Maine Geological Survey
DEPARTMENT OF CONSERVATION
Walter A. Anderson, State Geologist

OPEN-FILE NO. 83-4

Title: Bedrock Geology of the Lewiston 15-Minute Quadrangle, Maine

Author: Arthur M. Hussey II

Date: 1983

Financial Support: Preparation of this report was supported by funds furnished by the Nuclear Regulatory Commission, Grant No. NRC-04-76-291.

This report is preliminary and has not been edited or reviewed for conformity with Maine Geological Survey standards.

Contents: 12 page report and 2 maps

INTRODUCTION

Metasedimentary rocks of the Lewiston 15-minute Quadrangle include Early (?) to Late (?) Silurian age extensively migmatized pelitic and calcareous rocks assigned to the Sangerville, Waterville, Smalls Falls, and Vassalboro Formations. The metasedimentary sequence has been extensively intruded by foliated to massive two-mica granite, granodiorite, quartz diorite, and pegmatites of the New Hampshire Plutonic Series of Early Devonian age, and by basalt and diabase dikes of Late Triassic (?) age. The metasedimentary sequence was complexly folded by at least two stages of major deformation during the Acadian Orogeny. Metamorphism to sillimanite and sillimanite-K-feldspar grades, migmatization, and granitic plutonism are probably the results of the Acadian Orogeny. Minor high-angle, post-metamorphic faulting is inferred between Sabattus Mountain and Oak Hill on the basis of topographic lineaments.

PREVIOUS WORK

Fisher (1941) mapped the area of the Lewiston 15-minute Quadrangle and made correlations with the lower metamorphic grade and fossiliferous sequence in the Waterville area, demonstrating the Silurian age of at least part of the highly metamorphosed rocks of the Lewiston area. He divided the sequence into the Pejepscot, Taylor Pond, Androscoggin, and Sabattus Formations. However, from the work of the present writer in the Lewiston Quadrangle, it is apparent that some of Fisher's formations include two or more formations as the sequence is now understood; e.g., the Pejepscot Formation includes equivalents of the Vassalboro, Cushing, and Cape Elizabeth Formations; the Sabattus Formation includes equivalents of the Sangerville and Waterville Formations; and the Androscoggin Formation includes rocks now assigned to both the Vassalboro Formation and the Patch Mountain Member of the Sangerville Formation. In this present investigation, the writer has abandoned most of Fisher's local units and uses formation names established by more recent work in the surrounding areas by Osberg (1968, 1980) and Pankiwskyj and others (1976).

STRATIGRAPHY

Introduction

Recent work by Osberg (1982, pers. comm.) has resulted in a reinterpretation by him of the stratigraphic succession in central Maine on strike to the northeast from the area of this report. He now suggests that the oldest formation of the Silurian sequence is the Sangerville Formation, which is succeeded upward by the Waterville Formation, a thin rusty metapelitic unit, and the Vassalboro, which he regards to be the youngest unit of the area. He correlates the Sangerville with the Rangeley Formation, the Waterville with the Perry Mountain, the thin rusty unit with the Smalls Falls, and the Vassalboro and Mayflower Hill Formations with the Madrid Formation.

Sangerville Formation

The oldest formation as now interpreted in the Lewiston 15-minute Quadrangle is the Sangerville Formation, which includes parts of the Sabattus, Androscoggin, and Taylor Pond Formations of Fisher (1941). The assignment of these rocks to the Sangerville is based on the tracing of the Sangerville Formation on the southeast limb of the Currier Hill Syncline (Ludman, 1977) to the northeast corner of the Lewiston Quadrangle by Pankiwskyj and others (1976).

The general lithology of the Sangerville Formation, Ss on Plate I, is non to slightly rusty-weathering variably bedded to massive metapelite, in most areas very extensively migmatized. The dominant lithology is migmatized biotite-muscovite-quartz±sillimanite-garnet schist with minor 3 to 15 inch (8-40 cm) interbeds of quartz-plagioclase-biotite granofels. Just to the northwest of Oak Hill (EC ninth) where it is least migmatized, the Sangerville consists of thin to medium-bedded alternations of fine-grained medium gray quartz-plagioclase-biotite granofels and medium brownish gray biotite-muscovite-sillimanite-garnet-quartz-plagioclase schist. Graded bedding is common in this area. The Ss lithology stratigraphically below the Patch Mountain Member of the Sangerville is equivalent to the Turner Member of the Sangerville of Pankiwskyj and others (1976). Since similar lithology also overlies the Patch Mountain Member in the Lewiston Quadrangle, the use of the term Turner Member is discontinued and the pelitic/psammitic assemblage above described is referred to as Sangerville undivided.

Five lithic subdivisions of the Sangerville are mapped in the Lewiston Quadrangle: 1) the Taylor Pond Member (Sstp); 2) the Patch Mountain Member (Ssp); 3) the Thorncrag Hill Member (Sst); 4) sulfidic, very rusty weathering schist (Ssr), and thin marble and calc-silicate lenses (Ssl).

The Thorncrag Hill Member is a distinctive unit consisting of dark gray heavily migmatized gneissic metapelite locally with abundant sillimanite and large (up to 5 cm) anhedral garnet poikiloblasts. Thin dark greenish gray hornblende-rich calc-silicate beds are sporadically present.

The Patch Mountain Member consists of thin well-bedded alternations of light to medium greenish gray calc-silicate granofels, quartzo-feldspathic biotite granofels, and fine-grained impure granoblastic marble. In places, the Member is composed of massive marble only. Bedding is frequently accentuated on weathered surfaces by the differential solution of the marble beds. In the belt just east of Sabattus Mountain (EC 9th) the Member consists of ribbony-bedded metalimestone similar to the metalimestone of the Waterville Formation, and punky-weathering medium brownish gray biotite-calcite granofels.

The Taylor Pond Member consists of dark gray quartz-plagioclase-biotite-hornblende granofels, quartz-plagioclase-biotite granofels, salt and pepper-textured amphibolite, thinly bedded calc-silicate granofels and, rarely, pink coticule beds. Rocks assigned to the Taylor Pond Member have been traced into the type locality in the Poland Quadrangle by Creasy (1980).

Unnamed rusty-weathering schist lenses are closely associated with the contact between the Patch Mountain Member and the Taylor Pond Member above the Patch Mountain and the Thorncrag Hill Member below. These lenses consist of very rusty-weathering muscovite-biotite garnet schist, quartz-mica schistose granofels and garnet-biotite granofels.

Within one of the rusty lenses and the Thorncrag Hill Member are thin lenses of thinly interbedded calc-silicate marble and quartz-plagioclase-biotite granofels similar to the Patch Mountain lithology. These lenses range from 1/2 km to 4 km in length, and 25 m to 75 m in width.

Contacts of the members of and other minor units within the Sangerville all appear to be conformable. The contact of the Sangerville with the Waterville Formation, although not exposed, nevertheless appears to be conformable on the basis of general conformity of bedding and schistosity on either side of the contact in the Sabattus Mountain-Oak Hill area. Rock units below the Sangerville Formation in the Lewiston Quadrangle are not known.

The Sangerville Formation occupies the northwestern two-thirds of the Lewiston 15-minute Quadrangle. The Patch Mountain Member occupies a broadly digitate belt extending southwest past Sabattus Mountain to the Lewiston city area and then northeast to the vicinity of Norris Hill (NE 9th) from where it extends into the Augusta area. A second belt extends from the Lake Auburn area north-northeast along the Androscoggin River into the Livermore 15-minute Quadrangle. The Thorncrag Hill Member occupies a belt varying from 200 m to 2.5 km in width and extending from the vicinity of Thorncrag Hill (WC 9th) northward to Greene Corner (NC 9th) and thence south-southwestward to the City of Lewiston. The Taylor Pond Member crops out in a belt extending from the general vicinity of Poplar Mountain south through the City of Auburn and around the nose and southeast limb of the Lewiston anticline to the contact with the Hedgehog Hill pluton (C 9th). Another belt of the Taylor Pond Member branches from the belt just described, extending northward from East Auburn to Berry Pond (NW 9th) where it terminates against the granite of the Leeds Pluton. The rusty schist occupies discontinuous belts both immediately above and immediately below the Patch Mountain Member in the Lewiston-Auburn area and just south of Poplar Mountain. Metalimestone lenses occur (1) just south of Fogg Corner (WC 9th) in the Thorncrag Hill Member; (2) just south of Thorncrag Hill (WC 9th), also in the Thorncrag Hill Member; and (3) in the South Lewiston area within one of the rusty schist lenses.

The thickness of the Sangerville Formation is difficult to determine because of the extensive multiple folding of these rocks. The total thickness probably does not exceed 500 m. The thickness of the Patch Mountain Member is probably about 150-200 m; of the Thorncrag Hill Member, 0-75 m; of the Taylor Pond Member, 0-150 m; the rusty lenses, 0-100 m; and calc silicate lenses, up to 50 m.

Waterville Formation

The Waterville Formation is traceable directly from the type area in the Waterville region. In the Lewiston Quadrangle the Formation consists of thinly and generally poorly bedded medium brownish gray biotite-muscovite-sillimanite-garnet-quartz schist and fine-grained quartz-biotite granulose schist, with sporadic thin beds and lenses of calc-silicate granofels. Fine lamination typical of the Formation at lower metamorphic grade is not preserved in these rocks at sillimanite grade. Mapped separately is a metalimestone member (Swl) which consists of fine-grained, medium gray thin-bedded metalimestone with thin interbeds of quartz-biotite schist. The metalimestone has a characteristic ribbony weathered surface.

The Waterville Formation is restricted to two belts of outcrop: (1) an anticlinal belt extending from Sutherland Pond in the town of Sabattus (EC 9th) to the east edge of the map; and (2) a belt extending from the northwest side of Oak Hill (EC 9th) southwestward to Woodbury Hill and the southwestern corner of the quadrangle. The metalimestone is exposed only in the crest of the Loon Pond anticline. Contacts with the Vassalboro and Smalls Falls Formations on the stratigraphically higher side of the Waterville and the Sangerville on the lower are conformable.

Osberg (1980) suggests a maximum thickness of approximately 1000 m for the Waterville Formation and 300 m for the metalimestone member in the Waterville area, but these values are probably too high for the Lewiston Quadrangle; here the thicknesses are probably on the order of 200 and 50 m respectively.

Smalls Falls Formation(?)

Rusty schist exposed at the top of Sabattus Mountain, along the crest of Oak Hill, and at the Waterville-Vassalboro contact at Loon Pond (EC 9th) are tentatively assigned to the Smalls Falls Formation. This stratigraphic assignment follows new interpretations of similar stratigraphic units by Osberg (pers. comm., 1982) in the Waterville area to the northeast. The Formation consists of very rusty-weathering muscovite-biotite sillimanite schist, rusty-weathering two-mica schist, and rusty-weathering thin-bedded quartz-plagioclase-biotite granofels. Graded bedding is common in the latter lithology.

The thickness of this rusty schist varies from 0 to an estimated 50 m. Contacts with the Vassalboro and Waterville Formations are apparently conformable.

Vassalboro Formation

The youngest formation in the Lewiston Quadrangle as now interpreted is the Vassalboro Formation, traceable directly to the type area in the Waterville region. The Formation consists of variably bedded to massive, medium dark gray, fine-grained quartz-plagioclase-biotite granofels with frequent thin interbeds of medium greenish gray calc-silicate granofels. The biotite granofels weathers to a typical dark brownish color and has a salt and pepper appearance due to contrasts between biotite and plagioclase.

The Vassalboro Formation occupies a synclinal belt in the Oak Hill area (EC 9th) and a broad zone in the towns of Lisbon, Sabattus (formerly Webster), and Bowdoin, where it is extensively migmatized and injected by pegmatites. No estimate of the thickness of the Formation can be made for this area because of the extreme structural variability, migmatization, and pegmatite injection of most of the area of its outcrop.

INTRUSIVE ROCKS

Intrusive rocks in the Lewiston Quadrangle include calc-alkaline granite (variable in composition to quartz monzonite) granodiorite, quartz diorite and pegmatite, which are correlated with the New Hampshire Plutonic Series of Early Devonian age, and basalt and diabase dikes of presumed Late Triassic age.

Granite occupies two larger plutons (Leeds and Wales Plutons) and several smaller plugs within the quadrangle, and, to the west of the quadrangle, forms the Sebago Batholith, the largest granitic pluton in the State of Maine. The granite is light gray, medium to fine-grained, weakly to moderately foliated and extensively permeated by irregular pegmatite stringers. Quartz, oligoclase, microcline, biotite, and muscovite are the principal minerals. Foliation is due primarily to the parallelism of mica flakes and only occasionally is formed by schlieren. The foliation forms no obvious pattern that can be related to regional structural trends. Contacts with metasediments are usually sharp and discordant, and the metasediments show no effects of contact metamorphism.

Granodiorite occurs in the Hedgehog Hill Pluton in the vicinity of the village of Sabattus. The rock is fine to medium-grained, medium gray, and moderately to strongly foliated, especially in the southeastern

end of the pluton. The foliation is due to partial segregation of dark and light minerals. The mineralogy of the granodiorite is similar to that of the granite except that biotite is much more abundant, giving it the darker color.

In the Taylor Pond Member of the Auburn-Berry Pond area, and in the Patch Mountain Member on the eastern shore of Lake Auburn, several dike or lens-like masses of highly foliated, medium dark gray quartz-plagioclase-biotite garnet gneiss, probably representing quartz diorite, have been noted. The garnets are large poikiloblastic anhedra up to 3 inches in diameter. These gneissic intrusives resemble the gneissic schist of the Taylor Pond Member except that they lack the migmatite leucosomes of the host rock. It is possible that these rock units represent locally homogenized and mobilized masses of the migmatite.

Pegmatite, occurring as concordant and semiconcordant lenses, dikes, and irregular masses, pervasively intrudes all rock units except the diabase dikes throughout all but the Oak Hill area of the Lewiston Quadrangle. The mineralogy of these pegmatite masses is simple: quartz, albite, microcline, biotite, muscovite, garnet, and occasionally schorl. Exotic minerals such as lepidolite, beryl, gemmy tourmaline, etc., that characterize the pegmatites of the Paris region to the northwest, are absent.

Diabase and basalt dikes, injected into pegmatite, granite, and the metasedimentary units, range in width from 4 inches to 15 feet. They strike northeast to east and have steep to vertical dips. They are confined to a belt 3 to 4 miles square, centered around the City of Lewiston. They are unmetamorphosed and represent the youngest igneous activity in the quadrangle. Although radiometric dates are not available for any dikes from this quadrangle, they probably correlate with late Triassic vulcanism and intrusion associated with Triassic to Jurassic age rift basins in the Appalachians.

STRUCTURE

Folding. Two contrasting structural domains are readily apparent from the geologic map pattern. These are 1) the Oak Hill fold domain characterized by tight upright folds and the absence of pegmatites and migmatization; and 2) the Lewiston fold domain, characterized by extensive meso- and macroscopic scale reclined or strongly overturned folds, abundance of pegmatites, and strong migmatization of the metasedimentary sequence. These domains are shown in Figure 1. The author's structural interpretation is shown in the structure section on Plate I.

In the Oak Hill domain the Vassalboro Formation is preserved in the keel of the Oak Hill Syncline and the Waterville Formation to the east in the tight crest of the Loon Pond Anticline. The Oak Hill Syncline in the

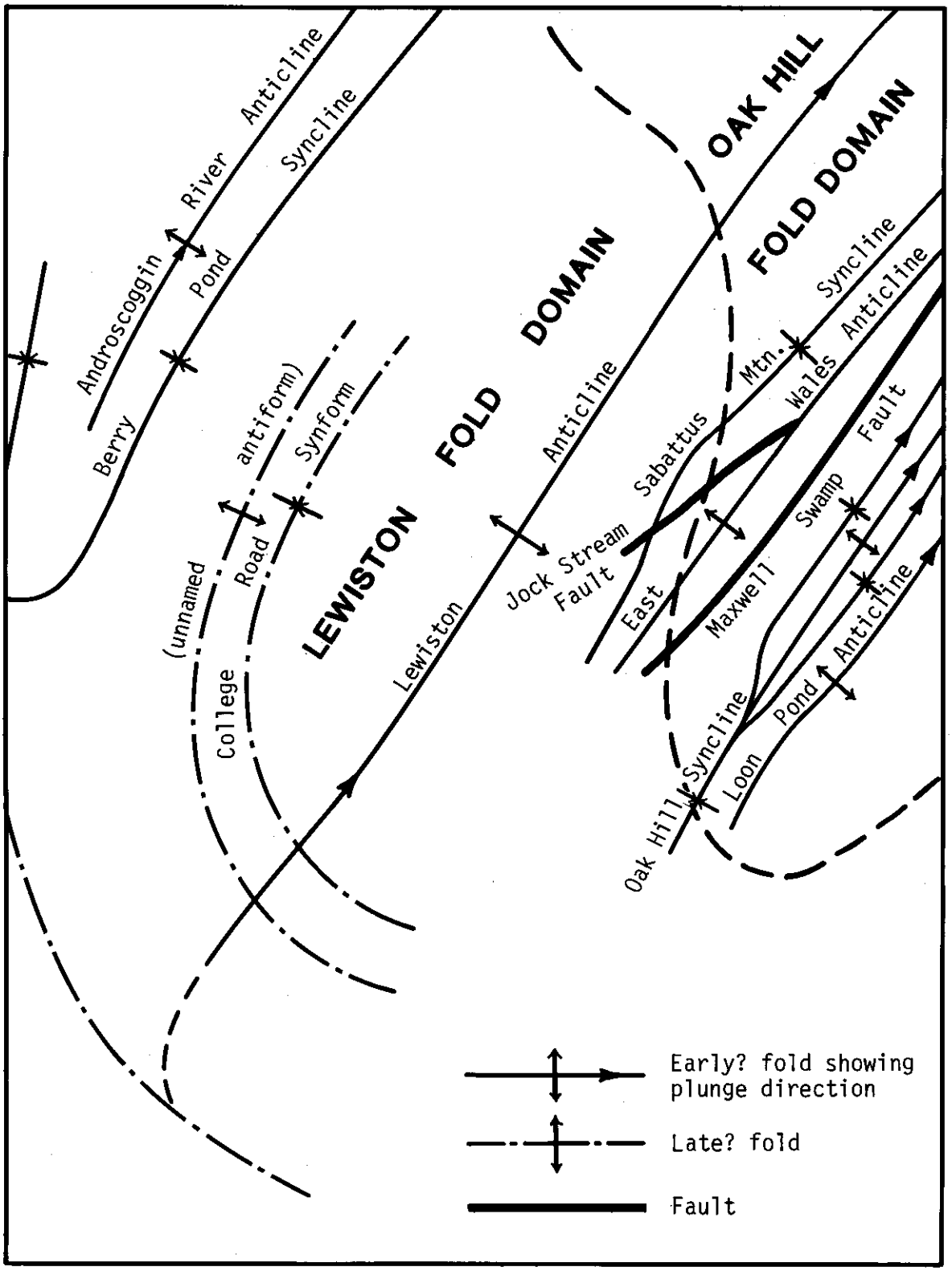

Figure 1

Structural sketch map of the Lewiston 15' Quadrangle.

Lewiston 15-minute Quadrangle is complicated by a minor anticline bringing the Smalls Falls (?) Formation to the surface centrally. These folds of the Oak Hill domain are inferred to face upward, and their axial surfaces are nearly vertical. To the north, in the Waterville area, Osberg (1980) reports downward facing folds indicating refolding of inverted limbs of recumbent folds; however, no evidence for downward facing folds is known in the Lewiston 15-minute Quadrangle. Minor parasitic folds with moderate (40-50°) northward-plunging axes are inferred to be a third fold generation unrelated to the macroscopic fold system. These minor parasitic folds, here designated as $\overline{F_3}$, may be correlated with minor asymmetrical folds described by Osberg (1968) in the Waterville area.

The Lewiston domain is characterized by numerous meso- and macroscopic folds that have variably oriented axial planes, but have rather uniformly northeast-plunging axes. These folds are especially well developed in the Lewiston City area. The relative age of these folds is uncertain. They may be the latest folds of the Lewiston domain, being related to stress generated by the emplacement of the Sebago Batholith, or may be parasitic to large early recumbent folds otherwise unobserved in this quadrangle. Originally the digitate outcrop belt of the Patch Mountain Member of the Sangerville Formation was interpreted by Hussey and Pankiswkyj (1980) to be the refolded hinge of a major recumbent syncline. This interpretation was based on the repetition of the rusty schist and gneiss of the Thorncrag Hill and Taylor Pond Members (then considered to be equivalent) symmetrically about the Patch Mountain belt. Although this interpretation cannot be ruled out, regional synthesis has failed to yield a valid structural interpretation based on this premise. The present structural interpretation is based on the stratigraphic interpretation that the Thorncrag Hill and Taylor Pond Members are different stratigraphic units, the Taylor Pond being above and the Thorncrag Hill Member being below the Patch Mountain Member.

The difference in structural style, migmatization, and pegmatite abundance of the two fold domains is interpreted to be related to proximity to the Sebago Batholith, which the author infers to be a relatively thin (1-3 km) sheet dipping gently to the east. It must be noted that in the Lewiston fold domain, all fold generations appear to deform migmatite leucosomes and thin concordant pegmatites. How this reconciles with Osberg's (1980) interpretation that both upright and recumbent folding in the Waterville area predate metamorphism remains a question for future resolution. The northward plunge of lineations and many mesoscopic fold hinges in contrast to the southern plunge of the Lewiston Anticline requires that these minor structures are later lineations and fold axes unrelated to F_2 in the Lewiston fold domain, but possibly related to F_3 noted for the Oak Hill domain.

Faults and Joints. Evidence for faulting is almost entirely lacking in the Lewiston 15-minute Quadrangle. Two presumed normal faults are shown on Plate I in the vicinity of Sabattus Mountain and Oak Hill. Their presence is inferred solely on the basis of the topographic lineament formed by 1) the linear southeast face of Sabattus Mountain and the course of Jock Stream, and 2) the low ground aligned with Maxwell Swamp on the northwest edge of Oak Hill. The latter, referred to as the Maxwell Swamp Fault by Hussey (1981), may cut out part or even all of the Waterville Formation locally (Plate I). No mylonite fault breccia, silicification, or slickensides have been observed in any exposures close to the inferred position of these faults.

The epicenters of four earthquakes reported since 1975 (Chiburis, 1981) are shown on Plate I. The epicenters of these events, for which Richter magnitude values are reported, are instrumentally determined, but confidence elipses are not given. The reader should bear in mind that the actual location of these epicenters may vary as much as 5 km from the plotted position. Five earlier events (1857 to 1935) reported by Chiburis (1981) were felt in the vicinity of Lewiston, but epicenters were not reliably determinable and are not shown on Plate I. There appears to be little relationship between the bedrock geology and the occurrence of earthquakes in the Lewiston area.

The rocks of the Lewiston 15-minute Quadrangle, igneous and metamorphic alike, are, as a rule, only poorly jointed. A stereographic plot of poles to approximately 600 measured joints (Figure 2) shows no significant preferred concentration that would indicate regional joint sets. No joint faces observed showed any evidence of small-scale shearing such as the presence of slickensides.

SUMMARY

Metamorphic rocks representing original pelitic, psammitic, and calcareous sedimentary rocks have been subdivided into the Sangerville Formation of Early Silurian(?) age, the Waterville Formation of Middle Silurian(?) age, the thin rusty unit correlated tentatively with the Smalls Falls Formation of the Rangeley-Phillips area (Middle to Late Silurian(?) in age), and the Vassalboro Formation of Late Silurian(?) age. The total thickness of the metasedimentary sequence may be on the order of 2000-3000 m.

The metasedimentary sequence has been extensively intruded by calc-alkaline granitic to intermediate igneous rocks of the New Hampshire Plutonic Series and to a limited extent by basalt and diabase dikes up to 4 m wide. The New Hampshire Plutonic Series includes light gray, massive to slightly foliated, variably-textured two-mica granite, strongly foliated medium gray granodiorite, very gneissic quartz diorite with large poikiloblastic garnets, and massive to slightly foliated pegmatite lenses and stringers. Although no radiometric ages have been determined

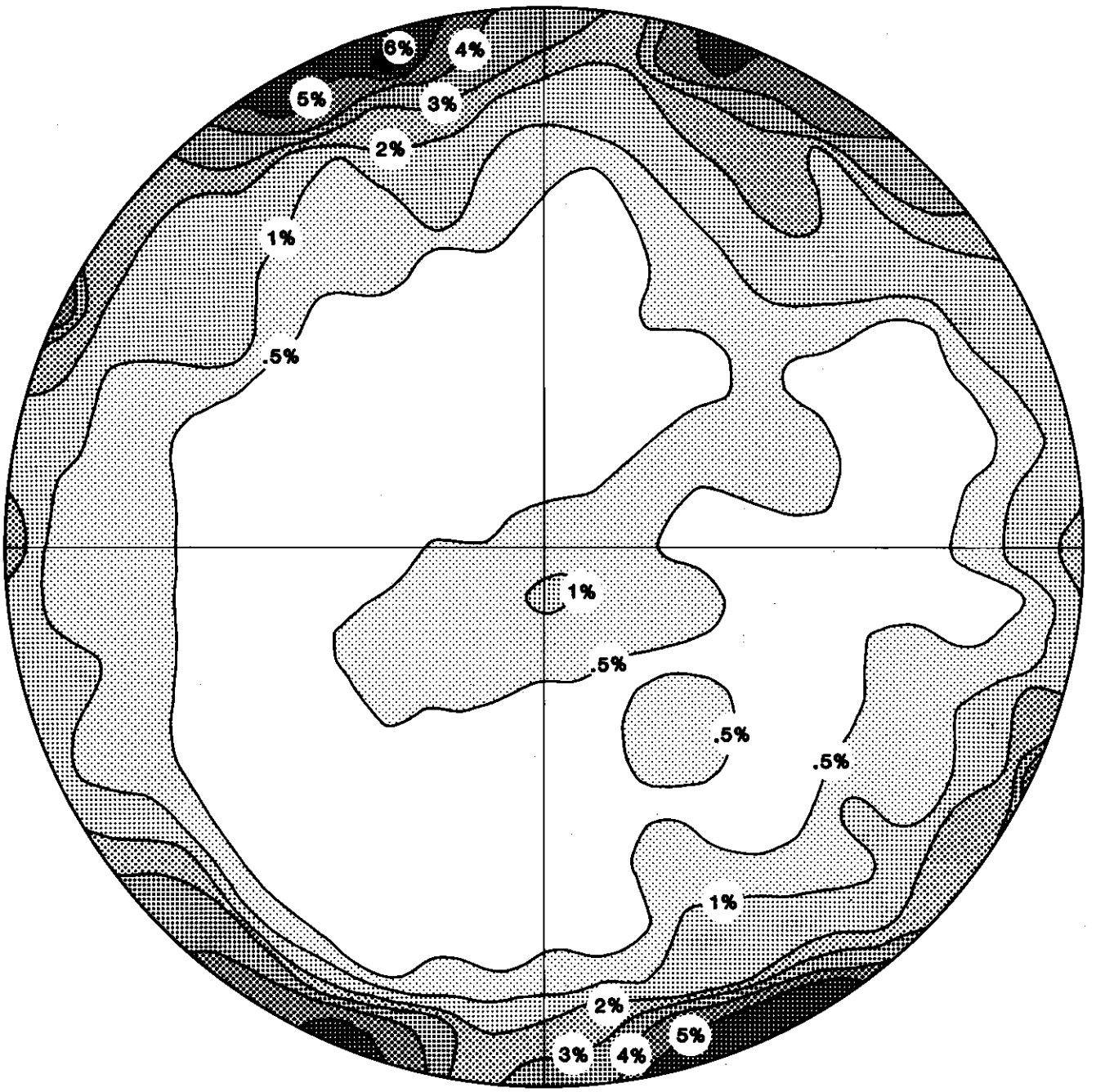

Figure 2

Pi diagram of poles to joints in all rock types, Lewiston 15' Quadrangle Maine. Based on 614 joints. Lower hemisphere plot.

for the New Hampshire Plutonic Series in the Lewiston 15-minute Quadrangle, these rocks are probably of Early Devonian age. The late diabase or basalt dikes are undeformed, non-metamorphosed, and restricted to a 5-9 km zone around the City of Lewiston. These dikes are of Late Triassic to Early Jurassic age (McHone, 1982).

Two contrasting structural zones are recognized. The Oak Hill fold domain in the northeast part of the map area is characterized by tight upright to slightly overturned upward-facing late folds. The metasedimentary sequences of this domain are non-migmatized and lack significant pegmatite intrusions. The Lewiston domain is characterized by macroscopic folds that are southward plunging. These correlate with the major upright macroscopic fold system of the Oak Hill domain. Smaller scale reclined to strongly overturned folds that are particularly obvious in the Lewiston anticline may represent later folds possibly correlative with the north-plunging late folds of the Oak Hill domain, or they may be earlier folds parasitic to as yet unrecognized major recumbent folding. The metasedimentary sequence in this domain is strongly migmatized, the leucosomes of which are deformed by both early and late folds. Pegmatite stringers and lenses are very common here.

Metamorphism to sillimanite/K-spar-sillimanite grade, early and late folding, intrusion of the New Hampshire Plutonic Series, pegmatite intrusion, and migmatization are probably the effects of the Acadian Orogeny of Early Devonian age.

Two relatively short post-metamorphic, high angle(?) faults of very minor (a few 10's of meters) displacement are inferred on the basis of topographic lineaments in the Oak Hill-Sabattus Mountain area. Age of faulting is uncertain but probably post-dates the Acadian Orogeny.

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