Using “An Introduction to Structural Methods” - An Interactive CD-ROM - In and Out of the Classroom

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TYPE OF ACTIVITY: Applications of this interactive CD-ROM to classroom demonstrations, self-directed lab or homework exercises, collaborative learning, and as a student study resource will be explored.

CONTEXT: “An Introduction to Structural Methods” is appropriate for a required undergraduate course in structural geology and, in some aspects, an introductory-level graduate course in structural analysis. This resource supports all aspects of a structural geology syllabus by taking advantage of the medium’s particular strengths in illustration: it is rich in animations, three-dimensional diagrams, photographs, and geologic maps and cross sections. It is not intended to replace conventional textbooks. The Table of Contents of “An Introduction to Structural Methods” is attached.

REQUISITE SKILLS: Knowledge of basic rock types and geologic time, and the ability to read and interpret a topographic map are essential and are not included in the CD-ROM. Later chapters build on concepts covered in earlier chapters. In these cases, reference to the appropriate sections is made and the user is encouraged to review the necessary key concepts.

GOALS: Use of the CD-ROM in and out of the classroom should support mastery of basic skills in structural geology, improve three dimensional thinking and visualization, and teach map reading and map interpretation.

DESCRIPTION:

This session will consist of three modules that will serve as examples of how “An Introduction to Structural Methods” can be used as (1) a visual aid for an in-class demonstration or lecture presentation; (2) the instructional part of a self-directed lab or homework project; and (3) a student study resource. Participants will be asked to brainstorm on uses for peer-led group exercises.

In-Class Demonstration

Many aspects of “An Introduction to Structural Methods” are intended to assist with concepts that have, in the past, been cumbersome or difficult to present in a conventional blackboard-based lecture format. We have tried to anticipate those times when a teacher finds her or himself saying to the class something like: “imagine this flipped on its side” or “then this moves over here”. For this session, we will use down-plunge visualization as an example.

One of the mantras my students are encouraged to chant regularly is: “the map IS the cross-section...the cross section IS the map”. My goal is for students to understand structures as three dimensional bodies and to appreciate that a map and a cross section are just two different planar sections through the same three dimensional volume. The most widely taught functional application of this concept is drawing and visualizing down-plunge projections.

Down plunge viewing is typically linked to teaching about folds (for example, see Disc One, Chapter 7, Viewing Folds Down Plunge, frames 720-743), but I have found that maps and cross sections in thrust belts are very effective for consolidating this skill, so I teach a lecture on this key concept as part of a segment on thrust faults, which is late in my syllabus. The following required concepts have therefore already been covered. Students can review these skills with sections of the CD-ROM as noted below.

Required skills:

• finding the plunge of a structure [Disc One, Chapter 7, Viewing Folds Down Plunge, frames 738-739; Disc Two, Chapter 9, Map Interpretation, frames 914-915]
• the geometric relationship between points on a map and corresponding points projected into a line of section (down-plunge projections) [Disc One, Chapter 7, Viewing Folds Down Plunge, frame 725 In Depth Comment; Disc Two, Chapter 9, Map Interpretation, frames 910-913]
• elements of thrust faults and thrust belts such as ramps, glides, fault-bend folds, and cut-offs [Disc Two, Chapter 9, Thrust Fault Geometry, frames 845-856]

The session will work through frames 916 to 931 of Disc Two. In this sequence, animations clarify the geometric relationship between thrust fault structures in map and cross section. One example is reproduced below:
Student Self-Directed Lab or Homework Exercise

“An Introduction to Structural Methods” is designed to be illustration-rich and text-light but, for all subjects, enough explicit instruction is included that a student can take her or himself through the steps of any technique and learn its application. This allows the CD-ROM to serve as the instructional introduction to specific homework or lab exercises in a typical structural geology course. The student can then learn how to do the associated exercise at his or her own pace, and go back during the course of the exercise to review steps that prove difficult to master.

Constructing the map pattern of a dipping bed will serve as an example of this type of application. Related topics that will be covered in the course of this exercise are structure contours and three-point problems (determining the strike and dip of a bed from its map pattern). Required skills are few and can be reviewed with sections of the CD-ROM as noted below:

Required skills:

- understanding strike and dip of inclined planes [Disc One, Chapter 1, Orientation of a Plane, frames 32-38]
- the rule of V’s [Disc One, Dipping Planes, frames 83-90]

The session will work through frames 106 to 172 of Disc One from the point of view of a student preparing to complete an exercise on projecting the map pattern of a dipping bed. The typical exercise that would follow this introduction would provide a simplified topographic base map on which three points of outcrop of a specific tabular geologic unit are designated.
The student would be asked to:

1. determine the strike and dip of the unit;
2. construct a structure contour map for the unit;
3. complete the outcrop pattern for the unit across the map sheet.

An excellent example of such an exercise can be found as Problem 2-4 in *Structural Analysis and Synthesis A Laboratory Course in Structural Geology* by S.M. Rowland and E.M. Duebendorfer (Blackwell Scientific Publications, 1994, ISBN 0-86542-366-0).

**Student Study Resource**

Self-directed study is promoted in “An Introduction to Structural Methods” by the use of interactive quizzes that follow the explication of each key concept. Students can use these quizzes to assess their progress for a given topic and will be prompted by their performance to review fundamentals as needed. An example [Disc One, Chapter 5, Recognizing Faults on Maps, frame 511] of one such quiz question (answered) is given below.

In many quiz questions, once an answer has been selected, the CD-ROM engages the user in a “dialog” on how the answer should be determined or what makes the right answer right. The session will review frames 511 to 514 on Disc One to see how this works. But the quiz format does not in every case lend itself to an in-depth exchange between student and computer. For some quizzes, a student who is somewhat lost might just keep clicking options until he or she finds the right answer by a process of elimination without ever coming to grips with the gaps in his or her understanding. Instructors can maximize the benefit of those interactive quizzes by requiring short written responses in addition to assigning independent study of any given section of the CD-ROM. This session will work through a quiz on kinematic indicators in frames 1486 to 1492 of Disc Two to explore the kinds of additional questions that might be used in written form. Suggestions include: “What geometric relationship or relationships in each picture record the sense of simple shear?” and “Which fabric elements [or components of the structure] correlate to elements of the strain ellipse?” Frame 31 on Disc One [Chapter 1, Orientation of a Line] shows a quiz where a student might be asked simply to articulate why each answer is correct or incorrect. Participants will be encouraged to create and share other short written assignments that might be used in conjunction with the CD-ROM.
Disc One

1 Elements of Lines and Planes
   Introduction
   Horizontal and Vertical Angles
   Orientation of a Line
   Orientation of a Plane
   Orientation of a Line in a Plane

2 Map Interpretation: Simple Planar Surfaces
   Understanding Map Patterns
   Introduction
   Horizontal Planes
   Vertical Planes
   Dipping Planes
   Determining Strike and Dip from Map Relationships
   Structure Contours
   Determining Depth
   Determining Stratigraphic Thickness

3 Stereographic Projection I
   Spherical and Stereographic Projection
   Elements of the Stereographic Net
   Plotting Lines and Planes
   Plotting a Plane
   Plotting a Line
   Plotting a Line in a Plane
   Plotting the Pole to a Plane
   Solving Problems Using the Stereonet
   Introduction
   Intersection of Two Planes
   Plane Defined by Two Lines
   Angle Between Two Planes

4 Constructing Geologic Sections
   Introduction
   Construction Procedures
   Section Considerations
   Section Conventions

5 Map Interpretation: Faults
   Fault Elements and Fault Types
   Recognizing Faults on Maps
   Slip Versus Separation
   Introduction
   Determining Vertical Separation
   Calculating Net Slip
   Using Cut-Off Lines

6 Stereographic Projections II
   Rotating a Line
   Rotating a Plane
   Solving Rotation Problems
   One Rotation Around a Horizontal Axis
   Two Rotations Around Horizontal Axes

7 Map Interpretation: Folds
   Fold Elements
   Fold Orientation
   Fold Geometry
   Fold Closure and Facing Direction
   Interlimb Angle and Symmetry
   Viewing Folds Down-Plunge
   Interpreting Folds on Maps
   Measuring Fold Elements on Geologic Maps

8 Map Interpretation: Unconformities, Intrusions
   Unconformities
   Intrusions

Disc Two

9 Map Interpretation: Thrust Faults
   Thrust Fault Geometry
   Dynamic Development of Thrust Belts
   Map Interpretation

10 Fold Analysis
   $\pi$-Diagrams and Fold Elements
   $\pi$-Diagrams and Fold Style
   Fold Asymmetry and Vergence
   Fold Shape and Dip Isogons
   Refolded Folds

11 Stress, Fracture, and Fault Analysis
   Introduction
   Stress
   Stress on a Plane
   Stress at a Point
   Determining Stress on a Plane
   The Mohr Circle for Stress
   Constructing the Mohr Circle
   The Coulomb Envelope
   The Role of Anisotropy
   Fracture and Fault Analysis
   Joints and Dikes
   Conjugates and the Anderson Model of Faulting
   Faulting in Anisotropic Rocks
   Stress Fields

12 Strain: Basic Principles
   Introduction
   Deformation and Strain
   Principles of Strain
   The Strain Ellipse
   Strain Analysis
Introduction
Deformed Circular or Elliptical Markers
Changes in Lengths of Lines
Changes in Angles between Originally Perpendicular Lines
Three Dimensional Strain
  The Strain Ellipsoid
  Fabric and the Strain Ellipsoid
Strain Paths
  Finite and Incremental Strain
  Pure and Simple Shear
  Shear Sense Indicators
ADDITIONAL EXAMPLES OF ILLUSTRATIONS FROM “AN INTRODUCTION TO STRUCTURAL METHODS” IDEAL FOR USE AS VISUAL AIDS DURING IN-CLASS DEMONSTRATIONS OR LECTURES:

- The Rule of V’s  
  Disc 1, Chapter 2, Understanding Map Patterns: Dipping Planes, frame 86
- Fault offset in map view  
  Disc 1, Chapter 5, Recognizing Faults on Maps, frames 468 and 470
- Cylindrical fold propagation  
  Disc 1, Chapter 7, Fold Elements, frame 673
- Movement of a thrust sheet over ramps and glides  
  Disc 2, Chapter 9, Thrust Fault Geometry, frames 849-850 and 855
- Mohr circle and Coulomb envelope in quartz vein development  
  Disc 2, Chapter 11, The Coulomb Envelope, frame 1148 In-Depth Comment
- Ductile shear zone development  
  Disc 2, Chapter 12, Shear Sense Indicators, frame 1479 (Compare frame 1463)

ADDITIONAL EXAMPLES OF PASSAGES FROM “AN INTRODUCTION TO STRUCTURAL METHODS” SUITABLE AS INSTRUCTIONAL INTRODUCTIONS TO STUDENT SELF-DIRECTED LAB OR HOMEWORK EXERCISES:

- Use of the stereonet in all aspects, for example, plotting the pole to a plane (perhaps in preparation for an exercise on making and interpreting $\beta$ diagrams)  
  Disc 1, Chapter 3, Plotting Lines and Planes, frames 296-304
- Construction of a geologic cross-section and/or the topographic profile for a cross-section  
  Disc 1, Chapter 4, Cross Section Construction Procedures, frames 395-408
- Using piercing points to determine net slip  
  Disc 1, Chapter 5, Slip Versus Separation, frames 545-566
- Constructing the Coulomb envelope  
  Disc 2, Chapter 11, Mohr Circle and the Coulomb Envelope, frames 1118-1129
- Methods of strain analysis, for example, the Wellman method  
  Disc 2, Chapter 12, Strain Analysis, frames 1367-1374

COMPREHENSIVE LIST OF INTERACTIVE QUIZZES IN “AN INTRODUCTION TO STRUCTURAL METHODS”

Chapter 1:  Elements of Lines and Planes  
frames 20, 22, 31, 42, 48-50

Chapter 2:  Map Interpretation:  Simple Planar Surfaces  
frames 73-74, 81, 96-104, 128-134, 150-155, 179-182, 193-196, 214-218

Chapter 3: Stereographic Projection I  
frames 235, 242, 273, 290, 310, 343-344, 373-375

Chapter 4: Constructing Geologic Sections  
frames 409-412

Chapter 5: Map Interpretation:  Faults  
frames 457-458, 511-514, 526, 544, 558, 579-581, 594

Chapter 6: Stereographic Projections II  
frames 631, 665, 667

Chapter 7: Map Interpretation:  Folds  
frames 684, 699-703, 716-719, 741-743, 761-765, 782-785

Chapter 8: Map Interpretation:  Unconformities, Intrusions  
frames 802, 811, 822

Chapter 9: Map Interpretation:  Thrust Faults  
frames 876-882, 904-907, 933-937

Chapter 10: Fold Analysis  
frames 968-970, 991-992, 1002, 1020-1021, 1044-1045

Chapter 11: Stress, Fracture, and Fault Analysis  
frames 1086-1089, 1113-1117, 1223-1228, 1156-1160

Chapter 12: Strain:  Basic Principles  
frames 1298-1300, 1308-16, 1376-84, 1408-17, 1432-37, 1487-92