

Experimental Partial Melting of a Pelitic Schist

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Introduction

A natural meta-pelite has been partially melted under both fluid-present and fluid-absent conditions. In vapor saturated environments, water facilitates melting at relatively low temperatures. In vapor absent environments, dehydration reactions must occur in muscovite and biotite to create a hydrous phase; hence, melting should occur at a relatively higher temperature. The sample melted is an upper sillimanite zone schist from Puzzle Mountain, ME (sample A53). The initial mineralogy of the pelite is muscovite (17.5% Pg), biotite (.44 Mg/Mg+Fe), garnet (~9% pyrope & 10% spessertine), plagioclase, quartz, sillimanite, and ilmenite.

Methods

Experimental runs were performed in a 3/4", end-loaded piston cylinder device at 10 kbar pressure and temperatures ranging from 750° C to 1050° C. In order to determine the effect of experiment duration on the phase assemblages and compositions of the phases, a time series study (1, 2, 4, and 14 days) was conducted at 850° C (Skjerlie, Patino Douce, and Johnston 1993).

All experiments utilized an NaCl + pyrex glass solid media assembly surrounding a graphite furnace with a graphite plug at the bottom. Within the graphite furnace a nickel sample holder (9mm long, 8mm in diameter) containing 2mm diameter Au tubing was seated in a pyrophyllite cup with lid. This cup was bordered above and below by corundum plugs. After the runs, samples were mounted in epoxy, polished, and carbon coated.

The compositions of each mineral phase in each sample were determined using the Zeiss Digital Scanning Electron Microscope/Energy Dispersive System and the LINK analytical system at Amherst College. The modes of phases in each sample are currently being calculated by collecting and averaging SEM X-Ray maps. The bulk composition of the original schist was determined using X-Ray Fluorescence analysis at University of Massachusetts.

Results

Results obtained on the SEM show that wet and dry runs at 850°C for one day, two days, four days, and two weeks all exhibit some degree of melting; the same is true for wet and dry runs at 950°C for two days and at 1050°C for one day. In each pair of runs, the water absent one produced less melt than the water saturated one. All glasses are silicious with compositions ranging from 60-73 wt.% SiO₂.

The four day, 750°C, wet run contains euhedral garnet, biotite, muscovite, aluminosilicate, and ilmenite, anhedral quartz, and glass. The corresponding dry run has the same assemblage plus euhedral staurolite. Interestingly, the garnets in the 750°C runs display little to no zoning. Most of the garnets, in fact, have no rims; these garnets reflect the core compositions of zoned garnets analyzed in subsequent runs.

The two week, four day, and two day, 850°C, wet and dry runs all contain euhedral garnet, biotite, aluminosilicate, spinel, and ilmenite, anhedral quartz, and glass. The 850°C one day runs display similar assemblages except that the wet run contains corundum, and the dry run contains muscovite. Curiously, the 850°C, one day, wet run does not contain garnet.

The two day, 950°C runs display the same assemblage as the two week, four day, and two day, 850°C runs with the exception of biotite. The 1050°C, one day, wet run contains a great deal of melt and some spinel and ilmenite; the corresponding dry run contains less melt and some spinel, quartz, and aluminosilicate.

The garnet crystals produced in the various runs (with the exception of the 750°C garnets) are zoned with high magnesium rims (~30% Py, ~5% Sp, ~1% Gr).

A mineral summary table is included indicating the phases present in each sample. Two SEM photos are also included: one shows the presence of almost all mineral phases in the 850°C, one day, dry run, and one shows the presence of only spinel, ilmenite, and liquid in the 1050°C, one day, wet run.

Thompson, A.B. (1982) Dehydration melting of pelitic rocks and the generation of H₂O undersaturated granitic liquids. *American Journal of Science* 282:1567-1595.

Vielzeuf, D. and Holloway, J.R. (1988) Experimental determination of the fluid-absent melting relations in the pelitic system. *Contributions to Mineralogy and Petrology* 98:257-276.

Table 1: Average Liquid Compositions for Results

Dry Runs	850 C	850 C	950 C	1050 C	
	<i>1 day</i>	<i>4 day</i>			
Wt % oxide					
SiO ₂	70.71	66.30	77.90	64.38	
Al ₂ O ₃	12.14	16.60	13.61	13.26	
TiO ₂	0.48	0.95	0.57	2.16	
MgO	0.85	1.59	0.56	1.52	
FeO	2.26	2.92	2.23	5.01	
MnO	0.00	0.00	0.02	0.51	
CaO	0.10	0.00	0.06	0.75	
Na ₂ O	0.82	1.11	0.43	1.00	
K ₂ O	5.47	9.91	4.25	6.07	
Wet Runs	850 C	850 C	850 C	950 C	1050 C
	<i>1 day</i>	<i>4 day</i>	<i>13 day</i>		
Wt % oxide					
SiO ₂	64.62	68.54	68.74	67.26	63.27
Al ₂ O ₃	12.65	12.38	11.99	12.94	14.14
TiO ₂	0.26	0.42	0.42	0.65	1.00
MgO	2.62	1.33	1.52	2.21	2.55
FeO	5.53	3.38	3.47	5.33	7.59
MnO	0.08	0.03	0.05	0.17	0.11
CaO	0.11	0.10	0.14	0.21	0.19
Na ₂ O	0.30	0.24	0.32	0.45	0.65
K ₂ O	3.10	4.15	3.92	2.85	2.24

Discussion

Preliminary modal analyses are included for the 1050°C wet and dry runs (see figs. 1 & 2). They verify that the wet run contains more melt than the dry. This behavior is basically what was expected, and it is evidenced in the rest of the run pairs. There are two generalizations that apply: 1) the higher the temperature, the more melt produced and 2) the more H₂O present, the more melt produced. Although the samples follow these generalizations, there are more specific relationships that exist.

Figure 3 shows that silicate content of the glasses decreases with increasing temperature in both the wet and the dry runs. Figure 4 shows that silicate content of the glasses increases with increasing duration of the 850°C runs. The dry, 850°C, time versus wt. % SiO₂ data, however, indicate a far less dramatic increase than the corresponding wet plot.

Figures 5 and 6 show temperature versus Mg/Fe for wet and dry runs, respectively. In both cases, glass, biotite, and garnet rim Mg/Fe values increase with increasing temperature, while garnet core values remain fairly constant. These plots are not affected by the presence or absence of a vapor phase.

Figures 7 and 8 show time versus Mg/Fe for wet and dry runs, respectively. Both plots reflect fairly constant biotite, garnet rim, and garnet core Mg/Fe values with increasing time. The glass at 14 days shows a marked decrease in Mg/Fe in both the wet and dry studies. The explanation for this is that the garnet rims in the 14 day runs are thicker than in the other 850°C runs. There is more garnet reaction with time, thus depleting the glass in Mg.

It is important to note that great discretion must be used when evaluating the short 850°C runs, for they most likely reflect disequilibrium.

References

- Skjerlie KP, Patino Douce AE, Johnston AD (1993) Fluid absent melting of a layered crustal protolith: implications for the generation of anatectic granites. *Contributions to Mineralogy and Petrology* 114:365-378.

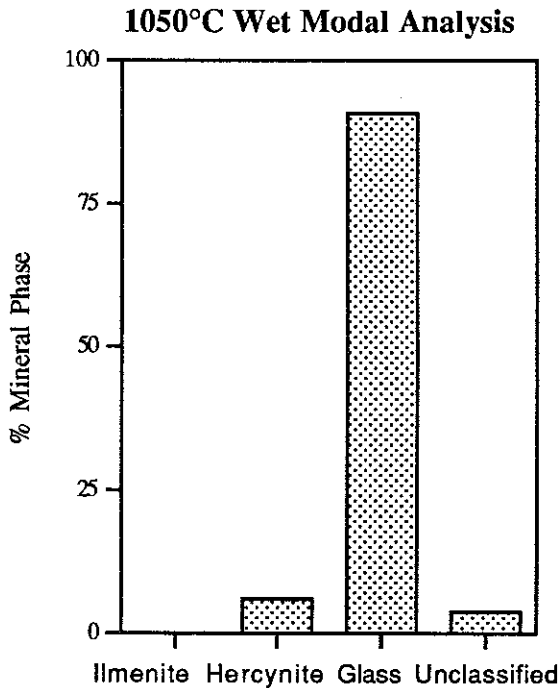


Figure 1

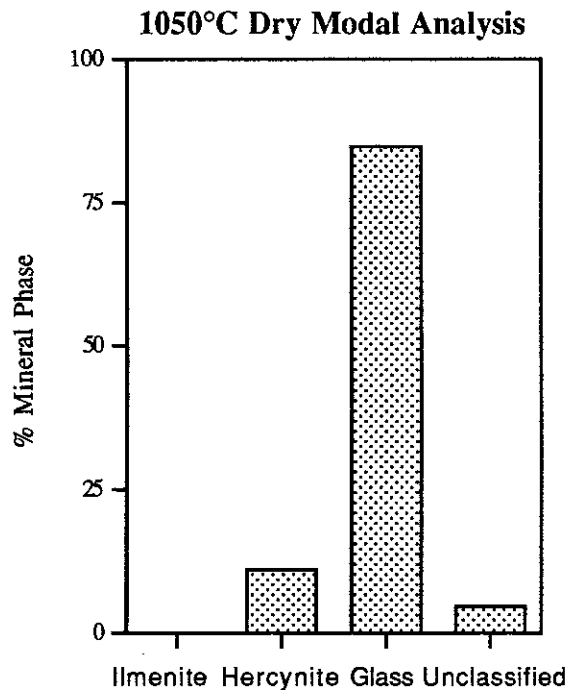


Figure 2

Temperature Vs. Wt. % SiO₂

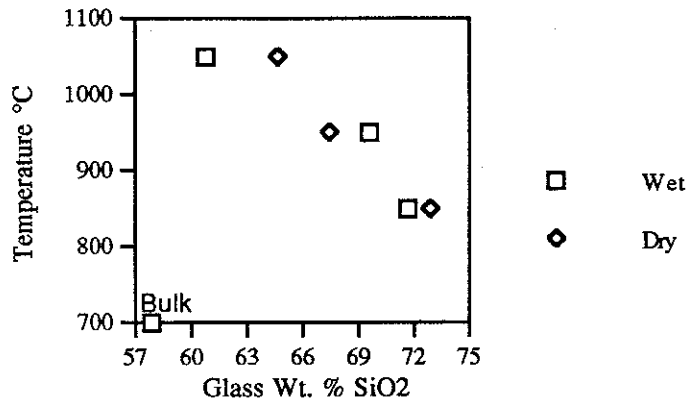


Figure 3

850° C Time Vs. Wt. % SiO₂

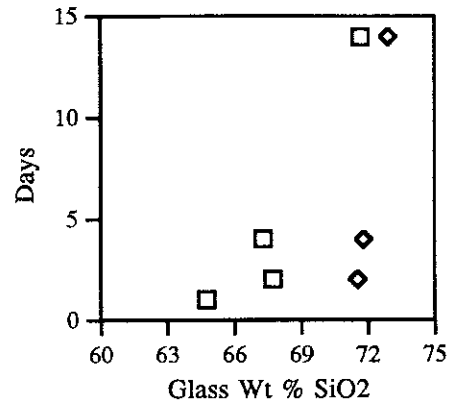
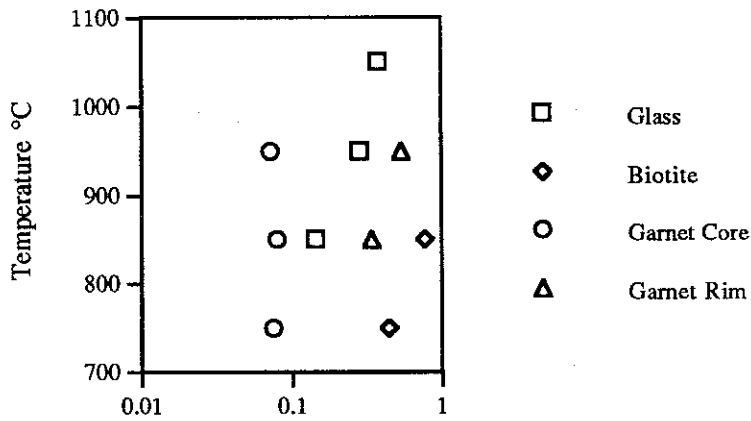


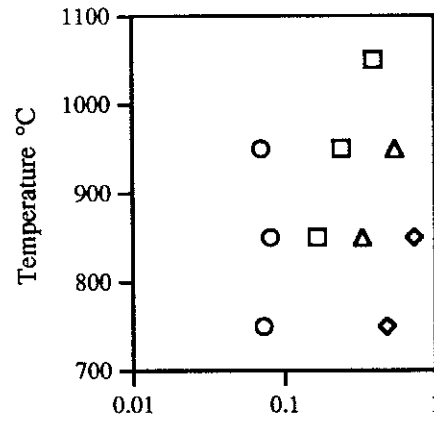
Figure 4

Wet Temperature Study



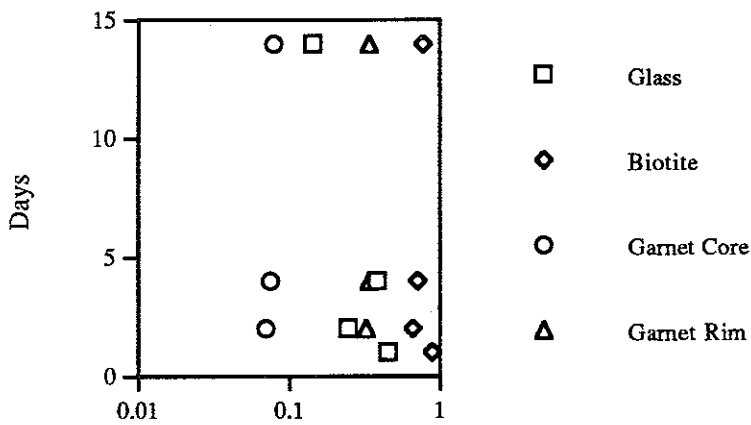
**Mg/Fe Ratio
Figure 5**

Dry Temperature Study



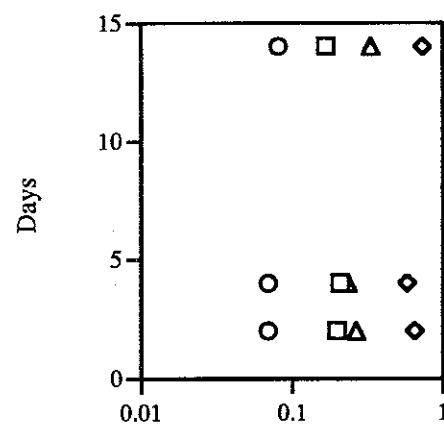
**Mg/Fe Ratio
Figure 6**

850°C Wet Time Study



**Mg/Fe Ratio
Figure 7**

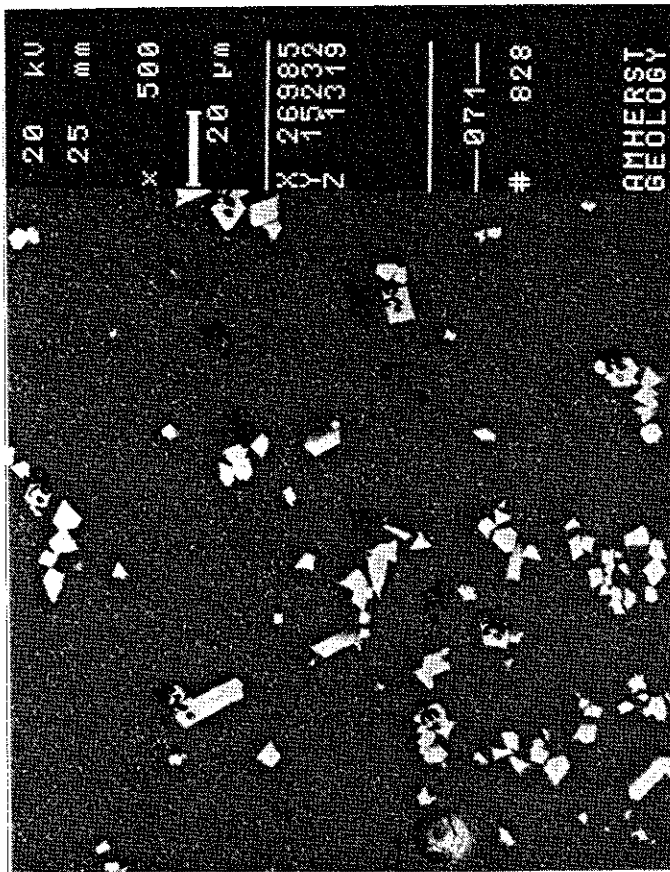
850°C Dry Time Study



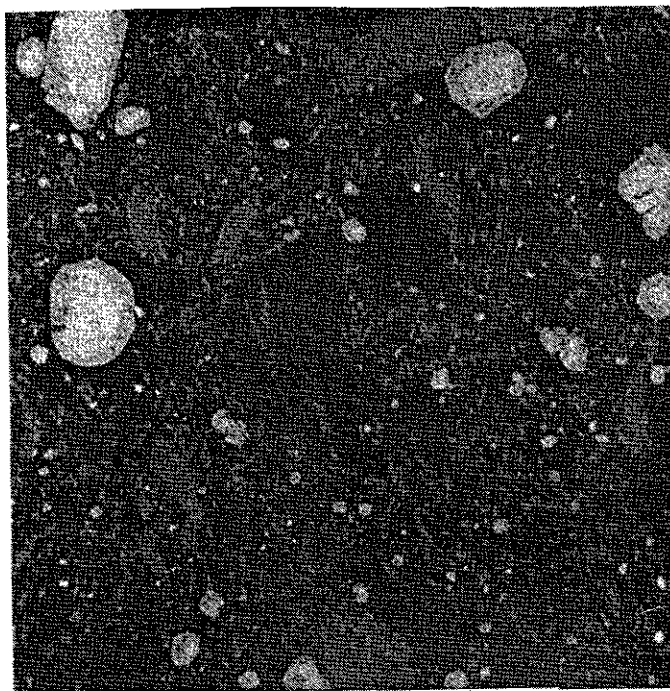
**Mg/Fe Ratio
Figure 8**

MINERAL SUMMARY TABLE

SAMPLE	GARNET	BIOTITE	MUSCOVITE	ALUMINOSILICATE	QUARTZ	SPINEL	ILMENITE	CORUNDUM	STAUROLITE
WET									
750°C-4 DAYS	X	X	X	X	X		X		
850°C-1 DAY		X		X	X	X	X	X	
850°C-2 DAYS	X	X		X	X	X	X		
850°C-4 DAYS	X	X		X	X	X	X		
850°C-14 DAYS	X	X		X	X	X	X		
950°C-2 DAYS	X			X	X	X	X		X
1050°C-1 DAY						X			
DRY									
750°C-4 DAYS	X	X	X	X	X		X		X
850°C-1 DAY	X	X	X	X	X	X	X		
850°C-2 DAYS	X	X		X	X	X	X		
850°C-4 DAYS	X	X		X	X	X	X		
850°C-14 DAYS	X	X		X	X	X	X		
950°C-2 DAYS	X			X	X	X	X		
1050°C-2.5 DAYS				X	X	X			



1050°C ONE DAY WET



850°C ONE DAY DRY

A CRYSTALLIZATION STUDY OF A THOLEIITIC BASALT FROM THE INDIAN HEAVEN LAVA FIELD, SOUTHERN WASHINGTON CASCADE RANGE

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Introduction

The Indian Heaven Lava Field is located in the Cascade range of southern Washington, between Mount St. Helens and Mt. Adams. There are more than twenty vents within a thirty kilometer (north to south) area. Periods of eruption began around 730,000 years ago and have occurred as recently as less than 10,000 years ago. The lavas extruded from the vents are mostly mafic. There are four dominant types of lava that define the Indian Heaven area: a calcalkaline basalt and a basaltic andesite (olivine, plagioclase and rare clinopyroxene), a porphyritic basalt intermediate in composition between the previous (olivine and plagioclase), a high potassium calcalkaline basaltic andesite (clinopyroxene, olivine and relict amphibole), and a tholeiitic basalt (Smith and Leeman, 1989).

The goal of this study was to find the path of crystallization of one of the rocks, a tholeiitic basalt, in the laboratory. The main areas of investigation were: what temperatures minerals formed at, the chemical compositions of each mineral, whether the chemical compositions changed as temperature decreased and the proportions of minerals to glass at a particular temperature.

Procedures

The procedures described by Donaldson (1975) were used as a basis for preparing the samples used in this study. These techniques were the most efficient for minimum contact with the sample holder and maximum contact with the gases. The procedures were modified to accommodate the available equipment.

A 4 mm diameter loop was made from 1.5 cm of platinum wire and placed at the bottom of a small graphite crucible. Two hundred mg of tholeiitic basalt powder were placed on top of the platinum loop. The crucible was placed in a 1 atm bulk furnace and heated for two minutes at about 1350°C. The powder melted into a bead and adhered to the platinum wire. After the crucible was taken out and allowed to cool, the bead and wire were removed.

Once cooled, the bead was ready to be hung from the sample assembly and lowered into a 1 atm gas mixing, vertical tube furnace. A problem often encountered in experiments of this nature is the sample hitting the sides of the furnace when it is lowered into or removed from the furnace. This was solved by hanging the basalt bead inside a platinum wire cage, and attaching the cage to the platinum wires coming through the bottom of the alumina tube with a loop of thin platinum wire.

To begin, the temperature inside the column was raised to 1300°C. The oxygen fugacity (fO_2) was controlled by flushing the furnace tube with a measured mixture of CO and CO₂. The ratio of CO:CO₂ was determined by using a chart relating fO_2 and temperature to CO:CO₂ (Kozak, 1994). The sample was then lowered into the hot spot of the furnace (determined by experiment). Samples 201-204 were run at $-\log fO_2=9$; the rest were run at $-\log fO_2=10$. In the first few experiments, the temperature was lowered manually, because the computer had a tendency to undershoot the desired temperature if it was brought down too quickly. Once the appropriate rate of cooling had been found, a program was run to decrease the temperature. Initially, the temperature was decreased at a rate of three degrees per minute, then one degree per minute when the temperature was within thirty to forty degrees of the ending temperature. Throughout the runs, the CO:CO₂ levels were adjusted to maintain the same fO_2 . When the desired temperature was reached, the sample was kept in the furnace for various lengths of time so that it could reach equilibrium. The times varied from one hour to almost sixty-seven hours.

The sample was quenched by dropping the bead into a 800 mL beaker of tap water. This was accomplished by running an electrical current through the wires holding the sample in the furnace. The current burned through the thin platinum wire, detaching the wire cage from the alumina tube assembly.

To prepare the beads for microanalysis, approximately half of each individual sample was placed in a hollow plastic cylinder (three to six samples per cylinder) that was then filled with Quikmount epoxy. After hardening, the samples were polished with wet sandpaper discs mounted on a lap, using progressively smaller grit sizes, down to a 1 μ diamond paste. The samples were also polished using a 1/4 μ diamond impregnated cloth covered lap. The cylinders were then coated with a thin film of carbon using a Pelco Advanced Coater 9500.

All of the phases present in each sample were analyzed for chemical composition using the JEOL JSM-6400 Scanning Electron Microscope and Quantex VI software on a Kevex Analyst 8000. The electron dispersive mode was used for chemical analysis; the working distance was 39 mm. The Feature II software program was used