

THE GEOCHRONOLOGY OF SOME PLUTONIC ROCKS
IN THE
CALAIS AREA, MAINE

by

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(1965)

Submitted in Partial Fulfillment
of the Requirements for the
Degree of Master of Science
at the
Massachusetts Institute of Technology
January, 1967

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ABSTRACT

A rubidium-strontium and strontium isotopic whole-rock analysis of sixteen rocks from a suite of twenty-seven specimens collected from the plutonic complex in the Calais area in the extreme southeast of Maine has yielded an age of 401 ± 8 m.y. and an initial ratio of 0.7093 ± 0.0016 from a computer linear least squares regression on ten points, ($\lambda_{\text{Rb}}^{87} = 1.39 \times 10^{-11}$ year⁻¹).

The specimens analyzed include six granites and an associated quartz diorite all of which may be distinguished in the field on petrologic grounds.

The scatter of the data indicates initial inhomogeneities in the granitic bodies, especially in the case of the Baring granite, and there also appears to have been a migration of Sr^{87} in the case of the quartz diorite which was sampled in the proximity of the contact with the Meddybemps granite.

The close agreement of the "isochron" with previous K/Ar biotite determinations precludes regional metamorphism of this plutonic body.

Recently published determinations on the Upper Silurian Eastport formation and the Lower Devonian Hedgehog formation (Bottino and Fullagar, 1966) give a combined age of 413 ± 5 m.y. The age provided in this study gives an upper limit for the Silurian-Devonian boundary and this age is consistent with field relations and previous age determinations in the region.

Acknowledgements

The writer wishes to thank his thesis supervisor, Professor H. W. Fairbairn for his interest in this study.

Professor P. M. Hurley has kindly offered to analyze two critical samples by isotope dilution methods.

Mr. Stanley A. Heath acquainted the author with the laboratory procedure and the idiosyncrasies of mass spectrometers.

Use was made of the IBM 7094 facilities of the Computation Centre, Massachusetts Institute of Technology in the least squares regression analysis of the isochron.

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INTRODUCTION

The plutonic rocks studied form part of an igneous complex located in the extreme southeastern portion of Maine which extends northeastward into southwestern New Brunswick. The specimens collected are, with the exception of one (R6310), from the Calais and Robbinston quadrangles¹ (Figure 1).

This area is of considerable importance in the geochronology of New England in that these granitic rocks are intruded into Late Silurian (Ludlow or Gedinne) fossiliferous slates and are, in turn, overlain by the Late Devonian Perry formation, a fossil-bearing sandstone containing detritus from these granites. Previous dates obtained from this region by Faul (1960, 1963) and Bottino and Fullagar (1966) provide close control for the boundary of the Silurian-Devonian periods. Such a study complements paleontological correlations in the area by providing "absolute" ages.

REGIONAL GEOLOGY

The region studied is underlain by metamorphosed Cambro-Ordovician sedimentary and volcanic rocks which are, in turn, unconformably overlain by thick sequences of Silurian sediments and volcanic rocks (Alcock, 1946a). In this region, the Cambro-Ordovician rocks (Charlotte group) consist essentially of argillite, quartzite, phyllites, micaceous gneisses and minor

1.

Published by the U. S. Geological Survey as 15 minute quadrangles on the scale of 1:62,500. Also available from the U. S. Army Corps of Engineers at a scale of 1:24,000 (partial coverage of the area only).

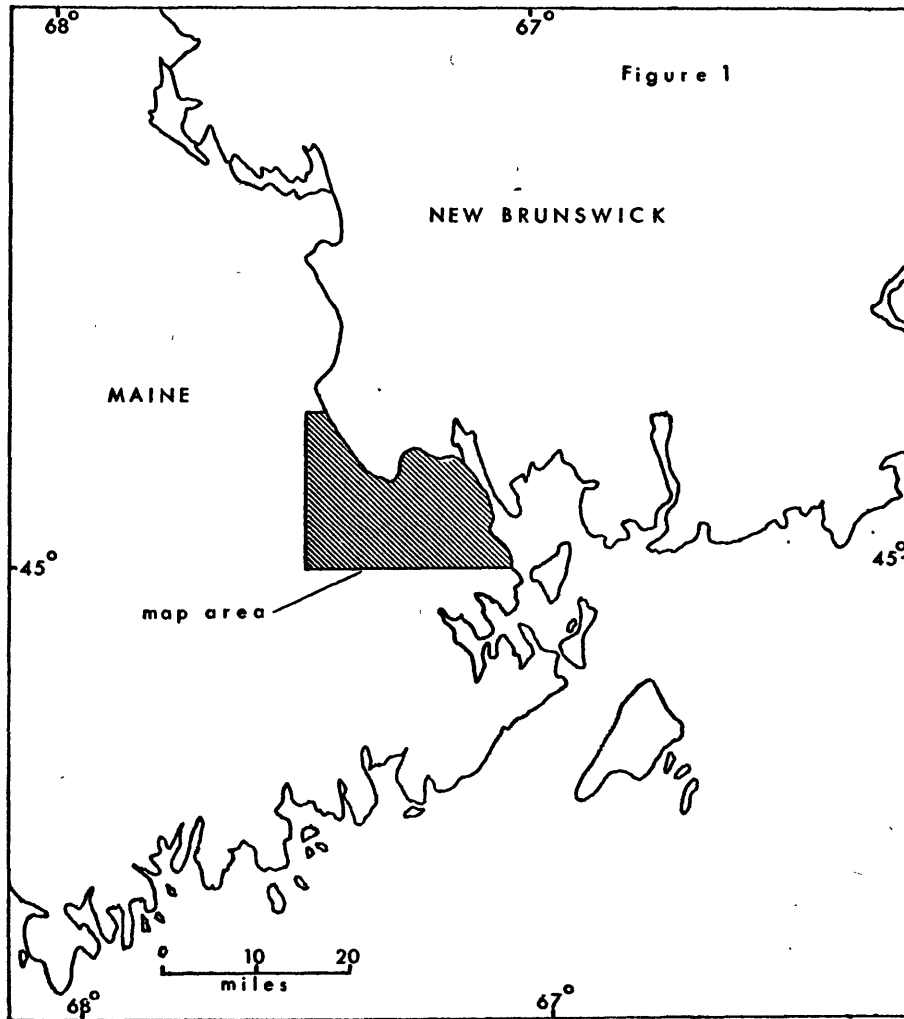


FIG. 1

metamorphosed tuffs and mafic lava flows. Progressive zonal contact metamorphism is invariably observed between the Charlotte group and the younger intrusive rocks. The thickest sequence of the Silurian in the immediate area is the Eastport formation, consisting of thick sequences of basaltic to andesitic tuffs interbedded with shales and argillite. Near contacts with the Red Beach granite, contact metamorphic effects are prominent. Bastin and Williams (1914) assign the Eastport to the Upper Silurian on the basis of paleontology, and recently Boucot et al (1964) and Naylor and Boucot (1965) have placed the Eastport in the Ludlow (Upper Silurian) or possibly as Lower Devonian (Gedinnian). Present opinion appears to favor an age younger than Ludlow but older than Gedinnian (Boucot, personal communication, in Bottino and Fullagar, 1966), and the Eastport formation has been placed tentatively in the Skala interval.

Isolated basins of Upper Devonian coarse clastic and volcanic rocks of the Perry formation unconformably overlies the granitic intrusions, and its lower members are coarsely conglomeratic containing poorly sorted angular pebbles of the Red Beach granite, particles of the hornblende phase being more numerous than those of the biotite phase. The Perry formation was dated as Upper Devonian in age from fossil plant remains found in the Eastport quadrangle and also in New Brunswick (Smith and White, 1905). On a regional scale these major rock units form a belted areal pattern with

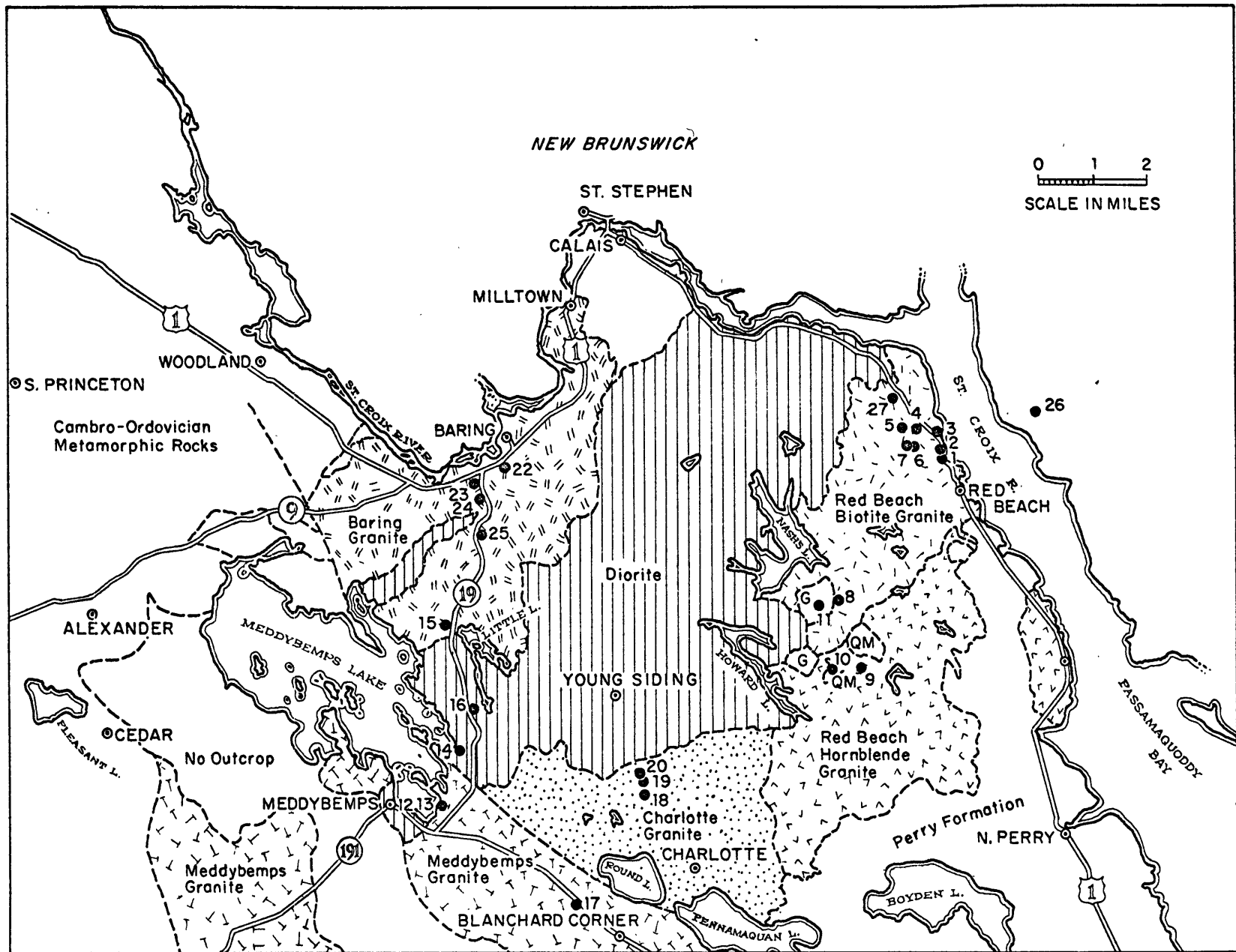


FIGURE 3 GEOLOGIC MAP OF ROBBINSON AND CALAIS QUADRANGLES, SOUTHEASTERN MAINE GEOLOGY (AMOS, 1963) AND SAMPLE LOCATIONS

extreme linear development in a northeast-southwest direction. The intrusive bodies are generally concordant with the regional trends but often show discordant relationships locally within individual bodies.

The detailed petrology of the post-Upper Silurian-pre-Upper Devonian rocks was undertaken by Amos (1963). He recognizes two major groups of rocks:

First, a medium-grained quartz diorite and an associated granodiorite adjacent to the granites form the bulk of the plutonic rocks exposed. Near the contacts with the underlying metasediments of the Charlotte group, the plagioclase is observed to become more calcic, and quartz and biotite are usually more abundant. Toward contacts with the granites and the granodiorite, the plagioclase in the diorite becomes more sodic and zoning is considerably more prominent. The granodiorite forms a narrow discontinuous belt between the diorite and the granites. Contact relationships reveal that the diorite is younger than rocks of the Charlotte group and the gabbro-norite but is older than any of the adjacent granitic rocks.

In the second major group, no less than five types of granite have been recognized by Amos (1963) on the basis of field and petrologic criteria and these granites invariably are observed to cut the more mafic rocks in the area.

Each granite is briefly described below:

Biotite Granite of Baring:

A white, medium-grained subporphyritic biotite granite

forming a large body which extends northeastward into New Brunswick (Alcock, 1946a). Near contacts with the older rocks, this granite is invariably more mafic and finer-grained.

Biotite Granite of Meddybemps:

A light salmon to white medium-grained granite which is locally subporphyritic occurs in the southwest of the map area (Figures 2 and 3). A K/Ar biotite determination by Faul (1960) on this granite gave an age of 404 my.

Biotite Granite of Charlotte:

A large body of very light tan to light brick-red medium-grained granite, locally subporphyritic, occurs to the east of the Meddybemps granite, outcropping to the west of the town of Charlotte. On the basis of contact relations, the Charlotte granite is clearly younger than the diorite, gabbro-norite or members of the Eastport formation and a K/Ar biotite determination by Faul (1960) from the same locality as specimen #20 (R6304) of this study gave an age of 406 my.

Red Beach Granite:

This granite consists of two distinct mineralogical types. The biotite granite occurs in the northwestern part and a hornblende granite in the southeastern part. Between the two is a gradational variant of both biotite and hornblende. Both phases of this granite are markedly uniform regionally although there are numerous local variations in texture and composition. The Red Beach granite is felt to be the youngest major rock unit in the plutonic belt since it cuts the Eastport formation and also contributes detritus to the Perry formation.

An average of four K/Ar biotite analyses by Faul (1960) gave an age of 404 ± 8 m.y.

Experimental Procedures:

(i) Sampling:

All outcrops sampled were of such a size that there was little chance of sampling glacial boulders in error. Large blocks (about 15" square) were broken down and smaller fresh hand specimens were removed and placed in small specimen containers at the outcrop. Since these plutonic rocks are for the most part fine-grained and no foliation was evident at the outcrop, the hand specimens chosen are believed to be well over ten times the major inhomogeneity in the rock (such as gneissosity etc. Phinney(1959)). Only fresh material having no signs of weathering or evident veining in the hand specimen was chosen.

(ii) Laboratory Preparation:

The samples were first passed through a coarse jaw crusher, care being taken to remove particles from previous samples by running two blank fragments. The machine was also cleaned by means of a jet of compressed air. The coarse powder was rolled and about 5 to 10 grams was reduced to -200 mesh in a Pica Blender Mill (Pitchford Scientific Instruments Corp.) The time required for the reduction was about 10 to 15 minutes. The ground sample was stored in a clean polyethelene vial.

(iii) Mass Spectrometry:

The strontium isotopic ratios of this study were obtained from three instruments of the M.I.T. Geochronology Laboratory, namely; Lulu, Nancy and Iris. All are 60° sector, six-inch radius, single filament and single Nier type collector machines utilizing a solid source. The ion beam is amplified by a Cary Model 31 vibrating reed electrometer, the output of which is measured on a Brown strip chart recorder. The mass range was scanned by a mechanical reversing magnet sweep.

In view of the possibility of drifting characteristics of each mass spectrometer, a standard was run at the beginning of use of a particular machine. These values are reported below normalized to a $\text{Sr}^{86}/\text{Sr}^{88}$ ratio of 0.1194. (see Table 3)

(iv) Determination of Rb/Sr Ratios by X-ray Spectrograph:

In this study all Rb/Sr ratios were determined by means of a Norelco X-ray Spectrograph using Mo radiation and a topaz analyzing crystal and a 0.004 inch entrance slit. The x-ray tube was operated at 50 Kv. and 35 ma. The amplifier gain of the pulse height analyzer was set at 60, the base line voltage at 1.40 (x6 volts) and the window at 6.0 (x3 volts). The DC power supply for the scintillation counter was set at 724 Kv.

Preliminary rapid analysis of all samples collected was made using a G-1 standard containing about 260 ppm Sr and 220 ppm Rb. This was done in order to obtain a suitable spread in Rb/Sr ratios. These data are given in Table I.

Precise determination of the Rb/Sr weight ratio was

made by scanning from 40° to $34^{\circ} 20'$ at a rate of $\frac{1}{2}^{\circ} 20'$ per minute with a chart speed of 1° per inch. The tracing was usually made twice to lessen ambiguity in the determination of the base line correction. Setting the goniometer at the $K_{\alpha 1}$ position for Rb (at $39.9^{\circ} 20'$) and Sr (at $37.65^{\circ} 20'$), the counting rate for 10,000 counts was determined at intervals of 2,000 counts. Also, the counting rate for 2,000 counts was made at $43^{\circ} 20'$ to determine the anchor point for the base line correction. Before each scan, the zero point was checked to within one half the pen width and the recorder was recalibrated each time. Two runs of three scans each, six in all, were made on each sample.

The powdered sample was packed into the holder by means of a spatula ground flat on each edge. Each sample was tamped until a flat, smooth surface was obtained.

Each scan was alternated with a dunite standard (W-1) which was enriched in Rb (as RbCl) and Sr (as SrCO_3) to about 2,500 ppm each. The counting rate was determined for 96,000 counts in three 32,000 count increments. A background correction was made and the Rb/Sr ratio was calculated.

(v) Chemical Preparation:

The following procedure was followed for the dissolution of the silicates and the isolation of the strontium.

1. Sufficient sample was weighed out on a beam balance such that there was a minimum of 80 u gram Sr in solution.
2. The sample was wet with several milliliters of distilled water.

3. Reagent grade HF was added, 10 ml per each 0.5 gm of the powdered sample added followed by 1.5 ml HClO_4 per 0.5 gram sample. The amount of HF added was kept to a minimum since there is approximately 0.02 u gram Sr per gm of sample per analysis contamination from the HF. (see M.I.T. Annual Report (1962) p.20, Tables 1 and 2 for degree of contamination).
4. The samples were left for several hours on a steam bath to dissolve (on low heat if left overnight). The samples were then stirred frequently with Teflon stirrers to hasten solution.
5. When a gel formed after the evaporation of the HF, another small amount was added and allowed to evaporate while stirring.
6. About 150 ml of distilled 2 N HCl was added to the platinum dishes under high heat. The sample was evaporated again to near dryness.
7. The samples were then removed from the steam bath and 20 ml of 2N HCl was added, the solution stirred (with some heating if required) and about 20 ml of distilled water was added.
8. The solution was allowed to cool for 2 to 3 hours and any Rb salts were allowed to crystallize.
9. The samples were filtered using a high grade ashless filter paper and the clear filtrate was carefully introduced into the column, care being taken not to disturb the level of the column resin. A Sr^{85} tracer was added (to about 3x to 4x background level).
10. The resin used was Dowex 50W-x8 and the ions were eluted using 2N HCl.

The order of emergence of the eluted ions is:

Fe	Ca
Na	Sr
K	Ba
Rb	

By means of a flame test, the Ca was discarded after elution and the Sr was collected in nalgene beakers. The beakers containing the most strontium were determined by means of a scintillation counter (on a 10 second count). Of some 6 to 8 beakers of solution only two were chosen and the remainder discarded.

11. The contents of the beakers was evaporated on a steam bath to about 10 ml. then the solution was carefully transferred to a Vycor beaker and was heated on a hot plate to near dryness. Several millilitres of HClO_4 were added to decompose any carbonaceous residue then several millilitres of distilled HNO_3 were added, the solution taken to dryness again, and another final addition of a few millilitres of HNO_3 was made after which the solution was taken down to complete dryness.

DISCUSSION OF RESULTS AND CONCLUSION

Twenty-seven field samples were collected and from these, sixteen were chosen for isotopic analysis on the basis of their variation in rubidium-strontium ratio (Table 1) and also on their petrologic variety.

It is seen from Plate I that ten of the samples show a reasonably linear distribution and, though not strictly an isochron, the straight line defined by these points gives an average age for this intrusive event.

The scatter of the data is somewhat greater than anticipated from the preliminary work on these rocks (Spooner, 1966) especially for specimens of the Baring granite.

Specimen R6298 of the Baring granite was collected close to the contact with the quartz diorite so that in all likelihood there has been a migration of radiogenic strontium from within this system. The same case obtains for the quartz diorite, R6305 and R6297 which was unavoidably sampled from areas containing extensive granite pegmatite veining.

Samples R6306, R6307 and R6308 were taken from the Baring granite proper, well away from border phases; nonetheless, the scatter is indicative of non-homogeneity at the time of emplacement. The smaller igneous bodies exhibit a greater degree of homogenization as seen from Plate I.

Only ten points showing the least degree of scatter were

used in the least squares regression analysis. Despite the closeness of fit of sample R6306 to the isochron, the incorporation of this point to the exclusion of R6308, based on geologic criteria, did not seem justifiable.

It is difficult to arrive at a conclusion regarding a comagmatic source for these approximately coeval granitic rocks owing to the large amount of scatter about the "isochron". On the basis of the samples collected however, there appears to be a twelve-fold increase in Rb/Sr ratio with differentiation from the Baring to the Red Beach granite, with the Meddybemps and the Charlotte granites between, if a comagmatic assumption is made.

The IBM 7094 program used in the least squares regression is shown in Appendix II and was provided by Derek York (1966) of the University of Toronto.

An initial slope of 0.00560 was chosen on a visually fitted line passing through the coordinates of the arithmetic mean. The least squares slope obtained was 0.00558 with a difference of 0.4% from the visually estimated slope. Following the procedure for calculating the age of the system given in Appendix I, an age of 401 ± 8 m.y. was obtained with an initial ratio of 0.7093 ± 0.0016 .

This result is in good agreement with the 404 m.y. K/Ar age obtained on the Meddybemps granite, the 401 m.y. age on the Red Beach granite and the 406 m.y. age on the Charlotte granite Faul (1960). It is also in accord with the 412 ± 5 m.y. and 413 ± 10 m.y. ages obtained by Bottino and Fullagar (1966) on

the older volcanics of the underlying Eastport formation.

The age obtained in this study confirms a post Silurian-pre-Upper Devonian intrusive event at 401 ± 8 m.y. and in conjunction with the ages obtained by Bottino and Fullagar (1966) provides a closer limit on the position of the Silurian-Devonian boundary.

TABLE I

Approximate Rubidium-Strontium Content of Rocks Studied:

M.I.T. #	Field #	Rb (ppm)	Sr (ppm)	Rb/Sr
R 6285	1	261	30	8.7
R 6286	2	235	41	5.7
R 6287	3	250	37	6.8
R 6288	4	271	51	5.3
R 6289	5	230	43	5.3
R 6290	6	261	51	5.1
R 6291	7	267	86	3.1
R 6292	8	248	41	6.0
R 6293	9	109	130	0.84
R 6294	10	122	126	0.97
R 6295	11	211	40	5.3
R 6296	12	75	112	0.67
R 6297	13	30	159	0.19
R 6298	14	47	235	0.20
R 6299	15	162	88	0.18
R 6300	16	77	153	0.50
R 6301	17	130	134	0.97
R 6302	18	220	87	2.5
R 6303	19	180	88	2.0
R 6304	20	220	53	4.2
R 6305	21	17	216	0.08
R 6306	22	126	70	1.8

TABLE I cont'd.

M.I.T. #	Field #	Rb(ppm)	Sr (ppm)	Rb/Sr
R 6307	23	132	125	1.1
R 6308	24	34	149	0.23
R 6309	25	81	347	0.23
R 6310	26	498	12	42
R 6311	27	207	50	4.1

TABLE II

X-ray Spectrographic Determination of Rb/Sr Ratio:

	Rb ⁸⁷ /Sr ⁸⁶	wt. ratio		K**	(Rb ⁸⁷ /Sr ⁸⁶) wt.
R6285	9.137	9.196	ave.		
	8.366	8.309			
	7.243		8.450 ± 11.9%*	2.9351	225.3827
R6286	6.403	6.142	ave.		
	6.805	6.235			
	6.335	6.459	6.397 ± 4.2%	2.9232	18.700
R6287	5.646	6.300	ave.		
	5.583	6.143			
	5.909	5.728	5.885 ± 4.9%	2.9217	17.194
R6292	6.346	5.612	ave.		
	6.150	5.829			
	5.910	6.069	5.986 ± 4.9%	2.92440	17.5055
R6293	0.762	0.841	ave.		
	0.792	0.781			
	0.760	0.786	0.787 ± 4.4%	2.89782	2.2806
R6294	0.725	0.767	ave.		
	0.739	0.756			
	0.774		0.752 ± 3.3%	2.89895	2.1800
R6296	0.7764	0.7743	ave.		
	0.7728	0.7501			
	0.7844		0.7760 ± 19.5%	2.8986	2.249
R6297	1.853	1.788	ave.		
	1.860	1.808			
	1.808	1.791	1.821 ± 1.6%	2.89474	5.2713
R6298	0.236	0.221	ave.		
	0.228	0.208			
	0.219	0.226	0.223 ± 4.9%	2.89510	0.6746

* at 95% 2σ Confidence Level.

				K	(Rb ⁸⁷ /Sr ⁸⁶) _{wt.}
R 6301	0.864	0.857	ave.		
	0.870	0.796			
	0.838	0.817	0.849 ± 3.2%*	2.9000	2.462
R 6302	2.123	1.945	ave.		
	1.895	1.897			
	1.930	2.026	1.969 ± 4.7%	2.9042	5.7184
R 6304	3.894	3.869	ave.		
	3.960	4.025			
	3.961	3.890	3.933 ± 1.6%	2.9131	11.457
R 6305	0.768	0.876	ave.		
	0.813	0.934			
	0.833	0.781	0.838 ± 9.0%	2.89446	2.4256
R 6306	2.001	1.444	ave.		
	1.918	1.607			
	1.963	1.991	1.821 ± 12.7%	2.9044	5.289
R 6307	1.702	1.758	ave.		
	1.762	1.800			
	1.740	1.718	1.747 ± 2.2%	2.9049	5.075
R 6308	0.516	0.500	ave.		
	0.513	0.520			
	0.553	0.542	0.524 ± 4.1%	2.8949	1.5169

*at 95% 2σ Confidence Level.

TABLE III

Mass Spectrometric Determinations:

Eimer and Amend Standard SrCO_3 (Lot number 492327)

July 20, 1966 Lulu

July 27, 1966 Lulu

0.7074	0.7097	0.7075	0.7073
0.7080	0.7096	0.7097	
0.7092	0.7080	0.7094	
0.7101	0.7089	0.7076	
0.7094	0.7064	0.7090	
0.7099	0.7093	0.7094	
0.7099	<u>0.70898 ave.</u>	0.7080	<u>0.7085 ave.</u>

October 24, 1966 Iris

0.7094	0.7090	
0.7071	0.7086	
0.7100	0.7091	
0.7097	0.7099	<u>0.70897 ave.</u>

TABLE IV

Mass Spectrometric Determinations:

Run	Mass	Sample	$\text{Sr}^{87}/\text{Sr}^{86}$	$\text{Sr}^{87}/\text{Sr}^{86}$ ***	Average
R6285	4853*	(L)**	0.8515	0.8523	0.8517 ave.
			0.8492	0.8514	
			0.8516	0.8525	
			0.8509	0.8539	
R6286	4840	(L)	0.8077	0.8069	0.8076 ave.
			0.8070		
			0.8071		
			0.8092		
R6286	4851	(L)	0.8091	0.8100	0.8097 ave.
			0.8111	0.8097	
			0.8099	0.8083	
			0.8105	0.8087	
			0.8102		
R6287	4858	(L)	0.8055	0.8025	0.8035 ave.
			0.8051	0.8021	
			0.8041	0.8038	
			0.8027		
R6292	4968	(I)	0.8128	0.8126	0.8125 ave.
			0.8117	0.8126	
			0.8126	0.8130	
			0.8114	0.8130	
R6293	4965	(I)	0.7182	0.7196	0.7188 ave.
			0.7183	0.7185	
			0.7178	0.7185	
			0.7197	0.7199	
R6294	4982	(I)	0.7221	0.7233	0.7229 ave.
			0.7223	0.7235	
			0.7234		
			0.7226		

* run number; ** (L)= Lulu, (I)= Iris, (N)=Nancy

***The $\text{Sr}^{87}/\text{Sr}^{86}$ values have been normalized to 0.1194.

Mass Spectrometric Determinations cont'd:

R6296	4859	(L)	0.7199	0.7219	
			0.7203	0.7202	
			0.7209	0.7204	
			0.7188	0.7220	0.7207 ave.
R6297	4866	(L)	0.7104	0.7067	
			0.7085	0.7074	
			0.7075	0.7075	
			0.7073	0.7080	0.7079 ave.
R6298	4977	(I)	0.7085	0.7082	
			0.7095	0.7088	
			0.7109		
			0.7090		0.7090 ave.
R6301	5013	(I)	0.7282	0.7268	
			0.7215	0.7259	
			0.7274	0.7262	
			0.7271	0.7279	0.7264 ave.
R6302	5023	(I)	0.7438	0.7396	
			0.7413	0.7401	
			0.7403	0.7420	
			0.7397	0.7411	0.7410 ave.
R6304	4979	(I)	0.7722	0.7729	
			0.7737	0.7723	
			0.7748	0.7728	
			0.7733	0.7736	0.7727 ave.
R6305	4972	(I)	0.7069	0.7057	
			0.7052	0.7052	
			0.7110	0.7075	
			0.7063	0.7053	0.7067 ave.
R6306	4915	(N)	0.7442	0.7419	
			0.7444	0.7420	
			0.7408	0.7403	
			0.7399		0.7419 ave.

Mass Spectrometric Determinations. cont'd:

R6307	5012	(I)	0.7468	0.7483	
			0.7408	0.7448	
			0.7421	0.7443	
			0.7366	0.7440	0.7435 ave.

R6308	4998	(I)	0.7071		
			0.7093		
			0.7092		
			0.7083		0.7085 ave.

Field Description of Samples:

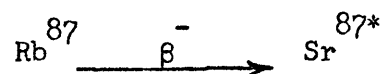
M.I.T. #	Field #	
R 6285	1	Red Beach hornblende granite, fresh pieces from 12" x 7" block, minor epidote (avoided).
R 6286	2	Same rock type as above, 15" x 15" block.
R 6287	3	Red Beach biotite granite, about 600' N of locality 2.
R 6288	4	Same as 3.
R 6289	5	Quarry near Red Beach, Me. Biotite granite
R 6290	6	Quarry 50' W of locality 5.
R 6291	7	Same as 6.
R 6292	8	Medium-grained biotite granite
R 6293	9	Porphyritic quartz monzonite
R 6294	10	Same as 9.
R 6295	11	Medium to fine-grained biotite granite.
R 6296	12	Granite of Meddybemps, biotite granite, medium-grained, near contact with gabbro-norite.
R 6297	13	Same locality as 12, diorite, some quartz veins about 5' away.
R 6298	14	Fine-grained biotite granite, texture quite variable, 1.9 mi. N of intersection Hwy. 214 and 19.
R 6299	15	Medium-grained Baring granite, uniform in outcrop, 2.6 mi. N intersection.
R 6300	16	Baring granite intruding diorite, minor quartz veins up to 4" across.
R 6301	17	Charlotte granite, N side of Hwy. 214, .34 mi. W Blanchard cnrs.
R 6302	18	Charlotte granite, biotite granite, 4.67 mi. S Young Siding.

R 6303	19	Charlotte granite, 4.4 mi S Young Siding.
R 6304	20	Charlotte granite, fine-grained biotite granite, 4.12 mi S Young Siding.
R 6305	21	Diorite with narrow bands of intruded granite, 1.48 mi N Young Siding, E side of road.
R 6306	22	Baring granite, coarse-grained hornblende granite, 0.2 mi W of RR crossing by St. Croix junc. and Hwy 1.
R 6307	23	Baring biotite granite, at junc. 191 and 1.
R 6308	24	Same as 23, 0.45 mi S on 191 and 1.
R 6309	25	Same as 23, 1.0 mi W of junc Hwy 191 and 1 on Hwy. 1.
R 6310	26	Red Beach hornblende granite, St. Andrews, New Brunswick.
R 6311	27	Red Beach biotite granite(vuggy), 7 mi. E of Calais on Hwy 1. S side of road.

A thin section examination was made on each specimen collected and almost without exception the potash feldspar showed varying degrees of sericitization and incipient alteration to kaolinite. However, in no case was there evidence of secondary veining either by quartz or carbonate. It is felt that there has been no redistribution of rubidium or strontium from the alteration (H. W. Fairbairn, personal communication).

APPENDIX I

Rubidium-strontium dating technique is based upon the β -decay of Rb^{87} :



with an approximate half-life of 50 billion years. In addition to the Sr^{87*} produced radiogenically, natural strontium has four stable isotopes: Sr^{84} , Sr^{86} , Sr^{87} , and Sr^{88} . In any chemical system that has remained closed with respect to rubidium and strontium, the amount of Sr^{87} present as a function of time "t" is the initial abundance of Sr^{87} : $\text{Sr}^{87}]_0$ plus the time integrated result of Rb^{87} decay to Sr^{87*} . Thus we have:

$$\text{Sr}^{87}]_t = \text{Sr}^{87}]_0 + \text{Sr}^{87*} \quad (1)$$

The basic equation for radioactive decay is:

$$dN/dt = -\lambda N \quad (2)$$

integrating and substituting for Rb^{87} and Sr^{87*} yields:

$$\text{Sr}^{87*} = \text{Rb}^{87} (e^{\lambda t} - 1) \quad (3)$$

substitution into equation (1) and expressing relative to Sr^{86} gives:

$$\frac{\text{Sr}^{87}}{\text{Sr}^{86}}]_t = \frac{\text{Sr}^{87}}{\text{Sr}^{86}}]_0 + \frac{\text{Rb}^{87}}{\text{Sr}^{86}}]_t (e^{\lambda t} - 1) \quad (4)$$

Where: t= age of the system since closure with respect to rubidium and strontium.

λ = decay constant for Rb^{87} in reciprocal years. ($\lambda = 1.39 \times 10^{-11} \text{ y}^{-1}$).

$\left. \text{Sr}^{87}/\text{Sr}^{86} \right]_0$ = the atomic ratio of these two isotopic species when the system became closed ($t=0$) to Rb and Sr.

$\left. \text{Sr}^{87}/\text{Sr}^{86} \right]_t$ = atomic ratio of Sr^{87} to Sr^{86} at t years following the closure of the system.

$\left. \text{Rb}^{87}/\text{Sr}^{86} \right]_t$ = atomic ratio of Rb^{87} to Sr^{86} at t years following last closure of the system.

In the B.P.I.* method, the present day $\text{Rb}^{87}/\text{Sr}^{86}$ ratio is plotted on the abscissa and the present day $\text{Sr}^{87}/\text{Sr}^{86}$ atomic ratio is plotted along the ordinate such that the slope defined by points falling along a straight line (an isochron) is given by:

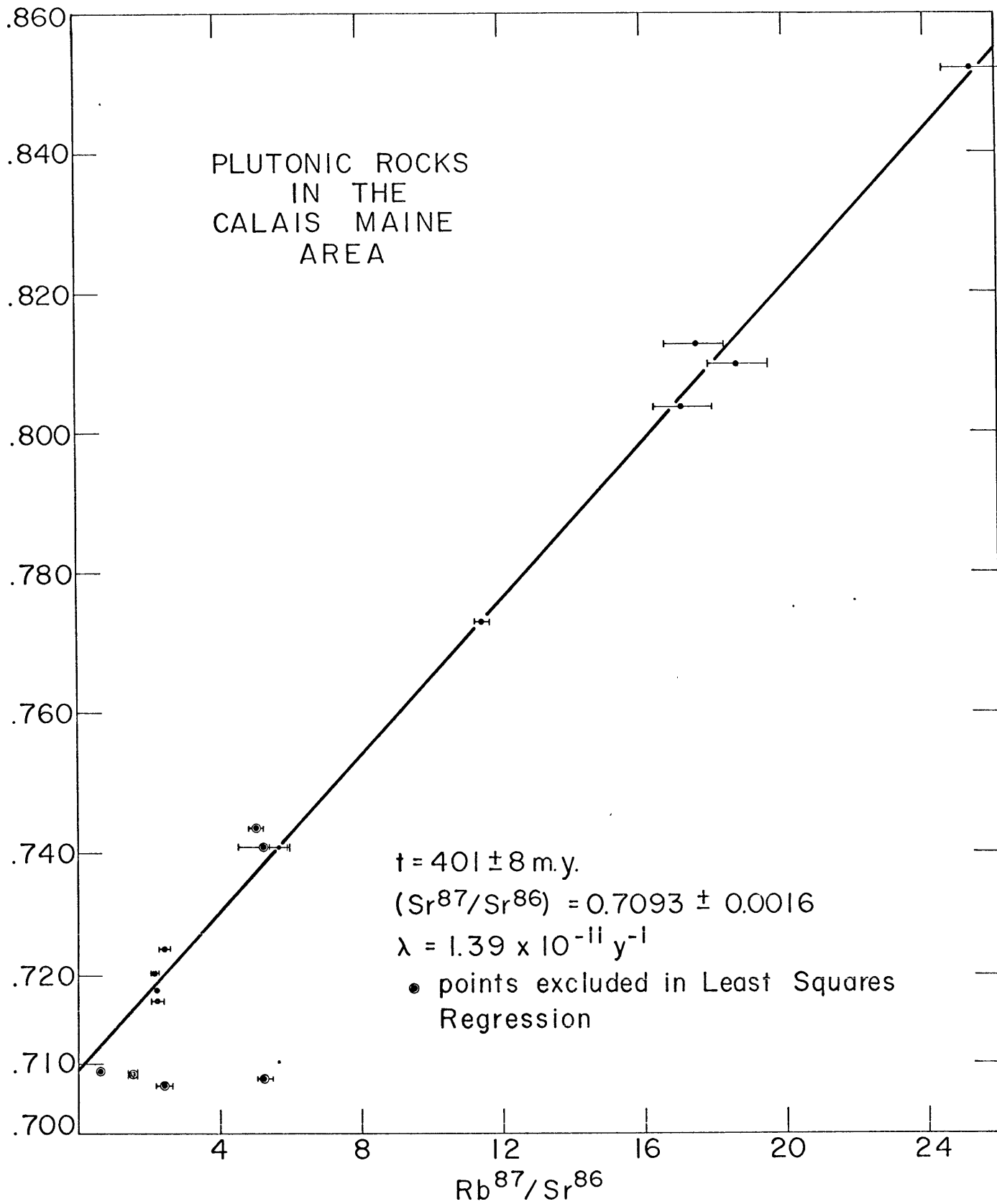
$$\tan \theta = (e^{\lambda t} - 1) \quad (5)$$

*

Bernard Price Institute.

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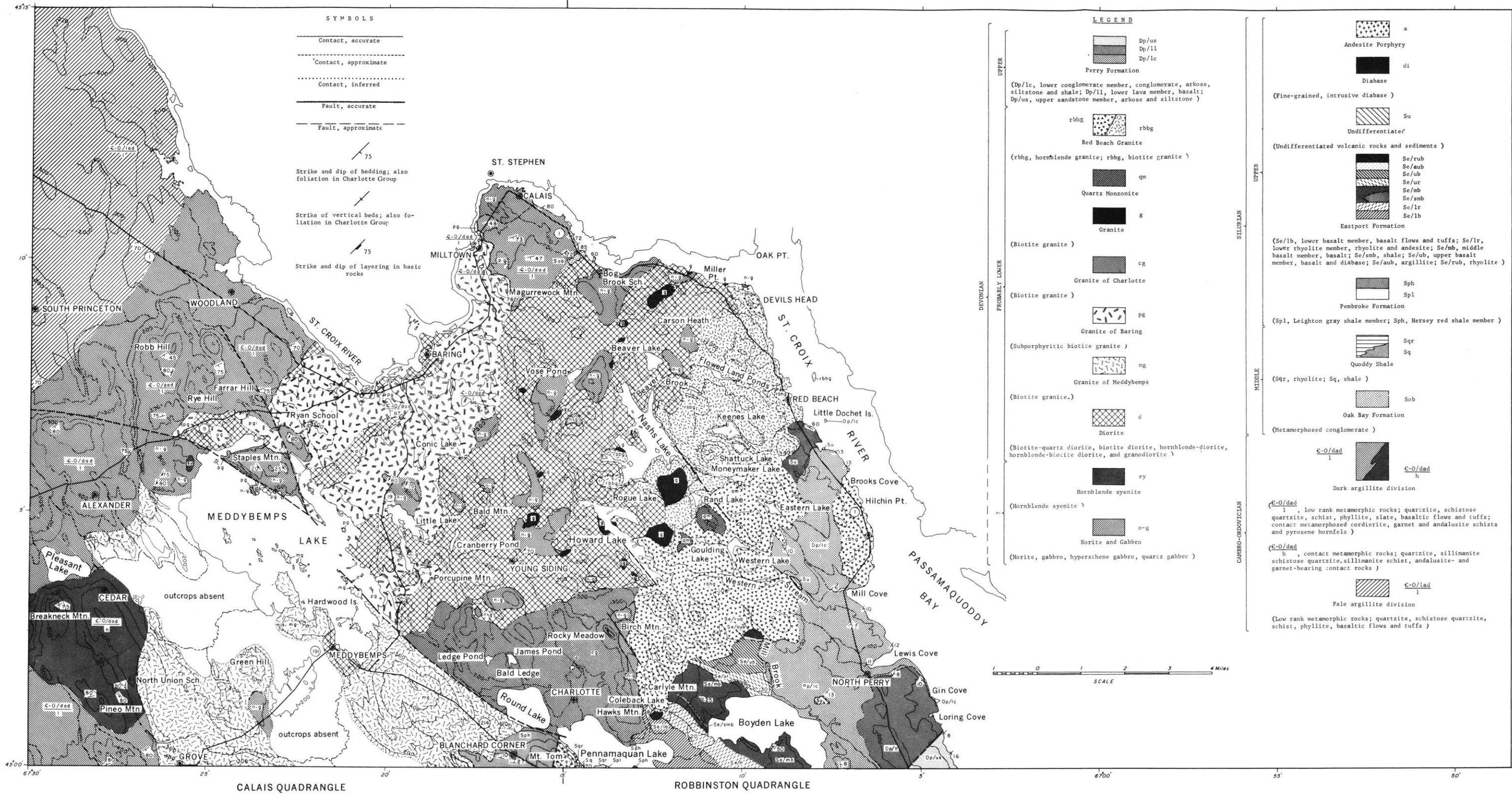
29

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$IBJOB          MAP,GO
$IBFTC          LIST,DECK
  DIMENSION X(50),Y(50),U(50),V(50),P(50),Q(50),W(50),SQW(50),
  1 RESX(50),RESY(50)
100  READ(5,1)B,N,(X(I),Y(I),P(I),Q(I),I=1,N)
1    FORMAT (F15.8,I10/(2F15.7,2E15.5))
      SUMW=0.
      SUMA=0.
      SUMB=0.
      SUMC=0.
      SUMD=0.
      SUME=0.
      SUMS=0.
      SUMT=0.
      XBAR=0.
      YBAR=0.
      DO 2 I=1,N
      W(I)=P(I)*Q(I)/(B*B*Q(I)+P(I))
      SQW(I)=W(I)**2
2    SUMW=SUMW+W(I)
      DO 3 I=1,N
      XBAR=XBAR+W(I)*X(I)/SUMW
3    YBAR=YBAR+W(I)*Y(I)/SUMW
      DO 4 I=1,N
      U(I)=X(I)-XBAR
      V(I)=Y(I)-YBAR
      SUMA=SUMA+SQW(I)*(U(I)**2)/P(I)
      SUMB=SUMB+SQW(I)*U(I)*V(I)/P(I)
      SUMC=SUMC+SQW(I)*(V(I)**2)/P(I)
      SUMD=SUMD+W(I)*(U(I)**2)
4    SUME=SUME+W(I)*U(I)*V(I)
      COA=0.6666667*SUMB/SUMA
      COB=(SUMC-SUMD)/(3.0*SUMA)
      COC=-SUME/SUMA
      CPHI=(COA**3-1.5*COA*COB+0.5*COC)/(COA**2-COB)**1.5
      IF(CPHI**2-1.0)6,6,10
6    ALPHA=(SQRT(1.0-CPHI**2))/CPHI
      IF(-ALPHA)7,7,8
7    PHI=ATAN(ALPHA)
      GO TO 9
8    PHI=3.1415927+ATAN(ALPHA)
9    SLOPEA=COA+2.0*SQRT(COA**2-COB)*COS(PHI/3.0)
      SLOPEB=COA+2.0*SQRT(COA**2-COB)*COS((PHI+6.2831854)/3.0)
      SLOPEC=COA+2.0*SQRT(COA**2-COB)*COS((PHI+12.566371)/3.0)
      GO TO 30
10   A=3.0*(COB-COA**2)
      C=-2.0*(COA**3)+3.0*COA*COB-COC
      Z=(-C/2.0+SQRT((C**2)/4.0+(A**3)/27.0))**(1.0/3.0)
      V=(-C/2.0-SQRT((C**2)/4.0+(A**3)/27.0))**(1.0/3.0)
      SLOPEA=Z+V+COA
      SLOPEB=0.00000000
      SLOPEC=0.00000000
30   AINT=YBAR-SLOPEA*XBAR
      BINT=YBAR-SLOPEB*XBAR
      CINT=YBAR-SLOPEC*XBAR
      DO 31 I=1,N
      SUMS=SUMS+W(I)*(SLOPEC*U(I)-V(I))**2
      SUMT=SUMT+W(I)*(X(I)**2)
      RESX(I)=-SLOPEC*W(I)*(CINT+SLOPEC*X(I)-Y(I))/(P(I)*X(I))
31  RESY(I)=W(I)*(CINT+SLOPEC*X(I)-Y(I))/(Q(I)*Y(I))
      AN=N
      SIGMAB=SQRT(SUMS/((AN-2.0)*SUMD))
      SIGMAA=SIGMAB*SQRT(SUMT/SUMW)

```

```
WRITE(6,5)SLOPEA,AINT,SLOPEB,BINT,SLOPEC,CINT,XBAR,YBAR,SIGMAA,  
1SIGMAB,B  
5  FORMAT(10X, 8HSLOPEA= ,F15.8,5X,6HAINT= ,F15.8//10X, 8HSLOPEB= ,  
1F15.8,5X,6HBINT= ,F15.8//10X,8HSLOPEC= ,F15.8,5X,6HCINT= ,F15.8//  
210X, 8H XBAR= ,F15.8,5X,6HYBAR= ,F15.8//10X, 8HSIGMAA= ,F15.8,  
33X, 8HSIGMAB= ,F15.8//10X, 8H B= ,F15.8)  
WRITE(6,20)(RESX(I),RESY(I),I=1,N)  
20  FORMAT(10X,28HRESX RESY//(9X,F11.8,13X,F11.8))  
WRITE(6,21)(X(I),P(I),Y(I),Q(I),I=1,N)  
21  FORMAT(56H X P Y Q  
1//(F15.7,2X,E15.5,2X,F15.7,2X,E15.5))  
WRITE(6,99)  
99  FORMAT(1H1)  
GO TO 100  
END
```



GEOLOGIC MAP OF THE ROBBINSON AND CALAIS QUADRANGLES,
SOUTHEASTERN MAINE

Geology mapped by D. H. Amos in 1950, 1956, and 1957, assisted by L. G. Toler, C. A. Chapman, J. A. Wehrenberg, and W. A. Weeks. Topography by U. S. Geological Survey, U. S. Army Corps of Engineers, and International Boundary Commission