Maine Geological Survey
Neotectonics of Maine
1989

Postglacial Bedrock Faulting in Maine

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ABSTRACT

Small faults offsetting glacially striated bedrock surfaces have been reported from Maine and elsewhere in northeastern North America by many workers since 1894. This study brings together information on postglacial faults in Maine that have been mentioned in geologic literature, and other faults reported to the author by recent workers. All of the faults which could be located in the field occur within layered rocks; and they are oriented parallel to bedding, schistosity, or joint systems. No systematic orientation with respect to a regional stress field is apparent. The faults examined may all be the result of frost heaving or glaciotectonic effects. Other tectonic forces may be involved in producing the postglacial faults, but there is no indication that these forces are required.

INTRODUCTION

Minor rock movements defined by offsets of features such as grooves and striations on glacially abraded bedrock surfaces have been reported in Maine and northeastern North America for many years (Barosh, 1976; Boone, 1979; Hodgson, 1970; Lawson, 1911; Matthew, 1894; Newman, 1979; Oliver and others, 1970; Rand, 1976; Rand and Gerber, 1976; Rast and others, 1979; Sbar and Sykes, 1975; Stein and others, 1979; Thompson, 1981; York and Oliver, 1976). In addition to the cases reported in the literature, a number of other occurrences were identified by recent workers in Maine, in personal communications responding to inquiries made in connection with this study.[1] All known occurrences are listed in Table 1. It was the purpose of this study to bring together these reports, both published and unpublished, to visit as many of the reported sites in Maine as possible, and to determine the extent to which tectonic, glaciotectonic, or other forces may have been involved in generating the apparent postglacial faults.

The locations of the sites reported to the author are indicated on the map of Maine (Figure 1), which also displays the general lithologic characteristics of Maine bedrock, including the distribution of sedimentary and metasedimentary rocks such as shales, slates, greywackes, schists, and the more massive plutonic rocks. (The site numbers in both Figure 1 and the text correspond to the numbers in Table 1.) It is apparent that reported occurrences of postglacial faults are restricted to the former types of rocks, particularly those of Units 2 and 3 on Figure 1. An example of faulting in this type of bedrock is shown in Figure 2.

Most of the faults exhibit small displacements, commonly in the range of 0.5 to 1.5 cm. The surfaces along which movement has taken place are usually vertical or nearly vertical, and parallel to the dominant structure of the outcrop, which may be bedding, slaty cleavage, or schistosity. The lateral extent of the faults may be from one to more than 16 m. Movement is generally dip-slip, though a strike-slip component may be present. Slickensides are not visible. There may be several parallel offsets at a single outcrop, and there may be cross-faults between adjacent parallel or sub-parallel faults. The only known

[1]Respondents include: G. Boone; T. Brewer; J. Briggs; D. Caldwell; O. Gates; N. Hatch; M. Loiselle; A. Ludman; D. Newberg; R. Neuman; S. Pollock; J. Rand; W. Thompson.

TABLE 1

No.	Quadrangle	Town	Coordinates		Formation[1]	Reported by	
1	York Beach 7.5'	York	43°12.5N,	70°35.5W	Diabase dike in SZk - Kittery Fm	Rand	1976
2	Portland East 7.5'	Falmouth	43°43.6N,	70°14.35W	Pegmatite in SOv - Vassalboro Fm	Rand	pers comm
3	Castine 15'	Searsport	44°26.16N,	68°52.86W	O€p - Penobscot Fm	Rand, Gerber	1976
4	Orrs Island 7.5'	Harpswell	43°48.5N,	69°53.37W	OZce - Cape Elizabeth Fm	Rand	
5	Somersworth NH 7.5'	North Berwick	43°22.23N,	70°44.75W	DSra - Rindgemere xenolith	Rand, Hussey	1976
6	Amity 15'	Orient	45°47.42N,	67°53.0W	O€us - Unnamed sediment	Brewer	pers comm
7	Passadumkeag 15'	Howland	45°14.13N,	68°40.0W	SOv - Vassalboro Fm	Newberg	pers comm
8	The Forks 15'	East Moxie Twp	45°21.75N,	69°52.25W	Dcm - Carrabassett Fm	Hatch	pers comm
9	Bingham 15'	Concord Twp	45°00.5N,	69°59.0W	Ssf - Smalls Falls Fm	Boone	1979
10	Boyd Lake 15'	Orneville	45°11.0N,	68°53.5W	DSm - Madrid Fm	Caldwell	pers comm
11	Bingham 15'	Concord Twp	45°03.0N,	69°53.17W	Ssf - Smalls Falls Fm	Caldwell	pers comm
12	Ragged Lake 15'	T2 R13, WELS	45°22.5N,	69°18.0W	Ds - Seboomook Fm	Caldwell	pers comm
13	Farmington 7.5'	Farmington	44°42.0N,	70°10.7W	Dsd - Day Mtn Mem Seboomook Fm	Caldwell	pers comm
14	Bucksport 15'	Orrington	44°03.08N,	68°49.0W	DOb - Bucksport Fm	Thompson	1981
15	Bucksport 15'	Orrington	44°42.92N,	68°49.0W	DOb - Bucksport Fm	Thompson	1981
16	Big Lake 15'	T27 ED	45°05.33N,	67°42.5W	DOf - Flume Ridge Fm	Thompson	1981
17	Big Lake 15'	T27 ED	45°05.1N,	67°44.73W	DOf - Flume Ridge Fm	Thompson	1981
18	Big Lake 15'	Grand Lake Strm	45°11.83N,	67°44.0W	DOf - Flume Ridge Fm	Thompson	1981
19	Kellyland 15'	Dyer Twp	45°21.5N,	67°27.83W	DOf - Flume Ridge Fm	Thompson	1981
20	Schoodic 15'	Lakeview Plt	45°24.33N,	68°48.8W	Dc - Carrabasset Fm	Loiselle	pers comm
21	New Sharon 7.5'	Industry	44°43.0N,	70°01.83W	Ss - Sangerville Fm	Boone	pers comm
22	Boothbay 15'	Georgetown	43°48.83N,	69°43.25W	OZce - Cape Elizabeth Fm	Rand	pers comm
23	Fish River Lake 15'	T13 R9 WELS	46°48.45N,	68°50.6W	Ds - Seboomook Fm	Thompson	pers comm
24	Allagash Falls 15'	T15 R11 WELS	46°59.85N,	69°12.0W	Ds - Seboomook Fm	Lowell	pers comm
25	Allagash Falls 15'	T14 R10 WELS	46°55.6N,	69°00.5W	Ds - Seboomook Fm	Lowell	pers comm
26	Allagash Falls 15'	T13 R11 WELS	46°45.17N,	69°09.8W	Ds - Seboomook Fm	Lowell	pers comm
27	Allagash Falls 15'	T15 R11 WELS	46°59.15N,	69°09.25W	Dsup - Unnamed pelite, Seboomook Fm	Lowell	pers comm
28	Allagash 15'	Allagash Plt	47°01.38N,	69°11.75W	Ds - Seboomook Fm	Lowell	pers comm
29	Allagash 15'	Allagash Plt	47°01.45N,	69°09.25W	Ds - Seboomook Fm	Lowell	pers comm
30	Allagash 15'	Allagash Plt	47°03.02N,	69°10.37W	Ds - Seboomook Fm	Lowell	pers comm
31	Allagash 15'	Allagash Plt	47°02.83N,	69°02.25W	Dsup - Unnamed pelite, Seboomook Fm	Lowell	pers comm
32	Caucomgomoc Lake 15'	T5 R14 WELS	46°07.5N,	69°20.5W	Ds - Seboomook Fm	Lowell	pers comm
33	Caucomgomoc Lake 15'	T5 R15 WELS	46°04.13N,	69°22.5W	Ds - Seboomook Fm	Lowell	pers comm
34	Caucomgomoc Lake 15'	Russell Pond	46°02.5N,	68°59.75W	SOf - Frontenac Fm	Lowell	pers comm
35	Clayton Lake 15'	T11 R14 WELS	46°35.93N,	69°30.25W	Dsup - Unnamed pelite, Seboomook Fm	Lowell	pers comm
36	Fish River Lake 15'	T13 R9 WELS	46°48.8N,	68°51.0W	Ds - Seboomook Fm	Lowell	pers comm
37	Mooseleuk Lake 15'	T10 R9 WELS	46°32.5N,	68°55.0W	O€cb - Chase Brook Fm	Lowell	pers comm
38	Musquacook Lakes 15'	T12 R12 WELS	47°43.78N,	69°14.25W	Ds - Seboomook Fm	Lowell	pers comm
39	Musquacook Lakes 15'	T11 R10 WELS	46°38.27N,	69°01.0W	Ds - Seboomook Fm	Lowell	pers comm
40	Norris Brook 15'	T7 R19 WELS	46°12.58N,	70°13.5W	Ds - Seboomook Fm	Lowell	pers comm
41	Norris Brook 15'	Dole Brook	46°00.18N,	70°12.5W	Ds - Seboomook Fm	Lowell	pers comm
42	Rocky Mtn 15'	T15 R12 WELS	47°00.43N,	69°20.25W	Ds - Seboomook Fm	Lowell	pers comm
43	Round Pond 15'	T13 R12 WELS	46°46.8N,	69°16.75W	Ds - Seboomook Fm	Lowell	pers comm
44	Round Pond 15'	T15 R13 WELS	46°55.43N,	69°23.05W	Ds - Seboomook Fm	Lowell	pers comm
45	Round Pond 15'	T13 R13 WELS	46°48.35N,	69°21.W	Ds - Seboomook Fm	Lowell	pers comm
46	Seboomook Lake 15'	Seboomook	45°58.1N,	69°03.0W	SOf - Frontenac Fm	Lowell	pers comm
47	Seboomook Lake 15'	Pittston Acad.	45°55.7N,	69°11.75W	SOf - Frontenac Fm	Lowell	pers comm
48	Seven Islands 15'	T14 R15 WELS	46°54.13N,	69°41.0W	Sfm - Five Mile Brook Fm	Lowell	pers comm
49	Seven Islands 15'	T14 R14 WELS	46°52.25N,	69°31.0W	Ds - Seboomook Fm	Lowell	pers comm
50	Seven Islands 15'	T14 R15 WELS	46°50.77N,	69°36.0W	Ds - Seboomook Fm	Lowell	pers comm
51	Umsaskis Lake 15'	T11 R14 WELS	46°35.6N,	69°29.75W	Ds - Seboomook Fm	Lowell	pers comm
52	Umsaskis Lake 15'	T11 R13 WELS	46°37.4N,	69°26.75W	Ds - Seboomook Fm	Lowell	pers comm
53	Umsaskis Lake 15'	T10 R12 WELS	46°35.28N,	69°16.25W	Ds - Seboomook Fm	Lowell	pers comm
54	Depot Lake 15'	T14 R16 WELS	46°50.35N,	69°47.5W	Odmp - Depot Mtn Fm	Lowell	pers comm
55	Anson 15'	Lexington Twp	44°59.83N,	69°59.72W	Sp - Perry Mtn Fm	Briggs	pers comm
56	Millinocket 15'	Medway	I-95, Mile 232.5		Dsm - Mt. Blue Mem Seboomook Fm	Koons	this rept

[1]Formations from Osberg and others, 1985

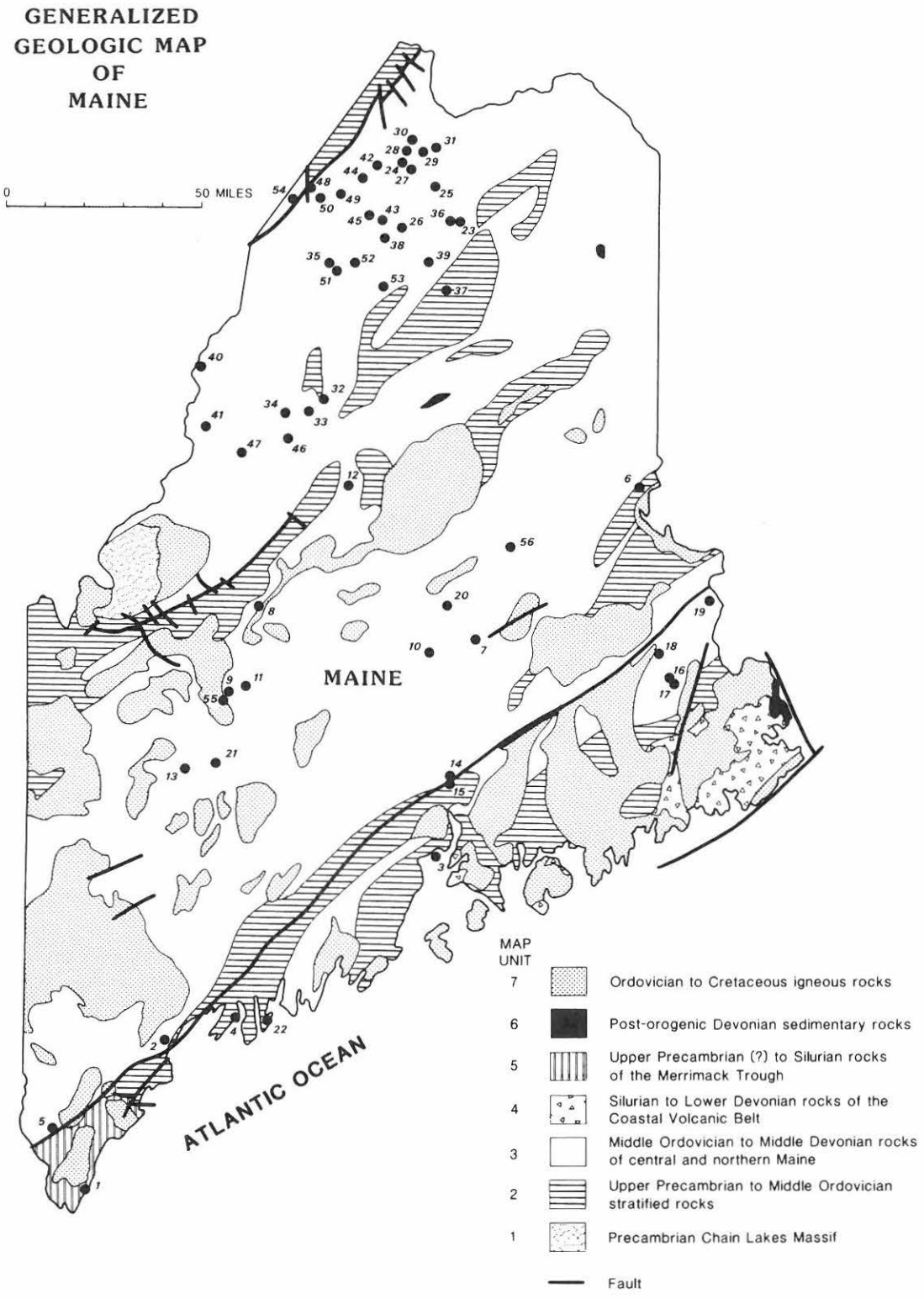

Figure 1. Map showing locations of reported postglacial faults. Numbers correspond to Table 1. Geology from Loiselle and Thompson (1987) modified from Osberg and others (1985).

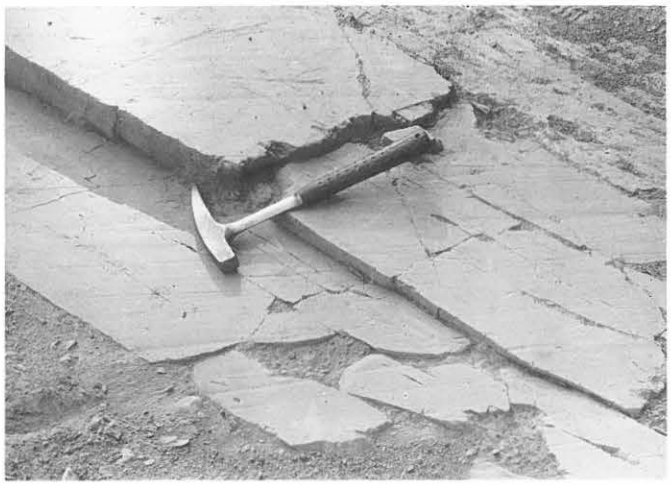

Figure 2. Postglacial offsets in glacially striated Flume Ridge Formation at locality 17, T27ED (photo from Thompson, 1981, p. 18).

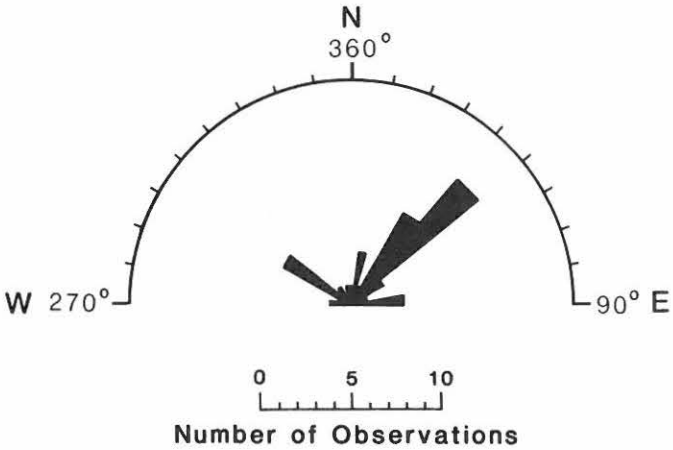

Figure 3. Plot of strike directions of fault planes.

site where the postglacial faults are not parallel to the foliation of the bedrock is that reported by Boone (1979) near Spruce Pond in Concord Township (site 9, Table 1).

The structural "grain" of Maine trends approximately N45E, and 72% of the observed fractures fall on or very close to that trend (Figure 3). Where there is a departure from the regional trend, the faults parallel the local structure. This is illustrated at Moxie Dam (site 8, described below), where the Carrabassett Formation is folded such that its strike differs by almost 30° from the regional trend. The postglacial faults at this locality are parallel to the local strike direction.

DESCRIPTIONS OF REPORTED FAULTS

Some of the postglacial bedrock faults are described below. These sites can be unequivocally located in the field. Other occurrences reported to the author, including those which are obscured by logging operations, could not be reoccupied and thus are not dicussed here.

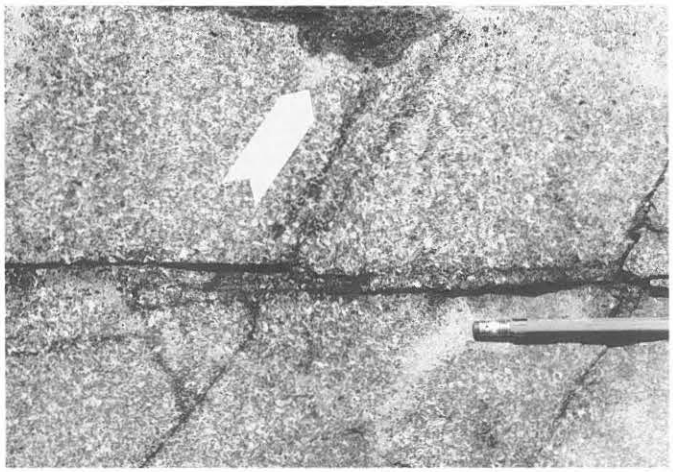

Figure 4. Left-lateral offset (approximately 1 cm) of fracture in diabase dike at Wadleigh Head in York (site 1). Arrow is 10-cm long and points north.

1: Wadleigh Head, York; reported by J. Rand

Glacial striations trending S55E and S45E are offset along a fracture striking N52E, which cuts a diabase dike trending N55E, intruded into the Kittery Formation. The northwest block is raised 0.6 to 1.3 cm. Fracture dips NW 68° to NW 72°. Striations are offset about 0.3 cm in same sense along a second fracture dipping 63° SE. Both dike and host rock are extensively jointed (Figure 4). Conclusion: offset is result of frost heaving.

4: Hopkins Island, Harpswell; reported by J. Rand

Glacial striations trending S30E are offset along N-trending fracture dipping 78° W, cutting foliation striking N5E in Cape Elizabeth Formation. West block is raised approximately 1.5 cm. Sheeting is common. A second, similar fracture is located about 2 m east, parallel to the first. Conclusion: offsets resulted from frost heaving in extensively fractured rock. However, in the report of the earthquake of 15 July 1905 (Rand, 1976b), a Captain Wallace describes "...a split in the ledge..." observed the following day near Phippsburg, approximately 3 miles east of Hopkins Island; the report is otherwise unconfirmed.

6: Orient, Amity quadrangle; reported by T. Brewer

Glacial striations trending S21E appeared to be offset along fracture trending N70E in unnamed sedimentary rock. Excavation showed that apparent fault is consequence of glacial plucking along joint.

8: Moxie Dam, East Moxie Twp; reported by N. Hatch

Glacial striations trending S25E are offset up to 3 cm along a complex of vertical fractures in Carrabassett Formation, trending

Figure 5. Offset in Carrabassett Formation at Moxie Dam, East Moxie Township (site 8). A small horst is seen in upper-center part of photo. Arrow points north.

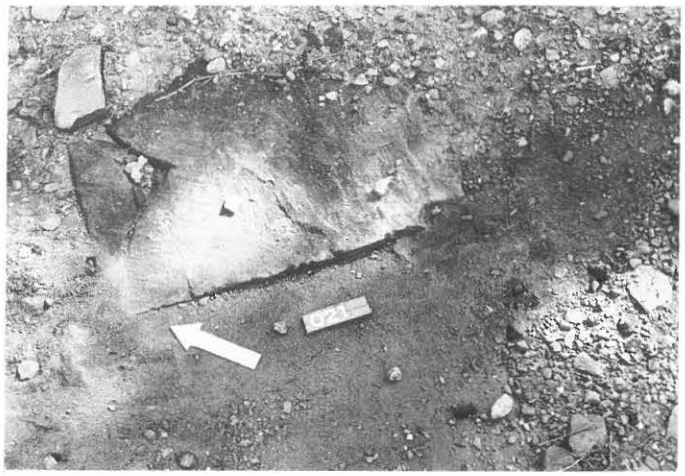

Figure 6. Apparent offset in Sangerville Formation at Industry (site 21). This feature is actually the result of glacial plucking along a N48W joint. 10-cm arrow points north.

N64E. Exposed faults are up to 16 m long, and extend beneath the dam. Figure 5 shows two parallel fractures with uplifted block between, bounded by joints. Sense of displacement is opposite on two major fractures. Conclusion: offset was produced by frost heaving along fracture systems and bedding planes.

9: Near Spruce Pond, Concord Twp; reported by G. Boone

Boone (1979) reported three closely-spaced thrust faults offsetting glacial striations in Smalls Falls Formation which strikes N15E and dips 85NW. Faults trend N10E, dip 40NW, and are offset about 15 cm along each fault, with the southeast sides raised. The locality is now concealed by forestry operations debris, but the description also applies to another locality located nearby. Displacement at this second locality is believed to result from frost heaving (see comments on locality 55, Hackett Hill).

21: Industry; reported by G. Boone

Glacial striations trending S17E are offset approximately 1 cm, with the south side raised, along bedding surfaces in the Sangerville Formation, which trend N57E. Corners of bedding surfaces are rounded and offsets appear to predate striations. An apparent offset occurs along a N48W joint, but excavation showed that this terminates and may have resulted from plucking (Figure 6).

22: Harmon Harbor, Georgetown; reported by J. Rand

Topographic offset along several small fractures in the Cape Elizabeth Formation, trending N80E. Examination shows these to be ancient fractures, now etched out by glacial and marine action. The outcrop surface does not retain striations or grooves in this area.

23: Fox Brook, T13 R9 WELS; reported by T. Lowell and W. Thompson

Glacial striations trending S53E are offset along bedding-plane fractures in the Seboomook Formation, which trend N35E, and along a cross-fracture trending N70E between bedding planes, with the northwest side raised. Cross-fracture is sharp-edged and terminates at bedding-plane fractures. Conclusion: displacement is probably the result of frost heaving, though some bedding-plane displacement may have resulted from expansion, as proposed by Lawson (1911).

55: Hackett Hill, Lexington Twp; reported by J. Briggs

Monolith in Perry Mountain Formation, trending N20E, dipping 82° NW. Block is offset 2 m along schistosity/bedding planes, bounded by joints (Figure 7). Upper surface of monolith shows weathered glacial grooves trending S50E, parallel to those on undisturbed adjacent outcrops. Monolith was originally 1.6 m wide at base, and 30 cm thick. A portion of the monolith about 40 cm wide has broken from the main mass and now lies on the ground. Conclusion: this is an exceptional example of frost heaving as described by Yardley (1951) in the Northwest Territories, and by Washburn (1969) in the Mesters Vig District of Greenland.

56: Mile 232.5, Route I-95, Medway; reported by D. Koons

Glacial striations trending S52E have been offset along bedding-plane fractures striking N40E, dipping 85NW, and by various

Figure 7. Hackett Hill monolith, site 55, Lexington Township.

cross fractures. The exposure is a road cut dating from recent construction of Interstate Route 95. Sub-horizontal sheeting extends from the surface to depth of approximately 2 m. Blocks of bedrock have detached along the sheeting fractures and shifted laterally toward the road excavations, indicating that the offsets postdate construction. Conclusion: the offsets resulted from recent and continuing frost action.

POSSIBLE CAUSES OF POSTGLACIAL FAULTS

Matthew (1894) discussed exposures of many small displacements in layered rocks near St. John, New Brunswick and concluded that the observed displacements were chiefly high-angle reverse faults caused by lateral pressure from the southeast. Woodworth (1907) reported that similar high-angle reverse faults in the slates near Troy, New York, were also the result of compression from the southeast. Lawson (1911) discussed postglacial faults in Archean slates near Banning, Ontario, reported to be parallel to the bedding, and described them as high-angle reverse faults, with the north sides upthrown. He suggested that the displacements resulted from volume changes, perhaps as a result of release from the load of the overlying ice, temperature changes, or hydration. Oliver and others (1970) in their discussion of postglacial faulting in New York and Quebec considered possible causes to fall into three categories: (1) surficial phenomena, including slumping and frost action; (2) regional phenomena, including expansion as a result of unloading or hydration, temperature changes, or absorption of gases; and (3) deep-seated tectonic forces. Sbar and Sykes (1973) accepted the analysis by Oliver and others and concluded, following Voight (1969), that the compressive stresses may be generated by the same mechanism that drives the large lithospheric plates. Rand and Gerber (1976) in their very detailed analysis of postglacial faulting on Sears Island (site 3) concluded that deformation resulted from glaciotectonic forces.

It is not clear to me that the many small fractures in Maine and elsewhere in the Northeast are the result only of regional compressive stresses, or in fact, that they result from any single cause. Sbar and Sykes (1973) found that the greatest principal stress is large, nearly horizontal, and trends east to northeast in a large part of eastern North America. Others (Matthew, 1894; Woodworth, 1907; Lawson, 1911) have identified the responsible stresses as coming from the southeast. It is interesting that the area of greatest crustal instability in Maine, reported by Anderson and others (1984) is one in which detailed study has so far revealed no postglacial faults in either layered or massive rocks (Gates, 1984; Ludman, 1985; Newman, 1984). Evidence of fractures related to tectonic forces seems to be restricted to a few occurrences such as Grand Falls (Tyler and Leick, 1985; Ludman, 1985).

All the postglacial fractures reported to me, and those cited by earlier investigators, occur in layered rocks. An apparent exception reported by Rand (1984) was located in pegmatite along Interstate Route 295 near Falmouth (site 2). Examination showed that the postglacial fractures originated at two shot-holes made during highway construction, and that subsequent movement resulted from frost action along these fractures. Another apparent exception, also reported by Rand (1984) as identified by Arthur M. Hussey II, was in a layered xenolith of the Rindgemere Formation within granodiorite near North Berwick (site 5). No displacement occurred within the host rock.

Wherever vertical sections of a meter or more are exposed, in rock of any lithologic type, sheeting joints which are subparallel to the local topography are found. On the east side of a hill the sheeting dips easterly; on the west side of the same hill, in the same formation, the sheeting dips westerly. The presence of small horsts between parallel offsets, as at Moxie Dam (site 8) and Fox Brook (site 23), the monolith at Hackett Hill (site 55), and the post-construction displacements along Interstate Route 95 at mile 232.5 (site 56) and elsewhere, indicate that recent frost heaving is a major cause of the faults documented in this report. Bedrock blocks are detached vertically along steeply dipping bedding planes or planes of schistosity, and horizontally along sheeting fractures subparallel to the surface, in the manner described by Yardley (1951) and Washburn (1969).

CONCLUSIONS

The fact that all postglacial faults reported in Maine are restricted to layered rocks, and that all are parallel to the local bedrock strike or joint systems rather than to the pattern to be

expected from the regional stress field, leads me to the conclusion that the fractures result chiefly from frost heaving or glaciotectonic effects in rocks broken by bedding, schistosity, and sheeting. Deep-seated tectonic forces may also have been involved, but I found no unequivocal evidence that such forces are required to produce the observed fault occurrences and distribution.

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