



## Using Google Earth for more effectively teaching undergraduate structural geology

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Geologic map interpretation, visualization of 3D geologic structures, and cross section construction is difficult for students. Learning how to interpret the shapes of contacts and rock units based on geologic map patterns involves learning new terminology and techniques while at the same time translating the 2D diagrams and block models that we use in class to real world geologic maps and cross sections. Many students, especially those with poor penetrative visualization abilities, memorize and apply rules, rather than visualizing structures. The interactive 3D terrain viewing capability of Google Earth is a terrific resource for teaching visualization of structures. Flying around in Google Earth 3D view helps students visualize rock volumes that both extend below ground and have been eroded away above ground. An ability to visualize is key to advancing past rote application of rules.

Google Earth can be used in many ways to help students learn to visualize structures. The Geode Project Fold Analysis Challenge (<http://geode.net/fac/>) helps students learn how to visualize dipping contacts based on what they can see in the landscape. Having students make their own geologic maps in areas with constant dip enables them to see how outcrop traces vary with topography and to develop the rule of Vs on their own. The elevation profile tool combined with the 3D view allows students to practice sketching cross section views rather than getting bogged down in applying rules and slavishly projecting surface dips into impossible structures. The USGS National Geologic Map Database ([https://ngmdb.usgs.gov/ngmdb/ngmdb\\_home.html](https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html)) has hundreds of geologic maps as kmz files that can be draped over 3D topography in Google Earth to help students visualize real-world geologic maps. I have also put together a huge collection of placemarks at [https://serc.carleton.edu/NAGTWorkshops/structure/Google\\_Earth/approach.html](https://serc.carleton.edu/NAGTWorkshops/structure/Google_Earth/approach.html) for building interpretation assignments.

Insights, surprises, and cautionary tales: 1) Being “pilot in command” of the mouse is critical for students to visualize well in Google Earth. Watching someone else zoom, tilt, and pan is not nearly as effective as being in charge of the controls. 2) Remember that students, as novices, do not see what we see. Don’t be surprised if students see only hills, valleys, ridges, rivers, and vegetation and do not initially even see the fabulous bedrock layers that are so obvious to us. 3) Making sense of patterns is at the heart of geologic map interpretation and geologic mapping. Many students don’t know what is meant by “patterns”. It’s useful to give students practice in describing patterns of other kinds before tackling geologic patterns. 4) When we use terms such as horizontal, vertical, above, below, before, after, etc., many students aren’t visualizing what we expect because they have different (and deeply ingrained) personal definitions for these words that are at odds with ours. Interactive classroom strategies that involve listening to your students are useful for daylighting and tackling these terminology issues that cause confusion.