INVESTIGATING THE MINERALOGY OF SYMPLECTIC GABBRO FROM THE HICKS BUTTE COMPLEX, CENTRAL CASCADES, WASHINGTON, SUPPORTS A FORMATION IN AN ISLAND ARC SETTING

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ABSTRACT

The Hicks Butte complex consists of variably deformed Late Jurassic (150–154 Ma) intrusive rocks with rare Early Cretaceous (ca. 144 Ma) dacite. Previous whole-rock and trace element geochemistry work suggest the Late Jurassic age intrusive rocks formed in an island arc setting; while the Early Cretaceous dacite are adakites which formed from melting of mafic lower crust. Mineral geochemistry determined by electron probe micro-analyzer, Florida Center for Analytical Electron Microscopy, from two hornblende olivine gabbro were studied to help constrain the origin of this complex. Plagioclase (n=24), olivine (n=8), pyroxene (n=7), and amphibole (n=7) were analyzed. The hornblende olivine gabbro have symplectite and corona textures. The corona textures are pyroxene surrounding olivine; while the symplectic textures occur as fine-grained pyroxene, amphibole and possibly quartz in contact with the pyroxene, olivine and plagioclase.

Plagioclase are anorthite and range from An_{92} to An_{98}. Olivine is forsterite and range from Fo_{67} to Fo_{74}. Pyroxene are enstatite and range from En_{74} to En_{78}. Amphiboles are Ca-rich, magnesio-ferri-hornblende with one ferri-tschermakite. Hawthorne's et al. (2012) classification for amphiboles was used. Al_2O_3 and Mg# of orthopyroxene plot along modern trends for low-pressure magma differentiation. Enstatite and anorthite percentages plot within fields defined by gabbroic samples from modern island arcs. Forsterite and anorthite percentages plot in the field defined by island arc gabbroic and ultramafic rocks. Amphibole thermobarometry of Ridolfi et al. (2010) resulted in temperature and pressure estimates of 896^{o}C ± 29^{o} and 2.61 kbar ± 0.12. Our new mineral geochemical data supports the interpretation of the gabbro initially forming in a Late Jurassic island arc setting. The temperature and low pressure of the symplectic amphibole suggests it formed as a late phase in the gabbro during structural emplacement of the complex. The symplectite textures, along with the pressure and temperature estimates from the amphibole, suggest the gabbro was the mafic crust which melted to produce the Early Cretaceous adakitic dacite.

INTRODUCTION

- Previous research suggests the Hicks Butte complex formed in an island arc setting (e.g., MacDonald, et al., 2017).
- More research required to constrain Hicks Butte's complex origin.
- Identify minerals' chemical composition using EPMA analysis.
- Determine magma type using the mineral chemistry.
- Chemical analysis of and pressure of the formation of the rock using a geothermometer. minerals amphibole, olivine, pyroxene and plagioclase within a sample of symplectic gabbro from the Hicks Butte complex were used to determine the temperature

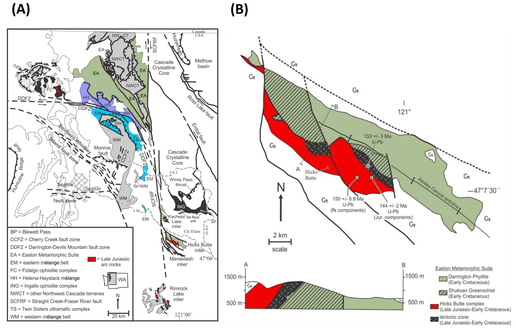


Fig. 1. (A) Geological map of the Northwestern region of Washington State. (B) Gabbro analyzed was collected from the Tectonic zone (black) within the Hicks Butte Complex (red) located in the Hicks Butte inlier. Modified from Miller, et al., (1993) & MacDonald, et al., (2017).

METHODS

- Amphibole, olivine, plagioclase, and pyroxene from 2 symplectic gabbros were analyzed on a JEOL 8900R Superprobe Electron Probe MicroAnalyzer (EPMA) at the Florida Center for Analytical Electron Microscopy
- The EPMA beam diameter was 1 – 2 µm
- The EPMA accelerating voltage of the probe was 15.0 kV
- The EPMA bean current was 20 nÅ
- Structure Probe, Inc., SPI-1 minerals were used as EPMA standards, while Electron Microscopy Sciences EMS-1 minerals were used as EPMA knows.
- A discussion of element standards can be found at http://www2.fiu.edu/~emlab/home.html
- To account for possible compositional zoning, each mineral analysis reported here is the average of 3 different spots.
- Amphibole mineral formula was calculated using 24 total O, OH, Cl, and F.
- Olivine mineral formula was calculated using 4 total oxygen
- Plagioclase mineral formula was calculated using 8 total oxygen
- Pyroxene mineral formula was calculated using 6 total oxygen
- Fe valency and (OH) for amphiboles were estimated using stoichiometry and classified utilizing the scheme of Hawthorne, et al., (2012).
- We utilized Ridolfi, et al., (2010) amphibole thermometry and barometer to estimate temperatures and pressures.

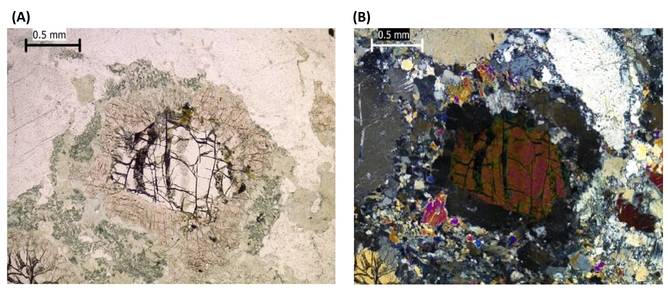


Fig. 2. Thin section symplectite and corona textures in plane-polarized light (A) from the Hicks Butte complex gabbro, and cross-polarized light (B). Olivine is mantled by pyroxene and lesser amphibole.

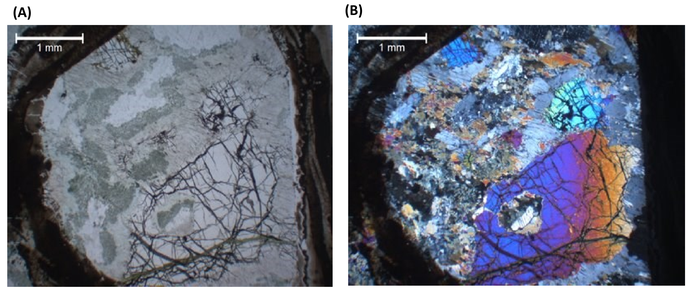


Fig. 3. Thin sections of Olivine in plane-polarized (A) and cross-polarized light (B).

RESULTS

Amphibole classification	Temperature	Pressure
Magnesio-ferri-hornblende	896^{o} C ± 29^{o}	2.61 kbar ± 0.12

Table 1. Amphibole classification, temperature, and pressure estimates of amphiboles from the gabbro. The amphibole classification is from Hawthorne, et al., (2012). The temperature and pressure estimates are derived using Ridolfi, et al., (2010) geothermobarometer. The amphibole pressure is from two samples, while the temperature is from six samples.

RESULTS CONTINUED

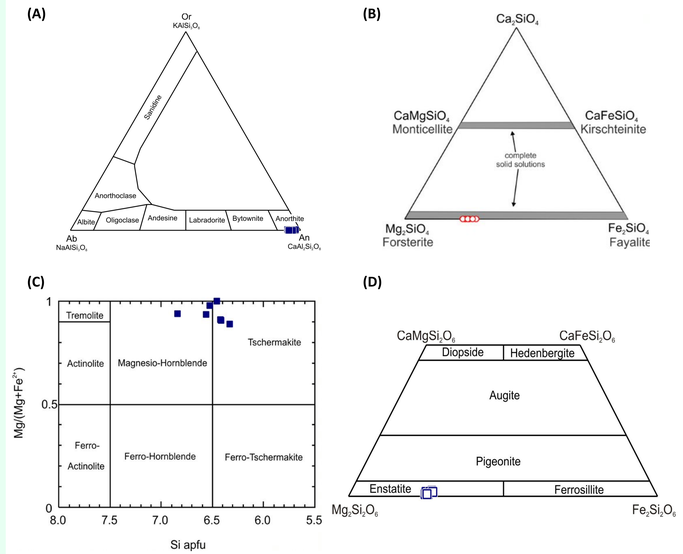


Fig. 4. Classification diagrams of the four minerals analyzed. (A) Plagioclase feldspar. (B) Olivine. (C) Amphibole modeled after Hawthorne, et al., (2010). (D) Pyroxene.

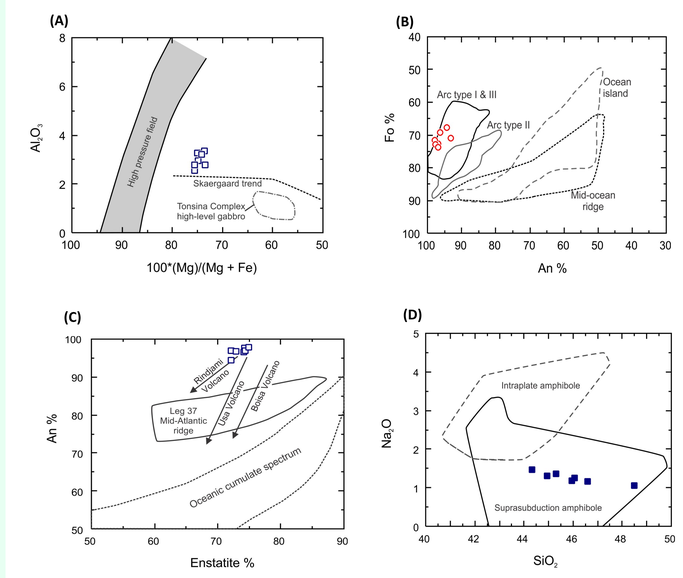
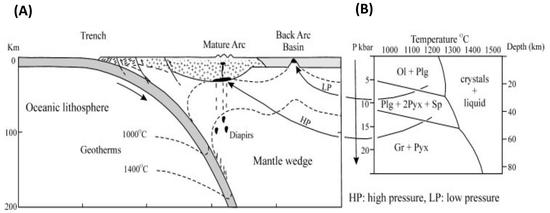


Fig. 5. Interpretive diagrams. (A) Orthopyroxene Mg# versus Al_2O_3 modeled after DeBari & Coleman (1989). (B) Olivine Fo vs. An from Beard (1986). (C) Enstatite percentages versus anorthite percentages based on Burns (1985), and Bagci, et al., (2006). (D) Amphibole Na vs. Si from Coltorti, et al., (2007).

DISCUSSION/CONCLUSION

- Olivine Mg# ranges between 0.68 and 0.74, confirming its forsterite.
- Olivine and plagioclase plot away from ocean island and the mid ocean ridge fields. They plot within the range of island arcs. This suggests the gabbro formed in an island arc (Fig. 5B).
- The amphibole samples have a supra-subduction affinities, which suggests they formed on top of the subduction zone in an island arc (Fig. 5D).
- Amphiboles can suggest temperature and pressure at which the magma crystallized to from the rock. Using Ridolfi et al. 2010 geothermobarometer we've estimated (Table 1):
  - Temperature average for gabbro was 896^{o} C ± 29 (Table 1)
  - Pressure is 2.61 kbar ± 0.12 (Table 1).
  - This is accurate because the gabbro is mafic, and the data is well within the normal temperatures and pressures for mafic magma.
- The magma chamber is estimated to have been about 7.9 km deep.
- Fig. 5A, and 6A suggests pyroxene formed at an island arc oceanic-oceanic convergent tectonic setting because it plots on the Skaergaard trend far away from the high-pressure fields.
- Fig. 5C shows a small fractionation trend following the Rinjani volcano implying the gabbro sample would have similar compositions as a convergent oceanic-oceanic tectonic setting.
- Our new mineral geochemical data supports the interpretation of the gabbro initially forming in a late Jurassic island arc setting.
- The temperature and low pressure of the symplectic amphibole suggests it formed as a late phase in the gabbro during structural emplacement of the complex.
- The symplectite textures, along with the pressure and temperature estimates from the amphibole, suggest the gabbro was the mafic crust which melted to produce the Early Cretaceous adakitic dacite that cut the gabbro.



Figures 6A and 6B. Formation of high and low pressure cumulate rocks in a mature island arc system based on DeBari & Coleman (1989) & Bagci, et al., (2006).

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