Origin and Tectonic Implications for Granite Bodies at Fort Phoenix State Reservation and the Permian-Aged Narragansett Pier Granite Using Whole-Rock Geochemistry

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Abstract

The origin and relationship between granite intrusions at Fort Phoenix State reservation and the Narragansett Pier Granite (NPG) along the south coast of Rhode Island were investigated using whole rock major and trace element geochemistry. The NPG is a peraluminous pluton that intruded high-grade metamorphic rocks ~273±2 Ma (Skehan & Rast, 1990). Although, granite plutonism is widespread throughout the Avalon Terrane, not much is known about their timing and relationships between these bodies.

This project investigated the question concerning the origin of granite bodies found intruding metamorphic rocks at Fort Phoenix. One model suggest they are related to the NPG and intruded about the same time, whereas another model suggests these granites at Fort Phoenix are different and significantly older than the NGP. This study addresses this question by applying x-ray fluorescence techniques to rock samples collected from Fort Phoenix and the NPG. This process gathers data on the the major oxide and trace element geochemistry of each lithology.

Project Objectives

- Compare and contrast the geochemical signature of granitic rocks from Fort Phoenix (FP) State Reservation with those of the Narragansett Pier Granite (NPG)
- Compare the geochemical signatures of the FP and NPG granites with highly deformed and boudinaged granite veins within the biotite gneiss country rocks
- Use geochemical data to determine the protolith of granites from FP and NPG
- Use geochemical discrimination diagrams to determine the tectonic affinity the granite intrusions from FP and the NPG

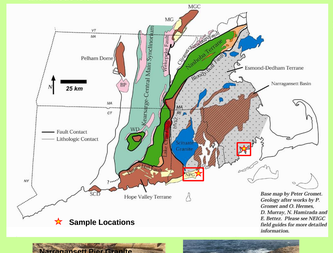
Geologic Setting

Rocks of the Fort Phoenix State Reservation are the product of a long and protracted geologic history spanning ~700 million years (Ma). This history involved several major mountain building events (orogeny's) including metamorphism, deformation, and igneous magmatic activity.

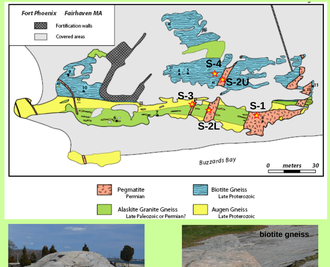
The Acadian Orogeny, occurring during the late Devonian (~370 Ma), resulted in the collision and accretion of the Avalonian microcontinent (eastern Massachseutts) with Laurentia, or Proto-North America (western Massachusetts). Formation of the Pennsylvanian-aged Narragansett Basin reflects post-Acadian tectonic activity under a strike-slip stress regime.

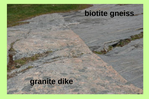
During the late Pennsylvanian and Permian periods this area was affected by the Alleghanian Orogeny which involved the collision between the newly accreted Avalonian terrane and Africa, closing the Iapetus Ocean. The Alleghenian Orogeny, a major mountain-building event in the central and southern Appalachians, played a major role in the evolution of the northern Appalachians, as well, including a significant period of igneous activity including intrusion of the 275 Ma Narragansett Pier Granite.

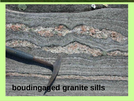
Simplified geologic map of the eastern Massachusetts, Connecticut, and Rhode Island



Simplified geologic map of the Fort Phoenix State Reservation. Sample locations for this study are shown by yellow stars.

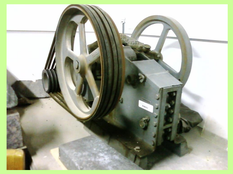




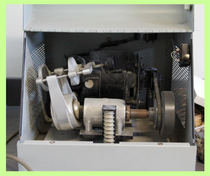


Sample Preparation & Analytical Methods

Samples were prepared for geochemical analysis using a jaw crusher to grind samples into smaller pieces. Samples were ground using a ball mill for a duration of 30 to 40 minutes to further reduce the grain size to a fine powder. The powder was split into 2 different aliquots; 1) used to make a fusion bead for the major oxides and 2) used to make a pressed pellet for trace element analysis.



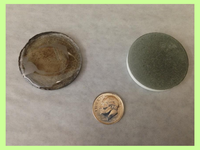
Jaw Crusher

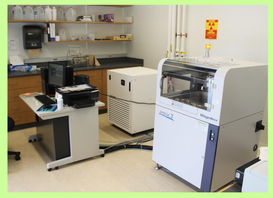


Ball Mill

Powder samples used for major oxide analysis were heated in a muffle furnace to 1000°C for 20 minutes. Samples were stirred in order to homogenize the melt. Once samples were adequately melted, they cool to room temperature and finally hand polished.

Powders for the trace element analysis were made into pressed pellets using a lithium borate binder and a 25 ton press.





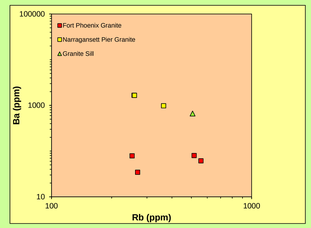
Samples were analyzed using a Rigaku ZSX-3 X-ray fluorescence instrument for major oxides (in weight percent) and trace elements (in parts per million, ppm).

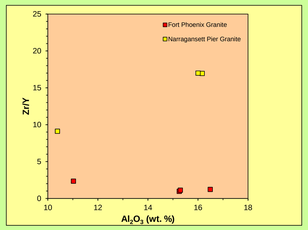
Standards were used to calibrate and daily drift corrections were made to ensure analytical accuracy and precision.

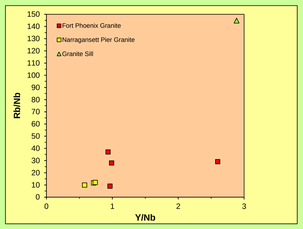
Geochemical Results

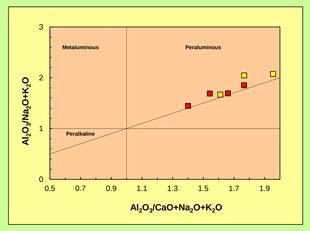
	Fort Phoenix Granites					Narragansett Pier Granites		
OXIDES	S-2-U	S-1	S-3	S-2-L	S-4	1-NPG-DIKE	NPG-3-DIKE	NPG-2-PHAN
	Granite	Granite	Granite	Granite	Granite Sill	Granite	Granite	Granite
SiO_2	75.09	81.07	74.49	74.88		82.25	75.49	74.94
TiO_2	0.07	0.03	0.02	0.02		0.01	0.15	0.26
Al_2O_3	15.25	11.02	16.49	15.30		10.38	16.17	16.00
Fe_2O_3	0.48	0.49	0.15	0.15		0.06	0.77	1.16
MgO	0.17	0.05	0.07	0.06		0.05	0.18	0.36
CaO	0.47	0.14	0.24	0.10		0.12	0.26	0.68
Na_2O	3.25	2.53	2.24	2.10		1.39	2.26	2.73
K_2O	3.41	3.21	4.82	5.15		3.64	3.77	3.08
P_2O_5	0.03	0.05	0.04	0.04		0.02	0.10	0.10
MnO	0.02	0.01	0.01	0.01			0.01	0.02
TOTAL	98.23	98.58	98.57	97.79		97.93	99.15	99.31
TRACE								
V	0.5	0.1	0.8	0.9	3.3	13.2	22.8	23.5
Rb	252.9	269.3	515.9	558.3	506.9	363.4	258.7	259.7
Sr	45.8	17.8	30.4	25.6	157.4	571.1	1063.3	1069.9
Y	27.0	9.5	13.0	49.9	10.1	21.2	15.9	16.0
Zr	26.0	22.3	15.9	55.9	11.2	193.3	269.6	271.9
Zn	25.5	8.3	13.3	9.2	14.3	33.3	68.4	68.9
Ba	78.9	34.5	80.1	61.4	664.5	982.4	1670.5	1661.9
Co	13.2	20.1	11.1	9.6	20.4	10.5	12.9	14.3
Cr	5.3	6.2	69.3	4.3	20.4	6.7	5.3	4.4
Cu	8.3	9.4	25.1	7.5	9.2	10.6	12.3	13.0
Nb	28.0	9.6	13.9	19.2	3.5	36.6	22.2	21.6
Ni	2.4	5.1	4.1	3.5	4.3	4.0	3.2	4.4
Mn	126.9	68.5	59.3	33.4	166.2	171.7	295.0	294.4
Mo	0.0	0.9	0.8	0.0	0.0	0.0	0.0	0.0
Pb	52.7	30.3	101.8	98.5	74.1	79.2	77.6	78.5
Ti	401.7	197.8	131.9	131.9	0.0	83.9	887.3	1528.7

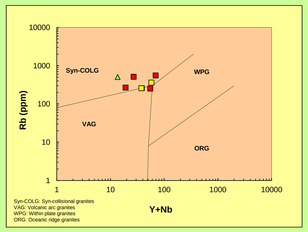
Geochemical Results











Summary

In conclusion, the data suggests that the granite dikes at Fort Phoenix, MA as well as the granite pluton in Narragansett, RI are peraluminous and formed during the Alleghenian orogeny in a syn-collisional tectonic regime. The major oxides from both sites are similar. However based on the trace element geochemistry of the granites, they were not likely derived from the same sedimentary protolith. Hence, the Fort Phoenix granite is not an extension of the Narragansett Pier Granite as some workers have suggested.

Acknowledgements

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