Contact Metamorphism of the Kittery Formation at Cape Neddick, Maine

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Abstract

The Kittery Formation is a Silurian- to Ordovician-age metasiltstone and metapelite sequence that spans from the coast of southern Maine into northern coastal Massachusetts. The Cape Neddick Gabbro is a Cretaceous- to Jurassic-age igneous body, believed to be the magma chamber of a Paleozoic volcano, that intrudes the Kittery Formation near York, Maine. During the emplacement of igneous bodies at depth, contact metamorphism of the surrounding country rock occurs, given the high temperatures produced by the intrusion, and the increased pressures at depth. For this project, the conditions of metamorphism that the Kittery Formation underwent were estimated using mineralogical, petrological, and chemical analysis techniques. My results suggest that the Kittery Formation underwent low-pressure, high-temperature metamorphism.

Approach

- In order to constrain the pressure and temperature (*P-T)* conditions the Kittery Formation underwent during contact metamorphism, petrographic thin sections were made for three samples near the contact between the Kittery Formation and Cape Neddick Gabbro, as shown on Figure 1.
- These thin sections were first analyzed optically using a Leica DM750 polarizing microscope and then analyzed the minerals chemically using the Scanning Electron Microscope (SEM) with Electron Dispersive Spectroscopy (EDS) in the University Instrumentation Center at Parsons Hall.
- With petrographic observations and data gathered from chemical analysis, *P-T* conditions were estimated using a petrogenetic grid from Winter, (2014), seen in Figure 7, and spinel + cordierite geothermometry.

Field Area

Figure 1. Simplified bedrock geology of Cape Neddick, Maine, with sample locations. Google Earth. Modified from Hussey *et al.,* 2014.

Photomicrographs

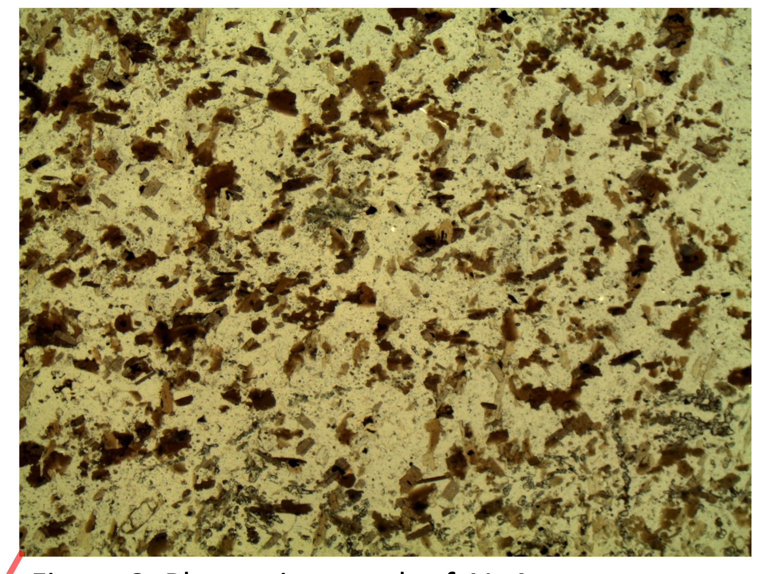

Figure 3. Photomicrograph of AL-4 in PPL at 4X magnification.

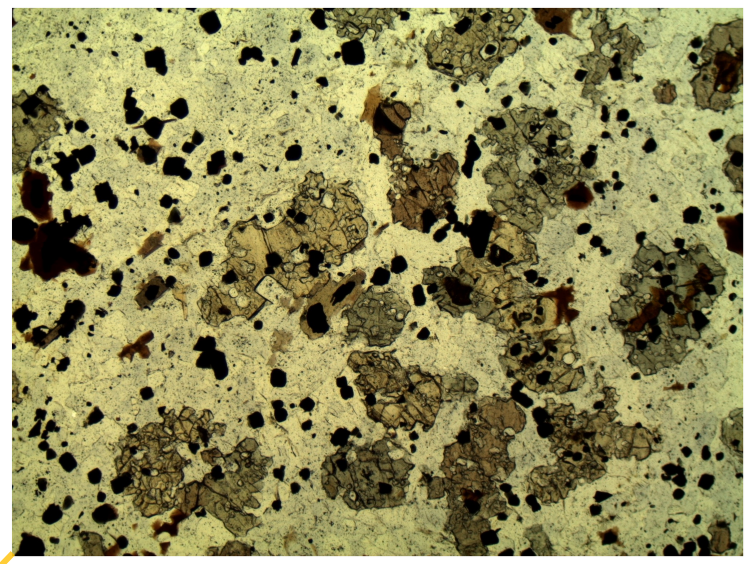

Figure 4. Photomicrograph of AL-1 in PPL at 4X magnification.

The increase in grain size from AL-4 to AL-1 can be readily explained by an increase in metamorphic grade toward the contact.

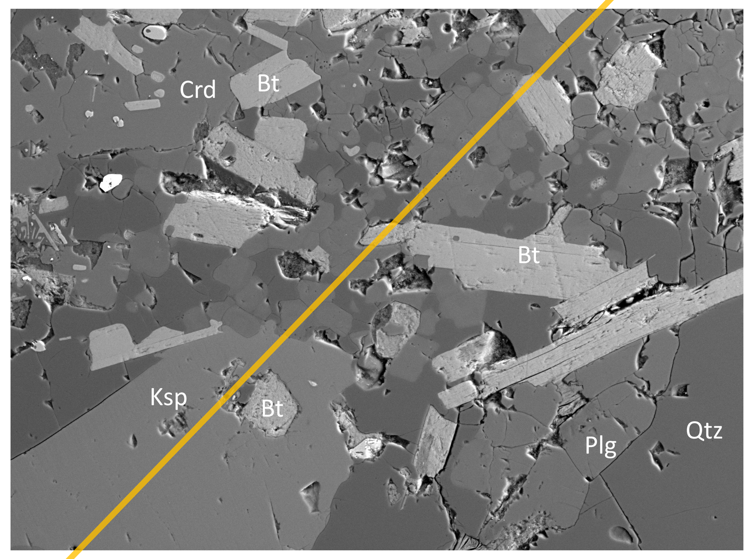

Figure 6. SEM scan of AL-4 at 550X magnification. Biotite (Bt), cordierite (Crd), plagioclase (Plg), Quartz (Qtz), and potassium feldspar (Kfs) are present.

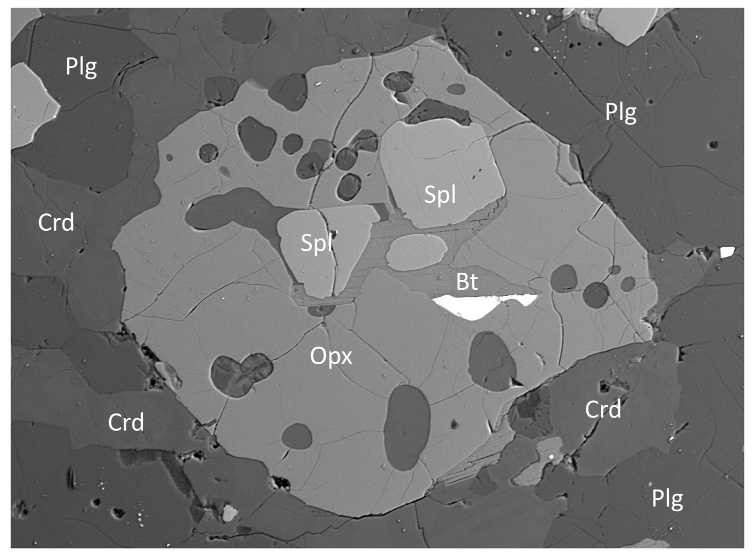

Figure 5. SEM scan of AL-1 at 550X magnification. Orthopyroxene (Opx) is embayed by cordierite (Crd). Spinel (Spl) is seen as inclusions in orthopyroxene.

Mineral Assemblages

Sample #	Plg	Hy	Bt	Crd	Kfs	Hc
AL-1	**X**	**X**	**X**	**X**		**X**
AL-3	**X**	**X**	**X**		**X**	
AL-4	**X**		**X**	**X**	**X**	

Table 1. Mineral assemblages of all samples.

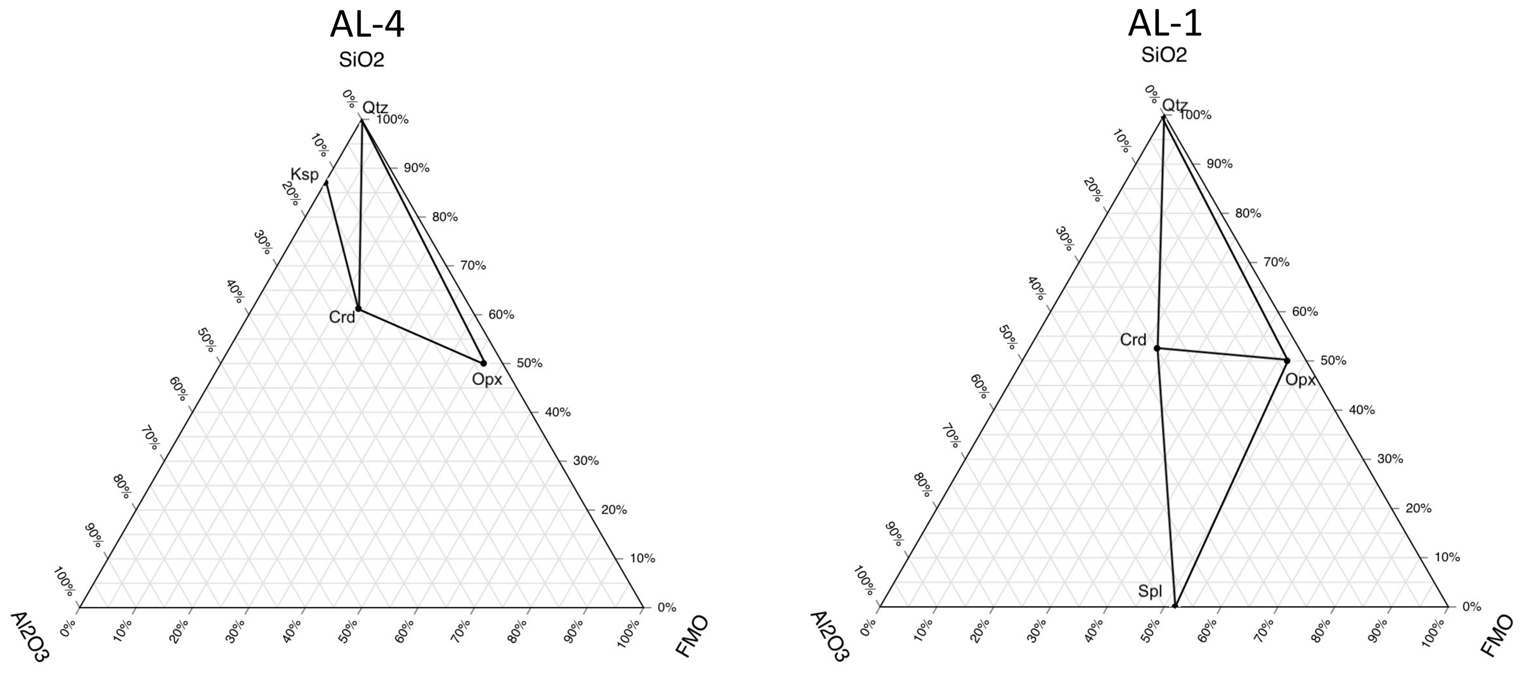

Figure 7. Ternary diagrams for samples AL-1 and AL-4, plotted with axes of SiO_2, Al_2O_3 and FMO (Fe,Mg,Mn).

Results & Conclusions

Results

- Sample AL-1, closest to the contact, contained the reaction of opx + spl + qtz = crd + bt. This reaction is indicative of high-temperature metamorphism, which is consistent with AL-1's close proximity to the contact. The reaction can be seen in Figure 6, as the orthopyroxene is embayed by cordierite.
- Spinel + cordierite geothermometry estimated that the minerals became equilibrated at ~1110ºC. Due to the mineral grains scanned during EDS not being adjacent, there is potential error in this calculation, as the two minerals were not equilibrium.
- Sample AL-4, furthest from the contact, contained felsic partial melt. This occurrence suggests the reaction of ms + qtz = kfs + bt + sil + <u>melt</u>. This reaction constraints the lowest temperature estimate during metamorphism. This is consistent with AL-4's distance from the contact, compared to AL-1

Conclusions

- The Kittery Formation underwent hornfels-facies metamorphism, with the highest temperatures, between ~650ºC to ~1110ºC occurring closest to the contact at AL-1. Pressure conditions likely ranged from 1 to 2 kbar.

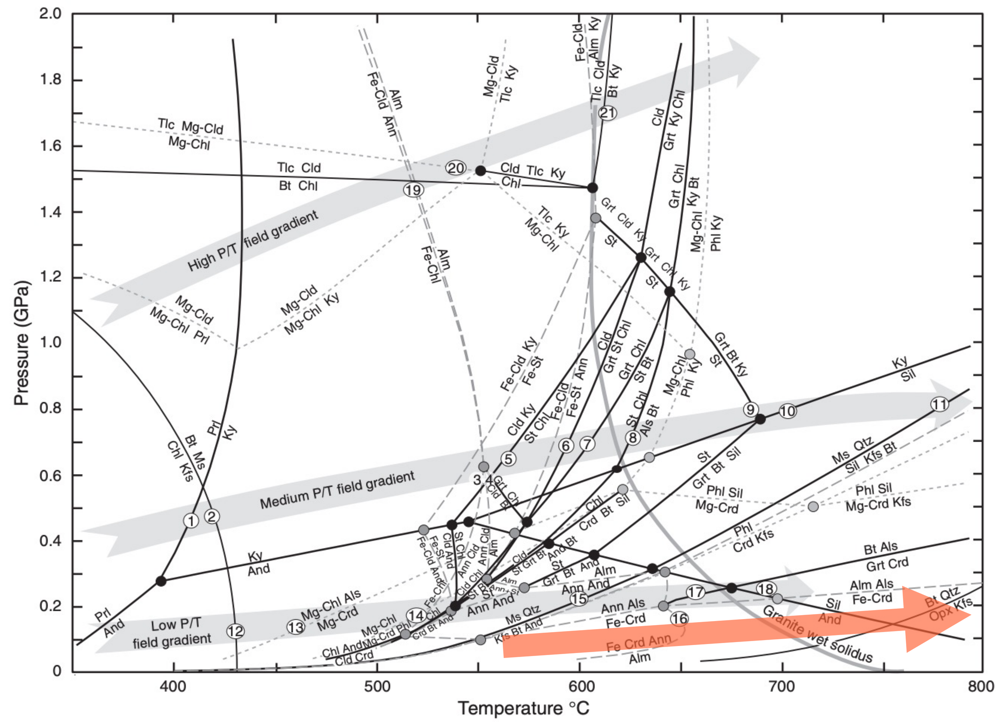

Figure 7. Petrogenetic grid for the system KFMASH at $pH_2O = p_{total}$, modified from Winter, 2014. The orange arrow represents the pressure-temperature-time path the Kittery Formation underwent. Starting lie at the ms + qtz = kfs + bt + Al_2SiO_5 reaction tie-line. Final temperature conditions of ~1110ºC estimated using spinel + cordierite geothermometry exceed the boundaries of this diagram.

Acknowledgments

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