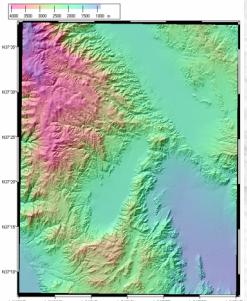


Computer Manipulation of Simple 3D Structures: Supplement, Complement, or Replace the Field Experience?



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ABSTRACT. Outcrop patterns of faults, dikes, and sedimentary beds reflect the interplay of 3D orientations and the topographic land surface. A key task for geologists, and hence geology students, requires extrapolating from the depiction on a geologic map to a visual model of the topography and geology. A related task starts with a measured orientation, and requires estimation of where the structure projects on the map. Two simple geometric problems from the basis for much of this visualization: the three point problem, and the projection of a measured dip and strike across topography. A geographical information system (GIS), starting with a digital elevation model (DEM), can easily manipulate both types of data with a variety of base maps: scanned topographic or geologic maps, air photos, or satellite imagery. Given suitable large scale digital base maps, students can digitize contacts and compute attitudes on the computer, observe 3D representations of the terrain and rotate them to any desired orientation. The MICRODEM GIS implements these geometric operations, in both a simple teaching version that emphasizes only the geometric relationships, and as part of a full-featured GIS program. MICRODEM can be used in preparation for going to the field to help students learn to visualize, for 3D stereo virtual field trips on the Geowall, and taken into the field on a tablet PC for improved mapping efficiency. GPS tied to the PC removes the tension students feel in locating their position on the map, and lets students can concentrate on matching the map features to the terrain in front of them and thinking about the geometric structures of the geologic features. In addition to improving geometric perceptions, using the GIS introduces students to valuable technology.

SOFTWARE REQUIRED. Operations described here use the freeware GIS MICRODEM, available at <http://www.usna.edu/Users/ocean/ocean/guth/website/microdem.htm>. Other GIS software might replicated some of these functions, but MICRODEM has many customized operations for geology.

DATA REQUIRED. Computer manipulation of geologic structures requires the following data, which can be downloaded free on the WWW:

- Digital elevation model (DEM):** digital topography provides the 3D skeleton upon which imagery or scanned maps can be draped. The DEM also allows calculation of the three point problem and tracing contacts. The best source of DEM data is 1° and 1/3° NED at <http://seamless.usgs.gov/>.

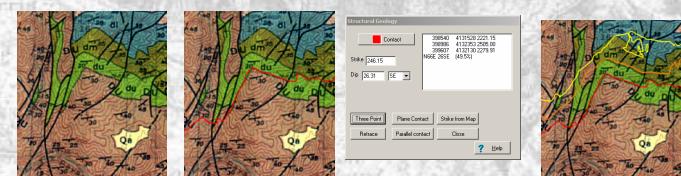
OPTIONAL DATA. Much of the image data can be downloaded free on the WWW. The help file for MICRODEM lists sources for a number of states.

- Digital raster graphic (DRG):** scanned topographic maps at 1:24K, 1:100K, and 1:250K. There is no single source of this data, but a google search will usually locate data for your area.
- Digital ortho quarter quads (DOQQ):** 1 m resolution aerial photography. A google search might find this data available, often compressed. Some DOQOS, and higher resolution data, are available at <http://seamless.usgs.gov/>.
- Landsat TM and ETM+ data:** satellite imagery at 30 m (6 multispectral bands) and 15 m (pan band on ETM+ data). The Global Land Cover Facility at <http://glcf.umiacs.umd.edu/index.shtml> has free data for most of the world.
- Scanned Geologic Maps:** limited large scale maps are available on the internet, such as the USGS maps at <http://ngmdb.usgs.gov/ImageLibrary/>. You can also scan and register maps with a desktop scanner.
- Maps in Electronic Journals:** large scale maps illustrating papers in journals like *Geology* or *GSAB* can be captured and registered.

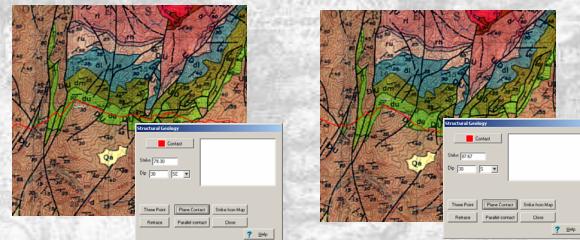
Three Point Problem. A scanned and registered geologic map of the White Mountains in eastern California by Clem Nelson (Blanco Mtn Quad, GQ-529) shows the operation of the three point problem. The user clicks on three points on the contact, and the program draws the projected place of the plane that passes through the points. The program also calculates the dip and strike of the plane computed from the points.

This example picked three points on the upper contact of unit **du**. Note that the calculated dip of 26.3° is very close to measured dips of 30° on either side of the contact, and that within the fault block the computed trace of the contact almost exactly matches the drawn contact.

The program can also compute parallel contacts. The orange and yellow lines trace contacts with the same orientation, and picked at the topographic crests at the upper and lower contacts of unit **dm**. Note that the mapped **du-dm** contact appears parallel to the contact at the top of **du**, but the lower contact of **dm** does not follow the computed trace, meaning that either the dip or strike must change.



Contact Tracing. The program can also draw the trace of a contact, given a location and the dip and strike. The two examples below compute the strike from the plotted symbols on either side of the contact at the top of unit **du**, use the measured dip, and then trace the contact from the saddle at the top of the hill. Note that the two symbols show strikes of 79° and 88°, whereas the three point computation gave a strike of 246° (=66°). Neither of these planes matches the mapped contact well, perhaps because the dip was rounded to the nearest 5°.



Accuracy. The accuracy of the results depends on:

- DEM quality and resolution. The technique works best in steep terrain.
- Image quality and registration.
- Dip of the geologic structures. Steep dips lead to the best results.

Last Chance Range Cambrian Section. This is a pan-sharpened ETM+ scene of the Cambrian section behind the Eureka Valley sand dune. The middle diagram shows the projected trace of two beds; the points selected for the three point computations are circled.

•Upper Red contact N25W 34NE

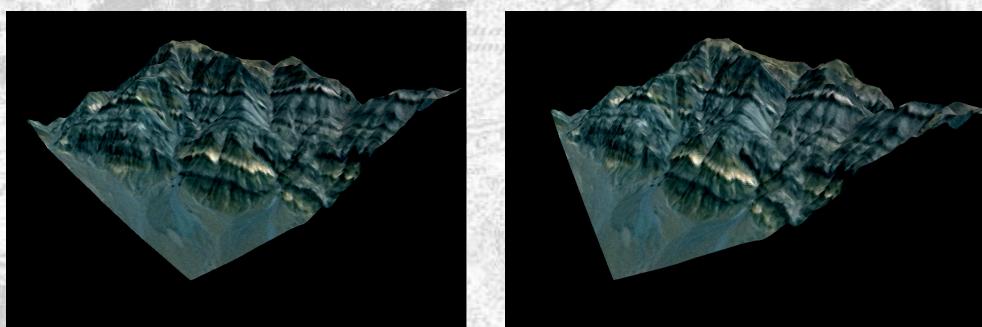
•Lower Orange contact N 8W 21E

Both match the bedding closely in the vicinity of the selected points. The upper red contact diverges significantly to the south, showing that the dip or strike must change, whereas the lower orange contact follows the bedding well. The traces of both contacts reveal a major normal fault, shown in purple on the third diagram.



3D visualization. Computer graphics can help show the relationships of dipping sedimentary rocks, and can be adjusted interactively. The two images below show different views of the same area, and clearly demonstrate the eastward dips computed above.

For a paper on how to present this type of display in interactive stereo, see paper 113-16, Ballroom 4, Monday, 5:15 PM GIS TO GEOWALL: HARNESSING 3D VISUALIZATIONS: GUTH, JOHNSON, DAL, and DELALEAU.



PCs in the Field. Tablet PCs offer the best feature set for field geology, compared to the PocketPC or PalmPilot alternatives:

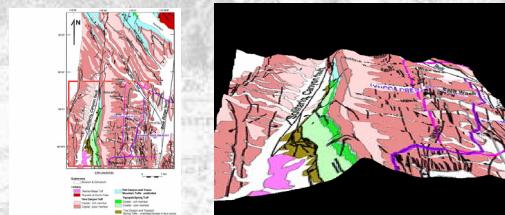
- Full version of Windows, and runs standard GIS software.
- Disk storage.
- Fast processor.
- USB input for GPS.
- Large screen resolution.
- Stylus input good for graphics, adequate for text.

For details, see Paper No. 62-28 (this session) or go to <http://geopad.org/>



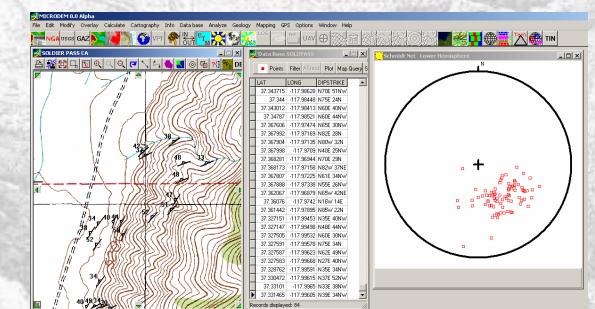
GPS Integration. Common hand-help GPS units offer three capabilities to combine with GIS. One requires a computer in the field, while the others can be used later during data compilation.

- Show the current location.** NMEA output capabilities allows the current location to be shown on the computer display. This frees students from having to locate themselves on the map, and allows them to concentrate on more fundamental processes like identifying the rocks and drawing contacts. When in doubt, students can walk out a contact and see exactly where it goes on the map or air photo.
- Record waypoints.** Students can record waypoints where they collect samples or measure dips and strikes. These can be downloaded to the computer lab, and overlaid on the map.
- Record tracks.** GPS units can record the location at specified times, giving a complete record of where the student went. This can be downloaded and overlaid on the map, letting students see a visual record of their traverses.



Electronic Journal Maps.

This map of Yucca Mountain was published online in the GSA Bulletin (July 2004). It was saved from the web browser, registered, and then draped on a DEM.



Smart Plotting of Dips and Strikes.

MICRODEM plots dips and strikes automatically, from standard notations entered into a database.



Conclusion: Supplement, Complement, or Replace?

Supplement: GIS can perform computations about simple planar geometry that enhance the field experience by pointing out impossible relationships or experimenting with different dips and strikes to verify the outcrop patterns. GIS visualizations can rapidly show the 3D geometry of a field area.

Complement: GIS is a marketable skill that students must master, and which makes creating geologic maps much simpler. Old skills of topographic map reading and drafting can be replaced with interpretation and model testing, and GIS visualization in 3D will make students better map readers with less effort and more confidence.

Replace: when students cannot go to the field, whether because of time, money, or physical limitations, GIS can take students on a virtual field trip. I ran such field trips this year to Afar, to look at block faulting, and to the mid-Atlantic ridge to observe the similarities in tectonic style. Students can measure the attitude of bedding and fault scarps in the GIS, and get a true 3D view of the geology.