Maine Geologic Facts and Localities
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*Primary Sedimentary Structures in Some Metamorphic Rocks*

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Introduction

In most introductory geology classes, be it in an elementary school or at a college, students learn that there are three fundamental rock types: sedimentary, igneous, and metamorphic rocks. Sedimentary rocks are formed by the deposition of sediment by several processes, either by settling of sediment particles in a body of water, by chemical precipitation in water, or by transportation of the particles by water such as streams and rivers, or by wind (Figures 1-3).

Figure 1. Glacial marine sand beds with nearly parallel, horizontal layering, Buckfield, ME (entrenching tool for scale).
Figure 2. Fluvial trough cross bedding in slightly gravelly, coarse sand. The cross bed sets are incised into one another and highlighted by the darker colored layers (entrenching tool for scale), Buckfield, Maine.
Figure 3. Coarse cobble gravel in a glacial fluvial deposit, Kingfield, Maine (entrenching tool for scale).
Formation of Sedimentary Rocks

Over time, the sediment eventually undergoes a conversion from a loose material into a solid rock by natural processes such as cementation, compaction, desiccation, or crystallization (Figures 4 - 6).

Figure 4. The basal conglomerate of the Trout Valley Formation. The conglomerate here is quite thick (at least 10 meters) and, amazingly, one layer makes up the entire wall of the valley.
**Figure 5.** Close-up of the conglomerate. The clasts are almost all rhyolite, with some being recognizable as sections of the columns seen farther upstream. Most are sub-angular boulders with a bit of ash between, but many cobbles and boulders lay directly on others rather than being supported by the ash.
Figure 6. Looking downstream at Haskell Rock in the East Branch of the Penobscot River. Roger Hooke and Claire Marvinney have attained the lofty summit. Bob Marvinney pauses in the inferior position. Stones in the conglomerate are prominent in the right foreground.
Metamorphism

Here in Maine, and in particular in southwestern Maine, many of the rocks we find today formed originally as sedimentary rocks in an ancient ocean, but over time the rocks were subjected to processes that altered their original composition, making them what we call metamorphic rocks. Figure 7 is a generalized map of the regional metamorphic facies (zones) in Maine.

Figure 7. Metamorphic facies map.
Higher-grade Metamorphism

At the highest degree of metamorphism, the minerals in the metamorphic rock are completely different from the minerals in the original non-metamorphic rock. Also, any physical features of the sedimentary rock, such as layering or current structures, usually can no longer be seen. Sometimes the original rock layering can be represented by the new metamorphic minerals, and based on the mineralogy a determination of bedding top, or which way is up in the layering, can be made (Figure 8).

Figure 8. Thinly layered dark schist and light granofels exposed at Tumbledown Pond. The schist is predominantly micas and andalusite while the granofels is predominantly quartz and feldspar. Each couplet of light and dark layers represents a graded bed with topping indicated toward the left. Each couplet is about 3 inches thick. Originally this rock was comprised of horizontal layers of alternating sand and mud as graded beds.
Higher-grade Metamorphism

In other instances, the new metamorphic minerals can help determine what the original rock type may have been and what the geologic setting was when it formed. (Figure 9-11).

Figure 9. The layer in the center has needles of the black mineral hornblende which grew in a white rock composed of the mineral plagioclase. Neighboring layers are dominated by these same two minerals, but in different proportions, giving a striped or layered appearance. Rocks of this composition were probably volcanic rocks before metamorphism.
**Higher-grade Metamorphism**

**Figure 10.** This rock has patches and streaks of a pale apple-green mineral (diopside) and a cinnamon-brown mineral (garnet), which grew in response to heat during metamorphism. The composition of these minerals indicate the rock has a relatively high content of calcium and silica, and was probably derived from sandy limestone (or limy sandstone).
Figure 11. White pebble-shaped rocks may have been fragments ejected during a volcanic eruption during the initial formation of the rocks. The high degree of subsequent metamorphism has undoubtedly distorted them, making it difficult to know their origins with certainty. Other interpretations are possible.
Metamorphic rocks at Two Lights State Park

In lower grade metamorphic rocks, sometimes it is possible to find primary sedimentary features that can assist the geologist in an interpretation of the origin of the rock and its original geologic environment where it was formed. Some examples of these rocks can be seen at Two Lights State Park in Cape Elizabeth (Figure 12 and Figure 13) where the rocks are weakly metamorphosed.

![Image](image.png)

**Figure 12.** Light brown quartzite beds and dark gray phyllite beds of the Kittery Formation at Two Lights. This nearly vertical exposure shows beds that are about 10 centimeters thick and gently inclined.
Figure 13. Close-up of portions of two graded beds. The upper portion of the lower bed is very fine-grained sand. There is a sharp boundary with the upper bed, the bottom of which is a coarser sand that gradually gets finer toward the top.
Metamorphic rocks at Kingfield Elementary School

Another location where primary sedimentary structures are present in rocks at a higher metamorphic grade than at Two Lights is in Kingfield, Maine, behind the Kingfield Elementary School off of Route 142 heading west out of Kingfield (Figure 14 - 16).

Figure 14. Cross-bedded metamorphic sandstone of the Madrid Formation (Silurian - Devonian age), Kingfield Elementary School. The mechanical pencil sits at the base of a thick sandstone bed, overlying a thinner sandstone bed, which in turn overlies metamorphic thinner siltstone and sandstone beds. The rocks are not lying horizontally, but have been turned upward by deformation, although the layering of the beds is closely parallel.
Metamorphic rocks at Kingfield Elementary School

The rocks at both of these localities were formed originally as sediment deposits in an ocean. Over time they became deformed and metamorphosed and now are found on dry land. They may have been deposited horizontally originally, but now they can be found dipping at very steep angles up on end.

Figure 15. Coarse-grained metamorphic sandstone beds separated by a metamorphic siltstone (spanned by the mechanical pencil). The interior of the siltstone bed adjacent to the pencil appears to have faint undulatory bedding. Tracking the bed toward the upper right corner, the siltstone is eroded in its core and shows what may be the trace of undulatory bedding. The undulatory surface could represent ripple marks, or possibly deformation by syndepositional slump folds. If so it would suggest the top of the beds is to the upper left corner of the photo.
Figure 16. Undulatory features similar to that in Figure 15 are seen in the center of the outcrop in the siltstone just to the left of the pick hammer point, and in the siltstone farthest to the left. This sequence of bedded metamorphic siltstone and sandstone layers, originally deposited horizontally, is now on end. The siltstone units have been eroded in this outcrop and as in Figure 15, the undulatory surface may represent ripple marks or slump folds. If so, it would suggest the tops of the beds are to the left in the photo.
References and Additional Information

A Geological Traverse along South Branch Ponds Brook, Baxter State Park

Haskell Rock, East Branch Penobscot River, T5 R8 WELS

A Geological Tour of Tumbledown Mountain

Stretched Metamorphic Rocks, Friendship Boat Launch

The Geology of Two Lights State Park, Cape Elizabeth