ROCK UNITS

The rocks exposed in the GM-2 area include eugeosynclinal facies metasedimentary and metavolcanic rocks of the Casco Bay Group of Ordovician, or Silurian, or Early Devonian age, granitic rocks and pegmatites of Middle to Late Devonian age, and basaltic dikes of probable Triassic age. The metasedimentary and metavolcanic rocks have undergone metamorphism to staurolite-andalusite, staurolite-sillimanite, and sillimanite grades. All Formations of the Casco Bay Group of Katz (1917), as redefined by Hussey (1968), crop out in the map area and include, in ascending order, the Cushing Formation, Cape Elizabeth Formation, Spring Point Formation, Diamond Island Formation, Scarborough Formation, Spurwink Limestone, and Jewell Formation.

CASCO BAY GROUP

The Jewell Formation (DOj, DOjs). The Jewell Formation in the GM-2 map area is divided into two lithic types: (1) nonsulfidic metapelites (DOj) and (2) very rusty weathering, sulfidic metapelite (DOjs). The DOj type consists principally of massive to weakly thin-bedded, mottled greenish and purplish muscovite-biotite-chlorite-garnet-quartz2 phyllite and schist with scattered thin (2 to 6 inch) beds of micaceous quartzite. Minor lithologies, also present, include thin boudined amphibolite beds, and coticule bands (1/2 to 2 inches thick) composed of garnet, quartz, and minor biotite. The DOjs type consists of massive to feebly thin-bedded, strongly crenulated, rusty weathering muscovite-biotite-garnet schist, and minor muscovitic quartzite. Thin (6 to 12 inch) boudined, medium to dark green amphibolite beds occur sporadically throughout both DOj and DOjs. Staurolite and andalusite are locally common in DOjs, but rare in DOj. Chloritoid coexisting with fresh staurolite has been observed at a few localities along the east shore of Harpswell Neck just south of Stover Point.

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2 In this publication, minerals comprising the different rock types are listed in the order of decreasing abundance.
The Jewell Formation, which is the highest unit in the Casco Bay Group crops out only within the axial zone of the Harpswell Sound syncline in the southwestern part of the map area.

Spurwink Limestone (DOsk). The Spurwink Limestone consists primarily of thinly interbedded, very fine-grained gray limestone and medium brownish-gray biotite quartz phyllite. Subordinate lithologies include biotite quartzite, calc-silicate quartzite with diopside, hornblende, and epidote, and medium gray calcareous biotite quartz schist. The unit is very thin (50 to 100 feet) and is gradational over an interval of approximately 10 feet into the lithologies of the rusty Jewell metapelite above and the nonrusty Scarboro metapelite below. The Spurwink occurs in outcrop along the western limb and the axial zone of the Harpswell Sound syncline, and on the western limb of the minor anticline mapped on Barnes Island.

Scarboro Formation (DOs, DOss). The Scarboro Formation is lithically identical to the Jewell Formation and, like the latter, has been subdivided into rusty-weathering metapelites (DOss) and nonrusty-weathering metapelite (DOs). Minor lithologies include thin to medium beds of hard quartzite and micaceous quartzite, boudined amphibolite, and coticule bands. As in the Jewell Formation, staurolite and andalusite are common in the sulfidic members but relatively rare in the nonsulfidic members.

The Scarboro Formation crops out extensively on Eagle, Little Birch, Thrumbcap, Bar, Upper Flag, and Barnes Island, and along the western edge of Potts Point in the southwestern part of the map, west of the axis of the Harpswell Sound syncline. In the principal belt on Harpswell Neck between Stover Cove and Ash Point Cove, outcrops are scarce. On the east side of the Harpswell Sound syncline the Formation crops out only at the very northwestern tip of Bailey Island.

3 Similar limestone beds have recently been observed at low water along the very western edge of the exposure belt of the Scarboro Formation at the northern end of Bailey Island. They are not shown on the map inasmuch as they were discovered after the map had gone to press. These beds may represent the Spurwink horizon or they may represent a similar but lower and local limestone unit within the Scarboro. If they represent the Spurwink Limestone, then a considerable thickness of the Scarboro Formation must be cut out along a fault for which there is no discernable physical evidence. A fault would be likely because the width of outcrop of the Scarboro on the west side of the syncline is approximately 1650 feet, whereas, on the east side, between the limestone beds and the Spring Point Formation, it is about 500 feet.
Diamond Island Formation (DOdi). The Diamond Island Formation lies conformably beneath the Scarboro Formation, and is well represented in the Casco Bay Quadrangle (Bodine, personal communication) and the Portland Quadrangle (Hussey, 1971) to the south. It has, however, a very limited distribution in the GM-2 map area, cropping out only in the area of and adjacent to Barnes Island (southwestern part of the map, between Basin Point of Harpswell Neck and Whaleboat Island). The Formation consists of uniform, massive, sulfidic, yellow and orange-weathering, dull coal-black quartz-graphite-muscovite phyllite. Paper thin quartz veins emplaced along cleavage planes locally impart a pin-striped appearance to the rock.

The Diamond Island Formation occupies an extremely attenuated belt approximately 4 feet wide on the west limb of a minor anticline extending through Barnes Island. On the east limb of that anticline the outcrop belt is much wider where the Formation crops out in a series of isoclinal parasitic folds. On the eastern limb of the Harpswell Sound syncline at the northwestern tip of Bailey Island, beds 2 to 3 feet thick of Diamond Island lithology are included in the lower 25 feet of the Scarboro Formation, but are not found in contact with the Spring Point Formation; instead, metapelite of the Scarboro Formation conformably overlies the Spring Point.

Undifferentiated Diamond Island to Jewell Sequence (DOdj). This sequence is a heterogeneous assemblage of rocks, whose stratigraphic assignment is uncertain. It crops out in an inferred fault sliver just east of Peter Cove near Barnes Island. Within this sliver are the following rock types which on a scale of 1" to a hundred feet are mappable as distinct units: (1) black graphitic phyllite identical to the Diamond Island Formation as exposed on Barnes Island; (2) buff irregularly thin bedded (?) quartzite; (3) buff to very rusty weathering coarse impure marble with abundant sulfide occurring as disseminated grains and as irregular vein segregations; (4) fine-grained, graded and ungraded, thin-bedded biotite-muscovite quartzite quartz-mica schist, and mica-garnet schist; and, (5) slightly rusty muscovite-biotite-quartz schist, locally with abundant garnet. The latter lithology is similar to parts of the Scarboro and Jewell Formations.

In no single Formation of the Casco Bay Group has such a varied assemblage of lithologies been yet observed. However, in view of the strong attenuation of Formations on Barnes Island, it is quite possible that this assemblage spans several of the Casco Bay units. From detailed and reconnaissance work throughout the Casco Bay area, the rock types in this sequence are not found below the Diamond Island Formation, but most lithic types can be found in the sequence from the Diamond Island Formation to the Jewell. For these reasons these rocks are designated "Undifferentiated Diamond Island to Jewell Sequence" on the map.
Spring Point Formation (DOP, DOps, DOpv). The Spring Point Formation lies conformably beneath the Diamond Island Formation. The Spring Point crops out (1) on Barnes Island, (2) at the very tip of Basin Point, and (3) on the limbs of the Harpswell Sound syncline. In the latter area the Formation is divided into two members. The upper member (DOps) consists principally of thin-bedded quartz-feldspathic metasediments and metafelsite tuff. The predominant lithology is light gray thin-bedded quartz-plagioclase biotite gneiss and granofels with sparing amounts of garnet. Other lithologies interbedded with the above include: (1) muscovite-biotite quartzite, (2) quartz-plagioclase-muscovite biotite schist, (3) hard quartzite with minor biotite, (4) calc-silicate gneiss, and (5) plagioclase-biotite-hornblende gneiss transitional to feldspathic amphibolite.

The lower member (DOpv) is principally a sequence of thin-bedded basic metapyroclastics. The most common lithology is dark greenish gray, thin-bedded amphibolite with abundant anhedral garnet porphyroblasts up to 10 millimeters in size, and minor disseminated biotite. Hornblende is the principal amphibole. Other lithologies include: (1) medium greenish-gray schist with chlorite and a light green amphibole; (2) plagioclase-quartz-cummingtonite + anthophyllite gneiss; (3) hornblende-biotite-garnet amphibolite with coarse garnet-biotite schist partings; and (4) reddish-gray quartz-plagioclase-garnet-biotite granulite with amphibolite interbeds. Calc-silicate rocks have not been observed with these amphibolites.

At the Barnes Island and Basin Point localities, the Spring Point Formation is not divisible into members. In these areas the Formation consists of a heterogeneous assemblage of medium gray, thin-bedded plagioclase-quartz-plagioclase cummingtonite + hornblende gneiss with garnet-rich interbeds; quartz-plagioclase cummingtonite + anthophyllite gneiss which is locally rusty weathering; and hornblende-garnet-biotite amphibolite. Light gray quartz-feldspathic biotite gneiss and granofels which comprises the major part of the upper member of the Formation around the Harpswell Sound syncline are absent at the Barnes Island - Basin Point localities.

The contact of the Spring Point Formation with the Cape Elizabeth Formation is exposed at several places along the west shores of Bailey and Orrs Island, and just north of Peter Cove near Barnes Island. At all observed localities the two Formation are clearly conformable and the contact is sharp. The Spring Point-Diamond Island contact is exposed on Barnes Island and is likewise sharp and conformable. The upper-lower Spring Point contact as exposed on the western side of Bailey Island and along the eastern shore of Harpswell Neck is gradational over a stratigraphic interval of approximately 25 feet.
Cape Elizabeth Formation (DOce, DOces, DOceg, DOcea). The Cape Elizabeth Formation is a sequence of quartzose metapelites and micaceous metapelites. Within this sequence four lithic types have been separately mapped. The principal type, DOce, consists of thin and well to poorly-bedded quartz-plagioclase-biotite-muscovite + garnet schist and feldspathic micaceous quartzite with partings or interbeds of muscovite-biotite-garnet-quartz schist. Sillimanite and/or staurolite are locally common in these partings. Thin (1 to 6 inch) beds and pods of calc-silicate granulite and six-inch to eight-foot boudined amphibolite beds occur sporadically throughout the sequence. The calc-silicate pods are composed primarily of quartz, plagioclase, hornblende, and clinozoisite, with grossularite and diopside occasionally present in centers of zoned pods. The amphibolites exhibit a variety of mineral compositions ranging from monomineralic hornblende amphibolite to amphibolite with 50% hornblende and 50% plagioclase and hornblende-quartz-plagioclase amphibolite. Included in the DOce unit are interunits varying from 5 feet to 100 feet thick of muscovite-biotite-garnet-staurolite and/or sillimanite schist which, although similar to DOces, are too thin or too intimately associated with DOce to be mapped separately.

Lithic type DOces consists of sulfidic muscovite-biotite-garnet-sillimanite and/or staurolite schist with minor thin interbeds of muscovite-biotite quartzite. The schist is generally massive but in places shows very weakly developed, thin beds. Calc-silicate pods and boudined amphibolite beds are absent, but two lenses of amphibolite (DOcea) have been mapped in this phase of the Cape Elizabeth on the east limb of the Hen Cove anticline. These amphibolites are thinly laminated and lithically identical to those of the Cushing Formation just to the west.

Unit DOceg on the western side of Harpswell Neck, is a thin-bedded, medium gray quartz-muscovite-biotite schist with minor garnet and plagioclase but no observed staurolite or sillimanite. The unit differs significantly from DOce in being a little darker gray in color, more uniformly bedded, and finer grained.

Quartz veins in DOces and in the more pelitic portions of DOce contain irregular patches of andalusite and/or sillimanite, and at several localities on Bailey Island and the southern end of Harpswell Neck, the andalusite in these veins includes small (1/2 to 2 mm) grains of blue translucent corundum. These corundum grains are never in contact with the vein quartz, but are always surrounded by andalusite. Where both andalusite and sillimanite are present, the sillimanite may occur as separate grains from the andalusite, or the two may be intimately associated, in which case the andalusite is clearly a relict phase.

The Cape Elizabeth Formation crops out in the area of the
Harpswell Sound syncline, and on the east limb of the Hen Cove anticline. In addition, three narrow belts of quartz-mica schist (DOce type) crop out on Whaleboat and Little Whaleboat Islands. These belts may represent isolated lenses of Cape Elizabeth lithology within the Cushing Formation, or, as tentatively inferred here, they may be facies intertongues of the Cape Elizabeth Formation in the Cushing Formation. Lithic type (DOces) occurs as narrow lenses at or near the base of the Cape Elizabeth Formation. DOceg is present as a narrow belt between DOces and the Cushing Formation only on the west limb of the Harpswell Sound syncline.

All observed contacts between the various mapped units of the Cape Elizabeth Formation, and between the Cape Elizabeth and the Cushing are conformable.

Cushing Formation (DOc, DOcs, DOcb, DOcy, DOcl, DOcg, COcr, DOcp, DOcm, DOca, DOcw). The Cushing Formation in the area east of the Harpswell Sound syncline is a complete sequence of metavolcanics (both felsic and mafic) and quartz-feldspathic, calcareous, pelitic, and sulfidic metasediments. A facies change toward a lithically simpler and more uniform sequence of metafelsites west of the syncline is recognized and necessitates a separate map explanation for the Formation on either side of the syncline. The western facies is very similar to the uniform metafelsite sequence in the Portland-Cape Elizabeth area at the southern end of the Cushing outcrop belt (Hussey, 1971).

DOc. This is the principal lithic type west of the Harpswell Sound syncline. It consists of a thick sequence of light gray, fine-grained, locally thin-bedded but generally massive, well foliated plagioclase-quartz-biotite gneiss, with minor muscovite or microcline. Blue quartz grains and milky white albite-oligoclase grains up to 5 mm in diameter, and distinctly larger than the groundmass, are found throughout most of this unit, and may represent relict crystal fragments of a crystal tuff. Other portions of the gneiss clearly show strongly sheared and elongated clasts of light and medium gray metavolcanics indicating an agglomeratic volcanic rock prior to metamorphism. In the gneiss, biotite occurs chiefly as small flakes disseminated throughout the rock, but commonly throughout the sequence the biotite flakes clump together to form thin, elongate glomeroblasts up to 15 mm in length. Similar biotite glomeroblasts occur in the DOcs lithology east of the Harpswell Sound syncline, and serve to demonstrate the equivalence of the Cushing sequence east of the Harpswell Sound syncline with the principal felsic lithology of the west. Such glomeroblastic structure does not occur in any other Formation in the Casco Bay Group.

Minor lithologies thinly interbedded with the quartzo-
feldspathic gneiss include: (1) calc-silicate gneiss composed of plagioclase, quartz, hornblende, diopside, clinzoisite, and minor microcline and biotite; and (2) pinkish-gray quartz-plagioclase-garnet-biotite gneiss in which garnet can occur in amounts up to 40%.

DOcw. Forming the highest part of the Cushing Formation west of the Harpswell Sound syncline is a distinctive sequence of very sulfide-rich, rusty-weathering, thin-bedded to massive dark gray rocks mapped as DOcw. DOcw includes the following lithic types: (1) garnet-quartz-biotite shist; (2) garnet-cummingtonite + hornblende-biotite-quartz-plagioclase gneiss and amphibolite; (3) biotite quartzite; (4) biotite-muscovite schist; and (5) coarse garnet-biotite schist. On the west shore of Harpswell Neck just north of Wilson Cove DOcw attains its greatest width of exposure of approximately 1000 feet. However, on Harpswell Neck south of Wilson Cove, the DOcw lithology occurs as bands 50 to 200 feet wide within the light gray quartz-feldspathic gneisses of DOc suggesting a gradual disappearance of DOcw to the south by facies intertonguing with DOc. DOcw is repeated in a belt on the west side of the inferred fault through Middle Bay. At the north end of this belt the width of outcrop is narrow (approximately 300 feet) but increases significantly to the south. In the central part of Middle Bay outcrops on scattered islands suggest a width of outcrop of about 1500 feet. The widening of the unit here and just north of Wilson Cove may be the result of a very gentle dip produced by drag along the inferred fault, or the widening may indicate the axial zones of a faulted syncline and adjacent anticline.

DOcm. Rusty weathering feldspathic two-mica schist that crops out on Merepoint Neck in a narrow, southwardly bifurcating belt, surrounded by DOc-type quartzo-feldspathic gneiss, has been mapped as DOcm. This unit is composed of poorly bedded to massive, relatively sulfide-rich quartz-plagioclase-muscovite-biotite schist and subordinate nonrusty quartz-plagioclase-biotite-muscovite schist very similar to DOce of the Cape Elizabeth Formation. Sillimanite and garnet are abundant in some beds, particularly on the southwest tip of Merepoint Neck. This unit is similar to, and provisionally correlated with the rust schist at Bethel Point on the east side of the Harpswell Sound syncline; however, DOcm is considerably more feldspathic than the schist at Bethel Point.

DOcs. The principal lithic type east of the Harpswell Sound syncline, designated DOcs on the map, consists of quartzo-feldspathic, calc-silicate, and pelitic gneisses, a sequence which is considerably more heterogeneous than the DOc rocks of the same stratigraphic interval west of the syncline. The most abundant rock
type is light gray relatively fine-grained, thin to thick, well bedded quartz-plagioclase-biotite ± muscovite or microcline gneiss. Quartz-feldspar ratios are variable, ranging between values typical of igneous rocks to those indicative of immaturesly weathered sediments probably derived from a felsic volcanic terrain. Biotite commonly occurs as thin glomeroblastic clots as noted above. Interbedded with this lithology in varying amounts are thin beds of (1) greenish quartz-plagioclase-clinozoisite-hornblende-diopside gneiss and (2) light to medium gray quartz-plagioclase-biotite-sillimanite and/or muscovite gneiss. The sillimanite occurs as fusiform, aligned porphyroblasts 4 to 6 mm long usually concentrated in central zones of beds. Minor lithologies present include thin beds of quartz-plagioclase-cummingtonite gneiss, and quartz-plagioclase-biotite-hornblende gneiss. Bedding in DOcs is, in general, well developed, with individual beds ranging from 1/2 to 5 inches.

DOcr. Three minor lenses of rusty-weathering gneiss, designated DOcr on the map are present within DOcs; two on the western limb of the Hen Cove anticline and one on the eastern. The rocks assigned to this lithic type are very similar to those comprising DOcs except for the high sulfide content which gives a rusty-weathered surface.

DOcg. Between Orrs Cove and Gurnet Strait in the northeastern part of the map is a 200 to 300 foot wide belt of dark gray, thinly laminated, rusty and non-rusty weathering quartz-plagioclase-biotite gneiss and feldspathic quartzite. This unit, designated DOcg on the map, separates the DOcl calc-silicate belt extending northward from Pole Island from the major amphibolite to the west. This unit is recognizable only on the western limb of the Hen Cove anticline; on the east limb this lithology is inseparable from DOcs. The contact with the underlying calc-silicate, as exposed at the junction of Route 24 and the turnoff to East Harpswell, is sharp and conformable. The contact with the overlying amphibolite is not exposed but is presumed to be conformable because of the parallelism of minor structures of the two units.

DOcb. On the east side of the Harpswell Sound syncline rusty-weathering schist designated DOcb separates the upper DOcs member of the Cushing from the lower DOcy member. DOcb is a very uniform sequence of massive to weakly thin-bedded quartz-muscovite-plagioclase schist which, due to relatively high sulfide content is very rusty-weathering throughout. This unit crops out in the axial zone of the Hen Cove anticline in the Cranberryhorn Hill area of Sebascodegan Island, and on the limbs of the anticline in the Bethel Point-Cundys Harbor-Yarmouth Island area. In the latter area, the eastern limb is steep, narrow, and apparently unfolded. The west limb, on the other hand, is affected by numerous parasitic folds that cause a 4 to 5 fold broadening of the outcrop belt.
DOc'y. The lowest unit of the Cushing Formation east of the Harpswell Sound syncline, lying below the rusty schist of Bethel Point, consists of light gray felsic metavolcanics. The principal lithology of this unit is poorly bedded, very light gray, medium-grained plagioclase-quartz-biotite gneiss, locally with abundant idiomorphic and xenomorphic crystals of garnet up to 10 mm in diameter, and long blades of dark brown gedrite. Other lithologies mapped with DOc'y include plagioclase-quartz-biotite-muscovite and/or sillimanite gneiss, light colored plagioclase-quartz-hornblende gneiss, and on the east shore of Hen Cove, opposite Bethel Point, plagioclase-quartz-biotite-garnet-sillimanite gneiss with relics to totally pseudomorphed staurolite. Chlorite is common as a retrograde mineral usually after biotite. This unit (DOc'y) differs significantly from DOc's in being much coarser grained, generally lighter in color, more feldspathic and more poorly bedded. Furthermore the gedrite and large garnets that are present throughout most of the unit, are not found similarly disseminated in other members of the Cushing Formation. DOc'y crops out in the axial zone of the Hen Cove anticline around the shores of Hen Cove and on the islands to the south. The southernmost exposure is on White Bull Island, 1/2 mile southeast of Ragged Island.

DOcl. Calc-silicate lenses which have been mapped within all major units of the Cushing Formation are designated DOcl on the map regardless of stratigraphic position. These units consist of light greenish gray plagioclase-quartz-microcline-hornblende-clinozoisite gneiss and hornblende-diopside-quartz-plagioclase marble. Quartz-plagioclase-biotite gneiss occurs as thin interbeds. Similar calc-silicate lithologies occur as interbeds within the DOc's unit. The largest DOcl unit crops out in a belt approximately 500 feet wide extending from Pole Island on the west limb of the Hen Cove anticline northward to Woodward Cove just beyond the north edge of the map. This belt cannot be recognized on the east limb of the anticline; these calc-silicate is intimately interbedded with the quartz-feldspathic beds of DOc's. Two smaller calc-silicate lenses have been mapped within the DOc'y unit, one on the west side of Hen Cove and the other in the axial zone of the Hen Cove anticline on Yarmouth Island. The latter lens overlies and pinches out on the limbs of the anticline against amphibolite. A third minor belt has been mapped along the southeastern shore of Merepoint Neck.

Amphibolites (DOcp, DOca). Amphibolites are common in the Cushing Formation in the area of the Hen Cove anticline but rare in the DOc unit west of the Harpswell Sound syncline. Three principal types are present in the map area, but two of these are too intimately associated to be mapped separately.

Amphibolite of the type designated DOcp crops out in one large and three small lenticular belts on the west limb of the
Hen Cove anticline. These bodies consist of massive, dark gray coarse-grained amphibolite with weak to moderately well-developed gneissic foliation. The mineralogy of these amphibolites is quite uniform and simple, consisting of subequal amounts of andesine and hornblende with minor biotite and quartz. In places where least foliated, the textural relation of hornblende to andesine suggest that these amphibolite bodies may have been medium-grained diorite prior to metamorphism, possibly emplaced as sills.

Two types of intimately associated amphibolites; one fine-grained, evenly gneissic and nonlayered and the other quite strongly layered and coarser-grained, are included in the lithic type DOca. Several lenticular amphibolites of this type are present at different stratigraphic levels throughout the DOcs and DOcy members of the Cushing in the Hen Cove anticline area, but only one belt has been mapped within DOc west of the Harpswell Sound syncline. The well layered amphibolites have a relatively complex mineralogy. They characteristically consist of thin (1 to 5 inch) layers of: (1) hornblende-labradorite-biotite amphibolite, locally with abundant cummingtonite and anthophyllite; (2) phlogopitic biotite-labradorite schist with minor cummingtonite, hornblende, anthophyllite, and prehnite (the prehnite being intimately interweaved with the phlogopitic biotite); and (3) calc-silicate gneiss containing hornblende, diopside, labradorite, clinozoisite, calcite, and quartz. The fine-grained nonlayered amphibolite has a simple mineralogy (labradorite to andesine, hornblende, biotite, and occasionally quartz) and a penetrative, uniform, finely gneissic foliation and lineation marked by parallelism of hornblende grains. In mineral composition these fine-grained amphibolites are very similar to DOcp-type amphibolites, but they occur only in close association with the well-layered amphibolites.4

Associated with the well-layered amphibolites are thin marble units ranging from 3 to 10 feet in thickness. Most of the marbles are very impure with up to 40% diopside, hornblende, and epidote, and many contain amphibolite interbeds. The principal marble unit in the map area extends through the northern half of the large DOca unit on the western limb of the Hen Cove Anticline. This is indicated by the dashed blue line within the amphibolite and is designated by the letter m. Other marble units occur with amphibolites at the following localities: (1) Ben Island and adjacent unnamed islands in the axial zone of the Hen Cove

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4 The amphibolite belt in DOc west of the Harpswell Sound syncline is almost exclusively the fine-grained, mineralogically simple variety. However, because of its lithic identity with the fine-grained amphibolites associated with the well-layered type in the area of the Hen Cove anticline, it is mapped as DOca.
anticline in Quahog Bay, (2) Bombazine Island in the New Meadows River in the northeastern part of the map, and (3) along the western of the two amphibolite belts near Foster Point in the very northeastern corner of the map.

Throughout the GM-2 area, wherever contacts are exposed, all amphibolite bodies appear to be conformable with the surrounding units. Crosscutting relations have not been observed in this area.

**INTRUSIVE ROCKS**

Granitic Rocks and Pegmatites (Dg). Late-tectonic sills and dikes ranging from 6 inches to 400 feet in thickness or width are common in parts of the map area, particularly in the area of the Hen Cove anticline, but only one of these, in the very northeastern part of the map area, is of sufficient size to represented on the map. These sills and dikes consist of fine-grained, light gray to buff gray foliated binary quartz monzonite and granite. Minerals present are microcline, plagioclase (approximately An20), quartz, biotite, muscovite, garnet, and opaques. These bodies have a uniform foliation produced by the parallelism of varietal biotite and muscovite, and this foliation is parallel to the contacts with the country rock. Neither contact metamorphic effects nor chilled margins have been developed, indicating that magma intrusion took place shortly after metamorphism while the country rocks were still quite hot.

Granitic pegmatites of varying shape and size are present, but are too small to represent on the map. They consist of quartz, perthitic microcline, albite, and biotite, with minor amounts of muscovite and garnet. Beryl and black tourmaline are present in limited amounts, but other exotic minerals frequently found in pegmatites elsewhere in Maine are not developed in these pegmatites. Structure of the metasediments has played a significant role in the localization of pegmatites in this area. Pegmatites are most abundant in the axial zone of the Hen Cove anticline, and to a lesser extent in the axial zone of the Merepoint Neck anticline; they are virtually absent in the Harpswell Sound syncline. In the axial zone of the Hen Cove anticline the pegmatites are mostly concordant lenses and irregular stringers. Toward the flanks of the anticline, the pegmatites become gradually more discordant and more dike-like, with straight even walls, as they also become less abundant. To the north and east of the map area, this structural control is lost. There, due to rising metamorphic grade, pegmatites become ubiquitous, and all the metamorphic rocks are strongly migmatized.

The granitic rocks and pegmatites are correlated with the
New Hampshire Plutonic Series of Middle to Late Devonian age on the basis of their calc-alkaline composition.

Diabase and Basalt (Trd). Sills and dikes of dark gray diabase and basalt are present sparingly throughout the map area, and have been intruded into all metamorphic rocks, granitic rocks and pegmatites. They range in width from 6 inches to 100 feet. Of these, only two (which are on strike with each other, and may represent a single discontinuous dike) are of sufficient width and length to map. The mineralogy of these dikes is quite uniform, reflecting uniformity of composition of the parent magma. They consist of labradorite, augite, pigeonite, an orthopyroxene (probably enstatite-hypersthene relics uninveted to pigeonite), micropegmatitic intergrowths of quartz and orthoclase in interstices between labradorite, brown biotite, chlorite, calcite, and a fibrous amphibole.

These dikes and sills are undeformed and unmetamorphosed, and are thus the youngest rocks of the map area. They are provisionally correlated with the igneous activity of Triassic age that took place in the Connecticut River Basin and other similar basins.

STRUCTURE

Major Folds. Three major folds form the principal structural framework of the GM-2 map area. From east to west they are the Hen Cove anticline, the Harpswell Sound syncline, and the Merepoint Neck anticline. These are recognized on the basis of regional map patterns, small-scale parasitic folds, and to a lesser extent, opposing directions of dip of opposite limbs. Axial traces of these folds are indicated on the map. Smaller scale folds, the axial traces of which are not sketched in, are present in the Basin Point-Basin Cove part of Harpswell Neck.

The Hen Cove anticline is the most clearly delineated of the major folds. The arch bend has been observed at five localities: (1) 1/4 mile north of the head of Brickyard Cove, (2) in the islands just east of Snow Island in Quahog Bay, (3) at the north end of Hen Cove, (4) within the DOcl unit on the east shore of Yarmouth Island, and (5) at the southeast end of Yarmouth Island in the DOca unit. Plunge reversals occur in the vicinity of Snow Island in Quahog Bay and between Yarmouth and Ragged Islands toward the south end of the structure. The anticline shows a marked change in style of folding from north to south. In the northern half of Sebascodegan Island, the arch bend of the anticline is indistinguishable from the many parasitic folds that form the major fold, and local attitudes of bedding or schistosity do not vary significantly from one
limb to the other. This is in sharp contrast to the area from Hen Cove south to Ragged Island. At Hen Cove parasitic folds are rare, the arch bend is broad, and local bedding attitudes clearly delineate the plunging nose and flanks of the anticline. On the east limb bedding and foliation are vertical, whereas on the west limb, they average about 65° to the west. On the arch bend, foliation dips between 15 and 20 degrees to the north. In the vicinity of Ragged Island the anticline is quite openly folded with a gentle southerly plunge. The anticlinal form and southward closure are clearly indicated by: (1) broadly converging strikes of foliation around the axial trace, (2) outwardly opposed moderately inclined foliation, and (3) trends of emergent and submergent topographic lineaments that are parallel to strike of foliation. This marked change in folding style is probably a response to the varying competences of the different lithologies in the stratigraphic pile.

The Harpswell Sound syncline, which has a southerly plunge throughout the map area is clearly delineated on the basis of map pattern, with successively higher units of the Casco Bay Group appearing in order to the south in the axis of the fold. Intermediate scale folds east of the major axis (see section BB') are inferred on the basis of the numerous small-scale parasitic folds in the Cape Elizabeth Formation which occupies much of the axial zone of the structure. Unlike the Hen Cove anticline, nowhere is the synclinal form indicated by inwardly opposed bedding dips.

The Merepoint Neck anticline is inferred on the basis of bifurcation of the DOKm unit at the tip of the Neck. The DOKm belt extending the length of Merepoint Neck is interpreted to occupy the axis of the structure which, because of lack of closure to the north, must be essentially nonplunging.

Smaller scale folds are inferred in the Basin Point-Basin Cove area of Harpswell Neck mostly on the basis of map pattern. Of these the small anticline on Barnes Island is very significant as it bears on the interpretation of stratigraphic sequence of the Casco Bay Group. The arch bend of this fold is clearly exposed within the Spring Point Formation on the island. The axis of this anticline can be clearly followed to a point on the mainland approximately 800 feet north of Peter Cove where small-scale parasitic folds of the Cape Elizabeth-Spring Point contact clearly outline the plunging nose of the fold. This fold has a gentle southerly plunge throughout its length. Schistosity of the Cape Elizabeth pelites is parallel to the axial planes of the parasitic folds of the Cape Elizabeth-Spring Point contact, and this indicates that the Barnes Island anticline is related to the earlier and principal fold generation of the area. This relationship then suggests that the Casco Bay stratigraphic sequence as exposed on Barnes Island tops from the Spring Point.
into the Diamond Island, the Diamond Island into the Scarboro and so on. Further to the north at the Cape Elizabeth-Spring Point contact the Cape Elizabeth Formation at the center of the fold would then top into the Spring Point.

**Major Faults.** A major fault extending along Middle Bay and trending inland at the head of Middle Bay Cove at the northern end of Harpswell Neck is inferred from the following relations: (1) apparent offsetting of the staurolite-sillimanite/sillimanite, and staurolite-sillimanite/staurolite-andalusite isograds, and (2) the widening of the outcrop belt of DOcw on either side of the break, possibly due to effects of drag along the fault. This fault is essentially on strike with the South Portland fault mapped by the writer in the South Portland-Scarboro area (Hussey, 1971), and extended by Bodine (personal communication, 1965) to the northeast into the central Casco Bay area. No rocks anywhere along or near the inferred fault position show any effects of brecciation of mylonitization. However, in DOcw and DOces on the west shore of Harpswell Neck just north of Wilson Cove, minor faults trending roughly east-west, dipping from 50° to vertical, and varying in movement from nearly strike slip to essentially dip slip, are common, and may be the result of secondary stresses set up in the bounding blocks during movement of the principal fault. One of these faults which is large enough to be mapped can be seen just north of Barnes Point on Harpswell Neck.

On the Basin Point Peninsula of Harpswell Neck, several faults have been inferred from outcrop distribution of the different Formations. The largest of the breaks extends from Basin Point northward, passing in a somewhat irregular course east of Barnes Island and Peter Cove, crossing Curtis Cove and extending northeastward approximately one mile. Numerous small-scale breaks in the Peter Cove area, mostly parallel to bedding and schistosity, show breccia zones up to 10 inches thick, some pyrite deposition, and movement that is usually dip slip.

A subordinate fault of relatively minor dip slip displacement which truncates fingers of DOcw in the Cushing Formation, has been mapped just south of Lookout Point on the west shore of Harpswell Neck. This fault can be observed along the shore

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5 From field work in the Freeport 15' quadrangle to the west, completed after GM-2 went to press, the staurolite-sillimanite/sillimanite isograd on the west side of the fault is mapped just south of Lower Goose Island, and the staurolite-sillimanite/staurolite-andalusite isograd, just south of Little Whaleboat Island. Both have an east-west trend. The offset of these isograds on either side of the fault would amount to approximately six miles.
where it heads out into Middle Bay. A breccia zone about 10 inches thick marks the break. This fault is parallel to the one on Basin Point peninsula.

A minor east-west trending fault on the north end of Yarmouth Island in the area of the Hen Cove anticline has been inferred from a marked topographic lineament that is best seen on aerial photographs of the area. Displacement must be minor because of the lack of significant offset of contacts of DOcb with DOcs and DOcy.

A northeast-southwest trending fault is very tentatively placed between Whaleboat Island and Barnes Island because of: (1) the very strong attenuation of thickness of the Spring Point, Diamond Island, and Scarboro Formations on Barnes Islands (possibly the result of thinning due to faulting), and (2) the tentative interpretation that the principal outcrop belt of the Cushing Formation would lie southeast of the Cape Elizabeth type exposures on the east shore of Whaleboat Island. This would then bring the Cushing lithologies into too close a proximity to Scarboro-Jewell lithologies to allow fold repetition.

Minor Structures: Folds. Parasitic folds are common throughout the Cape Elizabeth Formation and the DOcs and DOcb members of the Cushing Formation. Within the Cape Elizabeth Formation two sets of small-scale folds are recognized. The earlier set consists of nearly isoclinal folds with smooth parabolic arch bends, steeply-dipping axial planes and axial plane schistosity. In these folds, schistosity is parallel to bedding in the limbs, but transects bedding in the arch bends. This is the minor fold set that is congruent with the major folds in the map area, and it is this set that is shown on the map. The later set of folds deform schistosity as well as the thinner competent beds of a sequence. Arch bends of these folds are sharp and the axial plane schistosity of the earlier set is strongly folded and crenulated. These second set folds seldom have amplitudes greater than 10 inches, and are sporadically developed areally. Axial planes of these folds have gentle dips as compared to the steep dips of the early set, and the plunge of axes is quite consistently to the northeast.

Kink Bands. Kink bands are common in the Cape Elizabeth, Scarboro, and Jewell Formations in the area of the Harpswell Sound syncline. Nearly all observed to date involve counterclockwise rotation, strike essentially east-west, and have a vertical dip. Axes of kinking of the schistosity plunge moderately eastward. Some kink bands pass into minor vertical strike slip faults trending at high angles to bedding. Displacement on these faults seldom exceeds 5 feet, and effects of drag are very pronounced.
Joints. Joints are well developed in all rock types throughout the map area. They have not been systematically studied, but observations at scattered localities suggest several sets are developed. The two most prominent sets are parallel to bedding, and nearly perpendicular to bedding with a steep dip. Less systematically developed are diagonal joint sets, one with moderate angle of dip (50 to 60 degrees) to the southeast, and another with gentle dip to the northwest. Most joints are tight, have involved no differential movement, and are nonmineralized. Some joints, particularly in the amphibolites of the Cushing Formation have undergone minor hydrothermal alteration and mineralization with the deposition of thin selvages of prehnite and quartz. These joints tend to stand out in relief above the parent rock. Whether these joints represent a set of distinctly different age from the nonmineralized joints has not yet been determined.

Lineations. Lineations, which are present in all rock units of the map area except the igneous, are divided into five types for representation on the map. They are:

1. Mineral alignment. This includes both the parallelism of disseminated elongate minerals (mostly hornblende and sillimanite, less commonly, muscovite and biotite), and parallelism of elongate porphyroblasts or glomeroblasts (sillimanite, biotite, and muscovite).

2. Cleavage-bedding intersections. This includes lineations formed by the intersection of bedding surfaces with axial-plane fracture cleavage which is frequently developed in the more competent beds. A similar lineation is formed in some of the gneissic rocks of the Cushing Formation where fracture cleavage intersects the gneissic foliation surfaces.

3. Quartz vein rodding. This lineation is produced in part by stretching of small lenticular quartz veins parallel to fold axes, and in part by very tight folding of these quartz veins. Both mechanisms produce a rod-like appearance and striations parallel to the direction of elongation. This lineation can be quite varied in plunge even along a single schistosity surface. At several localities in the Cape Elizabeth Formation the direction of rodding can be observed to be flexed as much as 90° in a single exposure.

4. Ribbing of bedding surfaces. In the competent beds,
particularly of the Cape Elizabeth Formation, bedding surfaces are frequently raised into parallel ribs or rolls, spaced generally between 3 and 10 mm, and having a relief of approximately 2 to 3 mm. At some localities the ribbing can be demonstrated to be the effect of fracture cleavage-bedding intersections, but at most places no fracture cleavage is evident. This type of lineation is similar to the bedding mullions described by Wilson (1953).

5. Crenulation of Schistosity. This lineation is produced by the minute axes of folding of schistosity.

The first four lineations, in essentially all locations where observed, are b-lineations parallel to the fold axes of parasitic folds of the first stage of folding. The fifth type of lineation is clearly later than the other four. In the most micaceous beds of the Scarboro and Jewell Formation and DOces member of the Cape Elizabeth Formation, two crenulation lineations are frequently developed. One set rather consistently plunges to the northeast and is probably related to the second set of minor folds that deform the schistosity. The other set plunges nearly down dip of the schistosity, and must be related to a late north-south horizontal compression.
REFERENCES CITED


