations of major structures are well defined as are positions of relative depth to bedrock. In the absence of deep well depth to bedrock information, the absolute depths remain uncertain to perhaps ± 30%. This uncertainty stems from an imprecise knowledge of the basin fill and bedrock densities.

Results

Figure 12 is a color shaded relief image of the contoured bedrock elevation surface as derived from the modeling. The most prominent feature is the steeply dipping surface in the north-central portion of the figure. This surface represents an assumed fault structure related to the Walker Lane Fault Zone. Maximum thicknesses of sediment are found immediately to the east of this structure and range from 800 to 900 meters thick (2,600 to 2,950 feet). Lesser, but prominent bedrock slopes are found on the western and southern boundaries of this basin and are also assumed to be the result of faulting. Immediately south of the Town of Fernley, thick sequences of Tertiary gravels, are mapped (Greene, et.al., 1991) and are assumed to be uplifted as a result of reverse faulting. The horizontal gradients, indicated in the figure, were derived from the gravity data and help delineate basin boundary faults.

INTRODUCTION

The Washoe County Regional Water Planning Commission and the US Bureau of Reclamation are currently conducting water resources investigations in the Fernley/Wadsworth basin (see Figure 1). These investigations 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 alluvial aquifers. Therefore it is important that the subsurface alluvium-bedrock configuration of these valleys are understood and delineated which is the primary focus of this report.

Geophysical methods can provide a useful image of subsurface geologic structure. These methods include seismic reflection and refraction, 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 and the Town of Fernley contracted an airborne geophysical survey (Dighem, 1996) to map the total magnetic field and electrical resistivity response of these basins. The Town of Fernley also contracted land based gravity surveys (Carpenter, 2000 and 1998). 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 and provide geologic constraint on the potential fields modeling.

Acknowledgements

The author would like to acknowledge Dr. Gary Oppliger of the Mackay School of Mines, University of Nevada, Reno, for his comments and review throughout this project. The author also thanks Leonard Crowe Jr., former Washoe County Water Resources Planning Manger, for his vision and support in the use of geophysical surveys for water resource investigations.

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 Truckee Range in the northeast, the Pah Rah Range on the west, and the Virginia Mountains on the south. Elevations range from 1,229 meters (4,000 feet) at the Truckee River to 2,450 meters (8,035 feet) in the Pah Rah Range, 2,150 meters (7,074 feet) in the Truckee Range, and 2,135 meters (7,000 feet) in the Virginia Mountains. The Truckee River enters the study area from the west, flows to Wadsworth and then flows 32 kilometers (20 miles) north to Pyramid Lake. The Truckee River flood plain is the prominent flat lying region within the northwest area of Figure 1. Alluvial fans are not as easily discerned except along the eastern front of the Pah Rah Range, most notable being Dodge Flat located in the upper west central portion of the study area. Most of the valley fill area is relatively flat lying land that was formed from the Pleistocene lake Lahontan (Morrison, 1964).

There are few published reports on detailed geology of this specific area (Rose, 1969). The USGS and the Nevada Bureau of Mines and Geology are currently working in the area and have published geologic maps (Greene, et.al., 1991; Bonham and Papke, 1969). Figure 2 represents mapped geology taken from these published maps. Generally the study area can be described with five geologic units (Table 1), Cretaceous granodiorite, Mesozoic metavolcanics, 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, predominately exposed rocks are the Tertiary volcanics associated with the Pyramid sequence. These rocks are primarily mafic to intermediate volcanic extrusives and detritus. They have been intruded by Cretaceous granodiorite associated with the Sierra Nevada batholiths, dated at 90.7 million years (m.y.) (Bell and Garside, 1987). However, the uplift has only recently occurred within the last 2-3 m.y. (Schweickert, 1999). Other Tertiary (Miocene age) volcanics are comprised of basalt to rhyolite flows, intrusives, and ash flow tuffs which are also mapped in other areas of Washoe and Storey Counties. Tertiary sedimentary rocks are known to exist and are at least found within the Pyramid sequence of volcanic rocks. Tertiary sediments are assumed to form the basal unit of the basin fill deposits that underlie Quaternary alluvium. Lake Lahontan sediments cover the majority of the alluvial surface deposits and are estimated at 76 meters (250 feet) thick in some places (Morrison, 1964).

Little is known of the geologic structure prior to Basin and Range tectonic events or the Sierra Nevada orogeny that occurred in the last 3-4 m.y. 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. Bisecting the study area is the Walker Lane Fault Zone that trends south-southeast to north-northwest (Bell and Slemmons, 1979). The study area has also been described as wrench faulted (Bonham and Papke, 1969) with mapped antithetic and synthetic faults relative to the Walker Lane. This major fault structure is described as right lateral strike slip that extends from southern Nevada to northern California. This structure also appears to have normal faulting where the western slope of the Truckee Range is inferred to be the fault plane. Also mapped in the area is the left lateral strike slip Olinghouse Fault that extends from the Walker Lane west-south-west to Reno (Sanders and Slemmons, 1979).

Figure 2 shows fault structures currently mapped and inferred of the study area (ADGIS, 2001). The inferred faulting is comprised of lineations derived from geophysical and topographic data that were generally oriented in directions parallel, antithetic, or synthetic to the strike of the Walker Lane. A possible example of an antithetic fault to the Walker Lane is the Olinghouse Fault.

POTENTIAL FIELDS DATA

Gravity Data

Gravity information was compiled from two surveys. The Town of Fernley contracted Tom Carpenter for a gravity survey in 1998 in which 78 gravity stations were measured and in 2000 where 136 gravity stations were measured (Carpenter, 1998, 2000). 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 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 2.20 g/cm^3 as the slab density.

Magnetic Data

Dighem, Inc. was contracted by Washoe County and the Town of Fernley to conduct the airborne geophysical survey (Dighem, 1996). Instrumentation was installed in an Aerospatiale AS350B turbine helicopter (Skydance Helicopters, Inc.) which flew at an average airspeed of 100 kph (62 mph) with a magnetometer bird height of 50 meters (165 feet) above ground level. The survey consisted of 510 kilometers of traverse line (317 miles) oriented at 90°/270° to geographic north with 667 meters (2000 feet) line spacing. The tie lines (45 kilometers or 28 miles) were oriented at 0°/180° to geographic north. The magnetic data was collected with a Picodas 3340 optically pumped cesium vapor magnetometer. The sampling rate was 10 per second with a sensitivity of 0.01nT. Navigation and positioning consisting of a Sercel NR 106 real-time differential global positioning system with <5 meter accuracy. A Scintrex MEP-710 cesium vapor magnetometer was operated at the survey base to record diurnal variations. The base station clock was synchronized with that of the airborne system to permit subsequent removal of diurnal drift. Data processing by Dighem Inc. consisted of corrections for diurnal variations and leveling. Data processing by Washoe County consisted of reduction to pole and 100 meters of upward continuation (Geosoft, 1999).

Potential Field Maps

Figure 3a is a contoured grid of the Complete Bouguer Anomaly (CBA) gravity data overlain onto a color-shaded USGS digital elevation model (DEM) or topographic relief map. Also plotted are the gravity stations. The gridding was accomplished with a minimum curvature routine (Geosoft, 1999). The total range of gravity anomaly variation within the study area is -124 to -152 mGals or -28 mGals and is common for basin and range structure adjacent to the eastern Sierra Nevada. In eastern and central Nevada, variations in gravity anomalies can be as high as 60 mGals in basins as deep as 3 kilometers (10,000 feet).

This figure clearly shows that the low gravity anomalies are coincident with the lower topographic elevations and high gravity anomalies correlate with the high topographic elevations. The strong gravity gradients correspond to steep drops in the hard rock surface and are assumed to represent thickening alluvium overlying normal faults. Figure 3b is a color shaded relief map of the Complete Bouguer Anomaly (CBA) where the low gravity anomaly represents a relatively deep alluvial basin. This "trough" is oriented northwest to southeast. The basin is deepest north of Wadsworth. North of Fernley, the basin thins to the northeast and appears to be truncated at the eastern end of the study area. A small sub-basin is inferred in the south-central portion of the figure, south of Fernley.

Figure 4 is a color-shaded relief map of the total horizontal gradient of the gravity data. The contours are of the gravity anomalies (0.5 mGals interval). The total horizontal gradient is the maximum horizontal rate of change of the strength of gravity anomalies (first horizontal derivative of the gravity field). It is a useful analytic tool to determine where gravity slopes have their maxima. Fault structures can be inferred where gravity gradients reach their maxima. Figure 4 illustrates this where the steepest rate of change in gravity are delineated with blue lines parallel to these trends. Figure 5 shows these "gradient lineations" and mapped faults (see Figure 2) plotted onto the DEM where a good correlation is seen. The lineations are good indicators of basin boundary faults and are so inferred here. Of note is the south-central lineation that plots up slope of the Virginia Range in the Fernley area.

Figure 6a is a color shaded relief map of the total field magnetic data from the airborne geophysical survey with the flight lines plotted (gray). The gridding was accomplished using a minimum curvature routine (Geosoft, 1999). The magnetic data was reduced to pole and upward continued to 100 meters. The range between the low and high magnetic values is 2,200 nT (50,800 to 53,000 nT). Figure 6b shows these contours on a DEM of the study area. The structure of the magnetic signatures is somewhat subtle where relatively "stable" signatures are found within the valley and relatively "unstable" signatures are found parallel to the mountain range fronts. Unstable is explained as magnetic signatures in the same rock type that quickly change from high to low anomalies within a short lateral distance. A variable cooling and mechanical flow history is thought to be the cause of the chaotic patterns of reverse and normal magnetization. A better display of the "stable versus unstable" magnetic signatures is found with a shaded relief map of the magnetic susceptibility (Figure 7). It is interesting to note the apparent northwest oriented contrast between "stable" and "unstable" susceptibility in this figure are coincident with inferred basin boundary faults. Perhaps this is also an influence from the Walker Lane Fault Zone.

GEOLOGIC MODELS

Description of Units

Table 2 lists the major lithologic units found in the study area and their associated density range and magnetic susceptibility used in the modeling. These densities and magnetic susceptibilities were taken from similar rocks measured in the Sierra Nevada Carson Range, Washoe County, Nevada, approximately 30 miles to the southwest (Skalbeck, 1998). The alluvial values of density are assumed to be within the range of water saturated alluvium.

Table 2
Listing of lithologic units, densities and magnetic susceptibilities

Lithology	Density (g/cm^3)	Susceptibility (dimensionless cgs)
Quaternary Alluvium	2.07	0
Tertiary Sediments	2.17	0-0.004
Tertiary Volcanics	2.37 – 2.57	0.001-0.008
Cretaceous Granodiorite	2.67 – 2.77	0.002

Potential fields modeling is non-unique. By changing the density and/or susceptibility of lithologic units, the model thickness of these units will change and vice versa. The practice of the present modeling effort was to keep density and susceptibility estimates within a very tight range of values. No consideration was given to lithologic units of reversed magnetization because there was no direct evidence for these types of units although they probably exist and have been noted in the South Truckee Meadows (Skalbeck, 1998). The model separation of the Quaternary alluvium from the Tertiary sediments was arbitrarily set at 250 meters below land surface. The Quaternary unit is assumed to be a result of alluvial fan and lacustrine depositional environments, however the thickness is not known. The Tertiary sediments are assumed to be semi-consolidated to consolidated fine grained sediments, again the thickness unknown. Taken together they had influence on the gravity interpretation, but their thickness relative to each other could not be resolved. The Tertiary sediments were further divided into a unit with no magnetic susceptibility and a lower unit with a magnetic susceptibility of 0.004. An assumption was made that a magnetized tuff unit was located in the Tertiary sediments that solved a modeling problem common to most cross sections in this study. Tuffs are mapped within the study area.

The dominant rock units within the study area are Tertiary volcanics that occur as capping units in the three mountain ranges in the study area. Here again, the relative thicknesses of the volcanic units are subjectively modeled in order to render best fits to the gridded magnetic and gravity data. Their physical properties are assumed to be constant but probably vary widely. The Cretaceous granodiorite is considered basement rock. No consideration was given to the Mesozoic metavolcanics because of the lack of mapped outcrop though this unit probably exists within the study area.

Modeling Approach

Potential fields modeling was accomplished using the software package GM-SYS™ (Northwest Geophysical Associates, 1996). The gravity and magnetic data were formatted for modeling using Oasis Montaj™ software (Geosoft, 1999). Coincident line data was needed for the magnetic, gravity, topographic elevation and magnetometer sensor elevation data. Data sets for each were gridded and coincident profiles were generated. The elevation data came from the 30 meter USGS Digital Elevation Model. The sensor height elevation was recorded during the aeromagnetic survey. Mapped surface geology was strictly honored as control for each model cross section. The "gradient lineations" were mapped onto the profiles with the assumption made that they represented basin boundary faults. Where possible, lithologic data from water well drilling was also used in constraining the modeling. The observed and modeled gravity data were fit as closely as possible whereas the magnetic data was fit to a lesser degree, especially with the mountain ranges. It should be re-emphasized that the purpose of the modeling was to configure a bedrock elevation model. Consequently, the results should be considered "best-fit" models where importance was placed, in descending order, mapped geology, gravity and then magnetic data. Cross section orientation was chosen perpendicular to gravity gradients to maximize lithologic density contrasts.

Results

This section will discuss only three of the nineteen model cross sections. All modeled lines are contained in the appendix (where derrick symbols represent the locations of mapped faults and well sites). The discussion will start with a northern cross section and continue southward. Figure 8 shows the location and number of the model cross-sections. Figures 9-11 illustrate the geologic cross sections based upon the gridded gravity data and observed magnetic data, which are also shown. The magnetic curve (top section) plots the observed data (dots) and the calculated (solid line) data based upon the model geologic cross section. The middle section is the gravity data, again the observed (dots) versus the calculated (line). The lower section is the model geologic section where lithologic symbols (Table 1 and Figure 2) are shown. A distance scale is at the bottom and will be referred to in the discussion for each cross section.

<u>Line C9</u>

Figure 9 shows a geologic model for the northern portion of the study area. This represents a section from the western part of the study area in the Pah Rah Range, east to the Truckee Range in the northern part of the study area. At the left or west end of the model (distance = 8,000) volcanics are underlain by near surface basement granodiorite. The gradient lineament seen (distance = 10,000) does not appear to be significant in terms of a density contrast. The contact with the volcanics and the alluvium slopes moderately to the basin floor. The sediment is thickest (>1000m or 3,300ft) in this part of the study area. The vertical alluvial/volcanic contact at the northwest end of the model is very steep (80°?) and is well modeled as a basin boundary fault (gradient at 17,500). Note the two different volcanic units at the northeast (right) side of the basin where the horizontal contact is arbitrary. Tba represents Tertiary basalt/andesite and Tvol undifferentiated Tertiary volcanics. At the left Tp is the Pyramid sequence and Th the Hartford Hill rhyolite. Overall the gravity match of the calculated to observed is excellent and the magnetic match reasonable.

<u>Line C1</u>

Figure 10 shows a geologic model for the central portion of the study area. This represents a section from the most southwestern part of the study area in the Virginia Range northeast to the Truckee Range in the central part of the study area. The granodiorite basement is much deeper and not shown in this cross section. Volcanics underlay all of the sediments. These sediments are estimated at >800 meters thick (2,600ft). At a distance of 8,000m a well is plotted that penetrates the bedrock. Immediately east of this location the gradient lineament is shown and the geology is well modeled by a basin boundary fault. At the north end of the cross section profile (distance = 13,500), the gradient lineament or basin boundary fault does not appear to be steeply dipping. Overall the observed to calculated gravity fit is excellent and the magnetic fit is good.

Line B1

Figure 11 shows the geologic model for the east side of the study area. The geology is much more complicated. This section profile, starting from the left, is from the Truckee Range, south to the Virginia Range adjacent and southeast of Fernley. A peninsular shaped mass of rock extending southward from the Truckee Range, called the "Gooseneck", is bounded by alluvium and therefore modeled at a 2.5 dimension (NGA, 1996). Consequently the volcanics were modeled as two units with a third underlying the basin. The alluvium is estimated at 600m thick (2000ft) and abruptly terminated at the Virginia Range by an inferred reverse fault. However, this fault is not well documented and may not exist, although supported by the gradient lineation (noted at distance = 16,500). The Quaternary/Tertiary gravel unit is shown to be juxtaposed between the alluvial units and the Tertiary volcanics. In greater detailed sections the gravity data does support this relatively thick sequence of sediment. The volcanics were divided into three units to try and satisfy the observed magnetic data (better seen in cross sections B2 and B3). The calculated gravity and magnetic match to the observed is excellent throughout this section.

Model Accuracy

It is important to note that the depth of the alluvium modeled in these cross sections is highly dependent upon the density contrast between the alluvium and the igneous rocks. Absolute values assigned to the different lithologies is not as important as the absolute contrast between them. For example, if the contrast between units is modeled at 0.3 g/cm^3 but physically is 0.1 g/cm^3, then the relative thickness would actually be 1/3 less. Likewise, if the contrast is actually 0.4 g/cm^3, but modeled at 0.3 g/cm^3 the relative thickness would actually be greater. Therein lies the uncertainty of this modeling project.

In order to resolve this issue, a number of boreholes drilled to bedrock would be needed to confirm the actual alluvial thickness. Few wells have been drilled to confirm alluvial thickness and those are located at the margins of the basin. These wells have been used in the modeling effort. The shape of the basin is only as accurate as the lithologic mapping because the contacts mapped were strictly adhered to in the modeling effort. However, the gravity and magnetic data strongly support the lithologic mapping and deep basin structure. Therefore, it is felt that an accurate model of the basin shape has been accomplished and that depths are reasonably accurate, probably to ± 30%.

Configuration of Basin Bedrock

Once all nineteen cross sections were finalized, the bedrock-alluvial contact elevation was estimated at 250 meter intervals along each profile. These "data points" where then gridded and contoured. Figure 12 is a shaded relief image of the modeled bedrock elevation (in meters above sea level). The contour interval is 50 meters (164 feet). The locations of the "gradient lineations" and modeled cross section profiles are also visible. Figure 13 shows the results on a digital elevation model for topographic reference. Figure 14 is a map of the sediment thickness (50m contours).

The bedrock elevation contours reveal a more steeply dipping bedrock surface coincident with the inferred basin boundary faults ("gradient lineations") particularly along the western slope of the Truckee Range as well as the surface immediately west of Wadsworth. Here, sediment thickness is as much as 900 meters (2,950 feet). Although the Walker Lane Fault Zone is primarily a strike-slip fault structure, there appears to be significant dip-slip movement as well in this area on both sides of the Wadsworth basin. Northward, the basin narrows to 2,500 meters in width (8,200 feet). To the southeast, the basin broadens in width and rises in elevation to 750 meters above sea level (2,460 feet) where land surface elevation is generally 1,250 meters (4,100 feet).

At the northwest portion of the study area the gradient lineation is oriented antithetic (perpendicular) to the Walker Lane Fault Zone direction and oriented on strike to the Olinghouse Fault. To the southeast of this lineation, the bedrock is estimated to be much higher in elevation. This would reflect thicker volcanic deposits than at the other boundaries or that the granodiorite has been uplifted more relative to other boundaries. At the extreme western edge of the study area, the Truckee River enters the basin from a canyon that appears to be very shallow, but there is little gravity data to support this estimation. South of Fernley, the sediment thickness shallows quickly. Also noteworthy is a relatively steep slope on the Virginia Range southeast of Fernley. This indicates that the Quaternary/Tertiary (QTg) gravels mapped in this area are relatively thick. At the far southeastern study area (at the gradient lineation) there appears to be a near surface, reversely magnetized volcanic unit that truncates the basin, but this not well illustrated. There is no estimation of sediment thickness to the east-northeast of the study area.

DISCUSSION AND CONCLUSIONS

The magnetic and gravity data are complementary and consistent with the geology and topography. The gravity data displayed in Figures 3a and 3b defines basin structure where gravity gradients highlight the steep basin structure. The magnetic data also reflects lithologic and basin structure as seen in Figures 6a, 6b and 7. The use of the total horizontal gradient map gave good insight on the presence and location of basin boundary faults that were consistent with mapped faults. This interpretation was useful in the geologic cross section modeling effort.

At several boundaries of the basin the magnetic data was not modeled. As stated earlier the magnetic behavior of the volcanics changes rapidly over a relatively short distance. The magnetic signatures are most likely a result of lava flow "roll-over" during the depositional period. No structural sense can be made of this. It is interesting to note that total field magnetics are relatively stable within the confines of the alluvial basin (see Figure 7).

Constructed geologic cross sections are consistent throughout the study area with minor differences within the three mountain ranges. Actual depths to bedrock are uncertain and can only be verified through drilling methods. Accurate density contrasts between the sediment and bedrock are not available which vary horizontally and vertically, therefore average values must be used. To compensate for the natural increase in density with depth in the alluvial sequence a second sedimentary unit with a 5% increase in density was modeled. Differentiation of volcanic units was not possible and was not within the scope of this study, but mapped units were recognized. The assignment of density and susceptibility to the individual volcanic units was subjective and varied by 10%. The contact between the basement granodiorite and the volcanics was also subjective. Further, the magnetic susceptibility assigned to the basal alluvial unit (Tal) is based upon the assumption that ash fall was likely in the Tertiary. This assumption is supported by tuff units mapped in the study area (Greene, et.al., 1991). This assumed susceptibility greatly assisted in the modeling effort for most, but not all of the cross sections. Finally, an attempt was made to model the gravity gradient lineations as normal fault structures and this interpretation was mostly successful.

The reverse fault modeled in the Virginia Range is purely hypothetical. It is based upon a Tertiary/Quaternary sedimentary unit found in this part of the range not found elsewhere. This is best seen in Figure 11. The unknown dip of this structure (at the contact Qa/QTa) was highly constrained by the gravity and magnetic data, but should be considered subjective. This configuration appeared to give the best result. The orientation of the strike of this hypothetical reverse fault is consistent with a wrench-fault model proposed for this basin, antithetic to the Walker Lane. However, compression to the basin must have occurred for reverse faulting and this has not been fully worked out to date.

The bedrock elevation model conforms to the surface topography and generally continues these slopes in topography at depth. Modeled depths to bedrock do not appear to be surprising or to conflict with any of the data used. As noted earlier, actual depths to bedrock probably become less accurate as the basin deepens. Water well drilling that actually penetrated all the alluvium to bedrock are lacking and are mostly located near the alluvial basin margins. This information was also honored in the modeling effort. An exception to this was at the southeastern portion of the Virginia Range were depths to bedrock were reported to be relatively shallow. This information greatly conflicted with the gravity data.

REFERENCES

ADGIS, 2001. Various digital geographical information provided to Washoe County, Department of Water Resources, Reno, Nevada..

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

Bell, Elaine J. and Slemmons, David B., 1979. Recent crustal movements in the central Sierra Nevada- Walker Lane region of California-Nevada: Part II, the Pyramid Lake right-slip fault zone. Tectonophysics, vol. 52, pages 571-583

Bonham, Harold and Papke, Keith, 1969. Geology and mineral deposits of Washoe and Storey Counties, Nevada. Nevada Bureau of Mines and Geology, Bulletin 70.

Carpenter, Thomas. 2000, 1998. Gravity data acquisition and processing, Fernley Area Project, Washoe, Lyon and Storey Counties, Nevada. Consultant report prepared for both Washoe County Department of Water Resources, Reno, Nevada and City of Fernley, Nevada.

DIGHEM, 1996. Dighem^V survey for Utility Division, Washoe County Public Works, Reno, Nevada. Consultant report prepared for Washoe County Public Works, Reno, Nevada.

Greene, R.C., Stewart, J.H., John, D.A., Hardyman, R.F., Silberling, N.J., and Sorenson, M.L., 1991. Geologic map of the Reno 1x2 degree quadrangle, Nevada and California: USGS Miscellaneous Field Studies Map MF-2154-A, 1:250,000.

Geosoft, Inc.,1999. Oasis Montaj, data processing and analysis system for earth science applications, Version 4.3. Geosoft, Inc. Toronto, Ontario.

Morrison, R.B., 1964. Lake Lahontan: Geology of southern Carson Desert, Nevada. U.S. Geological Survey Professional Paper, 401.

Northwest Geophysical Associates, 1996. GM-SYS, Gravity and Magnetics Modeling for Windows. Version 4.00. Northwest Geophysical Associates, Corvallis, Oregon.

Rose, Robert., 1969. Geology of parts of the Wadsworth and Churchill Butte quadrangles, Nevada. Nevada Bureau of Mines and Geology, Bulletin 71.

Sanders, Chris and Slemmons, David., 1979. Recent crustal movements in the central Sierra Nevada- Walker Lane region of California-Nevada: Part III, the Olinghouse Fault Zone. Tectonophysics, vol. 52, pages 585-597

Schweickert, 1999. Oral communication, Mackay School of Mines, University of Nevada, Reno.

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, Reno, Nevada.

Figures

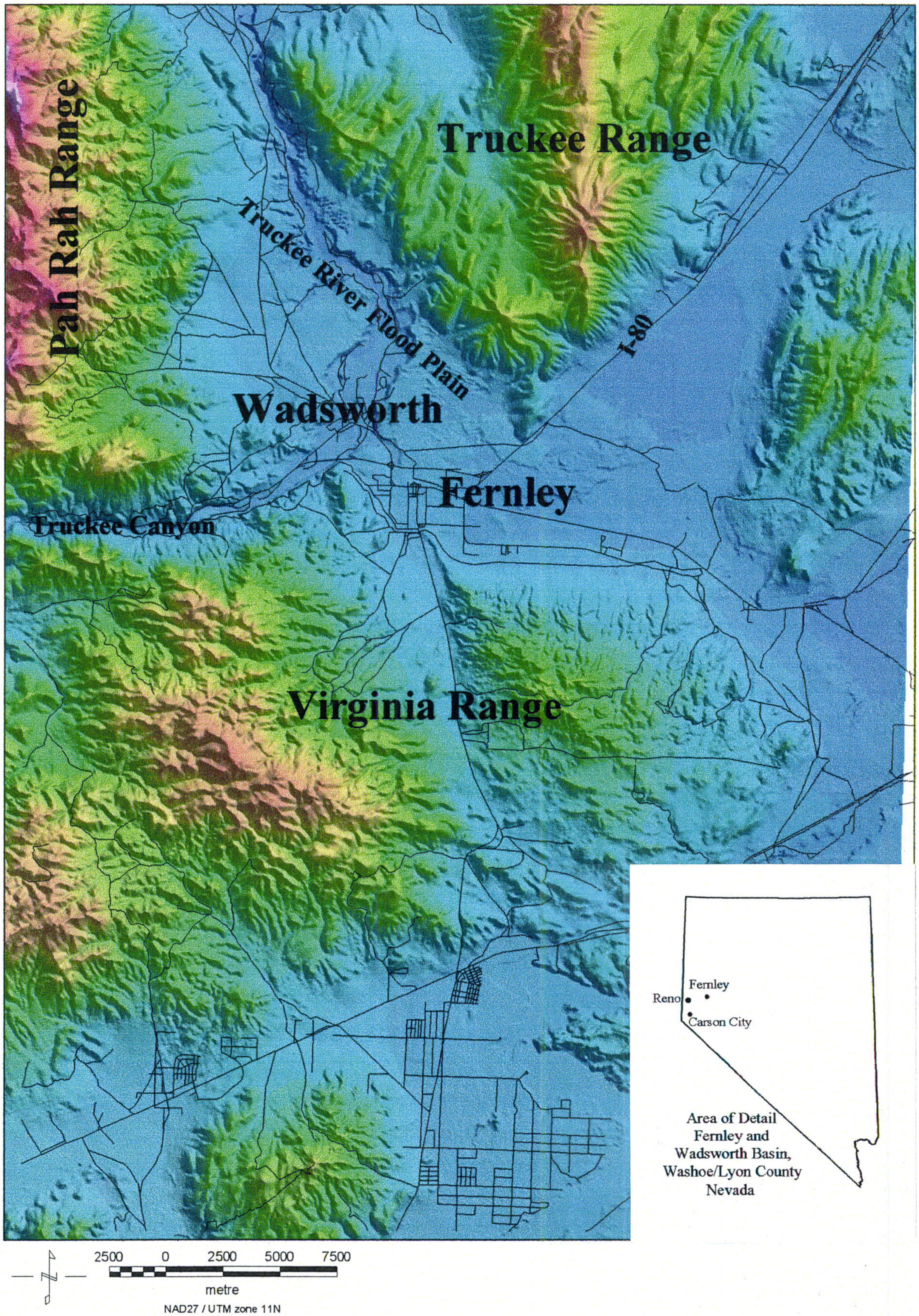
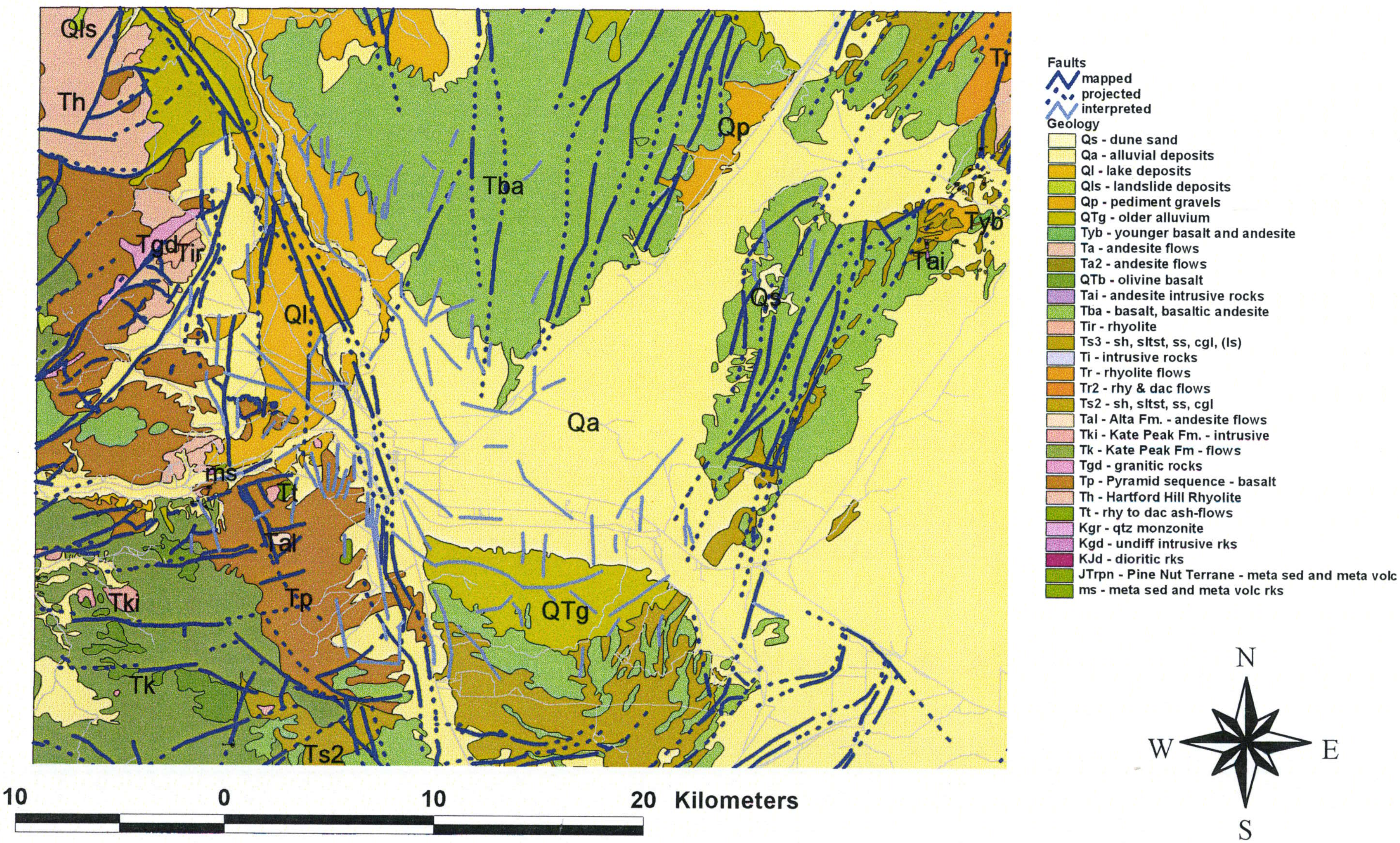


Figure 1. Location map of the Fernley/Wadsworth Basin.

Figure 2. Geologic map of Fernley and Wadsworth area



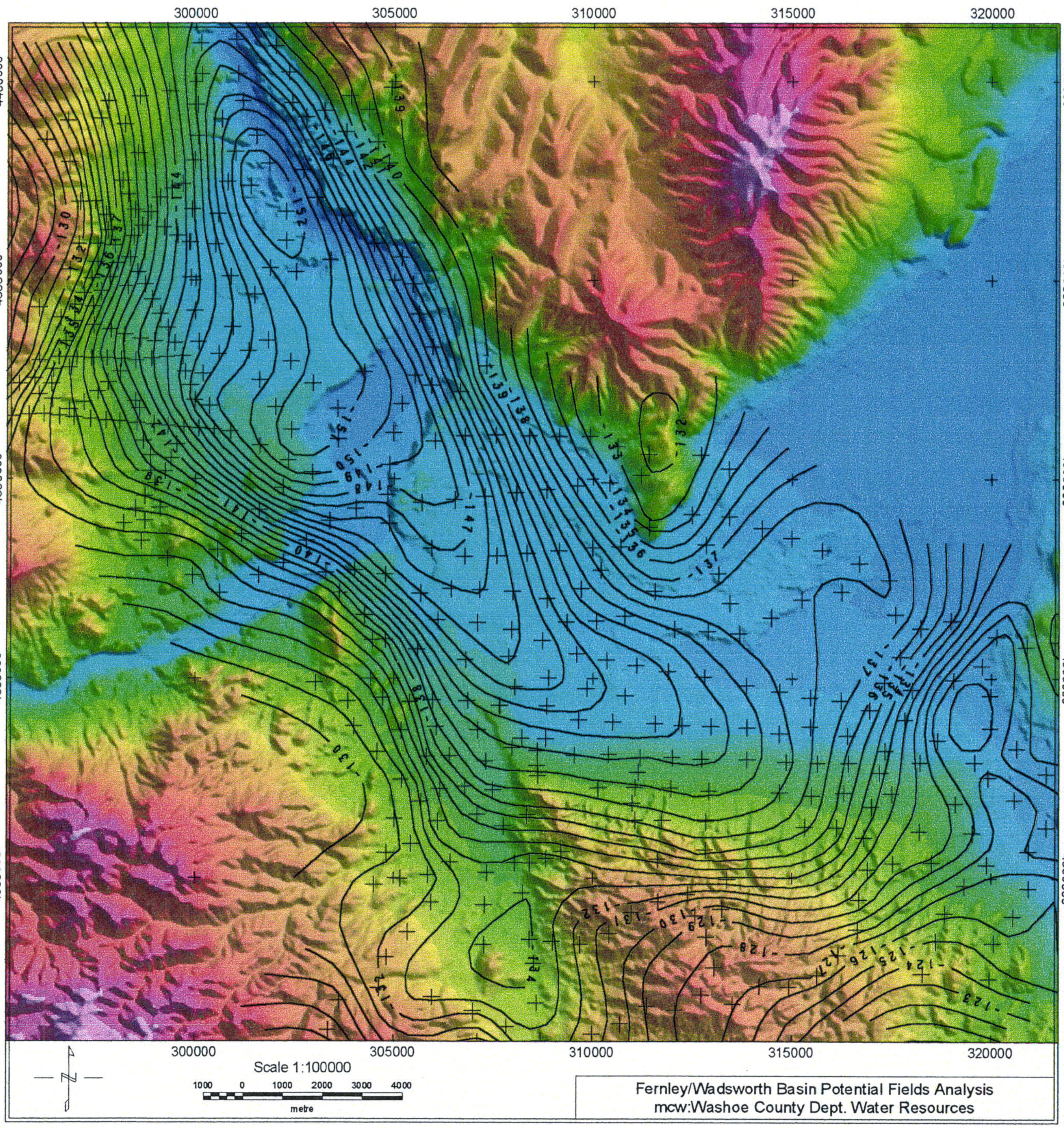


Figure 3a. Complete Bouguer Anomaly gravity map showing station locations (1.0 mGal contour interval).

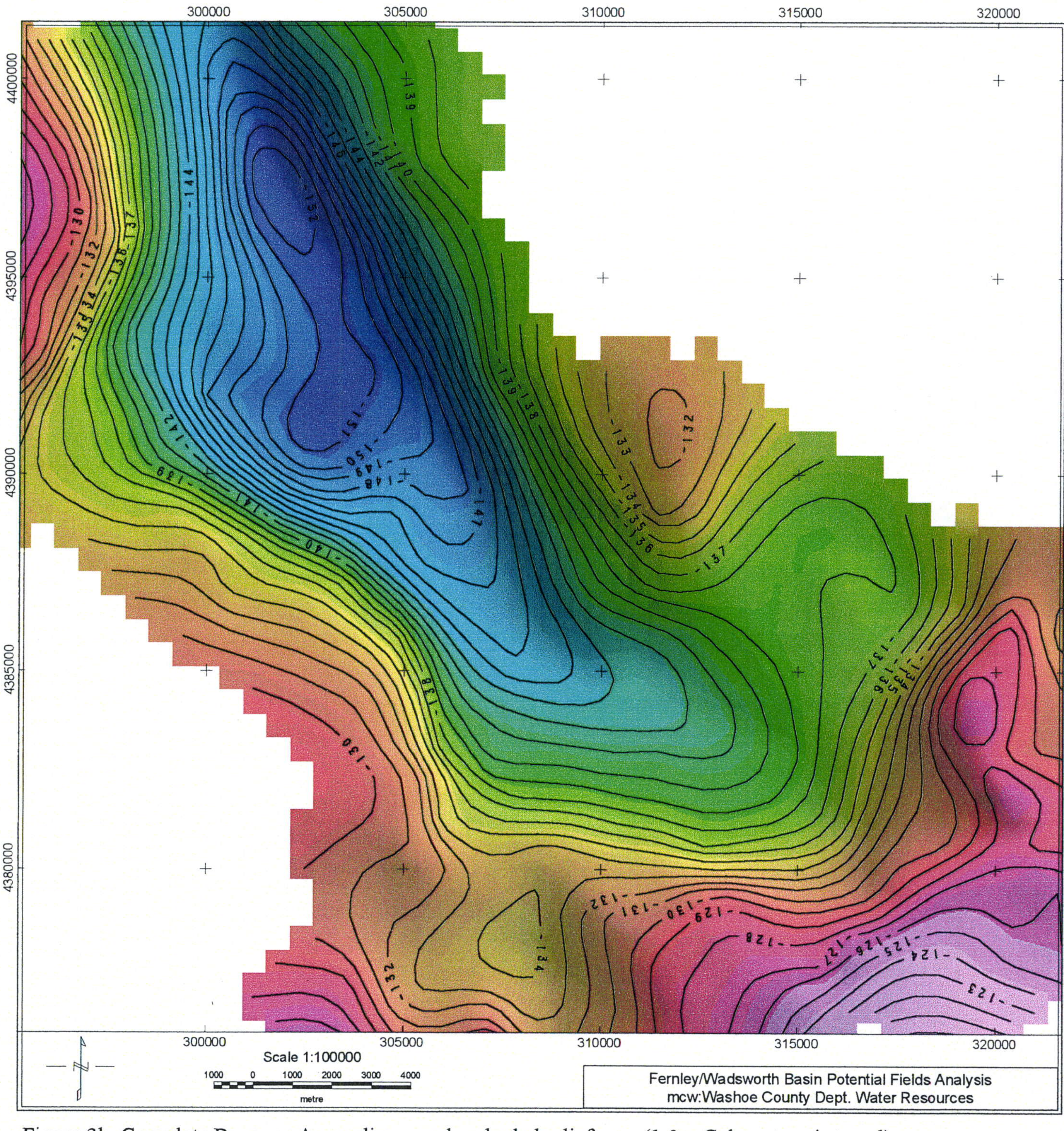


Figure 3b. Complete Bouguer Anomalies as color shaded relief map (1.0 mGal contour interval).

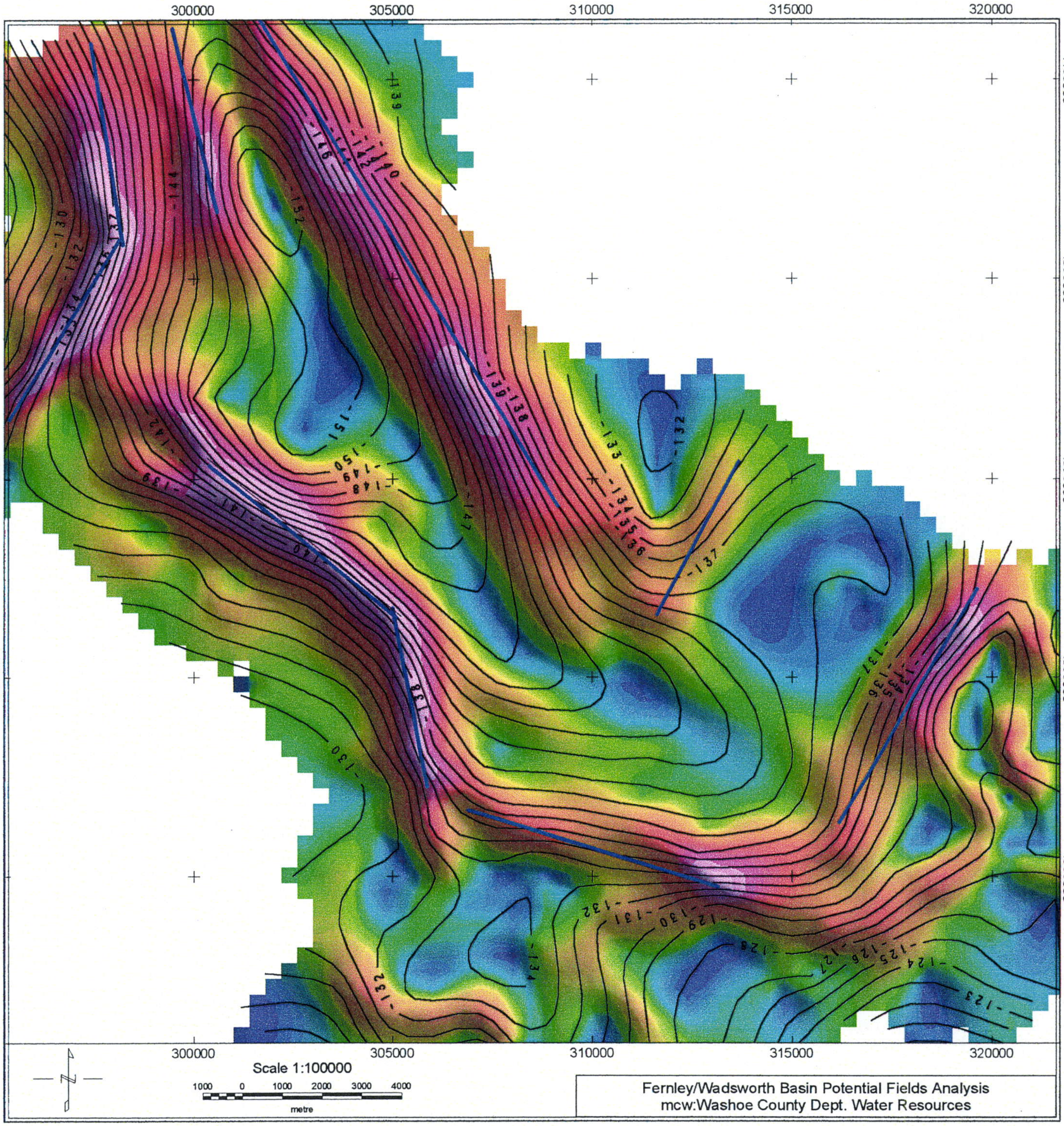


Figure 4. Total horizontal gradient of Complete Bouguer Anomalies as color shaded relief map. Contour interval is 1.0 mGals. Lineaments are drawn parallel to the maximum gradient.

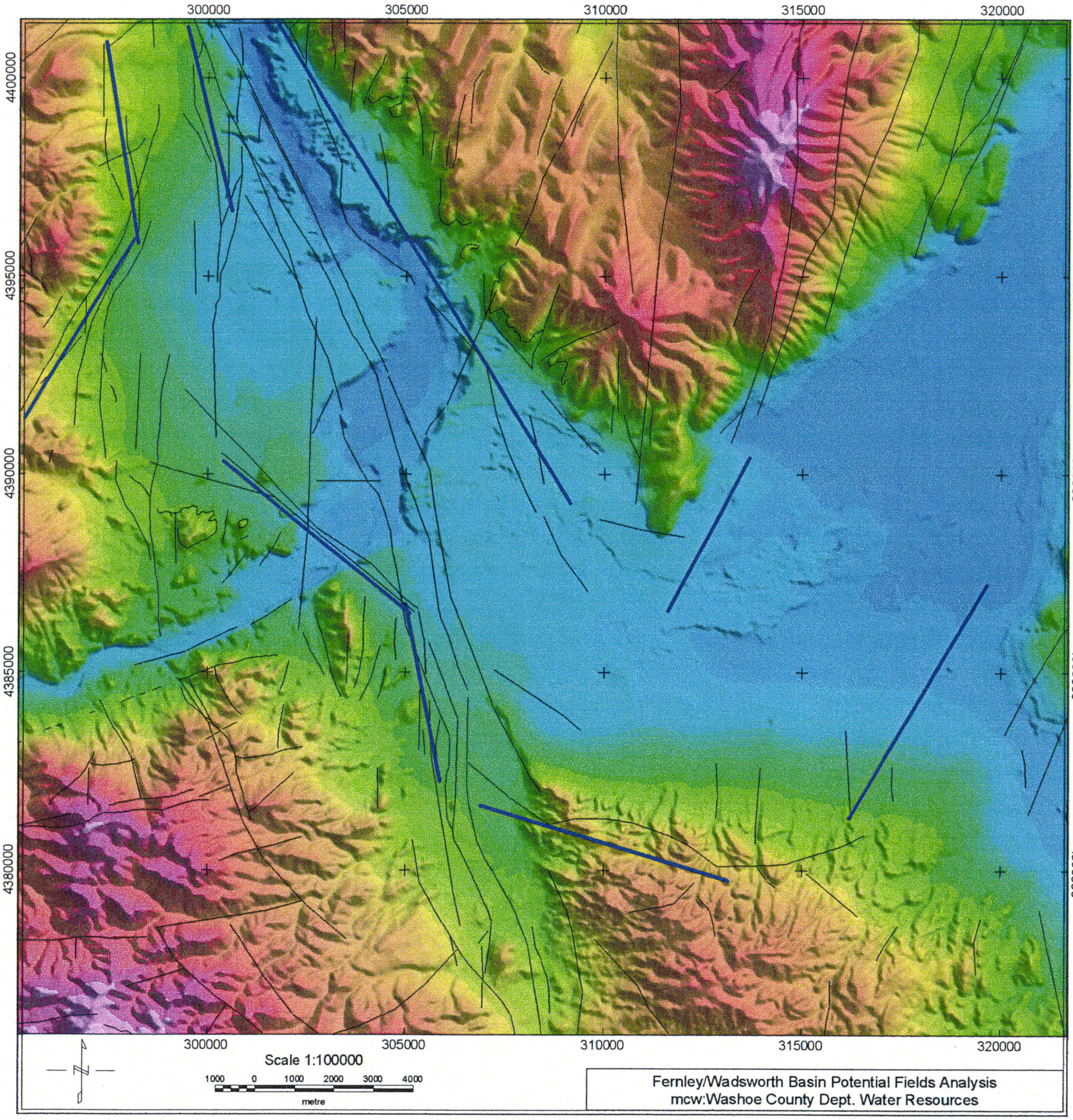


Figure 5. DEM with total horizontal gradient lineations and mapped faults.

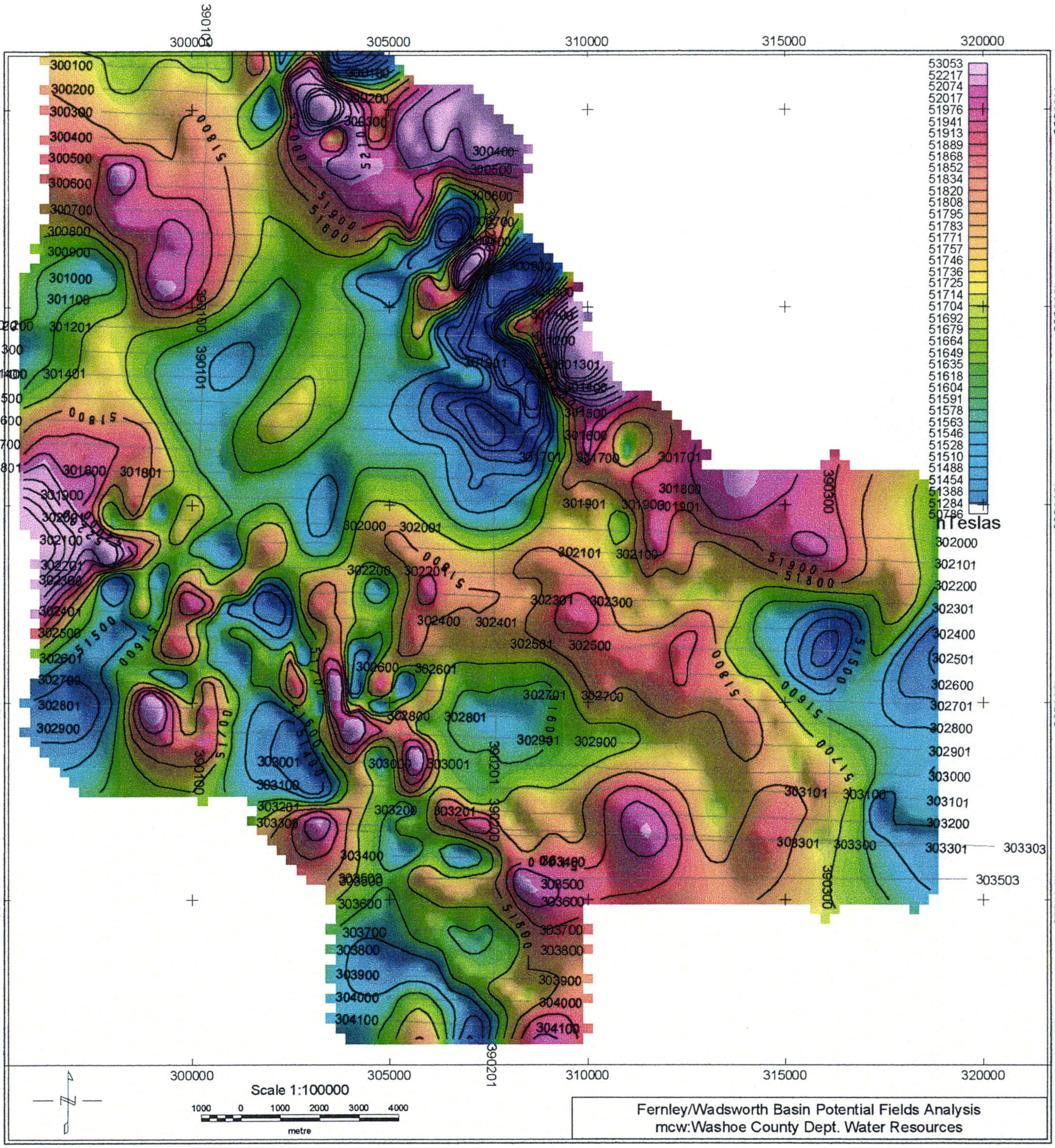


Figure 6a. Shaded relief of total field magnetics (100 nTesla contour interval) and flight line locations.

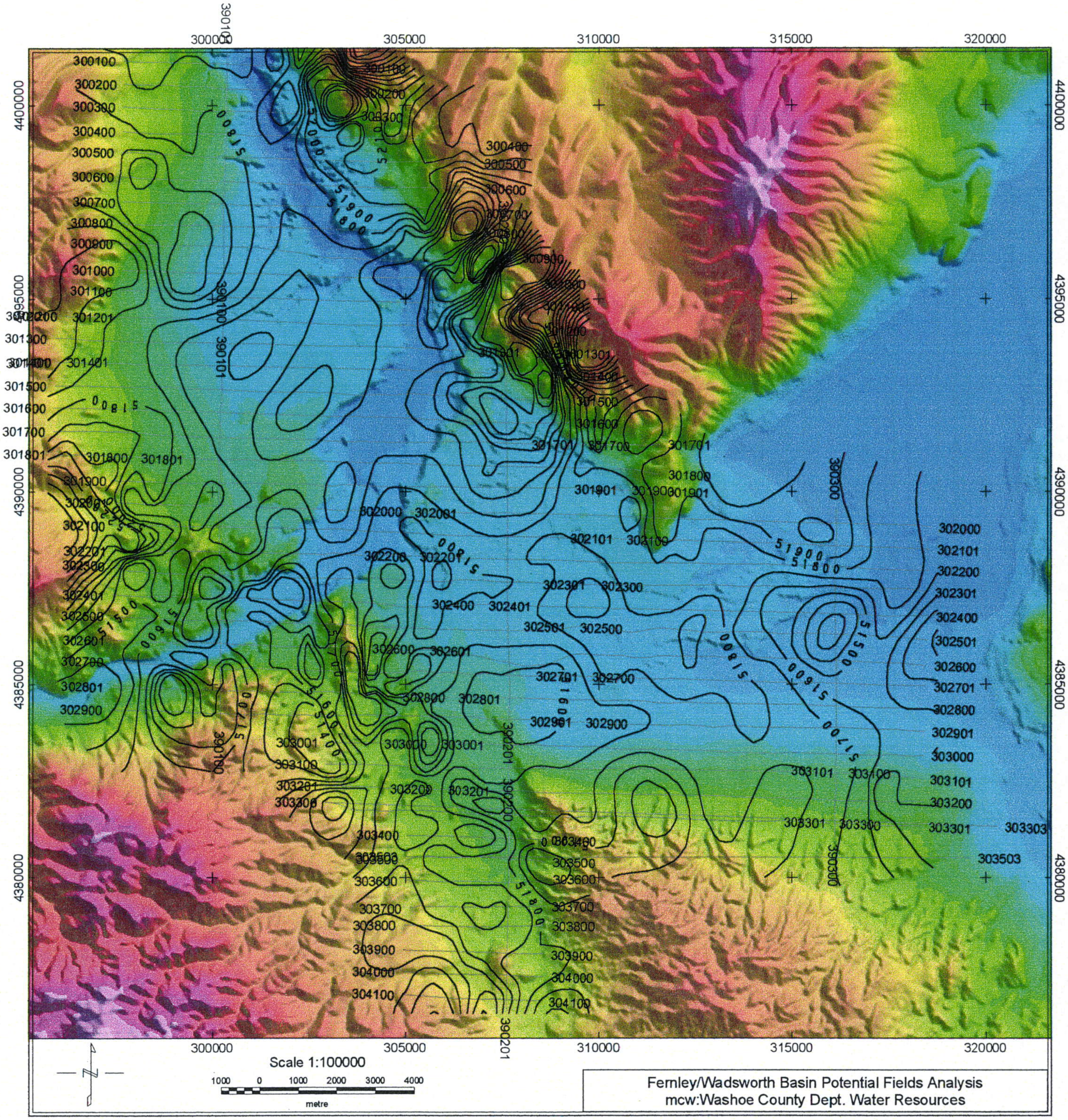


Figure 6b. DEM as shaded relief with total field magnetics (100 nTesla contour interval) and flight lines.

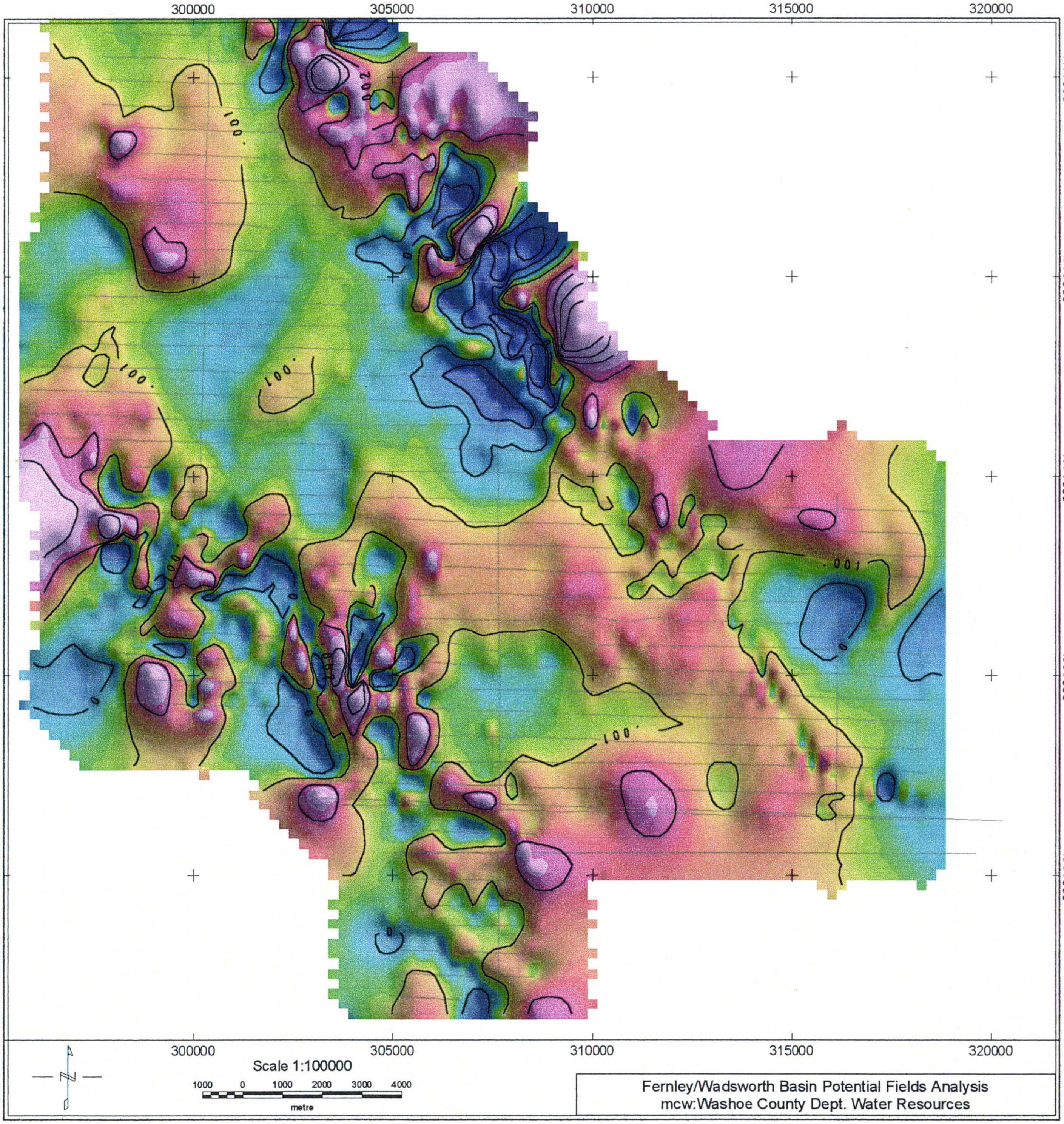


Figure 7. Color shaded relief of magnetic susceptibility (0.001 contour interval) and flight line locations.

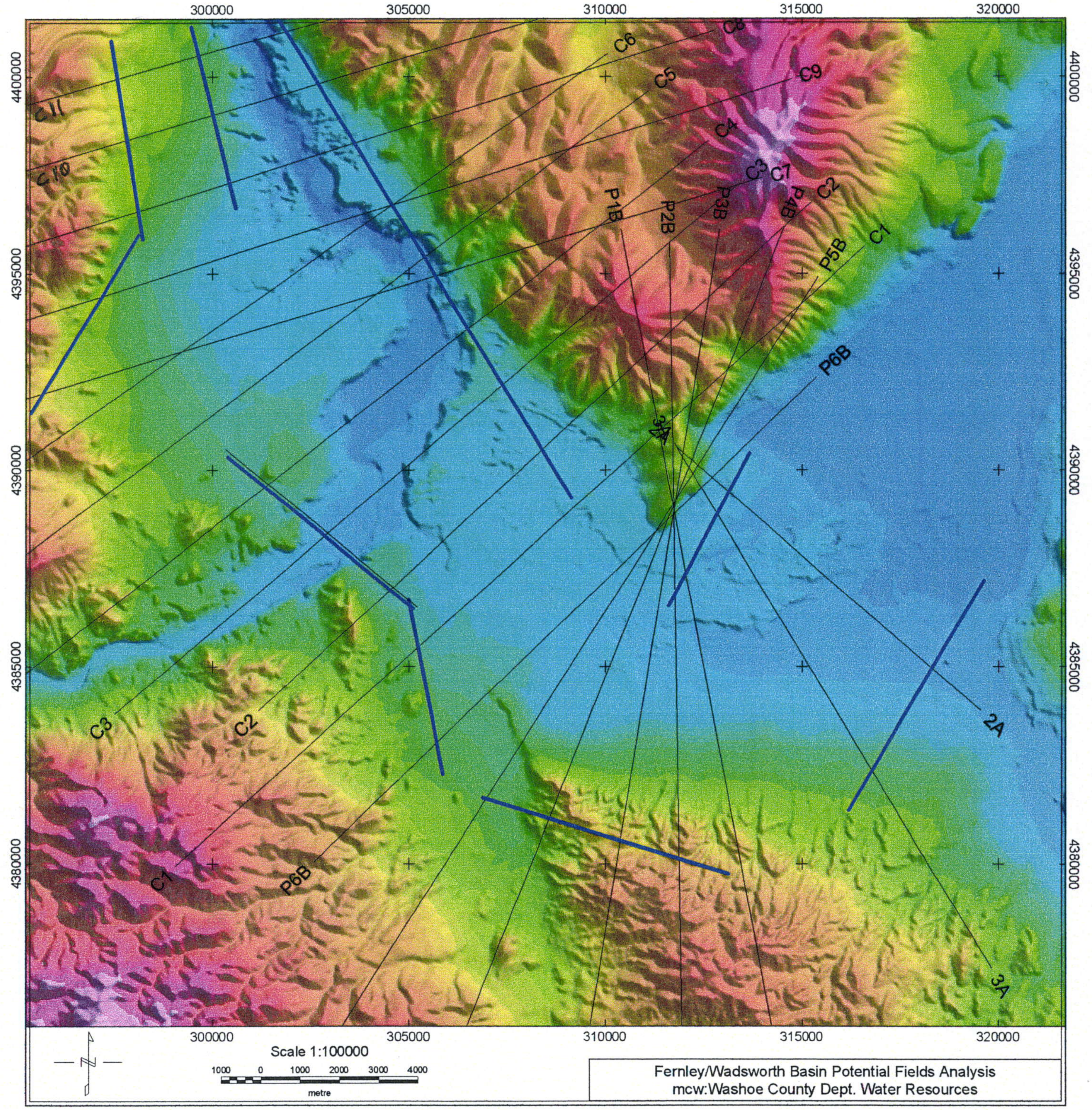


Figure 8. Location of geologic cross sections with total horizontal gravity gradient lineations.

Figure 9. Geologic cross section C9

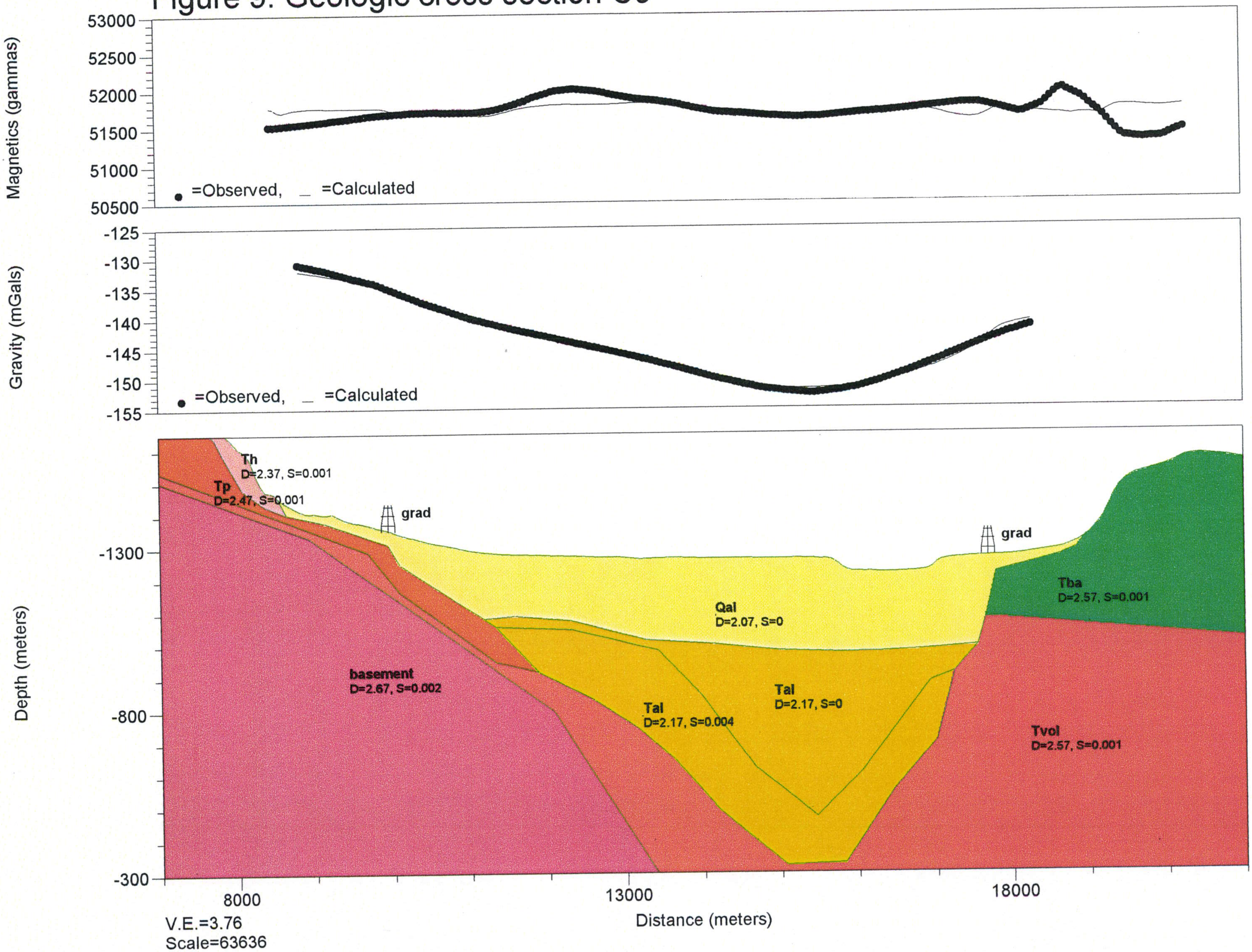


Figure 10. Geologic cross section C1

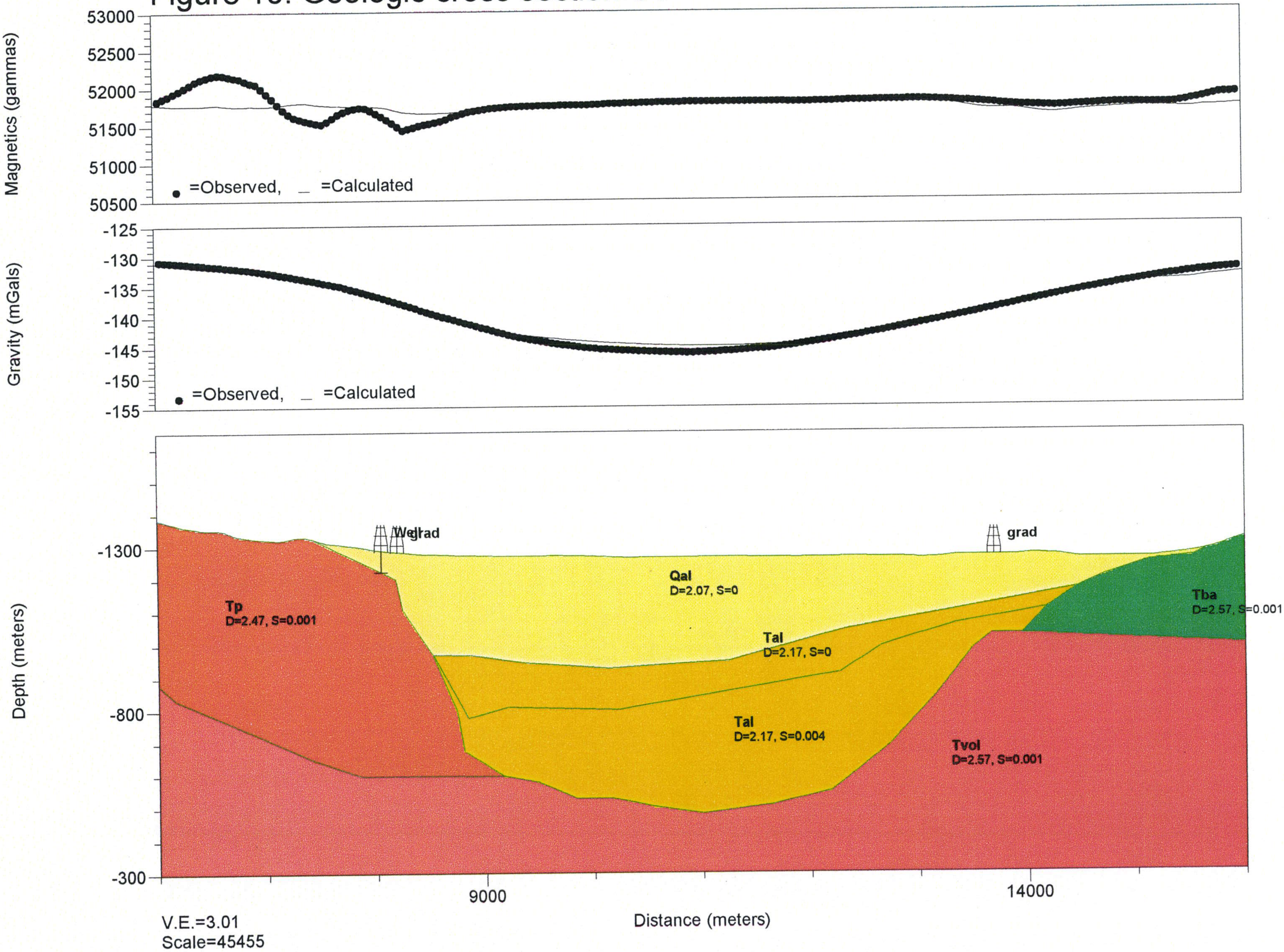
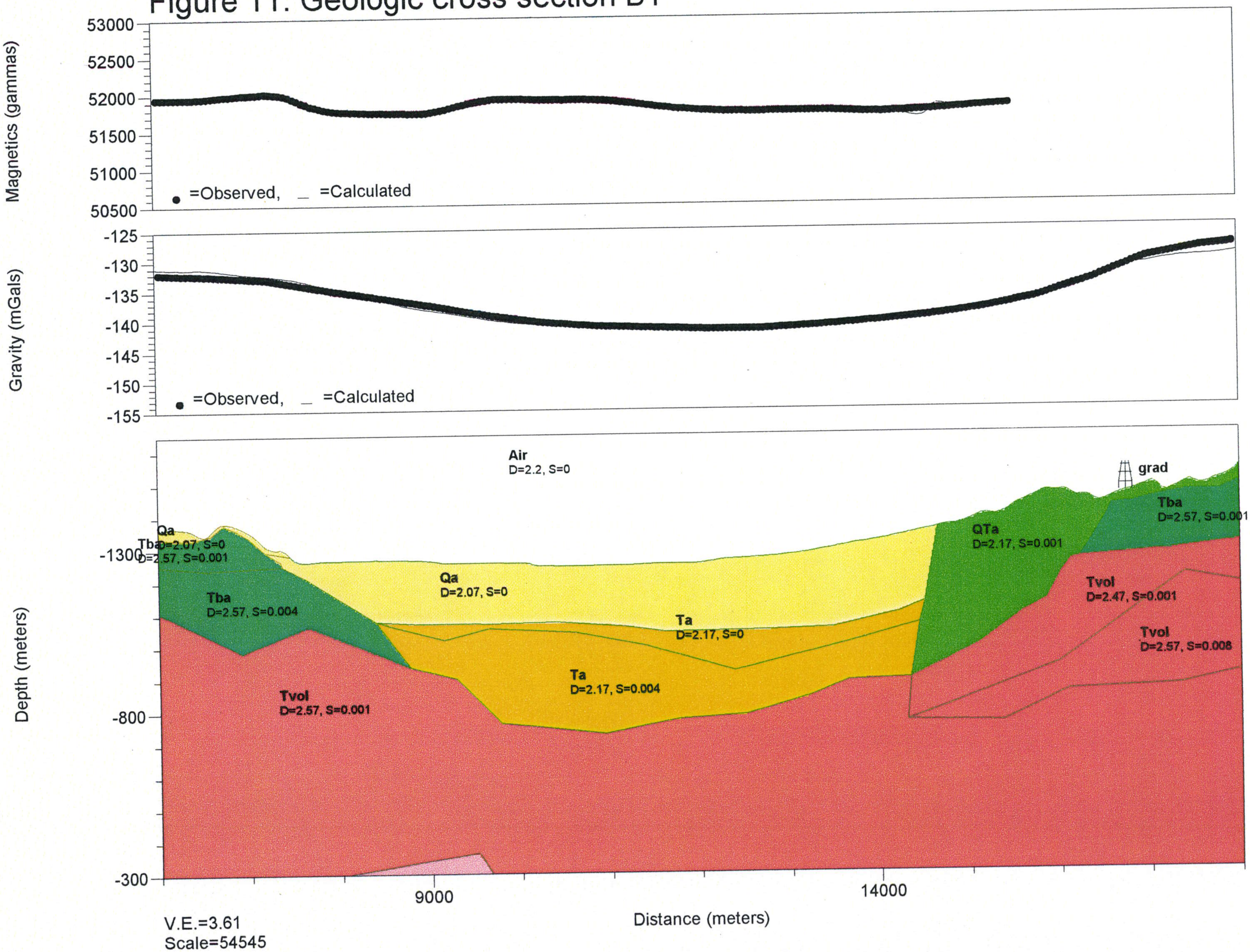


Figure 11. Geologic cross section B1



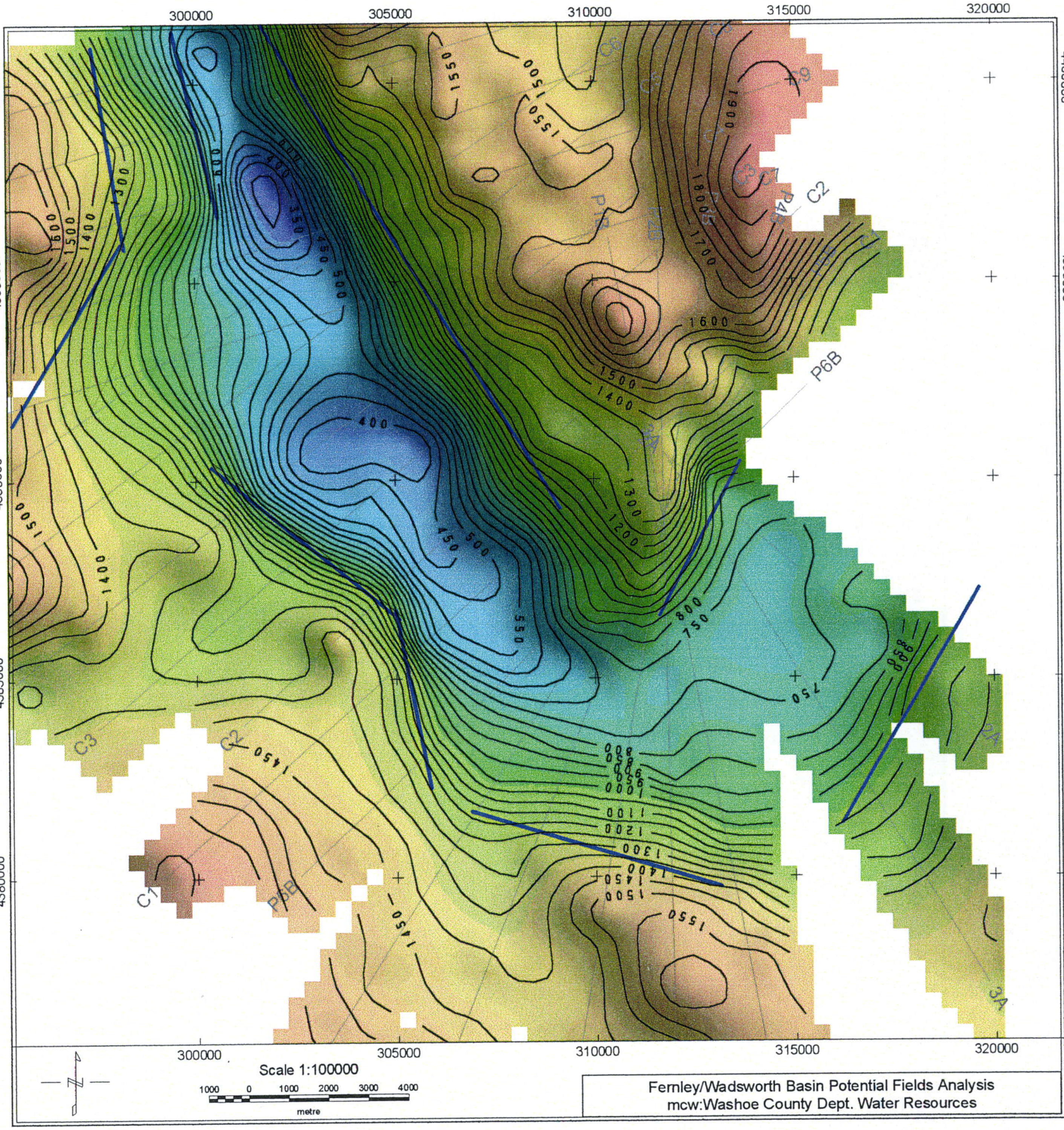


Figure 12. Color shaded relief of bedrock elevations (50m contour interval) with gradient lineations and profiles.

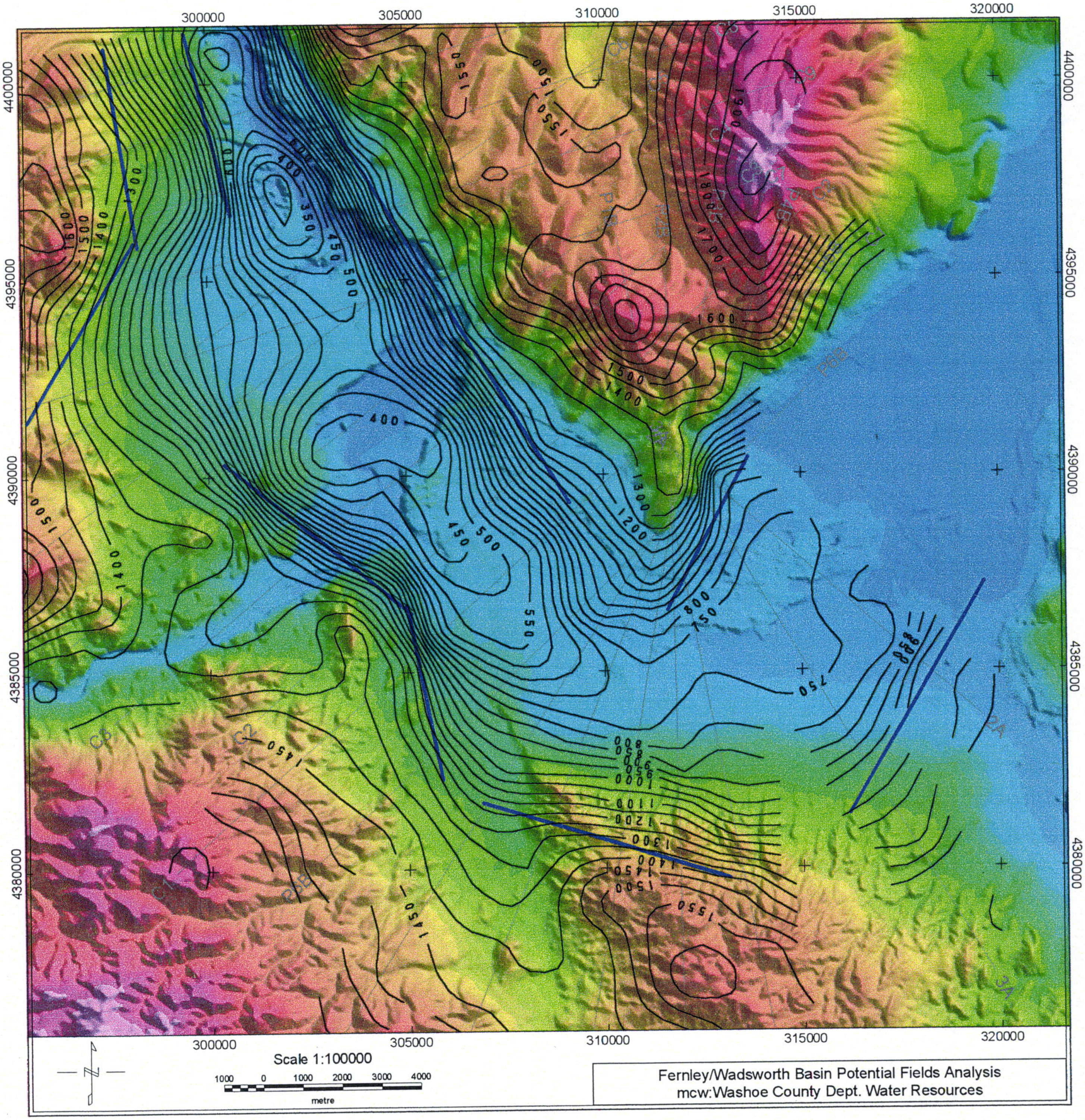


Figure 13. DEM with bedrock elevations (50m contour interval), gradient lineations and profile locations.

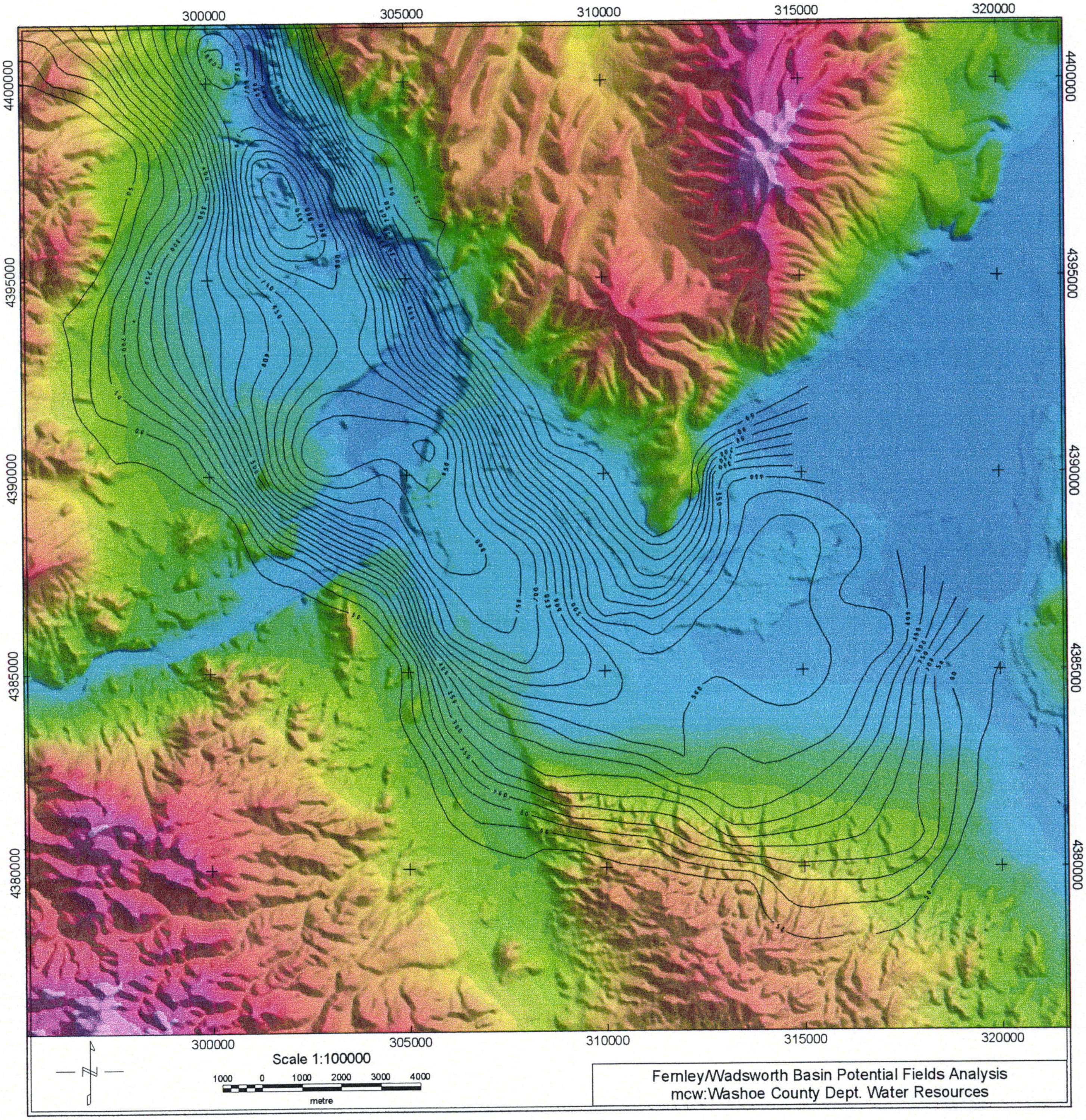


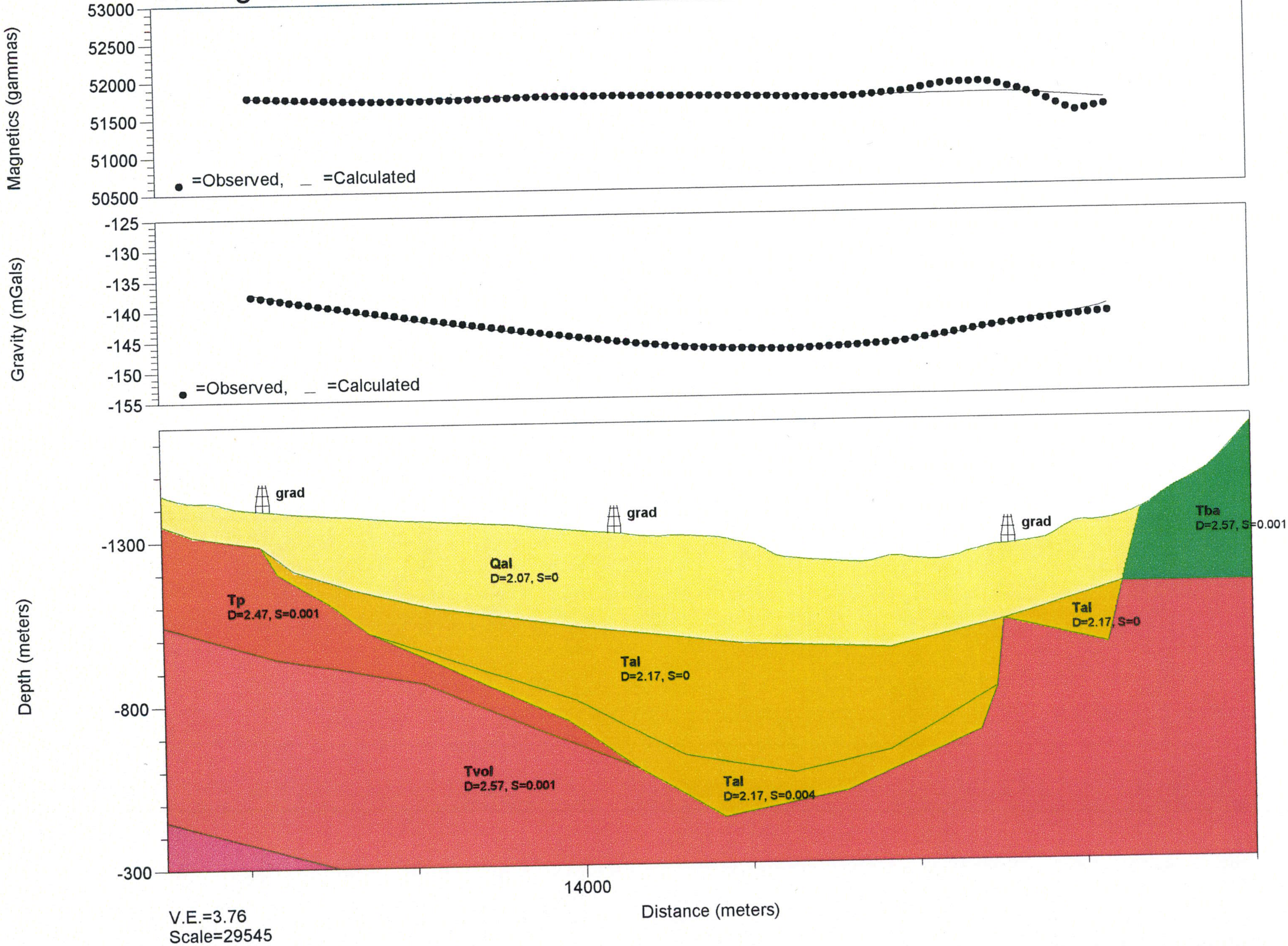
Figure 14. DEM with iso-contours (50m interval) of sediment thickness.

Appendix

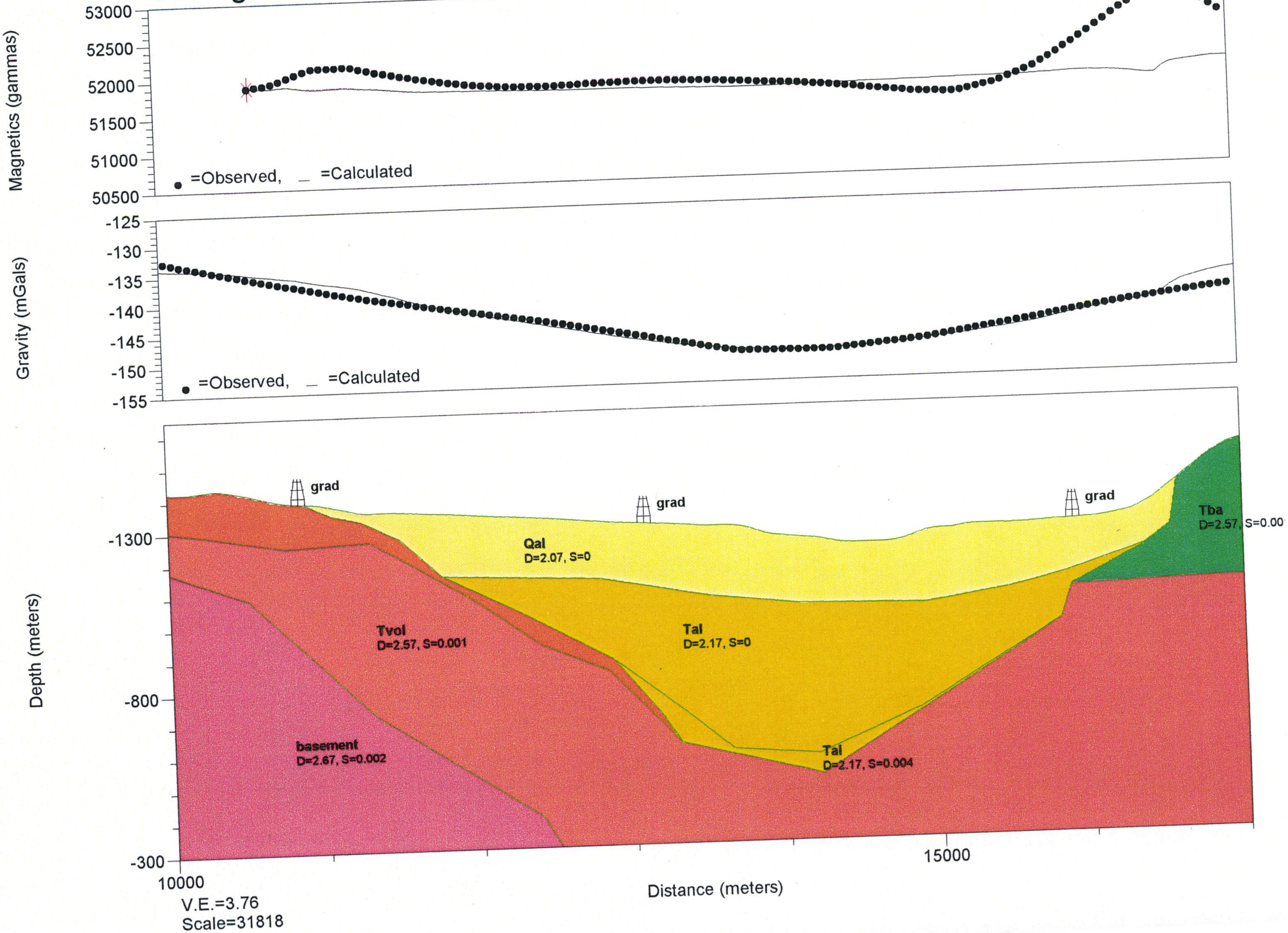
APPENDIX

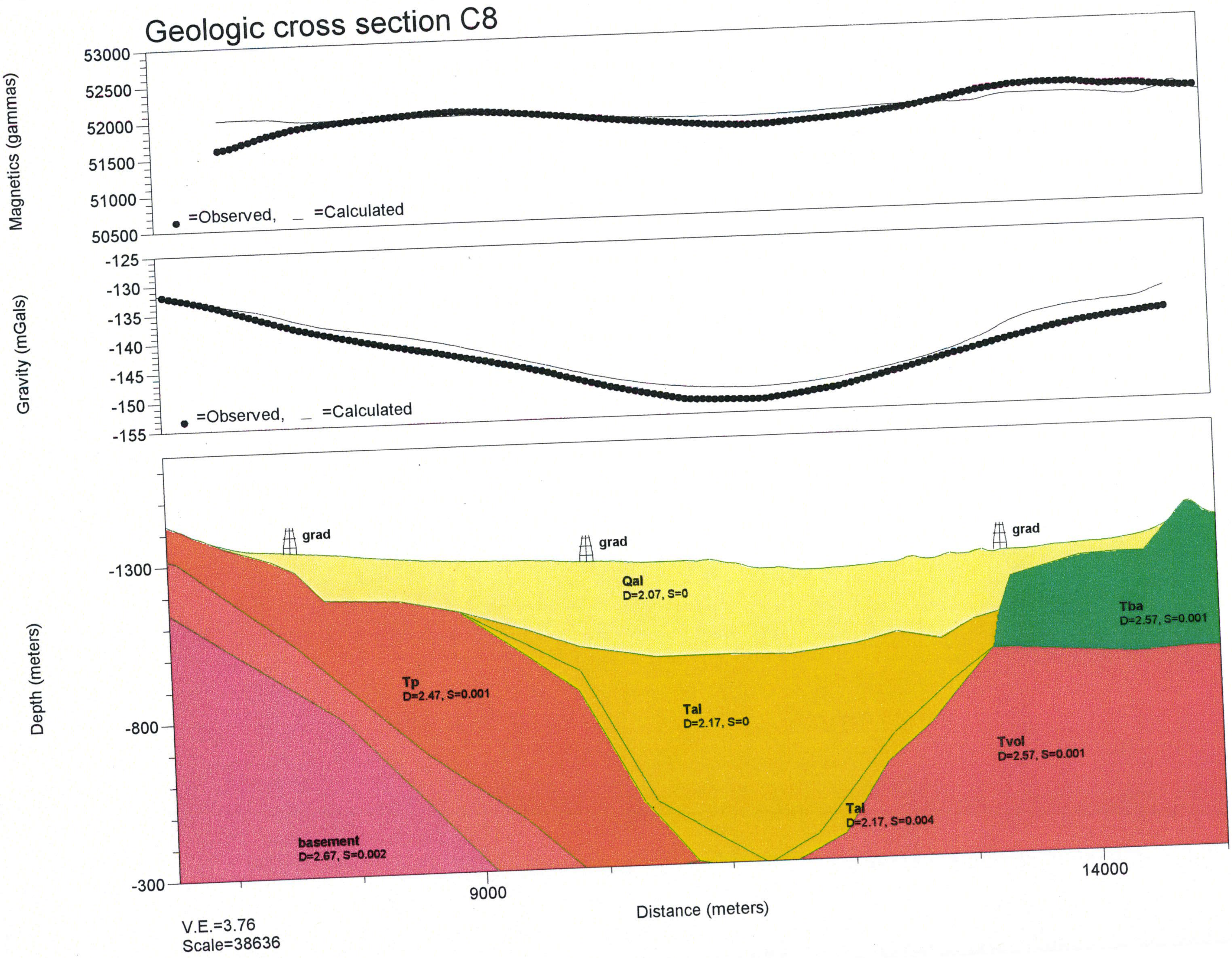
The appendix contains the potential fields modeling of nineteen geologic cross sections of Fernley/Wadsworth Basin oriented from west (left) to east (right). The first cross section is C11 and is the most northern. The cross sections continue southward to A2. See Figure 8 for the orientation of the cross sections.

Geologic cross section C11

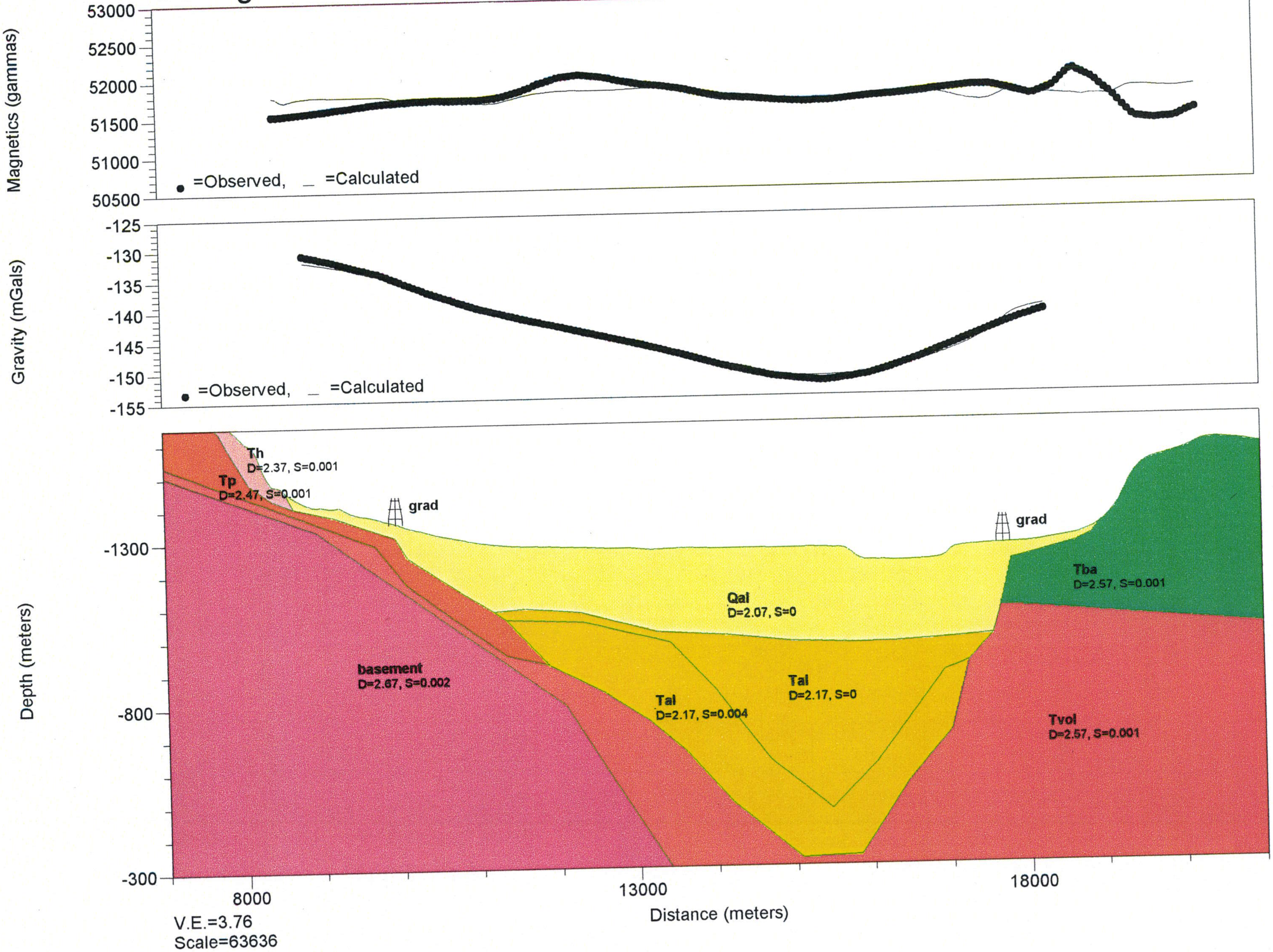


Geologic cross section C10

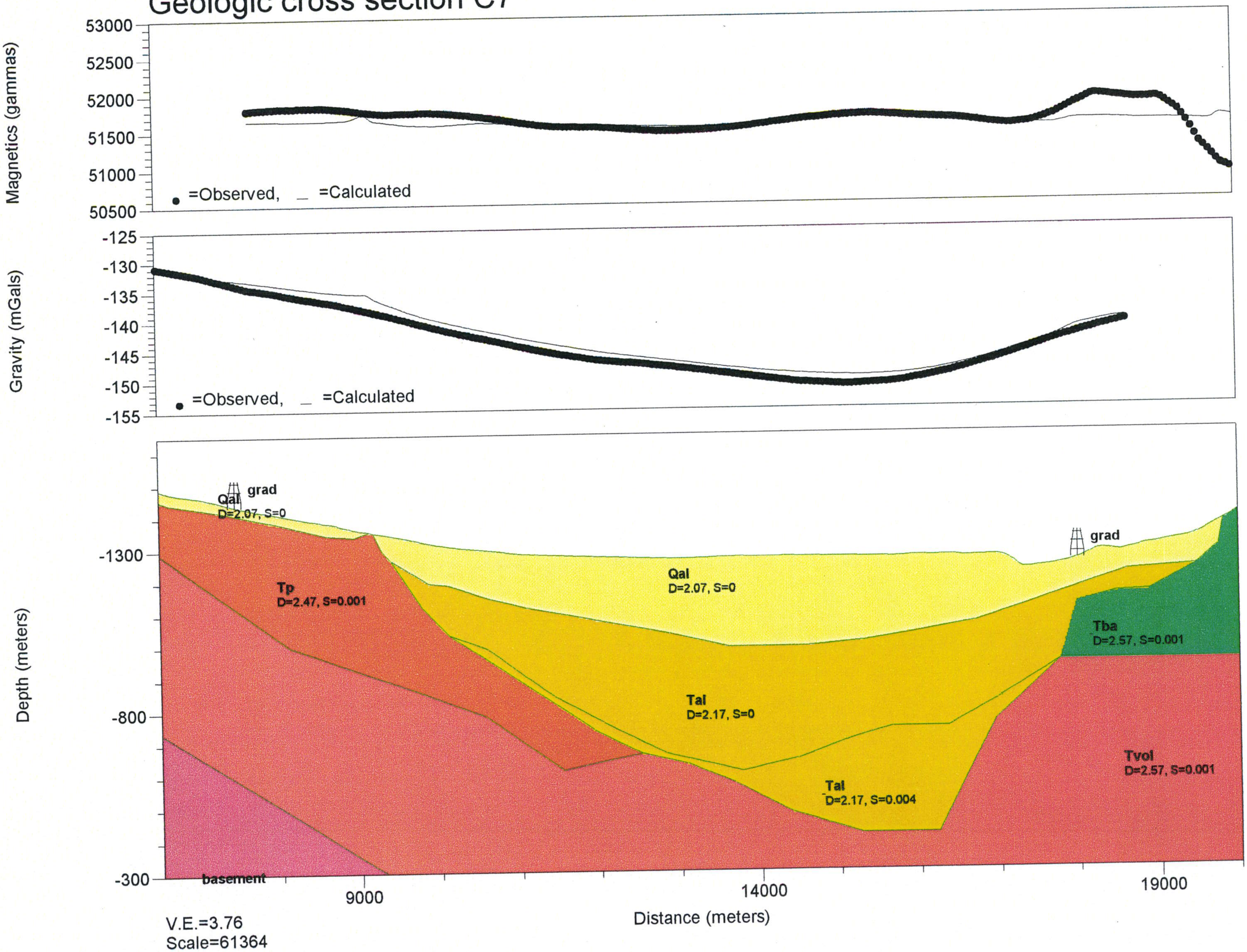



Geologic cross section C8
Magnetics (gammas)
53000
52500
52000
51500
51000
50500
● =Observed, _ =Calculated
Gravity (mGals)
-125
-130
-135
-140
-145
-150
-155
● =Observed, _ =Calculated
Depth (meters)
-1300
-800
-300
grad
grad
grad
Qal
D=2.07, S=0
Tba
D=2.57, S=0.001
Tp
D=2.47, S=0.001
Tal
D=2.17, S=0
Tvol
D=2.57, S=0.001
Tal
D=2.17, S=0.004
basement
D=2.67, S=0.002
9000
14000
Distance (meters)
V.E.=3.76
Scale=38636

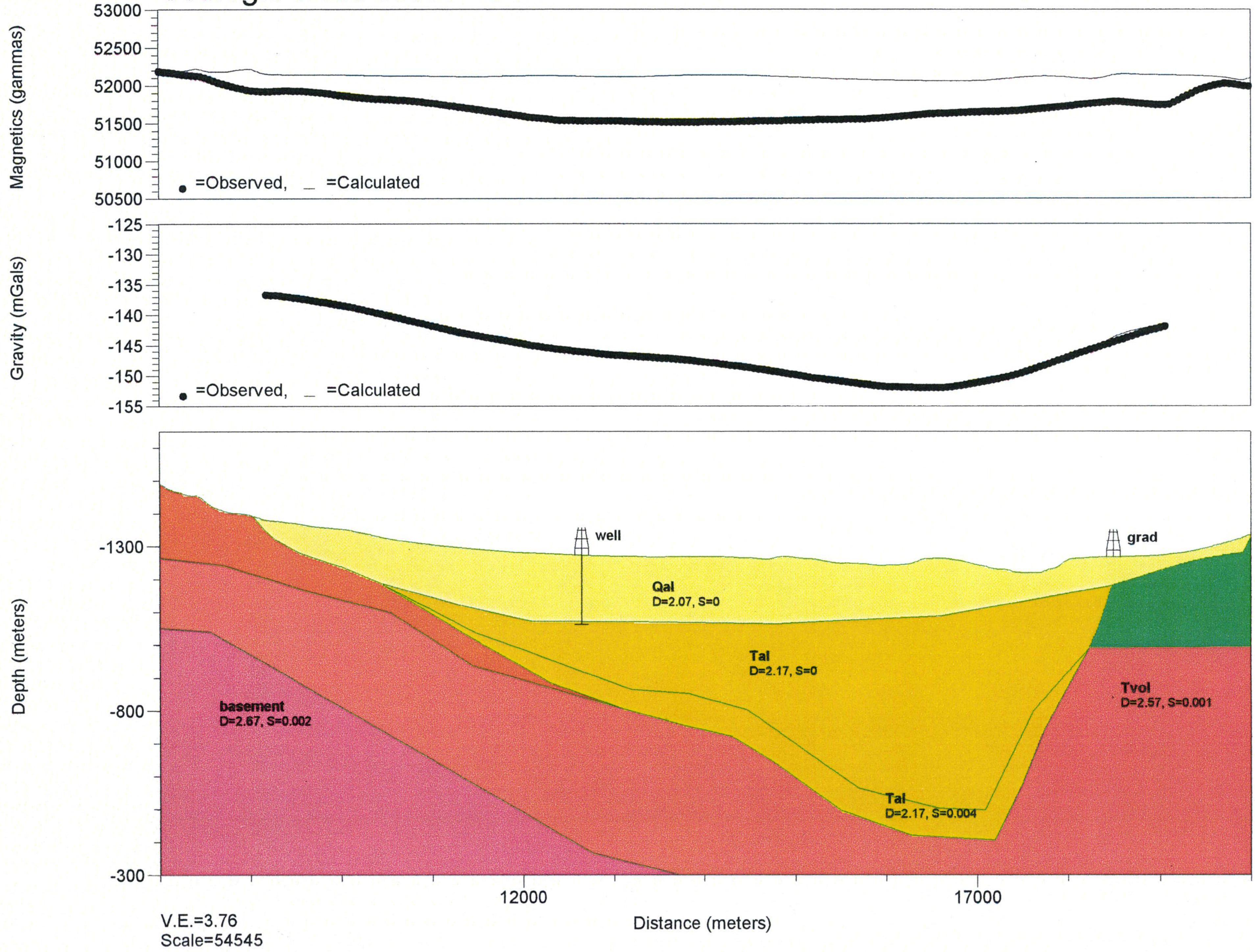
Geologic cross section C9



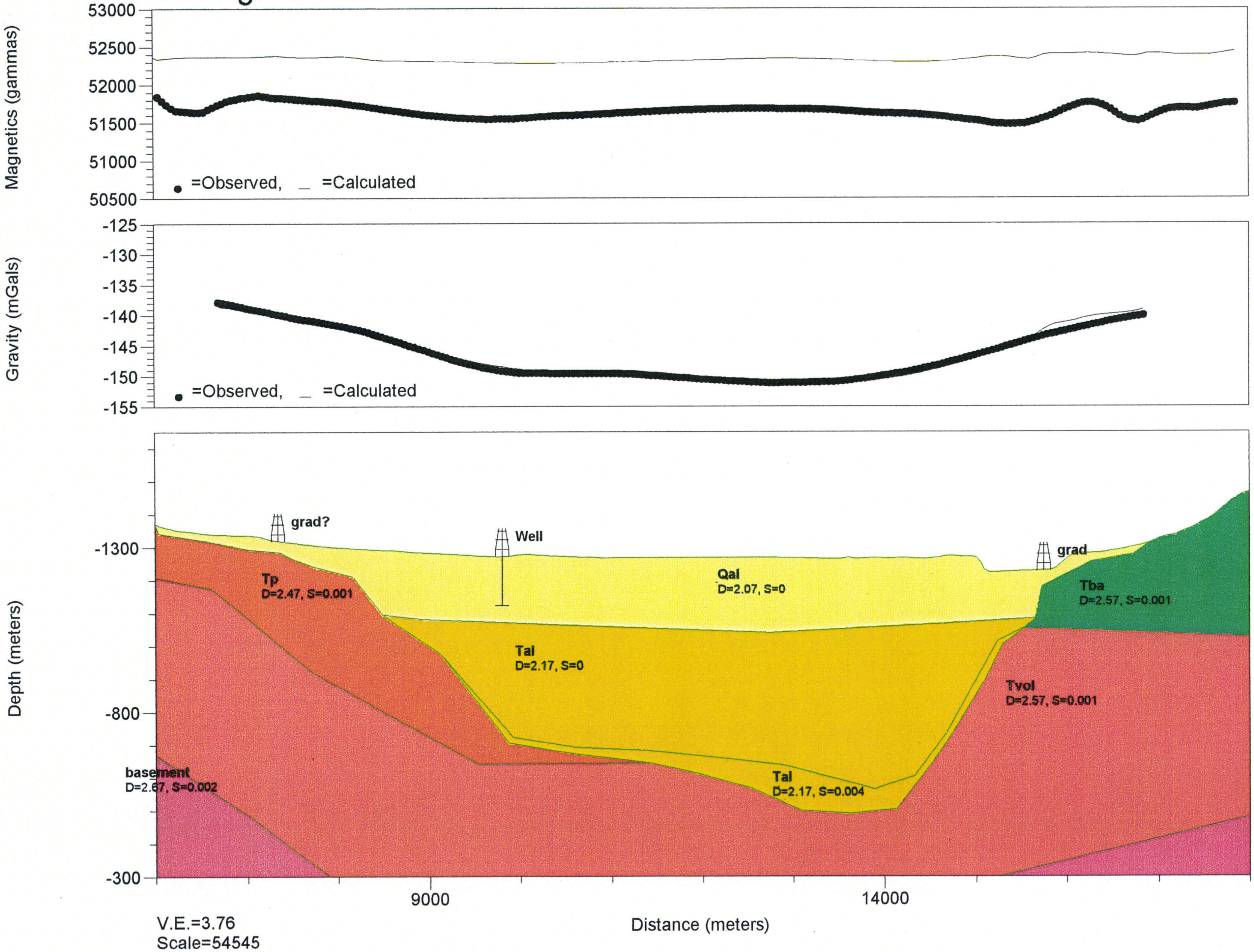
Geologic cross section C7



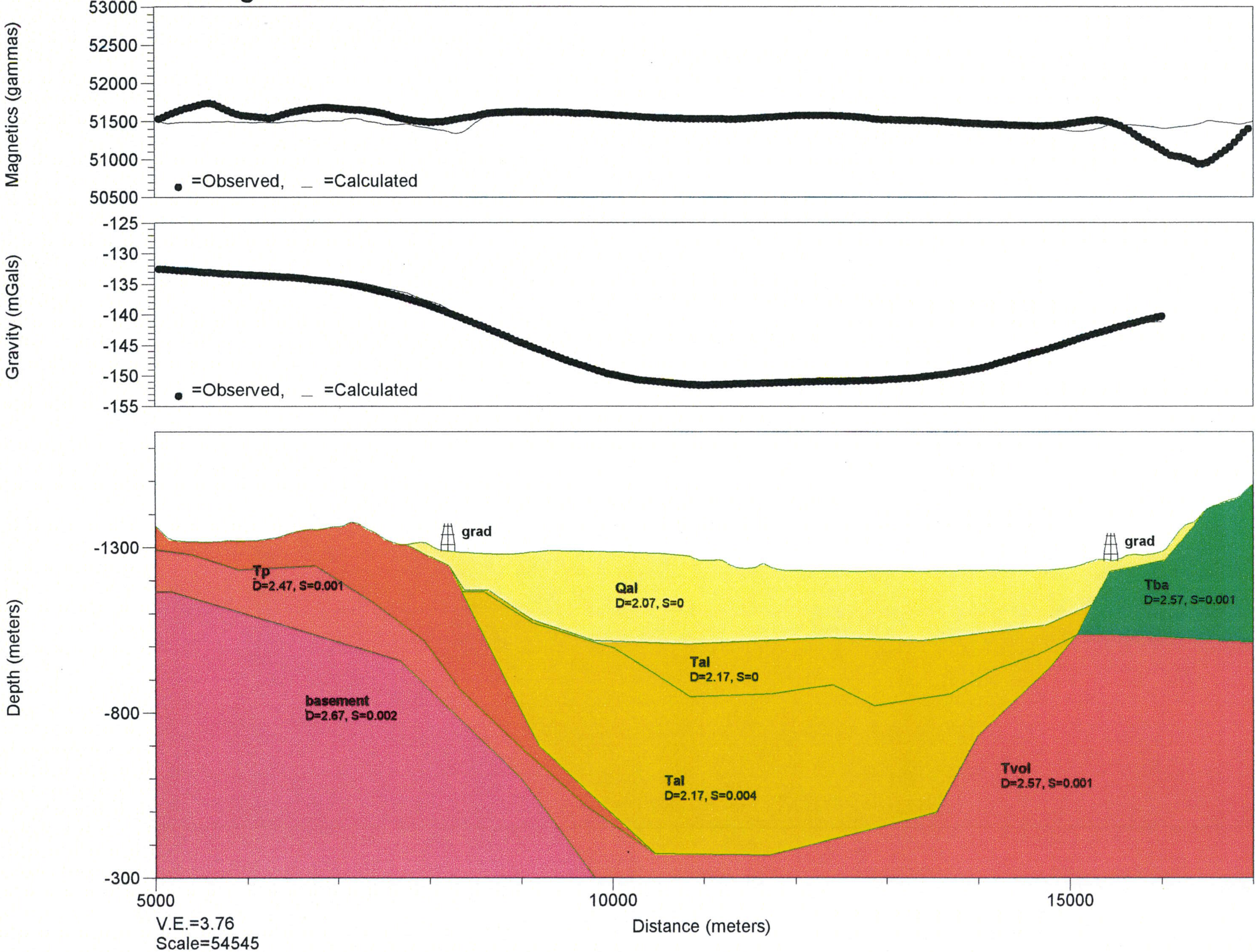
Geologic cross section C6



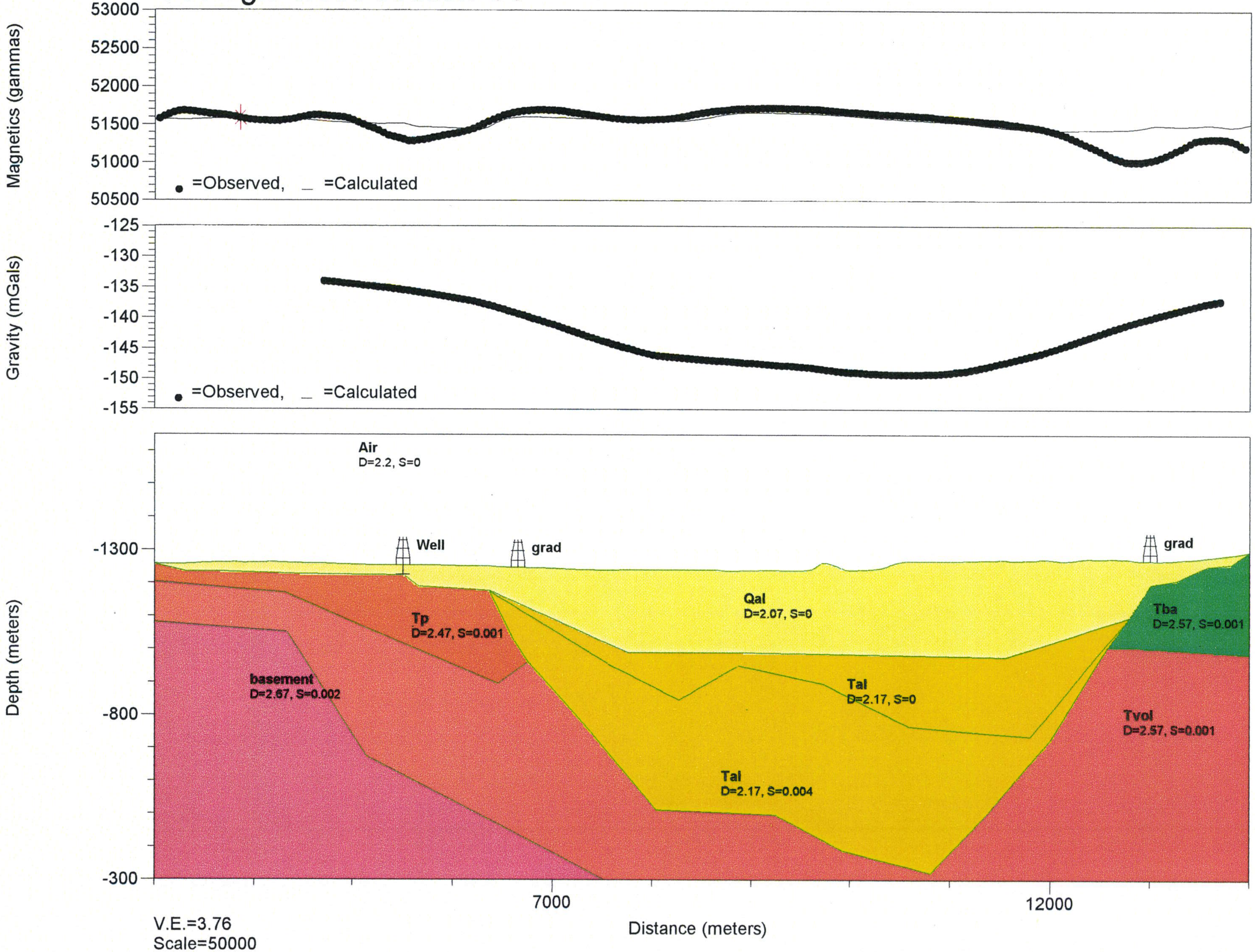
Geologic cross section C5



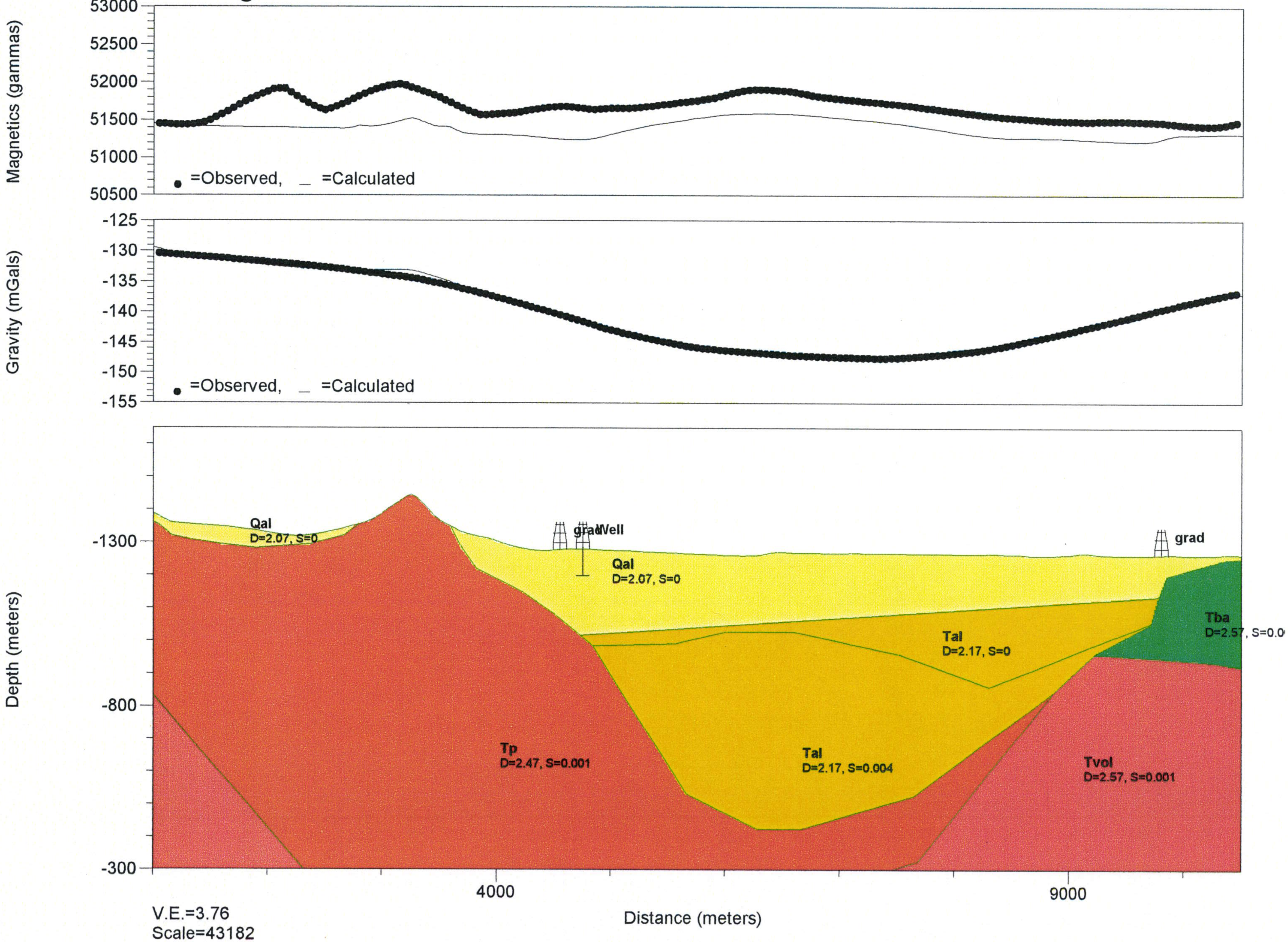
Geologic cross section C4



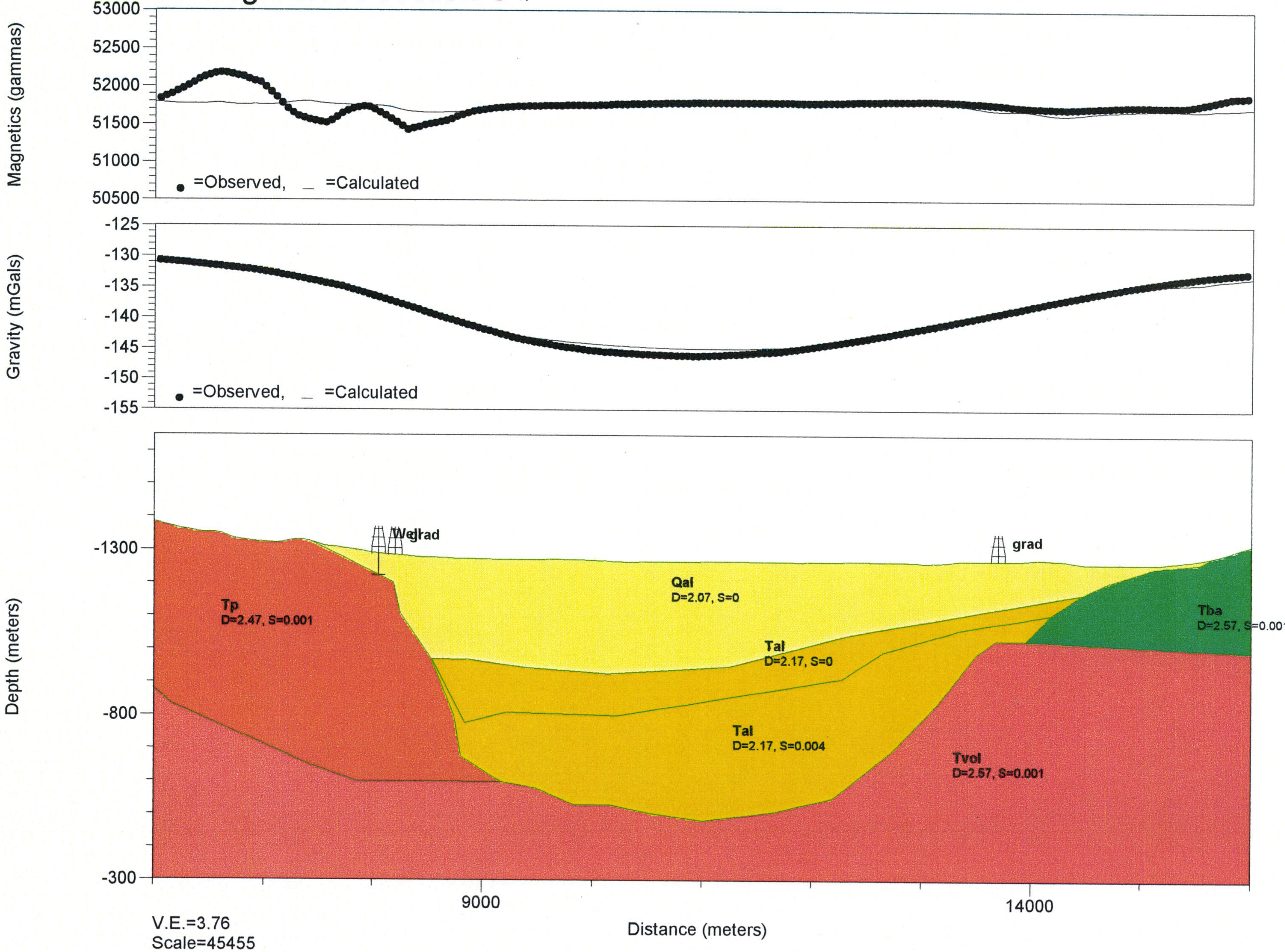
Geologic cross section C3



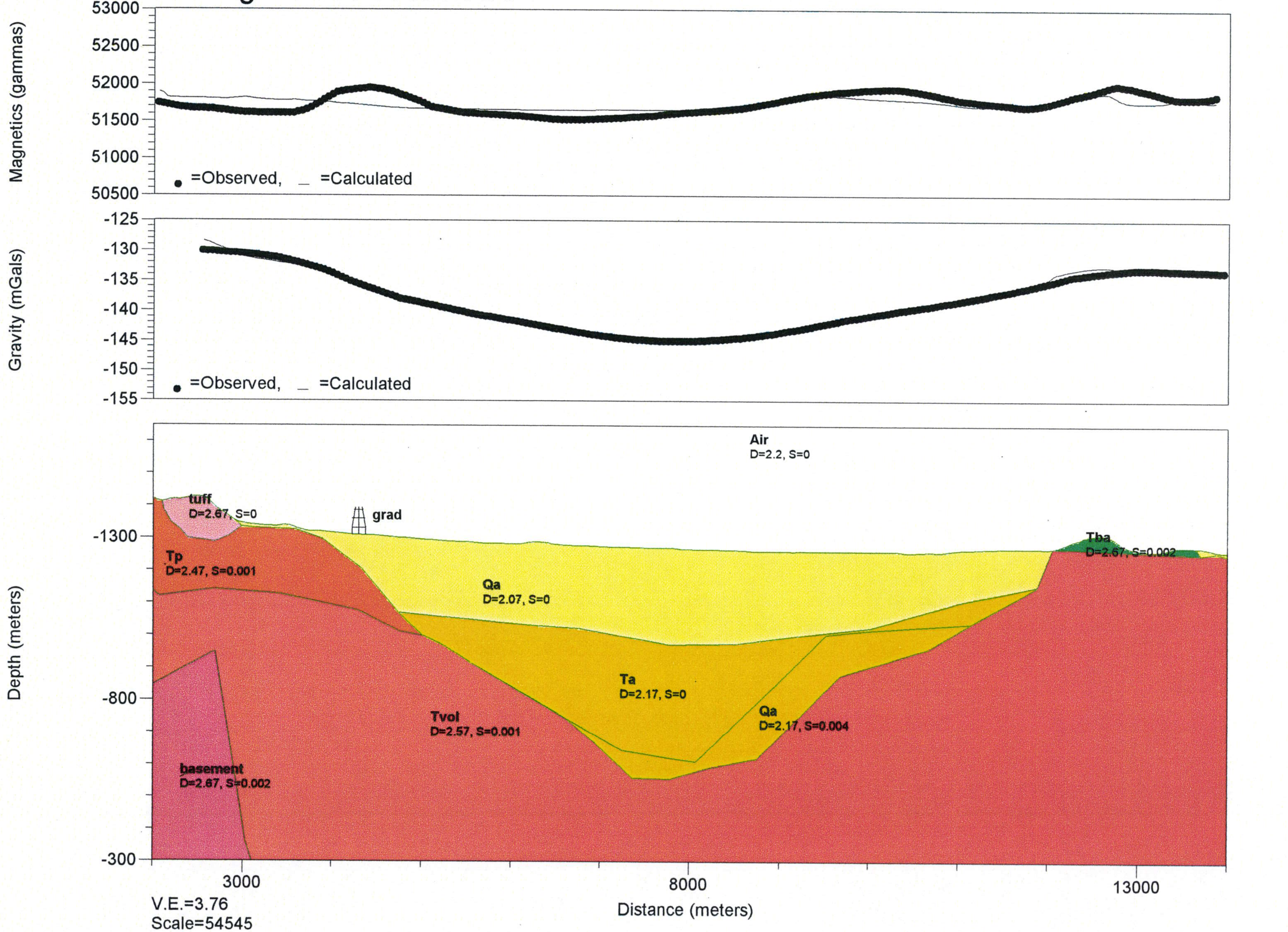
Geologic cross section C2



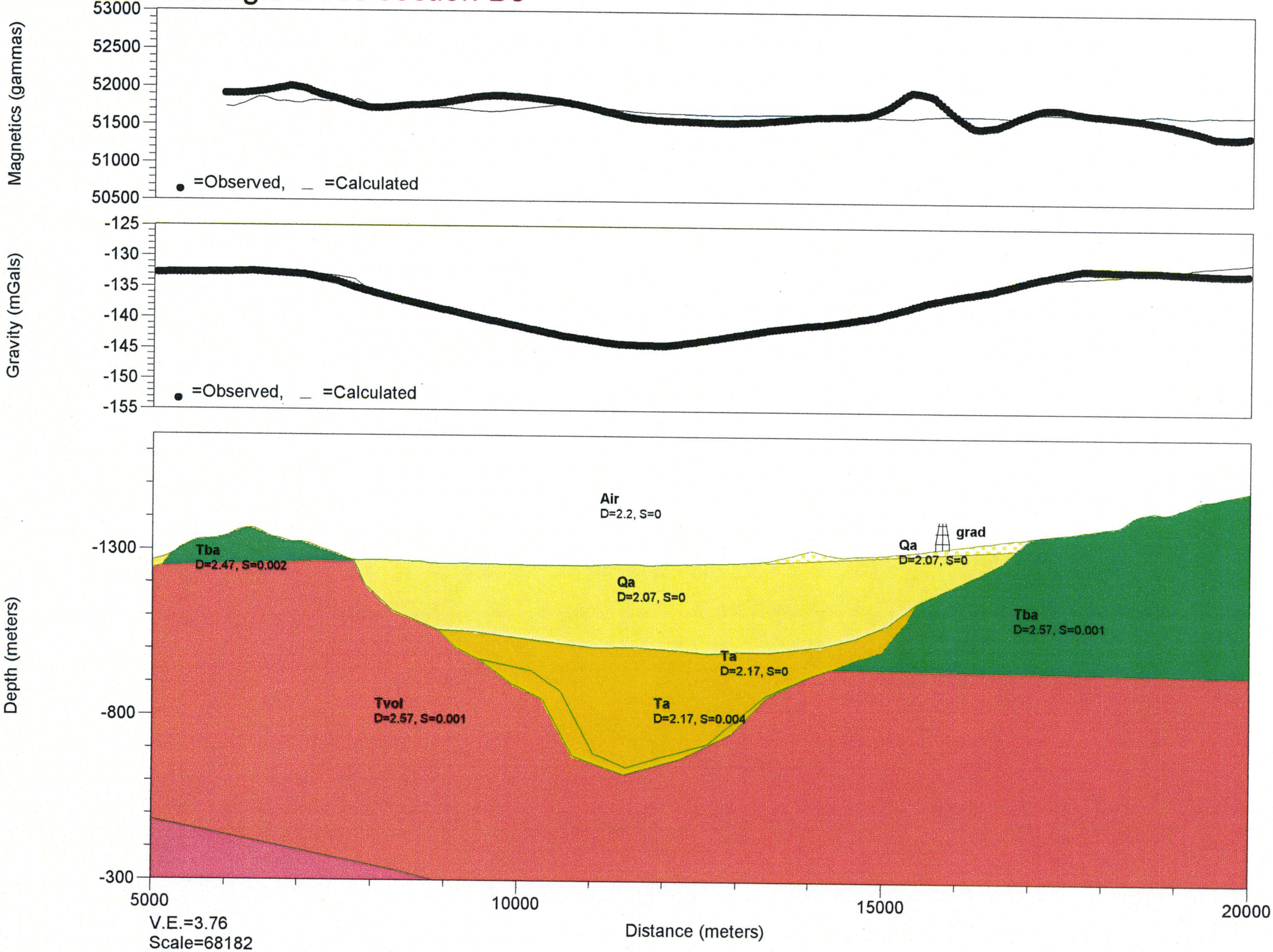
Geologic cross section C1



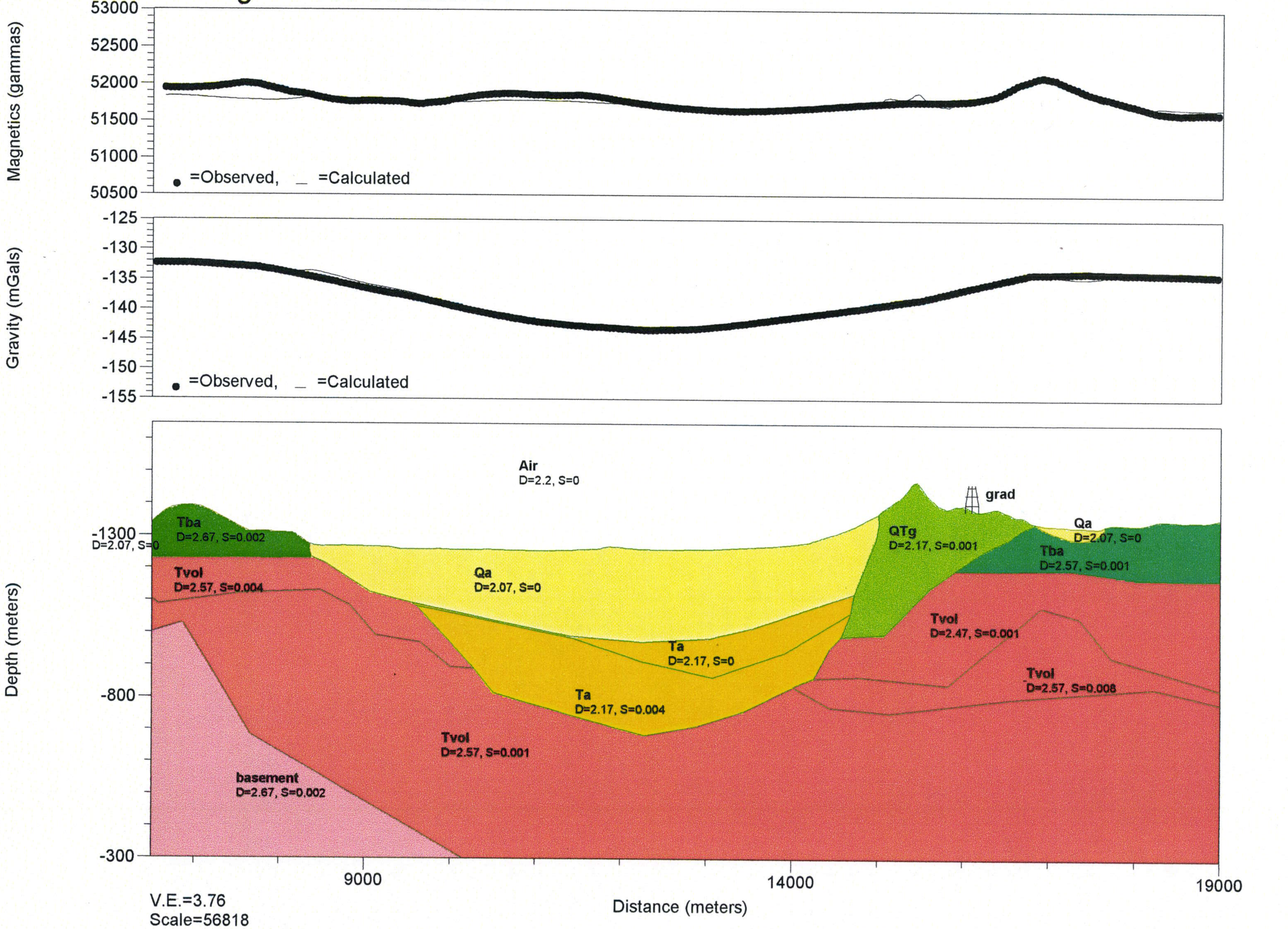
Geologic cross section B6



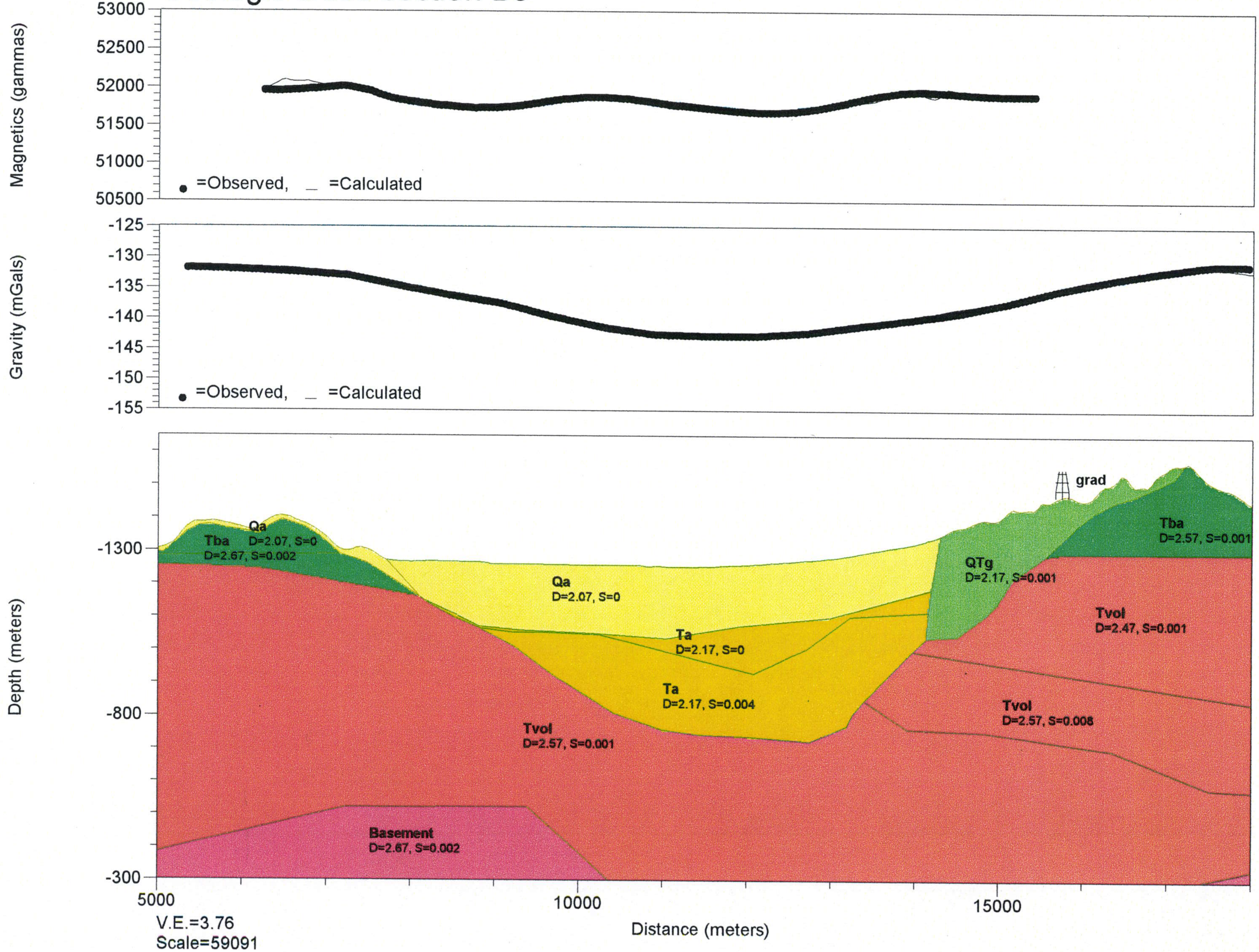
Geologic cross section B5



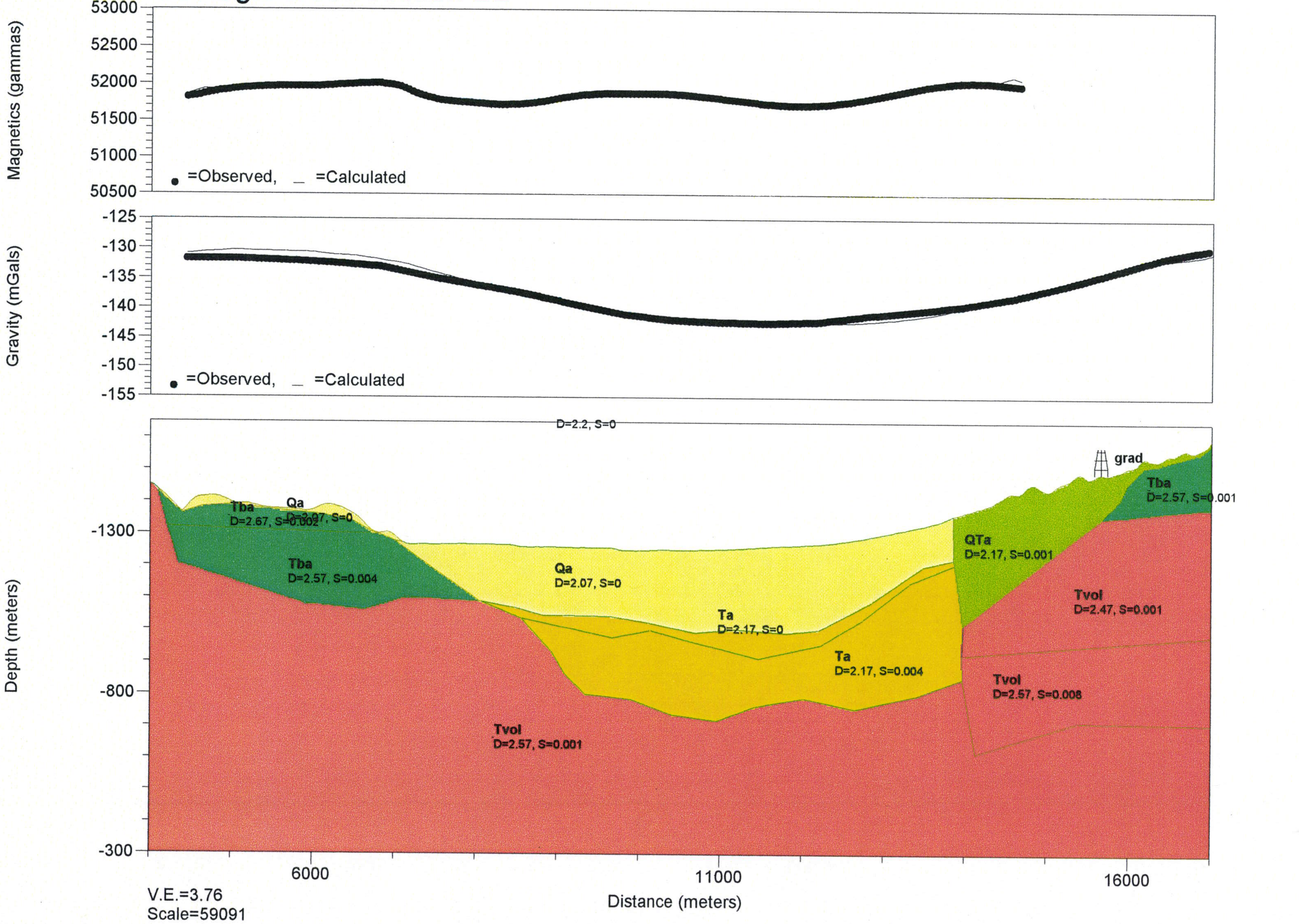
Geologic cross section B4



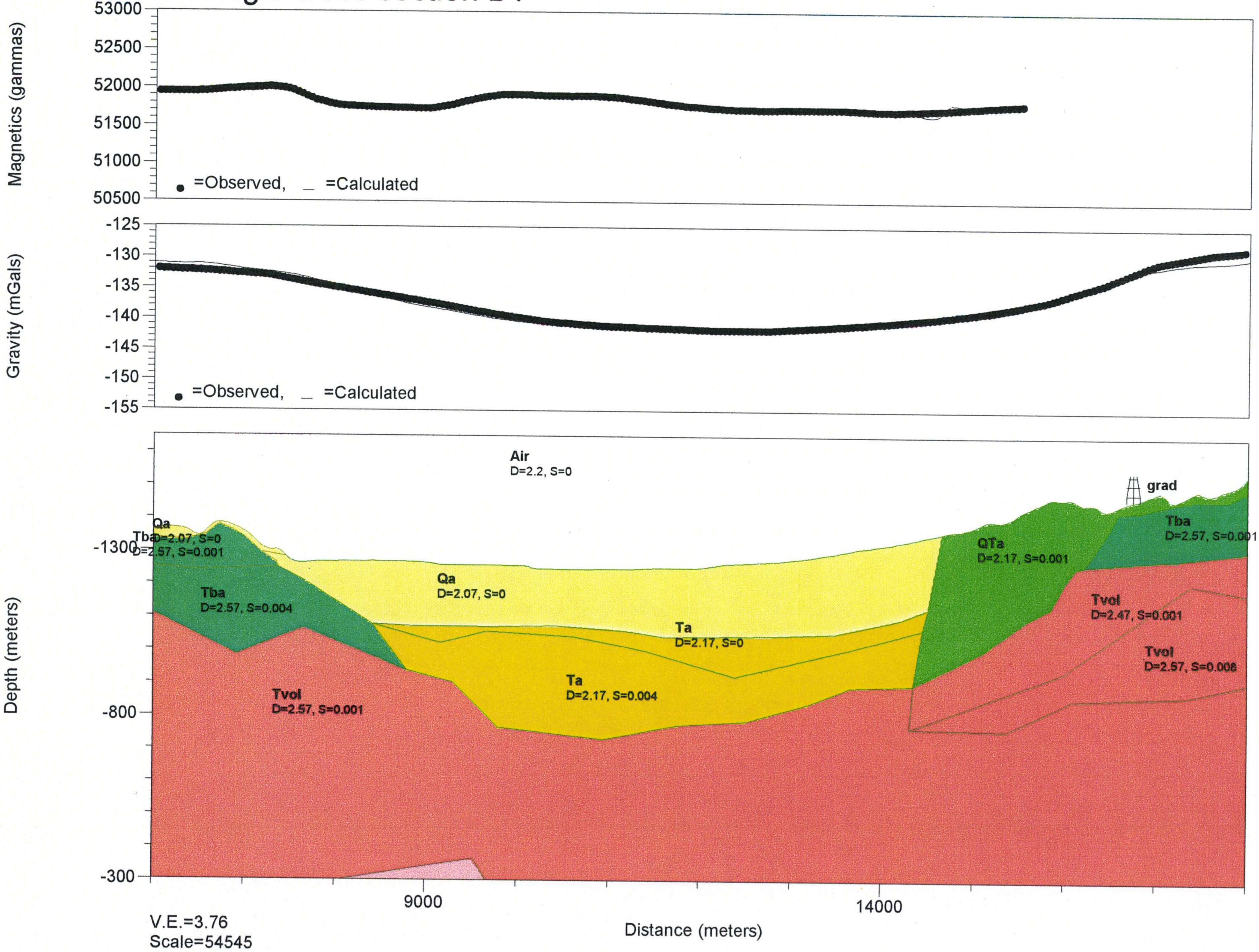
Geologic cross section B3

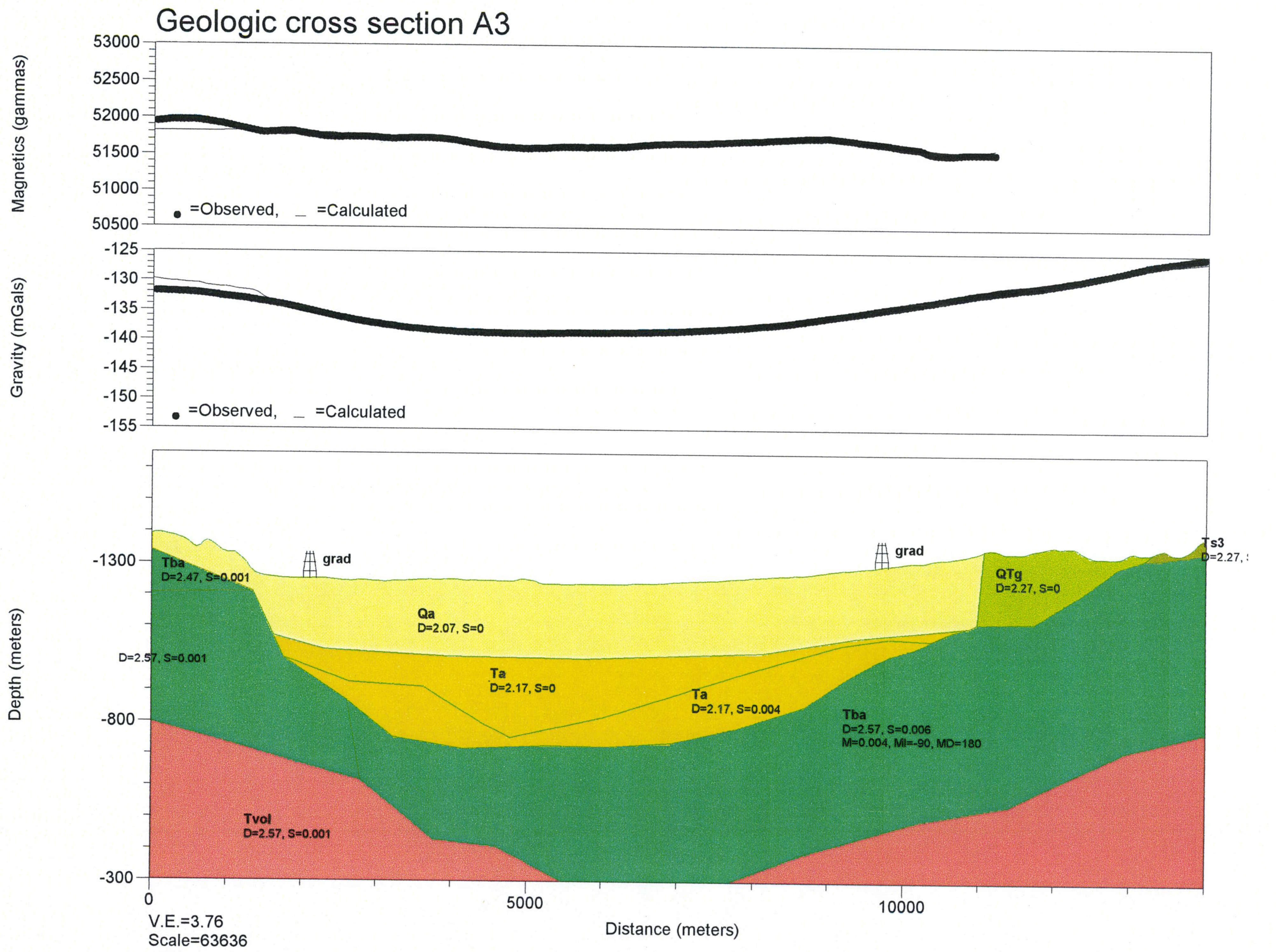


Geologic cross section B2



Geologic cross section B1





Geologic cross section A3
Magnetics (gammas)
53000
52500
52000
51500
51000
50500
=Observed,
=Calculated
Gravity (mGals)
-125
-130
-135
-140
-145
-150
-155
=Observed,
=Calculated
Depth (meters)
-1300
-800
-300
Tba
D=2.47, S=0.001
D=2.57, S=0.001
grad
grad
Qa
D=2.07, S=0
Ta
D=2.17, S=0
Ta
D=2.17, S=0.004
Tba
D=2.57, S=0.006
M=0.004, MI=-90, MD=180
QTg
D=2.27, S=0
Ts3
Tvol
D=2.57, S=0.001
0
5000
10000
V.E.=3.76
Scale=63636
Distance (meters)

Geologic cross section A2