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Rb–Sr WHOLE ROCK AGE DETERMINATIONS OF THE DEDHAM GRANODIORITE, EASTERN MASSACHUSETTS

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ABSTRACT. Rb–Sr whole rock age determinations have been carried out on samples from nine sampling localities in the Dedham granodiorite around the Boston Basin in eastern Massachusetts. The results point to an age of 608 ± 17 m.y. for the subalkaline granodioritic complex forming the eastern crystalline basement of southeastern New England. It appears that the complex has been locally intruded and metasomatized by 450 m.y. magmas and hydrothermal solutions probably related to the alkalic magmatism of this age in eastern Massachusetts. The Late Precambrian age for the primary granodiorites confirms the assignments of the Dedham granodiorite to the Avalonian orogenic belt.

INTRODUCTION

First defined as a lithological unit by Emerson (1917), the Dedham granodiorite extends over several hundreds of square km from near the northern border of Massachusetts down to the shores of Buzzards Bay, with an east-west extension of over 50 km. It forms the crystalline basement of a considerable part of southern New England between the eastern limb of the Merrimack synclinorium and the Atlantic Ocean.

Owing to variable mineralogical and chemical composition and extensive faulting, it has not been possible to subdivide the Dedham clearly into mappable lithologic units, despite large-scale surveys of the area by Emerson (1917), LaForge (1932), and Bell (unpub. ms) and the detailed quadrangle mapping by Chute (1966) and Nelson (1975). Geochronological studies in the past have not helped in this respect, except to confirm the Late Precambrian age given by Billings (1929) and confirmed by Dowse (1950). Fairbairn and others (1967) reported Rb–Sr total rock isochrons of 569 ± 4 m.y. (R_i = 0.7058 ± 0.0005) for the Northbridge gneiss to the west of the Dedham area, 514 ± 17 m.y. (R_i = 0.7128 ± 0.0067) for the Hoppin Hill granite, and 591 ± 28 m.y. (R_i = 0.7054 ± 0.0010) for three samples of Westwood granite and one sample of granodiorite, both within the so-called Dedham complex.

GEOLOGICAL SETTING

A generalized geological sketch map including sample localities is shown in figure 1. The map is based on the maps of Emerson (1917), Bell (unpub. ms), Nelson (1975), and on the unpublished work of Kaye (1975).

The lithological unit regarded as the Dedham granodiorite incorporates a wide variety of subalkaline igneous rocks ranging in composi-

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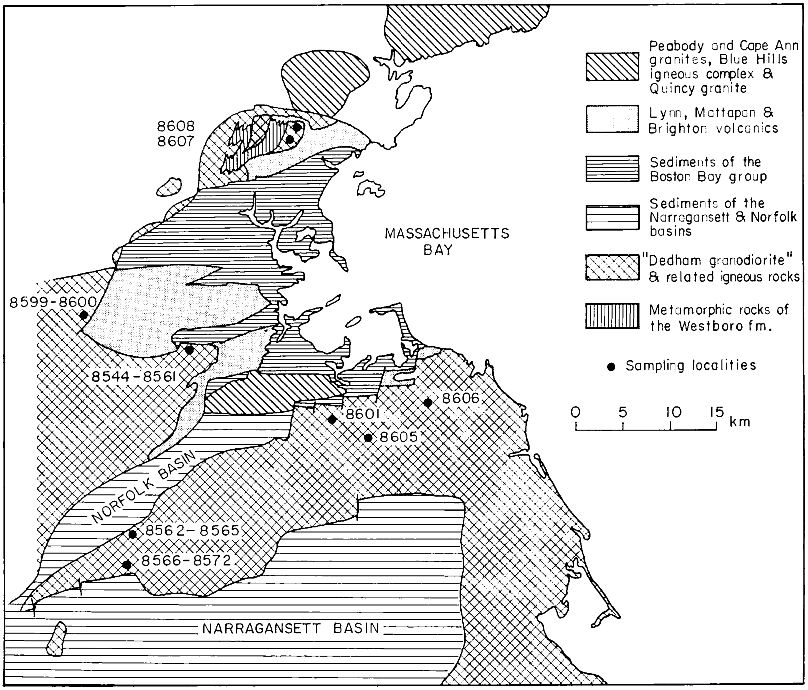

Fig. 1. Simplified geological map of eastern Massachusetts with sampling localities. Geology based on maps of Emerson (1917), Bell (ms), Nelson (1975), and on unpublished data of Kaye (1975). Geology northwest of the Boston Basin not shown.

tion from gabbrodiorite to granite with regionally continuous transition from one rock type to the other. It varies in grain size and texture too, but all varieties have common characteristics indicating similar history. The main mineral constituents are andesine, quartz, potash-bearing feldspars, and mafic minerals. The mafic minerals are mostly altered to chlorite, and the presence of epidote points to the effect of secondary processes. The mineral grains are often fractured or bent; the texture of the rocks is often cataclastic.

The only stratigraphic control for the age of the Dedham is the presence of Lower Cambrian sediments unconformably overlying the granite (Billings, 1929; Dowse, 1950). The isochron age of 514 ± 17 m.y. for the Hoppin Hill granite by Fairbairn and others (1967) was attributed to the alteration of the feldspars (microperthite) producing an apparent lowering of the original age and a high initial strontium isotopic ratio. A single zircon age (R. E. Zartman, quoted by Nelson, 1975) of 630 m.y. suggests that the age of 591 ± 28 found by Fairbairn and others for the remainder of the Dedham samples was more nearly correct.

In spite of the extreme diversity in the mineralogy and chemical composition of the Dedham, this subalkaline assemblage can be easily distinguished from the alkaline rocks occurring in several intrusive bodies around the Boston Basin (Cape Ann, Peabody, and Quincy granites). Rb–Sr whole-rock isochron studies (Bottino and Fullagar, 1968; Bottino and others, 1970; Zartman and Marvin, 1971) gave different and even conflicting ages for these individual instrusions, but the zircon ages for the three intrusions set a reasonably acceptable age of about 450 m.y. for the alkaline magmatism in eastern Massachusetts (Zartman and Marvin, 1971).

RESULTS AND DISCUSSION

Rb–Sr whole-rock isotopic analyses have been carried out on 31 samples from sampling localities shown on the map of figure 1. In the chemical preparation of the samples for mass spectrometry, standard ion exchange procedures have been used. Rb and Sr concentrations were determined by stable isotope dilution. All mass-spectrometric measurements have been carried out on a 30 cm radius, computer-controlled mass spectrometer with automatic data reduction, using tantalum filaments. The estimated accuracy of the concentration determinations is about 2 percent for both rubidium and strontium. The reliability of the $^{87}Sr/^{86}Sr$ ratios is estimated at ± 0.1 percent.

Analytical results are given in table 1 which includes Rb and Sr concentrations in parts per million, $^{87}Rb/^{86}Sr$ atomic ratios for each sample, and $^{87}Sr/^{86}Sr$ ratios normalized to $^{86}Sr/^{88}Sr = 0.1194$ and referred to $^{87}Sr/^{86}Sr = 0.7080$ for the Eimer and Amend standard strontium carbonate (lot no. 492327). Model ages given in table 1 for each sample are based on $^{87}Rb = 1.39.10^{-11}yr^{-1}$ and an assumed initial $^{87}Sr/^{86}Sr$ ratio of 0.7050.

Figure 2 displays in a single Rb–Sr isotope evolution diagram all the ages tabulated in table 1. This figure shows a wedge-shaped distribution of points between two bounding isochrons. The limiting isochrons have been calculated by a regression procedure, which started with all the points near the upper and lower limits respectively. Afterward, the number of points was decreased by omitting from the inner part of the wedge field those points that made the largest contribution to the sums of the squared residuals. This procedure was repeated until the deduced root-mean-square error became equal to the error originally assigned to the individual $^{87}Sr/^{86}Sr$ ratio determinations. In the final step eight and six points were used in determining the parameters of the upper and lower limiting isochrons, respectively. It is admitted that this is not necessarily the correct way of deriving isochrons from such a distribution. Its rationale is based on an assumption (to be discussed below) that there were two discrete major events, and that in some samples the younger event had caused a partial metasomatism within the older material so that mixed points gave values between the two limits. By eliminating the mixed values it could be determined how many valid unmixed samples would be left for each isochron within experimental error. After this procedure it was found that the older boundary defined an eight-point isochron of 608 ± 17 m.y. (R_i = 0.7065 ± 0.0011), and the younger boundary defined a six-point isochron of 449 ± 16 m.y. (R_i = 0.7048 ± 0.0008). All the errors represent a confidence level of 95 percent. The low initial ratio of the younger isochron indicates that the rock suffered selective loss of radiogenic strontium or exchange during new magmatism from deep in the orogene.

TABLE 1

Rb/Sr isotope analytical data for samples from the Dedham granodiorite area

MIT no.	Rb /ppm/	Sr /ppm/	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$*	T** /m.y./
West Roxbury					
8544	170.9	46.63	10.499	0.7814	522
8545	175.8	61.26	8.219	0.7744	605
8546	188.7	48.85	11.079	0.7919	562
8548	108.3	90.49	3.410	0.7271	465
8549	174.2	66.86	7.452	0.7613	541
8551	189.4	44.36	12.262	0.8044	581
8552	140.0	145.5	2.742	0.7259	546
8553	141.8	96.12	4.208	0.7329	475
8554	145.8	167.2	2.486	0.7278	657
8555	216.0	38.30	16.255	0.8393	592
8556	205.4	47.11	12.527	0.8057	576
8557	153.2	85.54	5.110	0.7374	455
8558	199.5	46.55	12.300	0.7967	534
8560	154.9	153.4	2.877	0.7273	555
8561	174.8	47.38	10.572	0.7813	517
Sharon area					
8562	159.9	102.6	4.450	0.7439	626
8563	131.6	169.9	2.204	0.7236	604
8564	99.8	362.8	0.783	0.7098	440
8565	118.5	273.9	1.232	0.7172	708
8566	153.0	57.64	7.598	0.7687	601
8567	167.8	57.89	8.294	0.7686	550
8569	173.1	66.96	7.398	0.7683	613
8570	165.0	57.35	8.241	0.7772	627
8572	138.0	100.6	3.917	0.7408	654
Wellesley area					
8599	91.43	202.4	1.286	0.7123	407
8600	78.07	344.3	0.645	0.7092	467
Weymouth-Hingham area					
8601	57.79	593.4	0.277	0.7063	/337/
8605	98.63	289.6	0.969	0.7123	540
8606	141.5	58.60	6.896	0.7475	442
Saugus area					
8607	81.46	237.1	0.978	0.7142	674
8608	63.62	295.8	0.612	0.7118	795

* Normalized to $^{86}Sr/^{88}Sr$ = 0.1194 and referred to $^{87}Sr/^{86}Sr$ = 0.7080 for the Eimer and Amend Standard strontium carbonate.

** Model age based on ^{87}Rb = $1.39 \times 10^{-11} yr^{-1}$ and an assumed initial $^{87}Sr/^{86}Sr$ ratio of 0.7050.

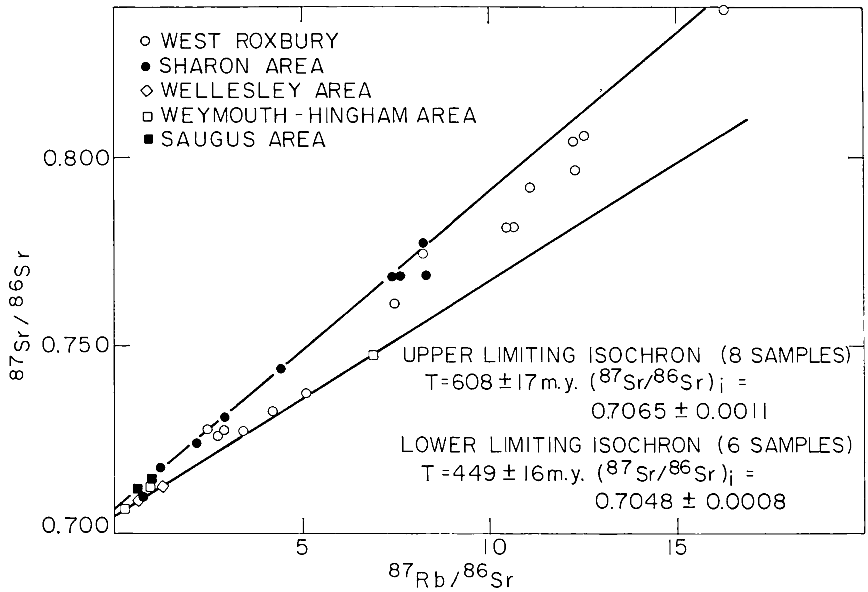

Fig. 2. Isochron diagram including all data obtained on total rock samples from the Dedham granodiorite area.

The coincidence of the upper age limit with the similar one given by Fairbairn and Hurley (1970) for the whole Northern Appalachian province is conspicuous and defines the Dedham granodiorite as one of the oldest magmatic formations of this province. It also agrees with the 607 ± 11 m.y. age determined by McCartney and others (1966) for the Holyrood granite on the Avalon Peninsula.

The reality of the 608 ± 17 m.y. age gains further support if we restrict ourselves to a single area represented by two sampling localities near Sharon, Mass., between the Narragansett and Norfolk Basins. Results on samples from this area alone are plotted in figure 3 and define a limiting isochron corresponding to an age of 604 ± 38 m.y. (The samples marked by circles have been omitted from the isochron calculations due to their excessive contribution to the sums of squared residuals.) This age is in agreement within error limits with the age determined by Fairbairn and others (1967) for the Dedham type locality.

While the upper age limit confirms the assignment by age of the Dedham to the Avalonian Orogen (compare Schenk, 1971; Cormier, 1972), the age corresponding to the lower limiting isochron (449 ± 16 m.y.) agrees with the age attributed to the onset of the Late Ordovician alkaline granite in eastern Massachusetts. Most of the points within the wedge-shaped envelope represent samples from a single quarry in West Roxbury (Newton quadrangle) and appear to show the effect of incomplete re-

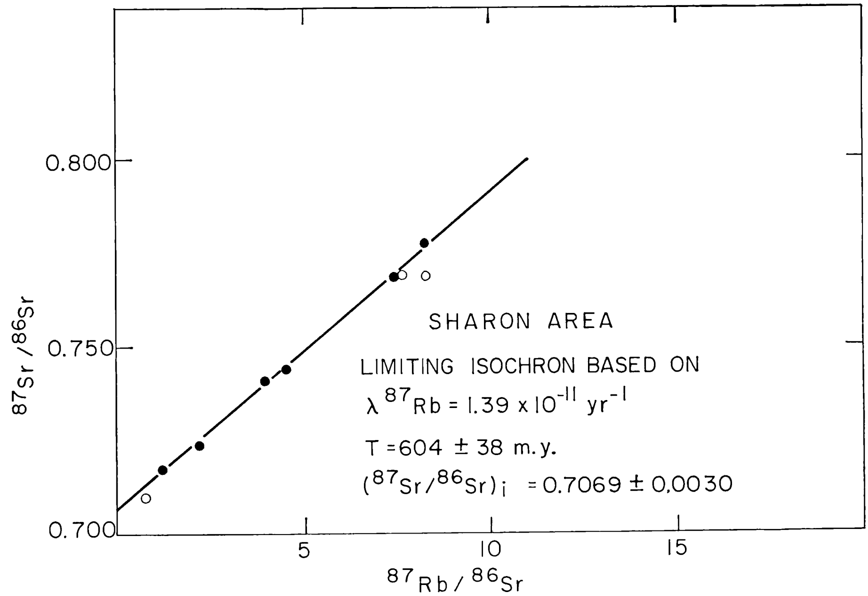

Fig. 3. Isochron diagram of samples from the Sharon area (two localities). Samples marked by open circles have not been included in the calculation of the limiting isochron.

setting of ages. This locality is close to the Blue Hills alkaline igneous complex which has been dated at 450 m.y., as mentioned above. The same applies to the samples showing younger age values in the Weymouth-Higham area. The presence of two K-feldspar generations in some of the samples, feldspar dissolution and incipient myrmekite development in others support the age evidence. We therefore conclude that the alkalic magmatism at 450 m.y. has been responsible for both the lower isochron and the intermediate points, and that the Dedham complex has been affected by this in its northeastern border region principally.

The primary age of around 600 m.y. for the Dedham granodiorite — besides the confirmation of its assignment to the assumed Avalonian orogenic belt now present in remnants only along the Atlantic coast of Canada and the United States — raises the question of a possible intercontinental correlation as well. Recent studies have revealed that the Devonian magnetic pole for eastern New England after pre-drift reconstruction coincides well with the African paleopole of similar age (Schutts and others, 1976) supporting the idea that this area once belonged to the African continent. If the Avalonian orogenic belt developed during a pre-Paleozoic subduction event in northwest Africa as proposed by Schenk (1971) and Hurley and others (1974), a subsequent rupture could leave parts of this ancient belt at both continental edges. It is notable that granitic-granodioritic rocks of similar Pan-African age have been found in the Siroua region of the Anti-Atlas in Morocco (Charlot, 1976). This correspondence of ages might be of further value in the reconstruction of pre-drift conditions at the continental boundaries.

ACKNOWLEDGMENTS

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APPENDIX

Sampling localities

M.I.T. no.	
R-8562 to R-8565:	Quarry operated by the West Roxbury Crushed Stone Co., Grove Street, West Roxbury, Newton Quadrangle.
R-8544 to R-8561:	On Route I-95, south lane, interchange 8.
R-8566 to R-8572:	On Route I-95, south lane, 3 km north from intersection with Route 140.
R-8599 to R-8600:	Wellesley, western side of Linden Street at Linden Shopping Center. Natick Quadrangle.
R-8601:	On Route 3, south lane, between Braintree and Weymouth, 500 m back from Summer Street. Weymouth Quadrangle.
R-8605:	On Route 3, south lane, Weymouth area. 1 km back from interchange 29. Weymouth Quadrangle.
R-8606:	Route 3, Cohasset Quadrangle.
R-8607:	On Route 1, north lane, at Saugus River, 70 m north of confluence of Saugus River and Bennets Pond Brook. Boston-North Quadrangle.
R-8608:	On Route 1, south lane. 500 m north of intersection with Main Street, Saugus, Boston-North Quadrangle.

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ERRATA

MINERAL EQUILIBRIA IN THE $MgO-SiO_2-H_2O$ SYSTEM: II TALC-ANTIGORITE-FORSTERITE-ANTHOPHYLLITE-ENSTATITE STABILITY RELATIONS AND SOME GEOLOGIC IMPLICATIONS IN THE SYSTEM

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In this paper (April 1977, p. 353-383), the last sentence of paragraph one on page 373 should read: "*The* accession of magmatic volatiles, when and where it occurs, produces, of course, an added metasomatic imprint," and on page 378, line thirteen from the bottom 1 kb should read *1 bar.*