# Using Interactive Animations to Prepare Students for the Field

## About Us

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## Brief Description of this Session

At ASU and many other schools, students use computer-based interactive animations to prepare for the field. Through such animations, students learn how to read topographic maps, to locate themselves and navigate on such maps, to visualize the 3D geometry of geologic structures, to investigate the interactions of layers and topography, to draw geologic contacts, and to reconstruct geologic history from geologic maps. The use of such animations prior to field work solves many of the problems common to first-time mappers, such as difficulties with location, a lack of appreciation for the way layers should intersect topography, and a tentativeness to actually draw contact lines on paper. In this session, we will explore these animations, observe the sequence in which they are used, and discuss their potential in structural geology and field geology courses. All animations are freely available online at http://reynolds.asu.edu.

## Aspects Common to the Animations[1]

All our animations are one of two types of QuickTime Virtual Reality (QTVR) movies: QTVR object movies and QTVR panorama movies. An easy way to understand a QTVR *object* movie is think of a grid or matrix of images (Figure 1), with rows and columns. In a QTVR object movie, clicking and dragging horizontally moves from image to image in a row, whereas clicking and dragging vertically moves within a column. In most of our animations, a row generally consists of images depicting a type of motion, such as rotation of a terrain, while moving within a column allows further rotations (about another axis) or changing aspects such as shading, transparency, and faulting. A QTVR *panorama* movie is a single image (perhaps stitched together from several images), across which a viewer can scroll and zoom.

To generate the images for both types of QTVR movies, we created, animated, and rendered virtual 3D objects using the Corel program *Bryce*. The individual images rendered by Bryce were then combined into QuickTime Virtual Reality (QTVR) files. *Bryce* uses sophisticated rendering techniques, such as ray tracing, to create the illusion of three-dimensional objects by using depth perception and varying lighting, shading, and color. Contour maps of hills, valleys, and other real geologic features were draped over digital topography using *Bryce*, to create the appearance of three-dimensional topography while simultaneously showing contour lines. Contour maps were created with Peter Guth's free program MicroDEM.

Many movies were then incorporated into modules written in HTML and accessed via Internet browsers. The modules were designed to be interactive, to promote active learning and to avoid mindless screen turning. Students progressing through the modules in an active way

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[1] Some of the text and figures in this contribution is from a paper by S. Reynolds and others, submitted to *Earth and Mind*, a book to be edited by Cathy Manduca and others.

should help students retain more information and understand more content from the movies. During initial piloting of several modules, we quickly discovered that students would stop and read two lines of text, but would be more likely to skip the text entirely as its length increased, so most text in the modules was shortened to one or two lines.

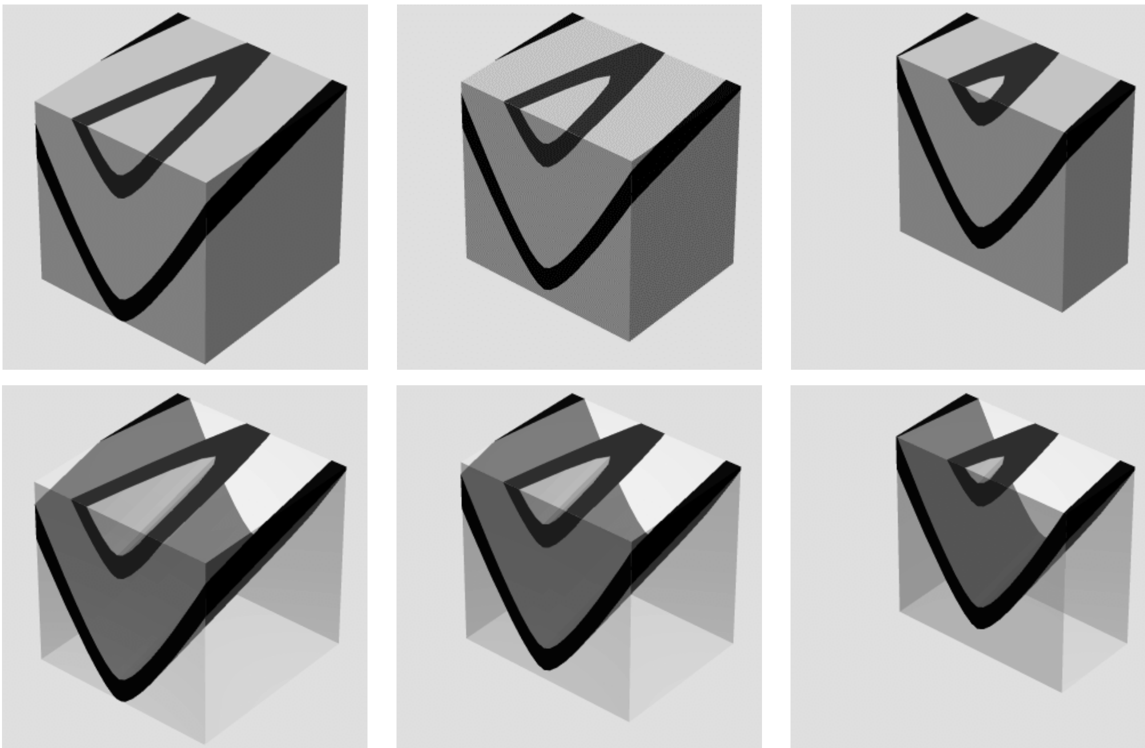


Figure 1. Matrix arrangement of images in a QTVR object movie, where clicking and dragging horizontally moves from image to image in a row, whereas clicking and dragging vertically moves within a column. In both rows, the user can slice into a block to reveal its internal geometry, but the block is partially transparent in the bottom row.

Worksheets were designed to maximize interactivity by requiring active involvement, such as sketching, predicting, and describing. In addition, students work in pairs and are asked at specific places in the modules to discuss their observations and predictions with one another. To encourage such discussion, most questions are open-ended questions or ask students to observe, interpret, and draw features they have seen on screen. The worksheets served as a focus of discussion between students.

Some movies are not incorporated into a module, but are instead accessed as stand-alone movies that are simply part of a written lab or homework assignment. In such cases, students are directed to the movie via a links page listing all the movies of a certain type or topic (such as geologic maps draped over virtual topography).

## Exercise 1 – Visualizing Topography

Students in our undergraduate structural geology course begin with the *Visualizing Topography* module, which some students used previously in their introductory geology lab. This module focuses on the skills required to visualize, understand, and use topographic maps and contour lines, such as identifying key features, identifying elevation changes, recognizing correspondence between the map and 3D perspectives, way-finding, and constructing topographic profiles.  Students are given topographic maps with four movie types:  (1) controlling the amount of shading in a black and white contour map draped over digital topography, (2) rotating colored contour maps draped over topography to gain a top view or side view, (3) raising and lowering virtual water levels on 3D terrains, and (4) slicing into terrains to understand how topographic profiles relate to spacing of contour lines and elevation changes. Figure 2 shows a simple hill landscape represented by three types of movies.

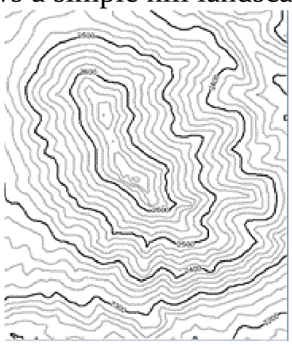


Figure 2a. Two-dimensional topographic map of a simple hill.

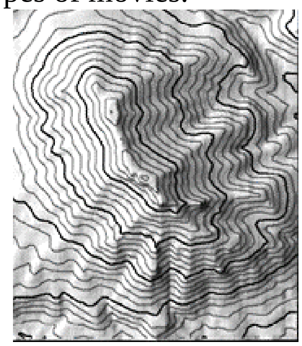


Figure 2b. Shading movie where users click and drag the mouse up and down to increase and decrease the amount of shading.

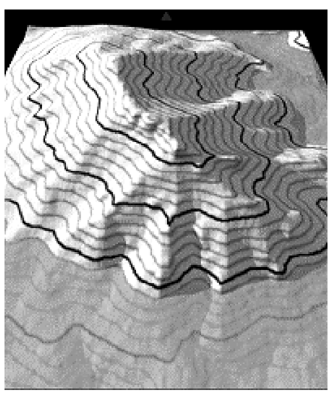


Figure 2c. Flooding movie.  Users change the water level by clicking and dragging up and down.

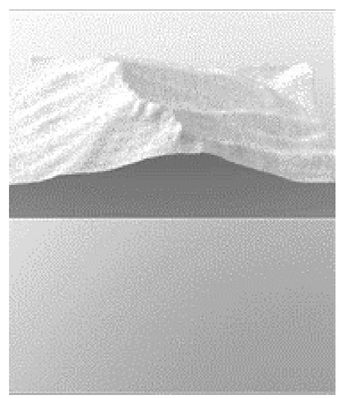


Figure 2d. Slicing terrains movie.  Users change the depth of cut by clicking and dragging up and down.

## Exercise 2 – Toponumber Movies

After structure students finish the Visualizing Topography module, they use QTVR movies we affectionately call “toponumber” movies.  These movies are shaded 3D perspectives of topographic terrains, onto which are imprinted small red numbers at specific locations (Figure 3). Students spin and zoom into these terrains to gain different vantage points in order to plot the location of each of the toponumbers on a paper version of a simplified contour map of the same terrain.  These movies are accessed from the *Gallery of Virtual Topography* on our main website.

For the first several toponumber movies, students work in pairs so that they can share strategies, compare locations, and hopefully gain confidence. In these first movies, numbers are placed on the tops of hills, near drainage intersections, and other places that are relatively easy to locate.  After students finish the “easy” movies, they work with their partner to try to determine what features and strategies they used to locate each numbered point (e.g., it was on top of a hill).  Then, we have a whole-class discussion to generate a list of all the distinctive features or other strategies that were used.  This list is largely generated from student contributions, but the instructor commonly volunteers some strategies that were not mentioned.  This explicit instruction, providing a comprehensive list of specific topo-location strategies, is very fruitful, but probably not done in enough structural geology courses.

Next, students take on more difficult toponumber movies, called “advanced versions” on the Gallery of Virtual Topography site.  Toponumbers on these movies are placed in more difficult locations, such as part way up a nondescript hill.  To successfully complete these movies, students will need all of the various strategies, including more complex ones like comparing the location of the number with an imaginary line connecting two hills on either side.  The Visualizing Topography module, “easy” toponumber exercise, and strategy listing takes most of a three-hour lab, so the advanced toponumber movies are typically assigned as homework with students instructed to work alone.

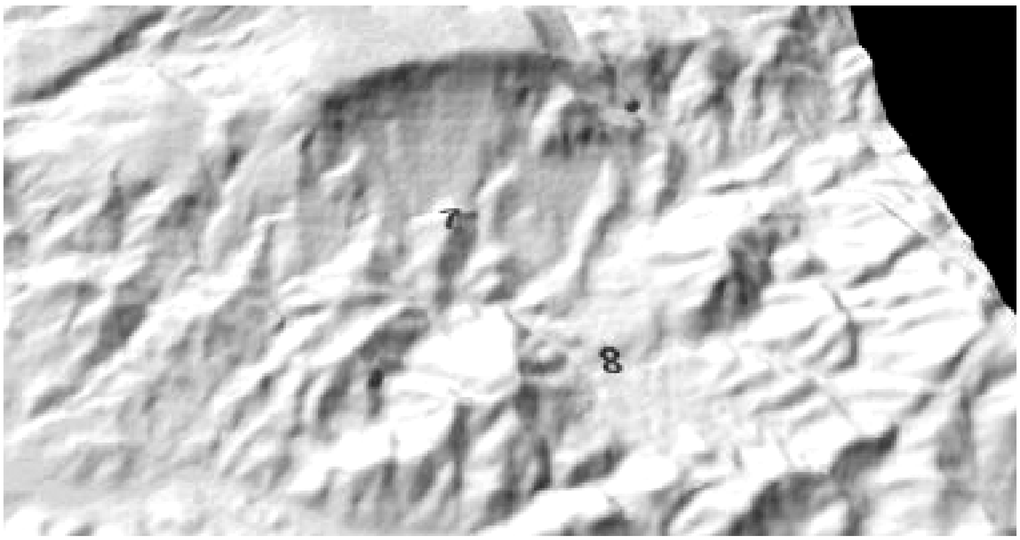
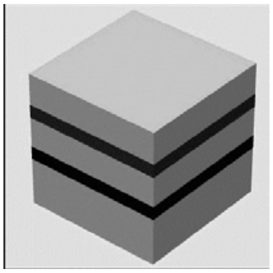



Figure 3.  Part of one scene from an “easy” toponumber movie.  The numbers are red in the version the students use.

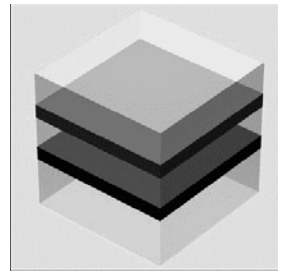
## Exercise 3 – Interactive 3D Geologic Blocks

During the following lab, students begin to explore the 3D geometry of geologic structures via the web-based *Interactive 3D Geologic Blocks* module.  The blocks module was designed to help students visualize how to visualize geologic features.  Techniques used to accomplish this included the rotation of blocks, making blocks partially transparent, slicing into blocks, offsetting faults, eroding the tops and sides of blocks, depositing layers, and revealing structures beneath a buried unconformity.  All movies in this module are QTVR object movies (Figure 1).

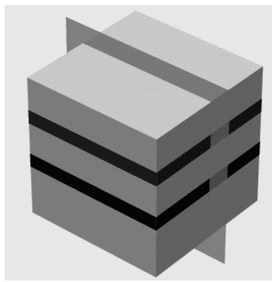
For this module, 3D block models were constructed within *Bryce* using a master animation file containing various possible depictions, such as rotating the block in 10-degree increments, both for an opaque block and a transparent one, hiding each visible face with a white plane, and slicing into the block from two sides and the top.  This animation file rendered a sequence of 206 images for each geologic block, and these images were then combined in



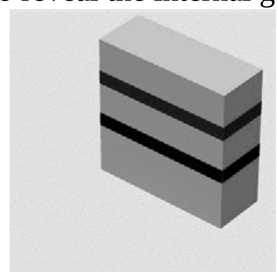
4a. Opaque block with horizontal layers students can rotate.



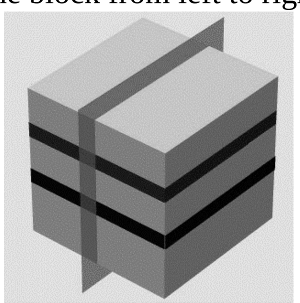
4b. Same block as 4a, but shown as partially transparent to reveal the internal geometry.



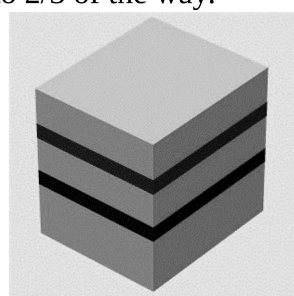
4c. Left cutting plane. Students are instructed to cut into the block from left to right.



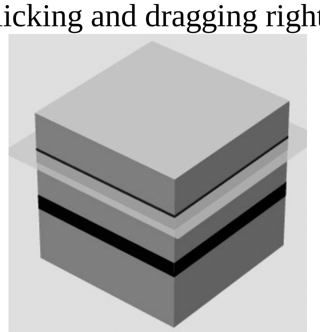
4d. Left cutting plane movie. The block has been cut into 2/3 of the way.



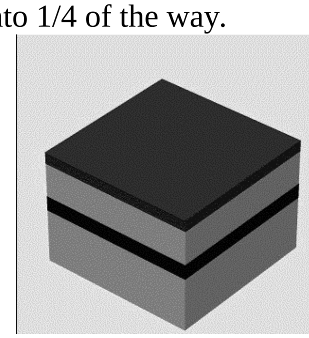
4e. Right cutting plane. Students cut into the movie by clicking and dragging right to left.



4f. Right cutting plane movie. The block has been cut into 1/4 of the way.



4g. Top cutting plane. Students can cut into the block from top to bottom.



4h. Top cutting plane movie. The block has been cut into 1/3 of the way.

Figure 4. Block movies (transparency and cutting) used for the layers section. The same blocks and movies were also used throughout the folds section.

various ways into a QTVR matrix.  One-row movies commonly permit the user to rotate a block or slice into a static block, whereas multirow movies allow other combinations, such as rotations and changing transparency or rotations with successive fault movement.  These movies, because they are totally controlled by the student (nothing happens if the student does nothing), permit students to interactively control the type and speed of changes that occur, thereby allowing students to learn at their optimal rate.

There are movies for layers, folds, faults, intrusions, and unconformities.  For each type of geologic structure, the module has movies for different orientations of the structure, such as horizontal, gentle, moderate, steep, and vertical layers.  Figure 4 shows examples of blocks from each of these screens for horizontal dips and plunges.  Students are commonly asked to make a prediction, such as to predict how the layers continue from visible to hidden faces of the block. Alternatively, students are shown a block with a “cutting plane” intersecting it and are asked to sketch how the block would appear if it were cut along this plane (Figure 4).  The purpose of a cutting plane is to cut into a block and understand how subsurface features are oriented.  In various movies, students can cut left to right, right to left, or top to bottom to fully understand orientations of features inside the blocks.  Students have access to various types of movies to check their predictions, such as by rotating, changing transparency of, or slicing into a block. Students record their answers on worksheets, like that in Figure 5.

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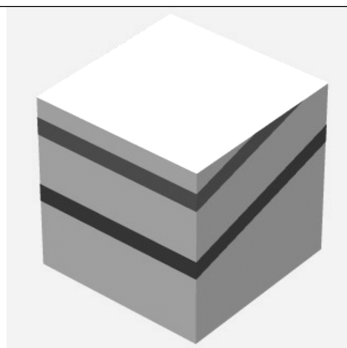
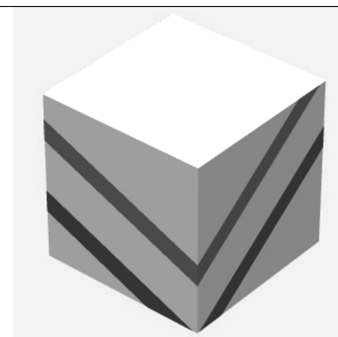
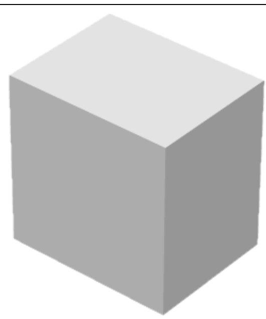
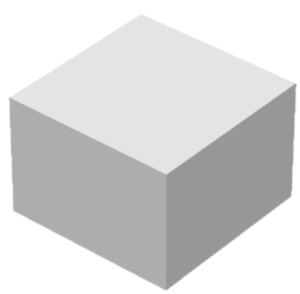
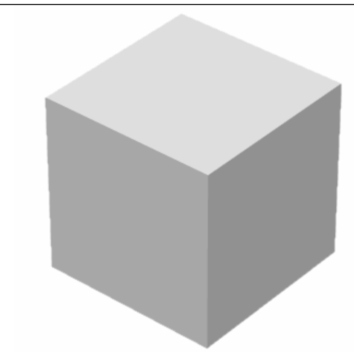
|---|---|---|
|  |  |  |
| L-1  Sketch | L-2  Sketch | L-3  Sketch |
|  |  |  |
| L-4  Sketch | L-5  Sketch | L-6  Sketch |

Figure 5.  Worksheet for part of the layers segment of the Interactive 3D Geologic Blocks module.

## Exercise 4 – Interaction of Layers and Topography

After students have worked with 3D nature of geologic structures in the relatively simple geometric context of a block, they explore how layers interact with topography. The movies for this exercise are contained in our *Structure Map 3D* web site. This site contains three main types of QTVR object movies: LayerTilt, Fixed Layer, and Multiple Layer movies.

*LayerTilt* movies contain topographic terrains that are intersected by a plane whose tilt (dip amount) can be interactively controlled by the user. In most LayerTilt movies, the terrain is draped by a simplified contour map (Figure 6a). Students begin with LayerTilt movies consisting of a single topographic feature, such as a hill or valley. They simply explore by adjusting the tilt and seeing how the layer interacts with hillsides, valleys, and ridges. Then they tilt the layer to a prescribed dip amount (e.g., 20 degrees) and draw (i.e. map) the trace of the layer on a paper topographic map that contains the exact same contours as are draped on the 3D terrain (Figure 6b). Having students be able to draw their first *contact* lines by using a terrain that is draped with the same contour map as their base map is incredibly helpful to students in starting to master the intimidating task of precisely mapping the trace of a contact.

In the second type of movie, the layer is fixed in orientation but the students can spin (and commonly tilt) the entire topographic terrain containing the layer to gain various perspectives and to vary the direction of lighting on a hillside. Students can zoom into the terrain and scroll sideways to gain just the right vantage. They map the trace of the layer on a paper contour map, but the terrains are simply shaded, not draped by contours. These terrains are quite detailed and complex, so students draw lots of contact length and have to assess how the layer interacts with lots of valleys, hills, and ridges.

In the third type of movie, Peter Guth's program MicroDEM was used to plot the projected trace of a layer with 5, 15, 30, and 45 degree dips (this capability is specifically built into his program). The resulting image was then draped over digital topography and rendered from various views. Students mostly just observe this movie, but it could be used to check their results in hand-constructed layer extrapolations, as are done in many structure labs.

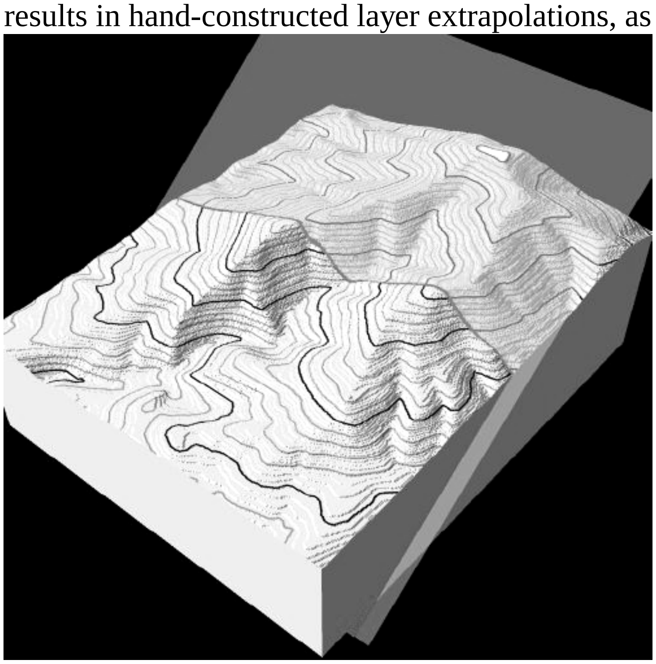


Figure 6a. One scene from a LayerTilt movie showing a plane intersecting a simple valley.

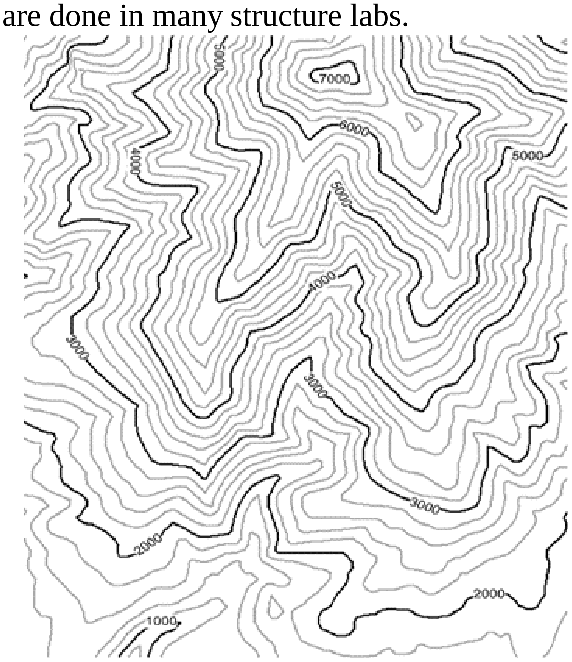



Figure 6b. Contour map of same terrain.

## Exercise 5 – Virtual Geologic Mapping

In this exercise, students use QTVR movies of geologic maps draped over digital topography to create more complex geologic maps of their own and to reconstruct geologic history and subsurface geometries from published geologic maps (Figure 7). These movies and scanned flat maps are available at our 3D Geologic Map Galley web site. We have created many additional movies of draped geologic maps, for various different types of geologic terrains, and have written exercises and worksheets keyed to these movies. We are currently finalizing the materials prior to their incorporation into the 3D Geologic Map Gallery later this summer.

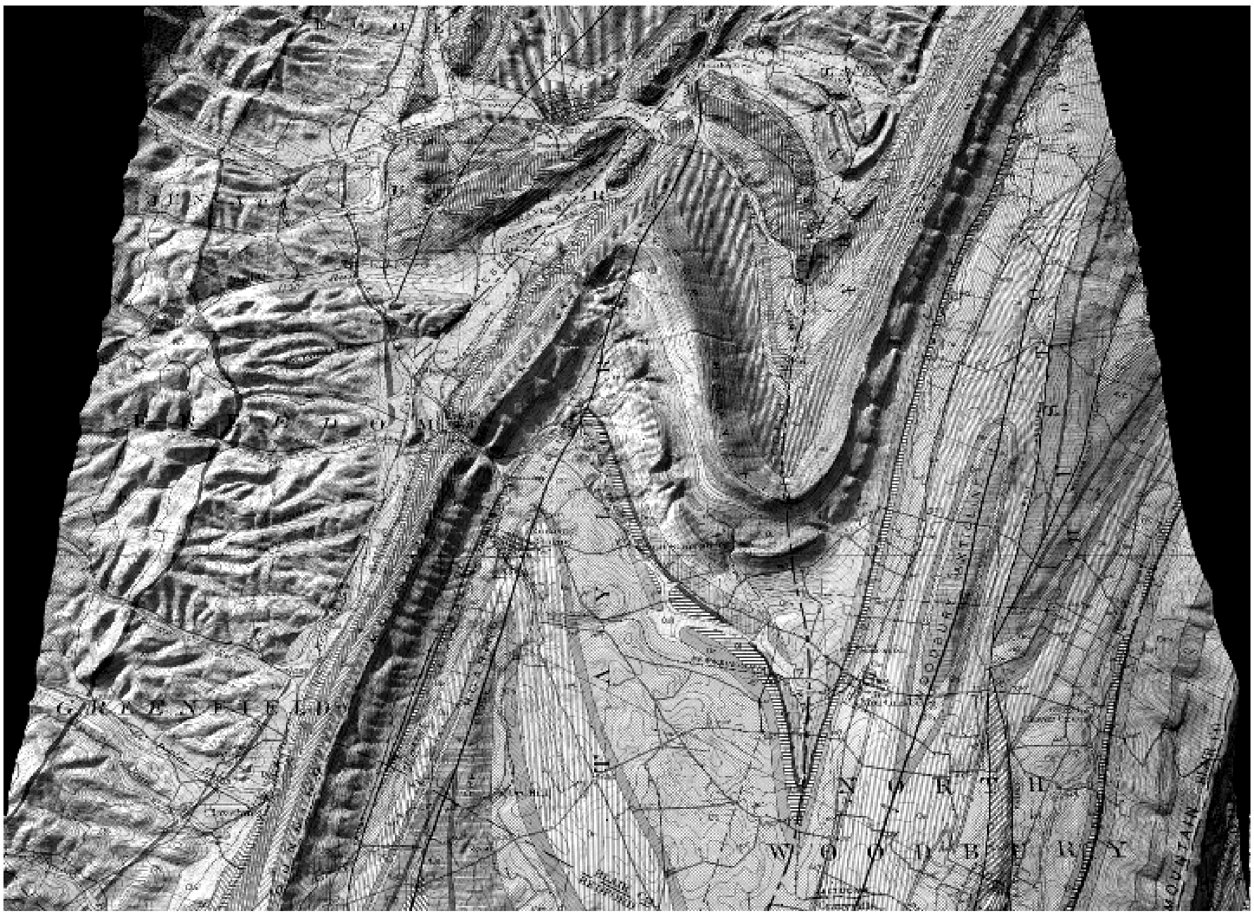


Figure 7. Geologic map of the Hollidaysburg Quadrangle draped over digital topography, shaded, and viewed obliquely toward the north. The original is color.

Most geologic-map movies on this site, like most published geologic maps, have sepia-tone contours in addition to the geology. We mostly use such maps by having students reconstruct the geologic history of these areas and sketch interpreted cross sections of the subsurface geology. In some movies, such as one of the Tucson Mountains, we were able to drape only the geologic lines and unit colors on the map, without any contours. Students use these contour-free movies to map the 3D geologic scene onto a paper contour map of the same area. This exercise is an excellent bridge to the field in that students can concentrate on drawing lines, not on having to determine what rock unit is present or having to deal with field issues such as tromping through vegetation and dealing with float and other cover. Also, in the virtual exercise students draw much more contact length for a given amount of time, because they are not having to spend time hiking along the contact as is required in the field.

Some movies on this site are QTVR *object* movies, so students can spin and tilt the map-draped terrain. The disadvantage of these movies is that to keep the movie file size down (many are already 3 to 15 Mb), individual scenes in the movies are only moderately sized (like 800 x 600 pixels). As a result of the small individual image size, zooming in quickly produces a rough, pixilated image. To counter this issue, we also use QTVR *panorama* movies for geologic maps because these movies can contain a single large, detailed image (such as 1500 x 3000 pixels or more), on which students can scroll and zoom. These movies can preserve the detail of original maps, such that individual strike and dip measurements remain visible. To help students visualize the 3D nature of the maps, we shade them with side illumination and commonly render the image from an oblique view, rather than straight down. Simple map-view versions are also used in cased where we wish to preserve the true map-view shape of rock units.

## The GeoWall

ASU was an early adopter of the GeoWall technology, which uses an off-the-shelf computer linked to two DLP projectors to project a true stereo image. A polarizing filter is mounted in front of each projector, and students wear inexpensive polarized glasses with different polarization orientations for the left and right eyes. The image (actually two images) is projected onto a screen and either the instructor or students can drive the GeoWall computer via the keyboard, mouse, or game controller. For more information, visit http://geowall.org.

All of the draped topographic and geologic maps we created in *Bryce* can be easily exported to the GeoWall, and we have used many of these to further help students bridge the gaps between real 3D, 2D representations of 3D terrains (like our QTVR movies), and simple 2D representations (flat contour maps, etc.). We typically have a GeoWall Demo for the topographic maps lab, and later have students drive the GeoWall themselves when they are using draped geologic maps. Using the GeoWall may help students lessen their cognitive load when trying simultaneously to visualize the 3D shape of the landscape, to interpret the geometry of rock units within that terrain, and to extract from the complex scene the key geologic points – students start with the advantage of actually seeing the terrain in 3D. This technology is relatively inexpensive ($6K or so) and is rapidly being adopted in many schools across the world. It's something to explore!

## Acknowledgments

Our development of these resources and research into their effectiveness was partially funded by two NSF Projects, the Hidden Earth Project (Reynolds, Piburn, and Tewksbury, P.I.s) and the currently ongoing Hidden Earth Curriculum Project. We greatly appreciate this support! Many college and high-school faculty use these materials, in places as far off as Papua New Guinea. We encourage such usage and our server is reliable and fairly fast, but please inform us if a large number of students will be using the site. In such cases, we typically provide upon request a CD or DVD of the materials so that large schools can place the site on their own sever.

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