JoVE: Science Education

Use of the Brunton Compass to Determine Spatial Orientation of Rock Layers

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Earth Science/Geology Science Education Title: Use of the Brunton Compass to Determine Spatial Orientation of Rock Layers

FIG 1: The Brunton Compass
"Brunton Pocket Transit" Made by Brunton Inc, Riverton, Wyoming. Used to measure orientation of rock surfaces.

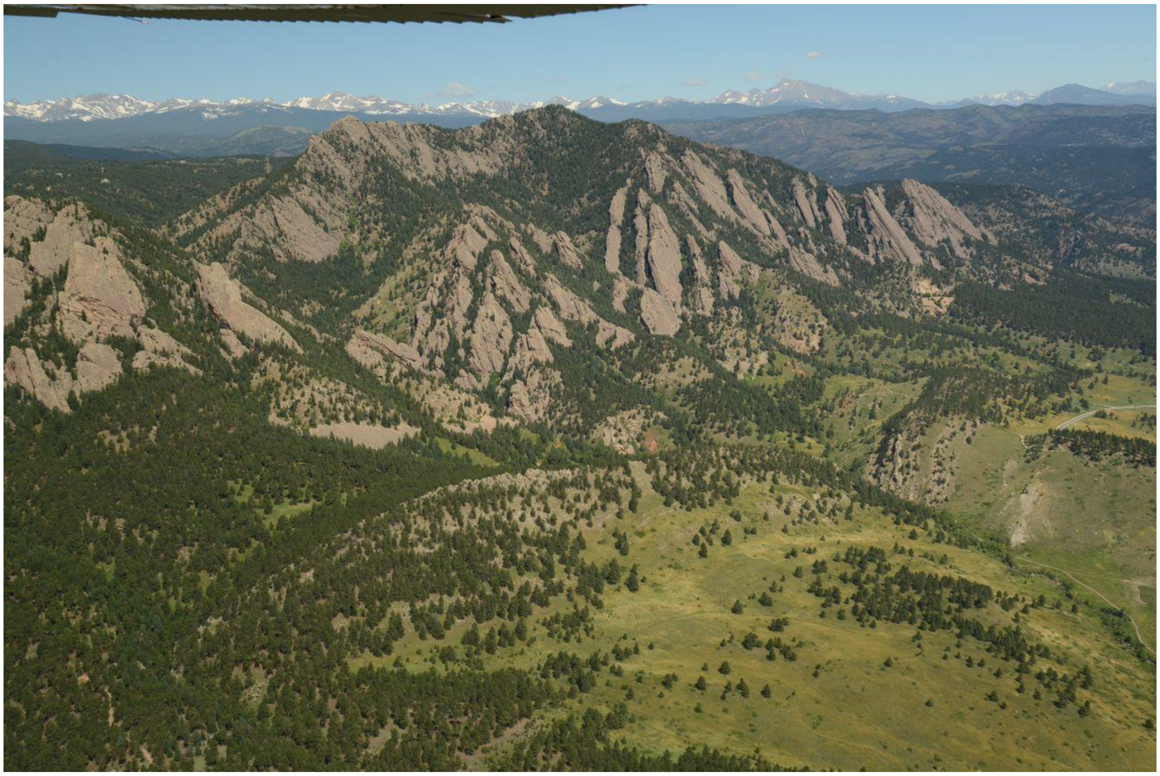

FIG 2: The Flatirons
Example of tilted layers of Late Paleozoic sedimentary rocks, located near Boulder, CO (image provided by Alan Lester)

Overview

Most rock units exhibit some form of planar surfaces or linear features. Examples include bedding-, fault-, fracture-, and joint-surfaces, and various forms of foliation and mineral alignment. The spatial orientation of these features form the critical raw data used to constrain models addressing the origin and subsequent deformation of rock units.

Although now over 100 years since its invention and introduction, the Brunton compass remains a central tool in the modern geologist's arsenal of field equipment. It is still *the* primary tool used to generate field data regarding the geometric orientation of planar rock surfaces or linear rock features. These orientation measurements are referred to as <u>strike and dip</u>, and provide the fundamental data for making geologic maps. Furthermore, the Brunton Compass can also function as a traditional compass for location exercises and triangulation. Finally, it can also serve as a pocket transit for measuring angular elevations.

Principles, Definitions, and Preparation

Most rock layers (either sedimentary layering, igneous layering, or metamorphic banding/foliation) can be described as a planar surface in space. As such, the surface has an angular deviation from horizontal of anywhere between 0 degrees and 90 degrees. This angular deviation is known as "dip." All rock surfaces that have greater than 0 degree dip have a linear intersection with an imaginary horizontal plane, and the compass direction of that linear intersection (the line formed by the intersection of the rock layer and a horizontal plane) is referred to as "strike."

To determine the strike and dip of a rock surface, the Brunton compass must be properly prepared and then aligned with the surface being evaluated.

Brunton compass usage involves some preparatory steps:

Step 1) Check for free needle motion. Verify that the needle is unimpeded when held in the horizontal plane. Some compasses have restrictor buttons that hold the needle in place, and if present, check to see that pushing the restrictor does not move the needle.

Step 2) Check the "bull's eye bubble" centering and continuity. This bubble is one of two leveling bubbles and is used to determine horizontality of the compass. The other bubble is used for inclination measurements.

Step 3) Check for correct magnetic declination setting. Since earth's magnetic and geographic poles are not coincident, in order to accurately assess compass directions (relative to true north) the declination pin must be set to the correct magnetic declination for the location of usage.

PROCEDURE

1) **Establish Suitable Representative Surface for Measurement**
1. 1 In the field, a geologist must establish suitable representative surfaces for measurement. The idea is to approximate the overall orientation of the feature being evaluated (bedding, jointing, foliation, etc.) at this particular location. One of the simplest ways to do this is to place a notebook or clipboard onto the rock in this average and representative orientation.

In a lab demonstration, any flat surface can be used as a representative surface (a board/model on a desk, or an architectural element of a building).

2) **Set the Compass on the Surface**
2.1 Next, the lower edge of the Brunton Compass is set upon the surface, such that the entire edge is flush with the surface.

3) **Center the "Bull's Eye Bubble"**
3.1 Without taking any part of this edge off the surface (critical, and the most common mistake amongst students!) the Brunton Compass is rotated until the "bull's eye bubble" is centered.

4) **Read the Azimith Orientation, or Measure Strike**
4.1 By centering the bull's eye bubble, the Brunton Compass becomes aligned in the horizontal plane, and this allows for reading the azimith orientation of the line formed by the intersection of the rock surface and the horizontal—i.e. the definition of "strike".

Note: By convention strike is measured in the northern quadrant. For example a direction of S30degE (30 degrees to the east of due south) would be reported as N30W.

5) **Measure Dip**

The final step is to measure dip. This is measured perpendicularly to the strike direction and is defined as the angular deviation of the surface from horizontal.   For example, a nearly vertically oriented rock layer might have a dip magnitude of 85SE, indicating that the surface is dipping 85 degrees from the horizontal, in a southeasterly direction.

Note: Dip direction is given in a general sense (NE, SE, SW, NW) because its exact direction is always 90degrees from strike.

RESULTS

Firstly, it's important to recognize that a set of strike and dip data for a non-dipping rock layer has a range of values. The *precision* of a single measurement is, of course, linked to mechanical compass-errors and the experience of the compass-user. The *accuracy* of the final analysis is dependent on the uniformity of the natural surface (many nominally "flat-lying" rock layers have some degree of inherent surface undulations) and the number of total measurements taken.

Secondly, strike and dip data are initially recorded in field notebooks, and then transferred to tabulated form, and ultimately onto geologic maps. All geologic maps show the boundaries between rock units, and the strike and dip data (bar and stick symbols) provides the three-dimensional component, describing the spatial orientation of each rock unit.

Strike and dip of bedding, the most common kind of rock orientation data, is shown at a specific location with symbols like the ones below.

Fig 3: Strike and Dip of Bedding on a Map

Strike and dip of bedding, the most common kind of rock orientation data, is shown at a specific location with symbols like the ones in the map.
Used Courtesy of the Virginia Department of Mines, Minerals, and Energy

Besides strike and dip of bedding, there are many other sorts of planar and/or linear rock features that have strike and dip and some of these are shown below.

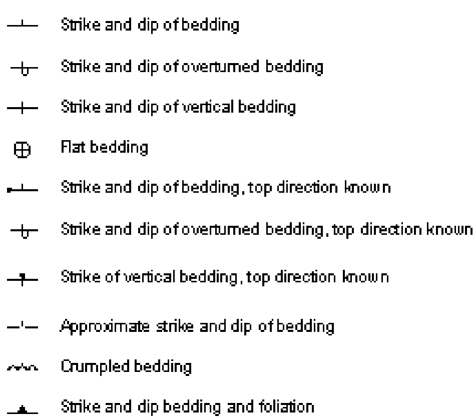

Fig 4: Strike and Dip Map Key

Map key for planar and/or linear rock features demonstrating strike and dip.
Credit: U.S. Geological Survey
Department of the Interior/USGS
U.S. Geological Survey

APPLICATION

Geologists strive to understand the earth in four-dimensions. The goal is to interpret the structure of rocks on the surface, in the subsurface, and through time. Strike and dip information generated by the Brunton Compass is the starting point with which geologists make geologic maps, and then those maps can be used to make cross sectional diagrams, showing the structures in the subsurface.

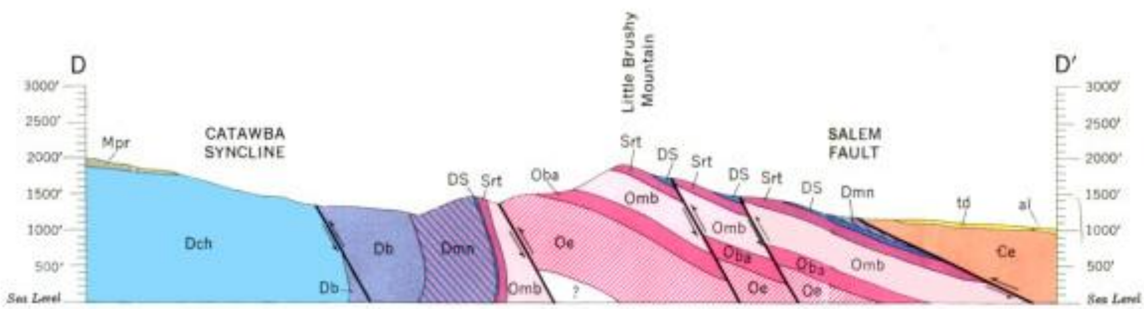

FIG 5: Geologic Cross Section

Geologic cross sections are representations of underground geology. The line (D-D') on the map is the line along which the cross section was drawn. Anticlines, synclines, and faults can be seen in cross sections.
Used Courtesy of the Virginia Department of Mines, Minerals, and Energy

Understanding rock structures in the three spatial dimensions and also through time provides a window on the physical evolution of our planet. In addition, this kind of knowledge is central to many industrial and economic applications. One example is the identification of rock up-warps, where layers have been bent in domes or fold structures called anticlines— and it is at the apex of these structures that oil and gas often collect.

Figures and legends.

Figure 1. Brunton Compass.

“Brunton Pocket Transit” Made by Brunton Inc, Riverton, Wyoming. Used to measure orientation of rock surfaces.
Editorial note: Placeholder. We’ll shoot a photo of a compass when filming.

Figure 2. The Flatirons
Example of tilted layers of Late Paleozoic sedimentary rocks, located near Boulder, CO (image provided by Alan Lester)

Figure 3. Strike and Dip of Bedding on a Map
Strike and dip of bedding, the most common kind of rock orientation data, is shown at a specific location with symbols like the ones below.

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Notes to the authors are italicized and highlighted.

General note: JoVE is okay with shooting outdoors with the following caveats: it can't be more than 250 words worth (5-7 steps), and it can be filmed on the same day if it's within ½ hour drive of the laboratory. From your comments, I believe we can keep to these guidelines.

Yeah, it's tricky…. If during shoot day, wx is good,,, then I think that this would be very worthwhile.

1. **Overview**

1.1. The role of geology is to understand the earth in four dimensions. One of the simplest tools in this endeavor is the Brunton compass.

1.1.1. Title card.

1.2. The Brunton compass, while over 100 years old, is still the primary tool for generating geologic field data. (**1.2.1**) *I'd like to include a quick introduction to the relevant components of the compass (the levels, index pin, clinometer, etc). If you think this would be valuable content for the video, could you write a short explanation of what would be useful?*

Yes…

The compass has several key parts, that should be physcally pointed out—

These are the compass needle, the sighting arm, the peep-hole, the index pin, the leveling bubble (clinometer), and the bull's-eye leveling-bubble

1.3. (**1.2.2**) The compass is used to collect field data regarding the geometric orientation of planar rock surfaces, known as strike and dip. (**1.2.3**) This information is the fundamental data for generating geologic maps. (**1.2.4**)

1.4. This video will demonstrate the proper way to measure strike and dip with the Brunton compass.

1.4.1. WIDE: Establishing shot of location of test.

2. **Principles**

2.1. Most rock units exhibit some form of planar surface or linear structure. Examples include bedding-, fault-, and joint-surfaces. (**2.1.1**) *Which of these formations (or other ones of note) could be photographed from the location you mentioned in your notes?*

Location shoot…very simple…. BEDDING…which is THE KEY feature that geologists measure strike/dip on.

2.2. The spatial orientation of these features form the raw data used to construct models for the origin of rock units. (**2.1.2**)

2.3. Rock layers can be described as a planar surface in space. (**2.2.1**) Any angular deviation for the horizontal is known as "dip". Dip is reported in degrees, with a range between 0 and 90. (**2.2.2**) The value is followed by the general direction of the dipping. (**2.2.3**)

2.4. In addition to the deviation from the horizontal, geologists also measure the deviation of the rock surface from North, or, "strike". (**2.3.1**) Strike can be visualized as the linear intersection of the horizontal plane and the surface being studied. (**2.3.2**) Strike is reported in degrees from North. (**2.3.3**)

3. **Setup of the Brunton Compass (filmed in lab)**

3.1. Before measurements can be collected with the compass, the functionality of the components must be verified.
  3.1.1. Title slide.

3.2. The needle must be unimpeded when held in the horizontal plane. If the compass has a restrictor button, verify that it is working properly.
  3.2.1. CU: Talent rotates compass in the horizontal plane, demonstrating free movement.
  3.2.2. CU: Talent demonstrates restrictor button. (Note to videographer: may not be available on filming day.)

3.3. Check the bull's eye level centering and uninterrupted function. The bubble is used to determine the horizontality of the compass.
  3.3.1. CU: Talent rotates the compass in 3D space to show the bubble can freely move.
  3.3.2. CU: Talent places compass on flat, horizontal surface, demonstrating its proper use.

3.4. While the geographic North Pole is a static location, the magnetic north pole moves over time. Because of this, a declination pin is used to correct for the difference. The declination is found on a local topographic map, and the adjust the set-screw to the appropriate value.

3.4.1. CU: Talent rotates compass in horizontal plane, showing needle movement.
3.4.2. CU: Topographic map with declination values.
3.4.3. CU: Talent adjusts set-screw.

4. **Collection of Measurements (filmed at site near CU Boulder)**

4.1. Because natural surfaces are inherently rough, a representative, flat surface must be established. A way to create the surface is the place a notebook or clipboard onto the rock in a representative orientation.
4.1.1. MED: A representative shot of natural rock, showing its roughness.
4.1.2. MED: Talent places flat item onto the rock.

4.2. Place the compass against the surface. Rotate the compass until the bubble is centered in the bull's eye level. (TEXT: Important: Don't lift the compass from the surface)
4.2.1. MED: Talent place compass to the surface.
4.2.2. CU: Talent rotates the compass.
4.2.3. ECU: Bubble centers in level.

4.3. With the bull's eye leveled, the compass is now aligned in the horizontal plane. The strike is indicated by the compass needle. The value at either end of the needle is correct, but by convention, the value closer to North is used.
4.3.1. CU: Reading of compass, showing value.
4.3.2. ECU: Compass face with values visible. (Highlight the end of the needle closer to North.)
4.3.3. CU: Talent records value in notebook.

4.4. Dip is measured perpendicular to the strike. Set the compass on its side, aligned along the downward slope. Adjust the inclinometer until the bubble is leveled. The dip magnitude is indicated be the inclinometer. In addition, the general direction of the dip is notated.
4.4.1. MED: Talent lays compass on its side, perpendicular to strike.
4.4.2. CU: Talent turns inclinometer dial.
4.4.3. CU: (Simultaneous with 4.4.2) Bubble centers in level
4.4.4. ECU: Indicator is pointing to the dip value.
4.4.5. MED-over the shoulder: Talent records the value and direction of dip.

4.5. The process of collecting strike and dip values is continued for all rock units of interest.
4.5.1. WIDE: Shot of surrounding area with multiple rock surfaces to analyze.

5. **Results (contains 1 field shot)**

5.1. When taking measurements, it's important to practice good technique and verify the compass is working properly. This will ensure good precision for the data.

5.1.1. Reuse 4.4.2 and 4.4.3.

5.2. The accuracy of the data is dependent on the uniformity of the natural surface. Taking multiple measurements of the same surface can increase the accuracy.

5.2.1. MED (field): Example of surface undulations.

5.3. Once the strike and dip values have been correctly recorded in the field, they are combined into geologic maps. These maps show the boundaries between rock units, and the strike and dip data provides the spatial orientation of each rock. Enough symbols should be included to show any variation within the unit.

5.3.1. Figure 3, without strike and dip data.

5.3.2. Strike and dip notation is added to the map, one at a time.

5.4. *Figure 4 is the map key. I was wondering which of the features in Figures 3 and 4 are especially common/useful (as they pertain to strike and dip, specifically), and please explain the significance of each. With this info, I take a few steps to explain in some detail the significance of geologic maps.*

Fig 4 shows a list of numerous different kinds of "measurable" strike/dip features.
Delineating all these different features is outside the scope of a video that should be focused on how to measure strike and dip of a surface.

Also-- Overturned and vertical bedding…. Should be obvious in meaning. (beds flipped upside down,,, and beds flipped on their side)
Discussion of the meaning of crumple structures, or crenulation cleavage , or foliation…would require the rudiments from a course in metamorphic petrology.

MY POINT,,, and the point of including that figure,,, is simply to show that there are a lot of rock features that can be thought of as "planar"…and measurable with S/D

5.4.1. Figures 3 and 4 with author input.

6. **Applications**

6.1. (**Lower Third: Application #1: Generating cross sectional maps**)
Once the geologic maps are created, geologic cross-sections can be generated. The information in the geologic map is extrapolated to determine

the structure of rocks below the surface. In turn, this can provide information about the physical evolution about the area. *Note: We're just briefly mentioning cross-sections here, and will go into detail in your other video.*

GOOD!—because any discussion of cross sections is outside the bounds of a video that should simply show someone how to use a brunton to measure strike/dip of a surface.

6.1.1. Figure 3.
6.1.2. Figure 3 rotates out of the plane of the screen, and Figure 5, matching the E-E' lines.
6.1.3. With last sentence, fade up dashed lines in Figure 5.

6.2. (**Lower Third: Application #2: Identifying patterns of deformation**) Another use of geologic maps is identifying past orientations of stress…. *Would I be correct that this could help with identifying faults, or something along those lines? Also, are there any visuals we can use for this, either from what we have already, or something we can film/illustrate?*

Sure!—recognizing the location of faults is certainly something that geologic maps be used for!....but how to do this?---Hmmmm….that's way outside the scope of a video that should simply show someone how to use a brunton to measure strike/dip of a surface.

Basically, you're asking me for a description of how to USE geologic maps… well, get someone to do another video on that topic…wow,,, it's a big one!

6.3. *Could you come up with one other real-world application of the compass/ strike and dip data/geologic maps? We can't use the one that's already in the Results section. Sometimes we can use JoVE articles, but sadly, we don't have any applicable videos we can use*.

HMMMMmmmm.,…. Not sure of what you are getting at, or what the problem is here…
I provided three examples of how s/d data are used.

In a nutshell….ANYTHING geological that displays a planar surface (or one can approximate as a planar tangential to a surface) is something that you can theoretically measure strike and dip on!
And WHAT CAN YOU DO with measuring planar surfaces??--- gosh, I would say that this is fundamental data for the whole business of geology…which is to interpret earth structure (orientation of rocks at depth) and the evolution of earth features (e.g. changing rocks and environments though time). In sense, I feel like I'm getting

asked --- What do geologists do?....because nearly everything they do, can at some point or some level make use of measurements of planar surfaces.

Don't get me wrong… I LIKE big picture stuff…and I would be more than happy to say something about how S/D data are fundamental to understanding earth in 4-D (spatial and temporal history)…but my sense is that the point of this video is to show folks how to use a Brunton compass to make simple strike/dip measurements… and NOT to describe the broad scope of geological work.

7. **Summary**

7.1. You have just watched JoVE's introduction of the Brunton compass. You should now understand the setup of the compass, proper usage, and how to take strike and dip measurements. Thanks for watching!

7.1.1. 4 quadrants with 1) 3.3.1 – free needle rotation 2) 4.2.2 – centering bull's eye level 3) 4.3.2 – recording values 4) 5.3.2 – strike and dip values adding to geologic map.