ScienceNews

Teacher Background Sheet: How to Read A Geologic Map

Geologic maps are tools that provide information about the distribution and characteristics of rocks at Earth's surface. For detailed instruction on how to read geologic maps and other remote-sensing imagery, refer to "Geological Mapping & Remote Image Interpretation" published by The Geoscience Pathways project and the government of South Australia or "How to read a geologic map" published by the Wisconsin Geological and Natural History Survey. Make available a dictionary of geological terms for students to reference.

Early geologic maps were constructed based on direct observations by amateur and professional scientists, who recorded information about rock layers exposed at Earth's surface in road cuts, outcrops, quarries and canyons. People gathered that information while exploring local surroundings and during expeditions to find resources to use in manufacturing, building and energy production.

Field work remains an essential component of geologic mapping projects. Scientists now also use satellite imagery, aerial photography, magnetic and gravity surveys, rock cores and ground-penetrating radar to improve map quality.

Geologic maps are built on different scales and with different levels of detail. For instance, a state-level map — which provides an overview of the entire state's geology — is larger in scale and contains fewer details than a local geologic map.

Geologic map symbols

Understanding the key or legend of a geologic map is essential for students to analyze the information provided by the map. Keys use colors, patterns and symbols for all important features. Such features may include rock or sediment type, age, orientation and angle or slope of rock layers; contacts between rocks of different ages or types; locations and orientations of faults and other geologic structures; and locations of bodies of water, quarries, mines and important outcrops.

Scientists have agreed on certain conventions for geologic maps to ensure that the information conveyed in maps is consistent. A record of these conventions can be found at the USGS Federal Geographic Data Committee's Digital Cartographic Standards for Geologic Map Symbolization. Refer to this document to explore variations of the common map symbols described below. A pdf of the report is available if you wish to download a complete copy for offline reference.

Rock units

Geologic maps provide essential details about Earth's surface, including the type and age of bedrock and sediments — commonly called the "map units" or "rock units" — in a given area. Rock units are defined as a distinctive segment or volume of rock that has an identifiable origin and relative age. Rock units can be made of a single layer or type of rock, or they can be collections of several layers that share certain characteristics.

On a geologic map, rock units will be defined by a color and/or a pattern that will indicate whether the rock is sedimentary, metamorphic or igneous. Alphanumeric symbols are commonly used to distinguish the age and type of rock on top of the colors and patterns.

Colors are outlined in Section 33 ("Suggested Ranges of Map-Unit Colors"), patterns are shown in Section 37 ("Lithologic Patterns") and alphanumeric symbols are outlined in Section 32 ("Geologic Age Symbol Font") of the Digital Cartographic Standards for Geologic Map Symbolization.

Rock units may also be called groups, formations and members. Important rock units may be named on the map. This practice is common for geologic maps of Utah, northern Arizona and the Grand Canyon region, where scientists can trace specific rock units across vast distances.

It is easier to make sense of geologic maps if you are familiar with the geologic time scale, which breaks geologic time into eons, periods, epochs and ages. Geologic map keys use the names of these time intervals as part of the alphanumeric codes used to identify rock units.

For example, the period in which we currently live is called the Quaternary Period. Students will notice that almost all maps contain map units describing Quaternary unconsolidated sediments. This is because the loose sedimentary material is relatively more recent and has not undergone the processes of burial and lithification. Therefore, the material is not considered rock.

The Geological Society of America continually updates the standardized Geologic Time Scale, from which the names of these time units — and in many cases, the colors for rock units shown on the map — are taken.

Select geologic structures

Strike and dip
Terms geologists use to describe the orientation of rock layers. Dip has two components: angle and direction. The dip direction describes the compass direction (N, S, E, W) in which the surface of the rock layer slopes. The dip angle describes the angle the strata make relative to the horizontal plane of Earth's surface. Strike is the compass direction that the horizontal plane of the rock layer trends. For example, a rock layer may strike northwest–to-southeast, and it may dip 30 degrees to the southwest. This information would be indicated by a symbol on the map.

The symbols used to denote strike and dip are outlined in Section 6 ("Bedding") of the Digital Cartographic Standards for Geologic Map Symbolization.

Contacts
Boundaries that separate rocks from one another. Contacts between rock units are generally indicated by a solid line if the contact is clearly defined or a dashed line if the contact is diffuse. These symbols also may indicate boundary areas that formed in different ways or where some rock is missing due to erosion, as well as the strike and dip of the contact between rock units.

The symbols used to denote contacts between rock units are outlined in Section 1 ("Contacts") of the Digital Cartographic Standards for Geologic Map Symbolization.

Faults
Fractures in rock along which adjacent blocks of rock move relative to each other. Blocks can move horizontally past each other, or they can move up or down relative to each other.

There are three main types of faults: normal, reverse and strike-slip. Normal faults and reverse faults are horizontal and their blocks move vertically. Normal faults form where tension, or extension, pulls blocks of rock away from each other and one block slides down along the fault. Reverse faults form where compression pushes blocks of rock toward each other and one block slides up along the fault. Strike-slip faults are vertical or nearly so, and blocks slide horizontally past each other as shear stress pushes the blocks in opposite directions.

Some larger faults may be identified by observing the patterns made by rock units over larger areas. For example, large strike-slip faults that occur at plate boundaries may offset entire sequences of rock. The resulting pattern of rock units stops abruptly and begins again some distance from the original sequence. This type of offset is visible in the image of China's Piqiang Fault, and it is a feature commonly identifiable in geologic maps.

The angle and direction of slip, or block movement, along a fault is indicated by symbols much the way that strike and dip are indicated. The symbols are outlined in Section 2 ("Faults") of the Digital Cartographic Standards for Geologic Map Symbolization.

Folds
Rock layers that are bent or curved. Folded rock structures can be identified in Appalachian states such as Virginia.

Upward folds, called anticlines, can be identified on a geologic map by observing a pattern of rock units in which the rocks get progressively older and then get progressively younger. This pattern suggests that the rocks at the top of the fold were eroded so that the older rocks at the center of the fold were exposed. Symbols for anticlines commonly use solid or dashed lines to indicate the center, or axis, of the fold and arrows pointing away from each other along that line.

Downward folds, called synclines, display the opposite pattern. As you move across the map, you will observe rock units get progressively younger and then begin to get progressively older. Symbols for synclines commonly use solid or dashed lines to indicate the center, or axis, of the fold and arrows pointing toward each other along that line.

The symbols used to identify types and orientations of folds are outlined in Section 5 ("Folds") of the Digital Cartographic Standards for Geologic Map Symbolization.

Few folds are symmetrical and parallel to Earth's surface, which can make them difficult to identify on a geologic map. The strike and dip of the layers in the rock tell you more about the shape of a fold so that it can be visualized in three dimensions.

Reference the American Geological Union's blog post "Valleys and Ridges: Understanding the Geologic Structures in Central Virginia Part 1" for a clear explanation of how to identify anticlines and synclines on a geologic map.

Interpreting geologic structures

The series of geologic and tectonic events and processes that shaped a region can be inferred by interpreting the structures shown on maps. Some geologic maps are constructed on top of shaded relief maps or topographic maps, which indicate the underlying terrain. The relief or terrain of the region can provide additional clues about the tectonic and geologic history of the region, especially by noting the locations and steepness of hills, cliffs, mountains, valleys and other features.

For details on how to read and interpret topographic maps, refer to the Additional Resources at the end of this document. Some tectonic features and landforms — such as rifts, plate boundaries and volcanic features — may be indicated directly on the map. For more details on these features, see Section 18 ("Volcanic Features"), Section 22 ("Plate Tectonic Features") and Section 23 ("Miscellaneous Uplift and Collapse Features") of the Digital Cartographic Standards for Geologic Map Symbolization.

The symbols that indicate the strike and dip of rock layers and the contacts between rock units provide valuable information about the tectonic and geologic history of rock units. These details can be used to infer whether and how rocks were disturbed by folding and faulting. For instance, sedimentary rock layers are deposited in flat, horizontal layers. If rock layers are not oriented horizontally, it suggests that the layers were disturbed by tectonic forces or other geologic processes.

In order to unravel the tectonic history of a region, you will need to think about how the different types of rocks formed and whether conditions were likely to have existed for certain igneous, sedimentary and metamorphic rocks to form. You will ask many questions. Are the sedimentary rock types in our state marine sedimentary rocks, which form from sediment that was deposited at the bottom of an ocean? Are our sedimentary rocks alluvial sedimentary rocks, which form from weathering processes on land? Are the metamorphic rocks folded, which indicates compression and mountain building as continents collided? Are the igneous rocks formed from the eruption of ash from volcanoes, from flowing lava or from magma that cools slowly beneath the surface?

Understanding the rock categories shown on the map enables you to determine early conditions. For instance, was the land once at the bottom of the ocean, and has it since been uplifted? Or might the land have been covered in a blanket of ash from volcanic eruptions along plate boundaries?

To perform this type of geologic sleuthing, it is generally best to start at the present and work backward. Begin by analyzing the current geologic and tectonic setting of your state. Determine whether the rocks that form the bedrock of your state could have formed in the current conditions in your state.

For example, states including Michigan, Florida, Ohio and Kansas are underlain by limestone, shale and other marine sedimentary bedrock. That indicates that at some point in the states' geologic history, those areas were covered by ocean. Some northern states may also be covered with glacial deposits, indicating that those areas had been covered by thick ice sheets.

In states where igneous and metamorphic rocks dominate, there may have been a history of tectonic activity from continental collisions or subduction of oceanic plates. Comparing those past conditions to the current geologic and tectonic conditions in the state forms the basis of determining how the rocks and landforms in a region came to be.

Additional resources:
Wisconsin Geological and Natural History Survey. How to read a geologic map
U.S. Geological Survey. Introduction to geologic mapping
U.S. Geological Survey. Geologic maps of U.S. states
U.S. Geological Survey. National geologic map database
U.S. Geological Survey. The state geologic map compilation (SGMC) geodatabase of the conterminous United States
U.S. Geological Survey. GeMS (Geologic Map Schema)
U.S. Geological Survey. Topographic maps
U.S. Geological Survey. The national map
American Geosciences Institute. Interactive database for topographic maps of the United States
ArcGIS. USA topographic map
National Park Service. Tectonic landforms and mountain building
Geological Society of America. Geologic time scale
Topozone

SOCIETY FOR SCIENCE