Bedrock Geology of the Southern Part of the
Carmel Quadrangle, Maine

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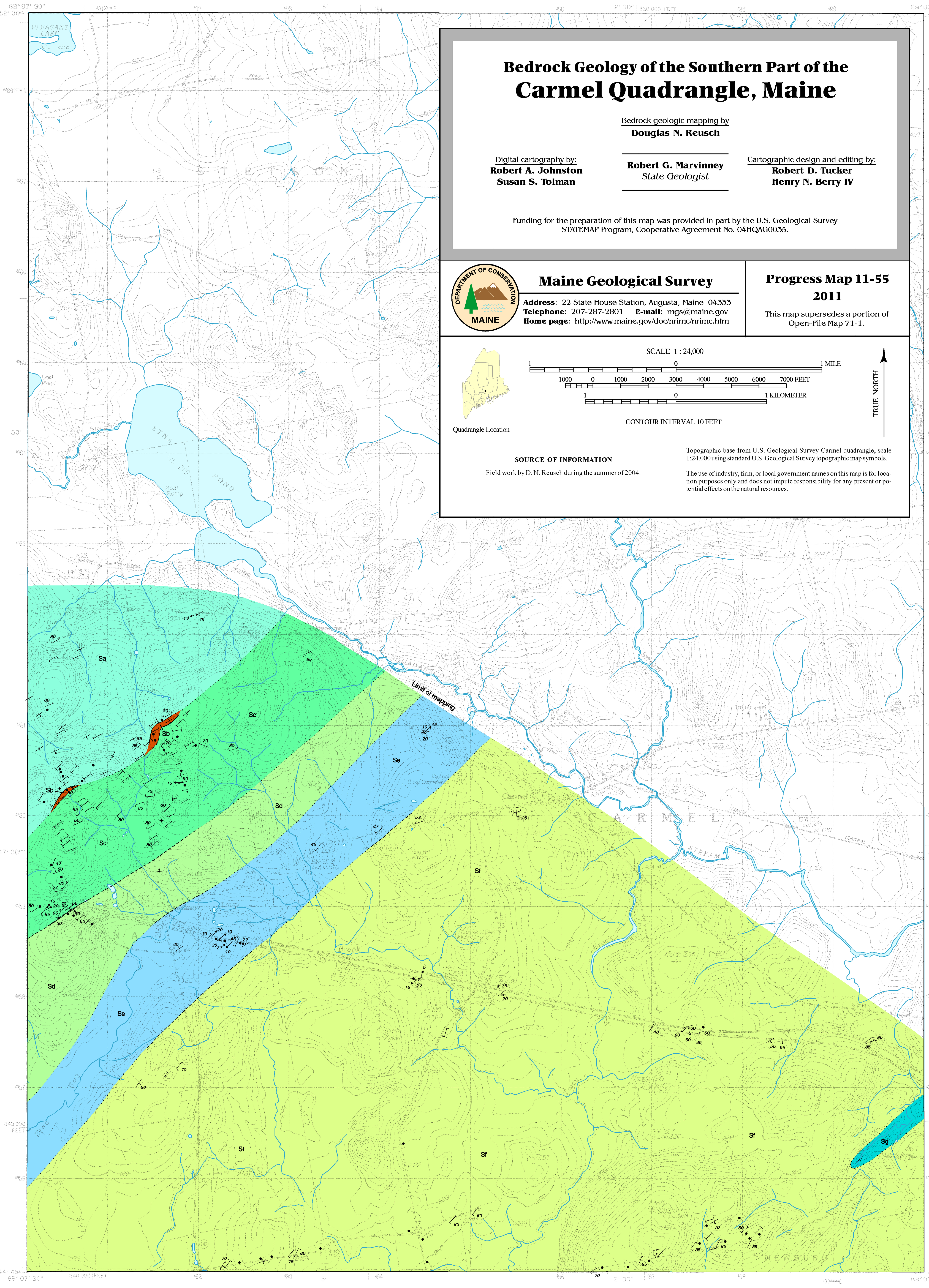
Progress Map 11-55
2011
This map supersedes a portion of Open-File Map 71-1.



SOURCE OF INFORMATION

Field work by D. N. Reusch during the summer of 2004.

Topographic base from U.S. Geological Survey Carmel quadrangle, scale 1:24,000 using standard U.S. Geological Survey topographic map symbols.

The use of industry, firm, or local government names on this map is for location purposes only and does not impute responsibility for any present or potential effects on the natural resources.

EXPLANATION OF UNITS

Stratified Rocks

[Note: No stratigraphic names are yet assigned to these map units.]

Silurian(?)

Sg — **Shale and metasiltstone.** Dominantly thinly bedded, dark gray slate with siltstone. Underlies a small area at the southeast corner of the map. Griffin (1971) reported limestone in this unit, which was not located in this study.

Sf — **Thickly bedded metasandstone.** This unit includes common, very thick beds of quartz-rich sandstone and rare thin beds of black slate. Concretions were observed in a few places. Sandstone stringers in a fine sandstone bed, east of Route 143 near the south edge of the map, may represent worm burrows. This unit crops out over a wide area in the central part of the map.

Se — **Thinly bedded slate, metasiltstone, and metasandstone.** Generally fine-grained unit of very thinly to thinly bedded green-weathering slate and tan-weathering siltstone or white-weathering sandstone. Contains minor sandstone beds.

Sd — **Thickly bedded metasandstone.** Thickly bedded, generally medium-grained sandstone, locally in graded beds, with interbeds of green-weathering slate. Includes thickly to very thickly bedded sandstone west of the Etna interchange on I-95. Local grading indicates tops to southeast. This unit also includes very thinly to thinly bedded green-weathering slate and tan-weathering siltstone or white-weathering sandstone.

Sc — **Massive metasandstone and slate.** This unit is mostly massive very fine sandstone and silty slate. Sections of very thinly bedded to thinly bedded green-weathering slate and tan-weathering siltstone or white-weathering sandstone occur locally. Map unit **Sc** crops out in the hills between Etna and Etna Center, immediately southeast of the breccia unit, **Sb**.

Sb — **Breccia.** This thin, discontinuous unit is a distinctive breccia of angular sandstone and siltstone fragments enclosed within a green slate matrix. It is probably of sedimentary origin based on the absence of a tectonic foliation and very intricate contact relationships. Fragments range in size from approximately one centimeter to several tens of centimeters and possibly much larger. Rocks adjacent to the southeast, along power line east of Route 143, are badly sheared.

Sa — **Massive metasandstone and slate.** This unit, in the northwest portion of the map, consists mostly of massive very fine sandstone and silty slate. Very thinly bedded to thinly bedded green-weathering shale and tan-weathering siltstone or white-weathering sandstone are also present. Coarse sandstone is uncommon, though coarse to very coarse sandstone is present, some with visible angular quartz and feldspar grains, and weakly developed graded bedding. A bed of medium to coarse sandstone in excess of 1.5 meters thick was observed at one place.

Reference

Griffin, J. R., 1971, Reconnaissance bedrock geology of the Stetson [15-minute] quadrangle, Maine: Maine Geological Survey, Open-File Map 71-1 (scale 1:62,500).

EXPLANATION OF SYMBOLS

- Outcrop of mapped unit.
- Strike and dip of bedding, stratigraphic topping direction known. (upright, overturned, vertical - ball toward top)
- Strike and dip of bedding, topping direction unknown. (inclined, vertical)
- Strike and dip of cleavage. (inclined, vertical)
- Strike and dip of fold axial plane.
- Trend and plunge of fold axis.
- Trend and plunge of lineation.

EXPLANATION OF LINES

Stratigraphic contact.
(Well constrained, Approximately located, Inferred)

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-65
Mesozoic Era	Cretaceous Period	65-142
	Jurassic Period	142-200
	Triassic Period	200-253
Paleozoic Era	Permian Period	253-300
	Carboniferous Period	300-360
	Devonian Period	360-418
	Silurian Period	418-443
	Ordovician Period	443-489
	Cambrian Period	489-542
Precambrian time		Older than 542

* In millions of years before present. (Okulitch, A. V., 2004, Geological time chart, 2004: Geological Survey of Canada, Open File 3040 (National Earth Science Series, Geological Atlas) - REVISION.)

SUMMARY OF THE BEDROCK GEOLOGY

Stratigraphy

The map area is underlain almost entirely by metamorphosed sedimentary rocks of siliciclastic composition with grain size of sand and finer. The lack of significant variation in composition and grain size, absence of age control, and poor exposure have made it challenging to subdivide the rocks into map units. Bedding thickness is probably the most variable feature, although many small outcrops do not display bedding surfaces. Seven map units are tentatively suggested on the basis of several lithofacies, as described in the Explanation of Units. Whether all of these units are mappable beyond the current map area remains to be seen.

Structural Geology

The breccia unit, **Sb**, is interpreted to be a sedimentary deposit. It need not be related to a contemporaneous fault, but this possibility should be considered because of the following relationships: (a) The breccia lies southeast of the only coarse-grained sandstone known from unit **Sa**, and (b) it lies northwest of sheared rocks along the contact between units **Sb** and **Sc**. This arrangement is consistent with the breccia forming the top of a coarsening-upward sequence, deposited proximal to an active fault, and subsequently emplaced beneath rocks to the southeast.

Most of the map area is underlain by moderately-dipping to steeply-dipping strata, as indicated by the structural symbols on the map. Graded beds good enough to determine tops are uncommon. The well-bedded sand-rich strata show a single cleavage, which is presumably axial planar to northeast-trending folds with steep axial planes. This cleavage is generally nearly vertical in fine-grained rocks. West of the Etna I-95 interchange, upright beds dip steeply southeast; the main cleavage dips northwest and is strongly refracted in the sand layers. Most commonly, the strike of cleavage is a few degrees counterclockwise of bedding, which may be consistent with an abundance of southeast-facing limbs and dextral transpression. An observed synclinal minor fold hinge is consistent with this geometry.

The style of cleavage varies according to rock type. In fine-grained sandstone, it is spaced typically at around 4 mm, and probably has a pressure solution origin. In coarse-grained sandstone, the spacing is typically greater, up to around a centimeter. Cleavage surfaces are most commonly approximately parallel, but locally they anastomose.

An area of conspicuously shallow dips is located just east of the Etna I-95 interchange. This may reflect a younger deformation that post-dates the principal cleavage-forming event.

The "main cleavage" is warped and folded in several sections of fine-grained rocks. One gets the impression that it was initially near-vertical, and the fine-grained rocks collapsed somewhat, creating small-scale horizontal folds with subhorizontal axial planes. Secondary cleavage is not developed in these folds, suggesting they formed at a high structural level. In a few places, the main cleavage is crenulated on a small scale, and the crenulation hinge lines are subhorizontal. Possibly, these crenulations are related to the "collapse" folds.

Rare dextral shear features were noted in the northwest portion of the map area in the vicinity of the breccia unit, **Sb**. These include an asymmetric anastomosing pattern of intersecting foliations, and an asymmetric quartz ribbon.

Two examples of very late, brittle faults were noted in the central part of the map area. They dip to the northwest and appear to be normal faults, with the hanging wall having moved down to the northwest.

Metamorphism

The metamorphic grade of all rocks in the field area is quite low. The pervasive green color is presumably due to chlorite. Some of the cleaner sandstones in unit **Sf** are gray, and a few have a pinkish cast. Many fine-grained rocks display a sheen and hence are phyllites. Quartz veins are moderately common. Antimony occurrences near Carmel are probably related to metamorphic quartz vein emplacement. (An attempt to find the old Carmel Antimony Mine reported by Thompson and others, 2000, was unsuccessful, as was an attempt to learn of its location from local sources.)

Regional Geologic History

A sedimentary basin developed in central Maine northwest of the Liberty-Orrington belt after Ordovician time. The sediments were most likely derived from a source that lay to the southeast, though evidence for sediment transport direction into the basin is sparse. Quartz and feldspar grains are minor constituents, and presumably the balance of detritus is lithic material. Such a composition is consistent with an eroding arc source. If the Liberty-Orrington rocks were thrust southeast over the Fredericton Trough at the end of Early Silurian time (Tucker and others, 2001), then they may have been the source of arc-derived sediments shed to the northwest. Angular quartz and feldspar grains observed in rocks of the present study suggest high sedimentation rates in a tectonically active setting.

The first and main deformation of the rocks occurred during latest Silurian time, in conjunction with the initial growth of the Acadian wedge (Bradley and others, 2000). The presence of southeast-younging sections is consistent with a fold-and-thrust belt that advanced towards the northwest. This may have been a dextral transpressive system, with dextral faulting most strongly developed along the Norumbega system to the southeast of the Carmel quadrangle. The wedge increased in thickness, and at some point its internal strength was exceeded and minor collapse occurred. Late, brittle normal faults imply extension, possibly contemporaneous with Mesozoic rifting.

Erosion has produced a relatively gentle topography in the Carmel area, without a strong anisotropy. It is difficult to demonstrate a correlation between highlands and resistant rock units, although the highlands in the southeast portion of the map may be supported by thickly bedded, coarse-grained rocks. The highlands in the northwest, however, are underlain by mostly fine-grained materials. The Etna Bog coincides with the unusual flat structural zone, which conceivably was more susceptible to scouring during glacial erosion.

References

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Thompson, Woodrow B., Wintringham, Neil A., and King, Vandall T., 2000, Maine mineral locality index, *in* King, Vandall T. (editor), Mineralogy of Maine, Volume 2: Mining history, gems, and geology: Maine Geological Survey, p. 355-426.

Tucker, Robert D., Osberg, Philip H., and Berry, Henry 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.