SCIENTIFIC NOTEBOOK 687E

STRUCTURAL AND GEOPHYSICAL ANALYSIS OF THE DOE NYE COUNTY CROSS SECTIONS, YUCCA MOUNTAIN, NEVADA

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OVERVIEW

Title: **Structural and Geophysical Analysis of the DOE Nye County Cross Sections, Yucca Mountain, Nevada**

Personnel: John Stamatakos is the Principal Investigator of this project. Analyses discussed and described in this notebook were conducted by Paul Landis, Katherine Murphy, and Michele Gutenkunst. All entries in the scientific notebook were created by Paul Landis unless otherwise indicated within the text.

Katherine Murphy and Michele Gutenkunst aided in the analysis of gravity data through developing gravity derived cross sections and in aiding in the analysis of the DOE geophysical methods.

John Stamatakos provided valuable input on the use and application of the geophysical data. He also provided guidance during the structural restoration of the cross sections.

Project: This notebook document procedures, codes, data, and results used in support of conclusions reached for the review of DOE response to USFIC.5.05 and RT.2.09 AIN-1 (Ziegler, 2002) and Intermediate Milestone: ______________. This notebook documents independent staff analysis of geophysical data used in the construction of the Nye County cross sections (Spengler and Dickerson, 2003), as well as independent structural analysis and restoration.

Specific tasks include analysis of geophysical methods used in the construction of the Nye County cross sections, forward gravity modeling of available gravity data, and structural restoration of the Nye County cross sections.

Data: CNWRA data contained in this report meet quality assurance requirements described in the CNWRA Quality Assurance Manual. Data used to support conclusions in this report taken from documents published by the U.S. Department of Energy (DOE) contractors and supporting organizations were generated according to the quality assurance program developed by DOE for the Yucca Mountain Project.

Codes: Maps and related Geographic Information System (GIS) data were generated and plotted by ArcView GIS© Version 3.2a (ESRI, 2000) and ArcGIS Version 8.3 (ESRI, 2003), which are commercially available software codes. Geophysical evaluation of gravity data was conducted using Oasis Montaj v. 5.1.8 (GeoSoft, 2000) and GM-SYS v. 4.8.45b (NGA, 2003). Structural reconstruction of the cross sections was performed using LithoTect v.1.20 (GLS, 2003). ArcView 3.2a, ArcGIS 8.3, Oasis Montaj, GM-SYS and LithoTect are commercially available software codes that are maintained in accordance with CNWRA Technical Operating Procedure TOP-018. All other codes used in this report are standard versions of commonly used commercial codes including Microsoft Excel and Microsoft Notepad.

ENTRIES **PSL 12/16/04**

Entry 1. Gravity Data Manipulation

Objective: To create a gridded gravity map from preexisting gravity stations for the area immediately surrounding Yucca Mountain. The gravity map will then be used to extrapolate cross sections along three profiles.

Gravity data were extracted from a USGS depth-to-basement map (Blakely and Ponce, 2001) of the Death Valley groundwater model area. The data set is publically available and is provided as **nevada_grav_master_halo.txt** in this scientific notebook. The gravity data were spliced and subset in ArcGIS 8.3 for the area immediately surrounding Yucca Mountain. The following coordinates (UTM NAD 83 Zone 11N) define the subset gravity data: 4038000 (south) to 4096000 (north) and 507000 (west) to 578000 (east).

To forward model the gravity anomaly, we needed to identify the spatial location of the Nye County cross sections and input the gravity data in the correct format. We determined the spatial position of the Nye County cross sections from Ziegler (2002) and imported the coordinates into ArcGIS 8.3. There, the coordinate data were converted into shapefiles representing the surface position of the cross sections (**Nye_1.shp, Nye_2.shp** and **Nye_3.shp** in the scientific notebook). The complete Bouguer gravity anomaly and the position of the gravity stations were imported separately into Oasis Montaj as a space-delimited text file (**nye_grav.gdb**; Oasis Montaj database format) in the scientific notebook). The **nye_grav.gdb** database only contains data points that were subset in ArcGIS 8.3. Furthermore, the database contains data columns of Easting, Northing, Bouguer gravity anomaly, complete Bouguer gravity anomaly, and free-air gravity values.

The complete Bouguer anomaly was gridded using the minimum curvature algorithm in Oasis Montaj with a 1000 m grid space (**Bgrav_1km.grd** in the scientific notebook). **Bgrav_1km.map** (Figure 1) is a color shaded representation of **Bgrav_1km.grd**. The Nye County cross section shapefiles were imported into the gravity map. The cross sections are located in a transition zone between a relative gravity 'high' and a gravity 'low'.

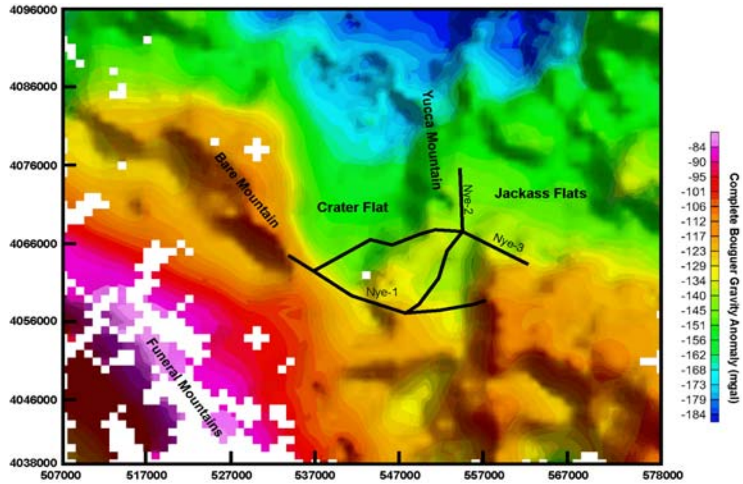

Figure 1. Map showing complete Bouguer gravity anomaly in the area of the Nye County cross sections.

Gravity-derived cross sections were generated by digitizing profiles in **Bgrav_1km.map** from the cross section shapefiles in Oasis Montaj. The Once a profile was digitized, it was directly imported into GM-SYS.

Entry 2: Forward Gravity Modeling **PSL 12/16/04**

Objective: To create simplified stratigraphic and structural cross sections from the gridded gravity data. Regional structural and stratigraphic trends will be identified and compared to the DOE Nye County cross sections.

Complete bouguer gravity anomalies consisting of fifty gravity stations were imported into GM-SYS for each cross section (Figure 2a-2c).

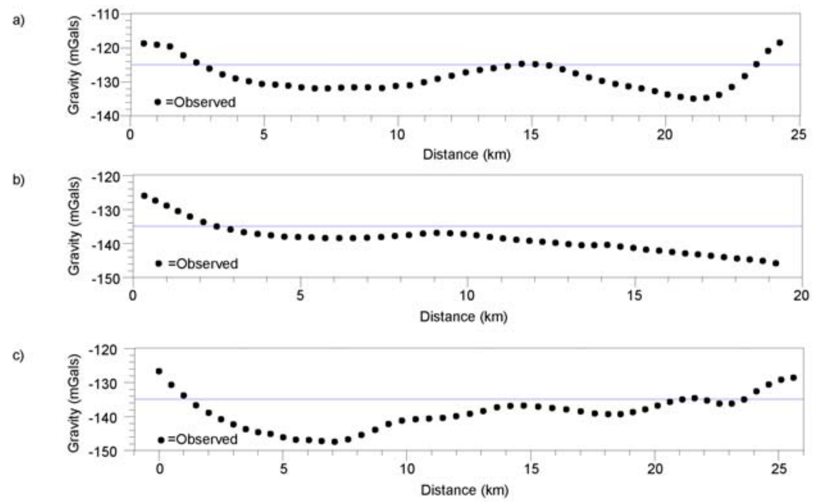

Figure 2. Complete Bouguer gravity anomalies for Nye-1 (a), Nye-2 (b), and Nye-3 (c).

The primary goal of forward gravity modeling is to create regional geologic cross sections that explain the observed gravity field. Fluctuations in the gravity anomalies (Figure 2A-2C) are the result of variations in subsurface stratigraphic geometries (ie. thickness changes and faulting). Density value were taken from gravity models in Crater Flat (Brocher et al., 1998). For simplicity, our gravity models consist of four broadly defined units: alluvium, Tertiary volcanic tuff units, basal Tertiary conglomerates, and Paleozoic basement (Table 1).

Table 1. Stratigraphic Units and Density Values for Gravity-Derived Cross Sections	
Stratigraphic Unit	**Density Value (g/cm^3)**
Alluvium	2.00
Volcanic Tuff Units	2.20
Basal Tertiary Conglomerates	2.30
Paleozoic Basement	2.72

Cross sections were constructed in GM-SYS by creating unit horizons with the parameters outlined in Table 1. GM-SYS calculates a root-mean square error value based on the difference between the observed gravity and the calculated gravity resulting from the modeled subsurface geometry. The goal of the process was to create subsurface geometries that minimize the error between the calculated and observed gravity and that are geologically realistic. This method is non-unique, and therefore can produce a mathematically infinite number of solutions.

Because the cross sections consist of 50 gravity stations that are spaced 300-500 m apart, identification of structures was limited to faults with greater than 100 m of vertical offset. In the Yucca Mountain region, block-bounding faults are defined as faults having greater than 100 m of displacement (Day et al., 1998). Examination of intra-block faulting was limited due to the regional nature of the project. Several assumptions were made concerning the cross sections prior to modeling. The first assumption is that the thickness of alluvium is less than 150 m except in Nye-2 and in Nye-1 and Nye-3 near the intersection of Fortymile Wash. Lithologic logs of Nye County Early Warning Drilling Program boreholes west of Fortymile Wash indicate that the thickness of the Quaternary alluvium is approximately 0-150 m thick (Spengler, 2001). Another major assumption is that the overall basin depth is between 1-4 km. Previous seismic, gravity, and magnetic studies confirm that overall basin depth is between 1-4 km (Langenheim, 1995; Brocher et al., 1998) in Crater Flat. With the assumptions in mind, figures 3A-3C are the resulting gravity-derived cross sections. The cross sections capture the overall basin morphology and configuration found in the DOE Nye County cross sections. However, the cross sections fail to reveal the numerous high-angle normal faults identified by the DOE, specifically in Nye-3. Many of these faults have greater than 100m of vertical offset and should produce a 1-3 mGal change in the observed gravity anomaly. The cross sections are provided in their original GM-SYS format named **nye1.50pts**, **nye2.50pts**, and **nye3.50pts** in the attached **'gravity'** directories.

Our gravity analysis reveals that simplified cross sections, with significantly fewer faults, can explain observed gravity anomalies. Because the gravity models are dependent on the unit gravity values, we identified the first-order controls influencing the overall shape of the anomaly and basin morphology. Density contrasts between the units, specifically between the basal Tertiary gravel unit and the Paleozoic basement, are a primary influence on the gravity anomaly. We determined that an increase in the gravity value of 0.1 g/cm^3 for the basal Tertiary units or a decrease of 0.1 g/cm^3 of the Paleozoic basement resulted in a 250 m increase in basin depth. Therefore, a 5% uncertainty in the density value of the units could greatly influence the subsurface stratigraphic interpretation.

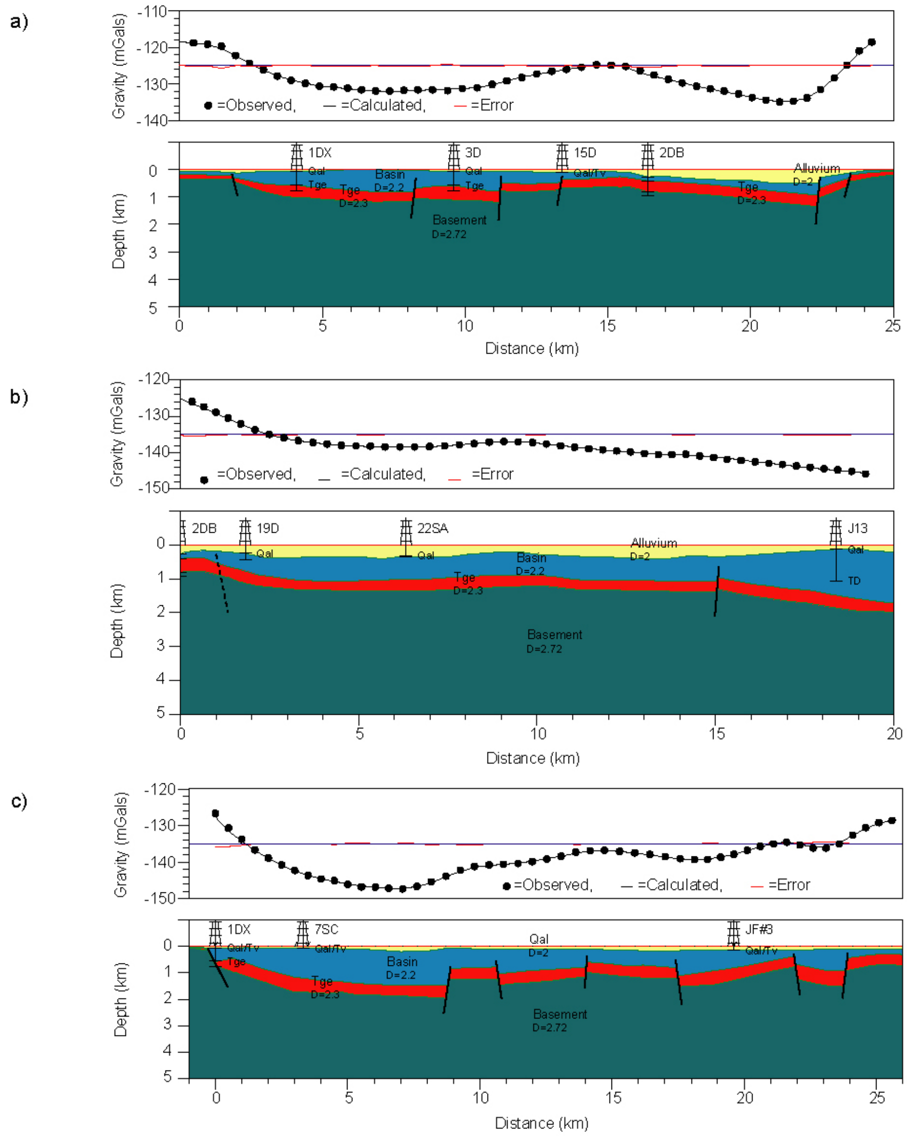

Figure 3. Gravity-derived cross sections for Nye-1 (a), Nye-2 (b) and Nye-3 (c). Note that the cross sections capture the overall basin morphology found in the original DOE Nye County cross sections. Only structural features with greater than 100m of vertical offset were identified.

Entry 3. Structural Reconstruction PSL 12/16/04

Objective: To structurally restore the Nye County cross section. Information pertaining to the timing of faulting and deformation and overall geologic validity of the cross sections will be discussed.

Accurately constructed cross sections yield information pertaining to the timing and history of tectonic deformation. Conversely, poorly constructed cross sections contain structural data that is inaccurate or unrealistic. Therefore, in order to assure structural and geologic validity, the Nye County cross sections were restored using LithoTect, version 1.2 (GLS, 2003). Furthermore, systematic structural reconstruction of the Nye County cross sections would yield information regarding the timing of faulting and the amount of regional extension.

The Nye County cross sections were imported into Lithotect as .jpg image files. The image of each cross section was registered to the original scale (1:25000) of the Nye County cross sections. Once the images were registered, the cross sections were digitized using the drafting and drawing tools. Care was given to ensure the geometry of the stratigraphic beds and faults were accurately preserved in the digitizing process. The cross sections were digitized at scales ranging from 1:600 to 1:2400.

The Nye County cross sections were restored using the vertical/oblique slip algorithm. Because the majority of faults dip between 75°-90°, the cross sections were restored using pure vertical (90°) slip. The complete restoration process is outlined below. The first ‘block’ restored for each section was the block (footwall or hanging wall) on the right side of the cross section. For the first block, the ‘deformed surface’ was the stratigraphic top of the original cross section, while the ‘restored surface’ was a horizontal line. For the next block (and every subsequent block) the parameters are different. The ‘deformed surface’ is the fault surface and the stratigraphic top of the next block, while the ‘restored surface’ is the horizontal line and the restored fault of the first block. This process was repeated until the basal Tertiary conglomerate was restored.

The Paleozoic units were not restored because there is insufficient stratigraphic data (borehole cuttings or sonic cores) to support the interpretation.

Figure 4A-4C are snapshots of the restoration process for each cross section, but do not document the entire restoration for each cross section. The entire LithoTect project file is located in the **‘structure’** directory of this electronic notebook and contains the entire restoration process as well as all auxiliary files.

Extension values (Table 2) measured during the restoration process produce similar values documented in other studies. Extension was calculated by the following formula:

$$e = ((l_f - l_o)/l_o)*100$$

where l_f is the final length and l_o is the original length. The absence of major block bounding faults resulted in extensional values similar to minimum extension values found in intra-basin settings in Crater Flat (Potter et al., 2004).

Table 2. Extensional values measured from the Nye County cross sections	
Cross Section	**Percent Extension**
Nye-1	7.8%
Nye-2	1.2%
Nye-3	5.8%

Successive restoration of stratigraphic units also revealed little to no growth along high-angle normal faults and major block bounding faults. Instead, most faults were active at constant rates after the deposition of the topmost volcanic tuff unit. Preliminary calculations and observations indicate that the majority of faults were active after the deposition of the Paintbrush Group (~12.7 MA) for an undeterminable amount of time. However, because the majority of faults do not displace the Quaternary alluvium in the DOE interpretation, faulting ceased prior to 2MA. Furthermore, the restoration revealed minor errors including abrupt changes in thickness of the basal Tertiary gravel unit and rotation along planar faults. However, the absence of major errors and structural inconsistencies indicates that the DOE cross sections are one of many possible stratigraphic and structural interpretations.

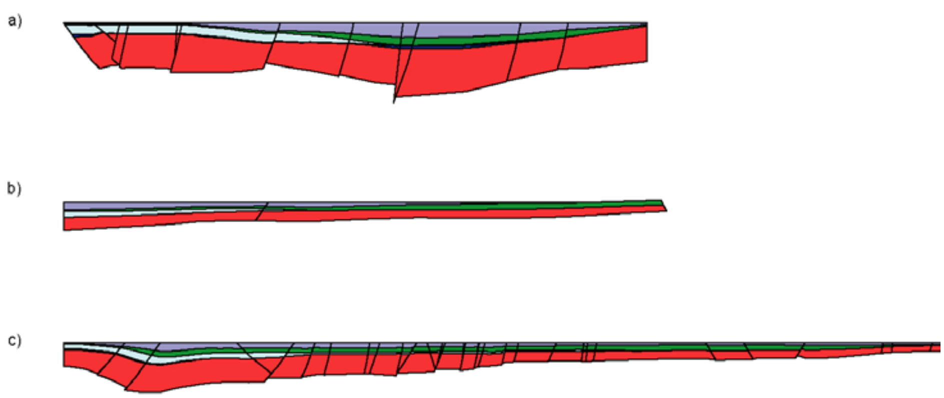

Figure 4. Restoration of the Nye County cross sections to unit Tcts. The restoration of Nye-1 (a) is west of the Highway-95 fault. Nye-2 (b) and Nye-3 (c) are restored entirely for this unit. The only identifiable problem with this restoration is the abrupt changes in the thickness of Tge in Nye-1 and Nye-3. Furthermore, there is little to no growth along faults indicating the faults were cut after the deposition of the topmost tuff unit.

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