Simplified Bedrock Geologic Map of Maine

DEPARTMENT OF CONSERVATION
Maine Geological Survey

Modified from Osberg, P. H., Hussey, A. M., II, and Boone, G. M., Bedrock Geologic Map of Maine, 1985, Maine Geological Survey

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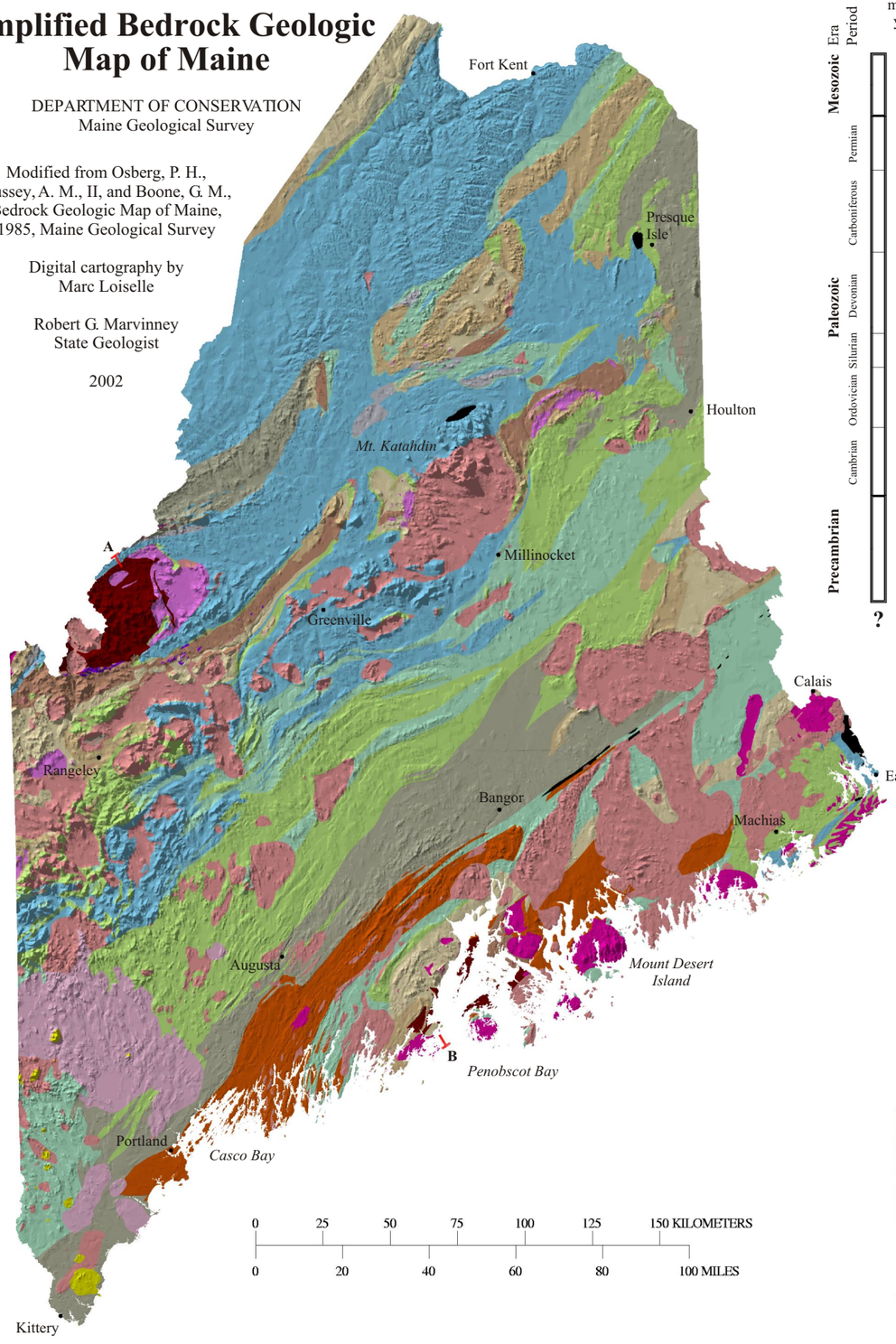


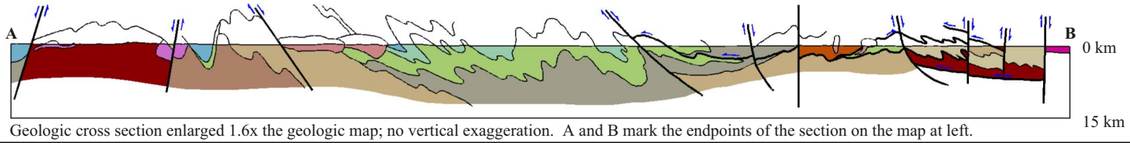
Stratified Rocks
(Sedimentary, volcanic, and metamorphic rocks)

- Devonian - Marine sandstone and slate in northern and central Maine. Gneiss and schist in southwest.
- Silurian - Limy marine shale in north grading to lime-bearing gneiss and schist in southwest. Volcanic rocks in southeast.
- Ordovician - Volcanic and related sedimentary rocks in north and west. Gneiss, schist, and marble along central coast.
- Cambrian - Volcanic and related sedimentary rocks in north. Volcanic rocks in central coast.
- Precambrian - Gneiss and breccia in northwest. Limestone, marble, sandstone, slate, and volcanic rocks in central coast.
- Late Devonian-Carboniferous - Unmetamorphosed terrestrial conglomerate and sandstone.
- Silurian-Devonian - Marine sandstone and slate in east grading to gneiss and schist in southwest. Some volcanic rocks in central coast.
- Cambrian-Ordovician - Mostly volcanic rocks and related sedimentary rocks in north and east. Schist, marble, and gneiss in central coast.
- Ordovician-Silurian - Marine sandstone and slate in east grading to gneiss and schist in southwest.
- Precambrian(?)-Ordovician - Wide range of volcanic and marine sedimentary rocks that have been metamorphosed to gneiss and schist.
- Ordovician-Devonian - Mixed volcanic rocks in north.

Intrusive Igneous Rocks

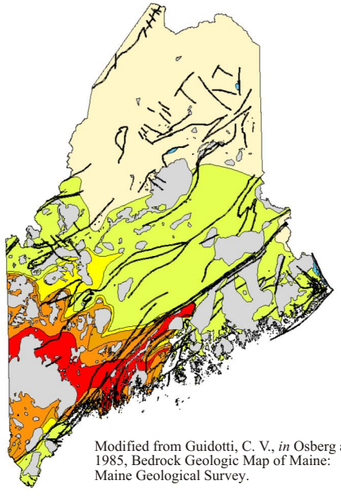
- Mesozoic - Small intrusions in southwest. Mostly syenite and related intrusive rocks with some associated volcanic rocks.
- Carboniferous - Large granite and small gabbro intrusions in southwest.
- Devonian - Granite, granodiorite, and gabbro throughout state.
- Silurian - Mostly granite in coastal Maine, gabbro in east.
- Ordovician - Granite, quartz syenite, diorite, and gabbro in north and west.
- Cambrian - Gabbro and related rocks in northwest.

Generalized geologic cross section



Geologic cross section enlarged 1.6x the geologic map; no vertical exaggeration. A and B mark the endpoints of the section on the map at left.

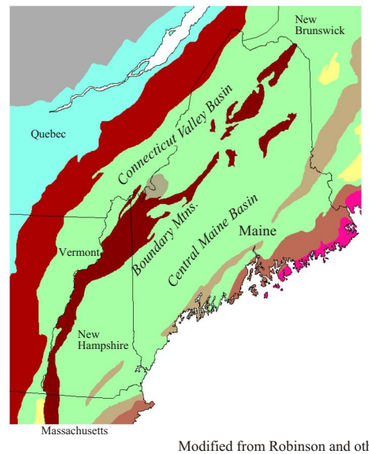
Generalized regional metamorphic zones



- Unmetamorphosed
- Weakly metamorphosed
- Low-grade metamorphism
- increasing metamorphism
- Highly metamorphosed
- Intrusive igneous rocks
- Fault

Modified from Guidotti, C. V., *in* Osberg and others, 1985, Bedrock Geologic Map of Maine: Maine Geological Survey.

Generalized Northern Appalachian geology



- Younger basins
- Late Ordovician-Devonian sedimentary basins
- Coastal volcanic belt
- Cambrian-Ordovician volcanic arc
- Composite Avalon microcontinent
- Ordovician oceanic crust and Cambrian rocks of the Penobscottian and Taconic events
- Ordovician oceanic crust and related rocks of the Taconic event
- Cambrian-Ordovician continental shelf-rise sequence
- Precambrian Chain Lakes rocks
- Precambrian North American basement (Laurentia)

Modified from Robinson and others, 1998, Paleozoic orogens in New England, USA: GFF, v. 120, p. 119-148.

A Summary of the Geologic History of Maine

Maine's bedrock records more than half a billion years of geologic history. Over this period of time, geologic processes such as erosion and sedimentation, mountain-building, deformation (folding and faulting), metamorphism, and igneous activity produced the complex pattern of bedrock geology that we see today. The large geologic wall map of the state by Osberg and others (1985) shows hundreds of bedrock formations and igneous intrusions distinguished on the basis of age and rock type. On this simplified map, these rocks have been grouped into units of similar geologic age. The theory of plate tectonics describes the interactions of large, mobile, semi-rigid plates that comprise Earth's crust. The movement of these plates is responsible for Maine's complex geology. Where plates collide, mountains are built. Volcanic island arcs form where one section of oceanic crust slides beneath another. Furthermore, mountain ranges such as the Appalachian Mountains are often composed of multiple, small plate fragments, both continental and oceanic in composition, which are distinctive and have had separate histories. While ongoing research continues to refine the nature and exact boundaries, it is generally accepted that the geology of Maine is composed of a mosaic of such terranes (e.g. Osberg, 1978; Zen, 1983; Berry and Osberg, 1989; Robinson and others, 1998; Tucker and others, 2001). These were once widely scattered microplates in Iapetus, an ocean which preceded the modern Atlantic Ocean. The geologic history recorded in Maine's bedrock spans several major cycles of deposition, deformation, and igneous activity related to plate tectonic movements. The simplified chart below recounts the histories of the various terranes that were later to become Maine's bedrock. In the chart, while the terranes have separate histories, they are shown in separate blocks. Laurentia refers to the ancient eastern margin of North America. The Iapetus terranes comprise a composite island arc, formed in Iapetus, that collided with Laurentia during the Ordovician Period. Avalon is a microplate which collided with early North America in the Devonian to form eastern North America as we know it today. Refer to the inset map of the northern Appalachians on the reverse side for the distribution of these terranes today. For a more detailed discussion of these events, see Marvinney and Thompson (2000). This chart is best read from the bottom to the top (from the oldest to the youngest events).

References

Berry, H. N., IV, and Osberg, P. H., 1989, A stratigraphic synthesis of eastern Maine and western New Brunswick, *in* Tucker, R. D., and Marvinney, R. G. (editors), Studies in Maine geology: Volume 2 - structure and stratigraphy: Maine Geological Survey, p. 1-32.

Marvinney, R. G., and Thompson, W. B., 2000, A geologic history of Maine, *in* King, V. T. (editor), Mineralogy of Maine: Volume 2 - Mining history, gems, and geology: Maine Geological Survey, p. 1-8.

Osberg, P. H., Hussey, A. M., II, and Boone, G. M., 1985, Bedrock geologic map of Maine: Maine Geological Survey, scale 1:500,000.

Osberg, P. H., 1978, Synthesis of the geology of the northeast Appalachians, U.S.A., *in* Schenk, P. E., and Tosier, E. T. (editors), Appalachian-Caledonide orogen: Geological Survey of Canada, Paper 78-13, p. 137-167.

Palmer, A. R., and Geissman, J. (compilers), 1999, Geologic time scale: Geological Society of America.

Tucker, R. D., and McKerrow, W. S., 1995, Early Paleozoic chronology: A review in light of new U-Pb zircon ages from Newfoundland and Britain: Canadian Journal of Earth Science, v. 32, p. 368-379.

Tucker, R. D., Osberg, P. H., and Berry, H. N. IV, 2001, The geology of a part of Acadia and the nature of the Acadian orogeny across central and eastern Maine: American Journal of Science, v. 301, p. 205-260.

Robinson, P., Tucker, R. D., Bradley, D., Berry, H. N., IV, and Osberg, P. H., 1998, Paleozoic orogens in New England, USA: GFF, v. 120, p. 119-148.

Zen, E-an, 1983, Exotic terranes in the New England Appalachians - limits, candidates, and dates: a speculative essay, *in* Hatcher, R. D., Williams, H., and Zietz, I. (editors), Contributions to the tectonics and geophysics of mountain chains: Geological Society of America, Memoir 158, p. 55-81.

Geologic Time		Age*	MAINE AND VICINITY	EARLY NORTH AMERICA	AVALON	LAURENTIA	IAPETUS TERRANES
Cenozoic Era		Present - 66	Continued uplift and erosion of the Northern Appalachian Mountains. Stress release during uplift and erosion produces numerous fractures in the bedrock. Erosion by glacial ice shapes the landscape. Maine became ice-free about 11,000 years ago.				
Mesozioc Era		66 - 248	**Late Mesozoic:** Continued widening of the Atlantic Ocean. Limited igneous activity (southern Maine). Limited faulting and fracturing. **Early Mesozoic:** Pangea breaks up. Combined Europe and Africa rift away from North America, opening the modern Atlantic Ocean. Faulting and fracturing of existing bedrock. Intrusive and volcanic activity; intrusion of basalt dikes (prominent in southwestern coastal Maine).				
Late Paleozoic Era	Permian	248 - 290	Continued uplift and erosion of the Northern Appalachian Mountains gradually bring deep rocks toward the surface. North America drifted north of the equator.				
	Carboniferous	290 - 354	Intrusion of Sebago granite. Last regional metamorphism and deformation. Deposition of sandstone and related sedimentary rocks, only remnants of which remain in eastern Maine. All Earth's crustal plates were joined as one continent, Pangea.				
Middle Paleozoic Era	Devonian	354 - 417	**Late Devonian:** Sedimentary rocks deposited in northern and eastern Maine following the last major mountain-building event. **Middle and Late Devonian:** Mountain building (called the Acadian event by geologists) – Major deformation of the Earth's crust caused by collision of the microcontinent of Avalon with early North America. Assembly of the varied terranes of eastern and coastal Maine and the Central Maine basin. Many significant faults develop during this period. Burial of sediments in southwestern Maine to depths greater than 9 miles transforms them into metamorphic rock. Final development of ancestral Northern Appalachian Mountains. Rocks at depth melt, producing widespread igneous activity during and after mountain-building episode. All of this occurred while the eastern margin of early North America remained south of the equator. **Early Devonian:** Youngest sediments deposited in major basins as precursor to major mountain-building event.				
	Silurian	417 - 443		Limited rifting apart of North American continental margin formed small marine seas. Deposition in the Connecticut Valley basin of northwestern Maine. Deposition of large quantities of sediment in central Maine as the Avalon terrane approached, closing Iapetus. Much sediment comes from the young mountains formed when Laurentia and the Iapetus terranes collided in the Ordovician. Early North America is situated well south of the equator at this time.	Considerable deformation in the Avalon composite terrane due to microplate collisions that formed the composite terrane. Continued deposition of sediments and increased volcanic activity. Some explosive volcanism related to crustal extension and intrusion now exposed in eastern coastal Maine. Intrusion of Silurian granite bodies in what is now central and eastern coastal Maine.		
Early Paleozoic Era	Ordovician	443 - 490		**Late Ordovician:** Additional sediment deposition following deformation and uplift. **Middle Ordovician:** Mountain building (called the Taconic event by geologists) – Deformation, uplift, and igneous activity related to the collision of several(?) offshore volcanic island terranes with Laurentia. This was part of an Ordovician island arc developed in Iapetus. Remnants of this arc are present in the Boundary Mountains.	**Late Ordovician:** Beginning of events that preceded the collision of the Avalon composite terrane with Laurentia. **Early and Middle Ordovician:** Continued deposition of sediments and minor volcanic activity produced rocks of the composite terrane called Avalon. The volcanic activity was related to tectonic events that assembled this composite terrane before its collision with Laurentia. The composite Avalon was located a considerable distance south of the edge of Laurentia at this time.		
	Cambrian	490 - 543			Sedimentation and significant volcanic activity produced rocks of the composite Avalon terrane which was separated from Laurentia by a portion of the Iapetus Ocean. These rocks are now part of the Penobscot Bay area and eastern coastal Maine. Avalon was situated in the southern hemisphere, much farther south than Laurentia and accumulated far less limestone.	Deposition of limestone and shale on the continental shelf of Laurentia. Laurentia was located much closer to the equator than North America is today, allowing for accumulation of large volumes of warm-water limestone. The limestone and shale is now exposed just south of Quebec City, in western Vermont, and in eastern New York state.	**Early Ordovician:** Continued deposition of sediments and volcanic activity. **Late Cambrian:** Mountain building (called the Penobscottian event by geologists) – Episode of deformation and metamorphism of rocks now found in northwestern to north-central Maine attributed to microplate collision within ancestral Iapetus Ocean. **Early to Late Cambrian:** Deposition of sediments and volcanic activity produced rocks now exposed in uplift features in north-central and northern Maine.
Late Proterozoic Era	Precambrian (most recent part)	543 - 650(?)		The edge of the ancestral North American continent, Laurentia, shed eroded material into the adjacent widening ocean. These sediments began to accumulate on the continental shelf.	Deposition of limestone and other marine sediments eroded from an ancient microcontinent bordering Iapetus. Approximately 650 million year old episode of metamorphism and pegmatite intrusion in unknown geologic setting (now northern Penobscot Bay).		As the ancestral supercontinent rifted, the Iapetus Ocean opened and widened. Sedimentary material from eroding continents was deposited in this ocean.
	Precambrian	> 650	Events prior to approximately 650 million years ago are essentially unknown. Rocks over a billion years old may be present in the units of the Chain Lakes in northwestern Maine. North American (Laurentian) basement rocks had been formed by about 1.1 billion years ago. Break-up of a supercontinent which included North America occurred around this time resulting in the opening of an ocean called Iapetus, predecessor of the modern Atlantic.				

* Age in millions of years before present. The calibration (in years) of the geologic time scale is continually under revision. The ages listed in this column are taken from Palmer and Geissman (1999) and Tucker and McKerrow (1995).

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