

# Teaching map interpretation & cross section construction

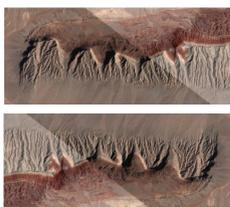
## What I used to do:

- Define strike and dip, types of contacts.
- Teach about outcrop patterns of horizontal contacts, then vertical contacts, and then inclined contacts.
- Derive the rule of Vs.
- Have students interpret geologic maps and draw cross sections.

## The value of Google Earth

Google Earth has tremendous value for teaching about geologic maps, mapping, and cross section construction.

- Areas with strong, contrasting colors for bedrock units already look like geologic maps.
- Imagery is seamless and high resolution.
- **It's free, and every student can work with it on his/her own computer.**



Dash't e Lut near Chahar Gas, Iran

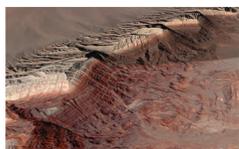
Interactive 3D terrain "tilt-and-fly-through" viewing is key to helping students visualize structures.

- Illumination direction varies in standard orthoimagery (left), and students can have difficulty determining what is high and what is low.
- Using tilt, rotate, and zoom in Google Earth, students can see the third dimension directly (right).

It is critically important that each student is "at the wheel" controlling the tilt and viewing angle on his/her own computer. Watching someone else's screen (or the instructor's screen via a data projector) is not the same visualization experience.



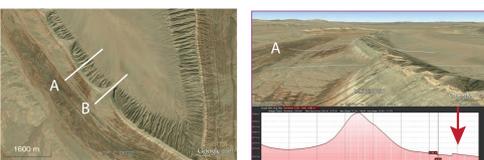
Ah, Digital Play-Doh®!!!



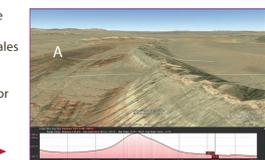
The level of detail in the 3D View is extraordinary.

## Cross sections and elevation profiles

Use the path tool in Google Earth to draw cross section lines. Select the line, and show the elevation profile, which appears in a new window with an arbitrary vertical scale.



Drag the elevation profile box down to equalize vertical and horizontal scales to give profile without vertical exaggeration. Students use the profile for sketching geologic cross sections.



Elevation profile with no vertical exaggeration through ridge (above) and through wadi (below).

Areas such as this one are great for having students draw geologic cross sections across units with constant dip but very different elevation profiles. They have to work out 1) that the geology in the cross section is exactly the same, even though the ground surface is quite different and 2) that the layers are actually continuous in the subsurface and are only thinly mantled by surficial deposits (B at left).

Dash't e Lut, near Chahar Gas, Iran



## Exploring outcrop patterns and topography

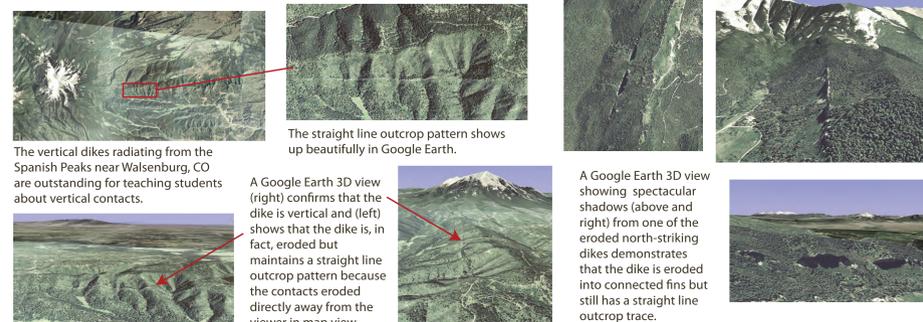


There are many excellent places in Google Earth to have students draw outcrop traces in a set of units with constant dip to see how outcrop traces vary with topography. This example comes from far western Algeria at the very southeastern edge of the Anti-Atlas. This kind of practice drives home the idea that strike and dip symbols for eroded planar units are not typically parallel to the outcrop traces.

Students typically confuse Vs in topo contours with Vs in outcrop traces. The area at right is an excellent place to have students see that the Vs in the outcrop traces point *downstream* SW of the star and *upstream* NE of the star, even though the dip direction remains consistently SW. This example from the western Tien Shan range in China.

## Visualizing vertical contacts and their outcrop traces

The outcrop pattern of vertical contacts is just a special case of the outcrop pattern of dipping contacts. Although it seems backwards to start with the harder concept of dipping contacts, students seem to benefit from spending more time on dipping contacts first. Then, using Google Earth, they breeze through vertical and horizontal contacts and their outcrop patterns.



The vertical dikes radiating from the Spanish Peaks near Walsenburg, CO are outstanding for teaching students about vertical contacts.

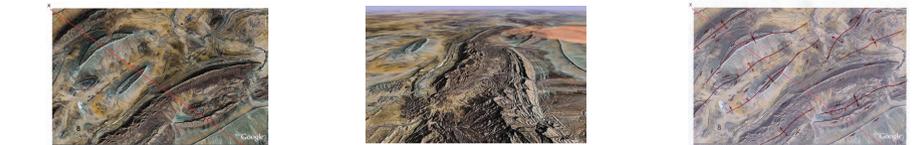
The straight line outcrop pattern shows up beautifully in Google Earth.

A Google Earth 3D view (right) confirms that the dike is vertical and (left) shows that the dike is, in fact, eroded but maintains a straight line outcrop pattern because the contacts eroded directly away from the viewer in map view.

A Google Earth 3D view showing spectacular shadows (above and right) from one of the eroded north-striking dikes demonstrates that the dike is eroded into connected fins but still has a straight line outcrop trace.

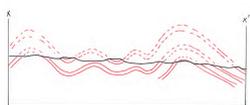
Once students are able to recognize the outcrop patterns of vertical contacts, they can tackle overturned folds and contrast the patterns of dips in an upright fold (far left) with those in an overturned fold (near left).

Flying in Google Earth around the overturned syncline, near left, in the Suleiman Fold Belt in Pakistan allows students to trace the NW right-side-up limb as it wraps around the nose of the fold, rolls through vertical, and flips upside down to form the SE limb of the fold.



The tilt, pan, and rotate features in Google Earth are instrumental in helping students make sense of more complex fold terrains, and students have little difficulty mapping folds and creating schematic cross sections of areas such as the one in the Anti-Atlas Mountains of Morocco shown here.

Simple exercises such as these are important in helping students develop a picture of real-world fold structures. Making schematic cross sections is also useful in helping students focus on visualizing, rather than getting bogged down in applying rules and slavishly projecting surface dips into impossible structures above and below the ground surface.

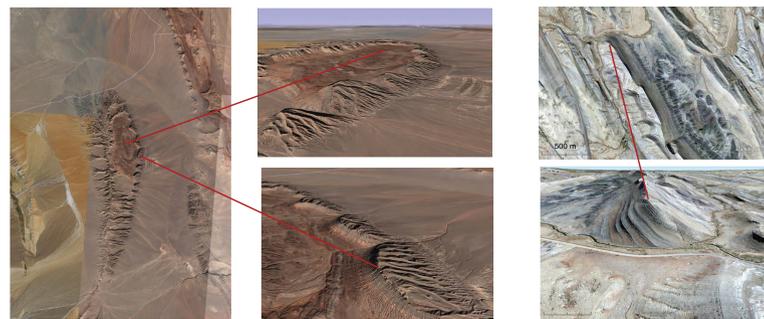


# Using Google Earth to Teach 3D Visualization of Structures, Interpretation of Geological Maps, and Cross Section Construction

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## Starting with visualizing dipping contacts

Google Earth has many fabulous areas that can be used to help students visualize that the color bands are not just 2D "paint stripes" but are actually tilted and eroded layers that extend below the ground.



Students do fly-throughs to visualize tilted layers.

- I use the term "tilt" at this point, because it's a word that they know and visualize appropriately. I avoid "inclined" because many students visualize inclined in an upward direction (i.e., they would describe a contact that dips SE as "inclined to the NW").
- These fly-throughs are also useful for drawing the distinction between the direction that the ground slopes and the direction that the layers are tilted (something that many students struggle with).

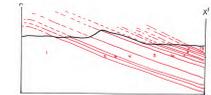


This portion of the Alkali Anticline in Wyoming is particularly good for having students distinguish bedrock from surficial deposits and to think about where the rock units "go" (do they just end??) where they intersect the surficial deposits on the valley floor.



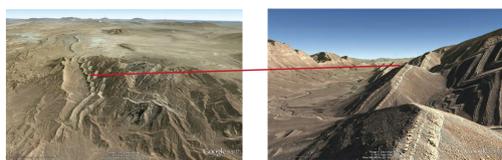
First assignment – geologic map and cross section:

- Define mappable units based on outcrop color and features in Google Earth.
- Draw lines separating the map units.
- Draw blue lines down the centers of major valleys.
- Draw red arrows that point in the direction of tilt of the units.
- Sketch a cross section. Tilting the view to very low angle and looking parallel to the ridge enables students to see directly both the elevation profile and the cross section view.



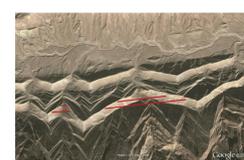
## Visualizing strike and dip of dipping contacts

Once students have a good visual grasp of dipping units and contacts, they explore the north flank of a spectacular whaleback anticline near Dekhuyeh, Iran. Students learn first about dip and then about strike, which is opposite to the typical order for teaching the two concepts. This seems to work well, because dip is actually a more intuitive concept than is strike.



I initially use the term "tilt" or "tilted" with students (for reasons described above). At this point, we switch to "dip" and "dipping".

As long as vertical exaggeration is set to 1 in Google Earth Preferences (Tools, PC), students can tilt the view to very low angle, look along the row of flatirons, and use a protractor to estimate dip angle. In the row of flatirons above the measured dip is about 40°.

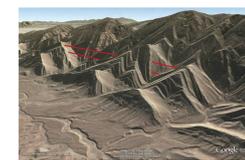


The path tool in Google Earth can be used to draw lines connecting points of equal elevation at the base of the cliff-former along the flatirons (red lines at left). The lines will stretch line telephone wires across the valley when viewed in 3D (right and below right).

As long as the Altitude of each line is set to "Relative to ground", the lines will stretch line telephone wires across the valley when viewed in 3D (right and below right).

Students then use trig to calculate the dip of the "filled in" surface, using the measure tool to get the perpendicular map distance between any two lines (below left). For this example, the calculated dip is about 40°, which matches nicely the dip amount that students measured with a protractor in "fly-through" view.

At this point, I define strike and structure contour, introduce the standard strike and dip symbol, and define outcrop trace. We make a geologic map together in class with strike and dip symbols, revisit the difference between dip and ground slope, and draw a geologic cross section. For homework, they do the same in a new area.



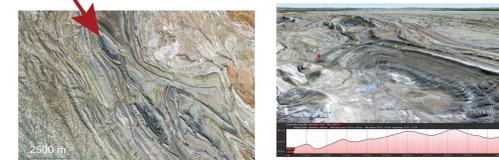
The 3D fly-through view is powerful for seeing the strike lines as outlining a plane.



## Visualizing folded contacts

There are lots of fabulous areas for students to have their first experience with folds, but I start with the Alkali Anticline in Wyoming because they worked with that earlier in the semester.

This is a particularly good structure because, unlike the whaleback anticlines of the Zagros, the Alkali Anticline is actually lower topographically in the core due to erosion, which helps address the misconception that students have that anticlines are always topographically higher in the center.



Students begin by mapping strikes and dips on opposite limbs of the northern portion of the Alkali Anticline (above left) and then fly around the area to work out what the structure is like. Students then fly to a vantage point (look direction shown with red arrow above left) to draw a cross section along a line across the structure (above right).

Folded contacts are just a special case of dipping contacts, so I have students work with folds and make cross sections before we get to the outcrop patterns of vertical and horizontal contacts. It is also an opportunity to introduce planar vs. non-planar contacts.

## Fold terminology and symbology



The area in the Anti-Atlas shown at left and right is perfect for helping students visualize fold hinges and fold plunge and for introducing fold terminology (hinge, nose, etc.) and map symbology for folds.



Students are then prepared to practice making cross sections and properly symbolized maps of simple folds and fold sets and to derive "rules" for interpreting fold plunge from outcrop patterns.



## Visualizing horizontal contacts and their outcrop traces

Once students have a good visual grasp of dipping and vertical contacts, horizontal contacts are simple.



This area in the eastern Dash't e Lut of Iran is a spectacular area for students to explore the transition between dipping contacts and horizontal contacts. The area also illustrates that dipping contacts have straight-line outcrop patterns where there is no topographic relief along the outcrop trace.

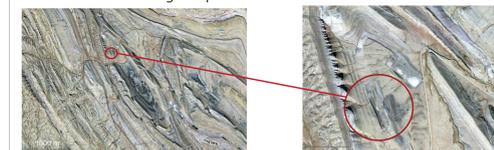
The area of the Comb Ridge monocline and the San Juan River Canyon to the west in Utah (right) is another wonderful area for students to explore the change in outcrop pattern as contacts transition from ESE-dipping in the monocline to horizontal in the canyon region.



At this point, students can write their own "rules" for how outcrop patterns of contacts vary with dip and topography, which is very different from having them first learn a set of rules and then apply the.

## Extensions and applications

One of the great reasons for using the Alkali Anticline is to draw connections with mining and petroleum.



In Google Earth, a zoom-in on the area circled above shows clear, stratigraphically controlled dark patches along with strip mining equipment (below) – locations of active and reclaimed mining.



In Google Earth, a zoom-in on the area circled above shows tanks and a pump jack (below) pulling petroleum out of a trap in the core of the anticline.

## Insights, surprises, and cautionary tales

When we use terms such as *horizontal*, *vertical*, *above*, *below*, *up*, *down*, *before*, and *after*, 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. For example:

- When asked to define horizontal and vertical, at least 1/4 of my structural geology students at the beginning of the semester define *horizontal* as something that is east-west and *vertical* as something that is north-south. This clearly stands in the way of students visualizing an accurate and meaningful picture of the orientations of structures. This is also a very difficult visual misconception to dislodge even when students have learned to write accurate definitions of the terms.
- Many students also use horizontal as a relative term and describe something as *horizontal* to something else (confusing it with *parallel* to) or *vertical* to something (confusing it with *perpendicular* to).
- Many students use *above* to mean to the north and *below* to mean to the south of.
- Many students think of *inclined* as being upward rather than downward and would describe units that dip to the SE as being inclined to the NW.
- When asked about stratigraphic order, some students will say that "the Cambrian units are after the Ordovician units". Whereas we use *after* in a temporal sense, some students use *after* in a "list" sense - they read a strat column from top down and get to the Cambrian units after the Ordovician ones.

In all of these terminology issues, students know what they mean, but either 1) we misinterpret their answers or 2) they visualize inaccurately when we use terminology because their internal definitions do not match ours.

Interactive classroom strategies that involve listening to your students, including using Google Earth as described in this poster, are useful for daylighting and tackling these terminology issues that cause students confusion.

Scan the QR code to take you to web pages where you can download a kmz file with a boatload of fabulous Google Earth locations, this poster, plus other materials for using Google Earth in structural geology.

