PALEOMAGNETISM OF SELECTED DEVONIAN AGE PLUTONS FROM MAINE, VERMONT, AND NEW YORK

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ABSTRACT

In order to better define the Devonian paleolatitude and cratonic pole position of North America, eight Devonian plutons were studied: the Black Mountain Granite (and associated rocks) from southern Vermont, the Hartland, Lexington, Center Pond, Chain of Ponds, Pleasant Lake, and Horserace units from Maine, and the Peekskill Granite located in southeastern New York. Of the eight units, the best results come from the Peekskill Granite of New York (age ~360Ma) and the Pleasant Lake Granite of Maine (age ~400Ma). The Peekskill yields a pole position of 117°E, 23°N, $\alpha_{95} = 16°$. This pole is identical to the pole from the earliest Carboniferous Deer Lake Formation from western Newfoundland, suggesting that the Peekskill Pluton has not suffered post emplacement rotation. However, the pole position is insufficiently precise to distinguish between rotation of one or both limbs of the Pennsylvania salient with respect to the craton in the Alleghenian orogeny or to evaluate the hypothesis that some portion of Newfoundland was offset from North America in the upper Devonian. Results from the Early Devonian Pleasant Lake Granite from Maine record a potentially Early Devonian magnetization with a pole position of 95°E, 2°N, $\alpha_{95} = 17°$. This magnetization suggests a paleolatitude of 42°S for the central Appalachians, consistent with results from the Early Devonian Andreas redbeds and so with the hypothesis that the Acadian orogeny resulted from collision of North and South America.

INTRODUCTION

The Paleozoic North American Apparent Polar Wander (APW) path has traditionally been defined largely by paleomagnetic results from the redbeds exposed in the folded central Appalachians. The reasons for reliance on these redbeds are simple: samples from these units have easily measurable magnetizations and the broad open folds of the Valley and Ridge provide an easily applied stability test in the form of a fold test. Recent restudy of the upper Ordovician Juniata (Miller and Kent, 1988), upper Silurian Bloomsburg (Kent, 1988), upper Devonian Catskill (Miller and Kent, 1986a & b), and lower Carboniferous Mauch Chunk Formations (Kent and Opdyke, 1985; Kent, 1988), sampled in the northern and southern limbs of the Pennsylvania salient, shows that the natural remanent magnetization (NRM) of these rocks is a composite of two magnetizations. One component which passes fold tests was acquired prior to the late Paleozoic Alleghenian deformation and may correspond with the rock age, while the second is a remagnetization acquired during the deformation (synfolding). The improved understanding of the synfolding remagnetization of the Appalachian redbeds and ostensibly better isolation of the prefolding magnetizations have provided a more complete view of the magnetization history of these units, but have also revealed new complications with the North American APW path.

One major complication revealed in the revised data from Appalachian redbeds relates to the formation of the curvature of the Pennsylvania salient. Contrary to the conclusions of previously published studies (Knowles and Opdyke, 1968; Schwartz and Van der Voo, 1983), the new results cited above from the central Appalachian redbeds now reveal good evidence for relative rotation of the northern and southern limbs of the Pennsylvania salient during the Alleghenian orogeny. The pre-Alleghenian magnetization declinations from the northern limb sites are on average 20° more clockwise than the declinations of the magnetization recorded in the southern limb in any of the thoroughgoing redbeds studied. The amount of rotation experienced by each limb with respect to the craton is however not known and thus is not possible to fully assess the applicability of Paleozoic paleomagnetic results from this part of the Appalachians as reference poles for the APW path for cratonic North America. Also, the rotational history of each limb with respect to the craton is

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important information for any structural analysis of how the salient formed.

A second problem relates to comparison of the revised results from the Catskill Formation (Miller and Kent, 1986a,b) and new results from the St. Lawrence Granite located in Newfoundland (Irving and Strong, 1985). An offset of Acadia some 20° south of its present location with respect to North America in the Late Devonian was hypothesized in the late 1970's based on comparison of paleomagnetic results from Late Devonian rock units from the craton and Acadia (Kent and Opdyke, 1978; Van der Voo et al., 1979). Central to this hypothesis were the results from the Catskill Formation redbeds which showed a near equatorial paleolatitude. Our restudy of the Catskill Formation revealed a previously unresolved component which predates Alleghenian folding and has an inclination indicative of a paleolatitude of 16°S±7° (Miller and Kent, 1986a,b). This is now consistent with the paleolatitude predicted for the Catskill outcrop area by the results from most of the Acadian rock units, hence requiring no offset of Acadia in the Late Devonian. However, the predicted Late Devonian paleolatitude on the basis of results from the St. Lawrence Granite is 35°S±9°. The Catskill and St. Lawrence data therefore suggest a latitudinal anomaly of 19°±12°. This discrepancy could be due to tectonic motions on either a regional (i.e., a latitudinal offset of part of Newfoundland some 20° south of its present position in the upper Devonian) or local scale (such as rotation of the St. Lawrence pluton about a horizontal axis). Another possible explanation could be that there is a sedimentary inclination error in the Catskill redbeds.

The pre-Alleghenian magnetization of the Catskill is likely to be either an early acquired chemical remanent magnetization (CRM) or a detrital remanent magnetization (DRM). While a CRM is thought to accurately record field direction, redeposition studies on modern hematitic sediments have shown that the inclination recorded in the DRM of the sediments (Io) is related to the true inclination of the magnetic field (If) by the relationship: $\tan(I_o) = 0.55*\tan(I_f)$ (Tauxe and Kent, 1984). Hence the observed mean inclination of the Catskill of ~-33° could have been flattened from a true field inclination of -50°. According to the dipole formula, the magnetization inclination provides a measure of paleolatitude through the relationship: $\tan[\text{inclination}] = 2 * \tan[\text{latitude}]$. So if the true field inclination of the Catskill deposition site were -50°, then the corresponding paleolatitude is 31°S, or approximately that recorded by the St. Lawrence.

Whereas the remanence of the redbeds might possibly be a DRM which may include an inclination error, any stable ancient remanence in plutonic rocks is likely to be a total or partial thermal remanent magnetization, associated with cooling of the unit below the Curie point of magnetite (~600°C), which should not record a shallowed inclination. In order to test the hypothesis that the Appalachian redbeds record a sedimentation inclination error, we sampled eight cratonic plutons which have radiometric age dates that suggest emplacement in the Devonian (408Ma to 360Ma, Harland et al., 1982). The reasons for sampling these plutons were that they are of comparable age to the Catskill and other Appalachian redbeds, but represent a very different tectonic setting and should have very different properties in recording ancient magnetizations. These units are located well away from the Pennsylvania salient and therefore could not have suffered any rotation associated with the formation of the salient. The units sampled were the Black Mountain Granite and associated rocks from southern Vermont, the Hartland, Lexington, Center Pond, Chain of Ponds, Pleasant Lake, and Horserace units from Maine, and the Peekskill Granite located in southeastern New York (Fig. 1; Appendix 1).

GENERAL GEOLOGY AND SAMPLING

Tectonic Setting

The Taconic orogeny in the northern Appalachians is manifested by involvement of the Cambro-Ordovician limestone and shale sequence in thrust sheets (Stanley and Ratcliffe, 1985) and widespread plutonism, with a peak in activity at about 440 Ma (Osberg, 1983) or roughly Late Ordovician (Harland et al., 1982). Also, Ordovician age metamorphism is preserved in eastern New York and western Vermont in the Green Mtn.-Sutton Mtn. Anticlinorium (Osberg, 1978). In the Silurian to Early Devonian the Merrimack Trough received shelf sediments and turbidites while the Piscataquis and Coastal Volcanic Arcs formed, the arcs presumably related to subduction on either side of the paleo-ocean now represented by the Merrimack Trough (Bradley, 1983).

The Devonian Acadian orogeny is also marked by widespread plutonism, more voluminous than of the Taconic, with a mean age of 380 Ma (Osberg, 1983; Middle Devonian according to the time scale of Harland et al., 1982). Additional Acadian features include intense deformation of pre-existing rocks and the formation of angular unconformities between Late Devonian and older units (Bradley, 1983). There are many tectonic models for the Acadian orogeny, most of which involve some form of continent/continent collision. In the model of Bradley (1983) the orogeny is described as the collision of two acretionary prisms, one of which was located to the east of the North American island arc represented by the Piscataquis volcanic zone, the other located to the west of Avalonia and represented by the Coastal volcanic zone. In this model, the Merrimack-Fredericton Trough system represents the paleo-ocean basin which was closed during the orogeny, perhaps driven by convergence of eastern North America and northwestern South America (McKerrow and Ziegler, 1972; Keppie, 1977; Miller and Kent, 1988).

Rifting in the Late Devonian and Early Carboniferous allowed localized clastic sedimentation in northeastern New England

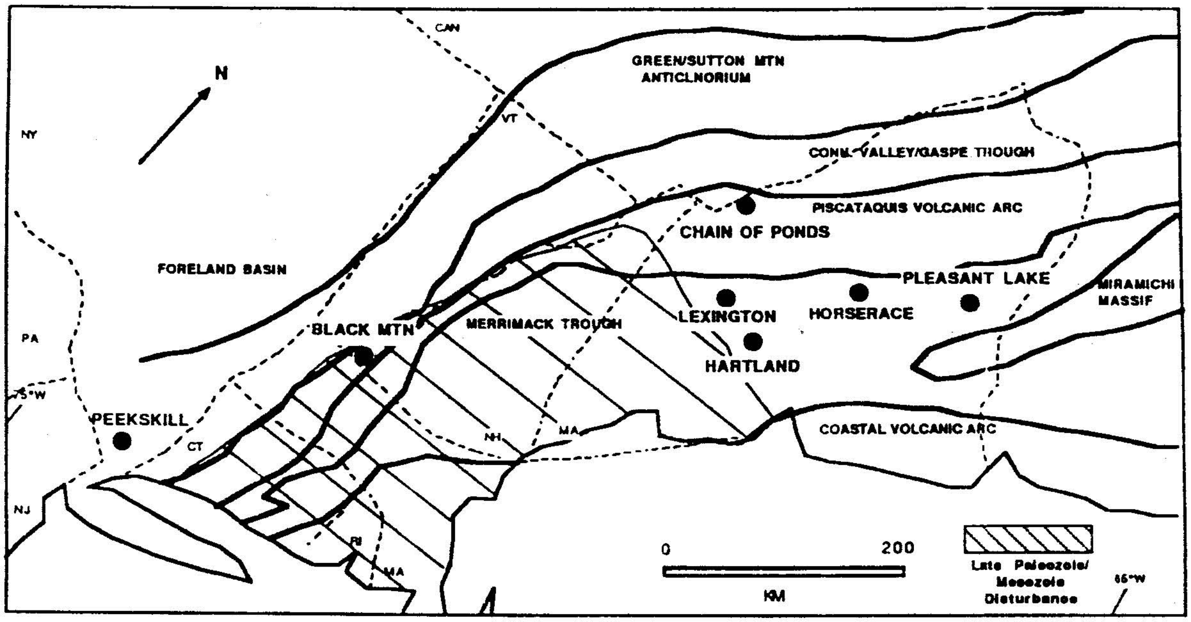

Figure 1. Location map showing locations of sampled plutons. Litho-tectonic terranes are those of Bradley (1983). Shaded area is zone of late Paleozoic and younger K/Ar ages from Zartman et al. (1970).

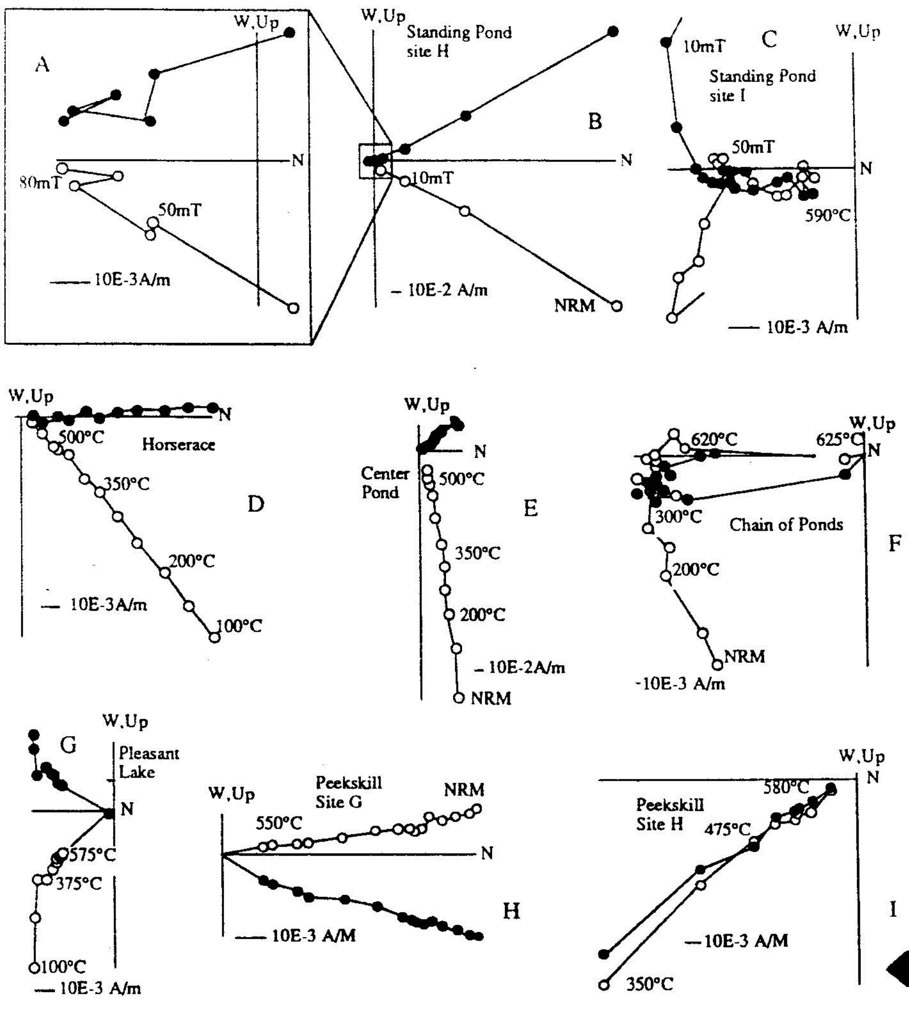

Figure 2. Representative Zijderveld diagrams. Open (closed) symbols are projection on vertical (horizontal) plane. A and B) removal of low coercivity component from sample of Standing Pond Volcanics with AF demagnetization and C) subsequent break down of high coercivity component from Standing Pond sample with thermal demagnetization. D and E) examples of demagnetization of present earth's field component from Horserace and Center Pond plutons. F) sample from Chain of Ponds with high unblocking temperature component. G) reversed polarity magnetization in sample from Pleasant Lake Granite. H and I) normal and reversed polarity (respectively) magnetizations from Peekskill Granite.

(Osberg, 1978). The main expression of the Alleghenian orogeny is an area of metamorphism in the southeastern area (Zartman et al., 1970).

Black Mountain Granite

The Black Mountain Granite, with an Rb/Sr date of 387Ma (Naylor, 1971), is located in the southeastern corner of Vermont along the border of the areas of Alleghenian and younger disturbance of K/Ar (mainly on biotite) ages defined by Zartman et al. (1970), thus making the thermal history of the unit somewhat suspect. However, the availability of outcrop and the geologic setting of the pluton provided strong reasons for sampling this unit since three lithologic types were easily available for sampling and study. The Black Mountain Granite intrudes the Siluro-Devonian Waits River metasediments and Standing Pond volcanics, both of which were sampled in close proximity to the pluton. Sites A-E (27 samples) were drilled in both the Waits River metasediments and interfingering granitic to pegmatitic dikes which presumably emanated from the Black Mountain Granite. Sites F-I (20 samples) were taken in the Standing Pond volcanics. Sites J-L (15 samples) were taken from an inactive quarry within the Black Mountain Granite.

Maine Granites

Samples were collected from 6 separate plutons in Maine in a reconissance sampling. The plutons were intruded into the sediments of the Merrimack trough and Piscataquis arc at various times throughout the Devonian. The Chain of Ponds pluton (4 sites/ 22 samples) has been dated at 375Ma (K/Ar-biotite; Zartman, 1970) and 372Ma (Ar/Ar-whole rock; D. Lux per. com., 1986). The Hartland Biotite Granite (2 sites/ 9 samples) yields dates of 363Ma (Ar/Ar-biotite/hornblende) and 360 (Rb/Sr) (Dallmeyer et al. 1982). The Horserace Quartz Diorite (4 sites/ 22 samples), which is part of the Katadin series, gives an Ar/Ar (biotite, muscovite, hornblende) date of 375Ma (Denning and Lux 1985), while the Pleasant Lake Granite (3 sites/16 samples) has been dated at 402Ma (Ar/Ar; Hubacher and Lux 1987). The Center Pond Granodiorite (4 sites/7 samples) and Lexington Granite (3 sites/ 16 samples) have been dated at 360Ma (Rb/Sr; Loiselle et al. 1983) and 400Ma (Rb/Sr; Gaudette and Boone 1985) respectively. In general, these Acadian plutons are tabular bodies which lack zoning, have low plagioclase content, initial Sr 87/86 ratios of .703 to .710, low CaO, and high SiO and have been interpreted as S-type granites (Wones, 1980).

Peekskill Granite

The Peekskill Granite is a post-Taconic grano-diorite which lies near the town of Peekskill, NY; a general description of the pluton is given by Mose el al. (1976). A total of 6 sites (36 samples) were drilled from the pluton. Mose et al. (1976) report whole rock Rb/Sr values which indicate an age of 371Ma, similar to the value of 356Ma reported by Long and Kulp (1962) based on K/Ar (muscovite) measurements. Nearby (but removed from the contact aureole of the pluton) metamorphic rock units known as the Manhattan Schist and Inwood Marble yield similar K/Ar (biotite) ages (Long and Kulp, 1962). One site (5 samples) was collected in the schist and 2 sites (10 samples) were collected in the marble.

PALEOMAGNETIC RESULTS

Procedures

Oriented cores were collected using a hand-held gasoline powered drill, Brunton compass, and inclinometer. At some locations, block samples were taken from which specimens were later cored. Specimens were demagnetized using standard progressive thermal and alternating field (AF) demagnetization techniques. Magnetic susceptibility of the samples was measured during thermal demagnetization in order to monitor magnetochemical alteration. All samples were measured using an ScT cryogenic magnetometer. Component magnetizations revealed in Zijderveld (1967) diagrams were calculated using least-squares line fitting (Kirschvink, 1980). Statistical parameters were calculated using standard Fisher (1953) statistics.

General Results

Remanent intensities for the granites were highly variable, some samples having barely measurable components while other samples having very strong, easily measured magnetizations (Table 1). Most samples were completely demagnetized by 600°C to thermal treatment and could be effectively cleaned at peak AF levels of <100MT, suggesting magnetite as the carrier of remanence. Some samples from the Pleasant Lake and Chain of Ponds units were not unblocked below temperatures of 630°C, perhaps suggesting that part of the remanence of these units is carried by hemo-ilmenite.

Black Mountain Granite

Samples from the Black Mountain Granite itself had weak, unstable remanences. The magnetization of the Waits River Formation was easily measurable but unstable and these samples exhibited no consistent vector removal during demagnetization.

Samples from the Standing Pond Volcanics had more interpretable demagnetization behavior. Samples from site F were characterized by nearly univectorial decay to the origin with the sample directions generally directed to the north and down, roughly consistent with acquisition in the present earth's field. Site G was characterized by samples which lacked consistent demagnetization behavior, however samples from sites H and I consistently exhibited subtle but distinct two component decay during demagnetization (Fig. 2). A low coercivity component was most easily removed through AF demagnetization and was directed to the north with a great deal of scatter (Fig. 3). This component is almost random with a k value of only 2.8. Grouping for the low coercivity component does not improve in the sample coordinate frame and so the component would not appear to have been induced by sample preparation. AF demagnetization was sufficient to isolate but not break down the high coercivity component, which could however be unblocked through thermal demagnetization

Table 1. Devonian Intrusive Data Summary

Unit	Age	method	Ref	Si/Sa	NRM	Notes
Center Pond	360	Rb/Sr	8			
Granodiorite				4/7	20.890	High intensity PEF magnetization
Hartland	363	Ar/Ar	3			
Biotite Gr.	360	Rb/Sr	3	2/9	1.598	Unstable magnetization
Peekskill	365	K/Ar	5			
Granite	371	Rb/Sr	6	6/36	0.165	D/I = 169.4°/43.4° (k = 7, n = 15, α 95= 15.9°) Pole 117°E, 23°N (α 95=16°)
Chain of Ponds	375	K/Ar	1			
Biotite Gr.	372	Ar/Ar	2	4/22	0.168	Low coercivity component (PEF) High coercivity component (Permian?) D/I = 175.1°/-0.4° (k = 137, n = 3, α 95= 10.6°) pole 116.9°E, 45°N (α 95 = 8°)
Horserace	375	Ar/Ar	4			
Qtz. Diorite				4/22	6.506	High intensity PEF magnetization
Black Mt.	383	Rb/Sr	10			
2-mica Gran.				3/15	0.008	Very weak magnetization
Waits River				5/27	0.194	Unstable magnetization
Standing Pond				4/20	4.658	Low coercivity component (Random?) High coercivity component (Permian?) D/I = 169.7°/-1.7° (k = 21.3, n = 7, α 95= 13.4°) pole 122.7°E, 46.9°N (α 95 = 11.2°)
Lexington	400	Rb/Sr	9			
Granite				3/16	0.010	Very weak magnetization
Pleasant Lake	402	Ar/Ar	7			
Granite				3/16	0.468	D/I = 203.0°/59.0° (k = 22, n = 6, α 95= 15°) pole 95°E, 2°N (α 95 = 17°)

Notes. Ages in Ma. References: 1-Zartman, 1970, 2-Lux per. com., 1986, 3-Dallmeyer et al. 1982, 4-Denning and Lux 1985, 5-Long and Kulp 1962, 6-Mose et al. 1976, 7-Hubacher and Lux 1987, 8-Loiselle et al. 1983, 9-Gaudette and Boone 1985, 10-Naylor 1971. Si/Sa is sites/samples. NRM is median NRM intensity in 10E-2 A/m. PEF is present earth's field. D/I is declination/inclination, k is Fisher's precision parameter, n is number of samples, α 95 is radius of circle of confidence.

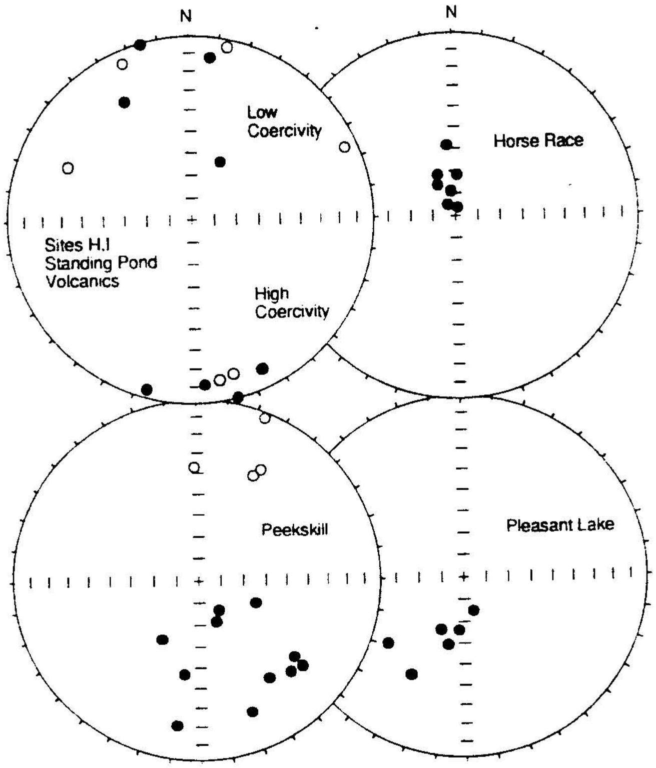

Figure 3. Sample component directions plotted on a stereographic projection. Letters indicate site. Upper (lower) case is projection on upper (lower) hemispheres.

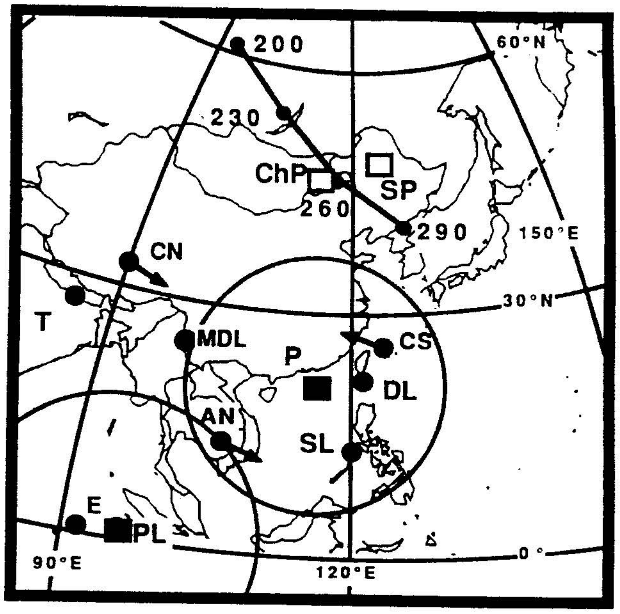

Figure 4. Paleomagnetic poles. Numbered points are average ages (Ma) of NAAPWP from Irving and Irving (1982). P is pole from Late Devonian Peekskill pluton, PL is pole from Early Devonian Pleasant Lake Pluton. Confidence envelopes are calculated at 95% level. SP is pole from Standing Pond Volcanics. ChP is pole from Chain of Ponds. CN and CS are the poles from the Late Devonian Catskill redbeds from the northern (N) and southern (S) limbs of the Pennsylvania salient (Miller and Kent, 1986a, 1986b). MDL and E are the poles from the Early Devonian Peel Sound Formation of the Canadian Arctic (Dankers, 1982). AN is from the Andreas redbeds Miller and Kent (1987). SL is pole from St. Lawrence Granite (Irving and Strong, 1985). DL is cratonic pole from Tournasian Deer Lake Formation (Irving and Strong, 1984). Arrows show direction poles would move if correction were made for oroclinal rotation of Pennsylvania salient.

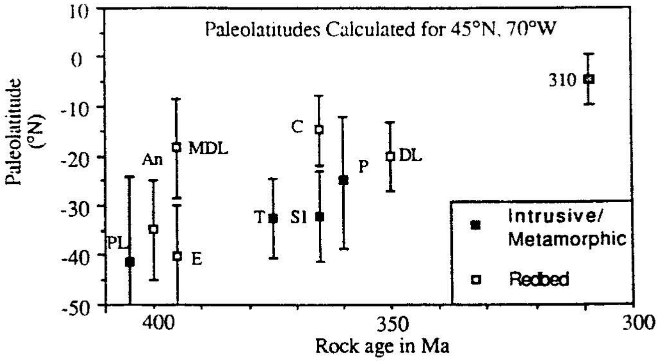

Figure 5. Paleolatitudes predicted for 45°N, 70°W from selected paleomagnetic poles. Abreviations same as Fig. 4.

to 600°C. The high coercivity component is consistently directed to the south with shallow inclination with a mean direction of declination/ inclination (D/I) = 169.7°, -1.7° (k = 21.3, R = 6.7184, n = 7 samples, α95= 13.4°) and an associated pole position of 122.7°E, 46.9°N (A 95 = 11.2°).

Maine Granites

The magnetization of samples from the Hartland Granite is characterized by variable intensity and lack of a consistent direction. The samples from the Lexington Granite have an extremely weak magnetization (Table 1). This stone would be the logical choice of any builder of zero remanence homes. The Center Pond Pluton and the Horserace Quartz diorite both had easily measurable remanences which were totally dominated by an overprint of the present earth's field (Fig. 2). The Horserace in particular exhibited extremely high fidelity in recording the present earth's field. The mean direction for 7 sample demagnetizations of 346.7°/70.1° (α95 = 9.6°, k = 40.7) is not statistically distinguishable from the expected present earth's field direction of 342°/71°.

The Chain of Ponds Granite exhibited a demagnetization behavior which was similar to that of the Standing Pond Volcanics in that there were sometimes two components of magnetization with the lower unblocking temperature and coercivity component being highly scattered and the higher unblocking temperature and coercivity component being southwesterly and shallow. Sample demagnetizations were not as consistent for the Chain of Ponds as they were for the Standing Pond and the high coercivity component could only be isolated in 3 out of 21 samples. The mean direction for the high coercivity magnetization is 175.1°/-0.4° (α95 = 10.6) which corresponds to a pole position of 116.9°E, 45°N.

The Pleasant Lake Granite showed the most promise of the units sampled in Maine as a possible recorder of a Devonian magnetization. Ten of the 16 samples were unstable, but the remaining 6 samples from sites B and C revealed magnetizations which were directed to the south with positive (down) inclinations during AF and thermal demagnetization (Fig. 2,3). The mean direction for these samples of 203°/59° (k = 22.1, α 95 = 14.6°).

Peekskill Granite

Thermal demagnetization was judged to be more effective than AF in separation of components of magnetization in the Peekskill and so was employed for most of the samples. All samples from sites F were rejected due to highly scattered directions of magnetization. Sites I and K had mixed normal and reversed polarity samples. The presence of dual components in one site was interpreted as indication of a complex magnetization history for these sites and resulted in the rejection of sites I and K from our best estimate of the mean Peekskill magnetization. One sample from each of the 4 remaining sites were rejected due to the absence of straight line segments on Zijderveld diagrams. The grouping of the directions for the 15 remaining samples is not overwhelmingly good with k equal to only 6.8, but a mean magnetization direction of 169.4°/43.4° (α 95 = 16°) is indicated.

Samples from the Inwood Marble and Manhattan Schist gave random, spaghetti-like Zijderveld demagnetograms.

DISCUSSION

A general problem with this data set is that plutons do not possess paleohorizontal indicators. We originally hoped that we could exclude the possibility that individual plutons have suffered local tilting, a problem with any igneous intrusion (e.g., St. Lawrence Granite, Irving and Strong, 1985), by regional sampling of different plutons of similar age. However, poor results from most of the units sampled did not allow us to evaluate the possibility of local rotations and to average out the effects, if any, of said rotations.

Magnetization ages

In any paleomagnetic study, identifying the age of the magnetization components is one of the primary objectives. Unlike folded sedimentary rocks which allow magnetization age constraint through the application of the fold test, there is often no easily applied field stability test with samples from an igneous body. Instead, indirect arguments must be made based on evidence such as radiometric age dating and comparison with other paleomagnetic data to infer the thermal and magnetization history of a unit. Rb/Sr dates may reflect the emplacement age of a unit but not identify any periods of later heating which may have reset the magnetization. The best radiometric age tool from the standpoint of paleomagnetics is incremental Ar/Ar study which gives sensitive thermochronometric constraints. However, calibration between Ar/Ar plateaus and magnetization components requires further work. Even mild heating events which produce only small changes in the Ar/Ar record may be sufficient to dramatically change the magnetization of the rock (e.g. Noel et al., 1988).

The observation that the high coercivity component pole positions from the Standing Pond Volcanics and Chain of Ponds Pluton magnetizations fall on the Permo-Carboniferous portion of the North American APW path (Fig. 4) suggests that these units either suffered a chemical remagnetization event in the Permo-Carboniferous or, perhaps more likely, that the area around these units was experiencing elevated temperatures at this time. The thermal activation properties of magnetite are currently poorly understood (e.g. Kent, 1985), so it is difficult to estimate, for example, whether this magnetization indicates a slow cooling following a Devonian emplacement for the Black Mountain Granite (Naylor, 1971), a younger date of emplacement (Lyons and Livingston, 1977), or the effects of general Permian reheating (Zartman et al., 1970).

The close correspondence of the Peekskill pole to the pole from the Tournaisian Deer Lake Formation (Irving and Strong, 1984) suggests that the Peekskill magnetization may be close to the late Devonian age of the rock

(Fig. 4). The Peekskill pole is also similar to the results obtained by Hurley and Shearer (1981) from a set of Devonian igneous bodies sampled in Massachusetts although these units outcrop in the area of possible Permian disturbance of Zartman et al. (1970) and were not subjected to progressive demagnetization. The Peekskill pole is, however, significantly different from the pole (48°N, 147°E, dp = 7°, dm = 13°: Ashwal and Hargraves, 1977) obtained from the Belchertown Pluton (380±5my: U-Pb) sampled in Massachusetts. The Belchertown magnetization was originally interpreted as evidence for a post-Devonian rotation of middle Massachusetts, but the close correspondence of the Belchertown pole to late Paleozoic North American poles suggests that this magnetization was reset near the time of the K/Ar disturbance.

The similarity between the poles from the Andreas redbeds (Miller and Kent, 1988) and Pleasant Lake Pluton suggests that both of these magnetizations are Early Devonian as implied by the ~400Ma Ar/Ar age of the Pleasant Lake. The relatively promising result from the few samples of the Pleasant Lake Granite which we report would support further sampling but to our knowledge we have sampled most, if not all, of the available suitable outcrop.

The magnetization of the Early Devonian Peel Sound Formation redbeds of the Canadian Arctic has been characterized as composed of two components from which are derived two pole positions: the MDL pole and E pole (Dankers, 1982). The MDL magnetization was originally described as the primary, possibly Early Devonian magnetization and the E pole as a Late Devonian remagnetization, although there were no direct stability tests to support these conclusions. The observation that the pole position derived from the Pleasant Lake directions is similar to the pole from the Andreas redbeds and the E pole of Dankers (Fig. 4), and that the MDL pole falls close to the revised Late Devonian Catskill poles, support the reinterpretation that the E magnetization is actually the primary component and the MDL magnetization is a Late Devonian remagnetization. Similarly, the observation that the composite pole from the Traveler Terrane (Traveler Rhyolite: Spariosu and Kent, 1983; Compton Metasediments: Sequin et al., 1982; Dockendorf Group: Brown and Kelly, 1980) falls near the Catskill pole from the northern limb of the salient suggests that the magnetization age of these units is also Late Devonian.

Regional rotations

The close correspondence of the Peekskill pole to the pole from the Tournaisian Deer Lake Formation (Irving and Strong, 1984) suggests that the pluton has not been rotated relative to the craton of North America since the Carboniferous. If this is true, then the observation that the pole from the Catskill sampled in the southern limb of the Pennsylvania salient falls within the 95% confidence envelope of the Peekskill pole position could suggest that the southern limb of the salient suffered less rotation relative to the craton than did the northern limb. However, rotation of the Andreas magnetization, which outcrops on the northern limb of the Pennsylvania salient, by even half of the amount needed to correct the observed declination anomaly around the salient would move it out of the 95% confidence envelope of the Pleasant Lake pole.

A possible rotation of the outcrop area of the Pleasant Lake pluton (and the other Maine plutons, but not the Peekskill pluton) has been proposed based on the paleomagnetism of the units which were grouped in the Traveler Terrane (Spariosu and Kent, 1984). The proposed rotation would have rotated any Early to Middle Devonian magnetizations in these units clockwise. The hypothesis that the Traveler Terrane was rotated in the Late Devonian was originally based on comparison of the Traveler composite magnetization (which was assumed to be Early Devonian in age) with the paleomagnetic results from the Late Silurian Bloomsburg redbeds (Roy et al., 1967). As discussed above, the age of the Traveler magnetization is more likely to be Late Devonian, but the close correspondence of the Traveler pole to the pole from the Catskill sampled in the northern limb of the Pennsylvania salient and the position of the Traveler pole to the west of the MDL pole may suggest that the rotation hypothesis is still valid; up to 15° of clockwise rotation of the Traveler Terrane is allowed by the currently available data. If the Traveler Terrane has been rotated as suggested by Spariosu and Kent, then the restorative rotation of the Pleasant Lake and Andreas poles would move both poles in the same direction, allowing for oroclinal rotation of the Andreas magnetization.

Latitudinal history

A broad scale regional rotation such as proposed for the Traveler Terrane would effect the declination of the plutons but not the measured inclination and therefore not the indicated paleolatitude. Translation of the pole positions previously discussed into predicted paleolatitudes allows the latitudinal drift of New England to be graphically displayed (Fig. 5). The general trend suggested by the data is one of northward drift from about 40°S in the early Devonian to near the equator by the end of the Carboniferous.

The Peekskill magnetization suggests a paleolatitude for the central Appalachians of 25°S±12°. The Peekskill paleolatitude is diplomatically consistent with paleolatitudes suggested by both the Catskill (16°S) and St. Lawrence (35°S). The Peekskill result therefore does not allow for any differentiation between the possibilities that the Catskill records an inclination which is too shallow or that part of Newfoundland was offset south of its present position with respect to North America in the upper Devonian. However, the paleolatitude that the Pleasant Lake magnetization suggests of 40°S±17° for the northern central Appalachians is consistent with the 35°S paleolatitude which is predicted by the result from the Early Devonian Andreas redbeds (Miller and

Kent, 1988). The observations that the paleolatitude corresponding to the mean Pleasant Lake magnetization is similar to the paleolatitude of the Andreas, and that the Peekskill paleolatitude is similar to the Catskill results suggest that there is no significant shallowing of the remanence vector in the redbeds and therefore that the prefolding remanence in these redbeds may be an early acquired CRM.

The paleomagnetic result from the Andreas redbeds has been interpreted as providing support for McKerrow and Zeigler's (1972) hypothesis that the Acadian orogeny resulted from a collision of eastern North America and northwestern South America (Miller and Kent, 1988). The similarly high southern paleolatitude observed in the Pleasant Lake Granite is therefore also consistent with this model.

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Appendix 1. Site locations.

Hartland (44.8°N,69.6°W): A - outcrop in small creek, and B - quarry, off Devils Head Road.

Lexington (44.8°N, 70.1°W): A - 1.5 miles south, B - 3 miles north, C - 4 miles north, of North New Portland on state road 16.

Chain of Ponds (45.3°N,70.7°W). All sites on route 27 measured in miles southeast of US/Canadian border. A - 1, B - 1.6, C - 1.5, D - 7.6.

Pleasant Lake (46.1°N, 68.2°W). A - quarry north of lake on S. Oakfield road, B, C - outcrops in home owner's yards (used with permission) off Walker Road.

Horserace (45.9°N, 69.1°W). A to D - set of outcrops 4 miles south of Ripogenus Dam on West Branch of Penobscot River.

Center Pond (45.4°N, 68.4°W). A to D - outcrops along route 6 west of Lincoln.

Black Mountain (42.9°N, 72.6°W). A-E = Waits River, F-I = Standing Pond Volcanics, J-L = Granite. A,B,C - Outcrop 0.2 miles north of small metal bridge over west river on route 30. D-E 0.1 mile north of A on 30. F,G - Unnamed road just east of pluton, outcrop in small stream, granite dikes visible in road ~50meters north of outcrop. H,I outcrop 0.5 miles west of Dummerston Center. J,K,L - granite quarry just opposite West Dummerston.

Peekskill (41.3°N, 73.9°W). F - outcrop on Stony Rd. south of Quarry Dr., G - Bear Mountain Expressway just east of junction with US6,. H - Junction Maqua and Mongul Drives, I - 20 meters west of H, J Dale and Sylvan Streets, K - east side of quarry located south of Crompond Rd. and east of Cronton Av. Note: sites A to E were sampled by DVK in the small quarry north of Crompond road. These samples were too weakly magnetized to be measured on the Digico magnetometer which was available at that time.

Inwood Marble (near Peekskill). A - 0.1 mile north of Peekskill exit on Taconic Parkway. B - junction of NY100 and NY 120.

Manhattan Schist (south of Peekskill). A - NY129 and Hunter Brook Rd.

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