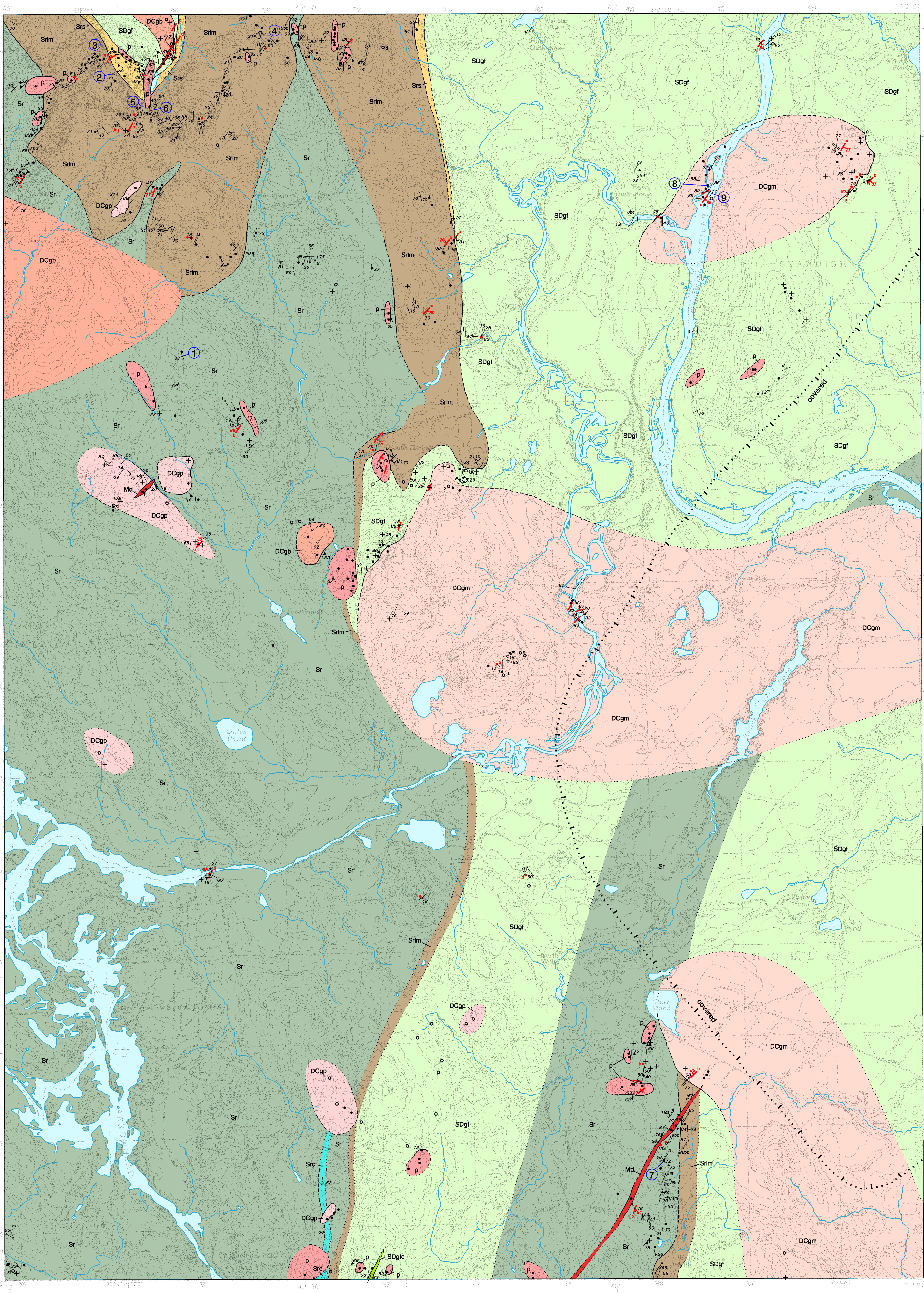
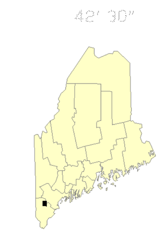
Bedrock Geology



SOURCES OF INFORMATION

Bedrock geologic mapping by Henry Berry completed during the 1996 field season; funding for this work provided by the U. S. Geological Survey STATEMAP program.



Quadrangle Location

SCALE 1 : 24,000

1 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 10 FEET

TRUE NORTH

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

INTRUSIVE ROCKS

Mesozoic

Md — Dark gray to black intrusive rocks. Mainly diabase but also includes basalt and gabbro.

Devonian (?) to Carboniferous (?)

p — Granitic pegmatite with muscovite, black tourmaline, and garnet. Biotite minor to absent. Non-foliated, but may include mineral concentrations or small patches in which minerals are aligned. Several small bodies are shown on the map, but this type of pegmatite also occurs as isolated outcrops or dikes within other map units.

DCgp — Granite and pegmatite. White, medium-grained to coarse-grained muscovite-biotite granite. Muscovite predominant over biotite. Interspersed with pegmatite like that of unit **p** within an outcrop or in adjacent outcrops.

DCgb — Biotite granite. Light gray, foliated, fine-grained to medium-grained biotite granite containing minor amounts of muscovite. Locally contains schlieren.

DCgm — White, weakly to moderately foliated, medium-grained, biotite-muscovite granite with pinhead-sized garnets. Ratio of biotite to muscovite is roughly 2:1. Significantly more muscovite than in **DCgb**. Locally contains muscovite-rich granite and pegmatite. Granite exposed on small hill 3000 feet southeast of South Limington is mildly porphyritic. Body of **DCgm** at southeast corner of map is northern end of the Lyman pluton.

STRATIFIED ROCKS

Silurian (?) to Devonian (?)

SDgf — Medium to light gray, quartz-plagioclase-biotite granofels. Textural varieties range from fine-grained and massive, to medium-grained and granular ("salt-and-pepper" texture), to medium-grained and schistose. Fresh surfaces of the finer-grained varieties have a faint purplish hue. Compositional and textural layering, in many cases representing relict bedding, ranges from less than a centimeter to tens of centimeters in thickness. Medium to dark green, diopside-plagioclase-quartz +/- garnet calc-silicate granofels is common, occurring mainly as layers, but in some places as trains of ellipsoidal pods a few centimeters to a few tens of centimeters across. Brown-weathering to rusty-weathering schistose granofels and quartzo-feldspathic biotite-muscovite schist occur in minor amounts.

SDgfc — Calc-silicate granofels unit within **SDgf**. Medium-grained, light greenish-gray, vitreous, quartz-plagioclase-diopside-calcic garnet granofels.

Rindgemere Formation

Silurian (?)

Srs — Sulfidic schist. Rusty to very rusty weathering sillimanite-muscovite-biotite +/- graphite schist.

Srlm — Libby Mountain member. Rhythmically interbedded white, granular quartzite and light silvery gray, quartz-mica-sillimanite-garnet schist. Individual beds are laterally continuous and typically 1/2 to 3 cm in thickness. Bedding contacts are generally sharp, although some graded beds are also present. The quartzite contains minor amounts of biotite, feldspar, muscovite, and garnet. Occasional beds of salmon-pink, fine-grained garnet-quartz granofels contain 30 to 60% garnet. The schist is rich in muscovite and biotite which occur as coarse flakes defining the schistosity. Prismatic sillimanite occurs as needles in the groundmass or in white, lumpy masses of sillimanite and quartz. Some such masses are probably pseudomorphs after andalusite. Megacrysts of staurolite and fresh, pink andalusite are present in this unit at several places in the map area.

Sr — Undifferentiated schist, granofels, and migmatite. Earthy reddish or brown-weathering feldspathic mica schist and quartz-feldspar granofels are common. In contrast with the Libby Mountain member, the granofels is more micaceous and the schist is more feldspathic making bedding contacts in this unit less distinct and harder to recognize. Bedding thickness is variable, with individual outcrops ranging from thin-bedded granofels to massive schist. The schist is characterized by medium-grained, scaly flakes of biotite and muscovite, commonly crenulated. Sillimanite and small garnets are common, but staurolite and andalusite were not observed in **Sr** in this map area. Most outcrops of schist are migmatitic, containing various proportions of dikes and stringers of granitic pegmatite, generally concordant to foliation but locally discordant.

Src — Calc-silicate granofels. Medium-grained to coarse-grained, light greenish-gray plagioclase-diopside-quartz-calcic garnet granofels. Some layers have a conspicuous texture of small green spots of diopside in a white plagioclase matrix. Seams along some layers weather brown, suggesting the presence of calcite. The layering is flaggy, from 2 to 8 centimeters in thickness.

LITHOLOGIC FEATURES

Outcrop of mapped unit.

Fine-grained mafic dike, too small to be mapped as separate unit. Presumed to be Mesozoic, equivalent to **Md**. Annotation shows predominant texture: b = basalt (aphanitic); d = diabase (phaneritic); unlabeled = not specified. Dikes are commonly 1/2 to 1 meter thick with chilled margins. Not metamorphosed, but may contain vugs mineralized with epidote or calcite. Dot symbol: orientation unknown. Line symbols are drawn parallel to strike and annotated with dip angle if known. (Dip unknown, Inclined, Vertical)

Outcrop of muscovite-tourmaline +/- garnet granitic pegmatite within another mapped unit. Due to poor bedrock exposure the extent of the pegmatite body is unknown. Larger bodies are mapped as unit **p**.

Pegmatite dike within another rock type. Presumed to be Devonian (?) or Carboniferous (?), equivalent to unit **p**. (Inclined)

Milky quartz vein within an outcrop. Age uncertain. (Orientation unknown, Strike only, Strike and dip)

Float. Large blocks or abundant small blocks of a single rock type presumed but not certain to represent the underlying bedrock. Used as a basis for mapping in areas where no other bedrock information is available.
Black = Rock type as indicated by mapped unit. Red = float of mafic dike rock (annotation as for fine-grained mafic dikes).

PLANAR STRUCTURAL FEATURES

Note: Structural symbols are drawn parallel to strike or trend of measured structural feature. Barb or tick indicates direction of dip, if known. Annotation gives dip or plunge angle. For planar features except inclined joints, symbol is centered at observation point. For inclined joints and all linear features, tail of symbol is at observation point. Multiple measurements at a site are represented by combined symbols.

Bedding, facing unknown. (Inclined)

Bedding, facing direction determined from relict primary features. (Upright, Overturned)

Schistosity or foliation in metamorphic rock. (Inclined, Vertical)

Foliation in granitoid rock. (Inclined)

Crenulation cleavage. (Inclined)

Planar ductile shear fabric. (Inclined)

Joint or planar brittle fracture. (Inclined)

Axial surface of open to tight minor fold in bedding. Commonly asymmetric with narrow, chevron-like hinge zones, and axial planar crenulation cleavage. These folds also deform schistosity and sillimanite lineations. Symbol indicates direction in which beds face along the axial surface. (Inclined with facing unknown, Inclined with beds facing upward along axial surface, Inclined with beds facing downward along axial surface, Vertical with facing unknown)

Axial surface of tight minor fold in bedding. These folds deform the schistosity and sillimanite lineations, but are inferred to predate the dominant crenulation cleavage. (Inclined)

LINEAR STRUCTURAL FEATURES

Structural lineation. Annotation indicates lineation type: m = mineral alignment lineation; cr = crenulation lineation; bc = bedding-cleavage or bedding-schistosity intersection lineation.

Measured hinge line of minor fold with axial planar crenulation cleavage. Symbol indicates fold asymmetry. (Unknown, Clockwise, Counterclockwise, Neutral).

Measured hinge line of tight minor fold that predates the dominant crenulation cleavage.

LINE SYMBOLS

Stratigraphic contact or intrusive contact between rock units. (Solid = well-located, Dashed = approximately located, Dotted = inferred)

covered — Large region of no bedrock exposure due to continuous cover of Quaternary sediment. Mapping of bedrock units in this east-central portion of map is conjectural.

PHOTOGRAPHS

4 — Location of photograph shown in sidebar.

Limington Quadrangle, Maine

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BEDROCK MAPS AND THEIR USES

The geologic map at left shows features of the bedrock, the solid rock that makes up the earth's crust. The overlying sediment, which is shown on surficial geologic maps, is disregarded here. Symbols on the map show locations where bedrock is exposed at the land surface. Closely related or distinctive rock types are grouped together into formations and other rock units (see map explanation). Boundaries between units are shown by either solid, dashed, or dotted lines on the map to indicate how well their locations are known. A widespread sand and gravel deposit in the eastern part of this quadrangle completely covers the bedrock, so the bedrock geology there is poorly known.

In most of Maine the bedrock is within a few tens of feet below the ground surface. Any significant subsurface activity, such as excavating for building foundations, installing bridge footings or power poles, quarrying gravel, or drilling water wells may encounter bedrock. A bedrock map is the geologist's prediction of what kind of rock will be encountered below the surface based on observed surface exposures. Quarries, whether for dimension stone such as granite or for crushed rock aggregate with particular strength characteristics, are best sited in appropriate rock types. Exploration geologists or mineral collectors looking for metal ores, industrial minerals, or gemstones may be interested in specific rock types likely to contain the minerals of interest. Engineers planning roads or transmission line routes may use bedrock maps in conjunction with surficial geologic maps to see where valleys, ridges, and hills are controlled structurally by shallow bedrock rather than by unconsolidated deposits. Soil chemistry, important to agriculture and natural plant ecology, is related to bedrock composition because rock weathering contributes to soil formation. Water from wells drilled into bedrock may contain dissolved iron, manganese, calcium, or other undesirable constituents that occur naturally in higher concentrations in some rocks than in others. Groundwater flow in bedrock, relevant to water supply and contaminant transport issues, is controlled in a complicated way by the rock structure, including lithologic layering, metamorphic foliation, folds, dikes, and fractures, any of which may be indicated by symbols on the map. The distribution of rock units, their geometric relationships on the map, and the map explanation together indicate the origin of each unit and the sequence of geologic events that occurred in the map area. This provides a regional context that allows information from one area to be applied to another if the bedrock is sufficiently similar.

BEDROCK GEOLOGY OF THE LIMINGTON QUADRANGLE

Stratified Rocks

The stratified, or layered, rocks of the Limington quadrangle are metamorphic rocks, primarily schist and granofels. Schist is a rock composed of small, flat minerals such as mica that are aligned to give the rock a sheet-like structure so that it splits easily. Granofels is a more uniform rock made up of equant minerals such as quartz and feldspar, which are not elongated in any particular direction so that the rock breaks into angular pieces. A particular schist or granofels may be distinguished by mineral content, grain size, or other characteristics. For example, a granofels made up of diopside and plagioclase, minerals which contain calcium and silica, would be called a calc-silicate granofels.

The stratified rocks were originally sediments that accumulated in an ocean basin during the Silurian to Early Devonian Periods (see Geologic Time Scale below). Geologic processes gradually turned the sediments into rock in a way that preserved many layers and other sedimentary features, but in a modified form. Beds of muddy sand and silt became granofels and schist of the Rindgemere Formation (**Photo 1**). Alternating beds of clean, quartz sand and fine, gray mud became quartzite and schist of the Libby Mountain member (**Photo 2**). Thin deposits of organic-rich, anoxic, sulfidic mud became rusty-weathering schist (unit **Srs**) of the Rindgemere (**Photo 3**). Layers of feldspathic, argillaceous sandstones and siltstones became biotite granofels of the unnamed granofels unit (**SDgf**).

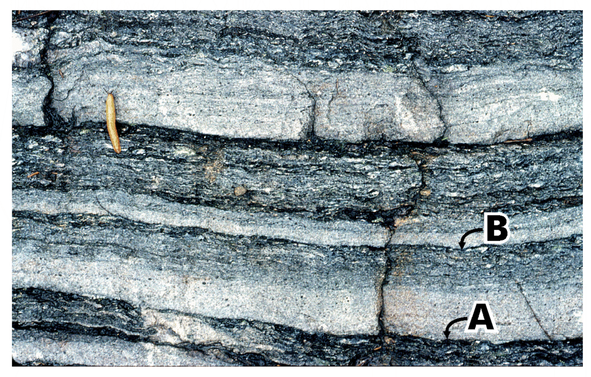

Photo 2. Alternating white quartzite and gray schist characteristic of the Libby Mountain member of the Rindgemere Formation. Graded beds indicate the beds are stratigraphically younger toward the top of the photo (northeast). Quartzite at the base of a bed rests in sharp contact against schist at A. The rock becomes gradually more schistose upward through the bed to where schist is in sharp contact with the next quartzite bed at B. Slug for scale. *Outcrop 8000 feet N55W of Limington.*

Photo 1. Layered schist and granofels. The rock has broken parallel to thin schist layers but irregularly across the granofels layers in steps. Brown-weathering schist surfaces sparkle due to reflective mica grains. *Rindgemere Fm; road cut SE side of Rt. 11, 1.3 miles SW of Limington.*

Photo 3. Rusty-weathering schist with dark purple-black weathered crust. The rust comes from weathering of iron sulfide minerals in the rock. *Sulfidic schist unit (**Srs**) of the Rindgemere Formation; 8600 feet N50W of Limington.*

Metamorphic and Structural Features

In the Devonian and Carboniferous Periods, New England was geologically active. Rocks now at the surface in southern Maine were then at depth, subjected to temperatures over 500 degrees Centigrade and pressure at least 3000 times atmospheric, suggesting minimum depths of 5 to 6 miles beneath the surface. Over time, these conditions caused metamorphism (literally, a change in form) of the rocks. Pre-existing layers were distorted into various folded shapes (**Photos 4, 5**). Parallel planes of cleavage developed which changed the rock structure (**Photo 6**). Metamorphic minerals which had grown in response to the heat, were themselves deformed (**Photo 7**). The geologic history included a complex sequence of deformation and metamorphic mineral growth. Symbols on the map indicate the variety of fold orientations and structural characteristics from place to place in the quadrangle.

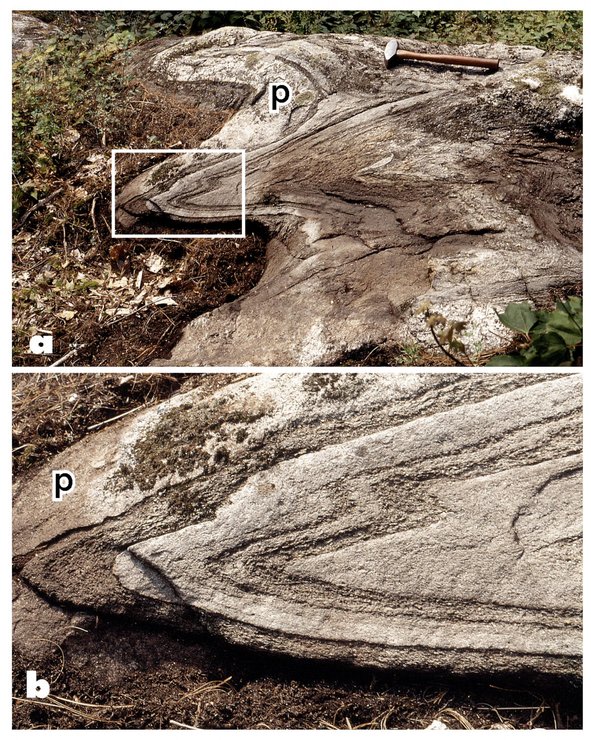

Photo 4. Upright minor folds in bedded schist and quartzite. Prominent layer along top of outcrop is a distinctive slightly pinkish, garnet + quartz rock that occurs in beds at many places in the Libby Mountain member. *Outcrop 50 feet east of Rt. 117, 1.1 miles north of Limington.*

Photo 5a. Folded layers of schist and quartzite. Pegmatite intrusion (p) is also folded. **b.** Close-up showing that layers continue smoothly around the fold without being broken. Layers are thicker in the hinge than on the fold limbs. *Libby Mountain member of the Rindgemere Formation; 6500 feet N60W of Limington.*

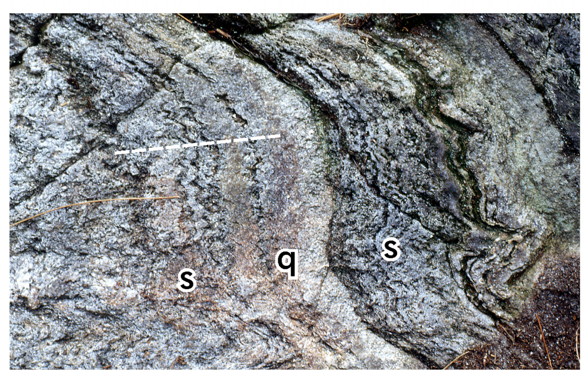

Photo 6. Crenulation cleavage. Small crenulation folds deform layering and schistosity. Axial surfaces of crenulations are aligned through the rock approximately parallel to the dashed line. Note that crenulations are more pronounced in schist (s) than in quartzite (q). *Libby Mountain member of the Rindgemere Formation; 6200 feet N58W of Limington.*

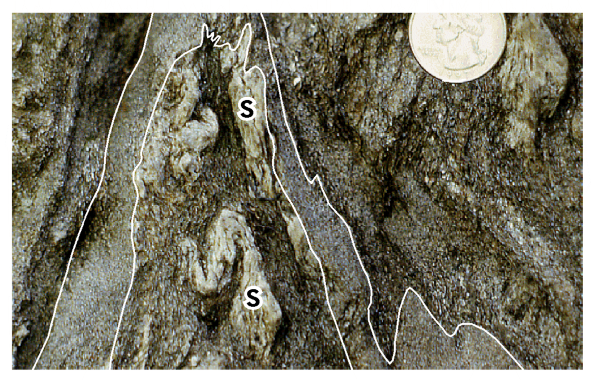

Photo 7. Folded sillimanite schist. A light-colored granofels bed (highlighted) outlines a fold. Clumps of metamorphic sillimanite (s) have been folded into "hook" shapes along with the bedding. This demonstrates that some folding occurred after the metamorphism. *Rindgemere Formation; 100 feet east of road, 0.7 mile north of West Hollis.*

Intrusive Rocks

During and after metamorphism, melting occurred in parts of the crust to produce magma (molten rock). The magma forced its way into rocks of the region, following or cutting across the pre-existing layers. It cooled slowly underground to produce coarse-grained igneous rocks such as granite and pegmatite. None of the granite bodies in the Limington quadrangle have been dated, but similar granites in southern Maine range from Devonian to Carboniferous age.

The youngest rocks of the quadrangle are thin dikes of black, fine-grained igneous rock (**Photo 8**), shown on the map by red symbols. They formed when magma intruded into relatively cool, solid rock along straight fractures. These dikes formed during the Mesozoic Era when Europe and Africa were rifting away from North America to begin opening the modern Atlantic Ocean. There is a large dike, locally containing gabbro, at the south edge of the map. Less common quartz veins and abundant brittle fractures (**Photo 9**) are probably also Mesozoic.

Photo 8. Dark gray Mesozoic dikes cutting Paleozoic granite. Their fine grain size indicates that the dike rocks crystallized rapidly from magma. Cross-fractures within the dikes, called columnar joints, form soon after intrusion when the dikes cool and contract. *At Limington Rapids Rest Area, west shore of Saco River south of Rt. 25.*

Photo 9. Quartz vein in Paleozoic granite. Brittle fractures, or joints, are closely spaced in the quartz vein and widely spaced in the massive granite. *About 100 feet south of **Photo 8**.*

Photos and text by Henry N. Berry IV.

GEOLOGIC TIME SCALE

Geologic Age		Absolute Age*
Cenozoic Era		0-66
Mesozoic Era	Cretaceous Period	66-144
	Jurassic Period	144-208
	Triassic Period	208-245
Paleozoic Era	Permian Period	245-286
	Carboniferous Period	286-360
	Devonian Period	360-415
	Silurian Period	415-443
	Ordovician Period	443-495
	Cambrian Period	495-545
Precambrian time		Older than 545

* In millions of years before present.

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