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GEOCHRONOLOGIC STUDIES IN MAINE—PART III: Rb-Sr GEOCHRONOLOGIC STUDY OF THE ELLSWORTH SCHIST, MAINE, AND COMPARISON WITH THE COLDBROOK GROUP, NEW BRUNSWICK

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Twelve whole-rock samples of the Ellsworth Schist, Maine, yield an isochron age of 510 ± 10 m.y. with initial $^{87}Sr/^{86}Sr$ = 0.7072 ± 0.0011. This Cambro-Ordovician age is very different from the suggested 778 ± 80 m.y. date recommended for the Coldbrook Group volcanics of New Brunswick (Cormier, 1969). A direct comparison of data for both the Ellsworth and the Coldbrook is impossible, largely due to lack of petrographic control for the latter. The Coldbrook Group is late Precambrian based on geologic evidence, whereas the Ellsworth Schist is pre-Middle Silurian based on geologic evidence and probably Cambro-Ordovician based on current geochronologic evidence.

THE ELLSWORTH SCHIST

This formation(?) is highly foliated and schistose; it crops out from near Ellsworth, Maine, northward to the Machias quadrangle. The following references contain detailed descriptions of the Ellsworth Schist: Gilman (1961), MacGregor (1964), Smith and others (1907), Stewart (1956), and Wingard (1961). Thicknesses from 22,000 feet (Stewart, 1956) to 25,000 feet (Wingard, 1961) have been assigned to the Ellsworth Schist, although the exact thickness is uncertain.

The Ellsworth Schist has been divided into three parts: lower, middle, and upper. The lower part consists of metamorphosed interbedded agglomerate, tuff, andesite, latite, quartz latite or rhyolite, and occasional impure quartzites. Metamorphosed agglomerate is characteristic of the lowermost portion and noticeably absent in the uppermost portion of the lower part. The agglomerates and tuffs are characterized by matrix consisting primarily of chlorite-quartz-biotite-alkali feldspar ± hematite that could have formed from either pre-existing ash or clay. Large masses of calcite are occasionally present in the groundmass; its presence may be due to recrystallization of a calcareous tuff or it may reflect postformational calcite invasion. Wingard (1961) has suggested that many of the tuffs in the Ellsworth Schist are water-laid varieties. In general, the fine-grained tuffaceous rocks are fissile and the coarser grained rocks are massive. Near the Sedgwick granite (Wingard, 1961) the Ellsworth rocks have been metamorphosed to hornfels; typical samples contain finely disseminated biotite, cordierite, quartz, ± anthophyllite ± oligoclase. These rocks are commonly layered although highly distorted with a few nonlayered, granoblastic rocks found as well.

The middle part makes up 90% of the Ellsworth Schist and consists of a monotonous series of pleitic schists, quartzite, and gneiss with minor flows of amphibolite. Near intrusive contacts the schists are changed to gneiss and hornfels while the flows change to feldspathic schist and gneiss. While the lower part is characterized by pyroclastic rocks and flows, the middle part is a well-foliated greenschist, feldspathic schist, and quartzite. The schists commonly contain fine-grained sericite, chlorite, feldspar, quartz with accessory amounts of talc, epidote, graphite, magnetite, and pyrite. They range from chlorite-quartz greenschists to impure quartz-feldspar schists. Feldspathic schists have been derived from either flows or from feldspar-rich silt and (or) clay. Secondary calcite, epidote, and chlorite are common. Amphibolites from the middle part are pre-metamorphism in age (Wingard, 1961) and probably derived from sills or flows. Impure quartzites are common in the middle part and range from light to dark green, argillaceous, quartzose rocks. These rocks contain up to 35% feldspar in places, suggesting origin from arkoses; for low feldspar varieties parent graywacke is probable. Conglomeratic quartzites are not overly abundant but are found sporadically distributed within the middle part. Cordierite, anthophyllite, and sillimanite are common in the contact metamorphosed rocks of the middle part.

The upper part of the Ellsworth Schist is found on Deer Isle and consists of feldspathic gneisses and schists, andesite, and greenstones, with occasional interbedded tuffaceous rocks.

THE COLDBROOK VOLCANICS

The Coldbrook Volcanics have been described by Hayes and Howell (1937) and Alcock (1940); only a short description will be presented here. The outcrops of the Coldbrook are extensive (Cormier, 1969, fig. 1) and thicknesses for the Coldbrook range from 18,000 to 35,000 feet (Alcock, 1940). The Coldbrook Volcanics have been assigned a late Precambrian age as they are unconformably overlain by Cambrian sedimentary rocks of the Saint John Group and pebbles of water-worn Coldbrook rocks are found in the basal conglomerate of the Saint John Group.

The lithologies present in the Coldbrook have not been reported in great detail; most of the descriptive material is to be found in Hayes and Howell (1937) and Alcock (1940). The volcanics consist of acidic to basic flows, tuffs, and breccias, all of which are commonly associated with tuffaceous sedimentary rocks, schists, and phyllites. Many of the rocks are very dense and fine grained; in thin section the more acidic varieties show phenocrysts of albite, quartz, and K-feldspar in a microcrystalline groundmass. Secondary minerals are common and include calcite, dolomite, zoisite and epidote; secondary quartz is also present. Sedimentary and meta-sedimentary rocks are commonly interbedded with the volcanics; these usually contain an abundance of volcanic-derived lithic fragments.

SAMPLES USED FOR GEOCHRONOLOGIC STUDY

Although some seventy samples were originally collected from various parts of the Ellsworth Schist, only twelve were selected for geochronologic study. Approximately ten of those discarded were virtually identical in Rb/Sr while roughly fifty were discarded because of the presence of calcite or other secondary minerals. This precaution is necessary because many calcite-bearing samples are not suitable for geochronologic study (Brookins and others, 1973, p. 1626, fig. 6). There is apparently no reliable way to distinguish between those samples that contained calcite at the time of formation opposed to those to which calcite is added later. With this in mind the reader is advised that the samples used both by Cormier (1969;

p. 395) and by Fairbairn and others (1966; p. 510) for the Coldbrook Volcanics (for the problem of possible Coldbrook:Ellsworth correlation) were not studied in thin section, and it is impossible to ascertain if unsuitable samples were included in either study. Certainly the scatter in data in both works is such that this aspect should be investigated further.

The twelve samples used for this study include a variety of calcite-free metavolcanics (dacitic and latitic tuffs and greenstones) and two contact metamorphosed felsic tuffs. A brief description of each sample is given in table 1.

ANALYTICAL PROCEDURES

Rb and Sr contents and Sr isotopic compositions reported in table 2 were obtained by standard methods. Sr isotopic composition was determined from both spiked and unspiked samples; agreement between runs using each method is ± 0.0003 (95% confidence level). All isotopic ratios are based on $^{86}Sr/^{88}Sr$ = 0.1194 and $^{87}Sr/^{86}Sr$ for Eimer and Amend standard $SrCO_3$ = 0.7080. Total Rb and Sr were determined by standard isotope dilution techniques using ^{87}Rb-, ^{86}Sr-, and ^{84}Sr- enriched spikes or by replicate x-ray fluorescence spectrography using G-1, G-2, GSP-1, and BCR-1 as standards (depending on rock type). The $^{87}Rb/^{86}Sr$ data in table 2 are precise to ± 0.3% (95% confidence level). The decay constant for ^{87}Rb is taken as 1.42×10^{-11}/y. The isochron (fig. 1) was calculated from data of table 2 using the least squares method of York (1969). The error margin for the age is based on one standard deviation.

DISCUSSION AND CONCLUSIONS

It is difficult, if not virtually impossible, to compare the present study of the Ellsworth Schist with the studies of the Coldbrook Volcanics by Cormier (1969) and by Fairbairn and others (1966) due primarily to lack of petrography reported in the later studies. As the study by Cormier (1969) includes more data than that by Fairbairn and others (1966), Cormier's study will be discussed with the present study. Cormier has grouped the data for massive varieties of the Coldbrook Volcanics into eleven subgroups based on different ranges in $^{87}Rb/^{86}Sr$. Five of these groups (Cormier, 1969, table II, nos. 7–11; not nos. 1–5) with $^{87}Rb/^{86}Sr \lesssim 1.0$ yield an apparent isochron age of 750 ± 80 m.y. (note: $\lambda = 1.47 \times 10^{-11}$/y) while the remaining data yield an apparent isochron age of 370 ± 38 m.y. Without petrography or other supportive means it is difficult to justify this arbitrary cutoff point at $^{87}Rb/^{86}Sr$ = 1.0; further, the suggestion that samples with $^{87}Rb/^{86}Sr$ > 1.0 may have been open systems while those with ratios less than 1.0 not so affected is also difficult to accept. As high Sr contents are the rule rather than the exception for

TABLE 1. Sample locations and brief descriptions.

Sample	N. latitude	W. longitude	Descriptions
Mel9	44°17′	68°40.5′	Dacite tuff. Fine-grained, felsic volcanic.
Mel77	44°18′	68°37.0′	Greenstone. Highly crenulated volcanic with quartz and feldspar phenocrysts in microlitic groundmass.
Mel78	44°18′	68°37.9′	See Mel77.
Mel80b	44°18′	68°37.9′	Felsic tuff. Very fine-grained tuff with some quartz and feldspar phenocrysts in matrix of microlites of quartz, feldspar, and some devitrified glass.
Mel81a-Mel81b	44°17′	68°37.2′	Latite tuff. Quartz and feldspar microphenocrysts in microlitic groundmass; some devitrified glass.
Mel83	44°18′	58°31.8′	Fissile greenstone. Very quartz-rich metavolcanic; some feldspar phenocrysts. Microlitic groundmass with some minor chlorite, magnetite, pyrite.
Mel85b	44°18.3′	68°37.4′	Similar to Mel81a,b.
Mel86	44°23′	68°34.1′	Felsic tuff. Plagioclase phenocrysts in microlitic groundmass; some cordierite, biotite, garnet.
Mel88	44°29.8′	68°32.5′	Contact metamorphosed felsic tuff. Plagioglase, cordierite, biotite in recrystallized, very fine grained groundmass.
Mel89	44°29.7′	68°31′	Similar to Mel88.
Mel91	44°29.7′	68°25.5′	Dacitic greenstone. See Mel77.

TABLE 2. Ellsworth Schist

Sample	$^{87}Sr/^{86}Sr$	Rb(ppm)	Sr(ppm)	$^{87}Rb/^{86}Sr$
Mel9	0.7243	18	19.7	2.64
Mel77	0.7457	152.0	80.3	5.51
Mel78	0.7475	210.2	107.8	5.68
Mel80b	0.7272	109.0	115.9	2.73
Mel81a	0.7910	191.2	44.7	12.50
Mel83	0.7353	79.0	58.5	3.92
Mel88	0.7407	193.8	116.7	4.82
Mel89	0.7417	287.0	164.0	5.08
Mel85b	0.7114	18.1	164.5	0.32
Mel91	0.7163	110.1	333.6	0.96
Mel86	0.7165	72.0	135.8	1.53
Mel81b	0.7970	194.7	48.9	11.61

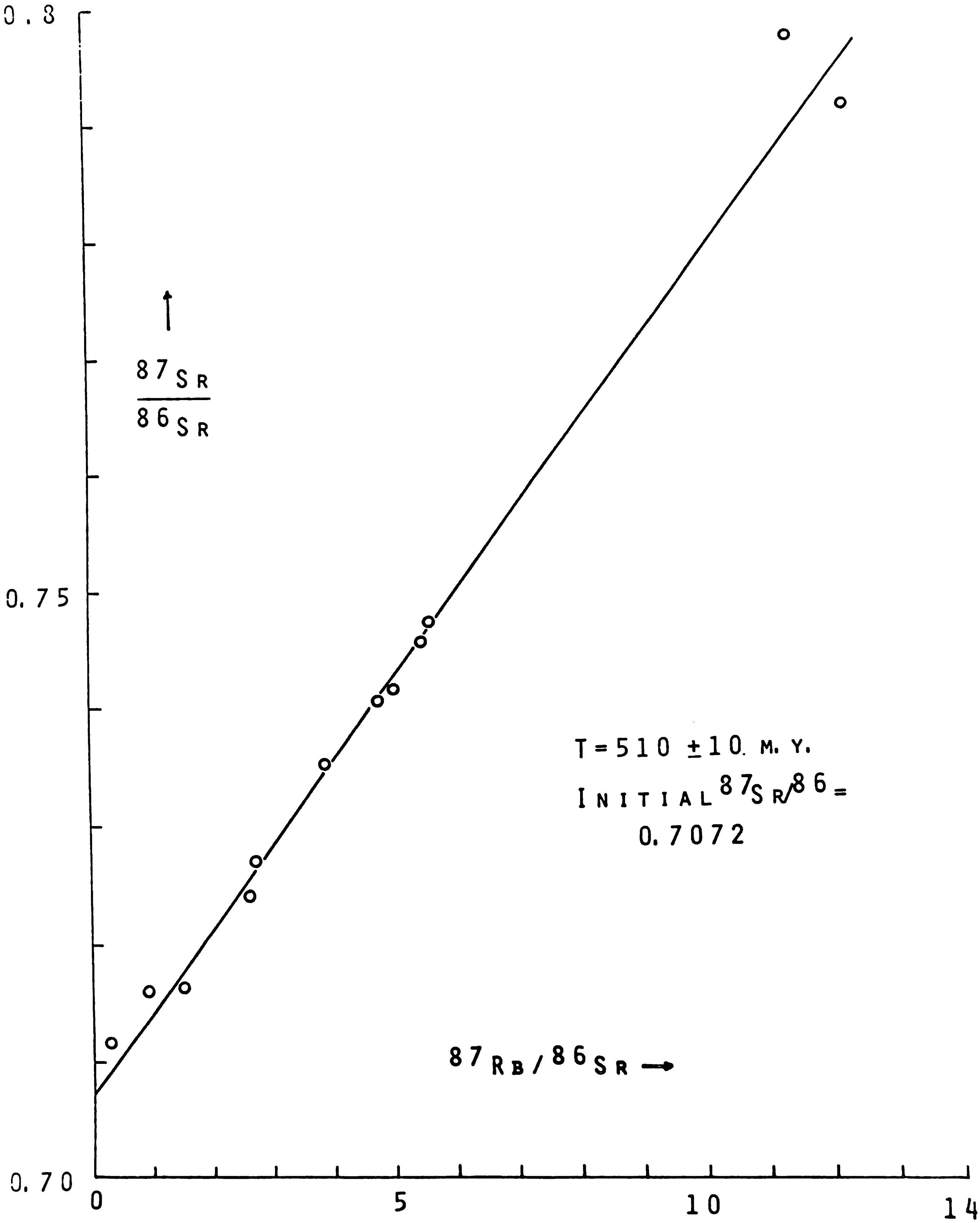

FIGURE 1. Ellsworth Schist—Rb-Sr whole-rock isochron.

Cormier's samples with $^{87}Rb/^{86}Sr < 1.0$, then it is also possible that Sr may have been added to these samples (see secondary Ca minerals mentioned by Alcock, 1940). Further, when plotted the various subgroups of Cormier with $^{87}Rb/^{86}Sr < 1.0$ (nos. 7–11) show four, not five, subgroups since numbers 10 and 11 overlap. Regardless, if maximum and minimum isochrons are constructed with these data, apparent isochrons ranging from 515 m.y. to 1150 m.y. ($\lambda = 1.39 \times 10^{-11}$/y) results. Group six, which Cormier states does not fit on either apparent isochron yet is used in construction of the 378 m.y. isochron can just as well be added to groups 7–11 and, as $^{87}Rb/^{86}Sr = 1.4$ to 1.9 with $^{87}Sr/^{86}Sr = 0.716 - .723$, inclusion of these data (i.e., subgroup 6) would lower the apparent isochron to the 500–600 m.y. range. We do not dispute the Precambrian age assigned to the Coldbrook Volcanics; however, there is no reason to assume that the Coldbrook Volcanics are 750 ± 80 m.y. (795 m.y. with $\lambda = 1.39 \times 10^{-11}$/y). Indeed, if the Coldbrook rocks are nearly 800 m.y. old it may be likely that the well-preserved pebbles of volcanic material found in the basal Saint John Group (Lower Cambrian) conglomerate belong to a formation other than the Coldbrook. An age of extrusion closer to 550–600 m.y. may be more reasonable.

Regardless of the above discussion, it is apparent that the age interpretation of the Coldbrook Volcanics remains unresolved until the question of systemal closure can be answered. The samples of the Ellsworth Schist, which represent volcanic material, do form a linear array on an isochron plot (fig. 1) with a considerable spread in both $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ values. The age of 510 ± 10 m.y., however, is post-Lower Cambrian, and thus a Coldbrook: Ellsworth correlation on that basis alone is precluded. No curvature of the isochron is noted in figure 1 and, as petrography supports closed system conditions, none should be expected.

In view of the arguments presented above, I can only conclude that the Ellsworth Schist and Coldbrook Volcanics are not correlatives. The Coldbrook Volcanics are assigned a late Precambrian age based on geologic control, and the Ellsworth Schist is assigned a Cambro-Ordovician age on the basis of geochronologic data.

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