

PETROLOGY, GEOCHEMISTRY AND Rb-Sr SYSTEMATICS OF THE  
PORPHYRITIC GRANITE AT HAMILTON MOUND, WISCONSIN

by

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ABSTRACT

The Hamilton Mound porphyritic granite is petrologically and chemically typical of what would be expected of a eutectic, two-feldspar granite. Field relationships suggest that the granite may have been emplaced along fractures in the quartzite that overlies it. Rb-Sr isotopic data for the granite yield a whole-rock errorchron age of  $1,940 \pm 400$  Ma with initial  $^{87}\text{Sr}/^{86}\text{Sr} = 0.702 \pm 0.008$  ( $2\sigma$ ). A Rb-Sr mineral isochron records a post-emplacement overprint producing strontium isotopic homogenization on the mineral scale at approximately 1,580 Ma. This event is probably the major cause of scatter in the whole-rock errorchron. A U-Pb zircon age obtained by Van Schmus (oral communication, 1983) indicates a primary crystallization age of  $1,764 \pm 4$  Ma, so the Hamilton Mound granite is in fact post-Penokean. However, chemical comparison with other Penokean and post-Penokean felsic rock in the region indicates that the Hamilton Mound granite is chemically more similar to the Penokean rock. This raises some doubt as to the validity of previous attempts to distinguish between products of the two periods of igneous activity on geochemical grounds.

INTRODUCTION

The focus of the present study was the red, porphyritic granite at Hamilton Mound, Wisconsin. The isotopic and chemical properties were investigated together with the possible relationship of the granite to other associated lithologies within the study area. Features or rock types which appeared in the field to be unrelated to the granite were not considered. Other lithologies which were studied include the quartzite that the granite intruded, a quartz breccia, and discontinuous veins found primarily within the quartzite. The complex nature of the local rock association was a major reason for undertaking the study. An attempt was made to relate the Hamilton Mound granite to other lower to middle Proterozoic granite within the region.

REGIONAL SETTING

The early to middle Proterozoic of Wisconsin was dominated by three periods of magmatic activity (Van Schmus, 1976). The first was associated with the Penokean orogeny, 1,850 to 1,900 Ma. The volcanic and plutonic rock associated with this orogeny form a complex which underlies most of northern Wisconsin. Scattered exposures of rock associated with the Penokean orogeny are also found in central and western Wisconsin.

The second period of magmatic activity post-dates the Penokean orogeny by approximately 100 m.y. The post-Penokean rock types are primarily epizonal granite and rhyolite. The rock is exposed mainly in central and southeastern Wisconsin (Smith, 1978; Van Schmus and Bickford, 1981). Some isolated exposures are found in northern Wisconsin. The post-Penokean rock has been dated by Van Schmus (1976) using U-Pb zircon methods at approximately 1,760 Ma. The rock yields younger ages by Rb-Sr rock and mineral dating methods. These younger ages are attributable to a pervasive low-grade, regional geochemical alteration and deformational event approximately 1,630 Ma (Van Schmus, 1976).

The third episode of magmatic activity is associated with the emplacement of the Wolf River batholith, 1,400 to 1,500 Ma. The ages of the various plutons were determined by Rb-Sr whole-rock and U-Pb zircon methods (Anderson and Cullers, 1978), which yielded generally concordant ages.

GEOLOGY OF HAMILTON MOUND

The Hamilton Mound area is located in Adams County in central Wisconsin (fig. 1). Precambrian rock is exposed extensively only in a quarry there. The major lithologies at the Hamilton Mound quarry are a red, porphyritic granite, a quartzite, and a quartz breccia. Minor features include a series of discontinuous pegmatitic and aplitic veins and schist inclusions within the granite. The only previous study of the area, by Ostrander (1931), identified just two lithologies present--the quartzite and the quartz breccia. Only recently has the quarry become deep enough, approximately 5 metres, to expose the granite.

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The quartzite is an extensive unit which varies in color from pinkish-gray to green-gray. The upper part of the unit contains obvious relict cross-bedding. Cross-bedding is much less obvious in the lower part of the quartzite. This lack of apparent cross-bedding in the lower part of the unit may be due in part to the influence of the granite intrusion. The quartzite is arkosic, with minor biotite or hornblende or both as the mafic component. Sericitization of the feldspar is common; this is the only mineralogic alteration observed in the quartzite. Some quartz grains have also been recrystallized. The discontinuous veins are found primarily within this unit. These do not appear to have caused significant mineralization in adjacent host rocks. The quartzite is also heavily fractured with conjugate joint sets prominent throughout it.

The breccia is exposed in a triangular-shaped mass in the topographic center of the Mound. The clasts within the breccia are mostly quartzite; however, there are a few granite clasts. The granite clasts are somewhat different in character from the granite in the main intrusion. Generally, these fragments are finer grained than the intrusion proper, and more equigranular than porphyritic.

The main body of porphyritic granite consists of a dark-colored matrix with phenocrysts of red feldspar. The matrix is primarily quartz, plagioclase, and microcline. In a few places the granite changes character and becomes more equigranular. In such places its color also becomes lighter with pink feldspars giving the rock an overall pink appearance rather than the dark, spotted appearance of the porphyritic parts.

The majority of the phenocrysts are microcline. Plagioclase is nearly as abundant in the rock overall, but does not usually form phenocrysts. Composition of plagioclase was determined optically from extinction angles, and ranges within the study area from albite to andesine, but individual grains are generally unzoned. Epidote, chlorite, and sericite occur as secondary minerals. Perthitic and myrmekitic textures are common throughout the granite. Myrmekite is found between plagioclase and quartz and occurs throughout entire grains rather than just along the grain boundaries. This type of texture is generally considered to be a product of eutectic crystallization (Cox and others, 1979). Zircon is conspicuous in most thin sections, although not present in all. There seem to be two populations of zircons. One appears to be of primary igneous origin with euhedral crystals. The other population has rounded cores with euhedral overgrowths and may indicate a minor inherited detrital component.

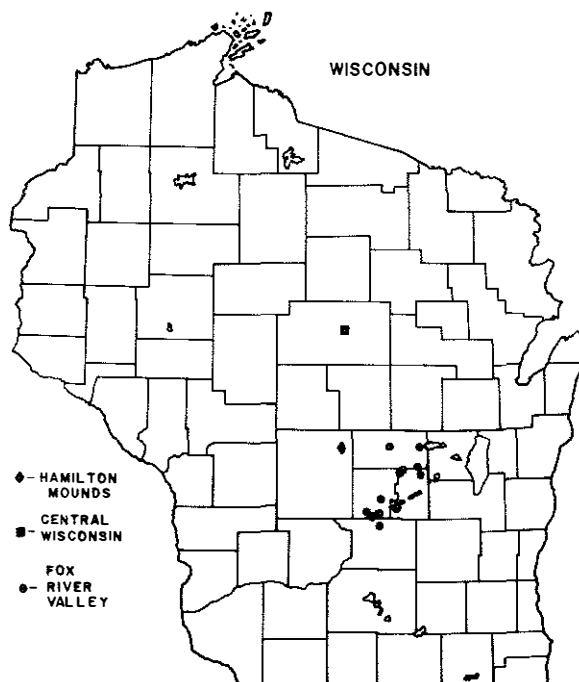


Figure 1.--Distribution of post-Penokean granite and rhyolite. Note location of Hamilton Mound (diamond).

The samples are altered to varying degrees. Sericite is the principal alteration product of the primary minerals in the granite, with microcline less strongly affected than other feldspar. There is a rough correlation between the depth in the vertical section at which the sample was collected and the degree of sericitization, the sericitization decreasing with depth. Small veins cutting the granite consist principally of calcite and quartz, with minor albite and epidote. Epidote is also found along contacts between the veins and host granite. It does not appear to be the product of alteration of minerals within the granite.

At several places within the granite, schist inclusions are found. These inclusions, which consist of quartz, biotite, hornblende, and trace amounts of albite, are finer grained than the granite host. The minerals within the inclusions do not show any secondary alteration. The mineralogy would suggest that temperatures within the schist never exceeded 500 °C. The outer part of the inclusions, although finer grained than the interior, has the same mineralogy. This would suggest that little reaction has occurred between the granite host and the inclusion. The origin of the inclusions is problematical, as the inclusions do not resemble any of the exposed lithologies in the area. It seems likely that these inclusions have been brought up from depth by the granite during emplacement.

The field relationship between the porphyritic granite and the quartzite suggests that the granite has been emplaced along fractures in the quartzite. Several such fractured areas contain quartz veins and granitic material. The fracture filling is not associated with any significant metamorphic effect. Epidote is found along some vein contacts, but otherwise there is little evidence of interaction between granitic material and quartzite. These fractured areas occur throughout the study area.

#### ANALYTICAL METHODS AND DATA REDUCTION

Details of all analytical methods may be found in Taylor (1983). For both chemical and isotopic analyses samples were chosen to be free of vein material and as little altered as possible. Granite samples were up to 10 kg in mass; smaller samples were taken of finer grained lithologies.

Most major and some minor elements were analyzed by atomic absorption (AA) spectrophotometry; silica and alumina were determined by inductively-coupled plasma (ICP) spectrometry. USGS rock standards G-2, GSP-1, AGV-1, and W-1 were the reference standards. Volatile contents reported are based on total weight loss on ignition. Accuracy of AA and ICP analyses can be estimated by treating some standards as unknowns and noting deviations from accepted values. Average deviations so measured were less than 0.5 percent of standard value for CaO and Na<sub>2</sub>O, 1-1.6 percent for SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, MgO, and MnO, and 2.2 percent for K<sub>2</sub>O.

Rubidium and strontium for isotopic analyses were extracted from approximately 0.2 g splits of rock powder by standard ion-exchange methods. All samples were analyzed on a semi-automated, 6-inch, solid-source, NBS-type mass spectrometer. Rb and Sr contents were determined by isotope dilution. Mineral separates were taken from the -60+150 mesh fraction of rock powder using acetylene tetrabromide separation followed by hand-picking. The feldspar separate is estimated to be about 98 percent pure. Because of the low total mafic content, a mixed biotite-hornblende separate was used for the other mineral fraction. This will not affect the determination of a mineral isochron, as a mixture of two minerals will still fall along the same isochron. Mineral separates were then analyzed by the same procedures as whole-rock samples. Precision of <sup>87</sup>Sr/<sup>86</sup>Sr ratios averaged ±0.1 percent (2σ) and is estimated at ±1 percent for Rb/Sr ratios.

Rb-Sr isochrons were fitted using a York (1969) Model II regression technique. This allows for correlation of errors, weighting of points on the basis of analytical precision, and consideration of geologic scatter in determining slope and intercept errors. Uncertainties are reported at the 95 percent confidence level (±2σ). The <sup>87</sup>Rb decay constant used was 1.42 x 10<sup>-11</sup>y<sup>-1</sup>.

#### ISOTOPIC DATA

Rb-Sr analyses for 11 samples of Hamilton Mound granite and several associated lithologies are reported in table 1. A Rb-Sr whole-rock isochron plot for the granite samples is shown in figure 2. The data show sufficient scatter that the regression line is really an errorchron with a poorly constrained age of 1,940 ± 400 Ma, and initial <sup>87</sup>Sr/<sup>86</sup>Sr of 0.702 ± 0.008. The scatter is possibly due to a low-grade, post-emplacement metamorphic event, as recognized in thin section (see petrographic description above). A mineral isochron, defined by a mafic fraction, a K-feldspar fraction, and the corresponding whole-rock point, indicates the approximate time of this event (fig. 2) of 1,580 ± 160 Ma with an initial ratio of 0.708 ± 0.004.

It is also apparent from figure 2 that the whole-rock data point furthest away from the intercept (sample 56) is strongly controlling the slope of the whole-rock errorchron. The remaining points scatter along the trend of the mineral isochron. If the regression program is performed for the whole-rock data, excluding sample 56, the result is a date of  $1514 \pm 314$  Ma, the same error as for the mineral isochron. The whole-rock Rb-Sr system thus appears to have been incompletely reset by the metamorphism with the rock data rotated toward the mineral isochron. There is no evidence that the controlling whole-rock point represents questionable data. A replicate analysis produced the same data point within error. In thin section the sample appears to be among the least altered, and thus may simply have been least reset by the thermal event.

Table 1.--Isotopic data for Hamilton Mound granite and related rock

Sample	$^{87}\text{Rb}/^{86}\text{Sr}$	$^{87}\text{Sr}/^{86}\text{Sr}$	Rb, ppm	Sr, ppm
Granites				
WIHM-1	1.679	0.7499	70.93	122.7
WIHM-4	1.710	0.7499	78.42	124.7
WIHM-7	1.084	0.7311	72.97	195.3
THM-40	1.335	0.7381	74.91	162.8
THM-42	1.298	0.7401	70.80	158.4
THM-43	1.274	0.7361	103.9	236.7
THM-50	0.7665	0.7275	73.55	278.2
THM-52	1.839	0.7519	93.51	147.7
THM-54	0.9610	0.7307	64.43	194.4
THM-55	1.391	0.7374	87.53	182.6
THM-56	2.308	0.7737	150.9	190.4
schist	2.481	0.7585	159.1	186.4
quartzite	2.422	0.7662	71.26	85.60
arkose	2.486	0.7592	116.7	136.5
mineral separates				
K-feldspar	1.940	0.7524	168.0	251.6
mafic	2.627	0.7668	208.8	231.3

A linear trend may in principle result from mixing of material from two different sources having different chemical and isotopic compositions. In the study area mixing between an incoming magma and an older lithology could have occurred by assimilation. The result would be a pseudo-isochron which yields a meaningless date. The possibility of mixing may be tested by plotting the ratio of  $^{87}\text{Sr}/^{86}\text{Sr}$  against total strontium content. If mixing has occurred, the data should fall along a hyperbolic curve between the two end member components which have been involved in the mixing (Faure, 1977). Such a diagram for the granite samples fails to define a good binary mixing hyperbola; therefore the granite errorchron, although imprecise, probably has age significance.

#### MODAL AND CHEMICAL DATA

The results of AA and ICP analyses are given in table 2; modal analyses are reported in table 3 and are based on 750 counts per thin section. When normalized and plotted on a quartz-alkali feldspar-plagioclase (QAP) ternary diagram, the majority of porphyritic granite samples indeed fall in the granite field of Streckeisen's (1976) classification (fig. 3).

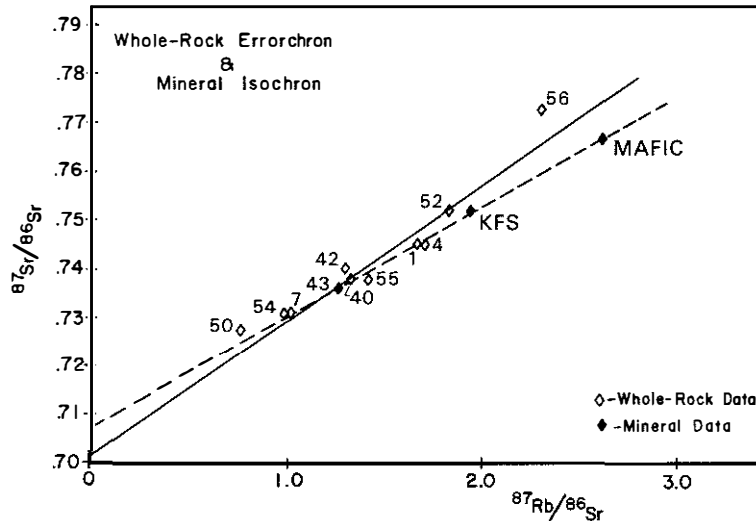


Figure 2.--Composite of whole-rock and mineral Rb-Sr data, Hamilton Mound granite.

The modal data were also converted to CIPW norms and plotted in the system quartz-albite-orthoclase to determine the relationship to a plausible ternary eutectic (fig. 4). The eutectic boundary line for  $P_{H_2O} = 1$  kb is plotted for comparison. The granite analyses do scatter about the thermal minimum. Increasing  $P_{H_2O}$  moves the thermal minimum toward the albite vertex, and increase in Ca content would cause a shift in the thermal minimum toward the quartz-orthoclase join. There is a broad linear trend toward the albite vertex which may indicate varying  $P_{H_2O}$  during emplacement. The scatter may in part also be a function of the later thermal event having caused some chemical alteration.

#### DISCUSSION

The attempt was made to relate the chemical and isotopic information obtained for Hamilton Mound to the three earlier periods of Proterozoic magmatic activity in Wisconsin. The whole-rock Rb-Sr errorchron obtained for Hamilton Mound has an uncertainty which is sufficiently large to encompass two of these periods of igneous activity; only the igneous activity at 1,500 Ma may be ruled out because it falls outside of the indicated age range of the granite. U-Pb dating of zircons has, however, pinpointed the time of crystallization of the granite at  $1,764 \pm 4$  Ma (Van Schmus, 1983, oral communication). The porphyritic granite thus formed during the 1,760 Ma magmatic event.

Taking into account the error, the date indicated by the mineral isochron could also correspond to either of two of the recognized events in the region. The resetting could be correlated with either the regional thermal event near 1,630 and 1,700 Ma, or with the emplacement of the plutons associated with the Wolf River batholith between 1,400 and 1,500 Ma. Because the thermal effects of the latter intrusive rock are more localized, it is more likely that the overprint corresponds to the earlier, regional event.

According to Van Schmus and Bickford (1981), Anderson and others (1980), and Smith (1978), the granite and rhyolite dated at approximately 1,760 Ma are considered to be distinct from the earlier Penokean suite. In addition to the age difference the separation had been supported by the hypothesis that the Penokean rock has a different chemical signature from rock regarded as post-Penokean. As the granite at Hamilton Mound appears on the basis of age determinations to belong to the 1,760-Ma group, one would expect its chemistry to be more similar to that of the post-Penokean felsic rock, rather than to Penokean units.

To test this expected relationship, the Hamilton Mound granite and related rock analyses were plotted on various chemical diagrams with the Penokean and post-Penokean fields as defined by Anderson and others (1980). The first of the diagrams is the quartz-alkali feldspar-plagioclase ternary plot (fig. 3). Anderson and others (1980) used this diagram to demonstrate that the post-Penokean granite is compositionally distinct from the earlier, synorogenic Penokean rocks, and also that the post-Penokean rock represents true granite (syenogranite of Streckeisen, 1976). According to Anderson and others (1980), this true granite represents a major change from the

Table 2.--Chemical analyses of Hamilton Mound granite and related rock

	granite										schist	quartzite	arkose	calcite vein
	WIHM-1	WIHM-4	WIHM-7	WIHM-8	THM-40	THM-50	THM-51	THM-52	THM-55	THM-56				
SiO <sub>2</sub>	69.66	67.44	69.68	69.13	67.42	70.00	64.57	69.48	68.68	66.34	68.45	79.85	63.11	42.04
Al <sub>2</sub> O <sub>3</sub>	14.10	14.66	14.05	14.83	15.51	14.54	16.14	14.97	15.29	14.91	6.93	9.03	19.51	10.52
FeO	3.80	4.66	2.66	3.90	3.89	3.20	6.11	4.03	4.30	5.94	11.46	1.86	3.47	1.15
MgO	1.19	1.07	1.44	1.39	1.04	1.14	1.71	1.03	1.27	1.91	3.90	0.99	1.90	4.02
CaO	1.25	1.45	1.49	1.78	1.69	2.38	1.41	1.62	1.77	1.96	2.82	1.47	2.56	20.26
Na <sub>2</sub> O	3.56	2.87	3.34	3.34	3.94	2.24	1.47	2.81	3.34	2.38	0.73	0.38	1.12	0.87
K <sub>2</sub> O	4.21	4.08	3.96	3.26	3.32	4.43	4.84	4.76	3.95	4.43	3.23	3.34	7.74	6.34
MnO	0.11	0.11	0.10	0.17	0.06	0.05	0.05	0.03	0.03	0.10	0.19	0.02	0.04	0.11
Volatiles	1.55	1.94	1.63	2.25	1.55	1.22	3.12	1.38	1.55	2.15	3.09	1.15	0.98	15.23
<b>Total</b>	<b>99.43</b>	<b>98.28</b>	<b>98.35</b>	<b>100.14</b>	<b>98.42</b>	<b>99.00</b>	<b>99.42</b>	<b>100.19</b>	<b>100.18</b>	<b>100.12</b>	<b>100.80</b>	<b>98.09</b>	<b>100.43</b>	<b>100.54</b>
Cu	7.8	12.0	14.9	25.0	13.0	14.9	3.9	5.0	2.0	10.1	4.3	2.8	11.9	25.7
Zn	85.7	73.2	76.2	97.0	67.7	57.6	89.3	64.4	55.7	69.5	84.4	51.7	127.4	61.1
Co	34.0	65.8	22.6	20.5	36.0	57.0	33.5	36.8	45.0	45.1	37.4	43.2	19.2	27.8
Ni	3.9	9.3	5.5	13.4	16.1	3.9	5.9	3.1	13.2	13.2	7.0	1.6	21.2	6.0
Rb	70.93	78.42	72.97		74.91	73.55		93.51	64.43	150.9	159.1	71.26	116.7	
Sr	122.7	124.7	195.3		162.8	278.2		147.7	182.6	190.4	186.4	85.60	136.5	

Major components in weight percent; trace elements in ppm.

Volatile contents determined by total weight loss on ignition.

Table 3.--Modal analyses for Hamilton Mound granite.

sample	quartz	K-feldspar	plagioclase	biotite	hornblende
WIHM-1	29.70	32.08	35.96	1.50	1.31
WIHM-4	30.66	33.53	31.61	2.00	2.20
WIHM-7	27.72	35.37	32.50	2.80	1.61
THM-40	29.04	37.75	30.01	3.20	-----
THM-42	31.42	39.98	23.80	2.01	2.80
THM-50	32.78	36.63	26.99	2.60	1.00
THM-52	30.72	38.40	26.88	2.00	2.00
THM-54	28.92	40.49	26.99	3.00	<1
THM-55	30.80	34.40	30.59	2.71	1.50
THM-56	26.54	39.82	28.44	2.50	2.70

Modes based on 750 counts per sample; all numbers in volume percent.

calc-alkaline activity of the Penokean orogeny to anorogenic, potentially rift-related igneous activity. Figure 3 shows the distribution of each group. The modal analyses for Hamilton Mound samples plotted with respect to those two fields fall between the Penokean and post-Penokean fields, and are clearly separate from the post-Penokean group.

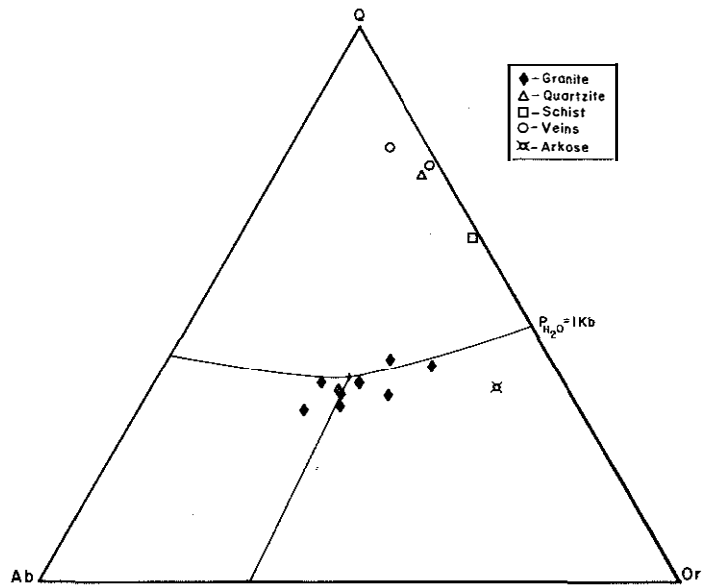


Figure 3.--Quartz-alkali feldspar-plagioclase ternary plot with Hamilton Mound samples plotted together with Penokean and post-Penokean groups of Anderson and others (1980).

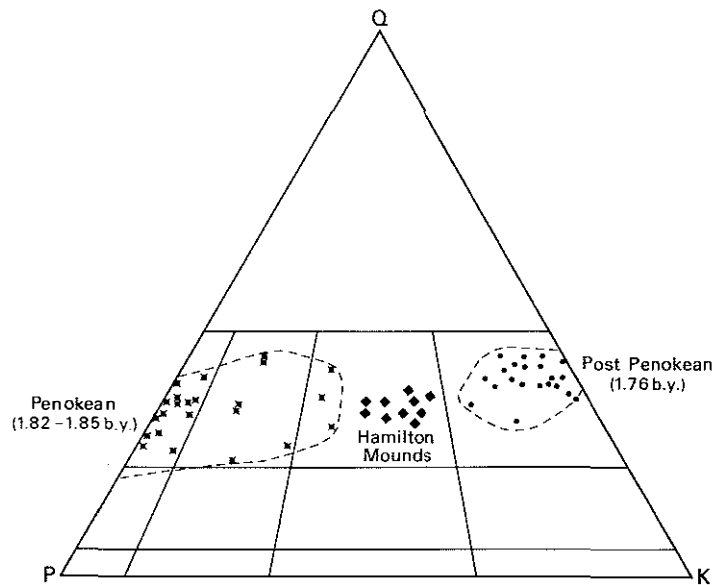


Figure 4.--Ternary eutectic diagram based on normative compositions for granite. Compositions of lithologies at Hamilton Mound plotted; granite is represented by diamonds.

Chemical distinction between the Penokean and post-Penokean has also been made on the basis of total alkali content and relative iron enrichment in comparison to the amount of  $\text{SiO}_2$ . A plot of total alkalis versus  $\text{SiO}_2$  was initially used by Anderson and others (1980) to demonstrate that both Penokean and post-Penokean rock fall within the subalkaline region for igneous rock. However, Penokean rock generally has lower total alkali contents than granite and rhyolite associated with the post-Penokean episode (fig. 5). On this diagram the data for Hamilton Mound fall entirely within the field for the Penokean. It is true that loss of alkalis could shift samples from the post-Penokean to Penokean fields. In the case of the Hamilton Mound samples a corresponding loss of  $\text{SiO}_2$  would also have been required. There is, however, no evidence for alkali migration at Hamilton Mound, and the granite contains abundant alkali acceptor phases. The presence of adjacent quartzite makes silica gain far more likely than silica loss.

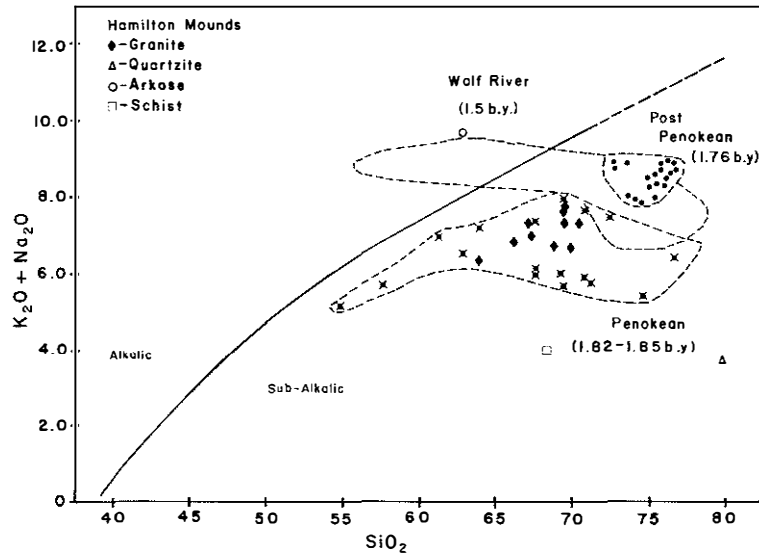


Figure 5.--Plot of total alkalis vs.  $\text{SiO}_2$ . Data for Penokean and post-Penokean samples from Anderson and others (1980).

Anderson and others (1980) argued further that whereas the Penokean and post-Penokean groups are both subalkalic in nature, the rock related to the post-Penokean is too iron-rich relative to magnesium to have the calc-alkaline character associated with the orogenic plutonism of the Penokean. The post-Penokean suite is then believed to be anorogenic. To demonstrate the compositional difference between the two periods of igneous activity, Anderson and others (1980) plotted the  $\text{FeO}/(\text{FeO} + \text{MgO})$  ratios against  $\text{SiO}_2$  for each rock suite. Hamilton Mound samples were plotted on the same diagram for comparison (fig. 6). The Hamilton Mound granite samples fall within the Penokean field; they seem compositionally to be more similar to the calc-alkalic, orogenic suite of the Penokean than to the anorogenic granite.

Granitic magmas which are derived from a single source should have similar initial strontium isotopic compositions as well as other chemical similarities. Other post-Penokean granite occurs near the Fox River and in central Wisconsin (fig. 1). A comparison of Rb-Sr data among Hamilton Mound and these two areas (data from Van Schmus and others, 1975) shows major differences with few similarities. The central Wisconsin samples are generally lower in total rubidium than the Fox River Valley suite, usually less than 100 ppm versus 100-200 ppm. Both regions have low total strontium contents (most samples below 50 ppm). As would be expected, the  $^{87}\text{Rb}/^{86}\text{Sr}$  and present  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios are correspondingly high. The Hamilton Mound samples present a striking contrast to these data. The Hamilton Mound granite has a similar total rubidium content to the central Wisconsin granite. However, it contains much higher concentrations of strontium than either of the two other regions, mostly 100-200 ppm, some samples over 200 ppm, and therefore far lower average  $^{87}\text{Rb}/^{86}\text{Sr}$  ratios and less radiogenic modern Sr. Some of these differences are apparent in figure 7.

The chemical variation among the three suites of rock may be explained by two processes. The first possibility is that the source for the Hamilton Mound granite is different from that of either of the other two groups of post-Penokean felsic rock. The second is that the melt and source were initially similar for all three regions, but that contamination of one or more units occurred during emplacement. The later explanation is more easily evaluated, at least with respect to lithologies now exposed in association with the Hamilton Mound granite.

There are three identifiable candidates for the assimilated material exposed near the granite. Two of these are an arkosic unit and the quartzite which the granite appears to intrude. The third is represented by the schist pieces included in the granite. The fact that fragments of this last rock type, which is not otherwise exposed in the study area, are found in the granite would indicate that some assimilation has taken place, and makes the schist a particularly obvious candidate for a melt-contaminating component.

Composition of the granite and the three possible contaminant lithologies at Hamilton Mound were plotted on a diagram of  $^{87}\text{Sr}/^{86}\text{Sr}$  vs. Sr content (fig. 7), together with Fox River Valley/central Wisconsin samples. There is a broad trend of higher  $^{87}\text{Sr}/^{86}\text{Sr}$  with lower Sr



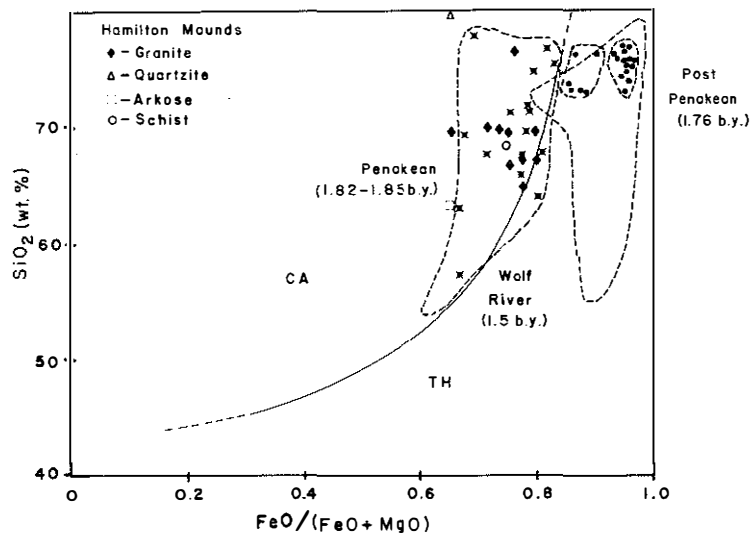


Figure 6.--Plot of SiO<sub>2</sub> vs. FeO/(FeO + MgO). Symbols same as in figure 5. Data for Penokean and post-Penokean samples from Anderson and others (1980).

content which might be interpreted as evidence of mixing. Several points should, however, be made. One is that such a trend will to some extent always be expected, especially when similar rock types are involved, simply as a consequence of the geochemistry of Rb and Sr. Second, simple binary mixing would produce a much tighter hyperbolic curve, although the observed considerable scatter does not necessarily rule out multi-component mixing. It can be seen by inspection of figure 7 that it is not possible to produce the composition of the Hamilton Mound granite by contaminating a Fox Valley/central Wisconsin-type magma with any of the potential contaminants observed at Hamilton Mound. The same conclusion may be reached by inspection of figures 5 and 6, on which the schist, arkose, and quartzite compositions are also included for reference. The diagrams indicate that the distribution of Hamilton Mound granite data points is not consistently attributable to the assimilation of one or more of these components by a melt similar to typical post-Penokean composition. This is true even if the present analyzed composition of the schist or other lithologies is partially altered by reaction with the granite, for the reacted compositions should fall along the same mixing trend. At least one additional high-Sr, low-<sup>87</sup>Sr/<sup>86</sup>Sr component is required, and no such material was observed in the area. Figure 7 might alternatively suggest the possibility of the reverse process, assimilation of an unknown contaminant by a Hamilton Mound-type initial magma to produce the Fox Valley/central Wisconsin array. However, in either case the heat budget of a granitic magma is unlikely to be sufficient to allow assimilation and complete digestion of enough contaminating material to cause the large shifts in bulk chemistry noted in figures 5 and 6, or the decrease of 50 percent or more in total Sr which would be required. In the case of the Hamilton Mound granite a modest heat budget is suggested both by the lack of high temperature mineralogy in the schist inclusions, and by the absence of flow structures, which supports batch emplacement of the magma. Also, boundaries of schist inclusions are generally sharply defined.

Mixing among the tested end members thus cannot account for the composition of the Hamilton Mound granite, and the apparent discrepancy between its age and the correspondingly expected composition. This is not to say that there has been no assimilation, but rather that a melt similar to that of the Fox River Valley and central Wisconsin felsic rocks could not have assimilated any of the metasedimentary rock types visible at Hamilton Mound to produce the composition of the porphyritic granite. The chemical and isotopic data require at least one additional component, so far unseen, if the granite's composition is to be accounted for by the mixing hypothesis tested. Taken together with the heat-budget argument above, the data strongly suggest that the original melt for the granite at Hamilton Mound was distinctly different from the source of the granite and rhyolite of the Fox River Valley and the central Wisconsin granite. This raises serious doubts about the possibility of distinguishing Penokean from post-Penokean felsic rock solely on the basis of geochemical signature.

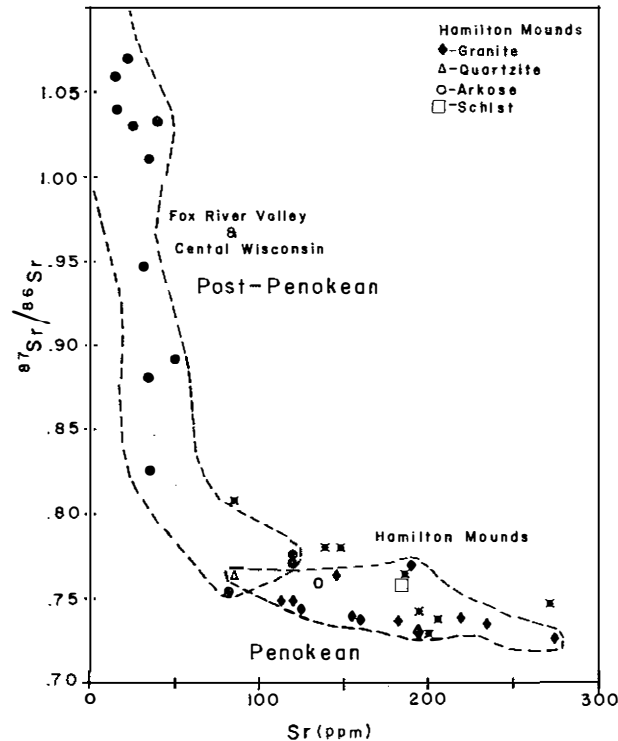


Figure 7.--Test of mixing hypothesis relating Hamilton Mound to post-Penokean rock of the Fox River Valley and elsewhere in central Wisconsin, and to Penokean felsic rock. Data on non-Hamilton Mound units from Van Schmus and others (1975).

#### SUMMARY AND CONCLUSIONS

Petrologically, the porphyritic granite at Hamilton Mound is a typical granite. The most abundant minerals are quartz, microcline, and plagioclase. The phenocrysts are usually microcline. Perthitic, myrmekitic, and graphic intergrowths are fairly common throughout the granite. Ternary plots of the normative and modal compositions indicate little compositional variation, as would be expected for a small, fairly homogeneous granite body. The overall composition is close to a plausible thermal minimum on a QAP diagram. The granite appears to intrude the overlying quartzite; its emplacement may have been fault controlled.

Rb-Sr whole-rock analysis of the granite yielded an errorchron with slope age of  $1,940 \pm 400$  Ma, and initial  $^{87}\text{Sr}/^{86}\text{Sr} = 0.702 \pm .008$ . The age is far better defined by a U-Pb zircon age obtained by Van Schmus (1983, oral communication) of  $1,764 \pm 4$ , Ma which presumably indicates the time of primary crystallization of the porphyritic granite. A Rb-Sr mineral isochron records a post-emplacement metamorphic event which accounts for the scatter in the whole-rock data. The age of this event as defined by the mineral isochron is  $1,580 \pm 160$  Ma; it probably corresponds to the pervasive regional overprint at 1,630 to 1,700 Ma observed throughout Wisconsin.

A comparison of chemical and isotopic compositions of the Hamilton Mound granite with other granite and rhyolite of similar age in central Wisconsin disclosed chemical differences. Other felsic rock has previously been divided into Penokean and post-penokean (1,760 Ma-old) suites on the basis of apparently distinct chemical signatures. However, the Hamilton Mound granite of post-Penokean age is chemically far more similar to the Penokean-age rock. Simple assimilation cannot readily account for the data. It may, therefore, not be possible to distinguish the Penokean from post-Penokean felsic rock in central Wisconsin on a chemical basis.

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