



# Constructing Geologic Cross Sections

Dr. Kurtis C. Burmeister

Department of Geology  
Sacramento State University

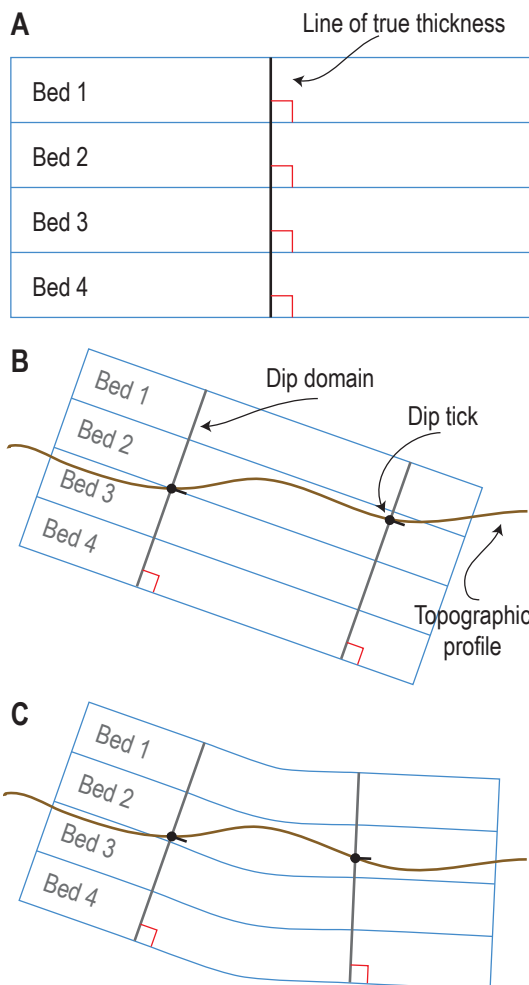
## Part 1: Introduction

I would like to introduce you to a new method that incorporates heavily modified aspects of the classic Busk (1929) and Kink (Suppe, 1989) methods for constructing geologically admissible cross sections. Please note that this method is only suitable for **concentric, parallel folds** (Ramsay classification 1B) that form in sub- to low-grade metamorphic conditions, where folded layers can be assumed to maintain constant thickness. This method is not suitable for similar or disharmonic folds that form under high-grade metamorphic conditions where the thicknesses of fold limbs and/or hinges change during deformation.

### Developed for field applications

This method is especially well suited for students participating in field methods and summer field courses, who must construct cross sections from their own geologic map data (as opposed to the idealized exercises often encountered in Structural Geology lab activities). Students in such courses are often encouraged to freehand sketch subsurface interpretations of their map data. This approach generally yields results that are only loosely based on their field data and are rarely geologically admissible interpretations.

**Figure 1.** Bedding planes that pass through a line that is perpendicular to bedding (a line along which you can measure the true thickness of a sequence) will be parallel when they cross the line. This relationship is true for horizontal (A), inclined (B), and folded (C) strata. Dip domains are essentially lines of true thickness and can be drawn perpendicular to the dip of a bed in a geologic cross section.



Unfortunately, while using freehand projections to construct cross sections is quick and effective, this technique requires a level of geologic experience and insight that most students are still developing. To compensate for this inexperience, students often rely upon traditional, mechanically rigorous methods of constructing cross sections (e.g., Busk/Arc and Kink methods). However, these formal methods are time consuming, cumbersome, and may require specialized drafting tools. Furthermore, even slight inconsistencies in student field data can seriously hinder the successful implementation of these traditional methods in the field and lead to frustrating complications.

### How the method works

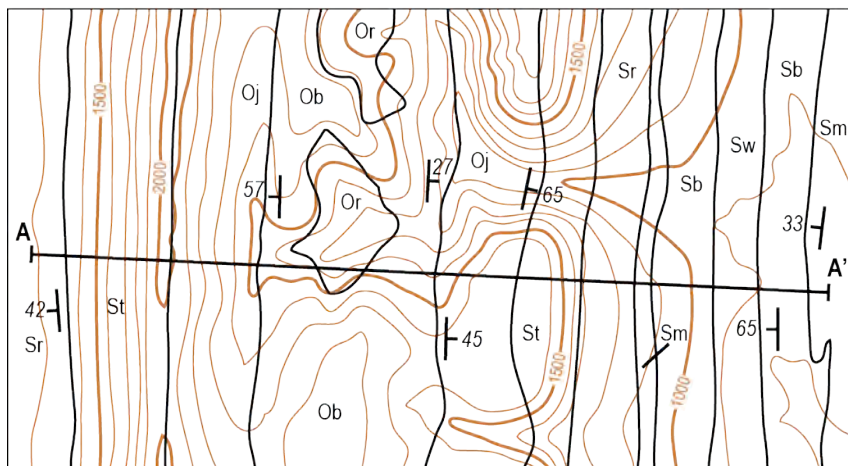
The method outlined below combines the mechanical rigor of traditional techniques with the quickness of the freehand sketch approach. The method begins with a topographic profile and the student's primary geologic map data: **contacts** between geologic units and **dip ticks** that illustrate the direction and magnitude of dipping strata. As with the Busk method, **dip domain lines** are extended perpendicular to each **dip tick** (**Figure 1**). To simplify complex fold shapes, intersecting dip domains are supplanted with a single dip domain that bisects the angle formed at their intersection. Then, once a framework of dip domain lines is established, geologic contacts (first) and **form lines** (second) are projected through the cross section as straight-line segments perpendicular to each dip domain. As with the Kink method, it is the intersections of these bedding-parallel straight-line projections that define the locations of fold hinges. Finally, in the freehand sketching part of the method the projections are smoothed by hand into a series of inflection points, circular-arcs, and straight-line segments.

## Part 1: Preparing your topographic profile

Cross-sections illustrate geologic relationships that are hidden below the earth's surface. The accuracy of such illustrations depends entirely upon the data used in their construction – the data you collect while mapping bedrock exposures. Your primary data establishes the basic framework for a cross-section, which is then ideally refined with supplemental subsurface data (e.g., drilling logs and/or geophysical data). However, supplemental subsurface data are often unavailable and geologists must rely entirely upon their map data to interpret relationships at depth. It is important to remember that such interpretations of subsurface relationships are non-unique. However, even though they are non-unique they can be quite effective at capturing the essence of geology at depth providing that you adhere to the basic principles of geology and a few basic rules.

### 1.1. Choosing a line of section on your map

A geologic cross section represents a vertical slice through the Earth that coincides with a **line of section** on a geologic map. In most course-related activities, lines of section are provided by instructors (**Figure 2**). However, should you be asked to choose a line of section that is representative of the geology in your study area, make sure that it is oriented as close to perpendicular to the **structural grain** as possible. Structural grain is defined by the regional trends of fold axes, strikes of faults, and strikes of bedding. Draw your line of section directly on your map and mark the ends with **references** (for example **A** and **A'**) that will help establish a frame of reference for readers examining your section.



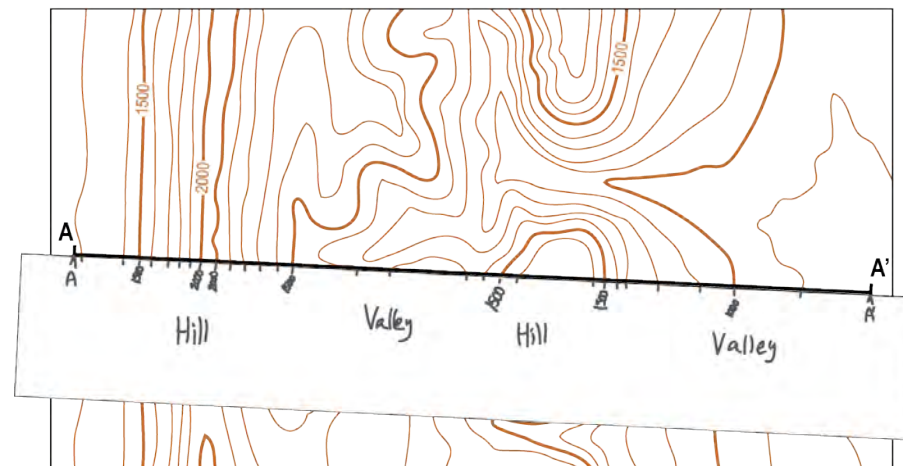
**Figure 2.** Line of section perpendicular to structural grain defined by the trends of fold axes and the strikes of faults and bedding. Note the placement of reference points A and A'.

**Tip:** Lines of section are rarely perfectly perpendicular to the structural grain everywhere along their lengths – so pay attention to the potential need to calculate **apparent dips!** Occasionally, lines of section must abruptly change direction to follow structural trends. Indicate these bends with an additional vertical axis in your cross section. You will need to account for apparent dips when map data are projected around bends in your line of section.

## 1.2. Constructing a topographic profile

Align the edge of a piece of scratch paper with the line of section that you marked on your map (**Figure 3**). Mark the locations of your reference points (A and A') on the paper's edge to help ensure your marks are properly registered. Then, make small marks along the edge of your scratch paper to indicate where each topographic contour crosses your line of section. You may also wish to indicate the elevations of some of these contours as well. Then, use the marks on your scratch paper to plot a topographic profile in X-Y space on a piece of graph paper you will use to construct your cross section. Take time to carefully plot your profile – sloppy profiles will make fitting your geologic map data into your cross section very difficult. In general, horizontal distances (map scale) and vertical distances (elevation) should be equal and plotted with **no vertical exaggeration** (1:1 scale ratio). One effective approach for creating matching graduations on your vertical scale bars is to simply rotate your map and trace the horizontal scale bars! To reiterate, vertical exaggeration in your topographic profile will greatly complicate the projection of map data to depth and should only be used when emphasis of subtle features is required (e.g., cross sections of very thin Quaternary units).

**Tip:** Constructing topographic profiles is time consuming. Don't use your nice copy for drafting your cross section... if you make a careless error, you might find yourself having to redraw your profile! Compile your profile on the piece of paper you intend to use for your final draft. Once you're happy with your profile – ink it. Then, trace that profile onto a piece of scratch paper that you can use to work through iterations of your subsurface interpretations. While



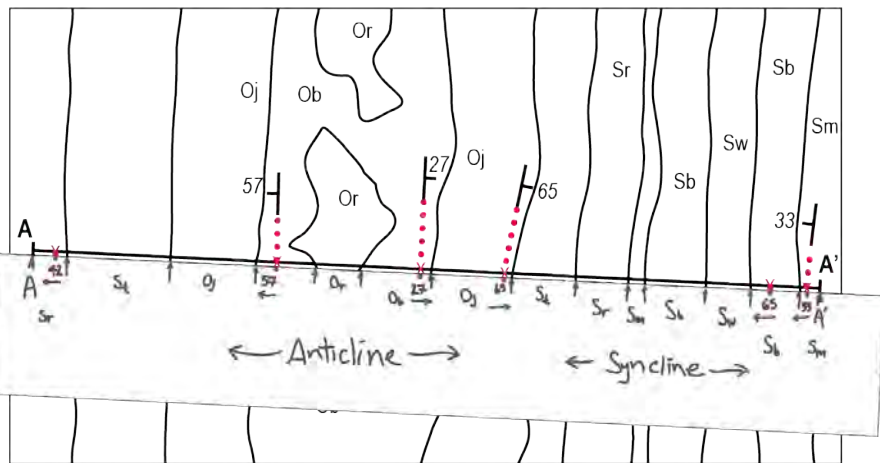
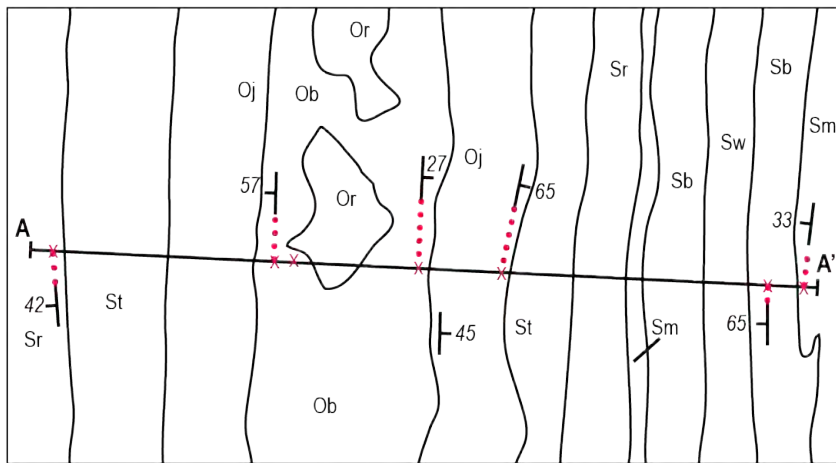
**Figure 3.** To transfer topographic data from your map, align the edge of a piece of scratch paper with your line of section. Mark your end reference points (A and A') and all of the places a contour line crosses your line of section. Be sure to indicate the elevations of index intervals and it may be helpful to note areas of high or low relief.

you work on the scratch paper, put your original profile someplace safe. When you finish constructing your cross section on the scratch paper, transfer the geology back onto your original profile on your final copy.

## 1.3. Harvesting your geologic data

Align the edge of another piece of scratch paper with the line of section on your map and mark your reference points (**Figure 4**). First, mark the edge of the scratch paper to denote where **geologic contacts** (depositional, intrusive, and fault) cross your line of section. Make sure to adequately annotate your marks. When a **fault** cross your line of section, use simple trigonometry to calculate its strike and dip. To determine the strike of the fault, find two points where the fault trace crosses the same topographic contour. Draw the line of strike by connecting these points of equal elevation. To determine the dip, draw a line perpendicular to your line of strike that extends from the line of strike to a third point along the fault trace where it intersects another contour at a higher or lower elevation than the contour used to determine strike, then use trig to solve for the true dip. Next, **project representative strikes and dips** onto your line of section. Use a straightedge to extend the strike symbols on your map to the line of section. It will take time to develop a feel for what strike and dip data are useful for constructing a representative cross section... and which are not. Remember this when mapping and consider using a ranking system to rate the uncertainty associated with the measurements you make in the field (e.g., is this a good strike and dip or a bad one?). You must calculate an **apparent dip** if your strike is more than 20° off of perpendicular to your line of section. Use apparent dip nomogram at the end of this handout.

**Tip:** Use common sense when determining which strike and dip data to use in the construction of a cross section. The farther away a measurement is from your line of section, the less likely it is to represent the geology in your cross section. Exclude measurements that are far away from your line of section, project into different geologic units

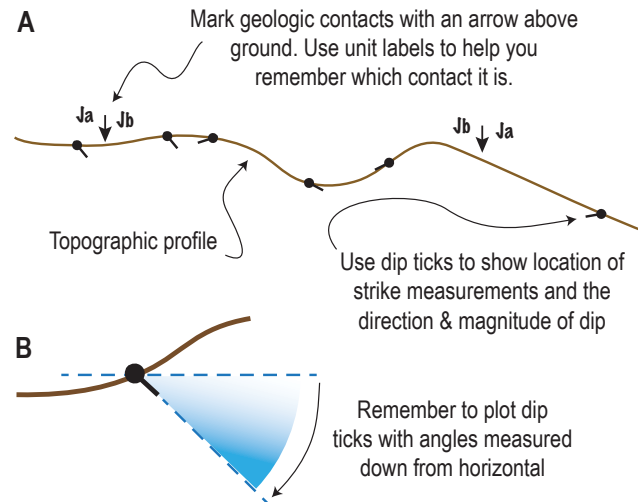


**Figure 4.** To transfer geologic data from your map, first project your strike and dip data onto your line of section. Only use representative data near your line of section. Avoid data far from the line of section as these may become problematic when projected onto the line of section.

*or across a fault, and those you are suspicious of (e.g., unclear bedding). Similarly, be aware of using data that are not representative of the geology along the line of section (e.g., strata dipping in the opposite direction, projecting strikes and dips across faults or into adjacent map units), because these might reflect errors you made in the field.*

#### 1.4. Transfer your geologic data onto your topographic profile

Use your reference points to align the strip of paper with your geologic data with your topographic profile and transfer your geologic data (**Figure 5**). In pencil, draw small vertical arrows above the topographic profile to indicate the location of geologic contacts. Locating these arrows above the topographic profile will keep them



**Figure 5.** Example (A) of a topographic profile with data transferred from geologic map. Small arrows showing the location of geologic contacts are drawn above the profile to keep them out of the way while working. Dip ticks (B) show the magnitude & direction of dip.

out of your way when it comes to projecting geology into the subsurface. Draw small solid circles (“**strike ball**”) directly on the topographic profile to mark locations where strikes were projected onto the line of section. Use a protractor to extend a 2-4 mm long line (“**dip tick**”) from the strike ball to illustrate the magnitude and direction of the dip. Remember that if the like of strike is more than 20° off of perpendicular to the line of strike, you must calculate the apparent dip of that measurement before plotting the dip tick.

**Tip:** Make sure that the tip ticks must be plotted as angles measured down from horizontal. Another good tip is to use a separate symbol to indicate dip ticks associated with overturned beds.

## Part 2: Using dip domains to project contacts & form lines

At this point, your topographic profile contains only primary data (the locations of contacts and strike and dip measurements that you determined in the field) and you are ready to begin using these data to interpret subsurface geologic relationships.

### 2.1. Drawing dip domains perpendicular to your dip ticks

The layers in a conformable sequence of strata directly above (now eroded away) and below (beneath the surface of the earth) the place you measured a strike and dip must all be parallel to the layer you measured (**Figures 1b & 1c**). For this reason, it is possible to connect all of the parallel points on these layers with a line that is perpendicular to the dip you measured (essentially a line of true thickness) that we will call a **dip domain**. Use a protractor or ruler to extend dip domain lines through each of the dip ticks that you plotted on the topographic profile you constructed in Part 1. Make sure that each of your dip domain lines pass through the center of its corresponding strike ball and is oriented perfectly perpendicular the dip tick.

**Tip:** Use light pencil marks when drawing dip domains – you will need to erase these later.

## 2.2. Projecting stratigraphic contacts through the dip domains

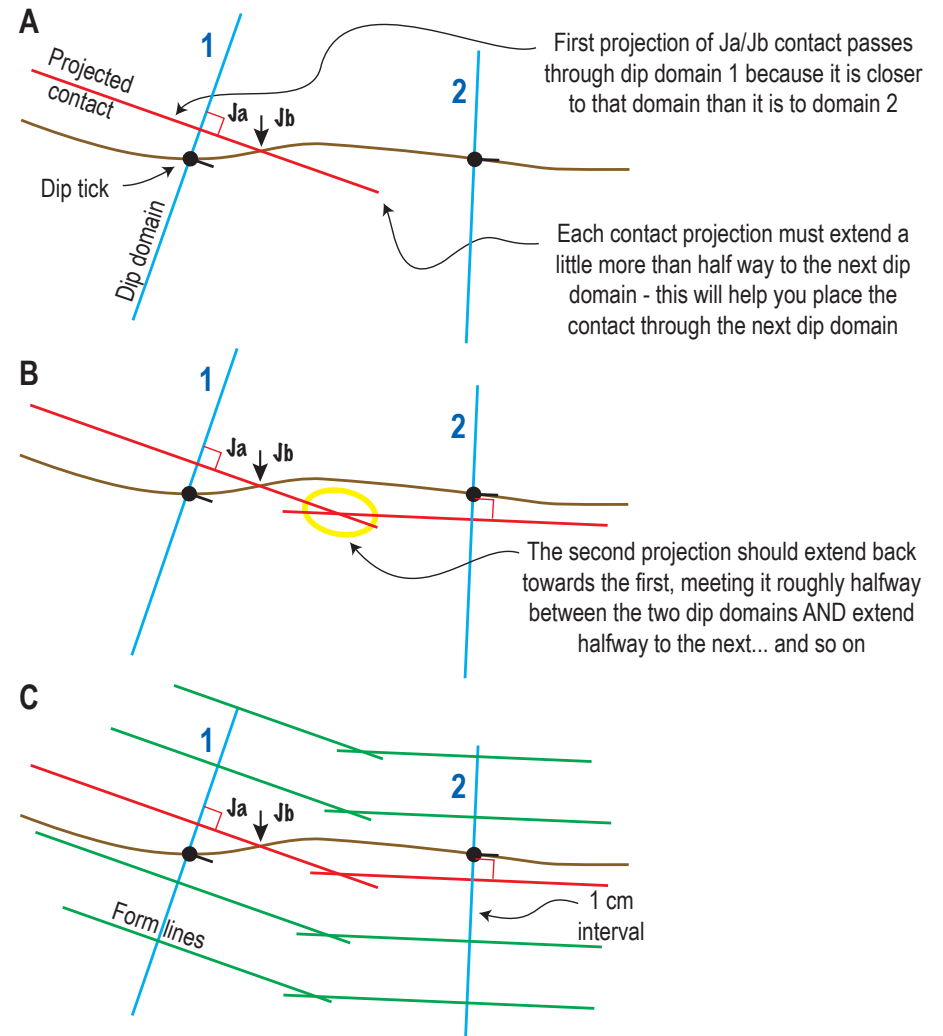
According to the relationships established earlier, all strata must be perpendicular to a dip domain line when they pass through it. For this reason, the first step in turning your primary data into a geologic interpretation is to project your mapped geologic (stratigraphic) contacts through nearby dip domains. Project your first contact by projecting a straight line segment that is both perpendicular to the dip domain and passes through the ground surface at the location the contact appears on your topographic profile (Figure 6A). When projecting contacts, make sure to extend your straight line segment a little beyond halfway to next the dip domain. The extension of this projection will help you place your second projection through the next dip domain. Once you've finished your first projection, draw a second straight line segment that is perpendicular to the second dip domain back towards the first dip domain (Figure 6B). Make sure your first and second projected contacts intersect at the midpoint between the two dip domains. Projections that meet at the midpoint between dip domains will ultimately allow you to define the most relaxed fold shape for that portion of your geologic cross section. Repeat this process for each subsequent dip domain until you have extended your contact through the entire cross section.

**Tip:** In some circumstances it may be necessary to shift the intersection of two contact projections to one side or another of the midpoint between adjacent dip domains. Shifting intersections will raise or lower where one of the contacts will pass through the adjacent dip domain. These sorts of adjustments are useful solutions for situations where contacts drawn without such fine-tuning will cross the topographic profile in places that are not supported by your mapping.

## 2.3. Using stratigraphic thicknesses to projecting contacts that don't intersect the topographic profile

Once you have projected your first geologic contact all the way through your section, do the same with any remaining geologic contacts. Projections of contacts that cross your topographic profile are pretty straightforward – their placement is easily resolved using the method outlined above. However, if your contact lies at depth (does not cross the topographic profile) or above the ground surface (eroded away), you must use established stratigraphic thicknesses to determine where contacts will cross dip domains. Fortunately, since our model is designed for parallel folds and assumes constant thickness, this is also a straightforward process. Once you have a unit contact projected through the section, you can measure out (using the vertical scale of your section) the appropriate thicknesses for each of the units stratigraphically above and below your contact along each dip domain. Make pencil marks where each stratigraphic contact will cross the dip domain and then project contacts through those points, extending the straight line segments a little beyond halfway to each adjacent dip domain. Extend these initial projections through all of the remaining dip domains using the same process outlined in above.

**Tip:** It is a good idea to use known stratigraphic thicknesses to measure the thicknesses of all the units that appear in your cross section. If the thicknesses in your cross section don't match known thicknesses, you know you have a problem that will need further investigation.



**Figure 6.** (A) Projections of stratigraphic contacts must begin with a geologic contact (location marked with an arrow) and the nearest dip domain. Draw a straight line segment (red line) that is both perpendicular to the nearest dip domain AND passes through the first contact where it occurs on the ground surface (tip of arrow). (B) Then, using a series of straight-line segments, project the contact through adjacent dip domains. Note, each segment is perpendicular to the dip domain it passes through AND is positioned so that it intersects the previous straight-line segment roughly half way between adjacent dip domains. (C) Form lines (green) placed at evenly measured (1 cm) intervals above and below the Ja/Jb contact and then projected through the cross section using the same method for projecting stratigraphic contacts. The form line projections will ultimately be drafted as dashed lines to help readers visualize bedding involved in geologic structures.

## 2.4. Adding form lines to highlight structure

Once you finish projecting all of your stratigraphic contacts through your dip domains, it is possible to use essentially the same method to add a pattern of decorative **form lines** to help your readers to visualize geologic structures. Form lines are NOT stratigraphic contacts. Form lines are dashed lines placed at evenly spaced intervals within formations to highlight subsurface bedding trends (**Figure 6C**). To create a pattern of form lines, start from the same position along each dip domain (e.g., the place where the same stratigraphic contact passes through each domain) and then simply measure and mark regular intervals (e.g., 1 inch) along each dip domain in both directions (up and down section). Then, use the same process outlined in Step 6 to complete projections for each interval of form line through your dip domains. The use of form lines in the subsurface is fairly standard. Whether or not to project form lines above the ground surface is generally left up to the author, but can be a beautiful way to illustrate structural relationships.

*Tip: It is best to wait until you have finished roughing in all of your stratigraphic unit contacts through your dip domains before you begin to project form lines. After all your contacts are projected, it will be much easier for you to see what the best interval of measurement will be for spacing out your form lines . . . you don't want them too close or too far apart!*

*Time to practice: Activity 1 - Plotting geologic data, dip domains, & contacts on a topographic profile*

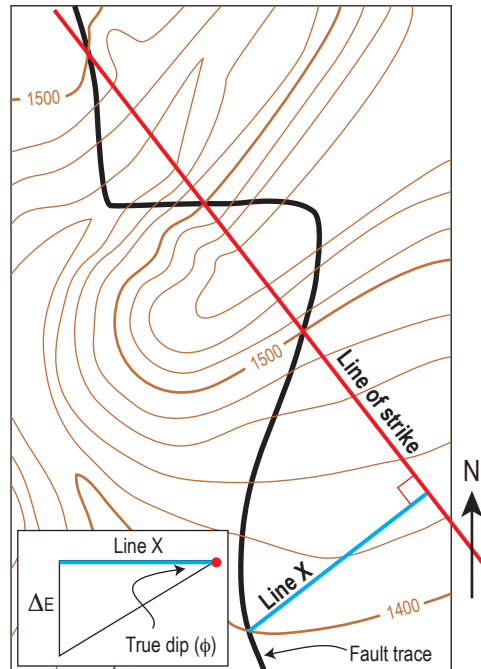
*Time to practice: Activity 2 - Simple syncline*

*Time to practice: Activity 3 - Simple anticline*

## Part 3: Dealing with simple faults

Faults cut strata, dividing portions of the lithosphere into separate **fault blocks**. For this reason, any dip domains used to characterize structural relationships in strata cut by a fault will also be truncated by the fault. Thus, you cannot use dip domains in one fault block to project geologic

**Figure 7.** Determining the strike and dip of a fault using its trace on a topographic map is pretty straightforward. The strike of the fault can be measured (in reference to north) using a line drawn through at least two points of equal elevation along the fault trace. To solve for true dip ( $\phi$ ), draw a perpendicular line (X) connecting the strike to another point of known elevation along the fault trace that is higher or lower than the elevation used to determine strike. Then use trigonometry, line length X (measured using the map scale), and the change in elevation between points along the fault trace to calculate true dip.



relationships into the strata in an adjacent fault block. Having said this, while you can't use dip domains to project strata across a fault, you can often use them to infer what strata might be doing on either side, because the two sides of a fault were adjacent at some point in the past. Furthermore, if piercing points (originally adjacent points along a fault) suggest that structures in both the hanging wall and footwall of a fault may be genetically related, it may be a useful exercise to use your surface data to construct a pre-faulted interpretation and then cut this structure with a fault.

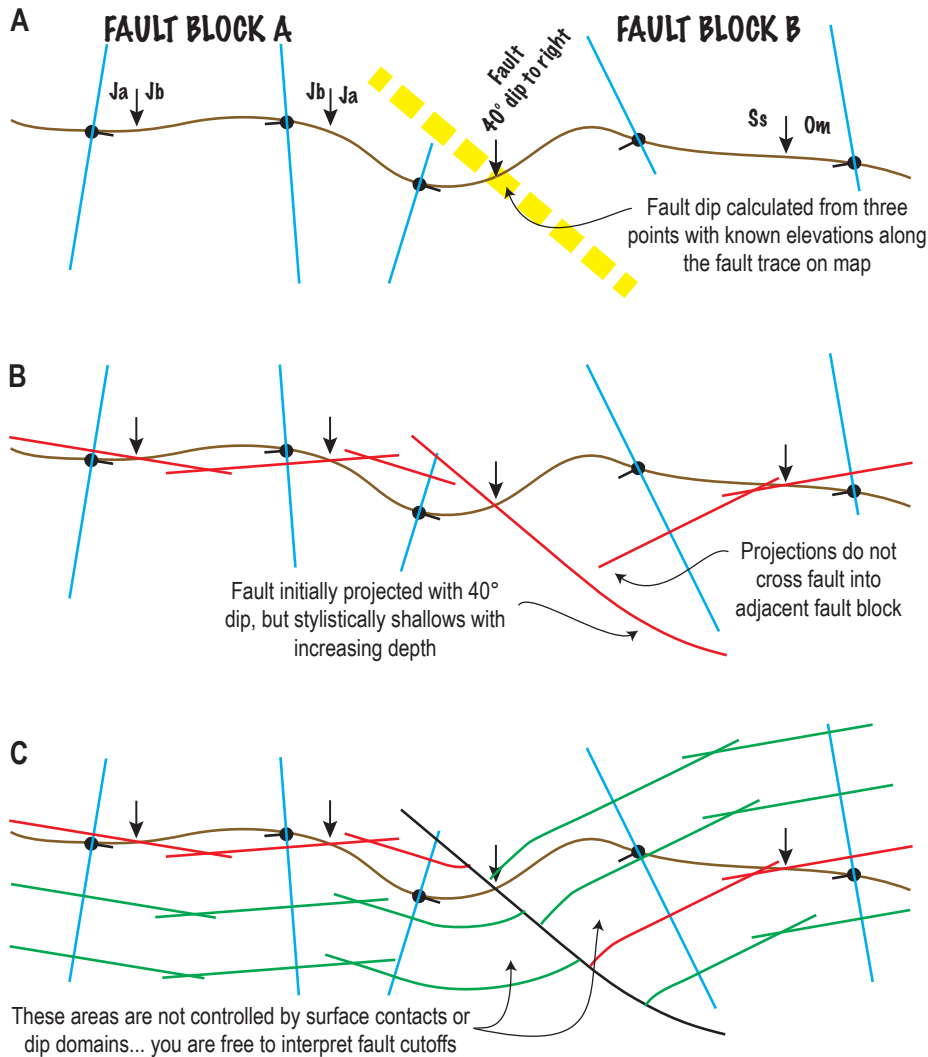
### 3.1. Determine the strike & dip of your fault

You will rarely have access to a fault surface that you can measure in the field. More commonly, you will need to calculate the attitude of faults using their trace across your map (**Figure 7**). To determine the strike, use a light pencil line to connect two points of known elevation along the fault trace (e.g., where the fault trace crosses the same topographic contour). This horizontal line is the **line of strike** on the fault surface and its orientation can be measured using the north arrow on your map. To minimize error associated with your mapping, try to select points of equal elevation that are reasonably far apart. To determine the **true dip** ( $\phi$ ), draw another light pencil line (**Line X**) that is perpendicular to your line of strike AND connects your line of strike to another point of known elevation along the fault trace that is either higher or lower than the elevation used to determine strike. Once again, to minimize error in your calculations, use a third point of known elevation as far away from the line of strike as possible. Use simple trigonometry (sin), the map distance (length) of Line X, and the change in elevation between your two points of known elevation ( $\Delta E$ ) to calculate the true dip ( $\phi$ ) of your fault.

*Tip: The accuracy and precision of strike and dip calculations based on map relationships are controlled by the quality of your map. This is a perfect example of why it is so important to be deliberate and careful when placing your measurements and observations on a map – make sure your placements are as correct as possible & double check your work!*

### 3.2. Projecting strata with a fault in the mix

Once you've determined the strike and dip of your fault (and an apparent dip correction if the strike of your fault is more than  $20^\circ$  off of perpendicular to your line of section), you can begin projecting contacts in your fault blocks (**Figure 8A**). Remember that dip domains are only used to interpret projections in the fault block that they are associated with . . . do not use dip domains to interpret geology in adjacent fault blocks. Use the fault dip you calculated to project your fault at depth. In general, the dip of non-vertical faults (not strike-slip) we observe at the surface will not persist at depth. On the contrary, it is very common for the dips of normal and reverse faults to begin shallowing at depth and you may wish to illustrate this trend in your projection (**Figure 8B**). Continue your contact projections through each of your fault blocks, but stop short of running these projections into the fault itself. Before you complete your contact projections by extending them into the fault, it is important to consider the nature of these truncations. In general, try to maintain consistency in the angles that strata are cut on opposite sides of a fault. For example, it would be odd to have high angle cutoffs in the hanging wall juxtaposed against low angle cutoffs in the footwall. Fortunately, once you've satisfied all of the structural (dip domains & fault projection) and stratigraphic (unit contact) controls in your section, you will generally be free to interpret what strata are doing adjacent to the fault (**Figure 8C**).



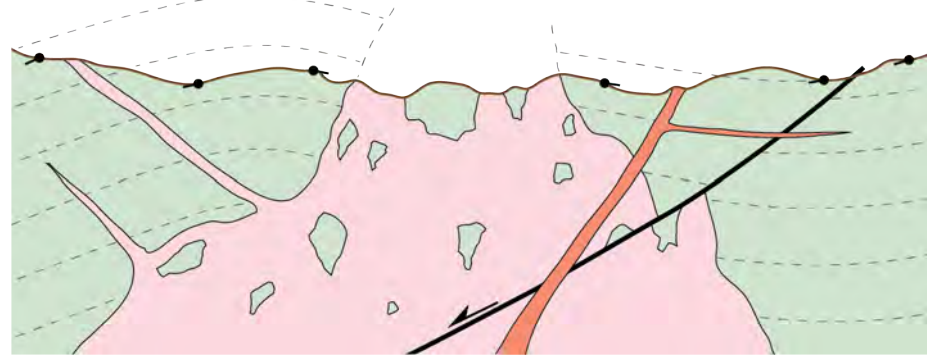
**Figure 8.** (A) When projecting strata through rocks that are cut by a fault, remember that dip domains should only be used to interpret geology in the blocks they are associated with. Do not use a dip domain to interpret geology in an adjacent fault block. (B) Project contacts through each fault block as normal, but stop short of extending contacts into the fault itself. The areas immediately adjacent to a fault are generally not controlled by dip domains and surface contacts, so you have a little extra freedom to interpret the geology here. Use your field observations and what you know about faults to interpret what the contacts will do in these areas. Do your best to maintain some consistency in the cut-off angles of strata on either side of the fault (C). Once you are happy with your interpretation, use form lines to help your reader visualize the structural relationships.

*Tip: Stylistic interpretations like those discussed above can be intimidating to less experienced geologists, but in many cases you will have seen things that can help you make these determinations. Keep your eyes open in the field and develop a feeling for the structural style of your study area. It is often possible to use the structural geometries and styles observed in the field to inform these interpretations.*

**Time to practice:** Activity 4 - Projecting contacts & faults

## Part 4: Quick comment on igneous rocks in cross section

The contacts between igneous intrusions and their host rocks do not follow any of the predictable rules that sedimentary rocks must follow. When including igneous rocks in cross section, use the geologic relationships you observe in the field to guide your subsurface interpretations (**Figure 9**). The strikes and dips of dikes



**Figure 9.** Example of cross-cutting relationships among a pluton, dikes, and a fault. Use the field relationships that you observe among units in the field to inform your cross section (e.g., include stopped blocks if you map them in the field). Always make sure the cross-cutting relationships in your cross section match those in your map.

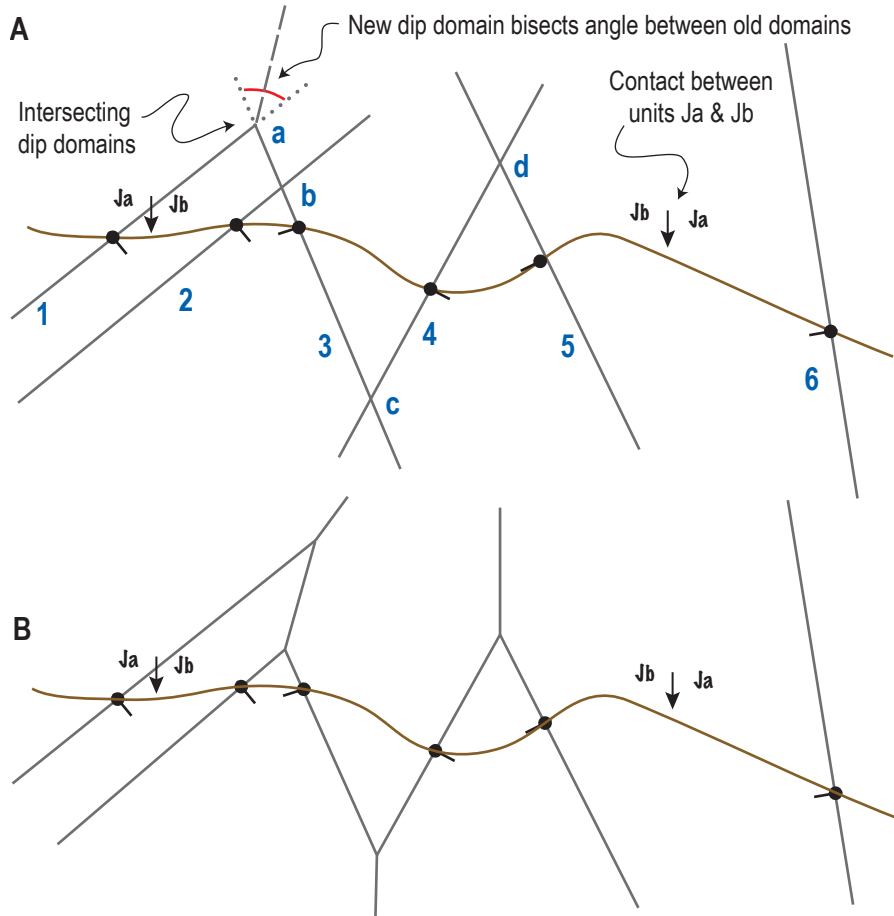
estimated from columnar jointing, the presence of xenoliths, and cross-cutting relationships among a series of intrusive bodies will help you create a geologically admissible interpretation. However, be sure to make certain that the cross-cutting relationships you show in your cross section match those in your map.

## Part 5: Potential complications

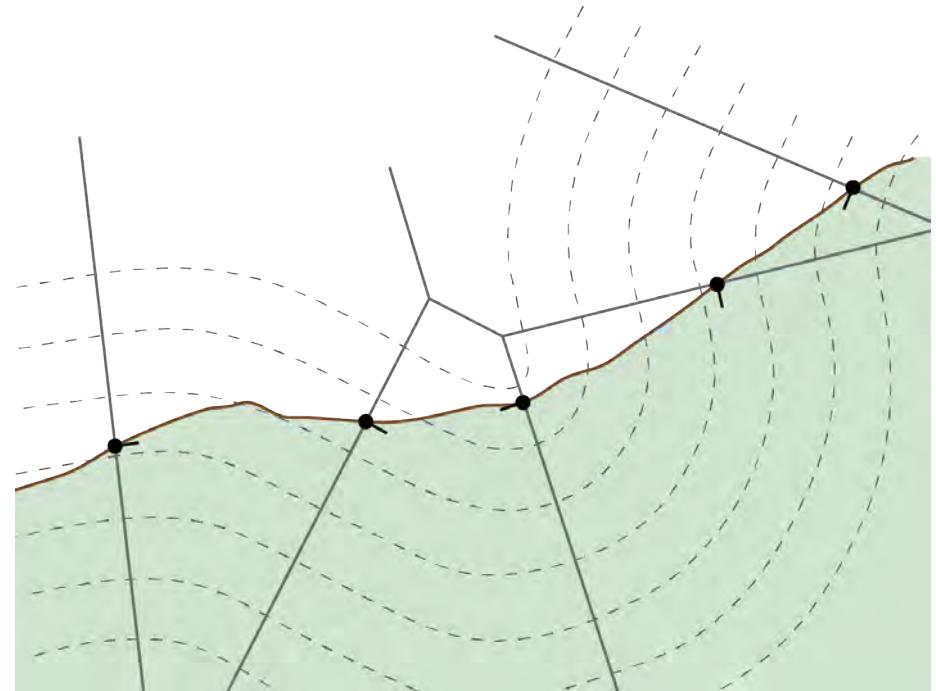
### 5.1. Merging intersecting dip domains

As we have seen earlier, dip domains that tilt towards or away from each other indicate the presence of a fold. The fold shape defined by layers in a concentric fold must simplify (become smaller) within the core of the fold. For example, consider all of the pages in a thick, paperback textbook folded into the shape of an imperfect anticline. Inconsistencies in fold shape (relatively flat areas versus angular bits, etc.) visible in the outermost layers in the folded textbook become less apparent and ultimately disappear near the core of the fold. Characterizing this irregular fold shape with dip domains would require many more domains in the outermost layers (one for each inconsistency in fold shape) than it would within the innermost core of the fold (perhaps

only two). The systematic reduction in the number of dip domains towards the core reflects the progressive simplification in the shape of a fold. To accomplish this simplification in your cross section, you must merge dip domains that intersect into a new, single dip domain that roughly bisects the angle between the two original domains. The systematic, iterative process for resolving overlapping dip domains is outlined in **Figure 10**.



**Figure 10.** (A) Topographic profile with dip domain lines extended perpendicular to each dip tick both above and below the ground surface. Intersecting dip domains (a) must be systematically supplanted with a single, new dip domain that bisects the angle formed by the two original intersecting dip domains. When simplifying cross sections with multiple intersecting dip domains, you must work systematically from either left-to-right or right-to-left (e.g., the sequence of domain intersections labeled a, b, c, d above). As you work, you may find that a newly drafted dip domain will change the nature of a previous intersection. In such a case, you will need to go back and make adjustments to previously edited dip domains before continuing forward in your work (e.g., resolving the overlapping dip domains at intersection b will affect the resolution you made for intersection a - you will need to update a before continuing on to intersection c).



**Figure 11.** Example of the projection of strata in an overturned syncline. Note that as you move from the outermost layers towards the core of the fold, two things happen. First, the geometry of the fold begins to simplify. Second, adequate space for folded layers quickly becomes limited in the core of the fold. Together, these complications are generally an indicator of the presence of an unknown structural complexity (ahem...fault...cough).

**Tip:** When merging domains, begin at one end of your section and work intersection-by-intersection towards the other end of the section. You may occasionally need to go back to make adjustments as you work.

**Time to practice:** Activity 5 - Resolving overlapping dip domains

## 5.2. Using stratigraphic thicknesses to project when folds get tight

As you develop your cross sections, you may notice that some folds get uncomfortably tight in their cores... too tight to continue to use the methods we've discussed above project strata. In these cases, use a ruler to measure the next appropriate interval (distance between stratigraphic contacts) and plot it by hand along the dip domain (**Figure 11**) – or – stop projecting strata altogether... these tight spots are usually the realm of evil structural demons... like faults.

## 5.3. Projecting overturned strata

Overtuned limbs of folds can be difficult to project (**Figure 11**). In general, overturned folds in sub-metamorphic rocks are generally fault-related folds and may be associated with a fault at depth that will not appear on your map. When projecting overturned folds, you may need to be extra selective with the dip

domains you use and how you use them. For example, dip domains associated with an overturned limb may not be indicative of the adjacent, upright limb. In these cases, do not extend overturned dip domains across the axis and into the upright limb of the fold, because the intersections they create will not resolve properly. Instead, only extend the dip domains in the direction away from the axis of the fold.

## Part 6: Finishing touches

### 6.1. Round straight-line projections (contacts and form lines) into folds

Once you've finished projecting all of the geologic contacts and form lines through your dip domains, you can begin to round off the intersections into smooth curves (Figure 12). While you are working, be sure to keep the thicknesses of these intervals constant as you round the corners off. If necessary, use a ruler to periodically check the thicknesses of intervals at fold axes.

**Tip:** Never use a straightedge to draw topographic profiles or to round out the arcs on contact or form line projections. Absolutely straight lines with angular beds are a rarity in nature, especially at the scale of maps and cross sections.

### 6.2. Cleanup

Once you've finished your projections, erase your dip domains. Do not erase dip ticks - ink them onto your topographic profile to provide your readers with the ability to evaluate how well your subsurface interpretations reflect your original map data. Contacts and faults should be solid lines (0.1 mm and ~0.8 mm, respectively) in the subsurface and dashed above the ground surface. All form lines should be drafted in 0.1 mm, dashed lines. You should use a pattern of shorter and more closely spaced dashed for form lines so they are easily distinguishable from the dashed lines you are using for contacts and faults above the ground surface.

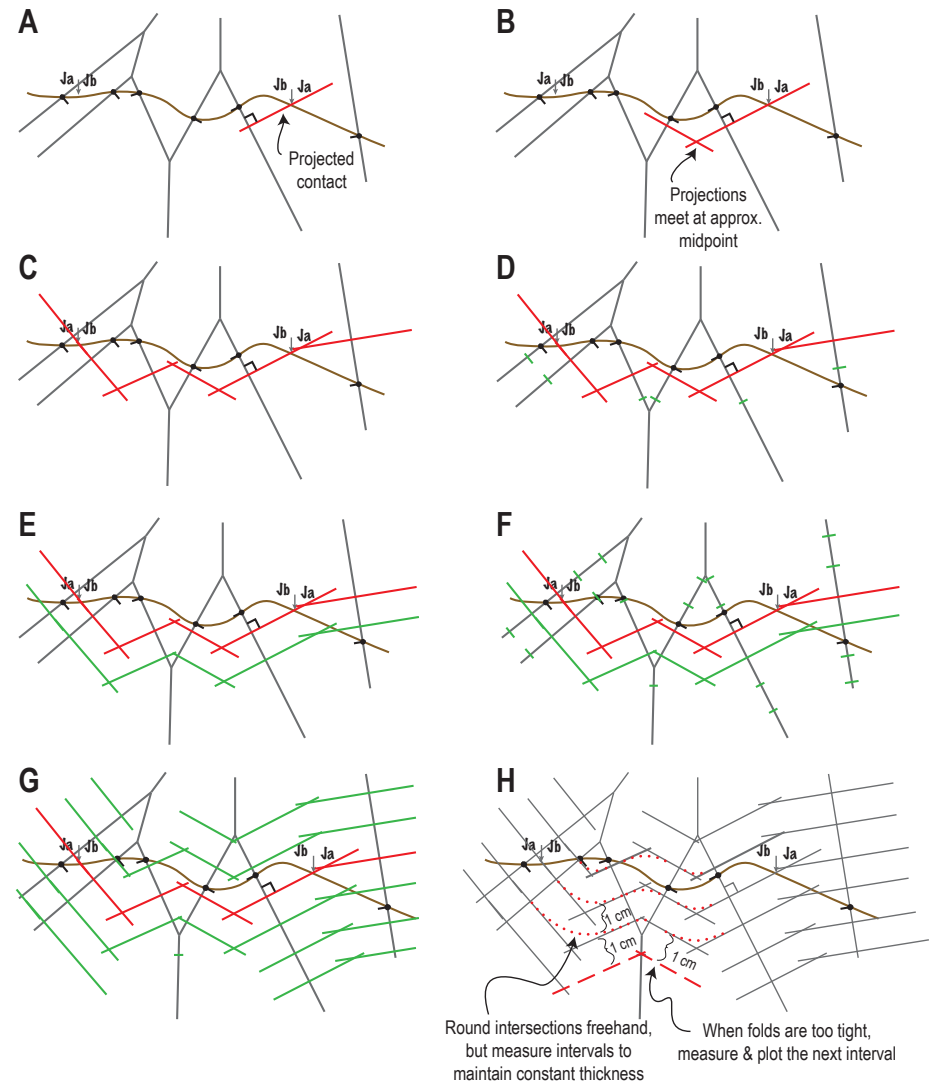
**Tip:** All subsurface geologic unit contacts should be drafted with solid lines. The "dashed where inferred" rule used when compiling a geologic map does not apply in a geologic cross section. Technically speaking, everything below the ground surface is an inference, so dashing some of your lines in the subsurface is a useless distinction. All above-ground geologic unit projections should be drafted with dashed lines. All form lines (above and below ground)

**Figure 12.** An example illustrating the entire process of projecting contacts and form lines through dip domain lines from start to finish. (A) Projections of strata must begin with a geologic contact (location marked with arrow). Choose the surface contact nearest to a dip domain for the first projection. Draw a straight line segment that is both perpendicular to the nearest dip domain and passes through the first contact (red line). (B-C) Then, using a series of straight-line segments, project the contact through adjacent dip domains. Note, each segment is perpendicular to the dip domain it passes through AND is positioned so that it intersects the previous and subsequent straight-line segments roughly halfway between control points (e.g., dip domains or data points on the topographic profile). (D-G) Once a contact is projected through the cross section, it is possible to use measurements to plot form lines (at regular measured intervals) and/or additional geologic unit contacts (using stratigraphic thicknesses). Simply measure the desired interval above or below the known contact along each dip domain and make a mark where the next projection will occur (green dashes in A). Then, follow the same procedure to project the interval through your section. (H) In places where structural complications hinder easy projection of strata, use stratigraphic thicknesses to measure appropriate intervals (even around bends associated with merging dip domains!) and project contacts. Finally, once all the straight-line segments representing contacts and form lines are projected, use freehand sketching to round them off into gentle arcs. Be careful to maintain constant thickness!

should be drawn with dashed lines. Use different lengths dashes to differentiate between form lines (smaller) and geologic unit contacts (larger).

### 6.3. Colors and patterns

When coloring your subsurface geologic interpretations, use the exact same colors for geologic units that are on your geologic map – and if you are drafting on vellum or tracing paper, try coloring on the back of the page. If you are using form lines to illustrate the structural geometries in your section, you might consider using stylized patterns (e.g., blocks for limestone, dots for sandstone) instead of simple dashed lines to highlight rock types.

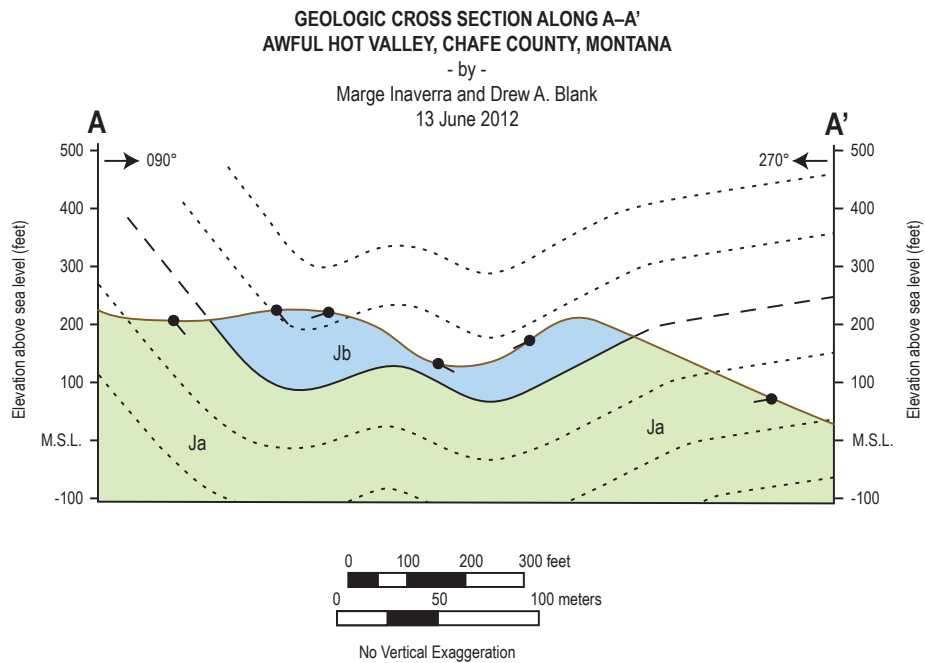




**Tip:** If you are drafting your cross section on vellum or tracing paper, try coloring on the back of the page. The color will show through the paper as a nicely subdued shade and make your line work and lettering stand out crisply.

### 6.4. Must-have components

Professional cross-sections should contain: **(1)** a title block including your name(s), date(s), reference to the location (specific geographic location along with county and state), and a horizontal scale (both bar and ratio scales... trace this information directly off of your map); **(2)** vertical scale bars with appropriate graduations along vertical axes ; and **(3)** references to the line of section on the map (A-A') atop the vertical axes and the bearings of your line of section from each vertical axis.



**Figure 13.** An example geologic cross section. Note that the dip ticks have been left along the topographic profile. These data are important, because they show the reader the locations of the strike measurements and the magnitude and direction of dips used to construct your interpretation. The geologic unit contact between Ja and Jb is shown with a solid line in the subsurface, but is dashed where it has been projected above surface. Form lines comprising shorter length dashes are used to illustrate bedding trends within geologic units. Necessary formatting elements including a title block, references to line of section on the map (A-A' and azimuths), appropriately graduated vertical and horizontal scales, and unit labels. Finally, please note that constant thickness in all layers has been maintained.

### 6.5. Items to omit

You do not need to include **(1)** a detailed legend of the geologic units and symbols used in the cross section (e.g., unit labels, colors, fault symbols, tip ticks, etc.). Cross sections are considered to be figures that support the geologic map that they are associated with – that map should contain all of the relevant supporting information. Similarly, **(2)** do not draft the axial plane of folds in geologic cross sections. Fold axes are plotted on geologic maps to help readers identify them, but the deformed geometries of stratigraphic contacts should be enough to visualize folds in cross section. If contacts might not be sufficient, use form lines to help your readers see the folds.

### Apparent Dip Nomogram

