Tectonometamorphic Evolution of Metamorphosed Mafic Dikes in the Archean Rocks of the Tobacco Root Mountains, Montana

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Introduction:

The Archean metamorphic rocks of Tobacco Root Mountains, as described by Burger et.al. (1994), consist of three suites: Indian Creek Metamorphic Suite (ICMS), Pony Middle Mountain Metamorphic Suite (PMMMS), and Spuhler Peak Metamorphic Suite (SPMS). The ICMS and PMMMS are meta-supracrustal rocks, and the SPMS contains primarily metamorphosed mafic volcanic rocks and is likely Archean ocean crust. All three suites were last metamorphosed at approximately 1.8 Ga (Burger et.al.). Well foliated Metamorphosed Mafic Dikes (MMDs) intrude both the ICMS and PMMMS amphibolite gneisses, crosscutting pre-existing foliation in the host rocks. However, these dikes have not yet been found in the SPMS. The lack of MMDs in the SPMS is consistent with the interpretation that the dikes intruded into the gneisses before these units were juxtaposed; and that the contact between the SPMS and host gneisses is a fault. The contact also appears to be folded, probably during regional simple shear (Owen, this volume) as MMDs are folded at some localities. The purpose of this study is to examine the mineralogy and petrology of the MMDs and to obtain pressures and temperatures of their metamorphism.

Methods:

Samples of MMDs were collected in the field from various localities in both the ICMS and the PMMMS. Approximately 95 samples were collected from which 24 thin sections were made. Seven samples were examined using the Zeiss Digital Scanning Electron Microscope (SEM) with a LINK Energy Dispersive Spectrometer (EDS) to obtain mineral composition data. Pressures and temperatures of these samples are being calculated using the program "Thermobarometry 1.9.1" (Kohn and Spear, 1995). Temperatures were calculated using the Perchuck et. al. (1985) garnet-hornblende thermometer, and pressures were determined by the Kohn and Spear (1990) garnet-plagioclase-hornblende-quartz barometer.

Results:

Field Data. MMDs are found intruding into quarzo-feldspathic and amphibolite gneisses throughout the PMMMS and ICMS. They occur within one meter of the contact with the SPMS, but have yet to be discovered in this suite of rocks. MMDs intrude both as sills, parallel or at extremely low angles to the foliation of the country rock, and as dikes, crosscutting foliation and folding of the country rock. They range in thickness from 20 centimeters to tens of meters, and seem to increase in thickness and in number close to the contact with the SPMS. MMDs are defined by a strong foliation that is always parallel to the outer walls of the dike. MMDs are folded at some localities and foliation is folded but still parallel to outer walls. There are at least two generations of MMDs, as "Secondary MMDs" crosscut "Primary MMDs". Yet, without the crosscutting relationships it is difficult to distinguish generations in the field.

MMDs are fine to medium grained, and exhibit a distinct gradation in grain size. Very fine grained hornblende and plagioclase/quartz near the dike walls grades to medium grained hornblende-plagioclase/quartz-garnet-clinopyroxene near the center of the dike. Plagioclase grains are especially coarser, grading from less than 1 mm at dike wall to greater than 2 mm in center of dike. Gradation in grain size is best observed in the thicker dikes. Secondary, crosscutting dikes have less variation in grain size

Petrography. The typical mineral assemblage of MMDs is hornblende-plagioclase-garnet-

clinopyroxene-quartz+/-biotite+/-ilmenite. Modal composition of minerals varies greatly with locality and within each dike. Near the dike walls hornblende and plagioclase/quartz make up approximately 80% of the mode, up to 95%, and garnet is entirely absent. Yet, farther in toward the center of the dikes, garnet and clinopyroxene make up approximately 40% of the rock composition. Biotite was observed in a few samples, and occurred along the dike walls, near the contact with country rock. Ilmenite makes up less than 1% of most samples.

What appear to be fairly equidimensional grains in hand sample, on the macroscopic level show much greater variation. Clinopyroxene and garnet can range from euhedral-subhedral, unaltered grains .05 mm in size, to subhedral-anhedral, broken or "chewed up" grains as large as .75-1 mm. Hornblende occurs as subhedral laths or tablets as large as .5 mm, and varies in pleochroic shade, from dark olive green, to light green, to tan, to brown. What appeared to be large grains of plagioclase in the field are in fact clusters of individual plagioclase crystals as large as 3 mm in size. Some plagioclase crystals are twinned, and as much as 40% of the plagioclase in a slide is sericitically altered.

Hanley and Vitaliano (1983) divided MMDs into three textural varieties produced by deformation and metamorphism: granoblastic, laminated, and clustered granoblastic. My samples fit into these categories. All of them are well foliated in hand sample, but vary texturally on the microscopic scale. Secondary MMDs are generally "clustered granoblastic," with large clusters of fine grained garnets and clinopyroxene, oriented parallel to foliation, defining the fabric. Some samples have all five major minerals in equilibrium with each other, whereas others have textures suggesting possible reaction sequences. Textures indicating garnet and pyroxene being replaced by plagioclase and hornblende were found in 6 of the 7 samples analyzed on the SEM. Intergrown clumps of hornblende and clinopyroxene with hornblende overgrowths and "shadows" of hornblende/clinopyroxene were fairly common. Garnet rings separating clinopyroxene and plagioclase indicate incompatibility of the minerals. Some garnets and clinopyroxenes are cracked and broken, indicating a new geometry, and multiple episodes of deformation.

Field and petrographic observations are consistent with previous studies of Tobacco Root MMDs or " metabasites" by Burger (1967), Gillmeister (1972), Cordua (1973), Hanley (1975), Hanley and Vitaliano (1983), and Burger et. al. (1994).

Chemical Analysis. Seven thin sections were analyzed on the SEM, and mineral composition data was obtained. Typical plagioclase composition is An_{40}, but ranges from An_{22} to An_{49}. While the Spessartine component (2%) of garnet doesn't change significantly from sample to sample, the Pyrope, Almondine, and Grossular components vary slightly. Compositions range from $Py_{11}Al_{65}Gros_{22}$ to $Py_{19}Al_{59}Gros_{20}$. Hornblende compositions vary greatly between samples, with compositions ranging from Mg^*_{40} to Mg^*_{58} ($Mg^* = Mg/Mg+Fe$).

Geothermobarometry. Preliminary geothermobarometry work has yielded temperatures of approximately 650°C, using the hornblende-garnet thermometer (See Figure 1). Calculations using the Pattison and Newton (1989) clinopyroxene-garnet thermometer yielded temperatures approximately 70° lower. However, recent work by Berman et. al. (1995) determined that by applying a new correction, temperatures should be similar to the hornblende-garnet thermometer. Calculations for pressure have yielded results between 6 and 8 kilobars.

The SPMS is polymetamorphic. It contains relict assemblages consistent with an earlier, >10 kilobar event. The absence of high pressure relict assemblages in MMDs is consistent with the intrusion of MMDs into the ICMS and PMMMS before assembly and metamorphism of all rocks to 650°C/5-6 kilobars at approximately 1.8 Ga. The Upper Amphibolite-lower granulite garnet-clinopyroxene-hornblende mineral assemblage of MMDs, as well as preliminary geothermobarometry work, is consistent with the peak metamorphic conditions of 6 kilobars at 650°C described by Cheney et.al. (1994) and DeGraaff (this volume) for amphibolites from the SPMS. Thus, both units were metamorphosed after assembly of the sequence.

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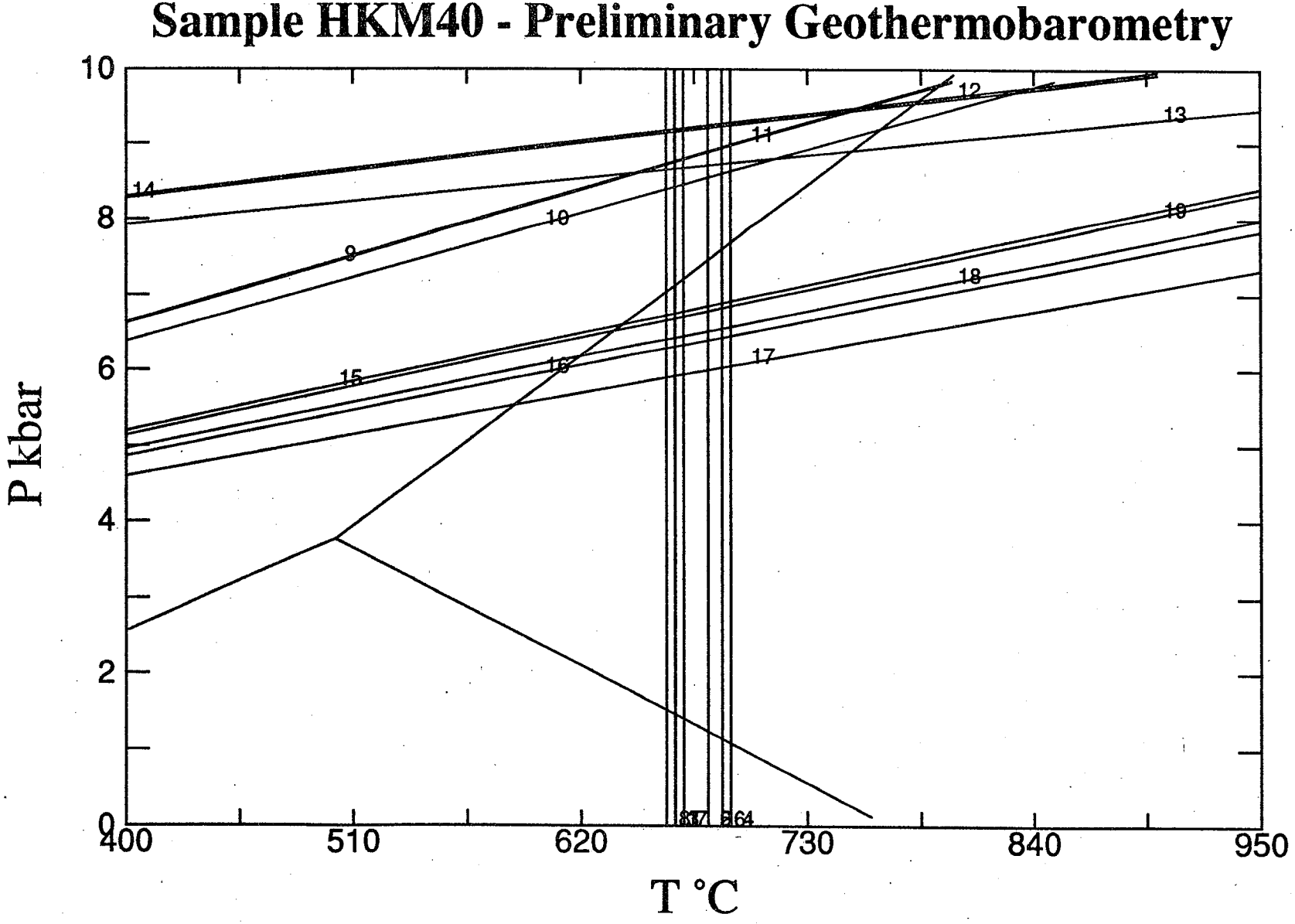
Sample HKM40 - Preliminary Geothermobarometry
P kbar
T °C
10
8
6
4
2
0
400
510
620
730
840
950
8
9
10
11
12
13
14
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16
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18
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Figure 1