SOFTWARE VALIDATION TEST REPORT FOR LITHOTECT™, VERSION 1.20

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1 SCOPE OF VALIDATION

This report documents the Software Validation Test results for the limited validation of the functionality of *LithoTect™, version 1.20*. *LithoTect™* was acquired by the Center for Nuclear Waste Regulatory Analyses (CNWRA) of Southwest Research Institute® (SwRI) to provide additional technical assistance capabilities to the Nuclear Regulatory Commission (NRC) in their high-level nuclear waste geologic repository program.

These test results are intended to validate *LithoTect™* program features that are used to create and display geologic data in map, cross section, and stratigraphic section views in addition to validate the cross section restoration and forward modeling capabilities. Specific features that will be validated include: (i) construction of maps from imported images, (ii) flexural slip kinematic restoration, (iii) interactive deformation of an undeformed cross section using the forward modeling algorithm, and (iv) vertical/oblique slip kinematic restoration. The tests described herein are based on the partial Software Validation Test Plan (SVTP) for the limited validation of *LithoTect™, version 1.20* (Landis and Smart, 2004).

2 ENVIRONMENT

2.1 Software and Operation System Requirements

LithoTect™ is developed and marketed by Geo-logic Systems, located in Boulder, Colorado. *LithoTect™* runs on Microsoft® Windows 95/98/2000/NT/4.0/ME/XP operating systems and Solaris and Linux platforms. *LithoTect™* is a pure Java application requiring Java 2 Runtime Environment Version 1.3.0_02 or later to operate correctly.

Data can be imported in a variety of formats depending on the type of data required. Images can be imported as, but are not limited to, .TIF, .JPG, or .GIF file formats. Data files consisting of line data or point data can be imported as ASCII comma delimited text files or input directly by the user.

2.2 Hardware Requirements

LithoTect™ requires an IBM-PC compatible computer or UNIX workstation with a 256 MHz or faster processor and at least 256 MB of RAM. The recommended configuration is a 1 GHz or faster processor and at least 512 MB of RAM. *LithoTect™* can print output to any installed printer and to CGM files that can be imported into Adobe® *Illustrator®*.

2.3 Test Machine Specifications

The validation tests were performed on a 6 x 1.2 GHz Sun Fire V880Z workstation. This machine is equipped with 24 GB of RAM, multiple hard drives and the SunOS 5.9 operating system.

3 PREREQUISITES

Prerequisites for successful installation and execution of *LithoTect*™ include the compatible operating systems defined in Section 2.1 and hardware specifications exceeding those detailed in Section 2.2. Installation of the program and license files requires administrator privileges. However, administrator privileges are not required to execute the program once installation is complete.

4 ASSUMPTIONS AND CONSTRAINTS

The user of *LithoTect*™ is assumed to have a basic understanding of structural geology, including cross section construction, and fold and fault kinematics. The program installation provides a HTML-format help page that contains an index of help files that explain most functions of *LithoTect*™. However, the help system is under construction and does not detail some advanced functions. In addition, a tutorial project is provided that describes the basic features of the program.

5 TEST CASES

This validation test results report follows CNWRA requirements as outlined in Section 5.10 of TOP–018 (CNWRA, 2003) and utilizes the test cases outlined in the *LithoTect*™ (version 1.20) SVTP (Landis and Smart, 2004). The success of the test cases is based on comparisons to published data and to files generated by *LithoTect*™ in other test cases. Specifically, files used and generated in test case 3 are compared to files in test case 4. The test cases are considered successful if functions within *LithoTect*™ produce results that are visually identical to published data or to *LithoTect*™ files.

5.1 Test Case 1 – Verification of Project Management Tools

The ability to create maps, stratigraphic columns, and outcrop orientation data is crucial to the development of structural projects. Without properly constructed project data, structural interpretation would be severely limited. This test evaluates the project creation capabilities including importing images, digitizing images, importing outcrop orientation data, and generating stratigraphic columns.

5.1.1 Test Input

The test input for this case consists of a published geologic map that contains outcrop orientation data (Rowland and Duebendorfer, 1994). The published map is provided in Figure 1A.

5.1.2 Test Procedure

A project was created by specifying the "New Project" option in *LithoTect*™. Initially, a stratigraphic column consisting of the map units, gabbro, and Formation M was created using the "new column" option (Figure 1B). The published map (Figure 1A) was imported as a .JPG image and was recreated using the digitizing tools in the map view window. Because the type of boundary between Formation M and gabbro is not specified by Rowland and Duebendorfer (1994), the boundary was digitized as a fault to test the creation of different line types. Units created in the stratigraphic column (Figure 1B) were then transferred to the regions digitized on the map. Finally, the strike and dip data present in Figure 1A was imported as sample/outcrop data from a comma-delimited ASCII text file.

5.1.3 Test Results

The digitized map created with *LithoTect*™ (Figure 1C) is identical to the published source (Figure 1A) (Rowland and Duebendorfer, 1994). As a result, test case 1 is considered successful.

5.2 Test Case 2 – Verification of Flexural Slip Restoration Functionality

Restoration of cross sections is used to evaluate cross section validity and interpretation. Properly constructed cross sections restore to an original state that is geologically valid. *LithoTect*™ allows the user to select from two different kinematic slip models, flexural slip, and vertical/oblique slip, to restore geologic cross sections. The flexural restoration option restores deformed sections through curvilinear vectors and assumes a parallel geometry in which layer thickness remains constant. The vertical/oblique slip kinematic model restores cross sections through straight-line vectors (either vertical or inclined at a user-specified angle) and assumes similar geometry.

5.2.1 Test Input

The test input for this case consists of a published cross section of a contractional fault-bend fold (Tearpock and Bischke, 1991). The undeformed fault-bend fold and the deformed cross section are provided in Figures 2A and 2B, respectively.

5.2.2 Test Procedure

The fault-bend fold (Figure 2B) was imported into a new project as a .JPG image with the “Import” –> “Image” option. There, the unit tops and fault were digitized in the depth profile view (Figure 3A). The fold was restored by selecting the “Restoration” tab and by using the “Interactive” –> “Flexural” –> “Regions” options. The hanging wall of the fault-bend fold was the block that underwent flexural restoration, and the restoration was performed on reference lines that extend from the footwall (Figure 3B). The configuration of the reference lines restored the hanging wall directly adjacent to the footwall (Figures 3A and 3B).

5.2.3 Test Results

The restored contractional fault-bend fold is provided in Figure 3C. The published undeformed section (Figure 2A) (Tearpock and Bischke, 1991) and the undeformed section created with *LithoTect*™ (Figure 3C) are nearly identical. Because the fault-bend fold was digitized from a scanned image, it was difficult to maintain unit thickness across the fault. Therefore, the undeformed cross section created with *LithoTect*™ contains areas in which stratigraphic horizons are not perfectly straight lines. This is a product of the scanning and digitizing process and does not reflect inaccuracies with the flexural restoration algorithm. Based on the comparison between the published section and the restored section generated with *LithoTect*™, test case 2 is considered successful.

5.3 Test Case 3 – Verification of Forward Modeling Functionality

Structural forward modeling is a technique used to deform an undeformed cross section to evaluate the stratigraphic response. *LithoTect*™ uses an interactive forward modeling algorithm that allows the user to quickly deform a section by selecting the fault to slip on, the angle of slip, the units undergoing deformation, and the amount of displacement. This technique enables the user to visualize deformation processes and aids in the construction of geologically valid cross sections.

5.3.1 Test Input

The test input for this case consists of an extensional geologic cross section and its corresponding restored section that was based on cross sections from Groshong (1999).

5.3.2 Test Procedure

The published extensional cross sections (Groshong, 1999) served as templates that were used to create a simplified extensional cross section consisting of a single hanging wall and footwall block (Figure 4A). The undeformed cross section (Figure 4A) was generated in the depth profile view. The hanging wall was deformed by selecting the

“Forward Modeling” tab and specifying the “Vertical/Oblique” –> “Lines” option. Figure 4A outlines the parameters used to deform the hanging wall. The cross section was deformed using 90° (pure vertical) slip.

5.3.3 Test Results

The deformed cross section generated using the forward modeling algorithm is provided in Figure 4B. Overall success of this test case is dependent on the output of test case 4. In test case 4, the output from test case 3 (Figure 4B) will be restored using the vertical/oblique slip algorithm. Because the undeformed section was deformed using 90° vertical/oblique slip, the restoration algorithm will restore the cross section to an undeformed state that is visually identical to the original digitized section (Figure 4A). If the files are visually identical, then test case 3 and test case 4 will be considered successful.

5.4 Test Case 4 – Verification of Vertical/Oblique Slip Restoration Functionality

In addition to flexural slip restoration, *LithoTect*™ provides a vertical/oblique slip restoration option for validating cross sections. While flexural slip restoration is used for contractional sections, vertical/oblique restoration is primarily used for extensional cross sections. Vertical/oblique kinematic slip restores cross sections along straight-line vectors, either vertical or inclined at a user-specified angle.

5.4.1 Test Input

The test input for this case will be the output from test case 3 (Figure 4B).

5.4.2 Test Procedure

The output from test case 3 was restored by selecting the “Restoration” tab and selecting the “Interactive” –> “Vertical/Oblique Slip” –> “Lines” options. The deformed cross section was restored using 90° (pure vertical) slip. The deformed horizon was the portion of the hanging wall directly adjacent to the fault and was restored along the entire length of the fault. Figures 4C and 4D outline the parameters used to restore the cross section.

5.4.3 Test Results

The undeformed extensional cross section (Figure 4D) generated by *LithoTect*™ for this test case was compared to the input file for test case 3 (Figure 4A). Although different algorithms were used to deform and restore the extensional cross section, the undeformed output from the restoration (Figure 4D) is visually identical to the digitized cross section (Figure 4A) used in the forward modeling algorithm. Based on this comparison, test case 3 and test case 4 are considered successful.

6 SUMMARY

All test cases were successfully completed. Therefore, it is concluded that the program features tested in *LithoTect™, version 1.20* are validated.

7 REFERENCES

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Tearpock, D.J. and R.E. Bischke. *Applied Subsurface Geological Mapping.* Upper Saddle River. Prentice-Hall PTR. 648 pp. 1991.

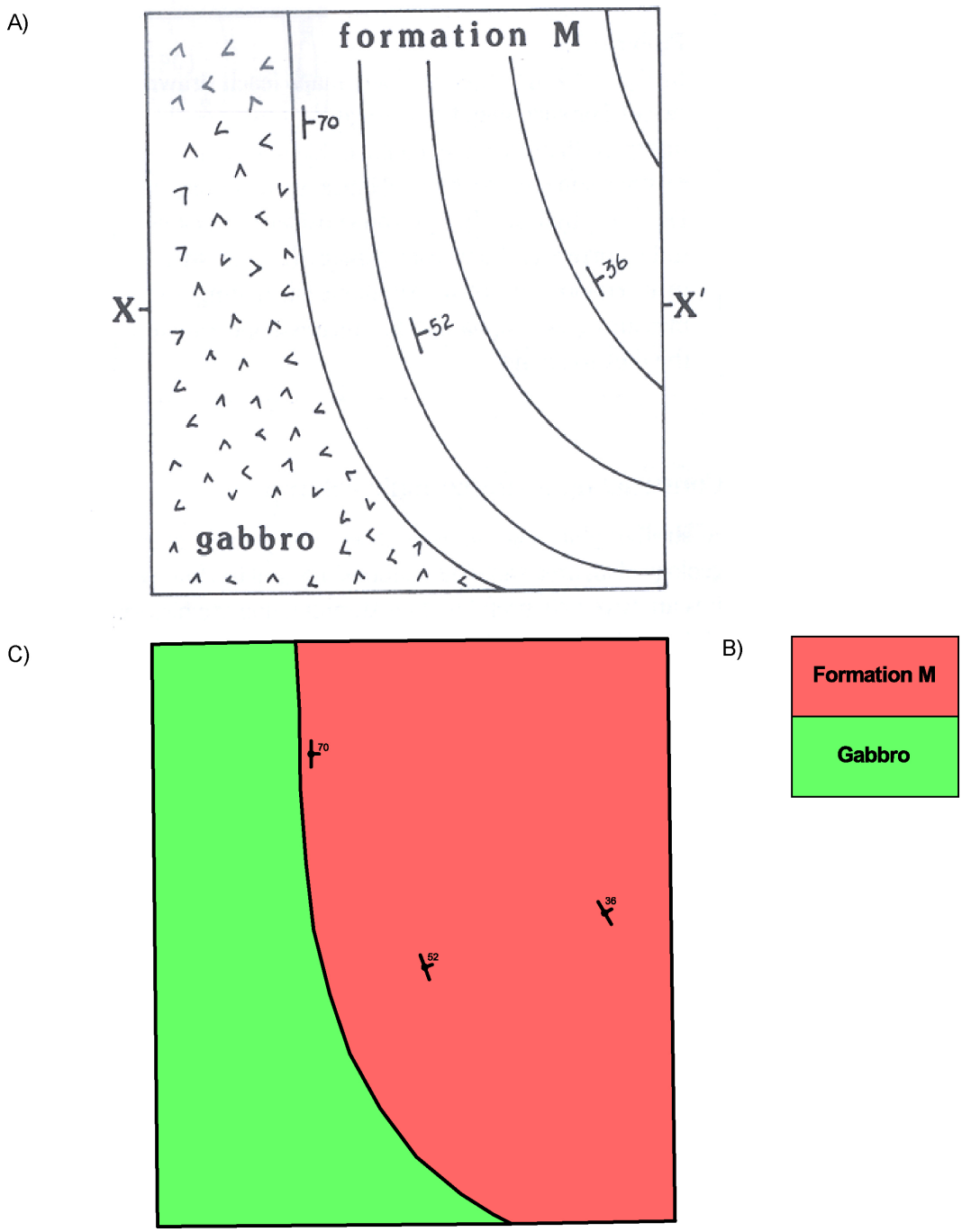

Figure 1. Published map (A) (Rowland and Duebendorfer, 1994) used as the input file for test case 1, and (B) stratigraphic column used to define units, and (C) digitized map generated with *LithoTect*™.

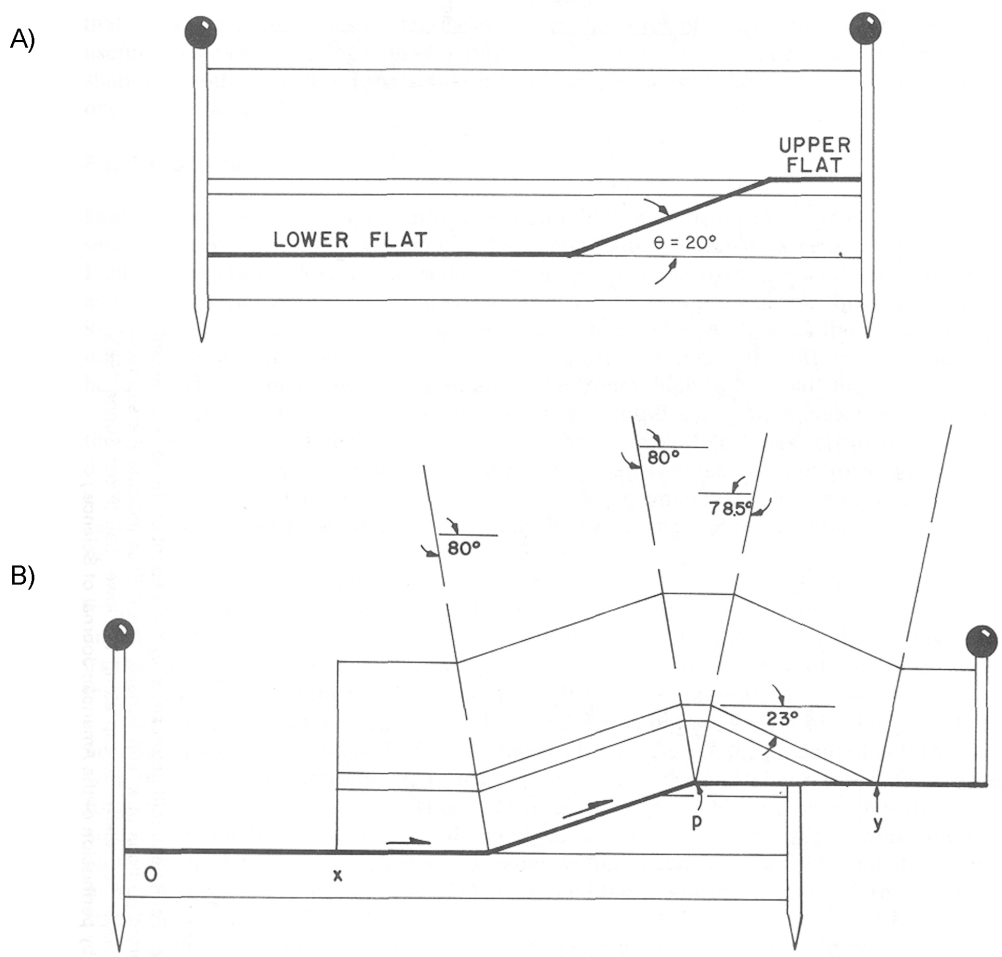

Figure 2. Undeformed (A) and deformed (B) cross sections of a contractional fault-bend fold (Tearpock and Bischke, 1991). The deformed section (B) is the input file for test case 2.

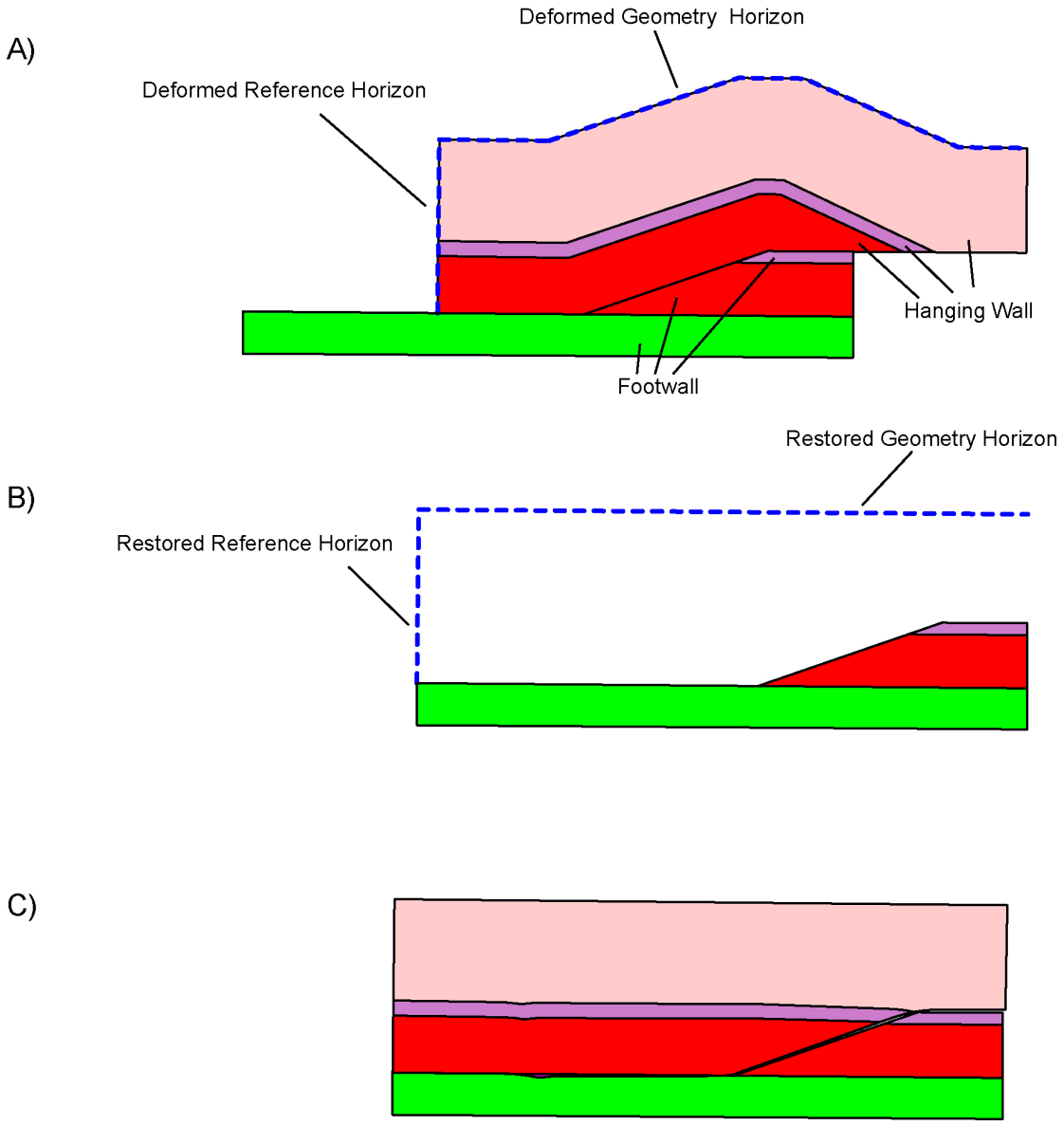

Figure 3. Digitized fault-bend fold showing (A) deformed horizons, (B) parameters used to restore the section, and (C) output generated with *LithoTect*™ using the flexural slip kinematic algorithm.

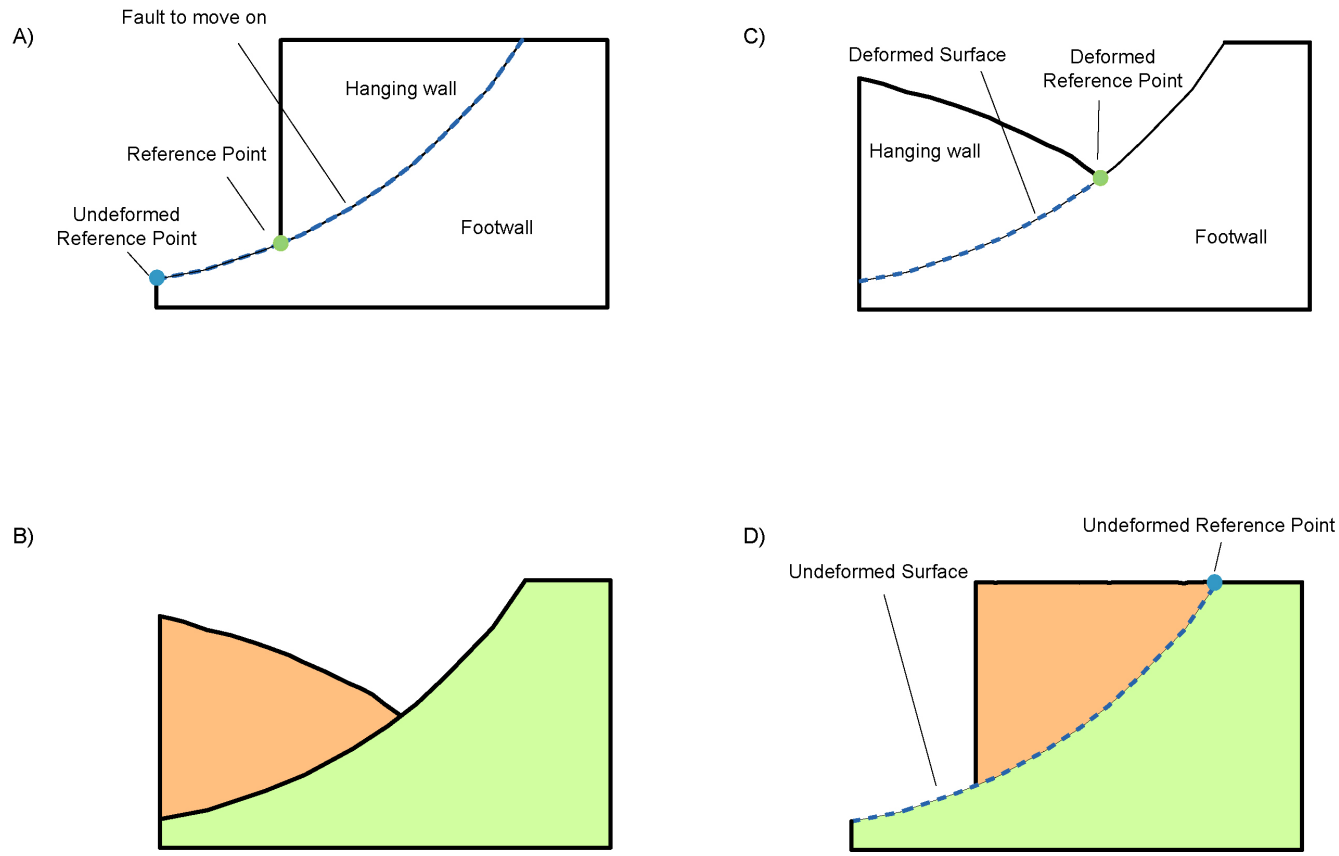

Figure 4. (A) Undeformed extensional cross section displaying parameters used to displace hanging wall block for test case 3. (B) Deformed section generated using the forward modeling algorithm. (C) Deformed cross section (B) used as input for test case 4. (D) Restored cross section using the vertical/oblique kinematic slip restoration feature. Parameters used to restore the cross section are noted in 4C and 4D.