Scientific Notebook 903E

Entry: Saurav Biswas
Date: August 15, 2007

Title: **Evaluation of Regional Scale Geologic Cross Section Interpretations by Modeling Aeromagnetic Anomalies in the Yucca Mountain Region**.

Personnel: John Stamatakos is the Principal Investigator for this project. Saurav Biswas is the lead investigator. All entries in this scientific notebook were made by Saurav Biswas unless otherwise indicated in this text.

Project: This notebook document procedures, data, and modeling results used in evaluating regional scale geologic cross-sections under **20.06002.01. 292 — SUPPORT PRELICENSING TRANSITION TO LICENSE APPLICATION REVIEW – General Information (Evaluation of Site Characterization)**. This text and supporting files are provided herein to meet the CNWRA requirements of QAP -001.

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 anomaly models were generated and plotted by the software Oasis montaj© Version 6.3.1 (6G) (Geosoft 2006), ~~GM-SYS© (Geosoft) 4.8.45b (Northwest Geophysical Assoc., 2001)~~ (S.B. March 7th, 2008) GM-SYS© (Geosoft) 4.8 (Northwest Geophysical Assoc., 2001) and GM-SYS© (Geosoft) 4.10 Copyright © NGA, Inc., which are commercially available software codes that are maintained in accordance with CNWRA Technical Operating Procedure TOP–018.

Background: The objective of the project is to evaluate the geologic interpretations of four regional cross-sections:

1) Geologic cross-section in Brocher etal., (1998), Figure 8 in Pg. 958.
2) Geologic Section Nye-1 (Ziegler, 2002; Spengler and Dickerson, 2002)
3) Geologic Section Nye-2 (Ziegler, 2002; Spengler and Dickerson, 2002)
4) Geologic Section Nye-3 (Ziegler, 2002; Spengler and Dickerson, 2002)

The simplified geology from these cross-sections would be used to create magnetic anomaly models. The model response would be compared with the observed aeromagnetic anomaly to evaluate the geologic interpretations in the cross-sections.

The total-field magnetic data for the current work was collected by the DOE using a helicopter-borne cesium-vapor magnetometer. The average elevation of the magnetic sensor was 30 m above ground. The primary flight lines were flown in an east-west direction, with a nominal flight-line spacing of 60 m. Secondary flight lines (tie lines) were flown in a north-south direction at a flight-line spacing of 600 m. The accuracy of magnetic data was ±0.01 nT. The measurement locations have horizontal accuracy of ±1 m and vertical accuracy of ±2 m. The total-field magnetic measurements were corrected for normal time variations in the earth's magnetic field with a base station magnetometer. Cogbill (2004) has summarized the aeromagnetic survey conducted to provide the data for this work.

Entry 1: The resulting anomaly map from the DOE survey is shown in Figure 1 with the location of the four cross sections used in this study: Line 2 and Line 3 from Brocher, et al., (1998) and the Nye-1, Nye-2, and Nye-3 sections from Ziegler (2002). The Oasis files are located in ***D:\01Projects\1.4_YMR_Regional_Mag\01YMR_Oasis_Regional_Mag***

References:

Geosoft, Inc. "Oasis MONTAJ™, Version 6.3.1 (6G)." Toronto, Ontario, Canada: Geosoft, Inc. 2006a.

———. "GM-SYS, Version 4.10.64." Toronto, Ontario, Canada: Geosoft, Inc. 2006b

Brocher, T.M., W.C. Hunter, and V.E. Langenheim. "Implications of Seismic Reflection and Potential Field Geophysical Data on the Structural Framework of the Yucca Mountain-Crater Flat Region, Nevada." *Geological Society of America Bulletin*. Vol. 110. pp. 947–971. 1998.

Ziegler, J.D. "Transmittal of Report Addressing Key Technical Issue (KTI) Agreement Items Unsaturated and Saturated Zone Flow Under Isothermal Conditions (USFIC) 5.05 and Radionuclide Transport (RT) 2.09." MOL.20020911.0119. Letter (July 28) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002. <www.nrc.gov/reading-rm/adams.html>

Spengler, R.W. and R.P. Dickerson. "Subsurface Geologic Interpretations along Cross Sections Nye–1, Nye–2, and Nye–3, Southern Nye County, Nevada." DTN:GS031108314211.005. U.S. Geological Survey. 2002.

Cogbill, A.H. "Aeromagnetic Survey Data Acquired near Yucca Mountain During 2004." Los Alamos National Laboratory, 2004.

Entry: Saurav Biswas
Date: August 15, 2007

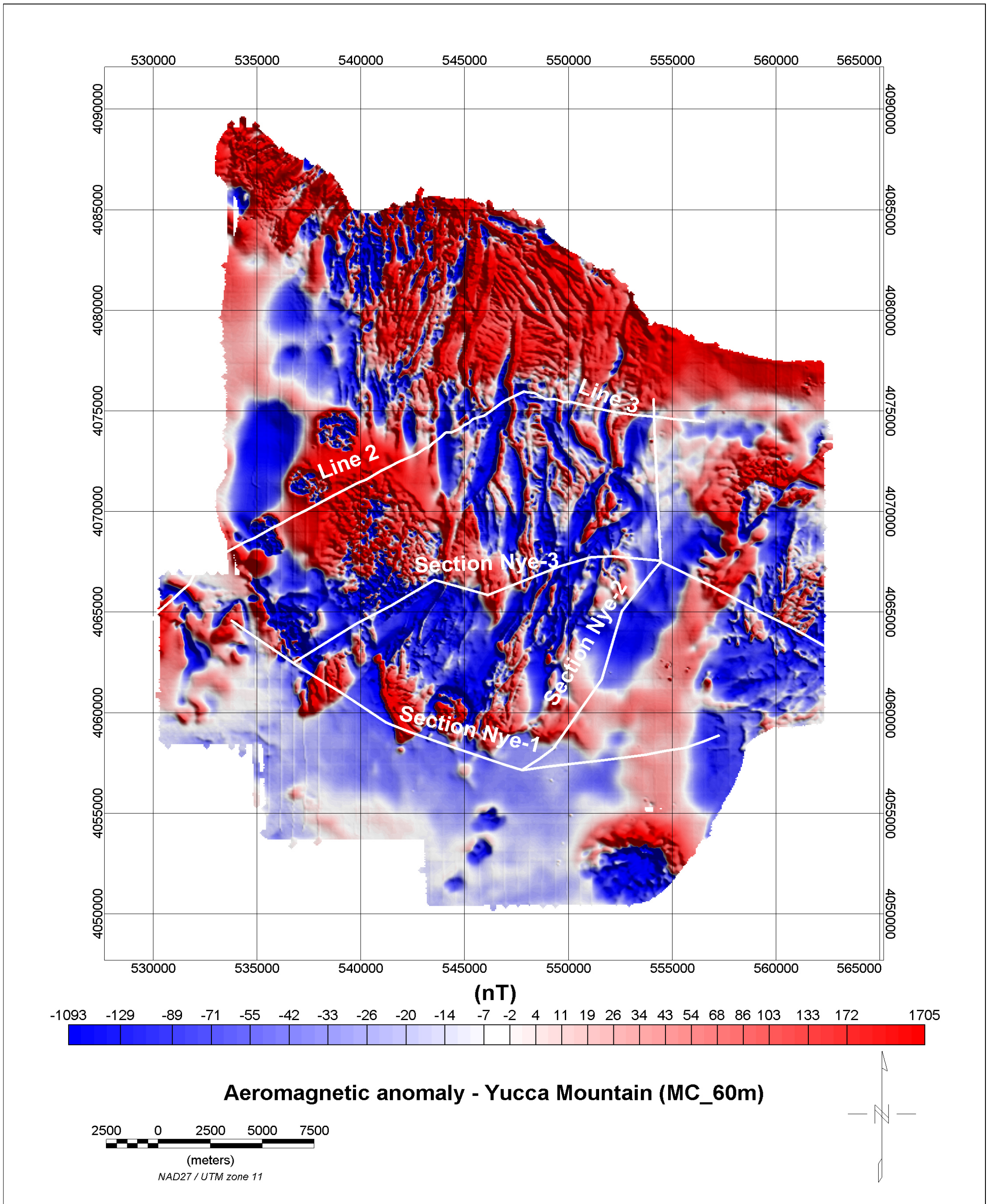


Figure 1. Total Field Aeromagnetic Anomaly Map Around Yucca Mountain , Nevada, Compiled at Approximately 30 m [98.42 ft] Above Ground Surface. The White Lines Show the Cross Section Locations.

Entry 2: For the interpreted geologic cross section along Line 2 and 3 in Brocher, et al. (1998), the locations of lines were digitized from Brocher, et al. (1998, Figure 1B), and the aeromagnetic anomaly data were extracted along the lines as input in GM-SYS. The corresponding layers in the cross section were created based on the interpreted geologic stratigraphy in Brocher, et al. (1998, Figure 8, bottom). The remanent magnetic properties of the lithologic units used in creating this magnetic anomaly model are listed in Table 1. The orientation of the Earth's magnetic field in this model is: magnitude = 39.8 A/m (50,000 nT), inclination = 60°, and declination = 14°.

Table 1. Source Parameters for Magnetic Anomaly Model*

Era/Epoch	Unit	Declination (°)	Inclination (°)	Magnetization (A/m)
Quaternary	Alluvium and colluvium (Qac)	0	0	0
Pliocene	Basalt (Tba)	178	−64	10
Miocene	Basalt (Tbb)	180	−55	10
	Ammonia Tanks Tuff (Tma)	0	59	0.58
	Rainier Mesa Tuff (Tmr)	168	−55	0.8–2.7
	Tiva Canyon Tuff (Tpc)	169	−23	0.94
	Topopah Spring Tuff (Tpt)	322	52	1.3
	Calico Hills Formation (Tht)	6	56	0.11
	Prow Pass Tuff (Tcp)	−4	50	0.26
	Bullfrog Tuff (Tcb)	12	41	1.7
	Tram Tuff (Tct)	131	−30	1.2
	Lithic Ridge Tuff (Tlr)	251	62	0.22
	Older Tuff (Tot)	50	60	0.3
	Older Tertiary tuffs and sedimentary rocks	0	0	0
Paleozoic	Magnetic Eleana Formation A†	14	62	4
	Magnetic Eleana Formation B†	0	0	4
	Paleozoic rocks (Pz)	0	0	0

*Based on Brocher, T.M., W.C. Hunter, and V.E. Langenheim. "Implications of Seismic Reflection and Potential Field Geophysical Data on the Structural Framework of the Yucca Mountain-Crater Flat Region, Nevada." *Geological Society of America Bulletin*. Vol. 110. pp. 947–971. 1998.
†Langenheim, V.E. and D.A. Ponce. "Ground Magnetic Studies of a Regional Seismic-Reflection Profile Across Bare Mountain, Crater Flat, and Yucca Mountain, Nevada. U.S. Geological Survey Open-File Report 95-834. 1995.

Scientific Notebook 903E

Entry: Saurav Biswas
Date: September 13, 2007

Similarly, for the interpreted geologic cross sections along sections Nye-1, 2, and 3 in Ziegler (2002), the locations of lines were digitized, based on Ziegler (2002, Figure 1), and the aeromagnetic anomaly data were extracted along the sections as input in GM-SYS. The corresponding layers in the cross sections were created based on the interpreted geologic stratigraphy in Spengler and Dickerson (2002).

To simplify and conserve the number of surface segments created in the GM-SYS model, two or more lithologic units with similar descriptions and magnetic properties were combined into one unit (e.g., Tpt = Tertiary Topopah Spring Tuff, Tpbt1 = Tertiary pre-Topopah bedded tuff, and Tpts = Tertiary pre-Topopah sedimentary rocks), designated as Tpt (see Table 2 for details). The remanent magnetic properties of the lithologic units used in creating the magnetic anomaly models for sections Nye-1, 2, and 3 are also listed in Table 1. The orientation of the Earth's magnetic field in these models is: magnitude = 39.8 A/m (50,000 nT), inclination = 60°, and declination = 14°.

Entry: Saurav Biswas
Date: September 13, 2007

Table 2. Simplified Geologic Stratigraphy for Cross Sections Nye-1, 2, and 3

Stratigraphic Units*	Stratigraphic Units, This Study
Quaternary alluvium (Qal)	Alluvium and colluvium (Qac)
Tertiary/Quaternary seds, undiff. (Qtu)	
Younger Tertiary basalt (Tby)	Basalt (Tba)/Basalt (Tbb)
Tertiary alluvium (Tal)	Not identified
Tertiary volcanic breccia (Tab)	Not identified
Tertiary rock-avalanche breccia (Trx)	Not identified
Tertiary Ammonia Tanks Tuff (Tma)	Tertiary Ammonia Tanks Tuff (Tma)
Tertiary Rainier Mesa Tuff (Tmr)	Tertiary Rainier Mesa Tuff (Tmr)
Tertiary Tiva Canyon Tuff (Tpc)	Tertiary Tiva Canyon Tuff (Tpc)
Tertiary pre-Tiva Canyon bedded tuff (Tpbt4)	
Tertiary Topopah Spring Tuff (Tpt)	Tertiary Topopah Spring Tuff (Tpt)
Tertiary pre-Topopah Spring bedded Tuff (Tpbt1)	
Tertiary pre-Topopah sedimentary rocks (Tpts)	
Tertiary Calico Hills Formation (Tac)	Tertiary Calico Hills Formation (Tht)
Tertiary Wahmonie Formation (Tw)	Not identified
Tertiary Prow Pass Tuff (Tcp)	Tertiary Prow Pass Tuff (Tcp)
Tertiary pre-Prow Pass bedded tuff (Tcpbt)	
Tertiary Bullfrog Tuff (Tcb)	Tertiary Bullfrog Tuff (Tcb)
Tertiary pre-Bullfrog bedded tuff (Tcbbt)	
Tertiary pre-Bullfrog sedimentary rocks (Tcbss)	
Tertiary Tram Tuff (Tct)	Tertiary Tram Tuff (Tct)
Tertiary pre-Tram bedded tuff (Tctbt)	
Tertiary pre-Tram sedimentary rocks (Tcts)	
Tertiary Lithic Ridge Tuff (Tlr)	Lithic Ridge Tuff (Tlr)
Tertiary pre-Lithic Ridge sedimentary rocks (Tlrs)	
Tertiary pre-Lithic Ridge bedded tuff (Trlbt)	
Tertiary Rhyolite of Picture Rock (Trr)	Not identified
Pre-volcanic sedimentary rocks (Tge)	Older Tertiary tuffs and sedimentary rocks
Devonian sedimentary rocks (undifferentiated) (Du)	Paleozoic rocks, undifferentiated (Pz)
Silurian sedimentary rocks (undifferentiated) (Su)	
Ordovician sedimentary rocks (undifferentiated) (Ou)	
Cambrian Nopah Formation (Ꞓn)	
Cambrian Carrara Formation (Ꞓb)	
Cambrian Zabriskie Quartzite (Ꞓc)	

*Spengler, R.W. and R.P. Dickerson. “Subsurface Geologic Interpretations along Cross Sections Nye–1, Nye–2, and Nye–3, Southern Nye County, Nevada.” DTN:GS031108314211.005. U.S. Geological Survey. 2002.

Scientific Notebook 903E

Entry: Saurav Biswas
Date: September 13, 2007

The results of the two-dimensional forward models of the interpreted geologic cross sections in Brocher, et al. (1998) and in sections Nye-1, 2, and 3 (Spengler and Dickerson, 2002) are shown in Figures 2–5. The GM-SYS models are located in ***D:\01Projects\1.4_YMR_Regional_Mag\01YMR_Oasis_Regional_Mag\GM-SYS_Models***

References:
Brocher, T.M., W.C. Hunter, and V.E. Langenheim. "Implications of Seismic Reflection and Potential Field Geophysical Data on the Structural Framework of the Yucca Mountain-Crater Flat Region, Nevada." *Geological Society of America Bulletin*. Vol. 110. pp. 947–971. 1998.

Langenheim, V.E. and D.A. Ponce. "Ground Magnetic Studies of a Regional Seismic-Reflection Profile Across Bare Mountain, Crater Flat, and Yucca Mountain, Nevada. U.S. Geological Survey Open-File Report 95-834. 1995.

Ziegler, J.D. "Transmittal of Report Addressing Key Technical Issue (KTI) Agreement Items Unsaturated and Saturated Zone Flow Under Isothermal Conditions (USFIC) 5.05 and Radionuclide Transport (RT) 2.09." MOL.20020911.0119. Letter (July 28) to J.R. Schlueter, NRC. Las Vegas, Nevada: DOE. 2002. <www.nrc.gov/reading-rm/adams.html>

Spengler, R.W. and R.P. Dickerson. "Subsurface Geologic Interpretations along Cross Sections Nye–1, Nye–2, and Nye–3, Southern Nye County, Nevada." DTN:GS031108314211.005. U.S. Geological Survey. 2002.

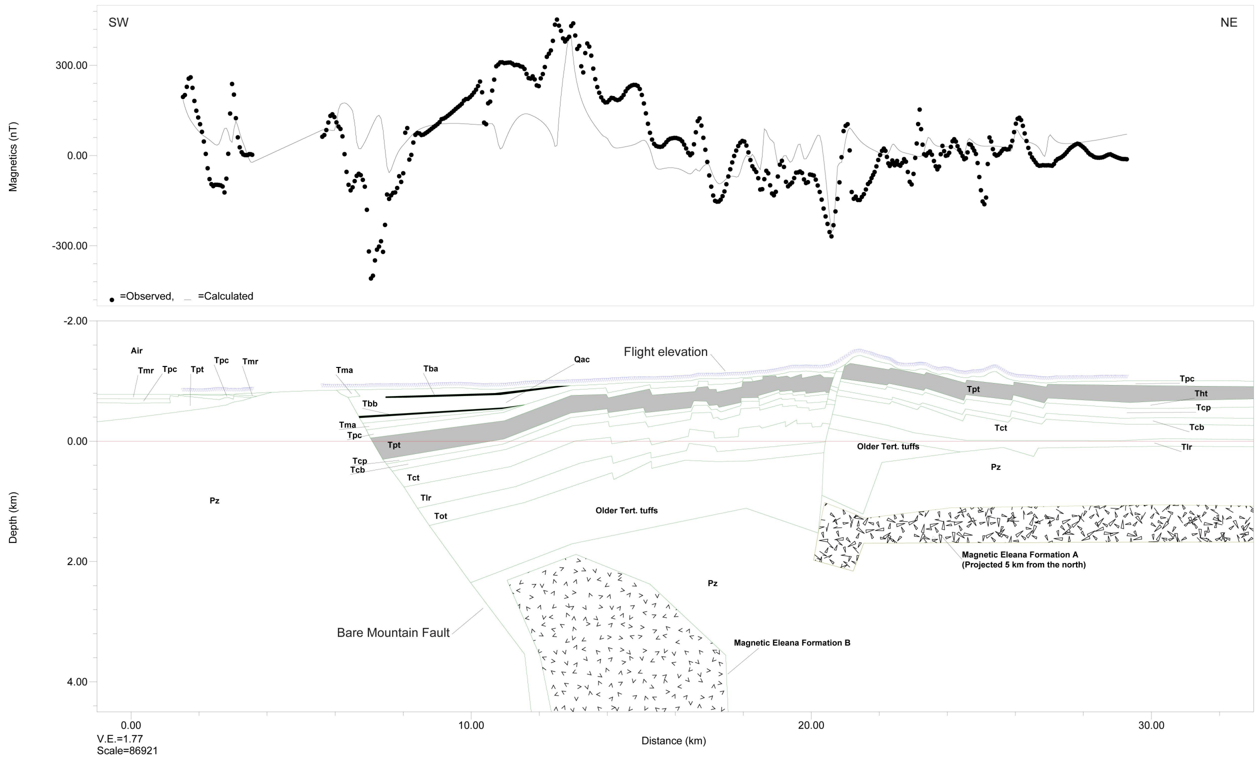


Figure 2. Two-Dimensional Model of Aeromagnetic Anomaly Along Lines 2 and 3 Based on Brocher, et al. (1998). (See Table 1 for Legend.)

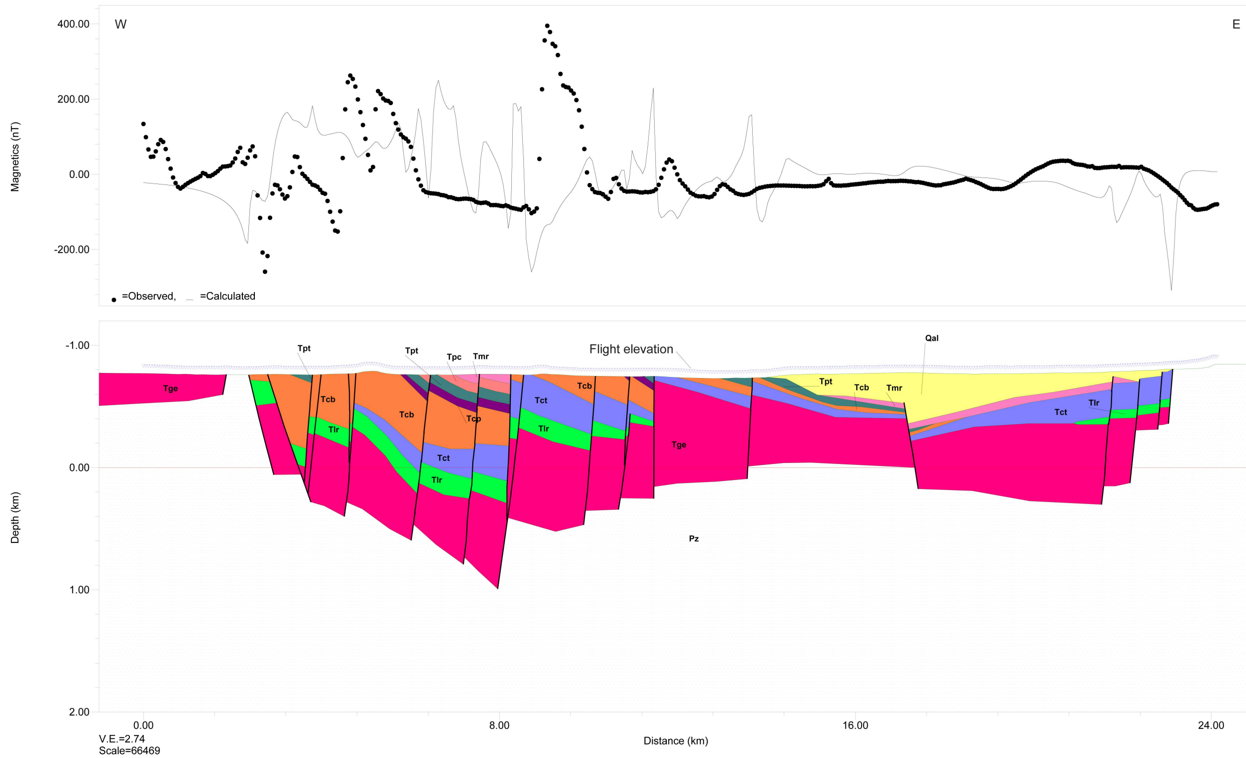


Figure 3. Two-Dimensional Model of Aeromagnetic Anomaly Along Nye-1 Based on Spengler and Dickerson (2002). (See Table 1 for Legend.)

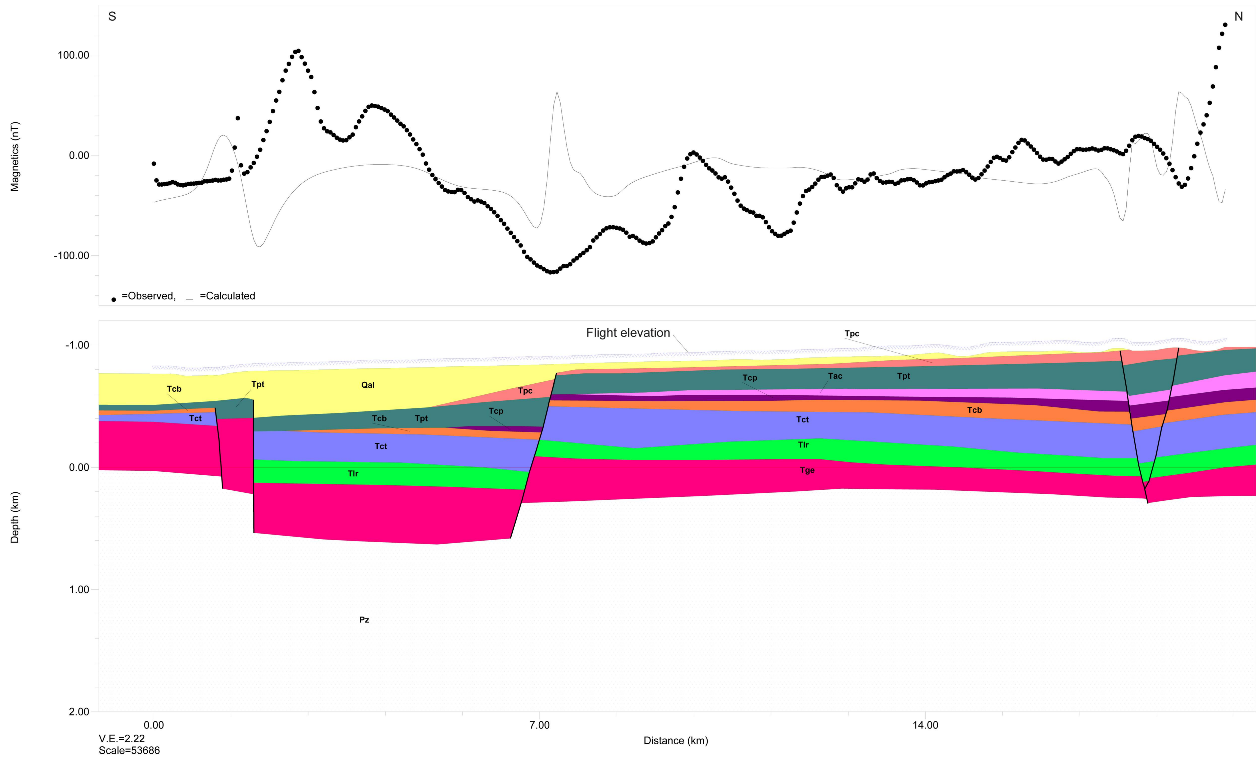


Figure 4. Two-Dimensional Model of Aeromagnetic Anomaly Along Nye-2 Based on Spengler and Dickerson (2002). (See Table 1 for Legend.)

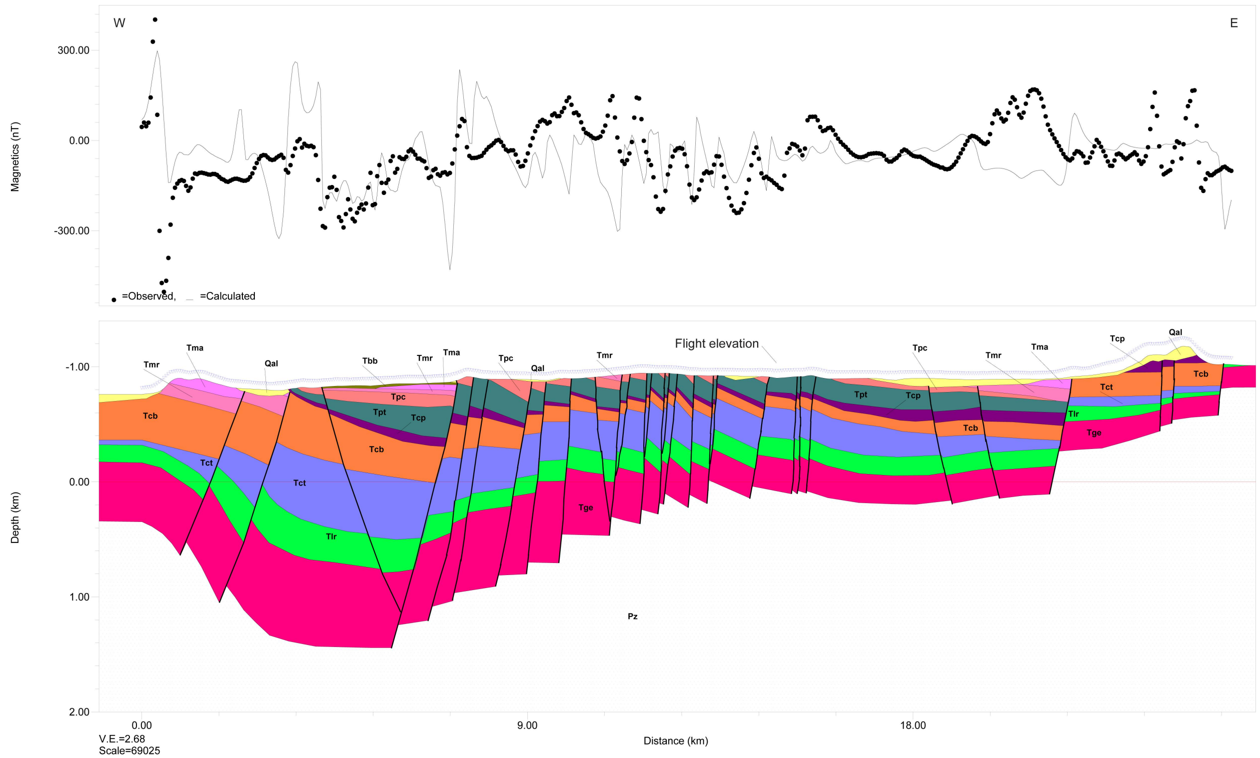


Figure 5. Two-Dimensional Model of Aeromagnetic Anomaly Along Nye-3 Based on Spengler and Dickerson (2002). (See Table 1 for Legend.)

Entry: Saurav Biswas
Date: September 14, 2007

Entry 3: GM-SYS 4.10 Installation Testing

Installation testing for GM-SYS 4.10 was performed by repeating the exercise for infinite cylinder model in Gonzalez (2004). Figure 6 shows the magnetic and gravity responses of GM-SYS model for the infinite cylinder. The model is located at ***D:\GM-SYS\GM-SYS_4.10\GM-SYS_Installation_Testing\ Test01_Cylinder.sur.***

Table 3. Buried Cylinder Model Parameters

Properties	**Air**	**Sediment**	**Cylinder**
Density, ρ (kg/m3)	0	2000	3000
Magnetic Susceptibility, k (SI)	0	0	0.0125663
Remanent Magnetization (A/m)	0	0	0
Inclination (°)	0	0	0
Declination (°)	0	0	0

Figure 7 compares the magnetic response of the cylinder model from GM-SYS with calculated (Hinze) response based Gonzalez (2004). Figure 8 compares gravity response of the cylinder model from GM-SYS with calculated (Jiracek) and calculated (Hinze) based Gonzalez (2004). The excel file is located at ***D:\GM-SYS\GM-SYS_4.10\GM-SYS_Installation_Testing\Test01_Cylinder.xls***

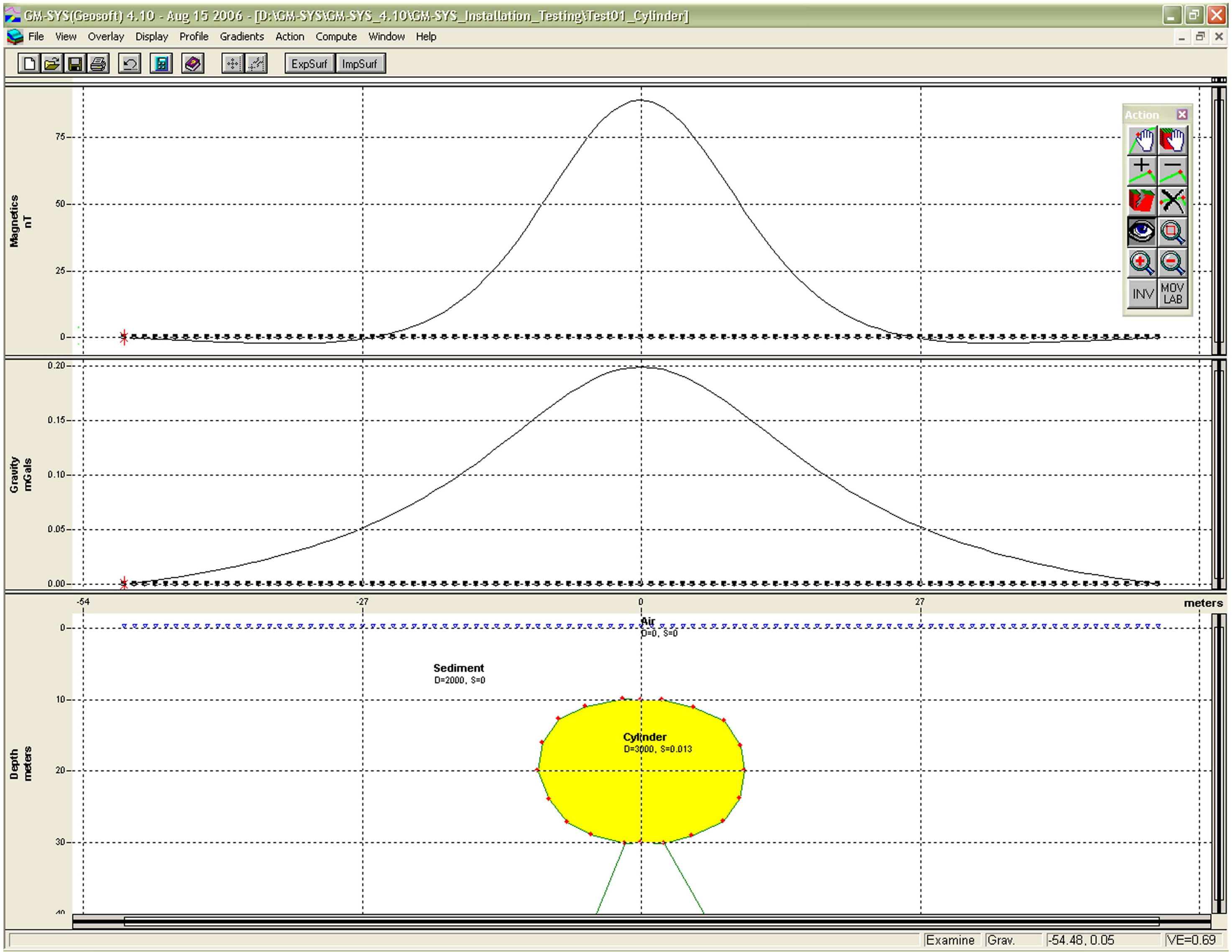


Figure 6. GM-SYS Infinite Cylinder Model and Corresponding Magnetic and Gravity Response.

Entry: Saurav Biswas
Date: September 14, 2007

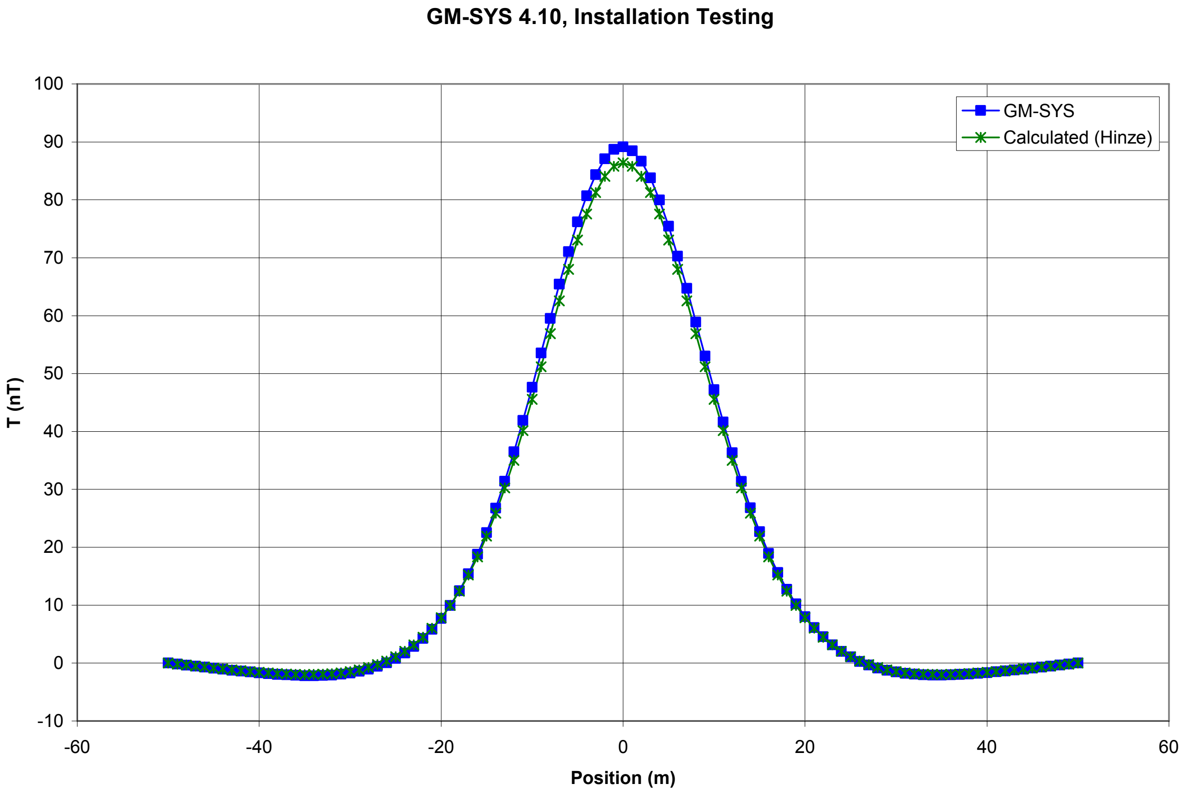
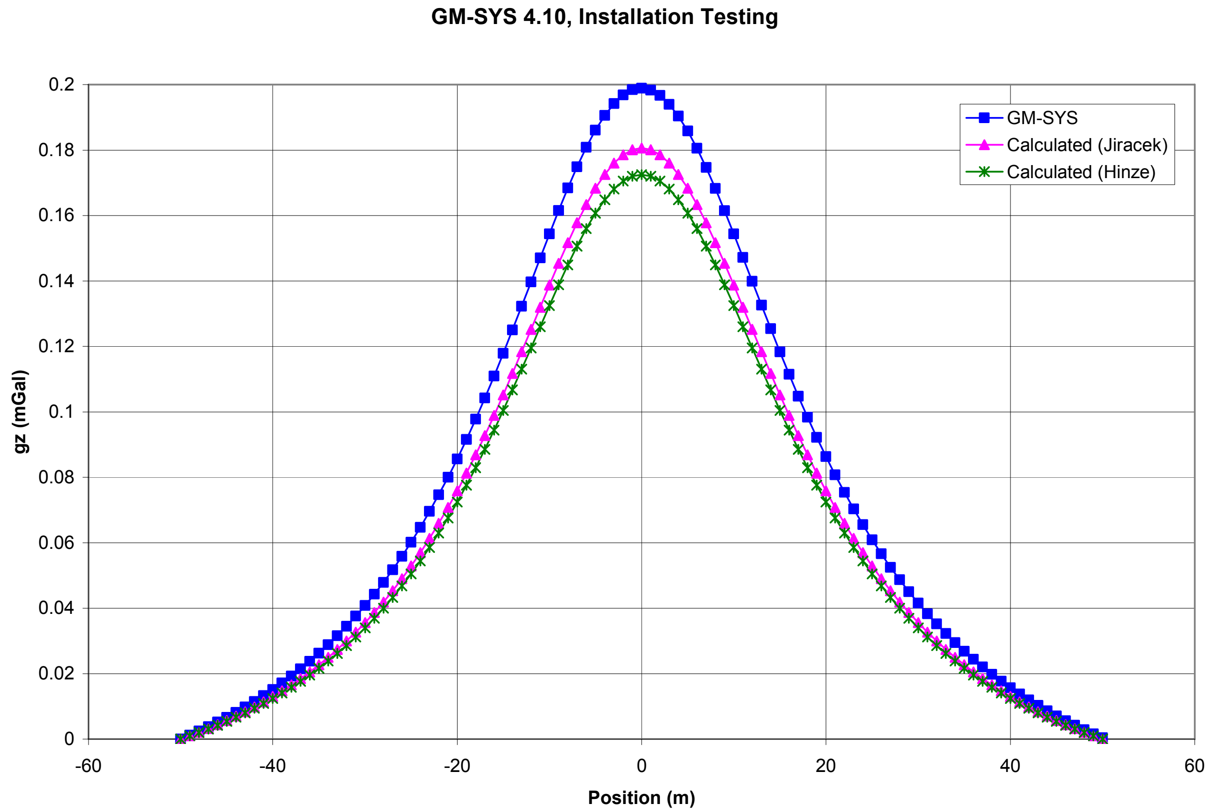


Figure 7. Magnetic Response Over a Horizontal Cylinder of Infinite Strike.

Entry: Saurav Biswas
Date: September 14, 2007



Reference:
Gonzalez, V.M. "Software Validation Test Plan and Report GM-SYS, Version 4.8.45b" San Antonio, Texas: CNWRA. 2004.

Hinze, W. J., 1990, The role of gravity and magnetic methods in engineering and environmental studies; in Ward, S. H., Ed., Geotechnical and environmental geophysics, Vol. I: Review and Tutorial; Investigations in Geophysics No. 5, Soc. Explor. Geophys., 75-126.

Jiracek, G. R., 1994, Gravity Method, in Hydrogeophysics class notes

Entry: Saurav Biswas
Date: March 7, 2008

Entry 4: Completion of GM-SYS 4.10 Validation Testing

Validation testing for GM-SYS 4.10 was performed by repeating the exercise for horizontal slab/vertical fault model in Gonzalez (2004). Figure 9 shows the magnetic and gravity responses of GM-SYS model for the horizontal slab/vertical fault. The model is located at ***D:\GM-SYS\GM-SYS_4.10\GM-SYS_Installation_Testing \ Test02_Horz_slab_Vert_fault.sur***

Table 4. Horizontal Slab/Vertical Fault Model Parameters			
Properties	**Air**	**Sediment**	**Cylinder**
Density, ρ (kg/m3)	0	2000	3000
Magnetic Susceptibility, k (SI)	0	0	0.0125663
Remanent Magnetization (A/m)	0	0	0
Inclination (°)	0	0	0
Declination (°)	0	0	0

Figure 10 compares the magnetic response of the horizontal slab/vertical fault model from GM-SYS with calculated (Hinze) response based Gonzalez (2004). Figure 11 compares gravity response of the horizontal slab/vertical fault model from GM-SYS with calculated (Jiracek) and calculated (Hinze) based Gonzalez (2004). The excel file is located at ***D:\GM-SYS\GM-SYS_4.10\GM-SYS_Installation_Testing\Test02_Horz_slab_Vert_fault.xls***

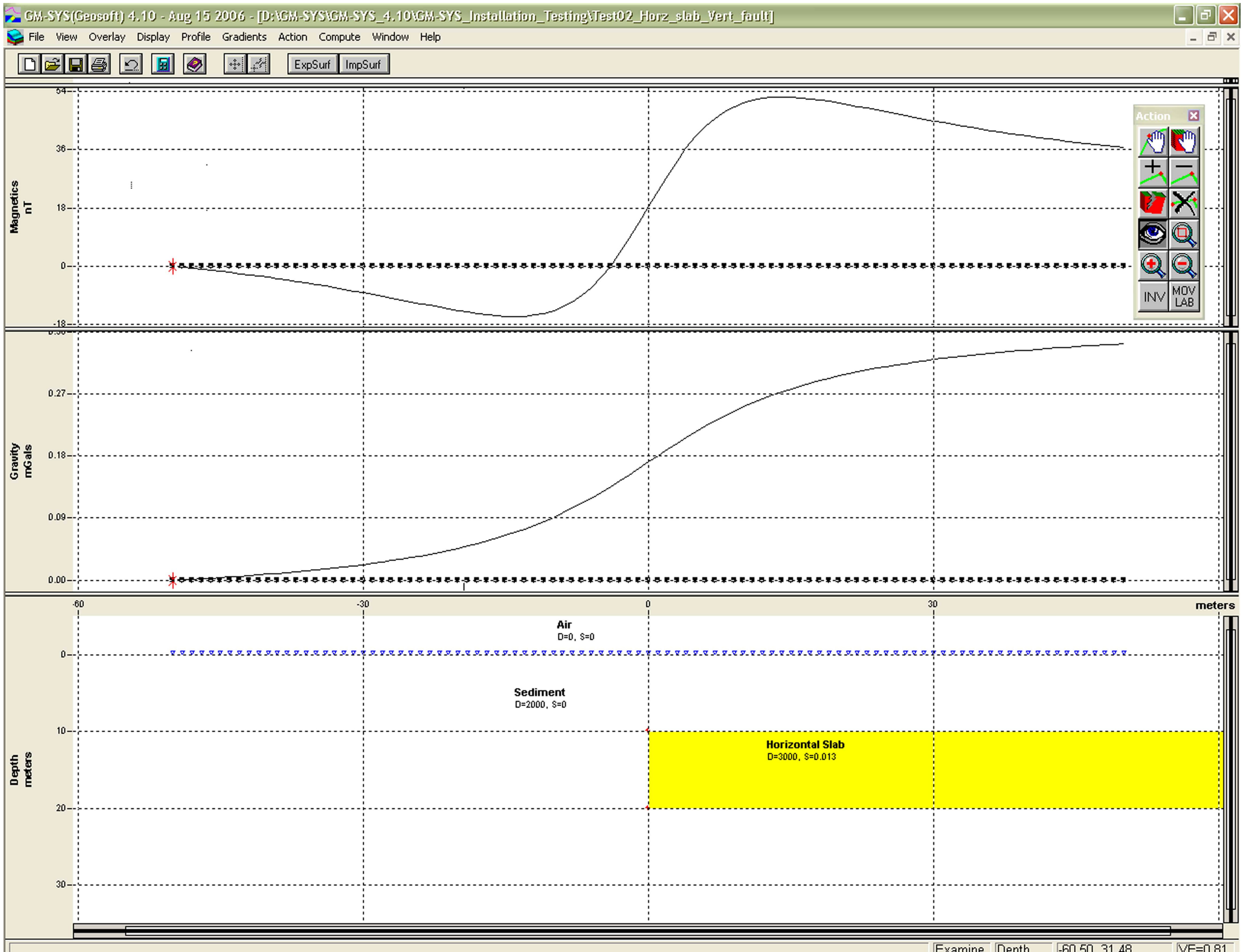


Figure 9. GM-SYS Horizontal Slab/Vertical Fault Model and Corresponding Magnetic and Gravity Response.

Entry: Saurav Biswas
Date: March 7, 2008

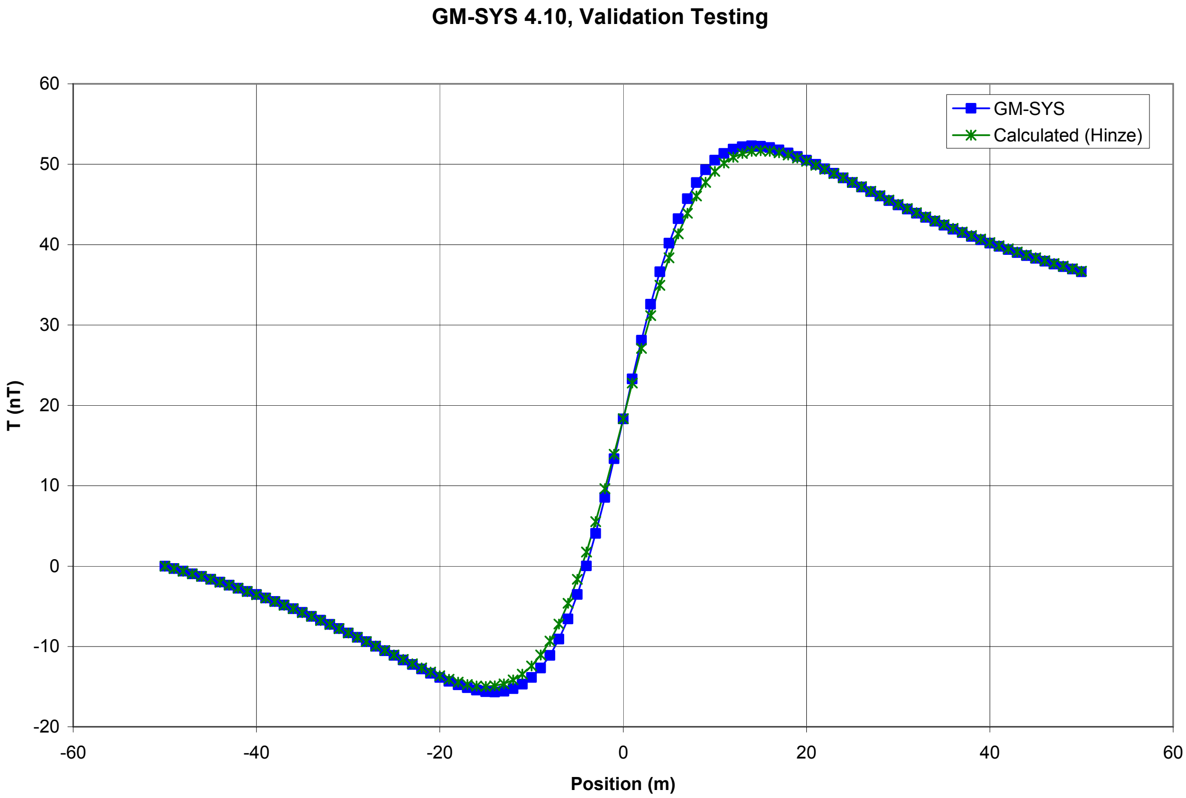


Figure 10. Gravity Response Over a Horizontal Cylinder of Infinite Strike.

Entry: Saurav Biswas
Date: March 7, 2008

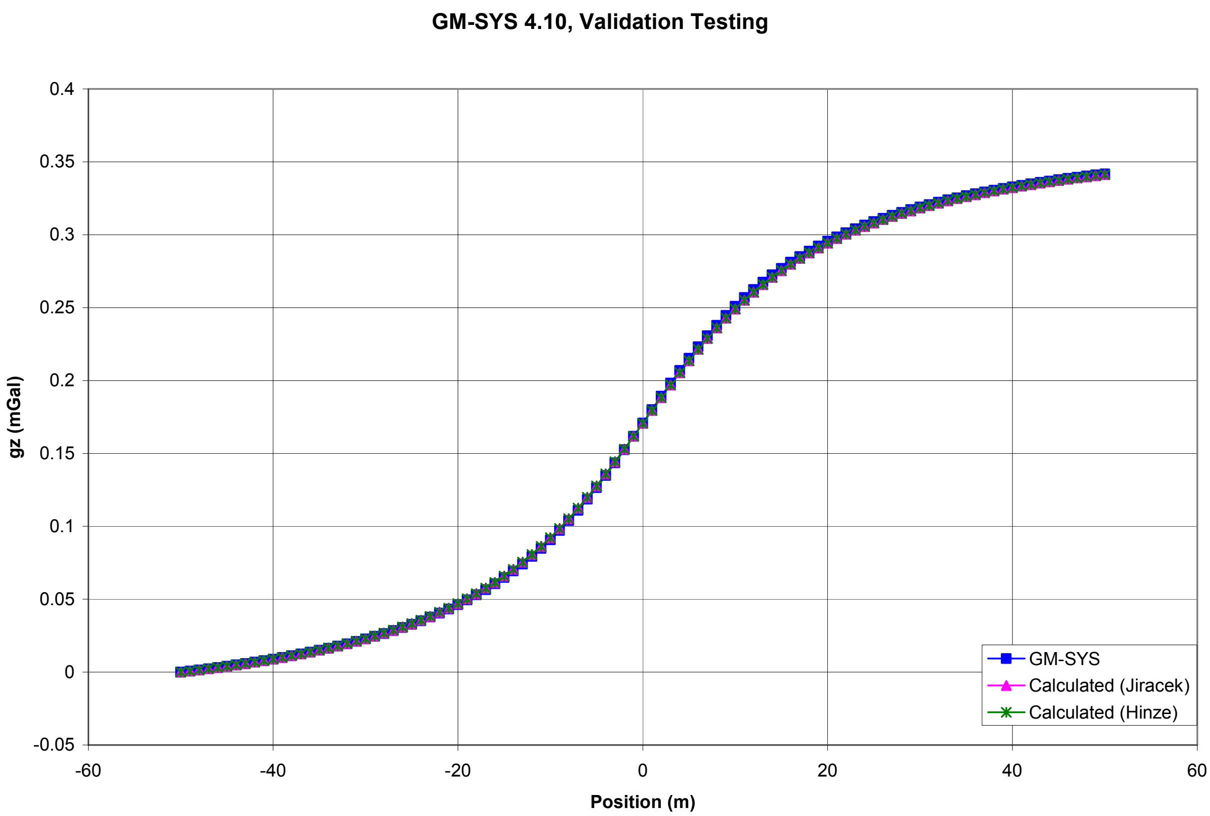


Figure 11. Gravity Response Over a Horizontal Cylinder of Infinite Strike.

Scientific Notebook 903E

Entry: Saurav Biswas
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The results of installation and validation testing for GM-SYS 4.10 as documented in entries 3 and 4 of this scientific notebook closely match the results documented in the "Software Validation Test Plan and Report GM-SYS Version 4.8.45b" by Gonzalez (2004). Thus, the software validation for GM-SYS 4.10 is successful and a corresponding Software Release Notice is released.

This completes the software validation for GM-SYS 4.10.

This concludes all the entries in this scientific notebook.

Reference:
Gonzalez, V.M. "Software Validation Test Plan and Report GM-SYS, Version 4.8.45b" San Antonio, Texas: CNWRA. 2004.

Hinze, W. J., 1990, The role of gravity and magnetic methods in engineering and environmental studies; in Ward, S. H., Ed., Geotechnical and environmental geophysics, Vol. I: Review and Tutorial; Investigations in Geophysics No. 5, Soc. Explor. Geophys., 75-126.

Jiracek, G. R., 1994, Gravity Method, in Hydrogeophysics class notes

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ADDITIONAL INFORMATION FOR SCIENTIFIC NOTEBOOK NO. 903E

Document Date:	02/08/2006
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