

UTILIZATION OF 3D PHOTOREALISTIC VIRTUAL MODELS OF OUTCROP
GEOLOGY AND IMPLEMENTATION OF CUSTOMIZED
GRAPHIC USER INTERFACES

by

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AND IMPLEMENTATION OF CUSTOMIZED GRAPHIC USER INTERFACES

by

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The University of Texas at Dallas, 2020

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This research demonstrates the use of 3D Photorealistic Virtual Models of Outcrop Geology. The primary goal of this research is to combine 2D geologic analysis and investigation with 3D virtual technology in order to maximize collaboration, efficiency (time management), and data management. A system of intuitive graphic user interfaces (GUIs) containing a collection of activities and instructions for 3D geologic analysis was developed to test the effectiveness, ease, and range of use of the virtual models. The graphic user interfaces were developed for various technologically capable levels to provide maximum usage by a variety of users without the need for extensive software training. The 3D models utilized provide opportunity for field visits that can be taken virtually multiple times. Models will not replace field geology experiences but will enrich analysis and inquiry opportunities.

Having access to a site multiple times using 3D virtual models and customized GUIs can provide the user more time to analyze and understand geologic concepts than allowed during a single field visit to an outcrop. The GUIs are designed to run using ArcGIS software and Microsoft

windows, both which will require minimum time investment (for learning software) on the part of the user. 3D models and GUI tutorials are also being made accessible to students via the internet www.utdallas.edu/igeology) and social networking sites like Face Book and YouTube. Social networking sites will provide easy and repeated access to the data.

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CHAPTER 1

INTRODUCTION

1.1 Overview

The use of 3D Photorealistic Virtual Models to perform analysis of outcrop geology is conducted through a system of intuitive graphic user interfaces (GUIs) to test the effectiveness, ease, and range of use. Traditionally, geology is conducted in the field, observing rock exposures in 3D and analysis is conducted via illustrations and photographs in 2D. Analysis, interpretation, and data logging which are taken from the 3D perspective and worked on in 2D undergo a translation of data which can result in distortion and produce ambiguous results. The 3D virtual models (see Wang, et.al. 2012 for details on model development and accuracy) and graphic user interfaces will not replace field geology experiences but provide opportunity for field visits that no longer need to be conducted solely on site.

They enrich analysis and inquiry opportunities. The 3D models utilized provide opportunity for field visits that no longer need to be conducted solely on site. Having access to a site multiple times using 3D virtual models and customized GUIs can provide the user more time to analyze and understand geologic concepts than allowed during a single field visit to an outcrop. Integration of virtual models of outcrop geology considers the aspects of a digital native's technological abilities and utilizes them to set up four components which guide the user from novice level geologic knowledge to in-field, real world research analysis via 3D photorealistic models and customized graphic user interfaces (Figure 1.1). All four sections of this dissertation (Digitally Integrated Stratigraphy Project-DISP, Ramsay Tool-RT, Physical Geology Tutorial-PGT, and Tablets for the Field-T4F) require system initialization setup up of

datasets and software and creation of work folders for each on the PC desktop or C-drive. All components are designed to extend the geologic applications beyond the field.

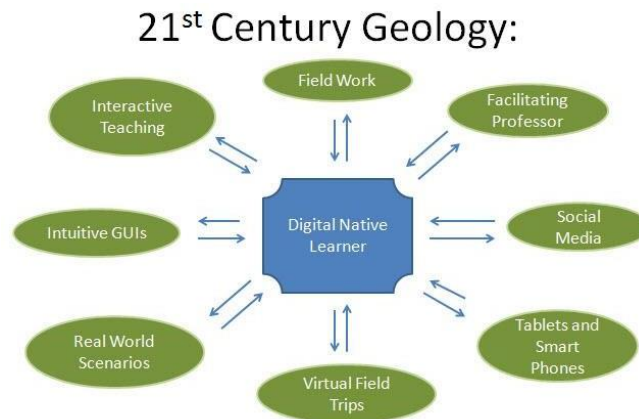


Figure 1.1. A graphic representation of the digital native and the interaction with technology via GUIs, social media, tables, smart phones, and virtual 3D reality

The GUIs run in ESRI ArcGIS software and Microsoft windows; both which will require minimum time investment (for learning software) on the part of the user. 3D models and GUI tutorials are also being made accessible to users via the internet (www.utdallas.edu/igeology) and social networking sites like Face Book and YouTube. Social networking sites will provide easy and repeated access to the data. The primary goal of this research is to combine 2D geologic analysis and investigation with 3D virtual technology in order to maximize collaboration, efficiency (time management), and data management.

1.2 Overall research aims and individual research objectives

This dissertation combines 2D geologic analysis and investigation with 3D technology in order to maximize collaboration, efficiency (time management), and data management of field procedures and provide less ambiguous data and open virtual access for geology. All the components center on user interaction with the study area through the integration of 3D

photorealistic models and customized graphic user interfaces and therefore improves the integration of 3D technologies utilized for analysis and interpretation. Fields like sequence stratigraphy receive criticism which is centered on the uncertainty of dating approaches and the few detailed examples of 3D analysis (Bhattacharya, 2011). The DISP portion of this dissertation was designed for these reasons. Designing connections between learning and exploring takes the user to improved visual experiences and knowledge acquisition and aids with capturing the complexity of real-world processes and parameters which many conceptual models still do not capture (Burgess, et.al. 2006).

This integrated system of graphic user interfaces serves as analysis tools for field work and enrichment supplements to existing curriculum for undergraduate geology courses. When working with cross-sections in field and lab, the analysis is done in two dimensions. The objective of evaluation and analysis of deformed regions should be three dimensional whenever possible to recognize the challenges of the real world which is addressed through the GUIs developed for this study (Woodward, 2012). Its accessibility in social network mediums such as YouTube and Facebook provides maximum ability to quickly and efficiently disseminate graphic user interfaces and video of virtual models for users to access. The module components investigate the potential of using graphic user interfaces in field work and research.

1.3 Value of this research

The contribution of using graphic user interfaces, tablets, PCs, and social media to interact with 3D photorealistic models creates a platform for efficient, less ambiguous interaction with geology. A variety of geoscience fields can utilize these customized GUIs to interact with the geology in many ways: before a field visit (virtual field trip), during field work (data logging,

note taking, analysis), and after field work (review, collaborate, discuss).

The work performed via the GUIs is preserved (saved in a file associated with the data file) and can be used in discussions conducted during lab work in undergraduate geosciences courses or during collaborative sessions conducted among different research groups who are conducting studies of the site (Stratigraphic data logging).

1.4 Dissertation Organization

Chapter 2 is the published paper which discusses the graphic user interface developed for Stratigraphic data logging of the Silurian stratigraphy of Measley Ridge, Ohio. The interface is developed using Microsoft Visual Studio 2010 in Vb.Net coding language and runs as an Add-In in the ArcGIS ArcScene platform.

Chapter 3 describes the procedure and workflow for the physical geology graphic user interface which is designed to teach the user basic geologic terms through imagery and explanations using the Proterozoic extrusive and intrusive rocks of the Arbuckle Hills, Oklahoma. The graphic use interface is developed using Microsoft Visual Studio software 2010 which facilitates Vb.Net coding language. The graphic user interface runs as an Add-In within the ArcGIS ArcMap platform.

Chapter 4 describes the procedure and workflow for the structural geology graphic user interface which is designed to teach the user the process of analyzing and categorizing fold structures according to the Ramsay Fold Classification method using the Proterozoic extrusive and intrusive rocks of the Arbuckle Hills, Oklahoma. The interface is developed using Microsoft Visual Studio 2010 in Vb.Net coding language and runs as a standalone program on the Microsoft Windows desktop.

Chapter 5 discusses the utilization of tablets (an Apple iPad in this case study) in the field for geologic analysis performed in 2D and displayed in 3D for use in educational settings. An outcrop in the Arbuckle Hills anticline, OK is used for structural analysis. Conclusions and future work are discussed in Chapter 6.

1.5 Accomplishments

1.5.1 Published paper

Michelle Iris Rodriguez-Gomez, Bradley D. Cramer, Brian Burnham, Miao Wang, Lu Chen, and Carlos L. V. Aiken. The Digital Integrated Stratigraphy Project (DISP) Development Phase II: On-site 3D access, analysis and integration of stratigraphic data using PCs and 3D Photorealistic Models, *Stratigraphy*, vol. (4), pg.255-260

Miao Wang, M. **Iris Rodriguez-Gomez**, Carlos Aiken. Interacting with Existing 3D Photorealistic Outcrop Models on-site and in the lab or classroom, facilitated with an iPad and a PC, Google Earth and Virtual 6 Visualizations in Geoscience Education and Research: Geological Society of America Special paper 492, p.263-283, doi:10.1130/2012.2492(19).

1.5.2 Conference efforts

M. Iris Rodriguez-Gomez, Amy Webber, Lionel White, Carlos L.V. Aiken. Demonstration of using tools for the analyses of 3D Virtual models in the classroom including the Ramsey fold classification, GSA Annual Meeting, 27-30 October 2013, Denver, CO.

Lu Chen, Tara L Graham, **Iris Rodriguez**, Miao Wang and Carlos L.V. Aiken, Demonstration of Attributing and Analyzing 3D Outcrop Models in Teaching and Research Using ESRI and Non-ESRI Modules, GSA Annual Meeting, 3-7 November, 2012 Houston, TX

M. Iris Rodriguez, Miao Wang, Brian Burnham, Lu Chen, Bradley Cramer, Carlos L.V. Aiken.

On-site 3D access, analysis, and integration of Silurian Bisher and Lilley Formations, Measley Ridge, Ohio, using digital tablets and a 3D Photorealistic Model IGCP 591 2nd Annual Meeting and 1st Foreste Symposium, IGCP 591 Annual Meeting and 1st Foreste Symposium, 22-27 July, 2012, Cincinnati, OH

Miao Wang, **Iris Alvarado (Rodriguez)**, Lionel White, Georgia Fotopoulos, Carlos Aiken, Quantitatively interacting with 3D photorealistic models using iPads, Engaging Youth, SPAR 21-24 March 2011, Houston, TX.

Miao Wang, **Iris Alvarado (Rodriguez)**, Carlos, Aiken, John Ferguson, Interacting with 3D photorealistic outcrop models using iPad, GSA annual meeting, 09-12 October 2011, Minnesota, MN.

Iris Alvarado (Rodriguez), Carlos L.V. Aiken, Brian S. Burnham, Georgia Fotopoulos, Ranyah Kharwat, Deanna Marine, Graham Mills, Miao Wang, 3D G.I.I.V.E: A collaborative program for disseminating and training with 3D virtual geology in the North Texas region, Paper No. 172-13, GSA Annual Meeting, 31 October –3 November 2010, Denver, CO.

Iris Alvarado (Rodriguez), Michelle Wurtz, Lionel White, Mohammed Alfarhan, Carlos Aiken, Virtual Model It and They Will Learn, GSA South-Central Annual Meeting, 16-17 March, 2009, Dallas, TX

Iris Rodriguez, Miriam Cabrelles, Jose L. Lerma, Lionel White, Mohammed Alfarhan, Carlos L.V. Aiken, A Comparison of The Effectiveness of Close-Range Photogrammetry, Laser Scanning, and Their Integration in Creating High Resolution 3D Virtual Models of Geologic Outcrops, GSA Annual Meeting, 18-21 October, 2009, Portland, OR

Iris Alvarado (Rodriguez), Mohammed Alfarhan, Lionel White, carlos L.V. Aiken, GeoIs: A

Software To Facilitate Teaching Geosciences K-12, GSA South Central Annual Meeting, 30 March- 1 April, 2008, Hot Springs, Arkansas

Iris Alvarado (Rodriguez), Mohammed Alfarhan, Lionel White, Carlos L.V. Aiken, K-12

Teacher as An NSF RET (Research Experience for Teachers) Participant in the NSF

INTERFACE (Interdisciplinary alliance for digital Field data Acquisition and Exploration)

Facility at UT-Dallas, GSA Annual Meeting, 5-9 October, 2008, Houston, TX.

White Lionel. Tarig Ahmed, Mohammed Alfarhan, **Iris Alvarado (Rodriguez)**, Alex Biholar, Brian Burnham, Prabin Shilpakar, Carlos L.V. Aiken, Application of the GeoDimensional Tools ArcGIS Extension for the Analysis of 3D Virtual Models of Outcrops in the Arbuckle Anticline and Other, GSA Annual Meeting, GSA Annual Meeting, 5-9 October, 2008, Houston, TX

Carlos Aiken, Mohammed Alfarhan, Lionel White, Tarig Ahmed, Miao Wang, Prabin Shilpakar, **Iris Alvarado (Rodriguez)**, “Analyzing 3D Virtual Models built with Terrestrial LiDAR: Now that I have it, what do I do with it?”, UNAVCO Science Workshop, 11-13 March, 2008, Boulder, CO.

CHAPTER 2
UTILIZATION OF 3D PHOTOREALISTIC VIRTUAL MODELS OF
OUTCROP GEOLOGY AND IMPLEMENTATION OF CUSTOMIZED
GRAPHIC USER INTERFACES

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2.1 Summary

This paper presents an update on Development Phase II of the Digital Integrated Stratigraphy Project which aims to integrate virtually any type of geologic/stratigraphic data into a visual, digital, cross-referenced system built upon 3D photorealistic models of outcrops. This graphic user interface (DISP Tools) is an innovative digital workspace which will form part of a digital library for laser-based surveying and scanning technology such as 3D photorealistic models and associated paleontological, litho-, bio- and sequence stratigraphy, geochemical, and chemostratigraphic datasets. The development of a web-based open access digital library with various resources (3D models and graphic user interfaces) addresses long-term stratigraphic data management issues by enabling end-users to access the captured outcrops and log their sample positions and/or other notes directly onto the digital model while in the field or office.

This information can then be uploaded back to the DISP website as a permanent repository of information available as an unambiguous reference for future comparison.

2.2 Introduction

This paper is an update of progress for Development Phase II of the Digital Integrated Stratigraphy Project (DISP), which is an interface between global stratigraphic studies for Earth history research and digital outcrop mapping technology using LiDAR (see Munneke et al.2012). The accumulation of multiple types of paleontological, stratigraphic and geochemical data from one single stratigraphic section can take many years and several field visits from various working groups. This span of time and multiple working teams often limit the level of certainty with which each of the collected data sets can be compared at the finest level of stratigraphic detail, and the DISP represents an opportunity to overcome this challenge to high-resolution

stratigraphic studies. The web-portal entrance to the DISP includes two options; one for scanners/developers of photorealistic models, and the other for stratigraphic end-users. The details for the scanner/developer side are included in Munneke et al. (2012) and readers should refer to that publication for further information. Here, we discuss the development of the Graphic User Interface (GUI) for the stratigraphic end-user side of the DISP.

A 3D photorealistic model of the Silurian stratigraphy exposed at Measley Ridge, Ohio (McLaughlin et al. 2008; Brett et al. 2012a), was created using recent advances in geospatial data collection and analysis via the integration of technologies such as Terrestrial Laser Scanning (TLS) LiDAR combined with centimeter GNSS (Global Navigation Satellite System (includes GPS(Global Positioning System[includes GPS-Global Positioning System])), high-resolution digital photography and GIS software for three dimensional modeling (Alfarhan et al. 2008, Munneke et al. 2012, Wang et al. 2012). This 3D photorealistic model was utilized here to demonstrate the Graphic User Interface (GUI) currently under development for the DISP (DISP Tools) through which users can interact with the digital outcrop by logging sample positions, writing field notes, or annotating lithostratigraphic boundary picks. The GUI provides access to view and interact with the previously produced 3D photorealistic model and, in the future, will allow users to upload, save, and ‘publish’ their information via the DISP website. Models, data, and documentation will be accessible and stored in one web portal making collaborations, discussions, and data access more convenient and uniform thus helping to address issues such as stratigraphic ambiguity, long distance collaborations, and data sharing/storage.

The final database and permanent home for the DISP are yet to be made available and represent the final stage of Development Phase II of the DISP. At present, DISP data and demonstrations are housed on the International Geoscience Program (IGCP) Project 591 website at www.igcp591.org.

2.3 Geologic Study Area: Measley Ridge

The Measley Ridge section, located in Adams County, southern Ohio, has been documented previously by McLaughlin et al. (2008) and Brett et al. (2012a), and contains surface exposures of strata belonging to the Telychian and Sheinwoodian stages of the Silurian System. The Estill, Bisher, and Lilley formations are well exposed at this location, which has become an outcrop of critical regional importance to the ongoing re-evaluation of Silurian strata of the North American Mid-Continent (e.g. McLaughlin et al. 2008; Brett et al. 2012b). The Bisher and Lilley portions of the outcrop, exposed along both sides of the James A. Rhodes Appalachian Highway (Rte. 32), just west of the town of Peebles, were digitally scanned using terrestrial LiDAR and GNSS in September 2011. This scan was made into a 3D photorealistic model to serve as the platform for demonstration of the initial end-user interface of the DISP Tools.

2.4 Development phase II: user interface and data management development of the Graphic User Interface (GUI)

A graphic user interface (GUI) for the DISP (DISP Tools) was developed using Microsoft Visual Studio 2010 (VS2010 software available for free download to educational entities and students at http://www.winportal.com/microsoft-visualstudio?utm_source=bing&utm_medium=cpc&utm_campaign=sistema&utm_content=javi

%20Microsoft%20Visual%20Studio, offers various scripting language options, and for the purposes of this project, VB.Net scripting language was used) and was run as an Add-In for ESRI's ArcScene software for field demonstration at the IGCP 591 2nd Annual Meeting in Cincinnati, Ohio, July 2012. An Add-In as developed for ArcScene becomes an integrated tool bar button that is included upon opening an ArcScene file. DISP Tools currently requires the user to work on a laptop or desktop computer. The tools compliment using tablets in the field on which data can be logged onto 2D photographs of the outcrop and then transformed into 3D for display on the model (Wang et al., 2012). This paper emphasizes all operations performed in three dimensions. The ESRI ArcScene component requires access to ArcGIS software but minimal software know-how. The final version of the GUI still under development will be produced using non-proprietary software that will be publicly available. Upon opening the ArcScene file, the user simply needs to click the Start-Up button to 'load' the 3D model and the interface with its accompanying DISP Tools. The layout of the GUI demonstrated here is intuitive and can be mastered in a matter of minutes. Users will have the option of logging into the DISP link on the IGCP 591 website directly from the field to access the captured outcrop and user interface or of downloading a complete file before leaving for the field to allow for lack of internet coverage at the field locality. Models of outcrops will vary in size because of detail and physical size of the outcrop. The models created, depending on detail, can run from a few tens of megabytes to hundreds of gigabytes. With the captured outcrop model, users can pan and zoom - in on an area of interest to view the geology in 3D and begin logging stratigraphic information. Once the DISP Tools Start-Up button (Figure 2.1) is clicked, the end-user interface loads and provides multiple interactive buttons which can be used on a previously scanned locality.

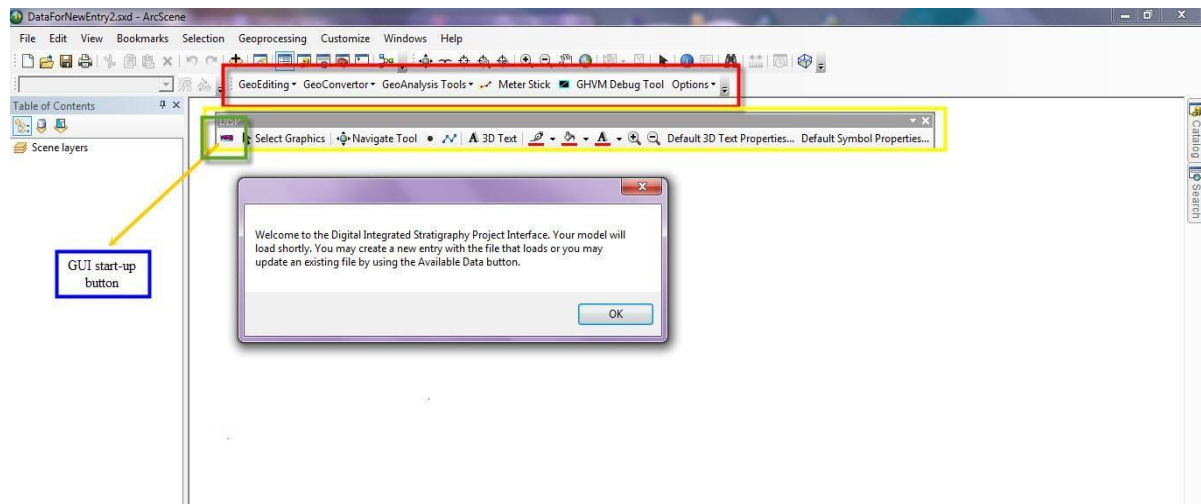


Figure 2.1. Initial view of DISP Tools window. The initial Start-Up button for the interface is found on the floating tool bar (boxed in green). An example of a DISP Tools toolbar for 3D digital interaction with the model of an outcrop in ArcScene can be seen (boxed in yellow). Shown also, is an example of an available analysis toolbox for ArcScene (the GeoAnalysis Tools package (boxed in red), from GHVM) (White et al., 2012).

Three initial options are provided including ‘Available Data’ ‘Create New Entry’ or ‘Save’ (Figure 2.2). The ‘Create New Entry’ button allows the user to plot (digitize) new 3D points/layer boundaries as well as affix labels to the areas of geologic interest within the outcrop. This new digital data is saved in 3D space. The user can save multiple files containing sample positions, lithostratigraphic measurements, locations of lithostratigraphic boundaries determined by the user at the time of sampling, or even written field notes. There is minimal initial data entry required to tag the data set prior to getting started. When initializing a new entry, the user is asked to input details of name, institution, 5-word data ID, 1-word data ID and email address. This serves as a documentation tool for work done in the field and an identifier for the location of archived samples. Field notes and stratigraphic information can be documented as field work is being performed and saved to the DISP website where it can either be immediately ‘published’

for viewing by others, or the user can wait to make it publicly available at a later date. Additional information can be added by the initiator of any data set after the fact. For example, if they would like to upload and link a photographic plate of fossils recovered from a specific sample position within the outcrop.

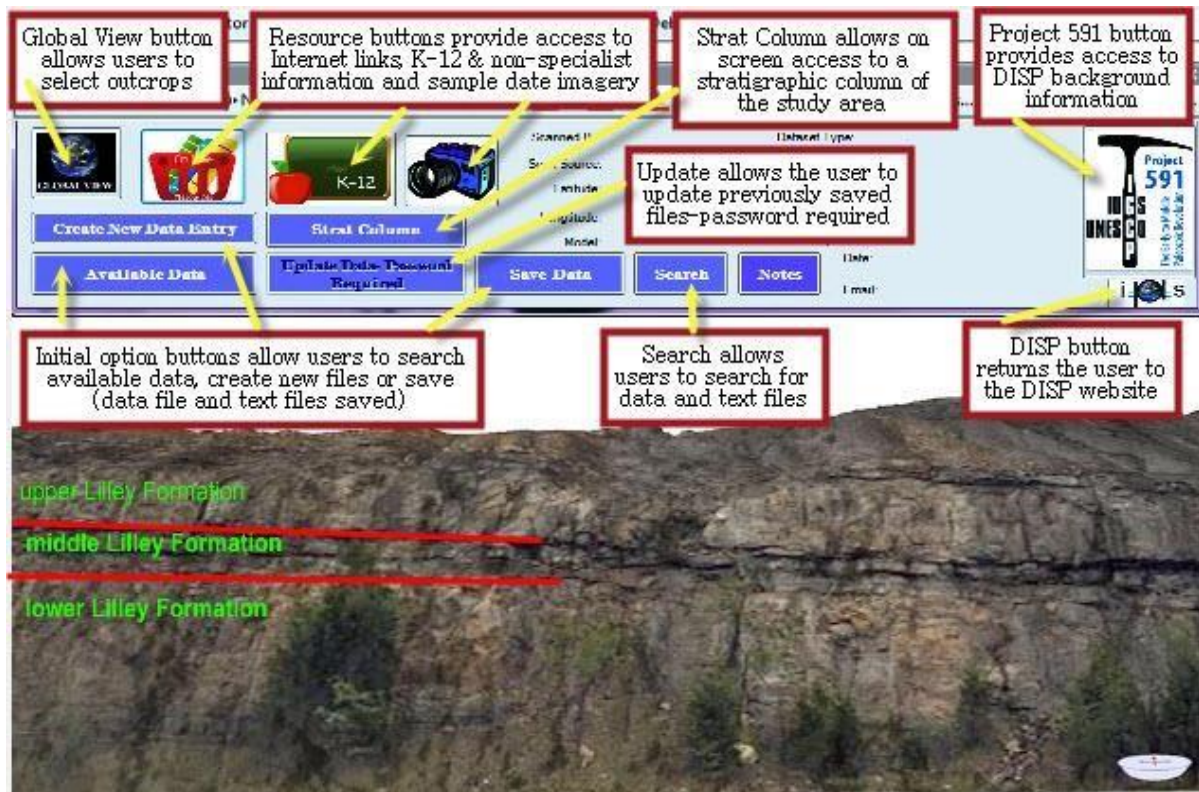


Figure 2.2. DISP Tools applied to 3D photorealistic model of Measley Ridge, Ohio. Once the interface and 3D model are loaded, option buttons such as ‘Available Data’, ‘Create New Entry’, and ‘Save’ become available. Other options available through buttons include three for Resource, and others for Update, Search, Notes, Global View, links to the DISP website and DISP background information and Stratigraphic Column of the study area.

The GUI includes access for primary and secondary educators and non-specialists to utilize in the field. Providing this information opens the interface to a wider audience who may choose to use this type of technology during labs, class lectures, and field visit preparation. This

‘teacher toolbox’ is accessible through the ‘K-12’ button (Figure 2.3). Clicking this button opens a new window with three button options: Earthtime, which displays the temporal context of the outcrop being viewed for the non-specialist; Ask a Geologist, where an email question can be sent to a project’s head coordinator/contact or previously loaded video can be accessed; and Teacher Resources, which contains links to useful books and websites for educators. The Earthtime button opens a separate window with additional information such as paleogeographic maps from the PALEOMAP Project (Scotese, 2001) to provide further context for the outcrop. These options provide immediate utility for the broader educational community and fulfill many of the public outreach components required by funding agencies.

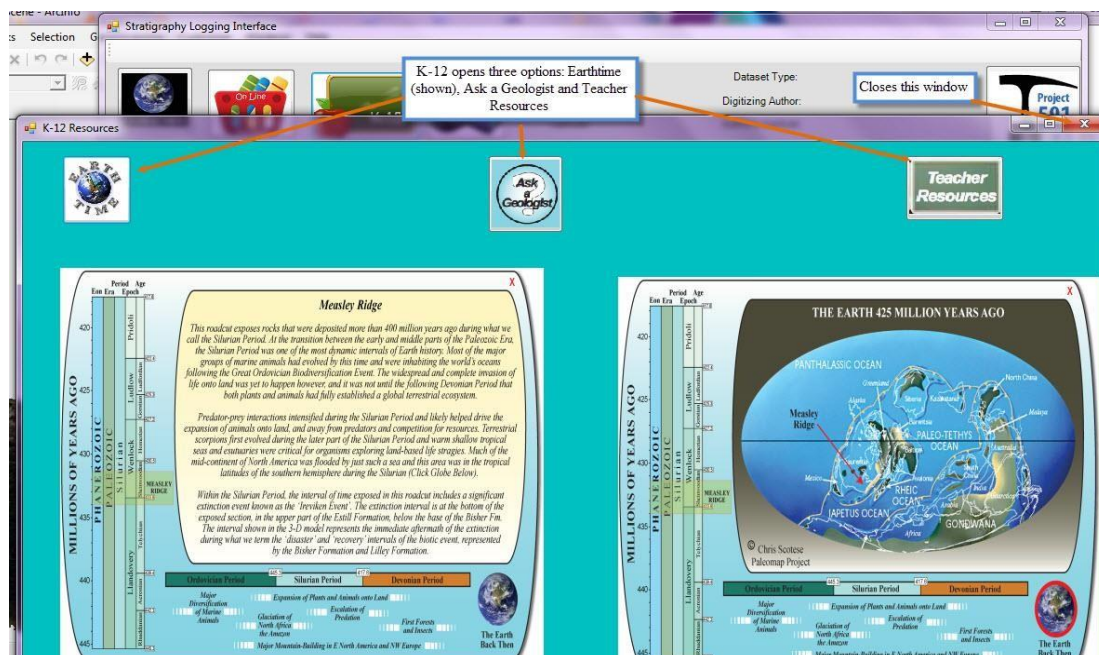


Figure 2.3. K-12 Teacher Toolbox. Selecting this button gives three options: Earthtime (selected), Ask a Geologist, and Teacher Resources. The Earthtime selection is displayed in the middle of the screen and provides background information for the non-specialist about the temporal and paleogeographic context of the outcrop being viewed.

If the user clicks the ‘Available Data’ button, a series of dropdown menus allow the user to overlay previously uploaded information onto the 3D photorealistic model (Figure 2.4). The user could then choose their desired information to overlay against the model for direct stratigraphic comparison against their own work while in the field. Specifically, this will allow users to choose their own sample positions with direct comparison against the sample position of previous investigators at the same outcrop. Once previous data has been displayed against the model, there are interactive options available with the data being displayed. Using the customized DISP toolbar, the user can change the appearance of the data being displayed, such as changing the color or size of text.

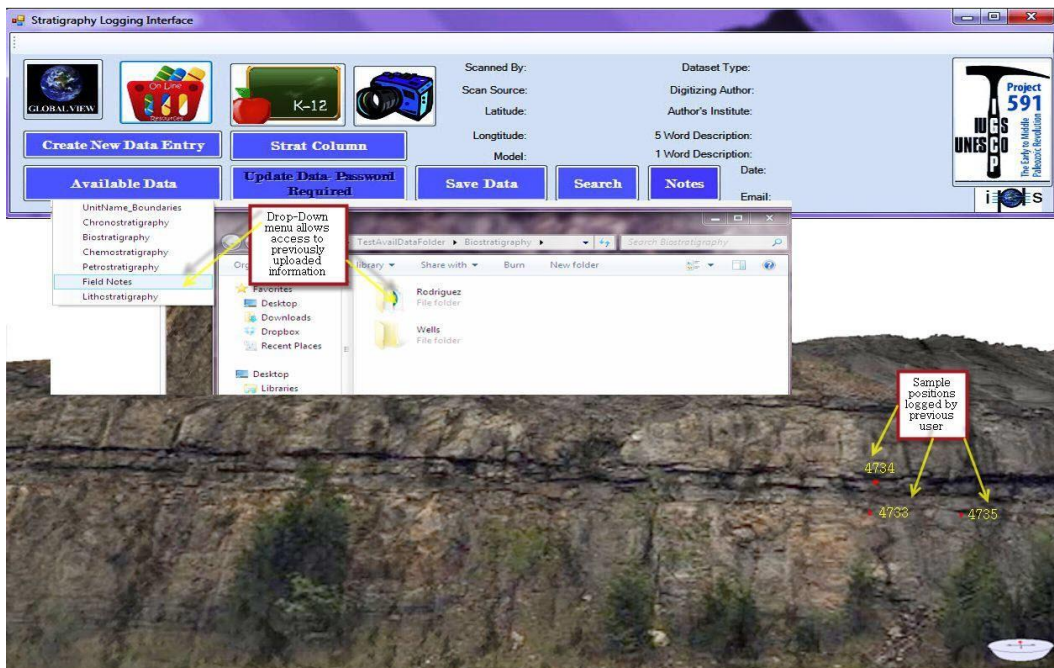


Figure 2.4. Example of logged point data for the site. Selecting the ‘Available Data’ button displays a drop-down menu of data that has been previously pinned to this 3D model of the outcrop by other users.

Multiple data sets can be opened at the same time (text-figure 5) and linked information within a given data set can be displayed as well. If the user wishes to create a new data set, the process is straightforward. After clicking the ‘Create New Entry’ button and entering a few pieces of information to tag the new data, the 3D model is ready for digital plotting. Any point, line, or text that is added onto the 3D model can be customized using the DISP toolbar.

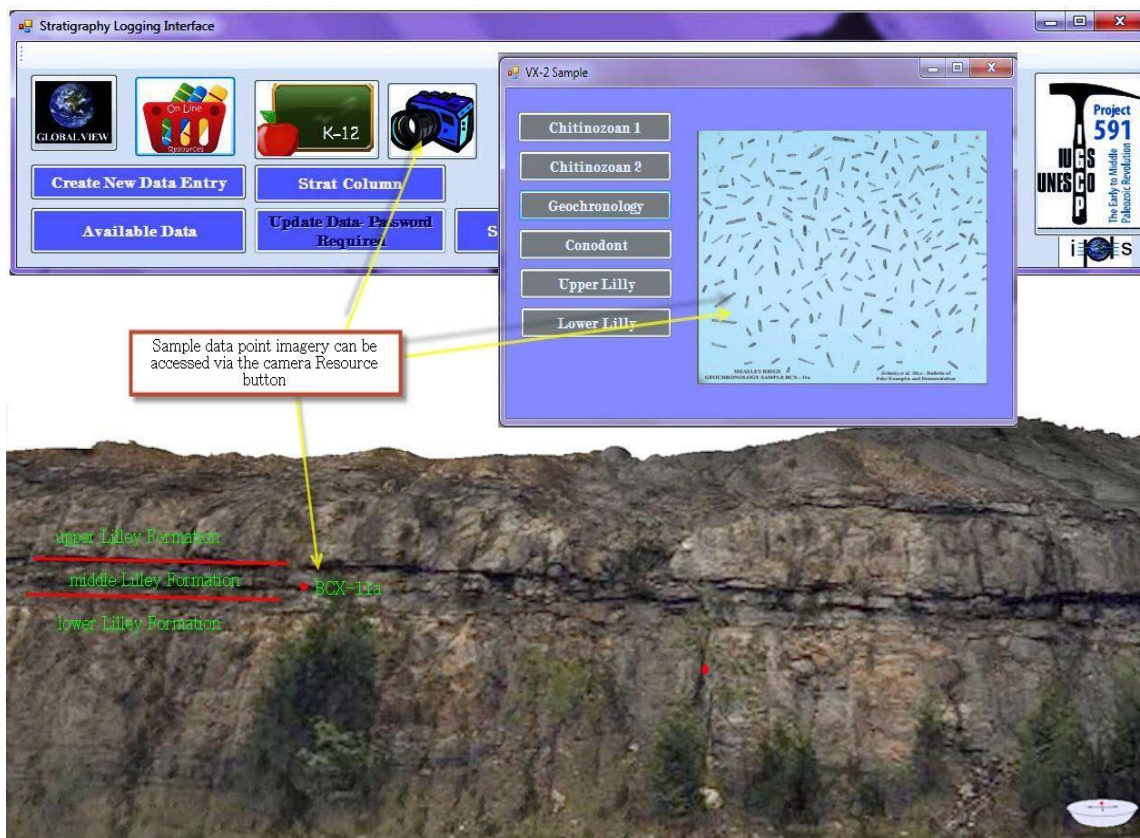


Figure 2.5. Example of logged point data for the site. Selecting the ‘Available Data’ button displays a drop-down menu of data that has been previously pinned to this 3D model of the outcrop by other users.

Additional options include free-form line drawing, new sample position point, a text box option, and the ability to select an item and delete it if desired (text-figure 6). When a new object is placed on the model, it is in three-dimensional space within the photorealistic model and becomes part of the file's graphic layer. The user can add a new notebook item, for basic field notes, or the user can link a photograph or other file to that object. These options are available after the fact as well, for example if the user wants to link a photomicrograph from laboratory work on a sample they collected previously in the field.

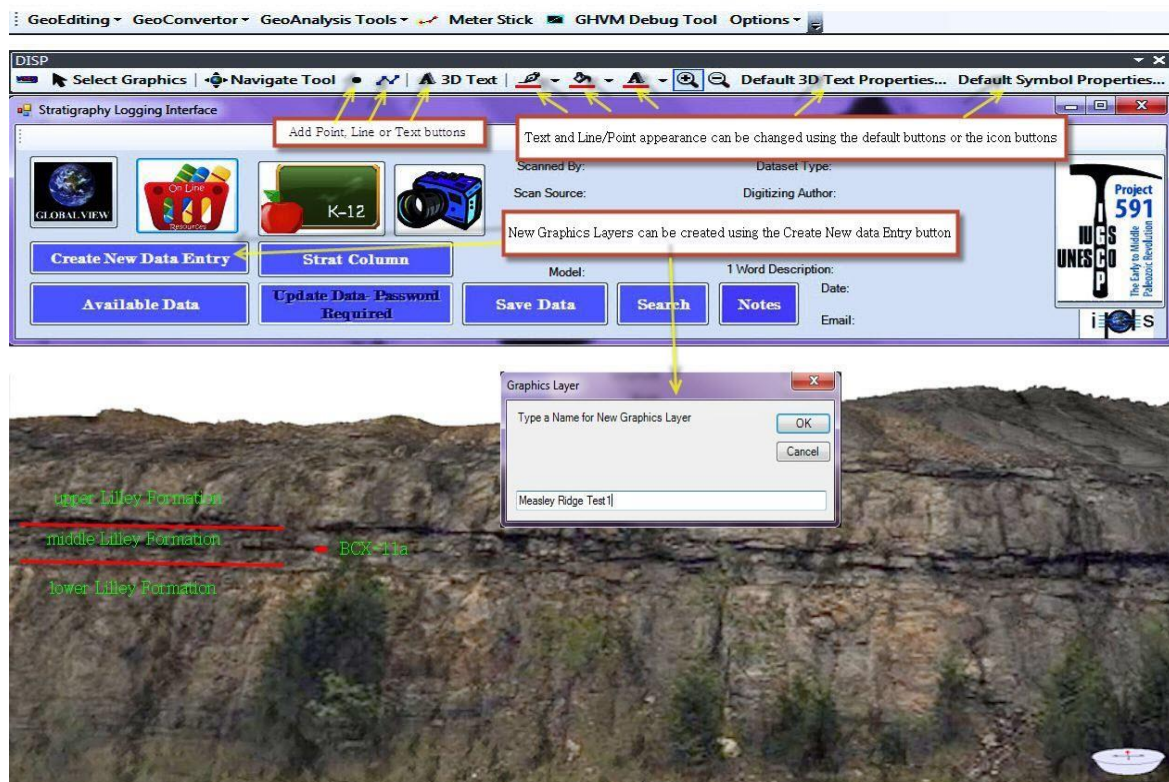


Figure 2.6. After selecting 'Create New Entry', the user names and creates a new Graphic Layer which contains all the digitized data. User can add text (shown in green), points and/or lines (shown in red) in 3D as well as personalize their color/size through options available on a customized tool bar.

2.5 Long-term data solutions

As each stratigraphic end-user logs onto the system, they will be asked to create a unique password associated with their email address, which will serve as their user ID. The password will then be required to make any changes to previously loaded information to ensure data integrity within the system. Multiple user ID's will be able to access a given data set, at the data initiator's request, to allow for a working group to make changes during a field campaign. Data logged onto the system will be made public immediately, unless otherwise requested by end users. The ability to 'embargo' the release of logged data for a given length of time will be included but details regarding the length of time allowed are still being worked out. The objective of this system is to make stratigraphic data accessible for the geologic and non-specialist community and the sharing of information across the community will remain the primary objective of the DISP moving forward. The long-term utility of the Digital Integrated Stratigraphy Project will rest on our ability to find a permanent home and host for the online system, and several options are currently being considered. The DISP will require a permanent 'behind the system' presence to ensure continuity and consistency of data and represents the next challenge to the development of the DISP.

2. 6 Summary

This paper presents an update on Development Phase II of the Digital Integrated Stratigraphy Project which aims to integrate virtually any type of geologic/stratigraphic data into a visual, digital, cross-referenced system built upon 3D photorealistic models of outcrops. This graphic user interface (DISP Tools) is an innovative digital workspace which will form part of a digital library for laser-based surveying and scanning technology such as 3D photorealistic

models and associated paleontological, litho-, bio- and sequence stratigraphy, geochemical, and chemostratigraphic datasets. The development of a web-based open access digital library with various resources (3D models and graphic user interfaces) addresses long-term stratigraphic data management issues by enabling end-users to access the captured outcrops and log their sample positions and/or other notes directly onto the digital model while in the field or office. This information can then be uploaded back to the DISP website as a permanent repository of information available as an unambiguous reference for future comparison.

2.6 Acknowledgements

This work is a contribution to the International Geoscience Programme (IGCP) Project 591 – *The Early to Middle Paleozoic Revolution*, and was supported by grants from the National Science Foundation (NSF) to BDC (#EAR-0948277) and to CLVA (#'s 632050, 632102, 651529, 632402). Initial funding of the DISP Develop Stage I was provided by a grant from the Deutsche Forschungsgemeinschaft (DFG) #Mu 2352/2. This paper was published in *Stratigraphy* and is available as:

Michelle Iris Rodriguez-Gomez, Bradley D. Cramer, Brian Burnham, Miao Wang, Lu Chen, and Carlos L. V. Aiken. The Digital Integrated Stratigraphy Project (DISP) Development Phase II: On-site 3D access, analysis and integration of stratigraphic data using PCs and 3D Photorealistic Models, *Stratigraphy*, vol. (4), pg.255-260

CHAPTER 3

DEMONSTRATION OF USING GRAPHIC USER INTERFACES AS TUTORIALS FOR UNDERGRADUATE GEOSCIENCE COURSES

3.1 Summary

Geoscience professors are faced with the challenge of teaching abstract Geoscience concepts to students who learn best in the concrete plane (with objects and materials that can be held and manipulated physically). Many of these concepts taught in lecture and lab are not fully understood until the student is in the field (Abdelsalam, et. al 2010, Boese, M.J, et.al. 2009). Yet, once there, it is a daunting feat to know what one is looking at and hoping to identify. Field sites provide a wealth of knowledge of complex geology and spatiotemporal scales. One to two days in the field, while helpful, do not provide enough time for the student to integrate and process the information. Integrating graphic user interface technology into teaching can bridge learning in the lab and learning in the field.

The graphic user interface uses 2D imagery obtained from high resolution, centimeter-scale 3D photorealistic models and provides further learning opportunities for the students who will access it outside of the classroom. They will be able to review data and images of the area. Supplementing current teaching methods through technology integration takes students to higher levels of engaged learning; thus, enabling their integration of geologic information into a coherent conceptualizing of Earth's processes and structure.

3.2 Introduction

Conventional geology can be enhanced by incorporating an alternative technique that combines reflector-less laser rangefinders or high-speed terrestrial laser scanners, GPS and the ESRI ArcGIS software platform (Alfarhan, et.al.2008). The laser gun was shown to be a simple, portable, and cost-effective approach; making it ideal for use in research and educational settings. The construction of 3D models with terrestrial laser scanning are being applied to sedimentary geology, engineering, structural geology and undergraduate geoscience education (Aiken et.al. 2008). In order to help students' understand and work with geologic concepts, GIS is being introduced and utilized in undergraduate courses.

Other research by Durbin (2002), Greer et.al. (2004), Thoen (1994), Butler (1994), and Johnson et.al. (2006) suggests that the internet and other technologies like GeoWall are vast and potentially valuable mediums for the geoscience professional to use for decimation of information to students. Durbin (2002) states "lecture style teaching limits student access". Information made accessible via internet in combination with available technology can vastly improve grades and interest in the geosciences field. The development of graphic user interfaces for tutorials serves as an aid to reach students and enhance learning of key concepts.

3.3 The Arbuckle Hills Anticline

The geologic complexity surrounding the Arbuckle Mountain region provides diverse and accessible geologic features for studying. Granitic rock exposed in the Eastern Arbuckle Mountains has been dated to 1400+ million years ago.

These were uplifted and eroded. Plate movement in southern Oklahoma began a rifting that caused a northwestern zone of weakness (the Southern Oklahoma aulacogen). Two separate

volcanic episodes produced rugged, low relief topography. These were eroded for the following 10-15 million years resulting in low hills reaching a few hundred feet. This low landscape flooded with marine waters from the south. During this time the rift valley and the uplifted areas remained fairly the same geologically. Within a few million years the shoreline migrated north and exposed a broad stable platform for carbonate deposits. Inside the aulacogen, the sediment is double that of the area surrounding it. Three hundred and fifty million years ago, the sediment ended, and a deposit of shale was introduced. This period marks a significant change in the geology between the rift and the shelf. Southern Oklahoma begins to experience significant structural deformation around 320 million years ago resulting in the aulacogen being compressed. Zones were uplifted as a result but rapidly eroded and deposited the debris into adjacent subsiding basins. As the plate movement ended, Oklahoma stabilized, and the sea retreated; leaving behind an eroding desert landscape. The geology after all the deformation is dominated by clastic redbeds (the result of uplifts and deposits by fluvial and eolian processes). The geologic record is unknown from the redbeds until Oklahoma again becomes covered by sea (Denison, R.E.T., et.al, 2004).

The 3D photorealistic models are accurate to centimeter scale with a portion of it at sub-centimeter scale. This will provide morphological detail at different scales within a single model. See Figures 3.2 and 3.3 for Google Earth imagery of the study area.

3.4 Physical Geology tutorial interface (PGT)

These three interactive graphic interfaces are developed using ArcGIS ArcMap software and VB.Net programming. The introductory level reinforces basic geologic concepts (Figure 3.1). The user can click on imagery of various sections of the 3D photorealistic model and obtain

definitions and an explanation of the geology being showcased in the photograph. It is designed to introduce geologic concepts through imagery to engage the learner more actively.

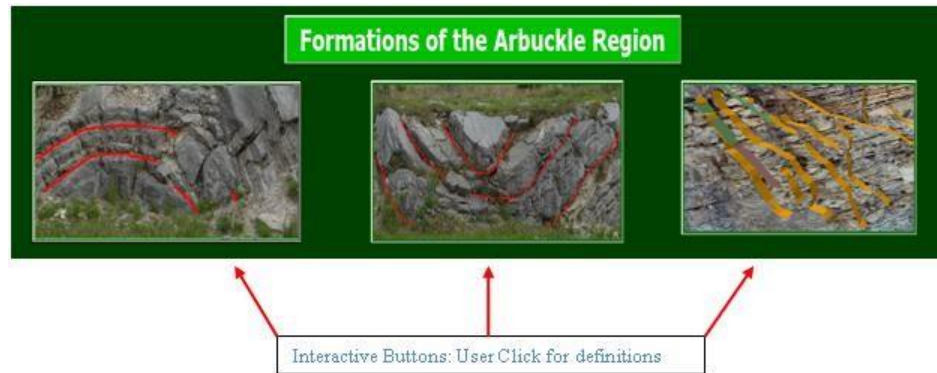


Figure 3.1. PGT interface number 1 is for an introductory (novice) level

The intermediate level contains two detailed descriptions of the geology and interpretation of the geology. This interface allows for more interaction and analysis of the geology being presented (Figure 3.2). The user can learn more in depth information about the geologic formations in the Arbuckle Hills region. Each interactive button provides detailed information of each formation.



Figure 3.2. PGT interface number 2 is the intermediate level and allows the user more interaction and analysis

The advanced (research/world application) level is designed to function as a digital field notebook. This level will allow the user to do analyses in the field or lab and includes an area for notes to be taken and saved to a separate file (Figure 3.3). The user has the option of picking a formation from a drop-down menu and can input any pertinent information about it in the 'Data Input' section of the interface. This data can be saved to a .txt file for later reference. By clicking on the buttons labeled with each formation name, the user can obtain geologic data about the formation such as thickness and Strike & Dip.

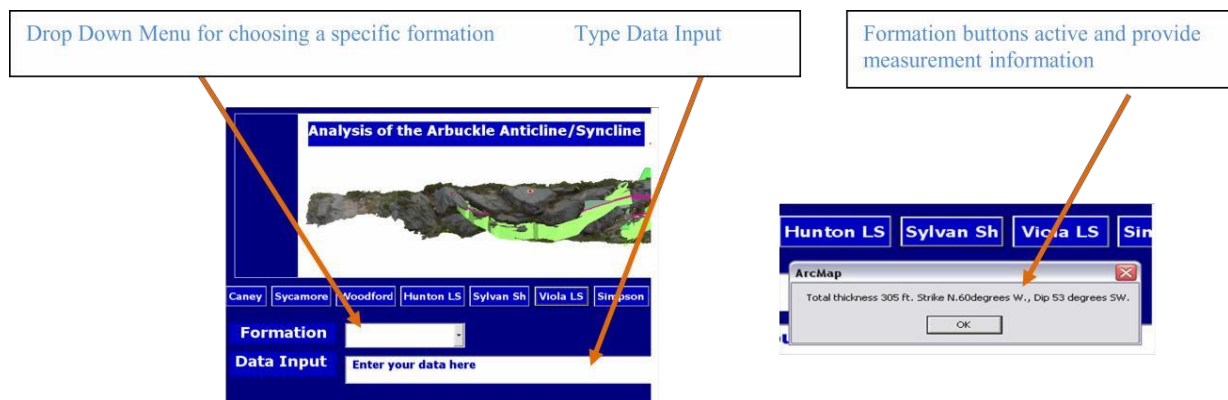


Figure 3.3. PGT interface 3 is the advanced level and serves as a digital field notebook

3.5 Educational Applications

Bronack, et. al. (2008) argue that proper pedagogy must be maintained in the implementation of any new technology into an educational setting. In order to avoid the technology from taking over the learning it must keep students active, constructive, collaborative, intentional, contextual, conversational, and reflective. White, et.al. (2010) developed a means of using 3D photorealistic geologic models in the ESRI ArcGIS ArcScene environment. These software tools enable the detailed analysis of geological outcrops that are

inaccessible to the geologist, but which can be captured by the LiDAR scanner and make the use of 3D models effective for use in educational settings.

Virtual learning environments provide new possibilities because today's students are exposed to a variety of computer environments and can harness the technological advancements with minimal effort. The potential of 3D virtual worlds in both traditional and distance learning was explored by Dickey (2003) suggesting that learning no longer remains confined to the walls of a classroom.

An instructor can use technology to provide a better understanding of the concepts being presented. Research showed that students can identify a geologic feature in one photograph but are unable to do the same in another photograph or in the field (Durbin, 2002). Students need to relate their previous knowledge with their newly acquired knowledge in order to retain it. Most Introductory Geoscience courses are very large and getting abstract concepts such as those essential to understanding Geology are difficult to teach in large scenarios (Hall-Wallace et.al. (2002).

Using traditional teaching methods to teach science to non-science majors is proving to have limits of effectiveness. More recent teaching models stress active student participation. The implementation of graphic user interfaces into geoscience courses can help the student relate their in-class learning to learning in the interactive interface. The multiple 'virtual field visit' can help eliminate the lack of geologic learning retention.

3.6 Discussion

PGT is intended to be supplemental material for existing curriculum in area junior colleges and UT Dallas undergraduate courses. It includes an integrated dataset of the Arbuckle

Mountain Region in Oklahoma. The interactive graphic user interfaces (GUIs) and images from the 3D virtual models of geologic outcrops highlight significant geologic features. *PGT* is divided into three levels for Physical Geology-introductory, intermediate, and advanced (research/world application). The introductory level reinforces basic geologic concepts. The intermediate level contains more detailed descriptions of the geology and includes instructions for interpretation (measurements and plane identification) by the user. The advanced (research/world application) level contains detailed data obtained in the field for the user to use as well as an area for the user to take notes and which are saved to a separate file.

CHAPTER 4

DEMONSTRATION OF USING TOOLS FOR THE ANALYSIS OF 3D VIRTUAL MODELS IN THE CLASSROOM INCLUDING THE RAMSAY FOLD CLASSIFICATION

4.1 Introduction

The Ramsay Tool (*RT*) is an interactive analysis tool which operates in ArcGIS's ArcScene (3D) and ArcMap (2D) software using 3D photorealistic models and GHVM GeoAnalysis Tools (GAT) to virtually mimic field exercises to include various geometric analyses in the classroom. The tool is designed for use in undergraduate Geoscience courses. To minimize the need for extensive software operation knowledge, graphic user interfaces were created to make the analysis more accessible to a wider audience.

Using 3D photorealistic models and customizes GUI tools allows for viewing of geology at multiple angles. For example, relative to the hinge of a fold and accurate geometric measurements made with digital tools as required for the Ramsay Fold Classification. Virtual models are not intended to replace field geology but allow a simulated interaction with an outcrop not readily accessible or for visiting a site before and revisiting it as needed afterwards. Since the exercises are digital all results can be archived for review. *RT* demonstrates the advantages of using georeferenced high-resolution 3D photorealistic models to teach geology.

4.2 The Arbuckle hinge zone

The Ramsay Fold Classification methodology was chosen due to the fundamental concepts associated with identifying fold types. After a completed run through of the *RT*

interface, the user has a better understanding of the Ramsay Fold Classification system and the geometries associated with the it.

The 3D photorealistic model developed for *RT* uses point cloud data and overlying distortion free digital photographs of the Arbuckle Hills Hinge zone, OK. (Figure 4.1).

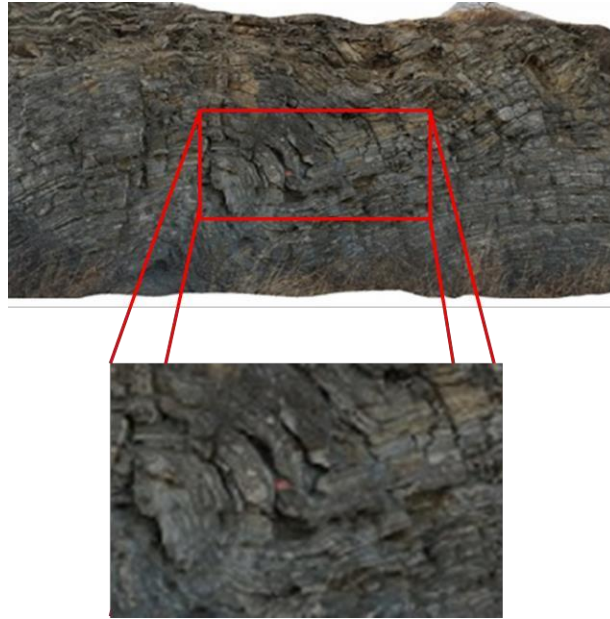


Figure 4.1. Screen shot image of the Arbuckle Hinge zone with close-up insert of the hinge

The 540-million-year-old Arbuckle Hills in Oklahoma are about 35 miles (56 km) east-to-west and 10–15 miles north-to-south (Figure 4.2 and Figure 4.3). The primary structure of the area is a doubly-plunging, NW-trending anticline. The core of the structure consists of Proterozoic extrusive and intrusive rocks, dominated by the Colbert Rhyolite followed by the Upper Cambrian limestone and dolomite of the Timbered Hill Group and the Butterfly dolomite. It is overlain by the almost horizontal Pennsylvanian-age Collings Ranch conglomerate, which form an angular unconformity. The Arbuckles are thought to have originated along an aulacogen in the Precambrian basement that was uplifted and folded during the Ouachita Orogeny.

The 3D photorealistic models of this area are accurate to centimeter scale. They were developed from TLS (terrestrial laser scanning) and digital photographs of two sites in the Arbuckle Anticline in southern Oklahoma (See Wang, et.al. 2012 for model development details). A portion of the model is sub-centimeter scale and was generated from close range stereo-photogrammetry. This will provide morphological detail at different scales within a single model.

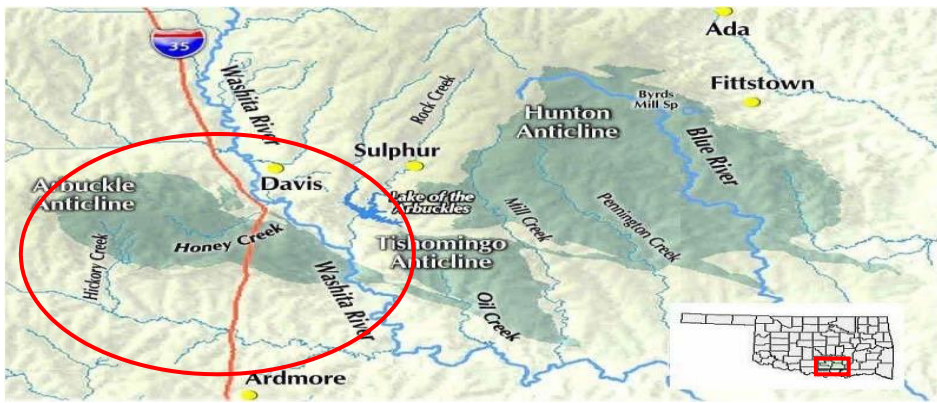


Figure 4.2. Google Earth map of the Arbuckle Hills and surrounding area; insert is a map of Oklahoma with the Arbuckle Hills area marked off



Figure 4.3. Google Earth satellite imagery of the Study Area

4.3 Ramsay Fold Classification

Before John Ramsay first developed the current standard for classifying a fold, there was a more simplified method used in the field which limited the geometry of a fold to either Similar or Parallel. In a Parallel fold, the orthogonal thickness (t), remains constant throughout the fold and is generally found in sedimentary layers. Whereas, a Similar fold, the variation of thickness between the limbs and the hinge differ, with more thinning in the limbs. This was the accepted classification method amongst structural geologists until 1967 when Ramsay proposed a new model for fold classification based on a continuum of folds stating that a fold could start developing as a Parallel fold, be altered, and ultimately end in an intermediate area, or a Similar Fold. Ramsay's method describes a more accurate and quantitative way of measuring a fold based on the layer thickness variations of orthogonal thickness (t), and Axial Surface Thickness (T), in relationship to the Hinge thickness (t_0) or, Axial Surface Thickness (T_0) classification (Ramsay, et.al., 1984).

In the Ramsay Fold Classification method, the style of the folded layer is determined by comparing the fold styles of the two surfaces (upper and lower) of the layer. Folds fall into one of five categories, based on the behavior of the dip isogons (Figure 4.4). Dip Isogons are defined as the line across the layer connecting two points of equal dip on opposite surfaces of the layer (Twiss, et.al., 1992) (Figure 4.5).

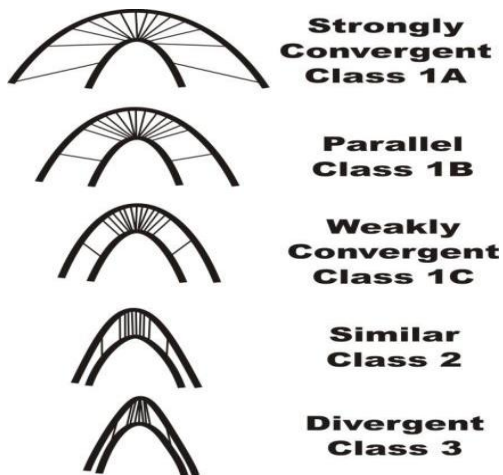


Figure 4.4. Ramsay's classification of folded layers

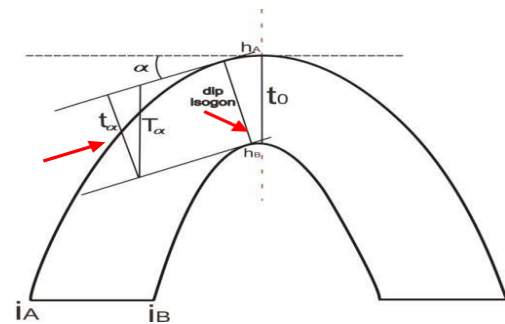


Figure 4.5. Folded layer with dip isogon and orthogonal thickness identified by red arrows

To classify folds using layer thickness variation, the Ramsay Fold Classification method uses the ratio between the Hinge measurement ($t_0 = T_0$), and the Axial Surface (T_α) or the Orthogonal Thickness (t_α) measurement, in relation to the change of dip angle. Orthogonal thickness is the perpendicular distance between the two parallel tangents (Twiss, et.al., 1992) (Figure 4.5). When the value of the t'_α has been calculated you can then plot the solution on the chart labeled t'_α (Figure 4.6). If you were measuring axial surface thickness you would use the appropriate chart for T'_α (Figure 4.6). A value needs be calculated every ten degrees and plotted on the appropriate chart.

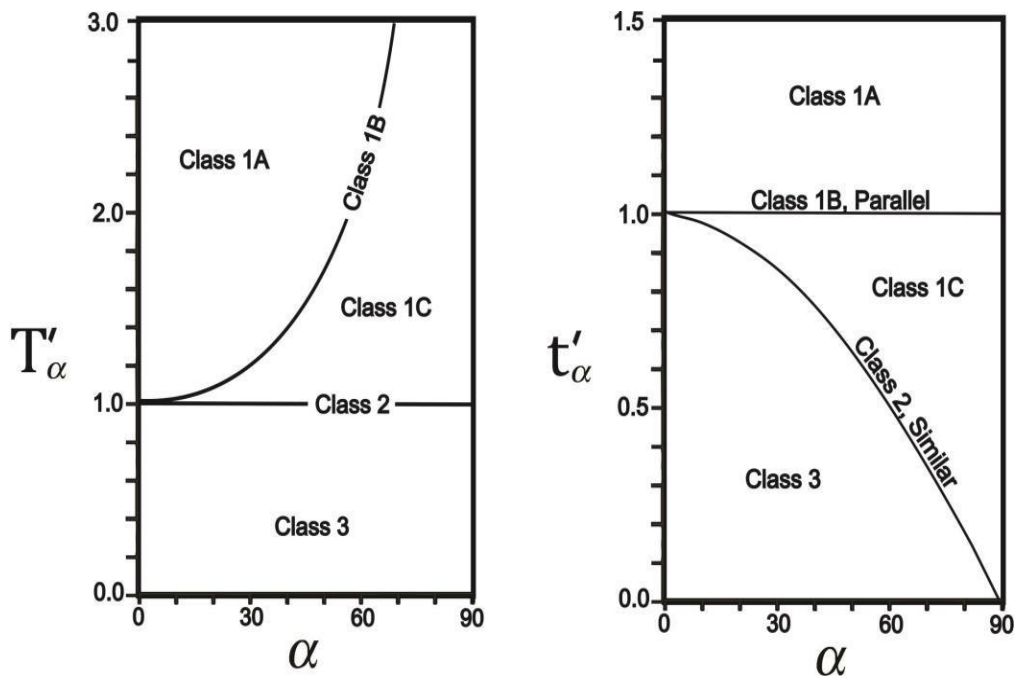


Figure 4.6. Plotting charts for T'_α and t'_α

The importance of the geometrical classification of fold morphology lies in the ability to express and identify strain, compression, flexure-slip, and slip mechanisms as they relate to the fold being studied. The identification of these key features helps to identify any tectonic environment present during the process of fold development. Important information such as amount of deformation, shear stress, and rheology (manner of matter flow) of the folded layers can be obtained from studying folds but the accuracy of the data depends on the accuracy of the individual performing the analysis. *RT* helps the user practice performing a fold classification much like is done in the field-with one exception and advantage; The user can rotate the outcrop relative to the hinge using the 3D photorealistic model unlike an actual outcrop in the field.

4.4 *RT* graphic user interface

The customized graphic user interfaces for the Ramsay Tool was developed using Microsoft Visual Studio 2010 and runs as a standalone interface on the Microsoft Windows platform. It was demonstrated at the Geological Society of America Annual Conference in Denver, CO, 2013.

This tool combines operations performed in three dimensions in ArcGIS' ArcScene software as well as two dimensions when using the CorelDRAW component of the interface. The ESRI ArcScene component requires access to ArcGIS software but minimal software know-how. Step-by-step instructions are provided to take the user through the process (See Appendix B, D, E, and F for instructions on installing Add-Ins, the Ramsay Tool, and CorelDRAW, respectively).

Upon clicking on the Ramsay Tool (*RT*) icon, the graphic user interface window opens (Figure 4.7). The window displaying contains 10 tabs of instructions, images, area for calculations and options to save, links for an online stereonet table (Figure 4.8) (Allmendinger, 2011) and a how-to video.

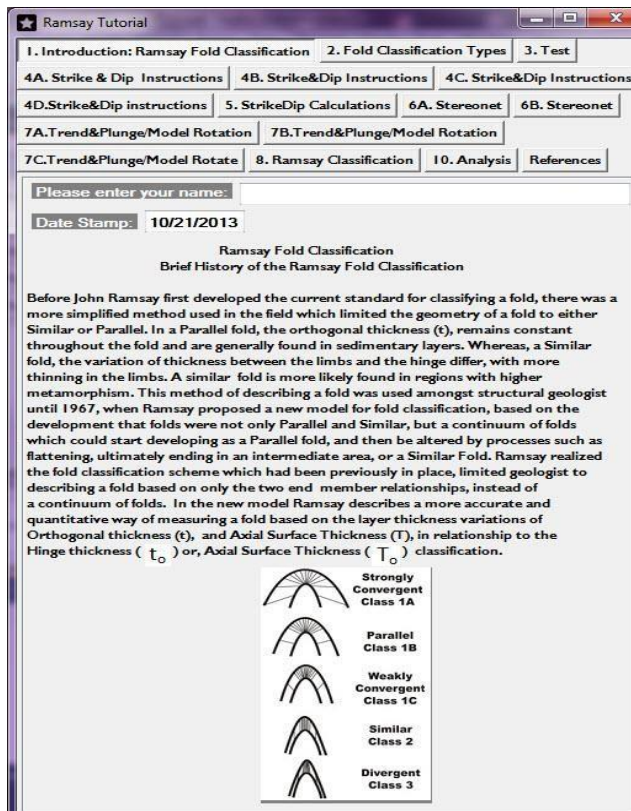


Figure 4.7. RT interface initial view

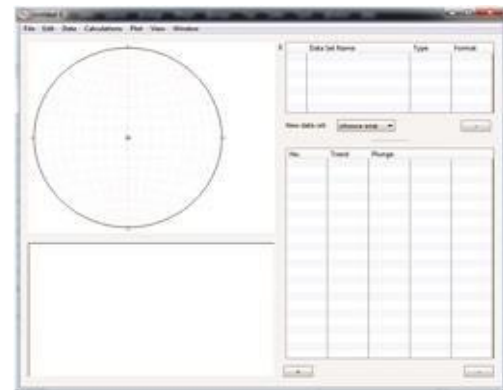


Figure 4.8. Online stereonet program

The first two tabs provide the user with a brief overview of the Ramsay Fold Classification method and fold types while the third tab is a short quiz. The user proceeds to perform various Strike& Dip exercises directly on the 3D model in ArcScene using GeoAnalysis Tools (Figure 4.9). The measurements are inputted into a table (Tab #5) along with a description of each and saved into a text file. This text file is later imported into the stereonet program. The user leaves ArcScene to work on calculations required for further analysis.

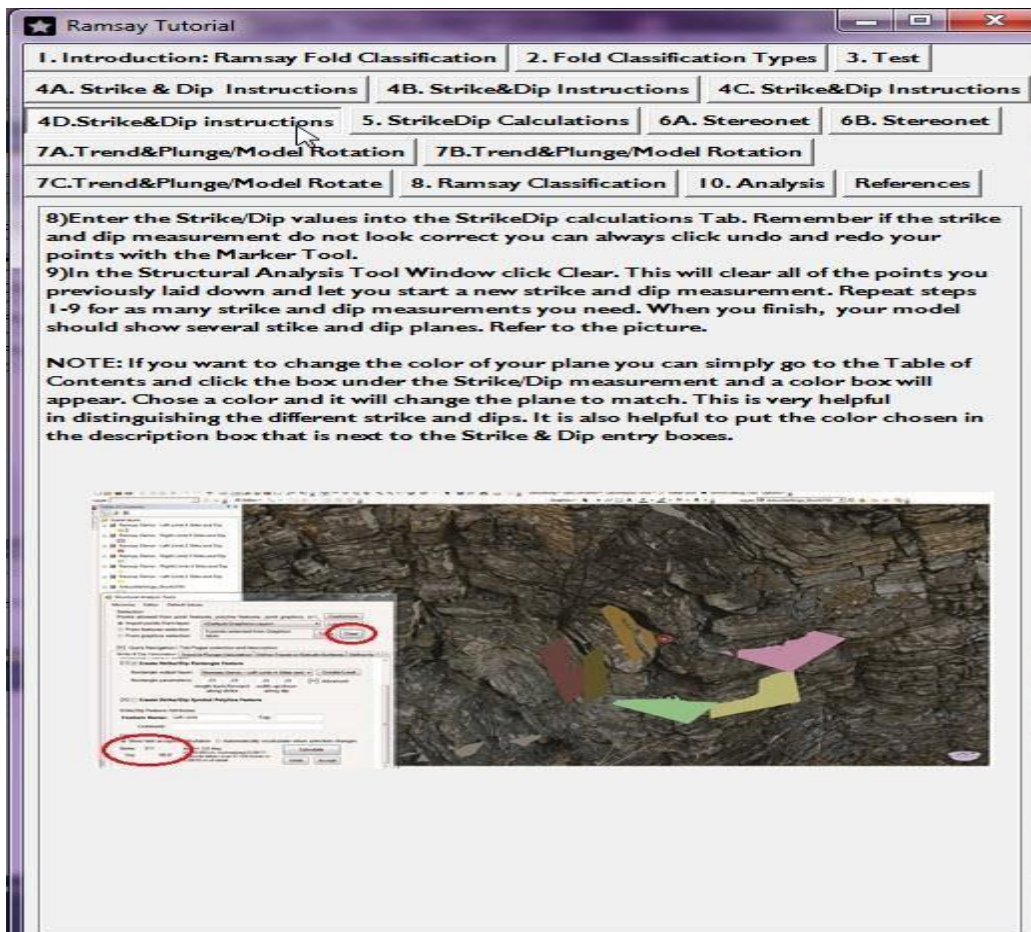


Figure 4.9. Image of a Strike & Dip tab with instructions and corresponding image

Upon completing the work in 3D, the user proceeds to open the stereonet program and imports the .txt file in order to calculate the Trend & Plunge value. Instructions for importing, labeling, and calculating are provided in the RT tabs (See Appendix E for instructions on using the stereonet program). After the Trend & Plunge calculations are completed, the user returns to the RT window and works on the 3D model in ArcScene once again (Figure 4.10). The user needs to create the Trend & Plunge line and rotate the model in order to be ‘looking down the hinge’.

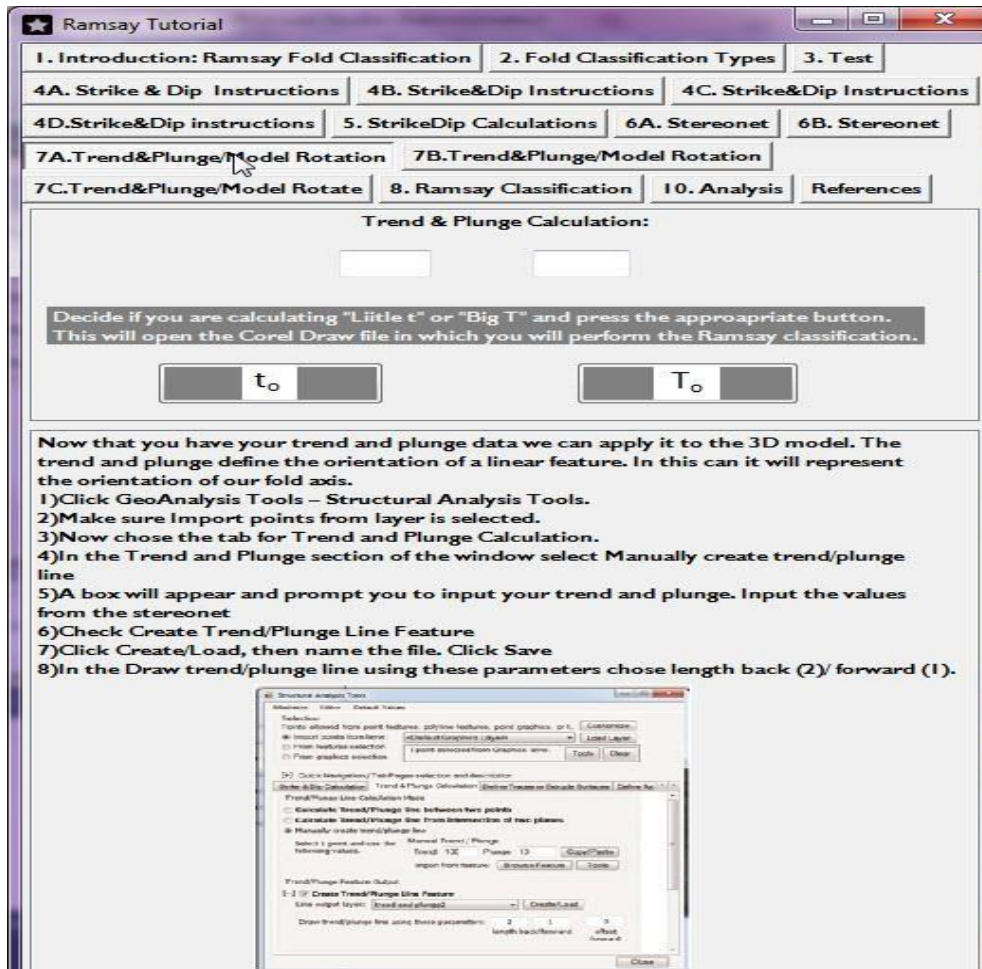


Figure 4.10. Trend & Plunge tab with instructions and choice of t_o or T_o buttons to open CorelDRAW

A screen shot is taken of the rotated model for later use in CorelDRAW. In order to determine the fold type, the user will need to calculate a value every ten degrees. These values are put into the boxes (Tab#8) and saved. These results are plotted onto the corresponding plotting chart-refer to Figure 3.6 for plots. In CorelDRAW the user can use a virtual scale and custom transparent contractor to measure every ten degrees and determine the value between the two-fold layers (Figure 4.11)

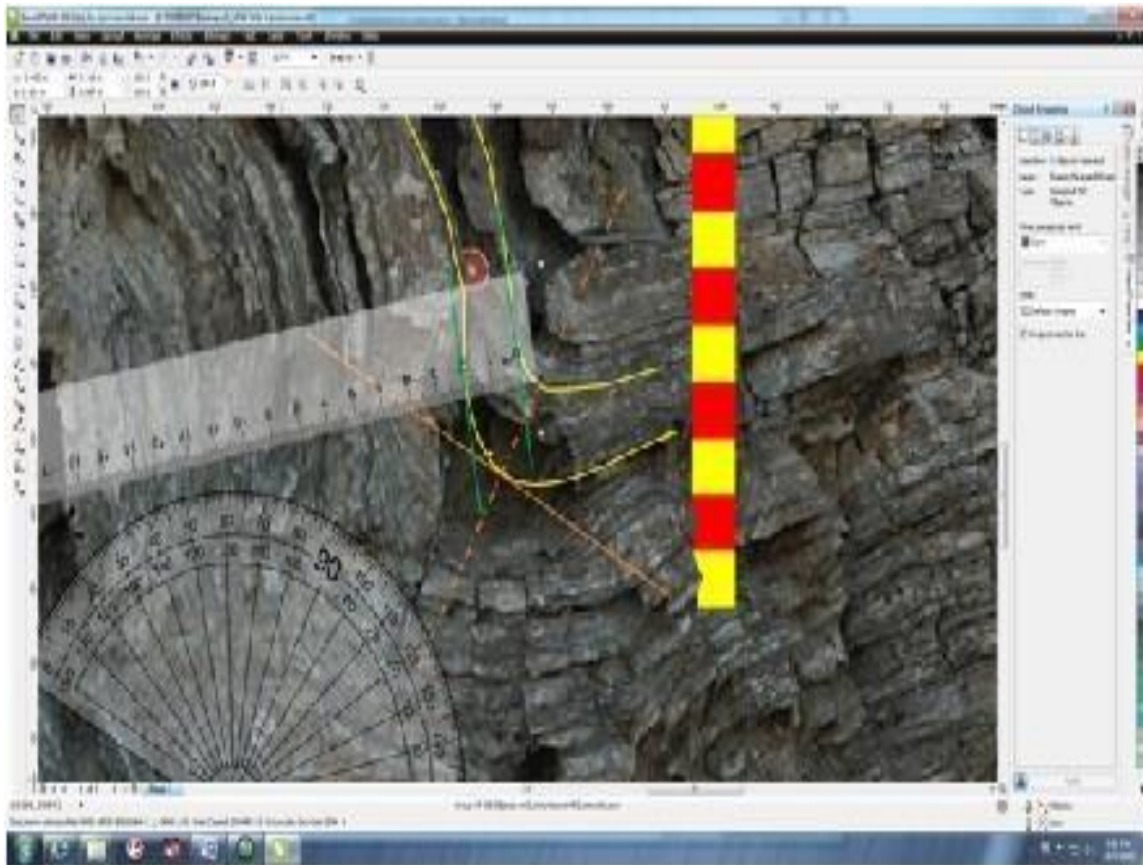


Figure 4.11. Screen shot of user calculating measurements every ten degrees using a custom scale and protractor

Once the plot is completed, the user can determine which type of fold they are viewing (Class 1A, 1B, 1C, 2, or 3)-refer to Figure 3.4. The final step in *RT* is for the user to input a brief description of the fold analysis performed. This information is also saved into a file with all the calculations performed. Below is the workflow for the development of a customized graphic user interface.

Workflow for graphic user interface (GUI) development:

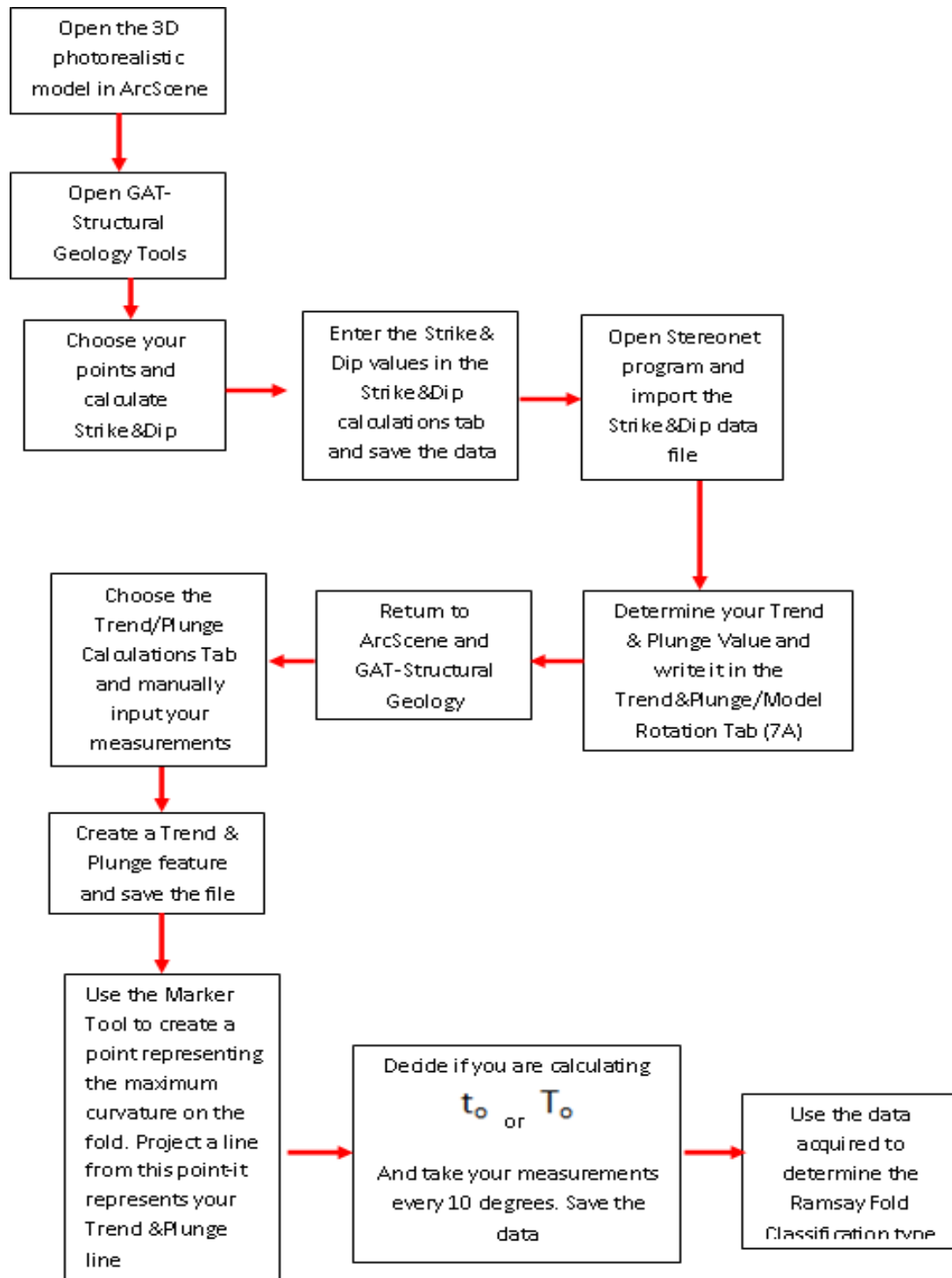


4.5 Educational applications

RT uses a 3D model of the Arbuckle Hills Hinge zone to explore geology virtually in preparation for a field visit. Students with the ability to digitally interact with the outcrop gain ‘hands-on’ experience that otherwise would not be available unless on site at the outcrop. They can run through the classification exercise multiple times at their own pace in order to grasp the concept of fold classification. Using a 3D model of the outcrop they are about to visit or are viewing in person exposes them to more opportunities for quantitative analysis and deeper understanding of the geology. It also helps eliminate ambiguous results. 3D models, unlike actual outcrops, can be rotated perpendicular to the hinge and measured digitally for classification.

Having explored the field site virtually prior to the visit focuses student attention and creates opportunities-teachable moments in and out of lab and lecture. “Teachable moments” in the field are opportunities for the dissection the geology at hand in an effective, visual manner. A field visit for an undergraduate course entails discussion at the site, notes and possible photographs taken, measurements, and collecting samples. *RT* enhances classroom scenarios before (virtual field trips), during (expanding teachable moments) and after (review and analyze) by creating opportunities for more in-depth analysis of the geology and make field time more effective.

A workflow of the Ramsay Tool is illustrated below:



4.6 Discussion

RT is designed to serve as a resource in the lab setting of an undergraduate structural geology course and mimics in-field calculations. These would include various geometric analysis using software built around ESRI ArcGIS-ArcScene and ArcMap as the platform. GIS type software can be intimidating so GUIs are used to create more accessible tools. Using such models and tools, the geology of the outcrop can be viewed from any angle. For example, relative to the hinge of a fold, and accurate geometric measurements made with the digital tools such as required for the Ramsey fold classification. Virtual models are not intended to replace field geology but to allow a simulated interaction with an outcrop not readily accessible or if accessible for use before and/or after visiting the site. Since the exercises are digital, all results can be archived for review by students and instructors. *RT* demonstrates advantages of using georeferenced high-resolution 3D photorealistic models to teach geology. It is not always time or budget efficient to visit every field site available to thoroughly teach the geologic concepts of structure. The integration of 3D technology provides professors and students the opportunity to participate in ‘virtual field trips’ during lab, prior to and after actual field trips. This, in turn, can facilitate the development of the student’s field ability.

CHAPTER 5

THE IMPLEMENTATION OF DEVICES FOR THE FIELD (D4F) FOR PERFORMING 2D ANALYSIS AND DISPLAYING IN 3D STEREO

5.1 Summary

Devices for the Field (*D4F*) is a case study performed in Ohio for research purposes and in Dallas for educational purposes to test the integration of distortion free photographs of previously developed photorealistic models into field analysis of Silurian stratigraphy and Proterozoic structural geology features. Users working in small groups (2-4 people) analyzed and annotated the geology of Measley Ridge, OH and the Arbuckle Hills anticline, OK using an iPad with preloaded, distortion free photographs of the site. Once the work had been performed, the photographs were emailed to a specific email address which had been set up for the project. These new versions of the photographs were then converted and set up for use in an original MATLAB code which extracts the color pixels and allows them to be displayed in 3D stereo using open source software. More detailed information is provided in Wang, et.al. 2012.

5.2 Introduction

Tablet integration into field work is an effort to expand the analysis of field work in lab and research efforts. This project includes the utilization of an Apple iPad which allows users to access a photograph of a previously produced 3D photorealistic model of an outcrop in order to log geologic data directly onto the photograph. The ability to interact with a 3D photorealistic model of an outcrop via a distortion corrected photograph in the field or lab provides multiple opportunities for analysis of the geology being examined and provides long-term data archive

capacity. Devices for the Field (*D4F*) provides an interaction with complex real-world geologic occurrences on digital outcrop via a light weight, relatively inexpensive piece of equipment. Tablets are an engaging resource for the analysis of geologic phenomena. *D4F* was field tested with photographs of the Silurian stratigraphy of Measley Ridge, Ohio at the IGCP 591 2nd Annual Meeting and 1st Foreste Symposium in July 2012 and with photographs of the Pennsylvanian Arbuckle Hills anticline exposure, OK and in October 2012 at the GSA annual meeting in Houston, TX.

Devices for the Field (*D4F*) is an interactive digital platform integrating tablet technology with photographs to access the geology of 3D photorealistic models in a 2D realm. The accumulation of multiple types of geologic data from a single outcrop section can take an exuberant amount of time and money. These obstacles often limit the level of certainty of the collected data sets which translates into limited use of said datasets. *D4F* is a project that enables multiple visits to the field without the need for travel into the field and can simultaneously increase the efficiency of field work. Through *D4F*, the users can interact with the digital outcrop and log data, write short/concise notes, and annotate to gain geologic insight. *D4F* provides access to view and interact with the photographs of a previously produced 3D photorealistic model and email the annotations to a central email address.

These annotated photographs undergo a conversion process which enables them to be used along with a MATLAB code (See Wang, et.al. 2012) and be projected onto a 3D model which is then displaced in 3D stereo using open-source software.

5.3 Research applications

Scientists in fields such as stratigraphy, metamorphic geology, sedimentary geology, physical geology, and structural geology perform field analysis such as lithostratigraphic boundary distinction, morphologic changes due to heat, grain size analysis, fault identification and fold classification, while annotating notes in field using traditional paper-based approaches. A lithostratigraphic boundary distinction exercise was performed by conference participants using digital technology during the conference field trip to Measley Ridge (Figure 5.1).

After field analysis, the digital photographs were processed and viewed in 3D stereo. The increased accessibility to collaborate amongst the groups provided opportunity for qualitative analysis of the data collected. The group or individual were distinguished by a different color 3D marking on the 3D model allowing for easier identification of data and open discussion of the results.



Figure 5.1. Google Earth View of Measley Ridge, OH outcrop

The ability to collect data on site in an efficient, low-cost manner such as through *D4F* embraces the use of technology beyond the lab and expands the options of data collecting while helping reduce ambiguity created among multiple datasets in one or more collections (Figure 5.2). This approach is designed to provide easy interaction and quantitative data extraction from existing virtual models.



Figure 5.2. Outcrop (Measley Ridge) which has been digitally annotated on a tablet

The portability feature of *D4F* enables users to interact easily with an outcrop while in the field and send quick updates back to the lab for later use. This system is not a field geology logging and mapping system like the two mentioned in Chapters 2 and 3 but serves as an additional resource for field work.

5.4 Educational applications

Field trips to visit geologic outcrops can be time consuming, costly, and at times inefficient due to various factors such as student to teacher ratios, travel arrangements, and inadequately prepared students (as in the case of non-majors conducting a field visit for the first time). The integration of technology such as a tablet through systems like *D4F* into ‘virtual field trips’ during lab, prior to actual field trips, facilitates the development of the student’s field ability (Figure 5.3).

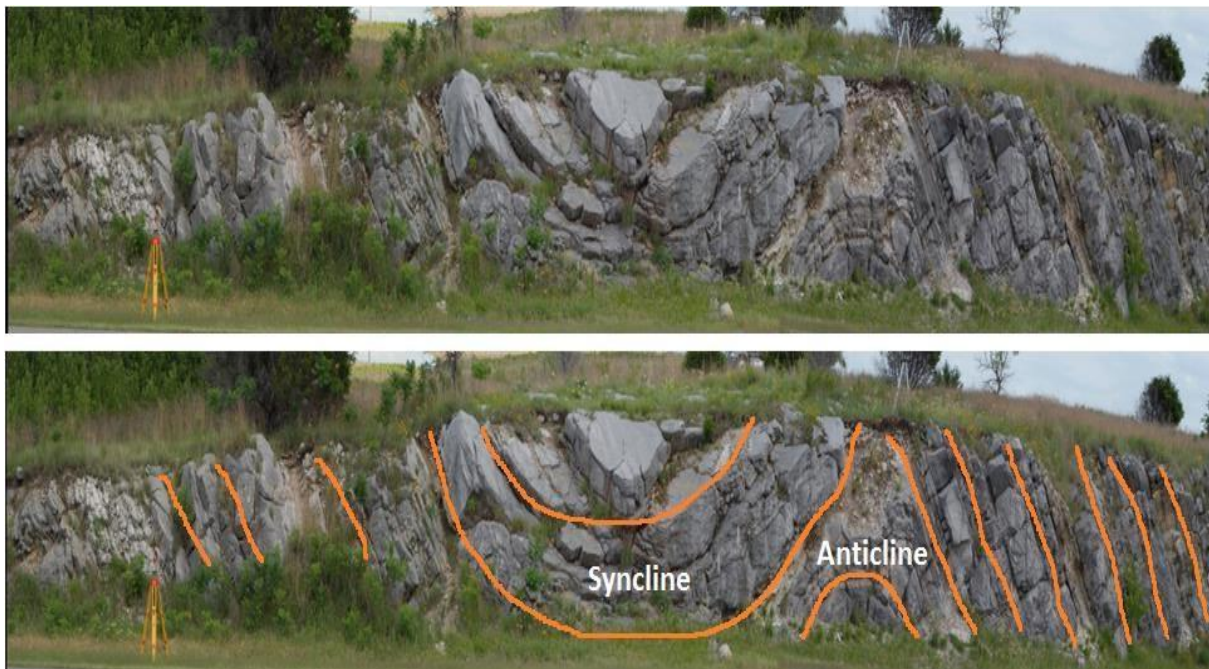


Figure 5.3. Digitized view of the Arbuckle Hills anticline and syncline used in lab as preview for a field trip



Figure 5.4. Google Earth view of the Arbuckle Hills, OK; insert of iPad with digitized view of the Arbuckle Hills anticline.

D4F using a 3D model of the Arbuckle Hills anticline is used in an undergraduate geoscience course to explore geology virtually in preparation for a field visit (Figure 5.4). Students with the ability to digitize and annotate their observations directly onto a photograph that correlates to a 3D model of the outcrop they are about to visit or are viewing in person are exposed to more opportunities for quantitative analysis and deeper understanding of the geology (Figure 5.5).



Figure 5.5. Professor conducting lab preview of an outcrop prior to visit using an iPad with students interacting and digitizing

Student to professor ratios are also addressed with *D4F*. Having explored the field site virtually prior to the visit focuses student attention and creates opportunities-*teachable moments*-for the professor to interact more efficiently with a group of students via the tablet. *D4F* takes the field trip to a higher level by allowing the creation of digital copies of observations, notes, and findings directly onto photographs of identified areas of interest. It, like the GUI components of this dissertation research, enhances classroom scenarios before (virtual field trips), during (expanding teachable moments) and after (review and analyze) by creating opportunities for more in-depth analysis of the geology.

Utilizing familiar technologies like tablets in preparation for as well as while in field has received more attention and consideration by the geoscience community (educational and research) in recent years. The ability to digitize the geology and make annotations directly onto the photograph that correlates to that section of the outcrop and saving the work for later discussion is an ideal platform for teaching and reviewing geology in undergraduate courses (Figure 5.6).



Figure 5.6. Digitally annotated outcrop (Arbuckle Anticline) used in lab

Integrating tablets with a low-cost document camera for classrooms further expands *D4F*'s utilization in education. Students having their own tablets can access the photograph files and work independently digitizing and annotating. These projects can be shared with the professor or other students by email or in class with the document camera. It is important that the

photographs used on the tablets have been taken with a calibrated camera and have been mathematically related for 3D model development. Therefore, though it is convenient for students to take their own photographs with their tablets for digitizing, those photographs will not serve useful in interaction with a 3D model.

5.5 Discussion

The integration of tablet technologies into field work provides a broader platform for analysis and interaction without the need for extensive software development and expensive system requirements. D4F does not serve as a field geology logging and mapping system but does allow for real time interaction with the geology of an existing 3D photorealistic model. There are limitations which include the need to be familiar with MATLAB, OpenScene Graph (an open source software) and .pdf converters. Though many classrooms today have visualization technology available, specifically a document camera will be needed for whole class display.

Ultimately, *D4F* serves as an additional field resource which provides quick start up, access to internet (if available), touch screen interaction, camera, applets, lower equipment expense, and overall sophistication to responsive field work and interaction with geology in 3D.

CHAPTER 6

CONCLUSIONS AND DISCUSSIONS

Today's world belongs to digital natives who rely on technology daily. The separation of technology and field work can hinder the advancement of analysis, exploration, collaborative interaction, and discovery. Through correct application of technologies such as 3D photorealistic models, graphic interfaces, and tablets, endless possibilities become available in the academic and research realms (See Figure 1.1).

Using 3D photorealistic models provides users with detailed replicas of the outcrop in a digital format. These models make the outcrop more accessible by allowing it to be viewed, inspected, rotated, measured, and manipulated in ways that the actual outcrop cannot be. Graphic user interfaces and tablet integration in the field are providing analytical capabilities when combined with available commercial (ArcGIS platform) and open source software (Open Scene Graph platform) along with GeoAnalysis Tools.

The contributions of this study provide a user more opportunity to perform analysis, interactive collaboration, exploration, interpretation, visualization, research, and study of geologic phenomena. A major accomplishment has been the development of this module which facilitates 2D and 3D digital geologic interpretation and documentation while in the field, lab, or lecture hall. This is accomplished through the integration of 3D photorealistic virtual models with customized intuitive graphic user interfaces and custom designed digital tools.

Two 3D photorealistic models were used for this study. A 3D photorealistic model of Silurian stratigraphy exposure in Ohio was used to log complex stratigraphic data and annotate short, concise field notes, real time collaboration, as well as log imagery of site data such as

fossil and specimen slides. This model was used to evaluate the effectiveness of 3D model use for the reduction of ambiguous data logging and the increase of collaborative interaction within one platform. As a conclusion to the field test, the interface was accepted as an integral part of Phase II of the Digital Integrated Stratigraphy Project (DISP) (See Munneke, et.al. 2012 for more information on DISP).

A 3D photorealistic model of the Arbuckle Hills (the hinge zone), OK was used to test the ability to perform field-like calculations and analysis. The Ramsay Fold Classification Method was the field analysis procedure tested. This model provided morphological detail at different scales within a single model and enabled users to perform higher order geologic analysis, investigation, and classification. A different section of the Arbuckle Hills model (the anticline zone) was used to test the development of digital tutorials for non-science majors in undergraduate geoscience courses. Distortion free photographs used to develop the model were used to integrate geology vocabulary, geologic formation data, and digital field notebooks into a series of three interfaces; each designed to move the user from a novice level to field ready.

Both the sites were used to develop and test innovative methods of interaction, collaboration, research, and exploration. The integration of the graphic user interfaces reduces data ambiguity, allow improved field analysis techniques, and increases geologic knowledge. This study provides significant contributions to digital mapping, unambiguous data logging and analysis of geology using 3D photorealistic models, customized graphic user interfaces, and devices such as tablets. These modules were designed for undergraduate geosciences course. Others can be developed and programmatically designed for the needs of other courses and employee training scenarios for a variety of fields.

APPENDIX A

INFORMATION ON ESRI ADD-INS

Add-Ins are a new method of application extension and customization introduced by ESRI. Once created, they can be installed and shared easily. These can be shared by uploading them to ArcGIS.com or via e-mail and can be installed by copying the file into a well-known folder (for example C:\Users\<username>\Documents\ArcGIS\AddIns\Desktop10.0). Uninstall of the Add-In file simply requires the user to delete the file and updates require the original file to be overwritten. All the necessary components for the Add-In are combined into a single zipped folder. There are three primary components to an Add-In file-the declarative aspect, the programmatic aspect, and the resources (see image below). The Add-In model uses XML to handle many aspects declaratively instead of through the traditional methods approached previously used and components are identified using strings rather than GUIDs.

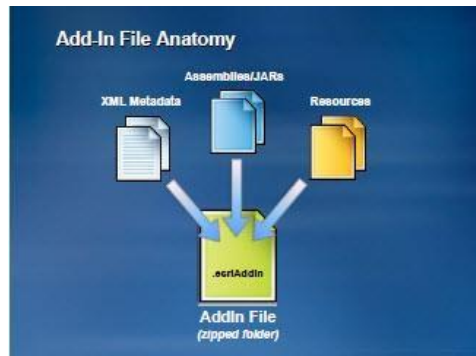


Figure A.1. Add-In File Anatomy

Once an Add-In has been installed, an Add-In Manager window can be accessed. This window shows details about the Add-In, provides the option for deleting it, and distinguishes

between personal and shared Add-Ins (see Add-In Manager image below).



Figure A.2. Add-In Manager Window

An advantage of the Add-In is that there is no longer a need to deal with Component Object Model (COMs). Add-Ins are automatically discovered from well-known folders on the computer or network and become incorporated into the application at runtime. They can be authored in many scripting languages and supported in various development environments including Visual Studio 2008, Visual Studio 2010, Visual C # 2008/2010 Express Edition, and others. There are many Add-In types such as buttons, tools, toolbars, combo boxes, extensions, and others (see extension window image below; the insert toolbar which appears over the extension window is an example of an extension which has been turn on and is available for use on the main program screen). There exit limitations with Add-Ins such as pre-existing dependencies and more restrictive sets of extensibility points.

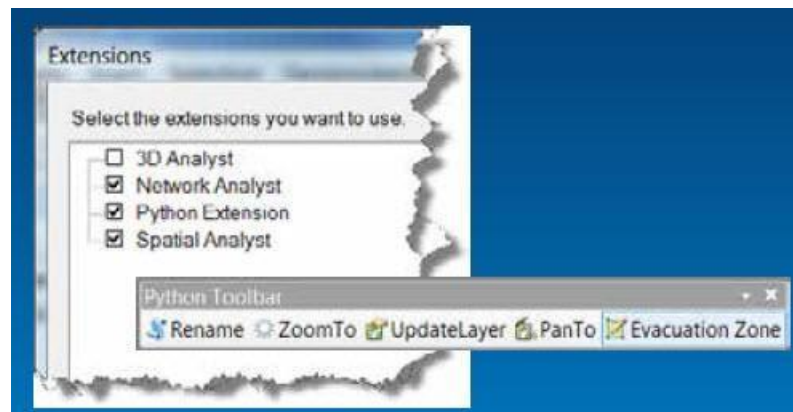


Figure A.3. Extension Window

More detailed information on Add-Ins can be found at ESRI.com.

APPENDIX B

INSTRUCTIONS FOR INSTALLING ADDINS

Once an Add-In file has been downloaded from the network, ESRI.com, or received via an email, it can be installed by double clicking the file and using the Installation Utility or through the *Add From File* options in the Customize tab of the Add-In Manager (circled in red in the image below). They do not require installation software, registration, or administrative rights. These files will either be under the My Add-Ins tab or the Shared Add-Ins tab of the Add-In manager dialog window. The manager window is available by clicking the Customize menu of any ArcGIS desktop application (see image below).

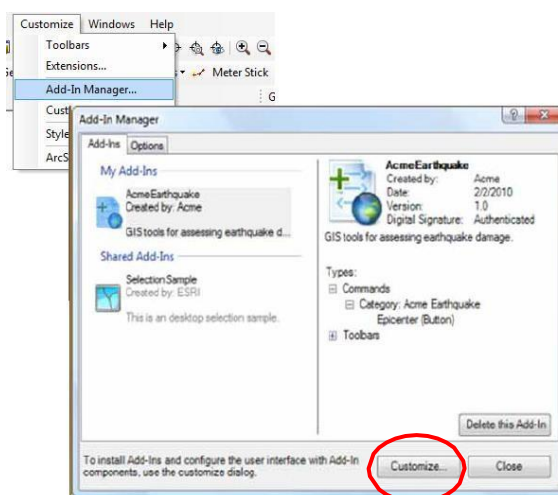


Figure B.1. Customization Menu Window

The manual approach to installing is explained in the following steps.

1. Right click on the Add-In file you have downloaded or received and click Copy.

Navigate to a well-known folder (for example

C:\Users\<username>\Documents\ArcGIS\AddIns\Desktop10.0) and Paste the file.

2. Launch your ArcGIS desktop application. Within the application, click on the Customize Tab across the top of the screen. A drop-down menu will appear, choose Add-In Manager to open the Add-In Manager window pictured above.
3. Click on the Customize Tab within the Add-In Manager window (circled in red in the image above). This will open a new Customize window (see below).

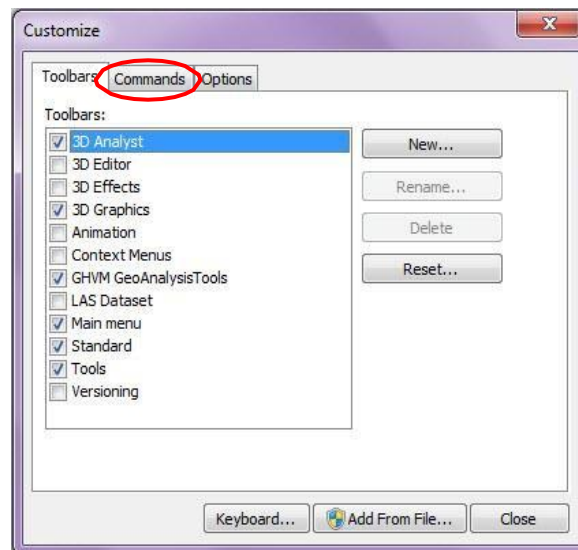


Figure B.2. Customization Menu Commands Tab

4. Click on the Commands Tab within this window (circled in red in the image above). A list of commands will appear including the Add-In Controls command (Circled in red in the image below.)

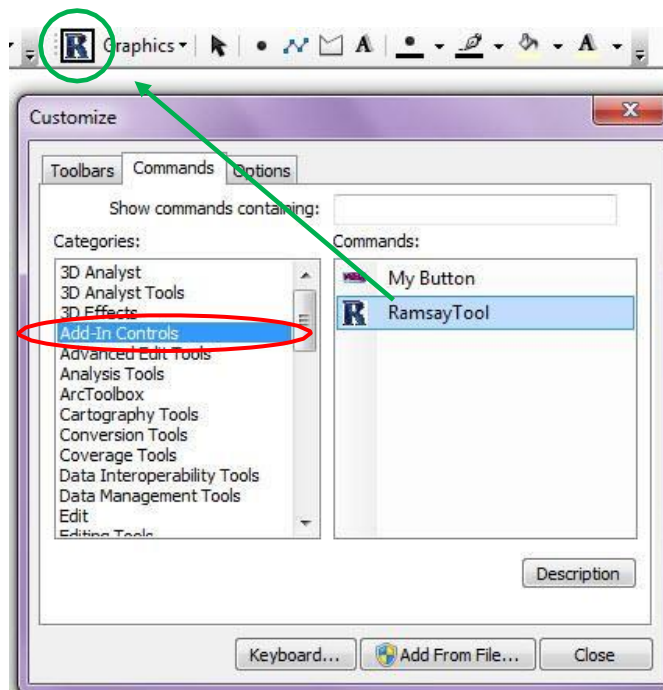


Figure B.3. Ramsay Tool Toolbar icon and Command Tab

5. Click on Add-In Controls and a list of available Add-Ins will be listed on the right side.
6. Click and hold on the Add-In you wish to install.
7. Drag the Add-In icon up to the toolbar area of your application.
8. Release the mouse and the Add-In is now installed within the application toolbar (see image above, icon installed in tool bar-circled in green).
9. Click on the Add-In icon to launch the Add-In.

The Installation Utility approach to installing is explained in the following steps. This is a safer alternative to Add-In installation.

1. Double click on the Add-In file (will have extension. esriaddin) you downloaded or received. This will automatically launch the utility (see image below).



Figure B.4. ESRI ArcGIS Add-In Installation Utility Window

2. When the Utility window opens, the user can see the author's name, a description of the Add-In, and if a trusted digital signature is attached to the file. Click the Install Add-In button (circled in red in the image above).
3. The utility will copy the file to a subfolder it creates within the well-known Add-In folder.

Note: Add-Ins are not designed to be backward compatible. If it was developed for version 10.1, it will work with 10.1 and above but not with 10.0.

Note: Though manual installation is an option, using the utility prevents security being bypassed and catches any name conflicts that may occur.

4. Follow steps 2-9 of the manual installation to complete the installation process of the Add-In.

APPENDIX C

INFORMATION ON CUSTOMIZING ARCGIS TEMPLATES FOR NON ESRI USERS

The graphic interfaces are intuitive and customized. When working in the ESRI environment, the user has access to many tools and options upon loading a new or preexisting file. In order to make the module interfaces more accessible to the non-ESRI user, the templates for ArcMap and ArcScene are altered and appear to the user with only toolbars associated with the particular interface that is loaded. The user no longer needs to understand the ESRI docked toolbars and navigate to find the interface toolbars. This customization eliminates the need to learn the software in order to use the GUI. The image below is a representation of the steps taken to customize the templates.



Figure C.1. Steps to customize the templates

It is often a better option to perform this customization after the GUI has been created. The developer is familiar with ESRI and can more readily navigate the toolbars. Having all the options available make it easier to pull tools onto the GUI toolbar prior to eliminating unneeded tools.

To begin, navigate to your computer's C drive. Once there, search for the Users folder. Within this folder, search for the folder with your computer's administrator name. That folder will contain the AppData folder which contains many folders related to applications housed within your computer's memory. Choose the Roaming File and then open the ESRI file. You need to find and click on the Desktop 10.X folder (the version will vary depending on the version of ArcMap you have installed). You will need to navigate to either your ArcMap or ArcScene folder. This folder contains the template folder which houses the NORMAL template. This is the template that we will change in order to load the ESRI software according to our needs. Once at the TEMPLATES folder, we change the .sxt or .mxd file by renaming the 'original' file and replacing it with a new template file. For example, the template that comes standard with the software is saved as NORMAL.xxx. This file can be saved as TEMPLATE_REAL.xxx and the original template can then be customized and saved as NORMAL.sxt (for ArcScene) or Normal.mxd (for ArcMap). Upon loading a file, the software will automatically load with the new look created for the GUI.

Before Customization

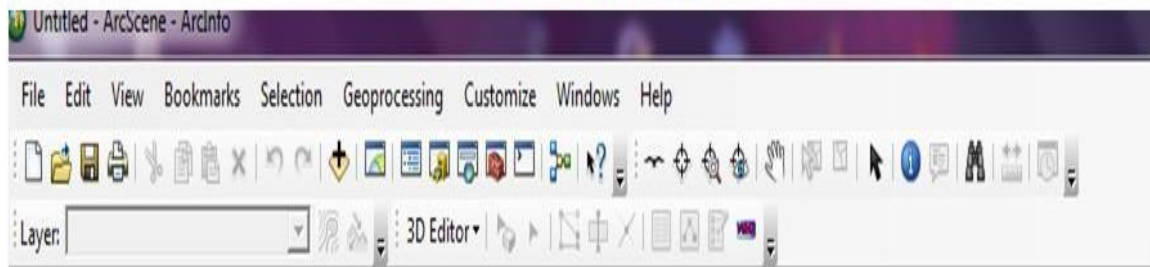


Figure C.2. Toolbar prior to Customization

After Customization



Figure C.3. Toolbar after Customization

If the developer needs to go back to the original software view, the TEMPLATE_REAL.xxx is renamed NORMAL.xxx and saved. The software will once again load in the view originally developed for the software.

APPENDIX D

INSTRUCTIONS ON USING THE RAMSAY TOOL IN ARCSCE

Directions for Measuring Strike and Dip on a 3D Model Using GAT

1. Determine the fold you will be using. Your screen should look like this with the addition of the tutorial on the right-hand side.

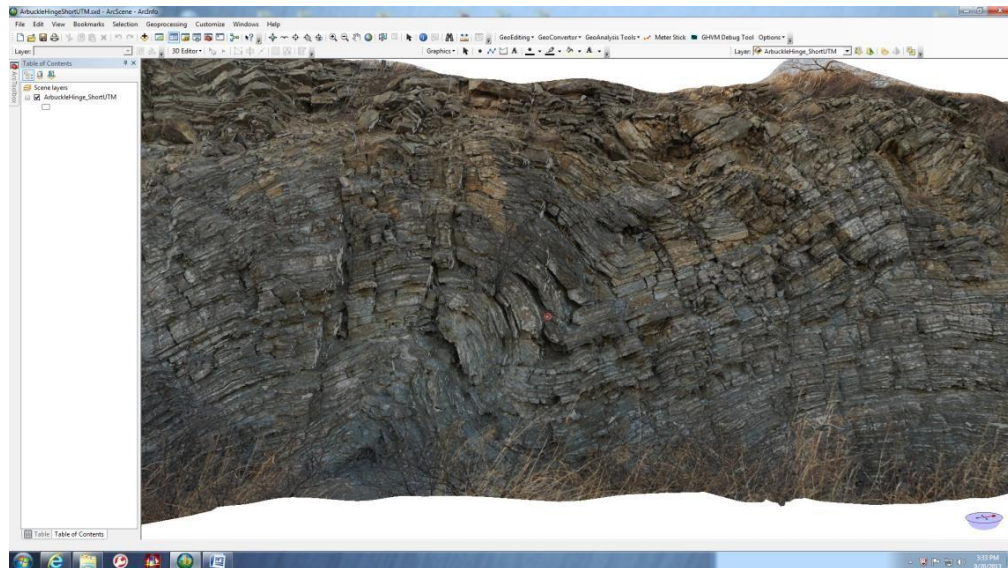


Figure D.1. Image of 3D photorealistic model within the Arc Platform

2. Rotate the model to look for an area in the model where a face is protruding out.

Although it does not necessarily follow field technique, it is crucial in getting an accurate strike and dip in a 3D photorealistic model. It is possible to get a strike and dip on a flat surface, but you must be cautious as to where you lay your points, making sure to cover enough area on the surface to get an accurate reading of the bedding. Refer to the picture below. A video is also included to help you in this process.

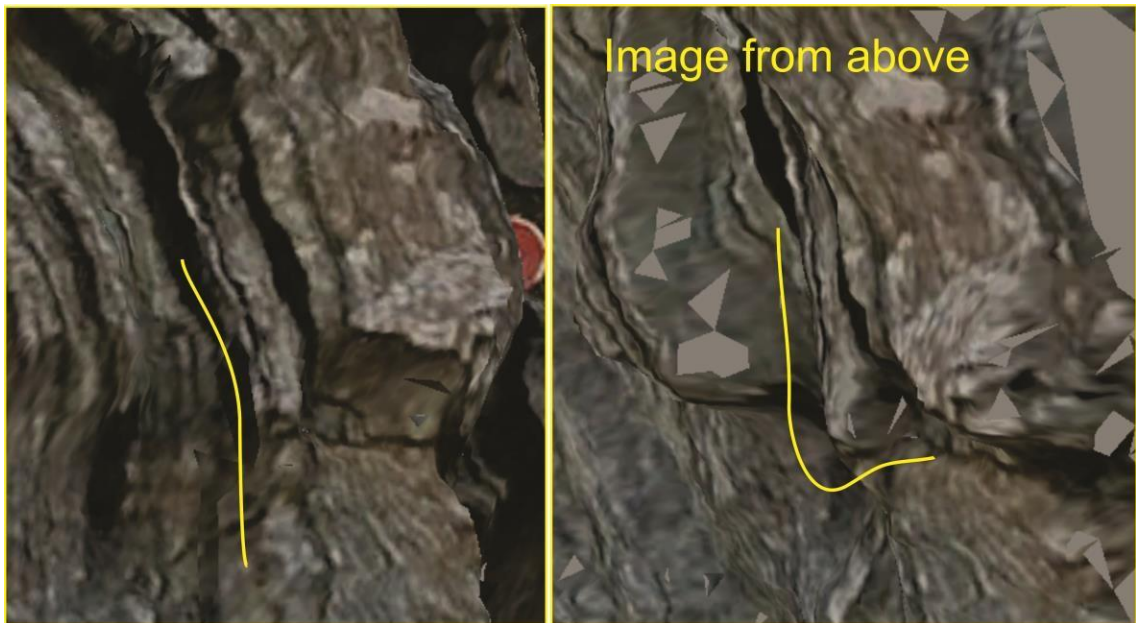


Figure D.2. Close-up of a ledge/view from above of a ledge from a 3D Photorealistic model

3. Once you have your area of interest, Click GeoAnalysis Tools in the GAT toolbar. In the drop-down menu chose Structural Geology Tools. The window below should appear.
Make sure *Import points from layer* is chosen. This will be the window you use to do all your strike/dip measurements and calculations. There is no need to close this window until you are done with all the measurements required for the exercise. Your instructor will provide you with how many strike & dip measurements the assignment requires.

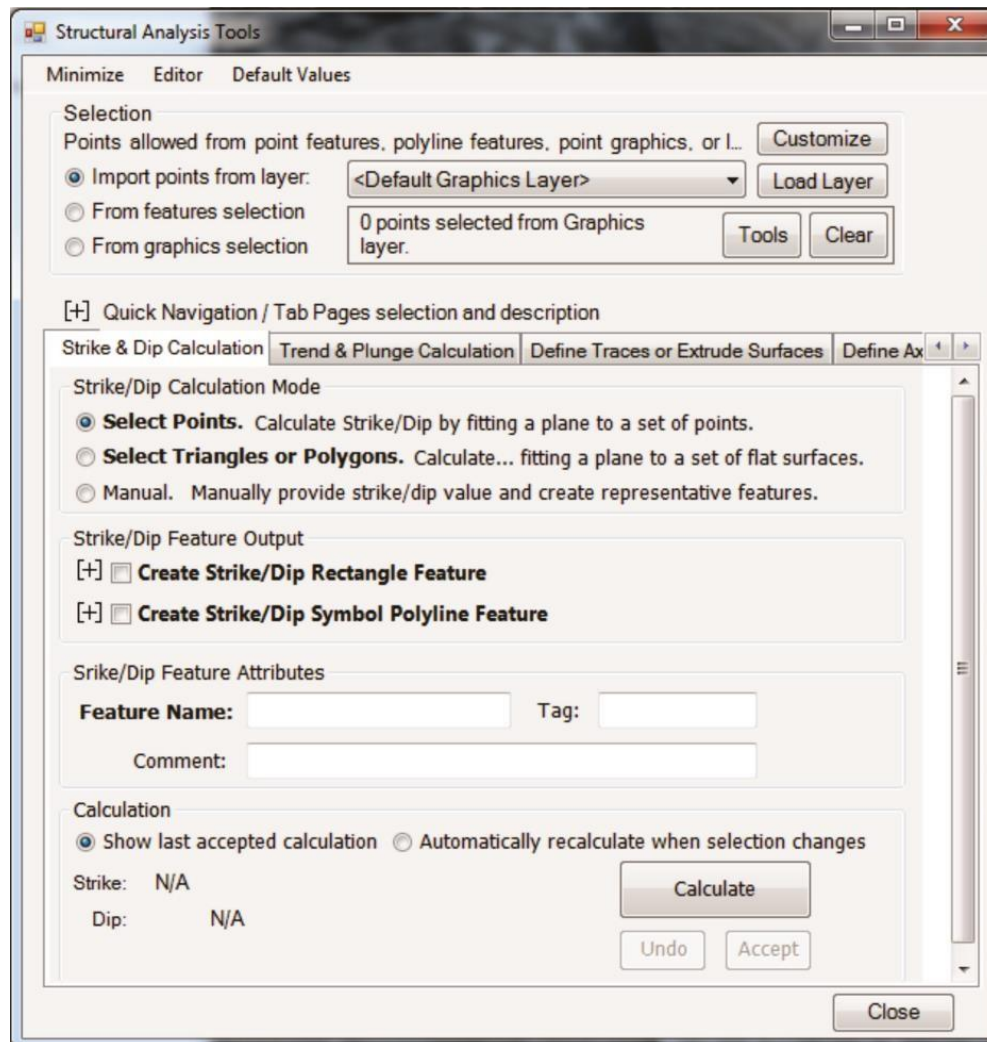



Figure D.3. Structural Analysis Tools Window

4. In the graphics toolbar chose the **New Marker Tool** (●). It is important to note you can rotate and navigate the model at any time by simply using the **Navigation Tool** , however to lay any points for calculation you will have to re-click the New Marker Tool. You can now lay your points onto the 3D model. Five points should be used as a minimum for each calculation and you can use more if need. Refer to picture below for a guideline to laying points. This part of the exercise is the hardest. Do not get discouraged

if you calculate a strike/dip measurement which makes no sense, you are learning a new skill and it takes practice. Simply disregard by clicking Undo in the Structural Analysis Tool Window and it will eliminate the plane calculated.

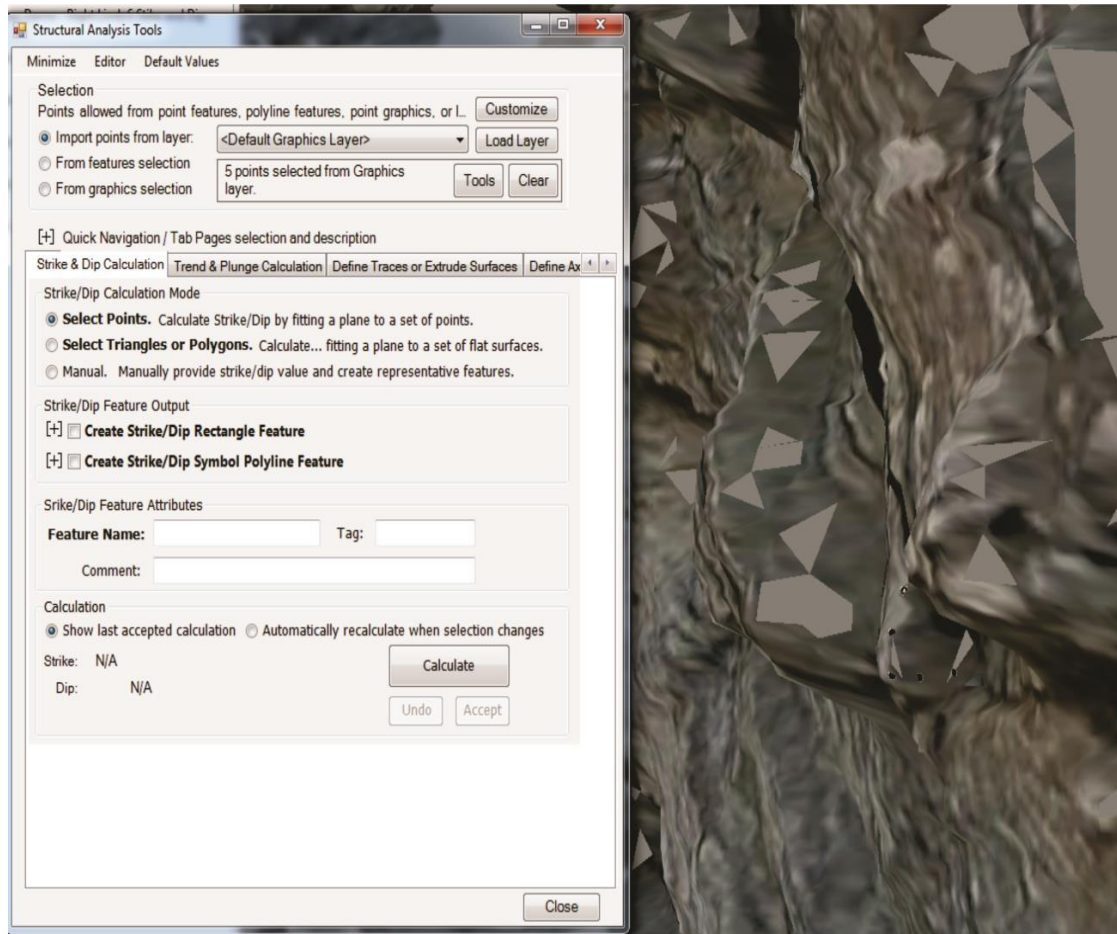


Figure D.4. Dialogue box for Structural Analysis Tools

Note that as you lay the points, the number of points will appear in the dialog box in the upper portion of the window.

5. Make sure *Import Points from layer* is chosen, as well as *Select Points*. Click **Create Strike/Dip Rectangle Feature**.

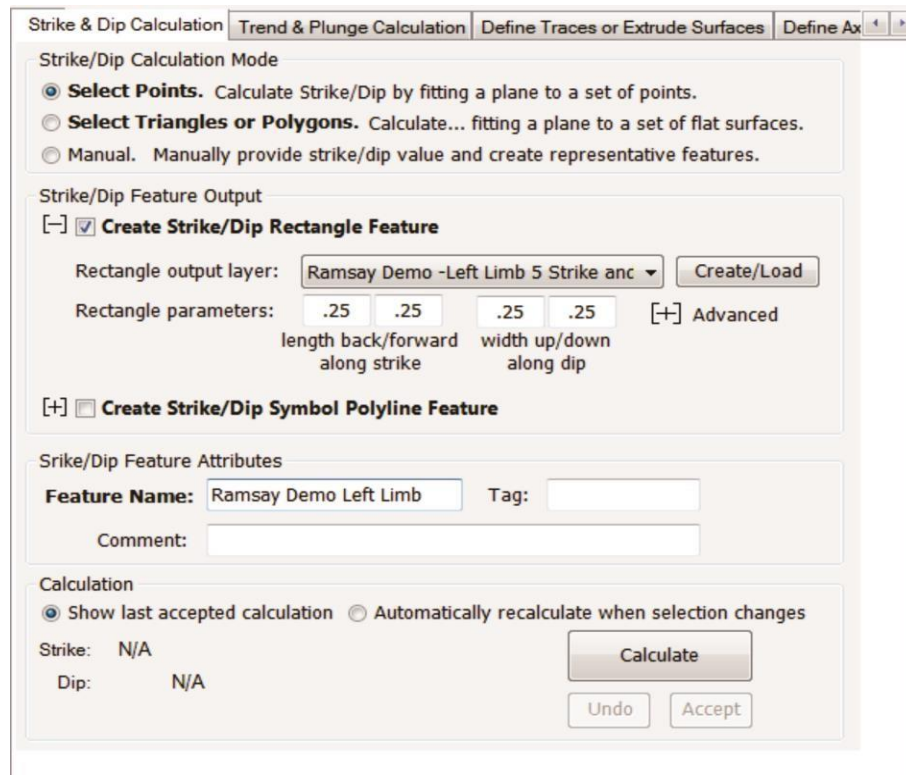


Figure D.5. Strike & Dip tab from the Structural Analysis Tools

You will now need to click the **Create/Load** button and name your shape file, Click **Save**. You will have to do this every time you create a new strike and dip plane, so it is important to be as descriptive as possible. Next, change the Rectangle parameters (size of the plane the program will draw). You can choose any size you like, however .25 for all the parameters is a good size for all applications.

6. Next, chose a *Feature Name*, the name you chose here does not have to be changed every time you recalculate.
7. Now click **Calculate**. You will see the strike and dip measurements appear in the dialog box to the left of the button, as well as a plane appear in the model. This plane represents your strike and dip measurement.

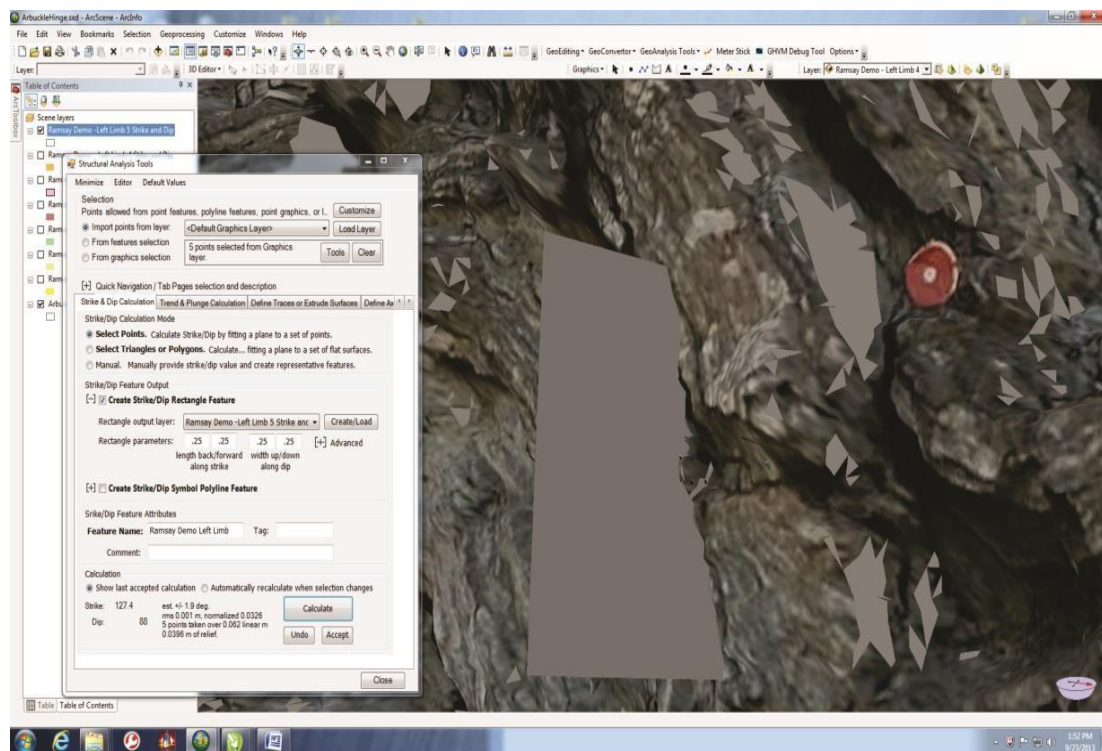


Figure D.6. Image with a plane representing a Strike & Dip measurement

8. Enter the Strike/Dip values into the Ramsay Tutorial. Remember if the strike and dip measurement do not look correct you can always click undo and redo your points with the **Marker Tool**.
9. In the Structural Analysis Tool Window click **Clear** on the top next to where the number of points displayed is. This will clear all the points you previously laid down and let you start a new strike and dip measurement. Repeat steps 1-9 for as many strike and dip measurements as you need. When you are finished, your model should show several strike and dip planes. Refer to picture below.

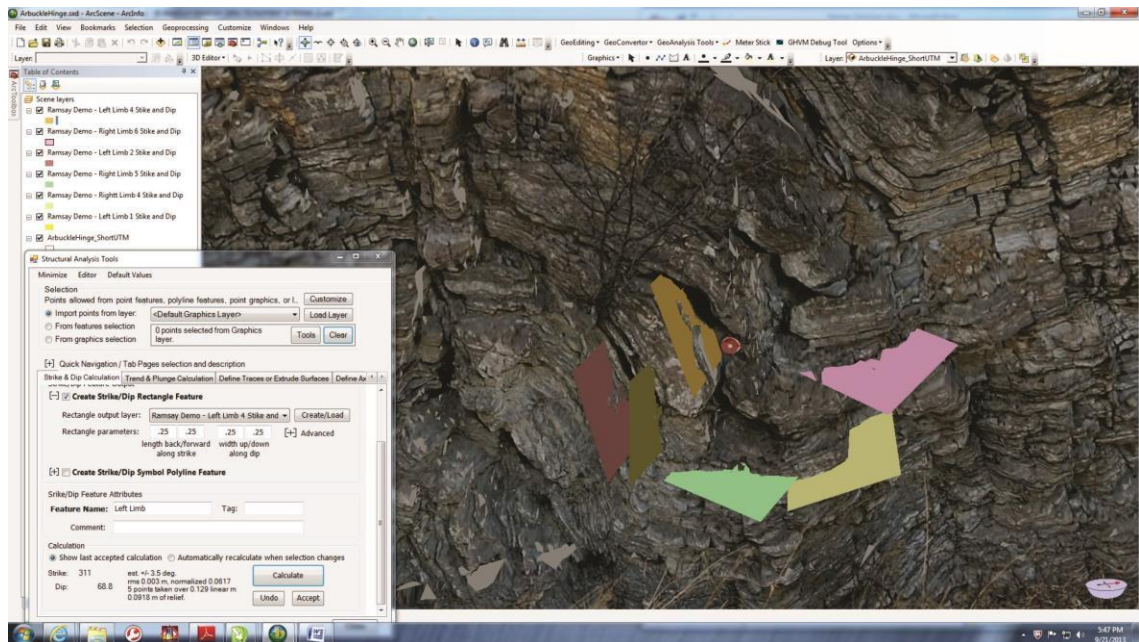


Figure D.7. Image with various planes representing Strike & Dip measurements in various colors

NOTE: If you want to change the color of your plane you can simple go to the Table of Contents and click the box under the Strike/Dip measurement and a color box will appear. Simply chose a color and it will change the plane to match. This is very helpful in distinguishing the different strike and dips and it is helpful to put the color chosen in the description in The Ramsay Tutorial next to the strike and dip.

APPENDIX E

INSTRUCTIONS FOR THE CORELDRAW COMPONENT

1. Tab # 8- Ramsay Classification- has a button labeled **Open Corel Instructions**, click on this button and you will have to *choose between measuring orthogonal thickness or axial trace thickness*. Refer to the introduction for guidelines on which choice to make. *This action will open a separate interface from the Ramsay Tool interface.*
2. Click – **Save As** – Save the file in the Ramsay Project Folder. Do not forget to save periodically throughout the Ramsay Classification.
3. When Corel opens you will have a screen with a protractor, a scale and a chart. Your screen should look like the image below. The screen shot below corresponds with the orthogonal thickness measurement. You may have a modified version of Corel and will only be allowed to use certain tools within the program. The tools will have the same names as the direction below, there will just be fewer options. **NOTE: Do not alter the size of the scale!!!!**

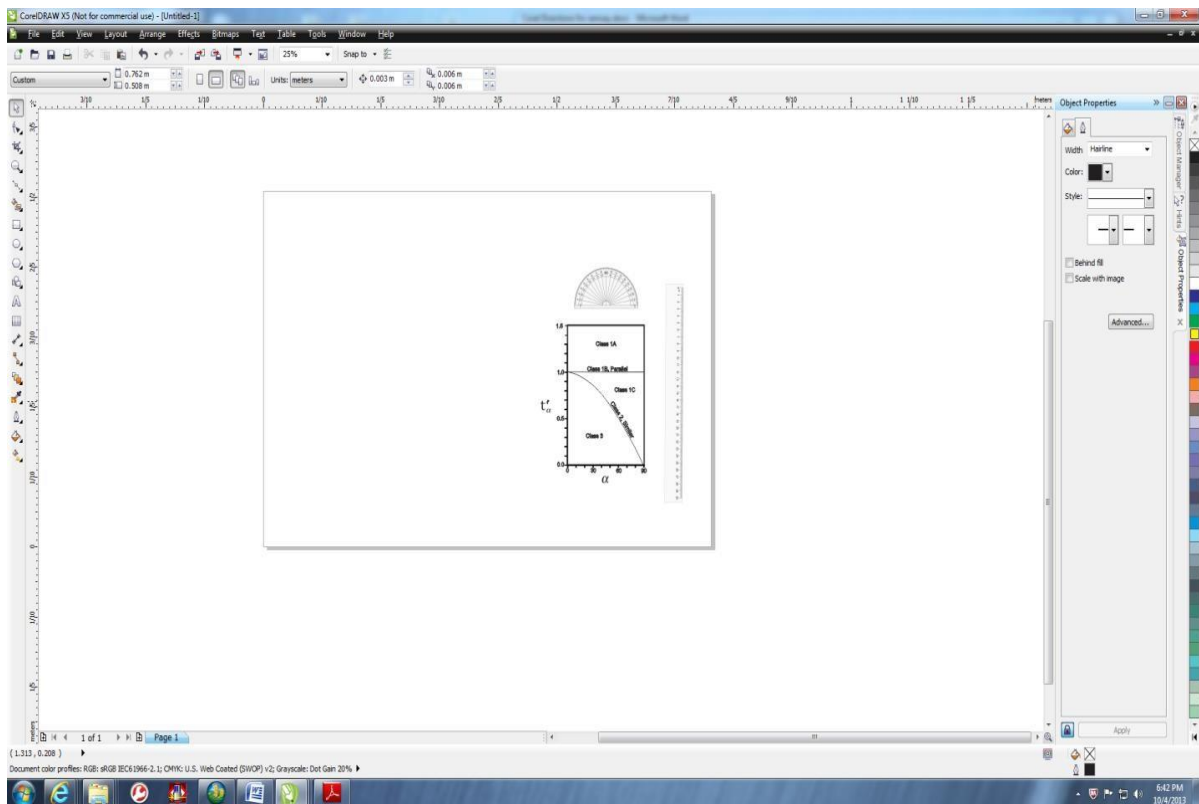


Figure E.1. Customized CorelDraw screen with a protractor, scale, and chart

4. **Right Click** your mouse and choose **Paste**. Your screen should look like the image below. You may have to move your pasted image around so that the protractor is available for use. Make sure you have included your meter stick in the image. You will want to measure this for accuracy. You can either resize the image so the meter stick is accurate in size or you can convert using a mathematical equation. The Ramsay is a ratio, so it does not require you use real world values. In our example we will use the size that we imported from the original print screen, just know your instructor may want actual values in which case you will have to use one of the previously suggested methods.

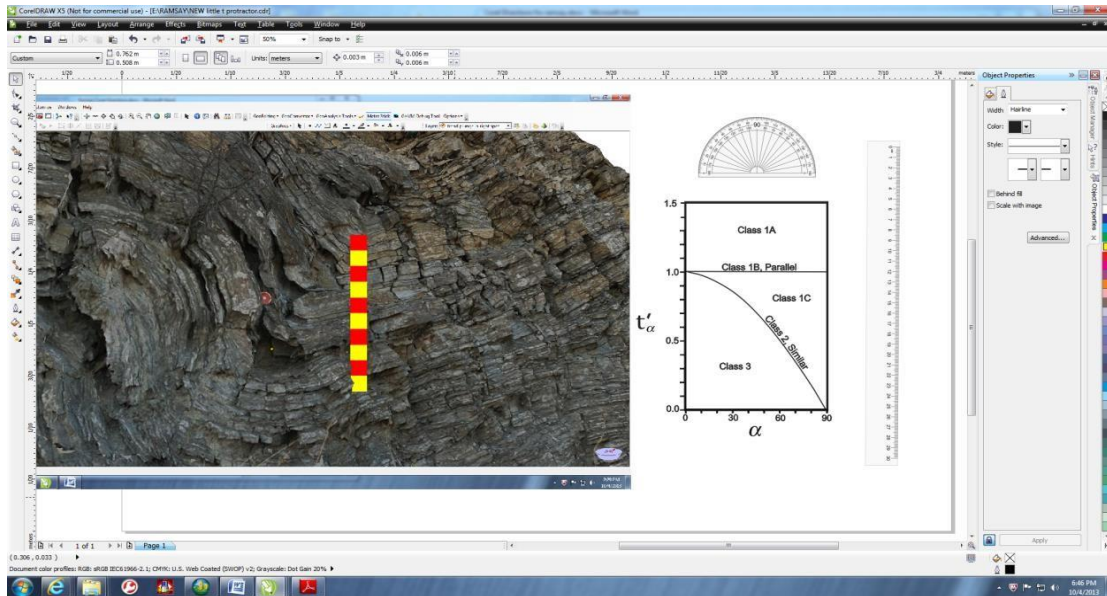


Figure E.2. Customized CorelDraw screen with a 3D photorealistic model

5. With the pasted image selected (it should be already selected when pasted), click – **Arrange**, click **Order**, click – **To Back of Page**. This is simply making the image you pasted as the bottom layer so you can lay the protractor over the outcrop.

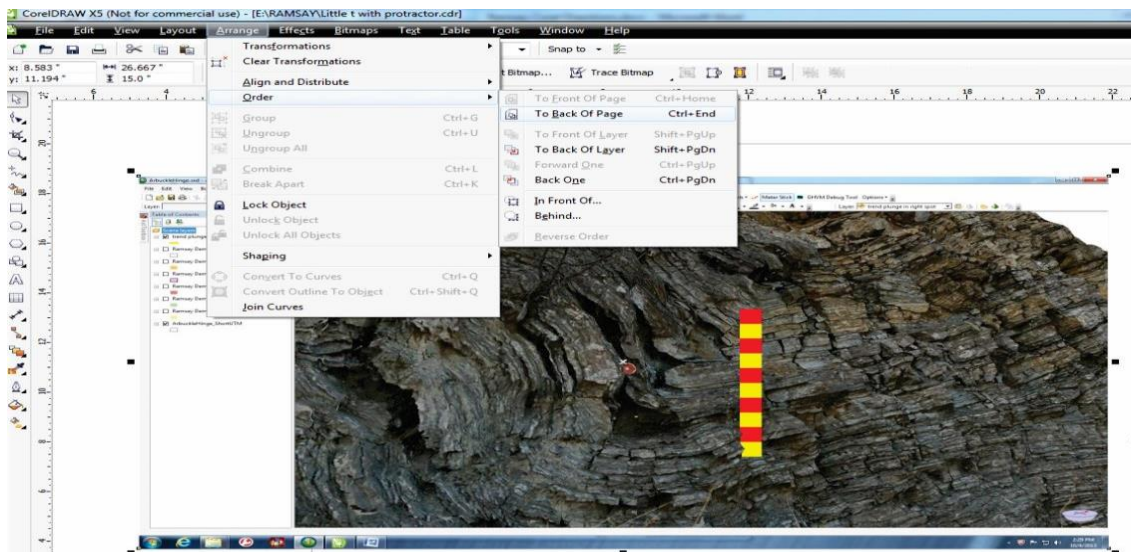


Figure E.3. Customized CorelDraw screen with windows to set the model as a bottom layer

6. On the toolbar to the left click the **Line Tool Button** and then click – **Freehand**.

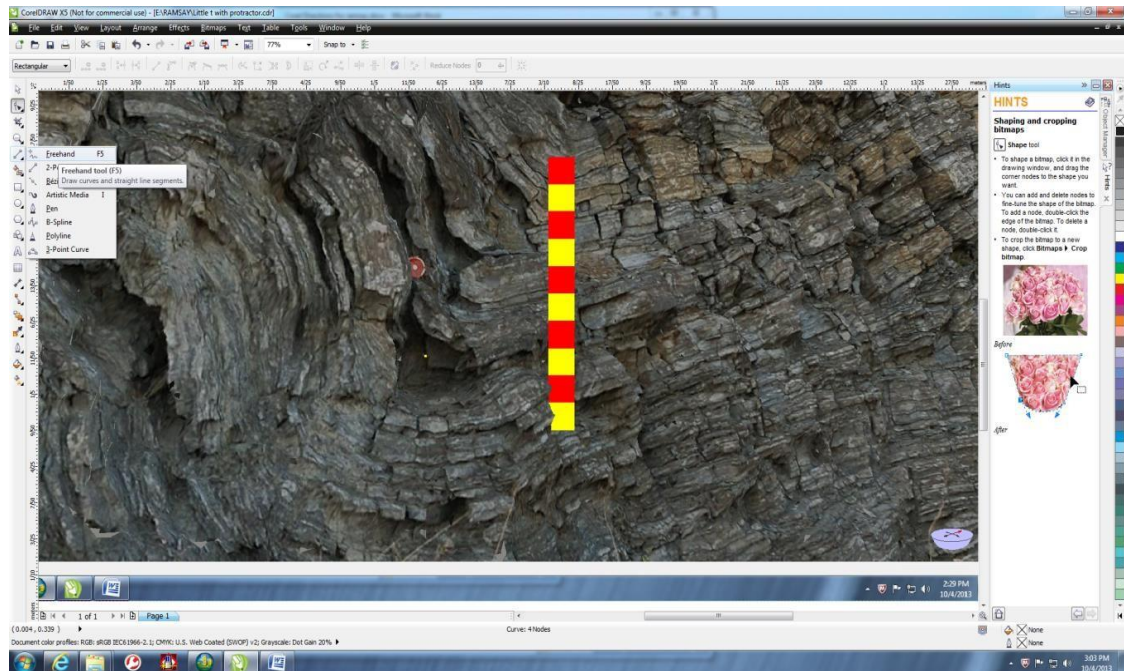


Figure E.4. Customized CorelDraw screen toolbar with windows to set-up Freehand

7. With the **Freehand tool** you can now outline your bounding surfaces, by simply left clicking the screen and tracing a bounding layer. The line will first appear in black. To *change the color* simply double click the pen image in the lower right-hand corner of the screen. This will bring up the Outline Pen Screen. On this screen you can change the color of the line as well as the width on the line you have drawn. It is strongly recommended you chose a color with contrast. The process of recognizing the bounding surface may take some creative geology. For instance, you may be partly blocked by the image. When this happens, open the model in Arc to be able to use the **Navigation Tool** to rotate and inspect the curve further.

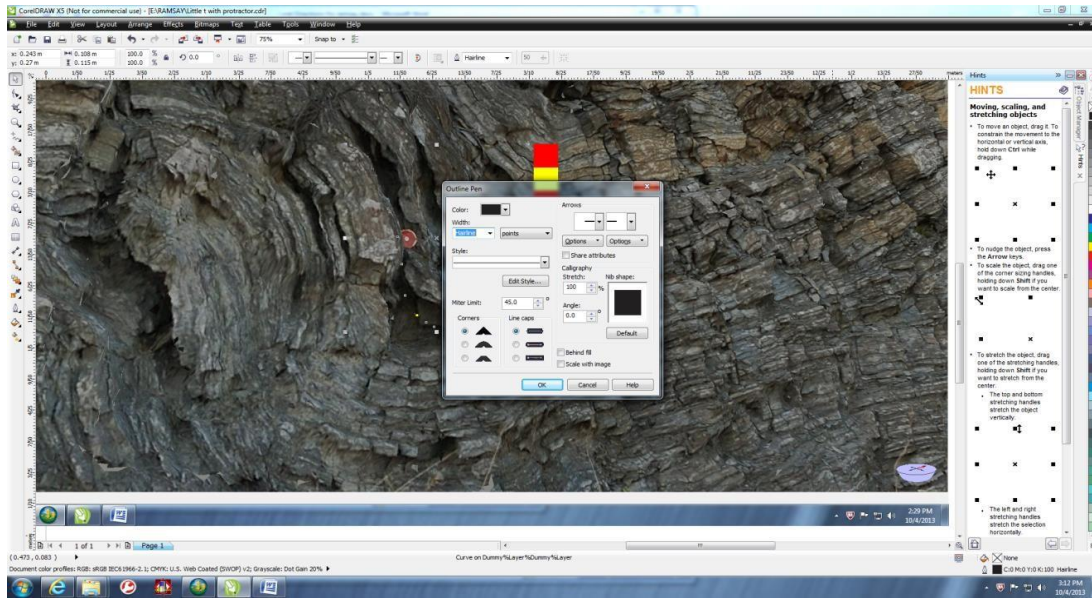


Figure E.5. Customized CorelDraw screen window to set-up color change

Note: If you need to adjust your lines at any time you can simply select the **Shape Tool** on the toolbar and then click the line you wish to alter. It will allow you to move certain points if needed to fit the bounding surface more accurately. You can also delete the line by simply selecting it and clicking **Delete**.

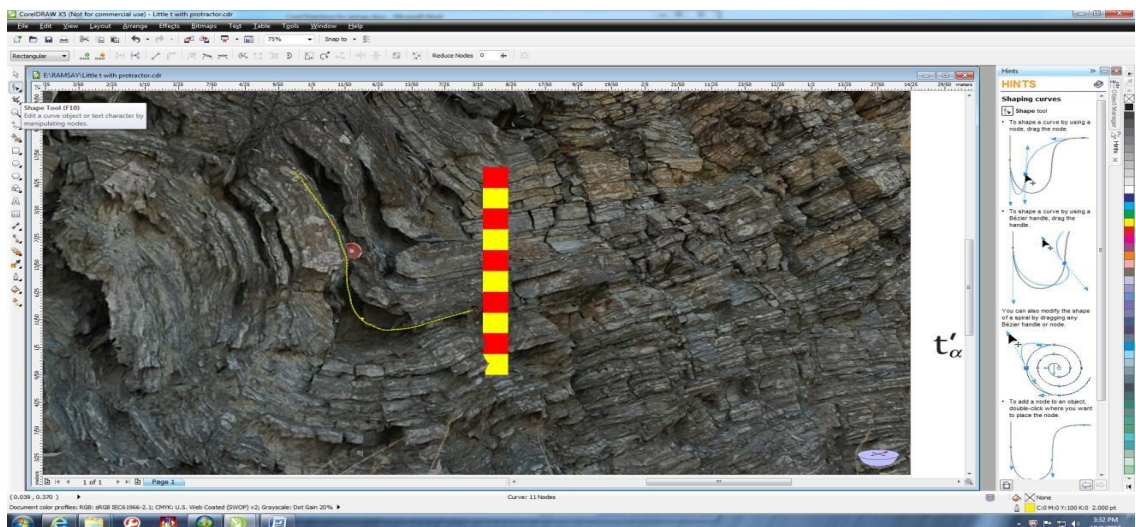


Figure E.6. Customized CorelDraw screen window to select the Shape Tool and Delete Tool

8. In order to do the Ramsay classification, you *need to have a surface bounded*. You will need to define a top and a bottom of the fold. When you are done the image will look like the image below.

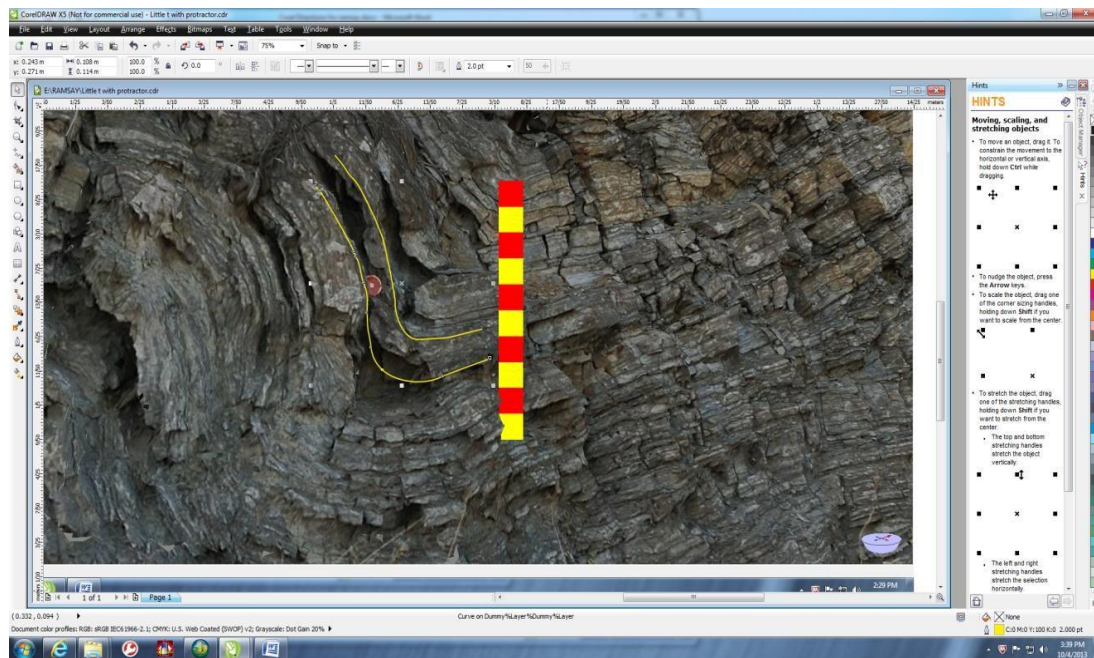


Figure E.7. Customized CorelDraw screen with a fold structure bounded

- 9) Next define the **Axial trace**. Since this will be defined by a plane the **2-Point Line tool** should be used. When you have selected the tool, simply left click and drag on the screen. When you release, a line will form. It is once again helpful to change the color. An **axial plane** is *normally defined by a dashed line*. You can change the properties in the same menu as before by clicking the pen on the lower right-hand side of the screen.

Note: Do not forget you can choose the **Shape Tool** at any time to move points on any image you have drawn.

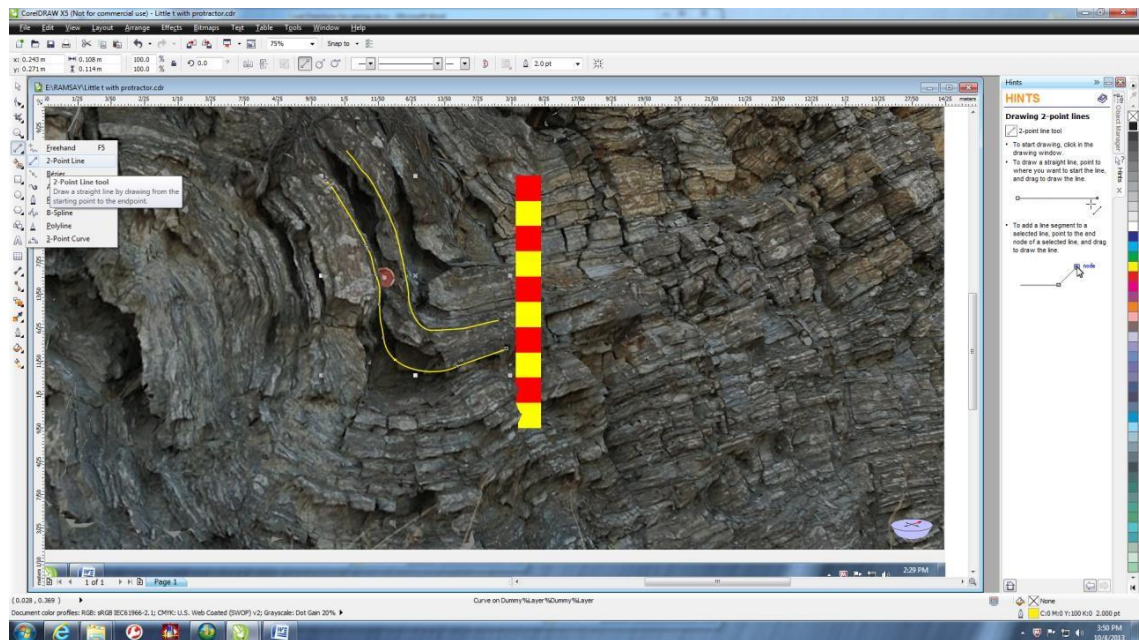


Figure E.8. Customized CorelDraw screen defining the Axial Trace

Axial Trace defined in image below.

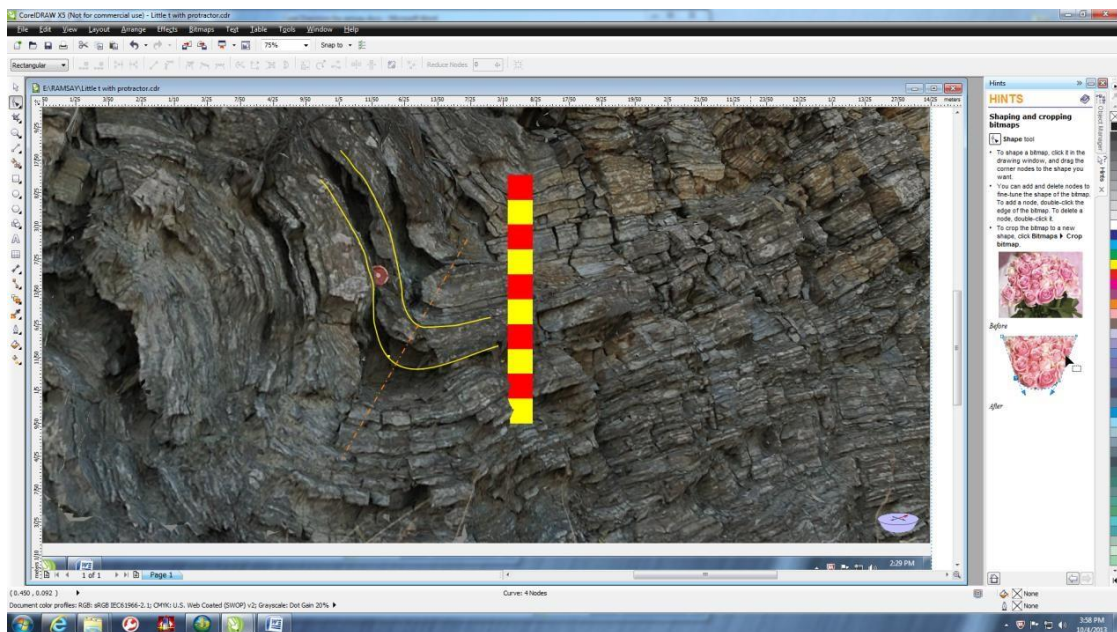


Figure E.9. Customized CorelDraw screen with the Axial Trace defined by a dashed line

9. To **measure T_0** (the axial trace measurement within the bounding surfaces) use the scale tool provided to lay over the image (Refer to image below). In this case it is 27mm.

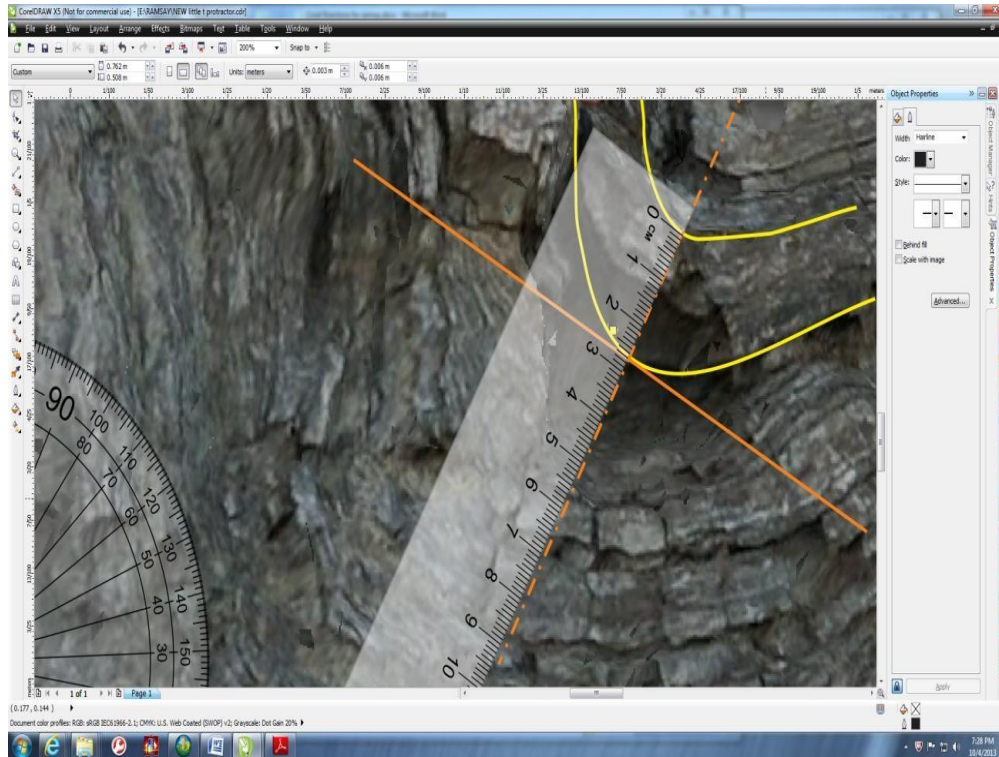


Figure E.10. Customized CorelDraw screen with the Axial Trace measurement within the bounding surface

10. Record the value in the **Ramsay Tutorial** as you t_0/T_0 value. This value will not change throughout the rest of the assignment.
11. Before starting to do angle measurements draw a line perpendicular to the axial trace on the maximum curve fold. You will not need the measurement on this line; it is just to help guide you when you are using the protractor tool.

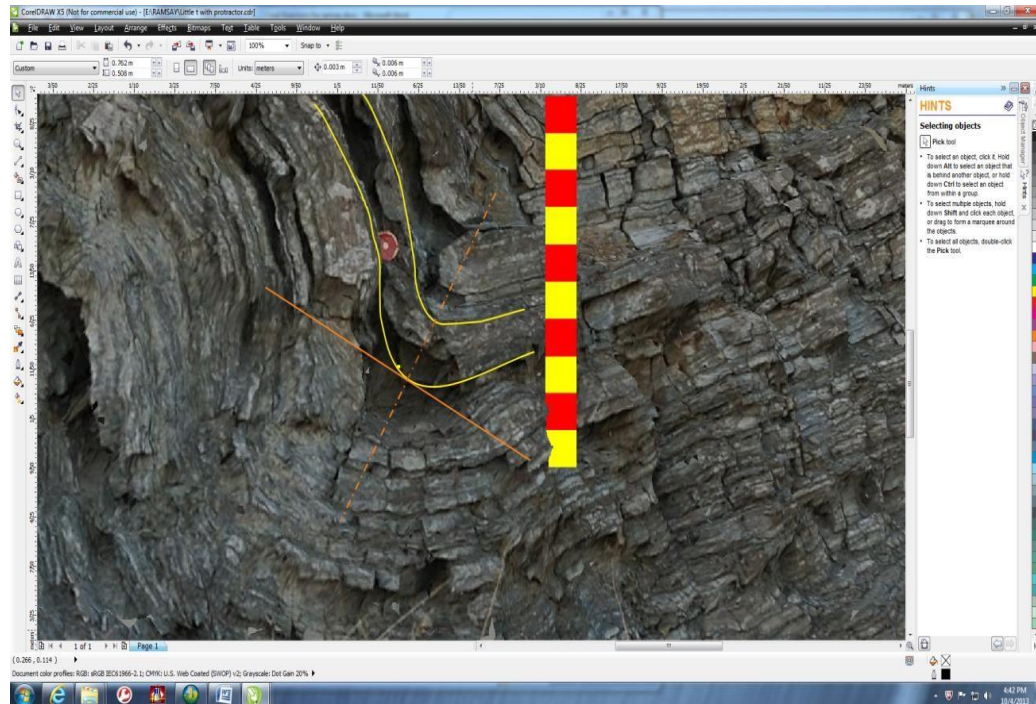


Figure E.11. Customized CorelDraw screen with a line perpendicular to the Axial Trace on the maximum curve fold

12. Use the protractor which was in the file when you opened it. You can change the size of the protractor at any time by simply selecting the **Pick Tool**, clicking on the protractor and grabbing the corner and dragging out or in, depending on if you would like to increase or decrease the size. Changing the size of the protractor will not affect your angle measurements. To rotate the protractor, click twice and rotational arrows will appear. You can drag these arrows to rotate the protractor. **DO NOT CHANGE THE SCALE SIZE**
13. Line up the protractor so the axial trace is at 90 degrees and the perpendicular line is at 0 and 180.

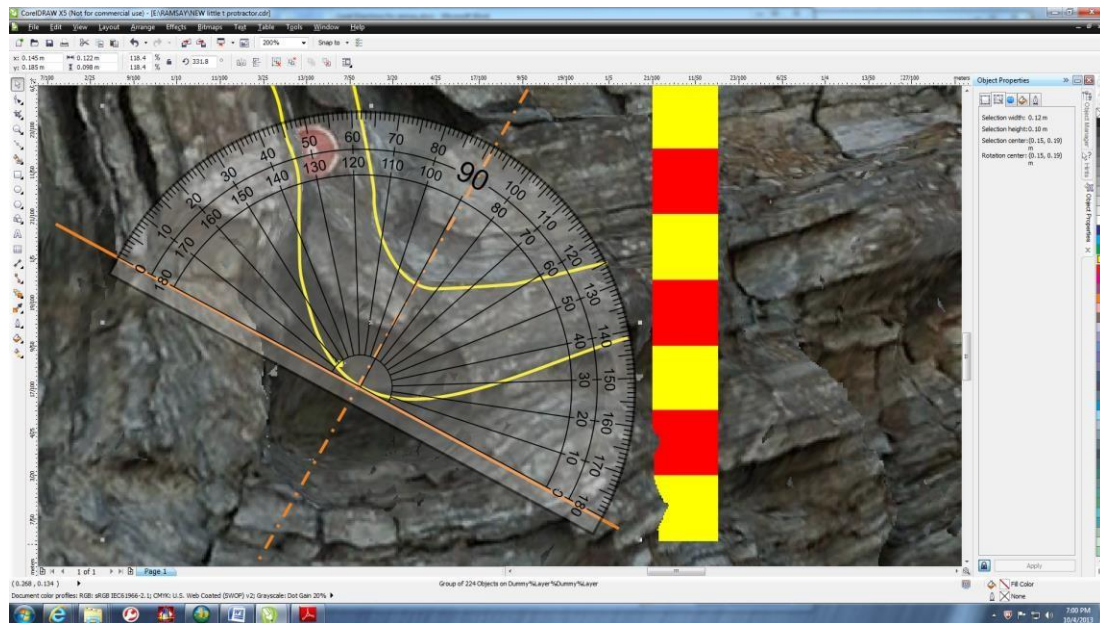


Figure E.12. Customized CorelDraw screen with the protractor lined up to the axial line at 90-degrees and the perpendicular line at 0- and 180-degrees

14. You will now **construct a tangent at the 10-degree mark**. Refer to the Ramsay classification directions for instructions on performing the Ramsay Classification. As before you can change the color of the line in the outline properties menu.

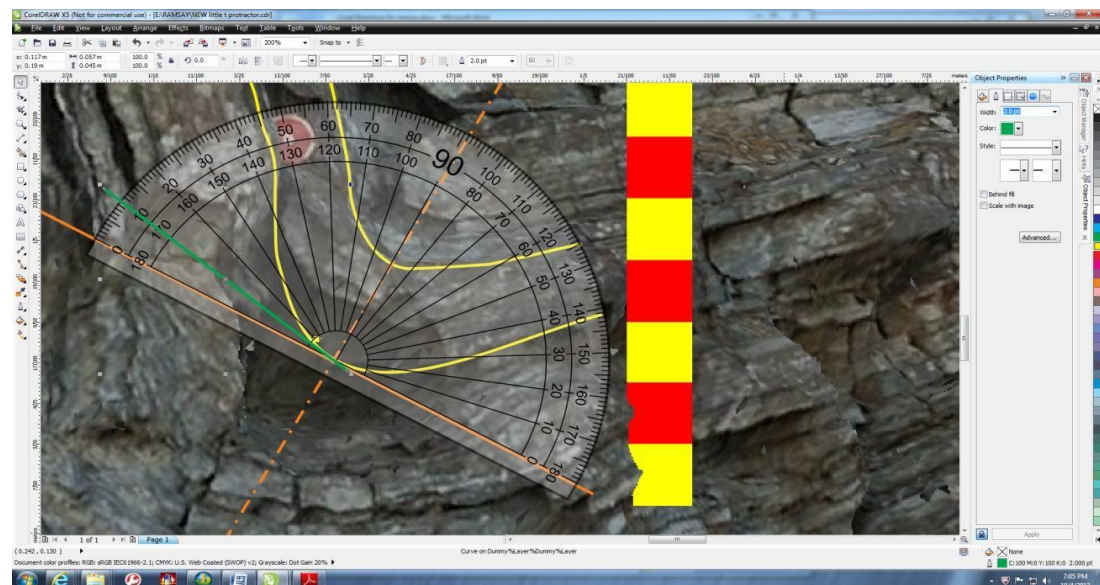


Figure E.13. Customized CorelDraw screen with a tangent line (in green) at the 10-degree mark

15. Move the protractor away from the fold.
16. Using the **Pick Tool**, click on the line you just created. Click **Edit – Duplicate**. Another line will appear. Position this line on the bottom of the fold where it is tangent to the curve with the same orientation. Do not rotate the line.

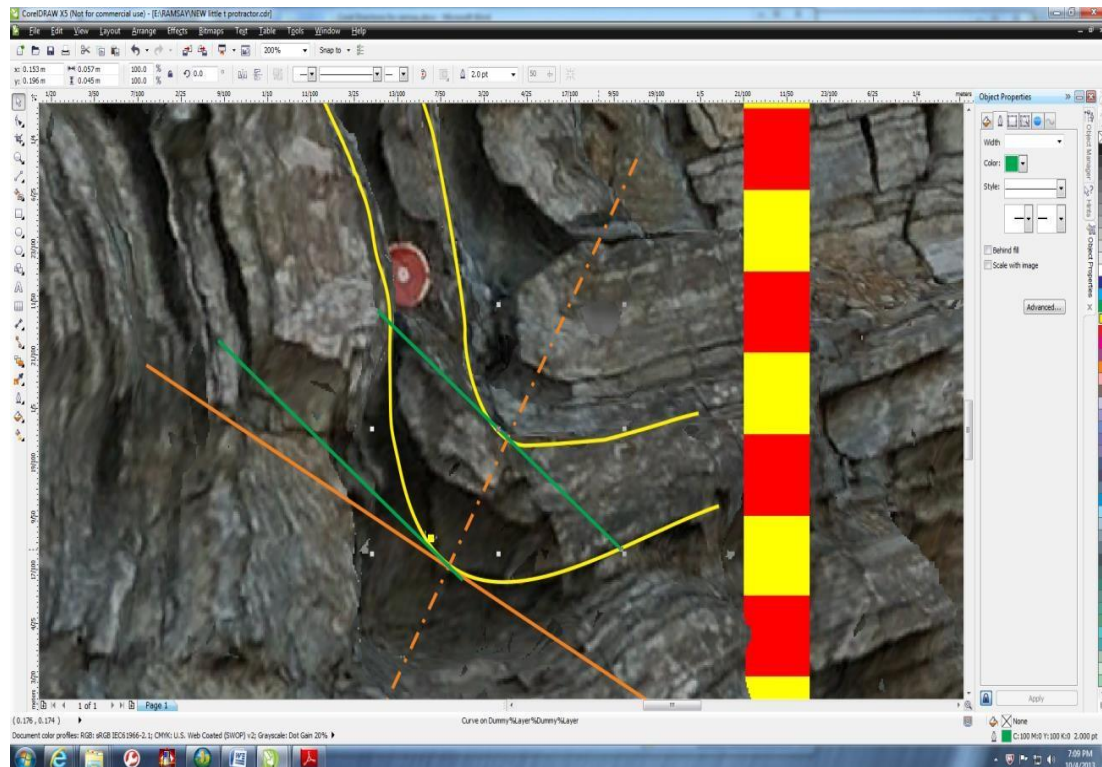


Figure E.14. Customized CorelDraw screen with a second green line positioned on the bottom of the fold where it is tangent to the curve with the same orientation

17. With the scale *measure the distance talpha perpendicular to the two tangents* (if you were using To , then you would measure the distance between the two tangents parallel to the axial trace Talpha. In this case, it would be 27mm. Make sure to keep the measurement units straight. Whatever units (for example millimeters) used for original to value, you will keep the same units on the rest of your measurements.

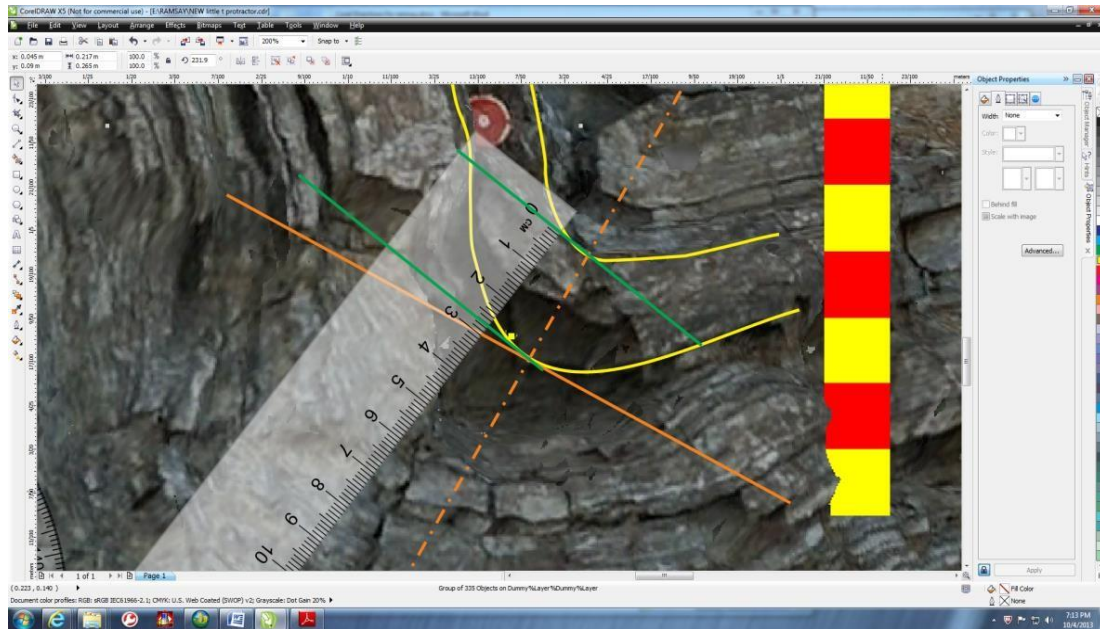


Figure E.15. Customized CorelDraw screen with the scale measurement of the distance t' perpendicular to the two tangents

18. Record the measurement in the Ramsay Tutorial under the 10-degree measurement.

The program will calculate the value for you and calculate the t' value.

19. When you have the t' or T' value you can now plot the value into the chart provided.

20. In this example it would be $t' = \alpha / t_0$, ($t' = 27\text{mm} / 27\text{mm} = 1$). Plot 1 for the 10-degree area. Use the ellipse tool to draw a small circle.

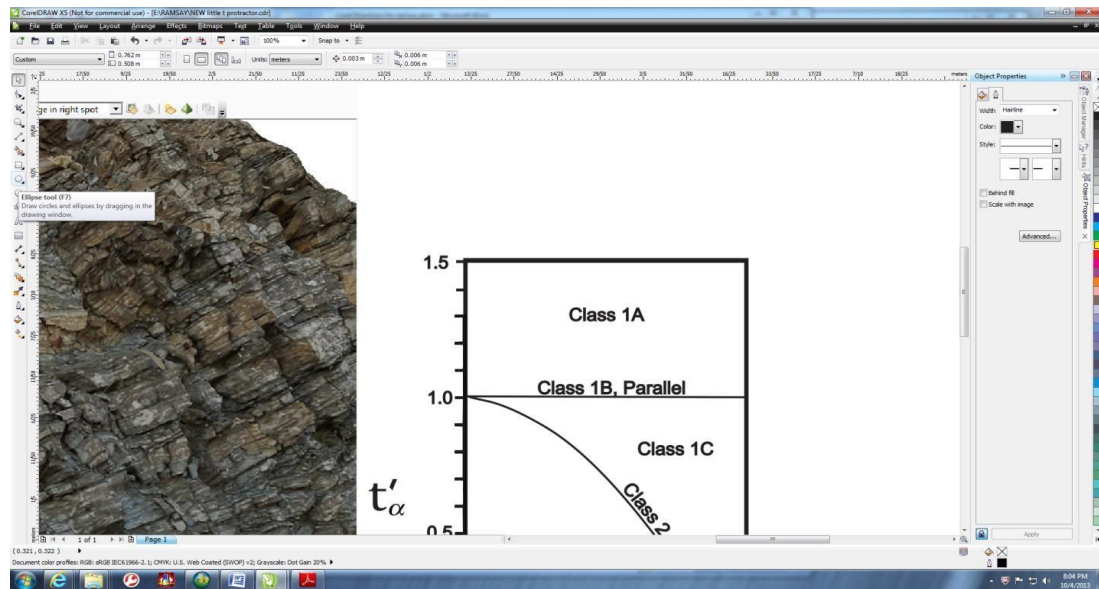


Figure E.16. Customized CorelDraw screen with t' plot chart

You can color your circle by clicking the fill tool on the bottom right of the screen next to the pen, and then selecting a color.

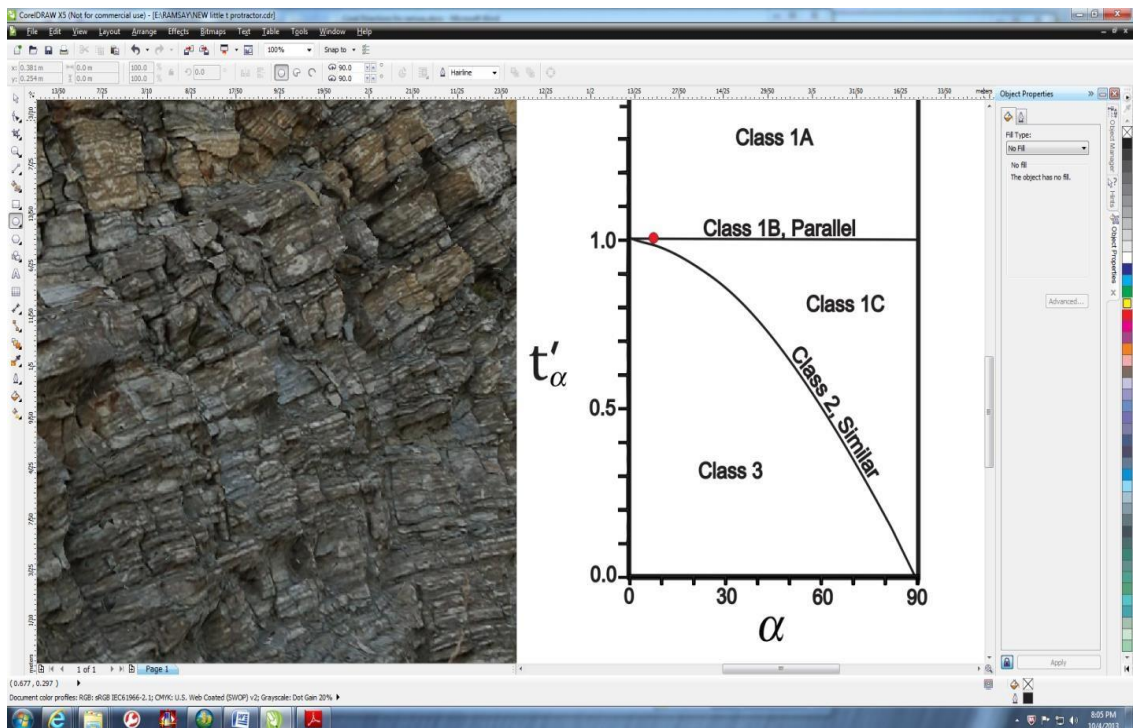


Figure E.17. Customized CorelDraw screen with t' plot chart and plot #1 (in red) for the 10-degree mark

21. **Continue to do this for all values up to 90 degrees.** It may only be possible for a portion of the angles to be complete due to the curvature of the fold. The example below shows you the angle at 50 degrees. Note how the protractor is moved across the perpendicular line, which is acceptable.

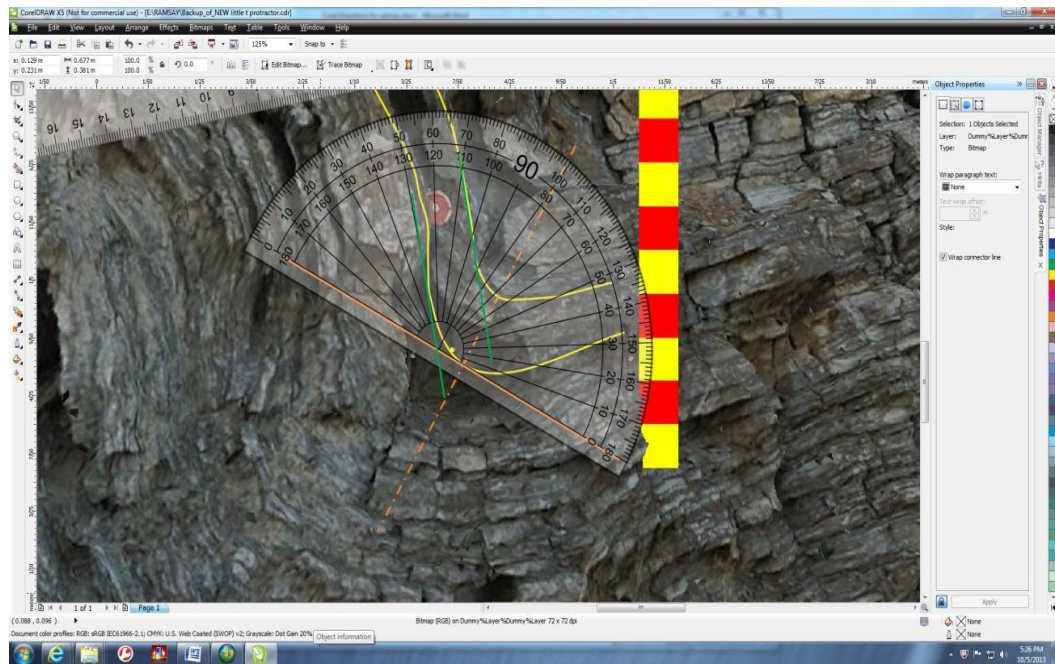


Figure E.18. Customized CorelDraw screen with tangent line (in green) at the 50-degree mark

The measurement is 20 mm on this example, enter 20 under the 50-degree section in the Ramsay Tutorial, and then plot accordingly on the chart. Once you have completed every 10 degrees through 90 degrees and plotted accordingly on the chart. You have completed the Ramsay classification.

Important: Your instructor may want you to analyze both sides of the fold, or multiple folds. If you need to do more than one, you should save each quarter wavelength as a separate file in your project folder and then analyze the data of each when you have completed the steps.

APPENDIX F

INSTRUCTIONS ON USING THE STEREONET COMPONENT

In this portion of the project, you will need to take the strike and dip measurements you previously acquired in the Strike and Dip section and find your trend and plunge. There are several ways you can do this. Your instructor will advise you whether he will want you to do it by hand using a Schmidt Net (Equal Area Projection), or if you will be allowed to use the automated Stereonet program provided in the Ramsay Tutorial. Included is a video of how to plot a strike and dip and acquire the trend and plunge with the data plotted on an Equal Area projection. However, aside from the video, directions will only be given on using the automated system. It is highly recommended you watch the video even if using the automated stereonet.

1. Before you start, you need to access the .txt file you saved in the strike and dip portion of this assignment.

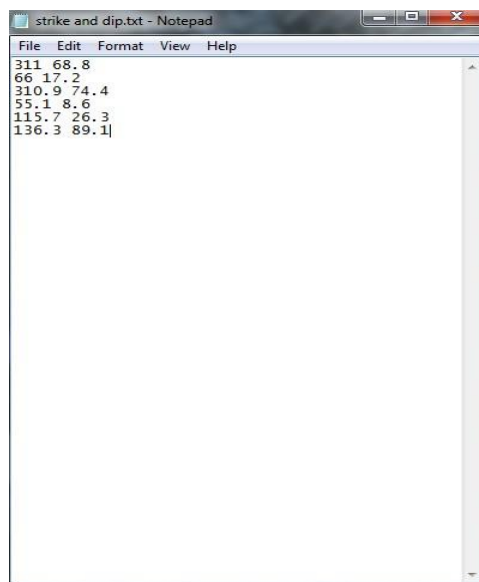
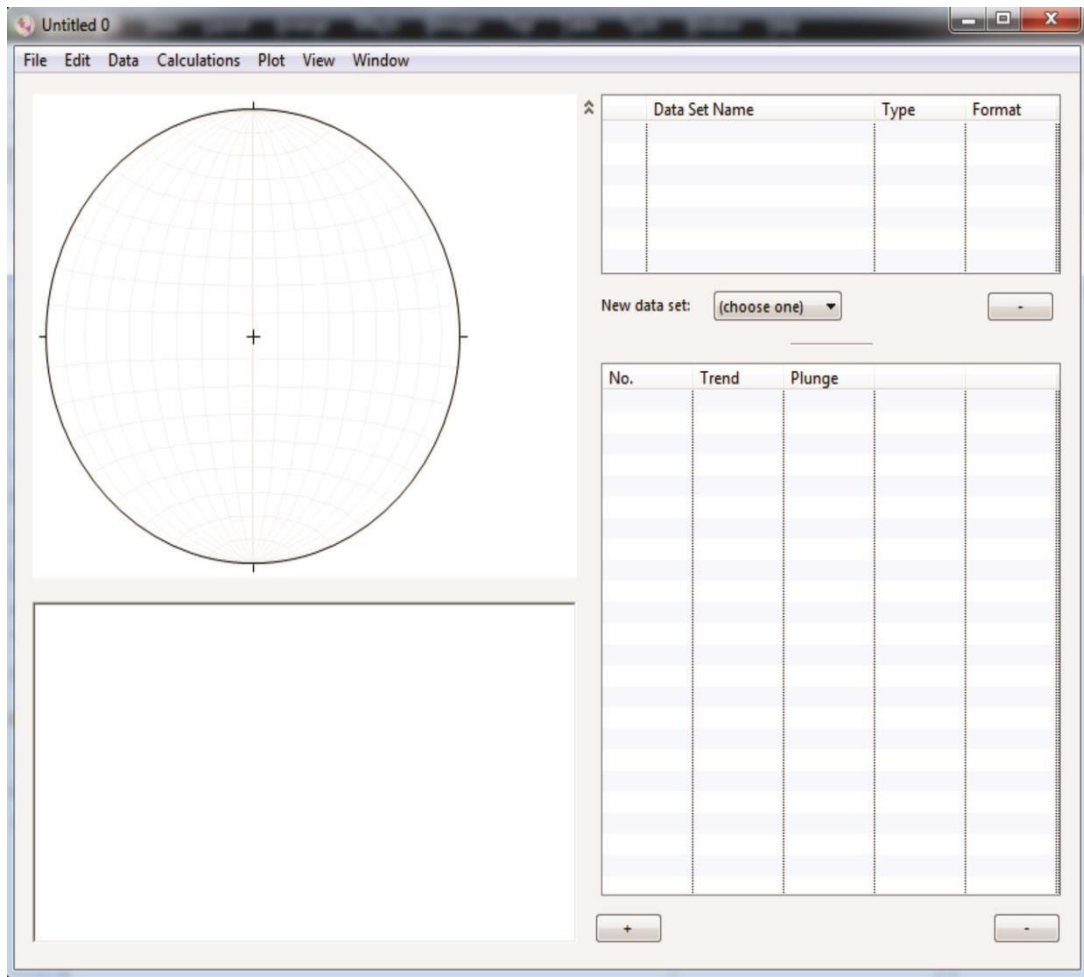


Figure F.1. Screen image of a .txt file with Strike & Dip measurements

2. In the **Stereonet** tab click **Open Stereonet**. The program should open and will look like the image below.



3. Once the program has opened click **File – Import Text File**
4. Navigate to where you saved the strike and dip .txt file and click **Open**. The *Parse Text File* screen below will appear.

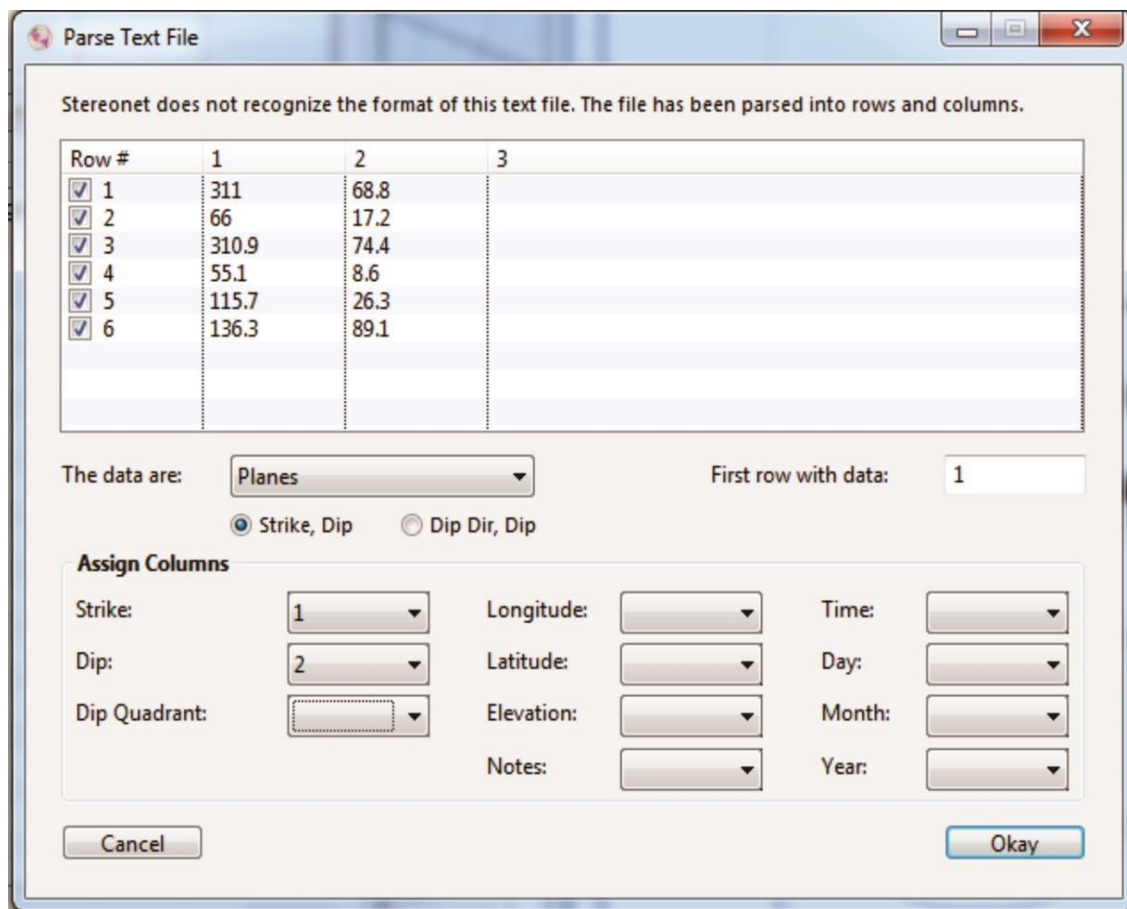


Figure F.3. Image of the Parse Text File screen

5. Make sure all strike and dip readings are included and checked.
6. In the Data are: section set at **Planes**. Make sure the **Strike Dip** button is selected underneath the **Planes** option.
7. In the **first row with data**: option type 1, unless you have a heading on your text file then you will need to select whichever column your data starts on.
8. In the **Assign Columns** section, select 1 for strike, and 2 for Dip. This is assigning the columns which the program will pull your data from, for plotting on the stereonet.
9. Click **Okay**. You will now see your data appear on the Stereonet program in the table.

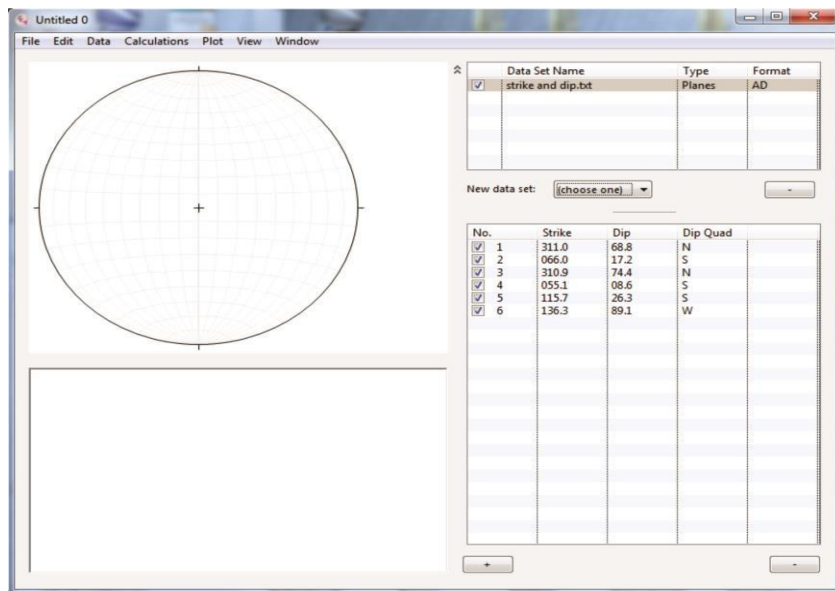


Figure F.4. Stereonet window with data table filled in

10. Under the **New Data Set: Select Planes**. You will see your planes appear on the stereonet.

These planes represent your strike and dip calculations.

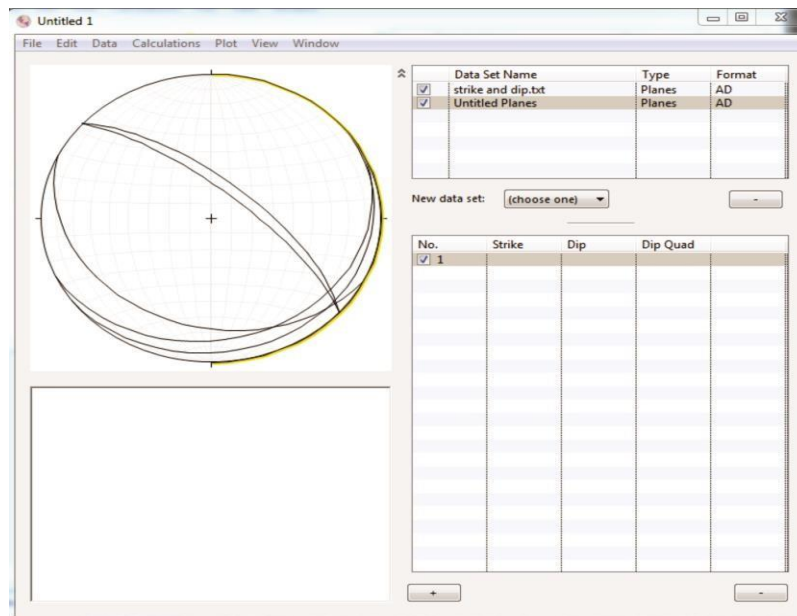


Figure F.5. Stereonet window with Strike & Dip planes

11. The easiest way to get the trend and plunge from the stereonet program is to find the area where all the bedding intersect. You can simply move the cursor in the area closest to the maximum and minimum planes and the trend and plunge will show just under the stereonet to the left. Refer to image below. Note: This is not the most accurate trend and plunge possible. To get a more accurate trend and plunge it is best to do your stereonet by hand. It is likely that some of your strike and dip values may be off, because you are new to gathering the information from a 3D model. Take note of what these planes represent when determining the trend and plunge.

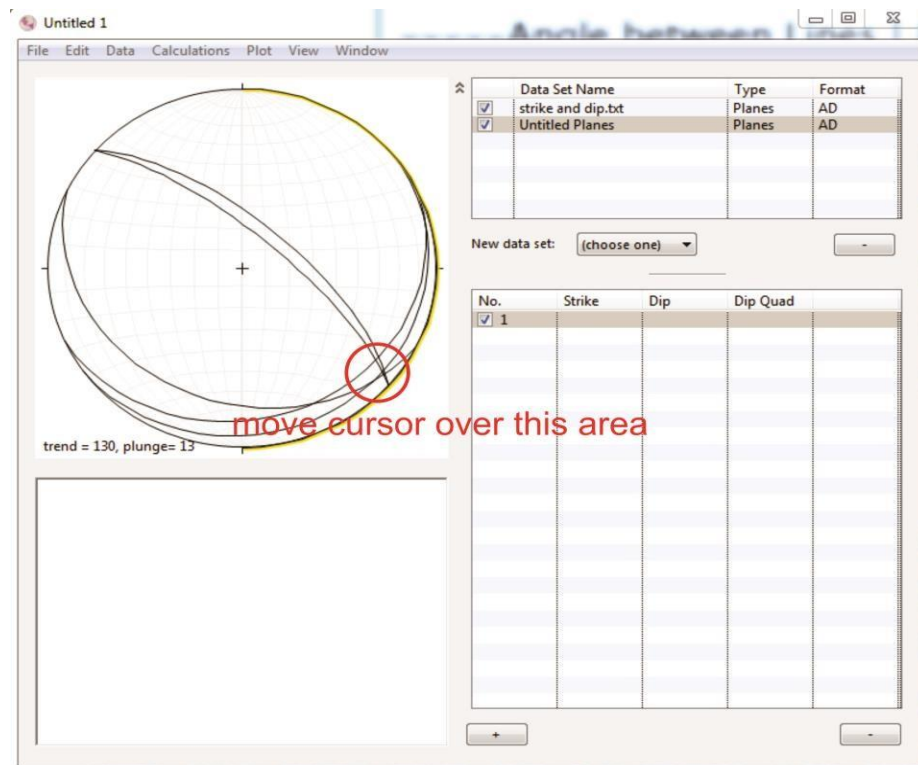


Figure F.6. Stereonet window with Trend & Plunge measurements

12. Click **File – Save**. Save the document in your project folder.
13. Click **File – Save Plot as PDF** into your project Folder

14. Take Note of your Trend and Plunge and proceed to the next tab (Trend and Plunge).

TREND AND PLUNGE

Now that you have your trend and plunge data we can apply it to the 3D model. The trend and plunge define the orientation of a linear feature. It will represent the orientation of our fold axis.

1. Click **GeoAnalysis Tools – Structural Analysis Tools**.
2. Make sure Import points from layer is selected.
3. Now chose the tab for **Trend and Plunge Calculation**.
4. In the Trend and Plunge section of the window select **Manually create trend/plunge line**
5. A box will appear and prompt you to input your trend and plunge. Input the values from the stereonet
6. Click **Create Trend/Plunge Line Feature**
7. Click **Create/Load**, then name the file. Click **Save**
8. In the **Draw trend/plunge line using these parameters** chose length back (2)/ forward (1).

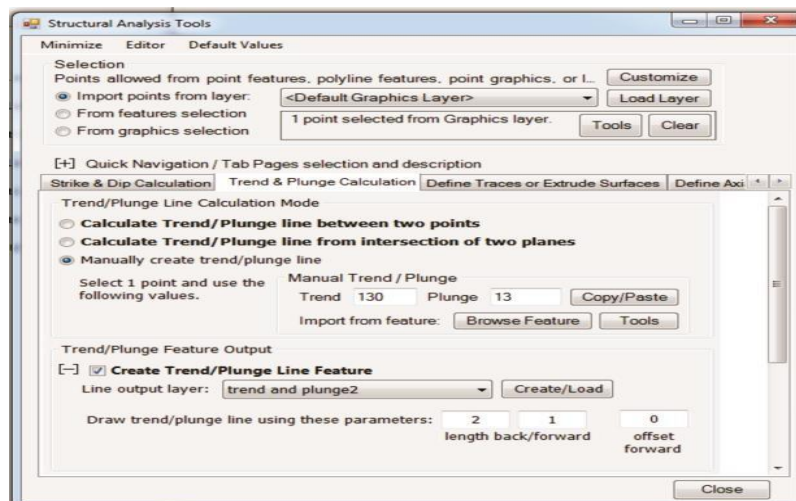


Figure F.7. Structural Analysis Tools window; Trend & Plunge tab

9. On the model select one point using the **New Marker tool**(●) which most closely represents your point of maximum curvature on the fold which you are analyzing. This point is where your trend and plunge line will project from.



Figure F.8. 3D photorealistic model close-up with marker (circled in red)

10. Click **Calculate**. A line will appear from the point.

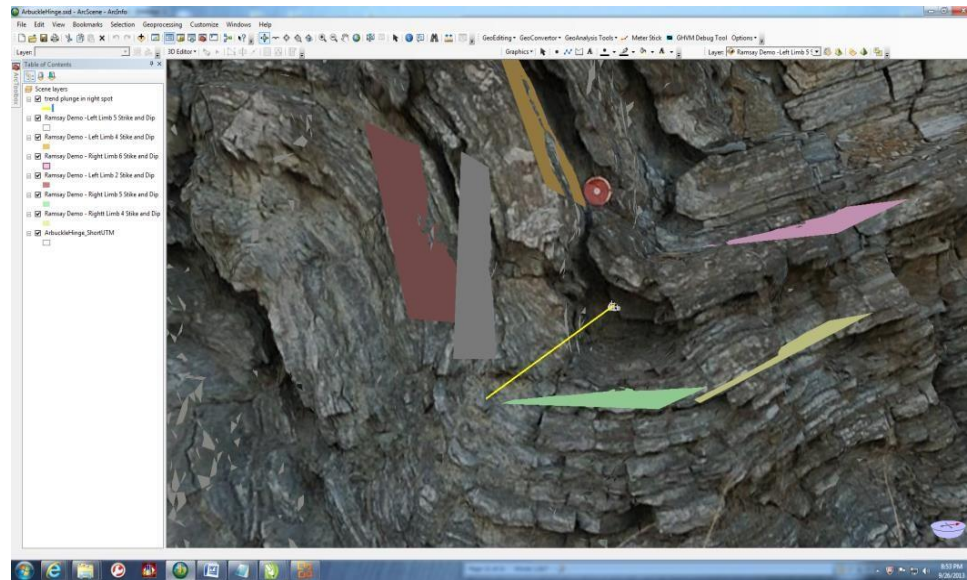


Figure F.9. Customized menu window with Trend & Plunge (in yellow) protruding from the marker

11. Close the **Structural Analysis Tool Window**.

12. If you would like to change the color of the line, you can left click on the line under the shape in the table of contents, under scene layers. It is sometimes helpful to have this more predominant.

13. Under the table of contents uncheck all of the strike and dips. They will disappear from the screen. Do not worry they are not gone forever. You can always re-click, and the plane will appear.

14. The next goal is to rotate the image, so you are looking down the hinge. Using the navigation tool simply rotate the model so you see just a point. Refer to picture below.

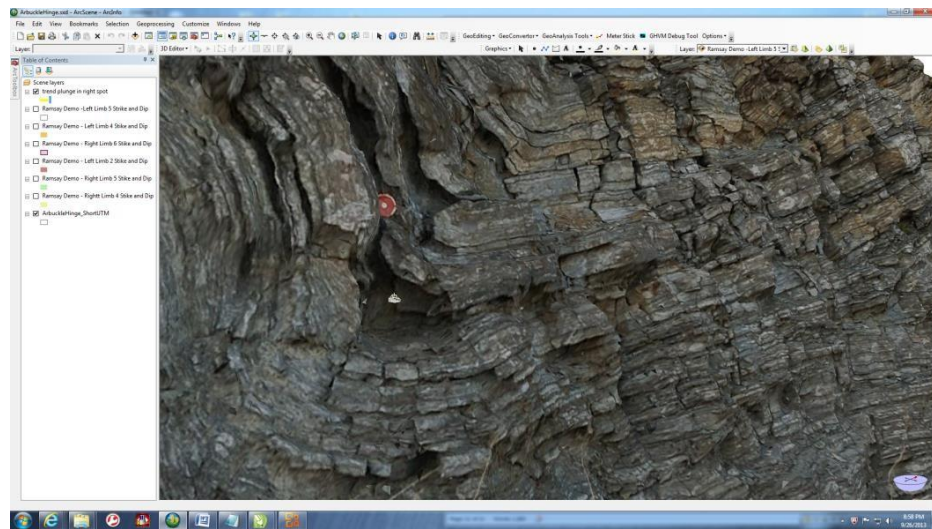


Figure F.10. Customized menu window with rotated model

15. Adjust the image so the complete fold is in view. Your instructor may recommend you do

both limbs for comparison. Click **Print Screen**.

If you are asked to do more than one layer you may want to consider two screen shots if the bedding is not in the same view or too far away.

16. Click **Next** to move to Ramsay Classification Tab

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BIOGRAPHICAL SKETCH

Michelle Iris Rodriguez was born in El Paso, Texas, on September 26, the daughter of Concepcion and Margarita Rodriguez. After completing her studies at Fabens High School in 1995, she entered The University of Texas at El Paso in El Paso, Texas. She received her Bachelor of Interdisciplinary Studies-Bilingual/ESL in 2000. In 2006, she received her Master of Arts in Teaching in Science Education from The University of Texas at Dallas. In 2008, she began work on earning dual degrees at The University of Texas at Dallas. In 2012, she was officially accepted into the Doctor of Philosophy program in Geosciences. She earned a Master of Science in Geospatial Information Sciences in 2013. A paper, The Digital Integrated Stratigraphy Project (DISP) Development Phase II: On-site 3D access, analysis and integration of stratigraphic data using PCs and 3D Photorealistic Models, was published in a special issue of *Stratigraphy* IGCP 591 in 2014. Throughout her educational career, she has worked as a teacher in the area of K-12, university, as well as with adults teaching English as a Second Language and English as a Foreign Language.

CURRICULUM VITAE

Michelle Iris Rodriguez

Objective: Utilize my extensive experience with 2D and 3D digital geology, Geospatial Information sciences (GIS) and education and integrate my knowledge and abilities in programming (Visual Basic .NET) analysis tools in order to facilitate the development of goals and objectives in a company in an effective, interactive and vigorous manner.

Relevant Education/ Credentials:

MS Geospatial Information Sciences	2013	University of Texas -Dallas
MA Science Education	2006	University of Texas -Dallas
BA Interdisciplinary Studies	2000	University of Texas -El Paso

PhD dissertation: Digital Integrated Geological Interaction Tools is a series of analysis tools programmatically designed for use in the Geosciences through graphic user interfaces (GUIs) and implemented in 3D using ArcGIS software. These tools enable the user to perform a variety of exercises such as research an area, log data, take notes, upload imagery, and interact with a 3D photorealistic model of an outcrop. The GUIs are designed for Geology courses including Physical Geology (Anti-syncline tutorial), Structure (performing Ramsay Fold Classification), and Stratigraphy (log real world data and collaborate with multiple users). The GUI's are for use in field exercises and serve multiple levels of technological ability.

Grant Author/Recipient:

National Science Foundation- Directorate for Geosciences	2008
Research Experience for Teachers Award	
Develop cyber-mapping teaching modules to be used in Introductory Physical Geology, Field Methods and Structural Geology classes at UTD to evaluate the effectiveness of using photo-realistic virtual outcrops in teaching	

Einstein Fellowship:

National Science Foundation Office of Geosciences and <u>National Oceanic and Atmospheric Administration</u> NOAA Einstein Fellowship Finalist	2009
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Educational Experience:

Teacher//Facilitator/Trainer	
Subjects: English, Math, Science, English as a Second Language (ESL)	2000-2016
Responsibilities:	
Differentiate/tailor classroom instruction	
Develop lifelong-learners through strong scaffolding	
Effective and motivational classroom management	
Knowledgeable use of student support systems	

Increase student achievement
 Collaborative team-teaching
 Aid in development of staff training courses
 Facilitate staff development/faculty meetings
 Develop common assessments for grade level
 Aid in grant development
 Program placement/monitoring of Bilingual students
 Translation of school communications

Awarded Teacher of the Year-Bradfield Elementary School 2001-2002

Small Business Owner:

Mary Kay Cosmetics Inc., Director 2007-2013

Geology/GIS Experience:

Digitally Integrated Stratigraphy Project –Measley Ridge, Ohio 2013
 Silurian Bisher and Lilley formations of mixed shales and limestones

Teaching Assistant-Department of Geosciences 2009-2010
 University of Texas at Dallas, History of Earth and Life, The Oceans

Austin chalk (Cretaceous) - Dallas, Texas 2009
 Prototype mapping of a proposed Global Stratotype Section and Point (GSSP) site for Cretaceous (Santonian) Limestone (Austin Chalk) (10-mile Creek).

Eagle Ford/Austin Chalk (Cretaceous)- Cedar Hill, Texas 2009

with J. Lerma of the Polytechnic University of Valencia, Spain

Rapid response monitoring of collapsed Salt Dome 2009
 Dassetta Sink Hole Dassetta, Texas

Developing and Applying in the field-ground LiDAR/photography for 3D modeling Department of Petroleum and Chemical Engineering 2008
 University of Calgary-Calgary, Canada

Publications:

Journal of Stratigraphy- Digital Integrated Stratigraphy Project (DISP) Special Journal
 Rodriguez-Gomez, M.I., Cramer, B.D., Burnham, B., Wang, M., Chen, L., Aiken, C.L.V.
 The Digital Integrated Stratigraphy Project (DISP) Development Phase II: On-site 3D access,
 analysis and integration of stratigraphic data using digital tablets and a 3D Photorealistic Model.
<http://www.micropress.org/microaccess/stratigraphy/issue-303/article-1858>
 2014

Geological Society of America Special Paper
Wang, M., Rodriguez-Gomez, M.I., and Aiken, C.L.V., 2012. Interacting with Existing 3D Photorealistic Outcrop Models on Site and in the Lab or Classroom, Facilitated with an iPad and a PC, Geol. Soc. America Spec. Paper 492, Google Earth and Virtual Visualizations in Geoscience Education and Research, Ch. 19, p. 263-285

Presentations/Abstracts:

Geological Society of America-Poster Using Digital Tools For The Analysis of 3D Virtual Models In The Classroom Such as the Ramsay Fold Classification	2013
Geological Society of America-Presenter The Digital Integrated Stratigraphy Project (DISP) Development Phase II: A Graphic User Interface for the web-based open access Digital Resource for Stratigraphy	2013
3D G.I.I.V.E: A collaborative Program for Disseminating and Training with 3D Virtual Geology in the North Texas Region (GSA, Denver, CO)	2010
Virtual Model It And They Will Learn (GSA, S. Central-Dallas, TX)	2009
A Comparison Of The Effectiveness Of Close-range Photogrammetry, Laser Scanning, and Their Integration in Creating High Resolution 3D Virtual Models of Geologic Outcrops (GSA, Portland, OR)	2009
GeoIs: A Software To Facilitate Teaching Geosciences K-12 (GSA, S. Central Hot Springs, Arkansas)	2008
K-12Teacher as An NSF RET (Research Experience for Teachers) Participant in the NSF INTERFACE (Interdisciplinary alliance for digital Field data Acquisition and Exploration) Facility at UT-Dallas (GSA, Houston, TX)	2008
Geological Society of America-Abstract Co-Author Interacting with 3D Photorealistic Outcrops Using an iPad	2011

Application of the GeoDimensional Tools ArcGIS
Extension for the Analysis of 3D Virtual Models of
Outcrops in the Arbuckle Anticline and Other 2008

AGU-Abstract Co-author
Monitoring Growth of the Daisetta, Texas Sinkhole With
Terrestrial Laser Scanning, Close Range Digital Photography
and GPS 2008

UNAVCO Science Workshop Co-author
Analyzing 3D Virtual Models built with Terrestrial
LiDAR: Now that I have it what do I do with it? 2008
Boulder, Colorado