

8.15 What Structural and Metamorphic Events Occurred Here?

VARIOUS GEOLOGIC STRUCTURES AND METAMORPHIC ROCKS are exposed in the area shown below. Much of the area is covered by vegetation, but bedrock exposures in isolated, blocky hills contain clues to the area's structural and metamorphic history. You will use these clues to interpret the history of events.

Goals of This Exercise:

- Use observations of outcrops and a subsurface cross section to locate the position of a major fold.
- Observe several metamorphic rocks to determine their relative metamorphic grade and the type of starting rock from which each metamorphic rock was probably derived.
- Use the orientations of structures to infer the direction in which the rocks were shortened and to consider which structures could have been formed by the same event.
- Use differences in metamorphic grade across the area, along with small-scale structural observations, to infer the structural history.

08.15.a1

This perspective to the north shows the locations of hills of bedrock that are surrounded by grassy areas in which no rocks are exposed.

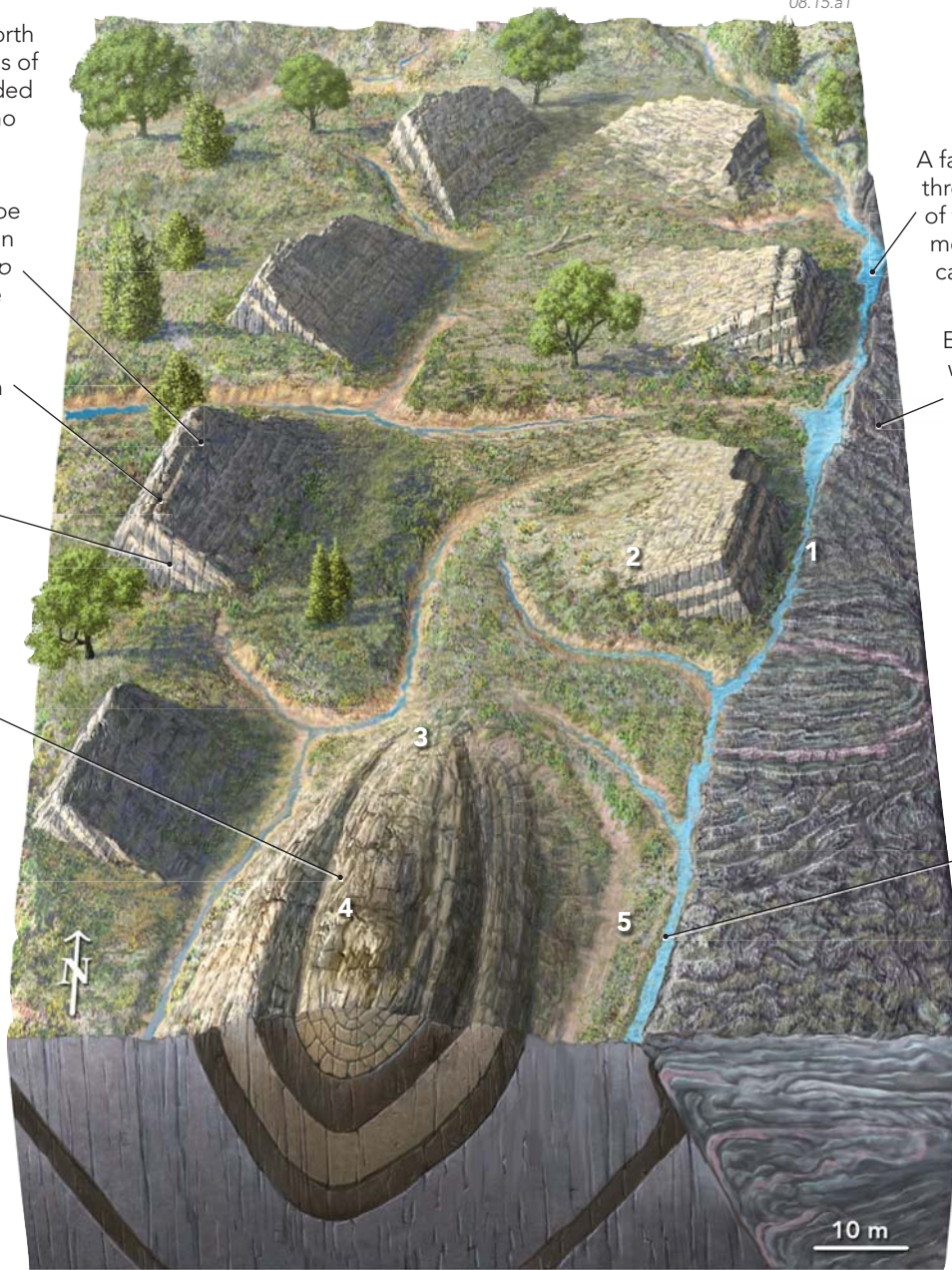
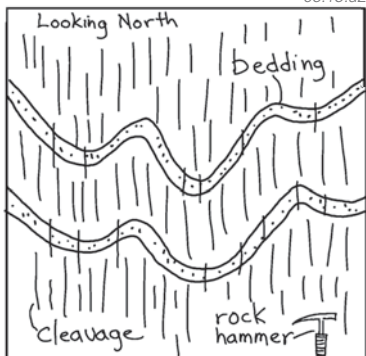
Each blocky hill has a shape that reflects the orientation of bedding. Each has a *dip slope* facing in toward the center of the area.

Bedding is defined by tan and gray layers.

Cleavage is expressed by near-vertical notches and lines down the front of each outcrop.

The field sketch below shows a cross section of an outcrop at the very top of the large southern hill, as viewed to the north.

08.15.a2



A fairly straight stream cuts through the eastern part of the field area and flows mostly along a topographically low notch.

East of this stream are well-exposed banded rocks with steep metamorphic layering and large folds.

Four samples (1, 2, 3, and 4) were collected from outcrops in the area. Photographs of all four samples, numbered 1 through 4 to correspond to the sample numbers, are presented on the facing page.

Observations were made at a fifth site (5), but no sample was collected.

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Some Field Observations

Field observations for locations 1 through 5 are listed below:

1. The eastern terrain exposes a black-and-white, banded rock (sample 1), which contains coarse crystals of biotite, quartz, and garnet. The rock has abundant folds and a foliation that dips steeply.
2. Small rock exposures in the grassy area expose a gray rock (sample 2). The rock cleaves apart and is dull, and in hand specimen the grains are too finely crystalline to distinguish. When observed under a microscope, the rock contains abundant fine-grained biotite and muscovite mica aligned parallel to the platy fabric in the rock.
3. On the flanks of the southern hill and forming the tan layers in the blocky hills is a tan and gray rock consisting mostly of visible, sand-sized quartz grains. The rock (sample 3) is very hard and its fractures cut across, not around, the sand grains.
4. The top of the southern hill is a cream-colored to light-gray rock that consists of finely crystalline calcite. The rock locally contains some deformed objects that were probably fossils. The hill contains a large fold with near-vertical cleavage, as shown in the field sketch. This rock is sample 4.
5. Along the western edge of the banded rocks is a stream that flows nearly in a straight line. Erosion along this stream evidently was aided by the fact that the rocks are intensely fractured and shattered into angular pieces all along the stream.

Procedures

Use your observations from this area to complete the following steps, and enter your answers in the appropriate places on the worksheet. Your instructor may provide you with specimens of these rocks.

1. Make observations of the four samples shown in the photographs below. Use your observations, along with the information provided above in the field descriptions, to identify each metamorphic rock type (i.e., provide an appropriate name for the rock, such as schist). For samples 2–4, interpret what type of sedimentary rock each sample was before it was metamorphosed; this task is too difficult to do for sample 1.
2. What type of fold is exposed on the front cross section, an anticline, a syncline, or a monocline?
3. On the map on the worksheet, mark where the fold goes through the grassy areas and hills based on the orientations of bedding as reflected by the dip slopes and bedding-cleavage relationships exposed on the fronts of the blocks.
4. Based on your observations of the samples and from the field observations presented above, determine which rocks are higher in metamorphic grade: the banded rocks to the east or the rocks in the grassy area and southern hill.
5. In the worksheet, present any evidence you have for what type of feature is located near the main stream. Use any observations from the map, cross section, samples, and field descriptions to interpret what type of deformation or displacement has occurred along this feature.
6. From the orientation of the fold and its relationship to cleavage, in what direction were the rocks shortened to form the fold and the cleavage?

▼ Sample 1 is a coarse metamorphic rock with swirled, black-and-white bands that define a foliation. It has coarse crystals.

08.15.a3



▲ Sample 2 is a metamorphic rock that is dull (not shiny) and has no visible metamorphic minerals. It has a strongly developed, near-vertical cleavage that cuts across tilted bedding (layers dipping to the left in this view). Cleavage causes the rock to break into thin slices. The rock does not contain garnet or other high-temperature minerals.

▼ Sample 3 is a metamorphic rock with visible, sand-sized grains of quartz. Cleavage (parallel to the marking pen) is at an angle to bedding, which is represented by the folded layers.

08.15.a5



▲ Sample 4 consists of fine crystals of calcite. In this photograph, taken from the very top of the southern hill, steep cleavage is perpendicular to nearly horizontal bedding.