Geothermometry of Garnet-Schist from Keystone, SD

Ben Osman

Geothermobarometry

- Mathematical analysis of chemical data of coexisting minerals to yield a pressure/depth and temperature of metamorphosis
- Comprised of two parts:
- Thermometry = temperature
- Barometry = pressure/depth
- Different minerals must be analyzed, meaning the two are independent parts of a whole

(Winter, 2010)

Geothermometry

- Yields a temperature of alteration
- Various minerals can be used
- Garnet- Biotite is the most common
- Fe-Mg exchange between biotite and garnet
- Allows calculation of rock formation temperature
- Empirically and theoretically understood
- Independent of barometry

(Winter, 2010)

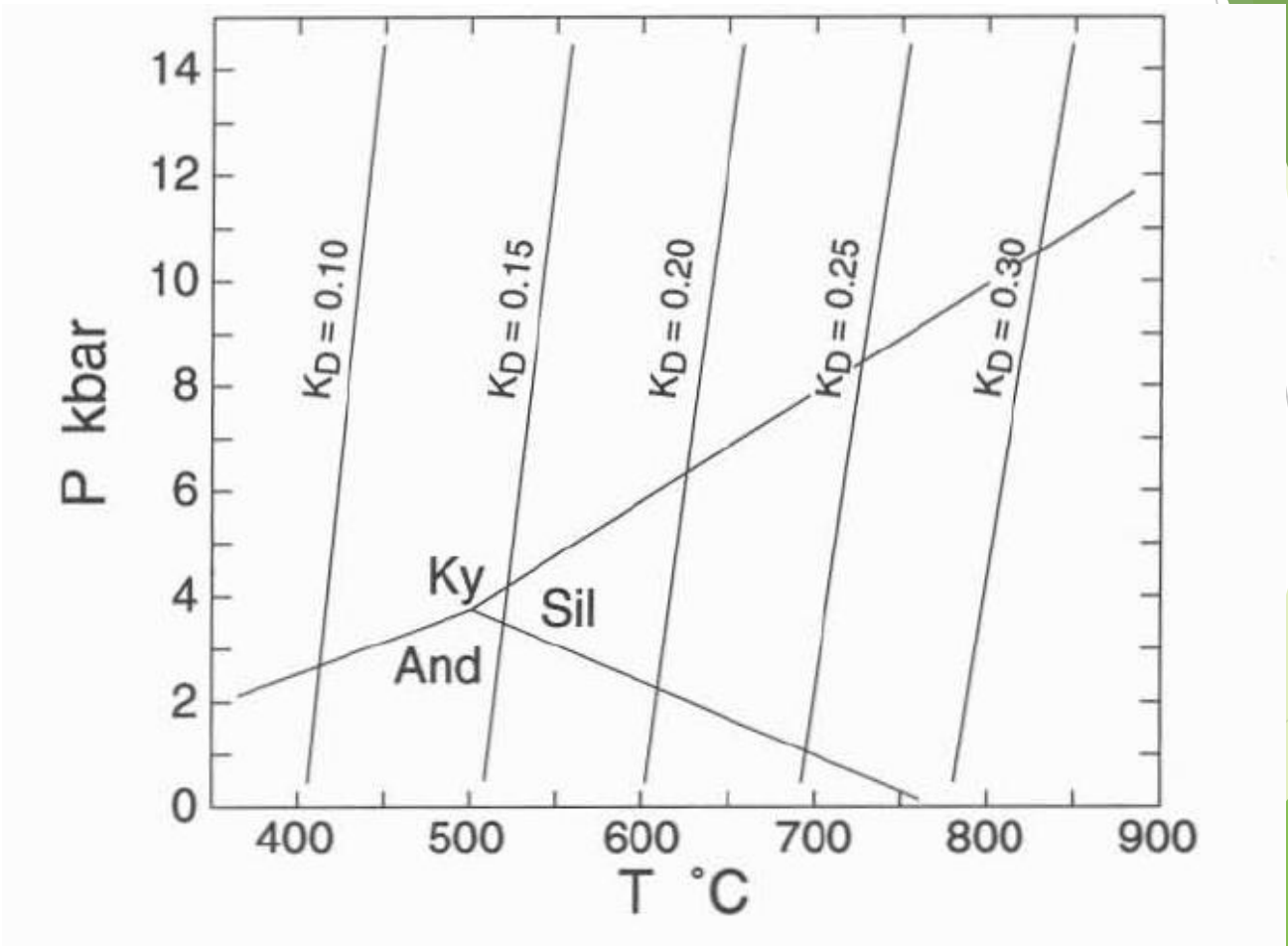
Geobarometry

- Yields a pressure/depth of alteration
- Garnet-silica-plagioclase
- Garnet-plagioclase-muscovite-biotite
- Garnet-plagioclase-hornblende-quartz
- Independent of thermometry

(Winter, 2010)

Important to Understand

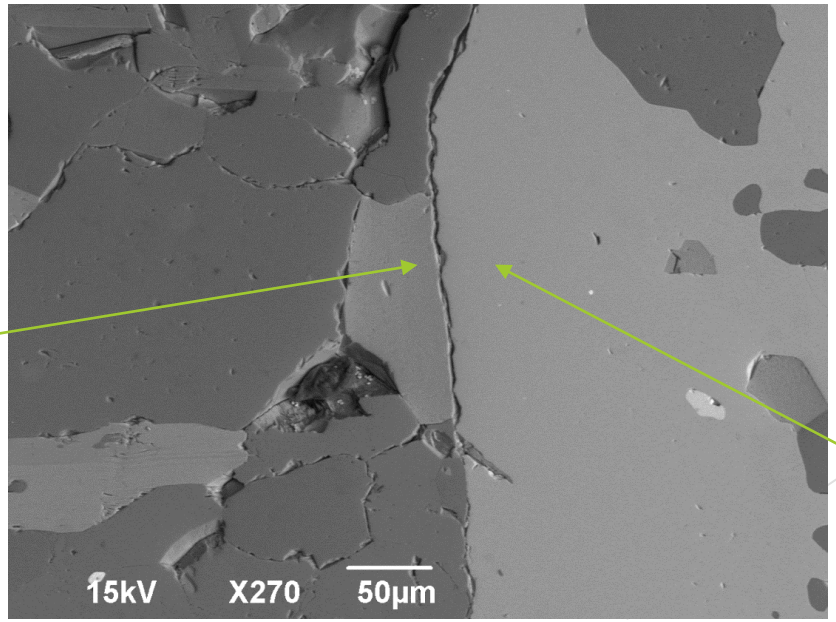
- Geothermometry yields an X value on our P-T diagram
- Geobarometry yields a Y value on our P-T diagram
- When the two are joined in Geothermobarometry, a point is attained (rather an area)


P kbar
T °C
$K_D = 0.10$
$K_D = 0.15$
$K_D = 0.20$
$K_D = 0.25$
$K_D = 0.30$
Ky
Sil
And
0
2
4
6
8
10
12
14
400
500
600
700
800
900

(Winter, 2010)

Assumptions

- Chemical equilibrium was achieved- minerals in contact
- Rock has not been retroactively altered

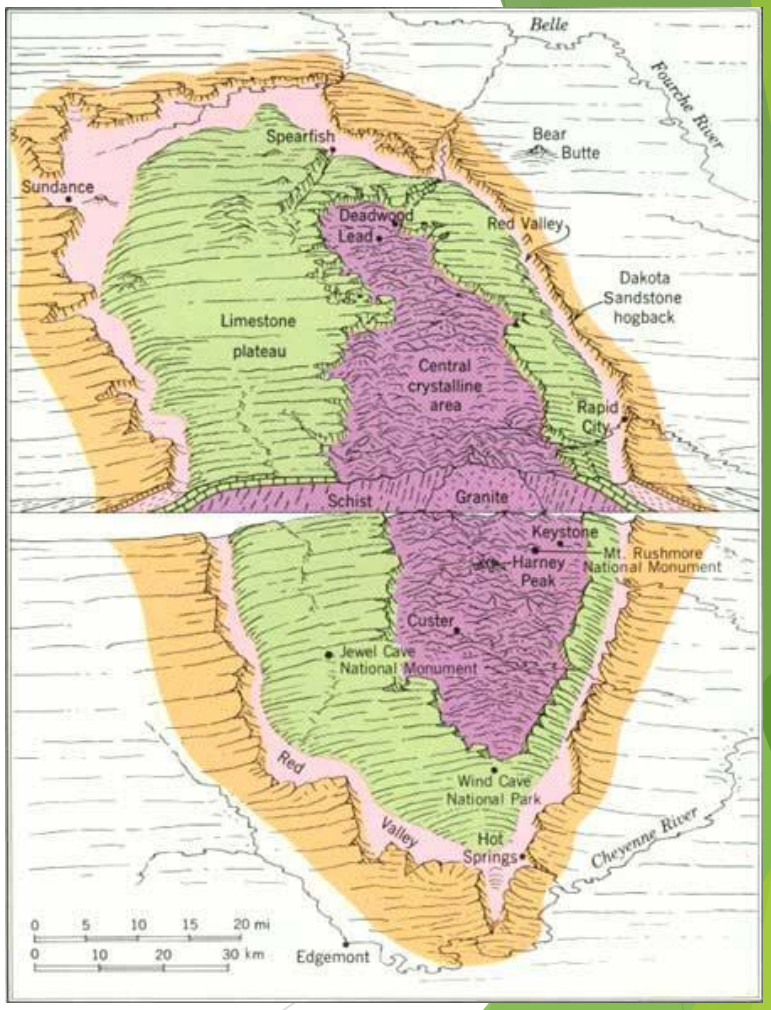


(Winter, 2010)

ScenicDakotas.com

Geologic Background

- The black hills represent an ovate dome
- Trans-Hudson Orogeny – collision of NA and a terrane
- Uplift and intrusion of granitic magma into sedimentary rocks- forms the core
- Sedimentary rocks metamorphosed- index minerals form
- Covered by sediment displaced by the Laramide Orogeny
- Sediment eroded away to reveal “target” shape characteristic of an eroded dome



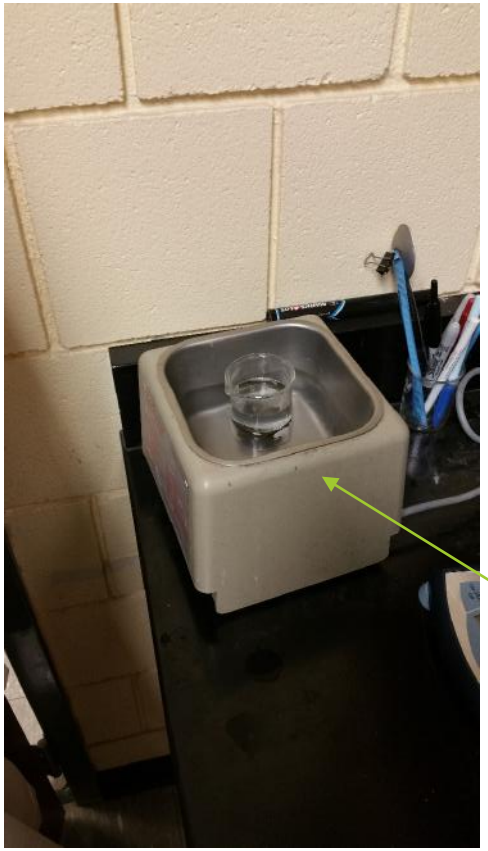
(Trimble, 1980) (Strahler and Strahler, 1978)

Guiding Question

- At what temperature did the Garnet-Schist near Keystone form?

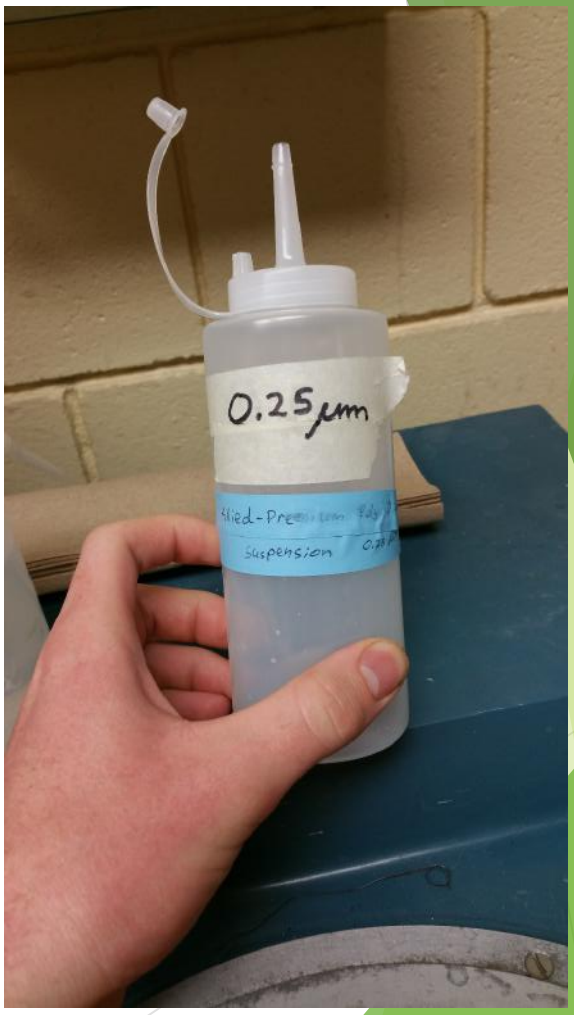

There must be water in this saw before running!!

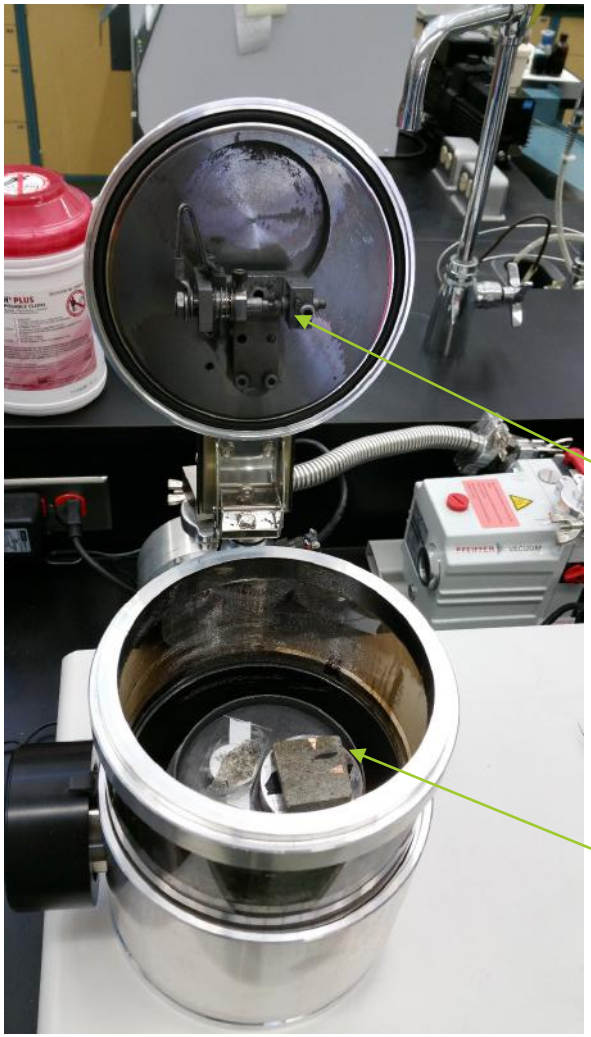

DI
H2O



Jiggly Jacuzzi


0.25µm
Iberbach


0.25µm
Suspension



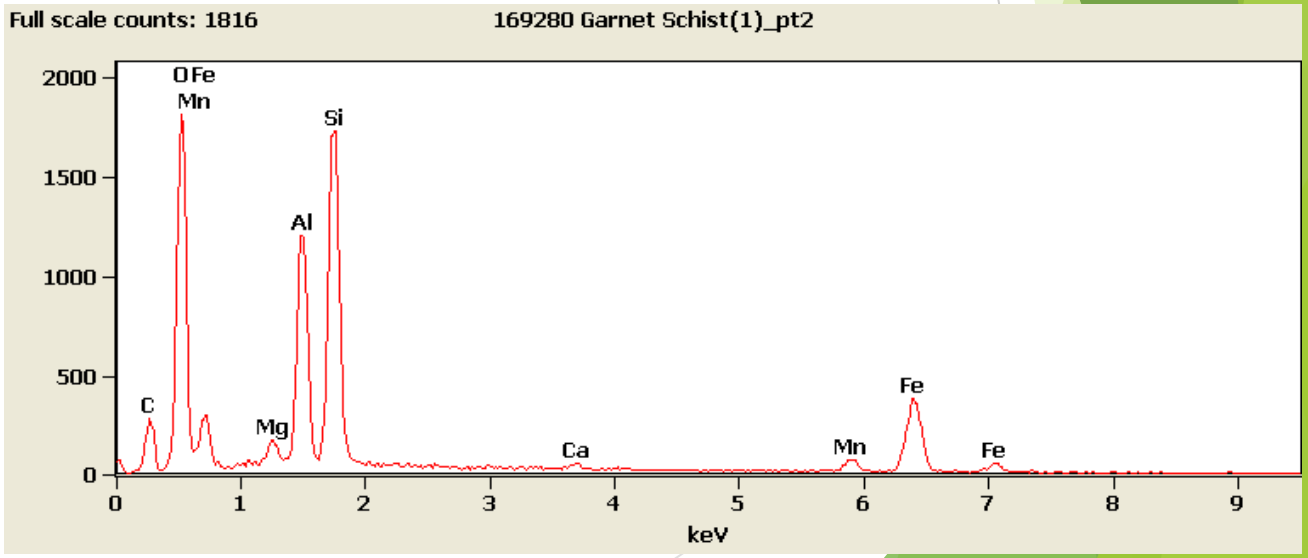
This machine carbon coats the sample so that during SEM analysis electrons do not build on the surface

Source of Carbon

Sample with visible copper arrows for navigation in the SEM

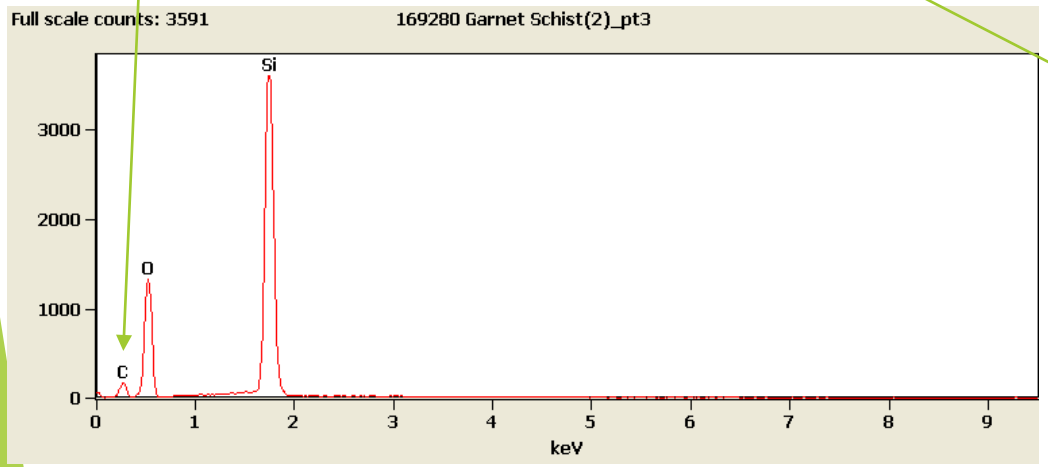
Garnets

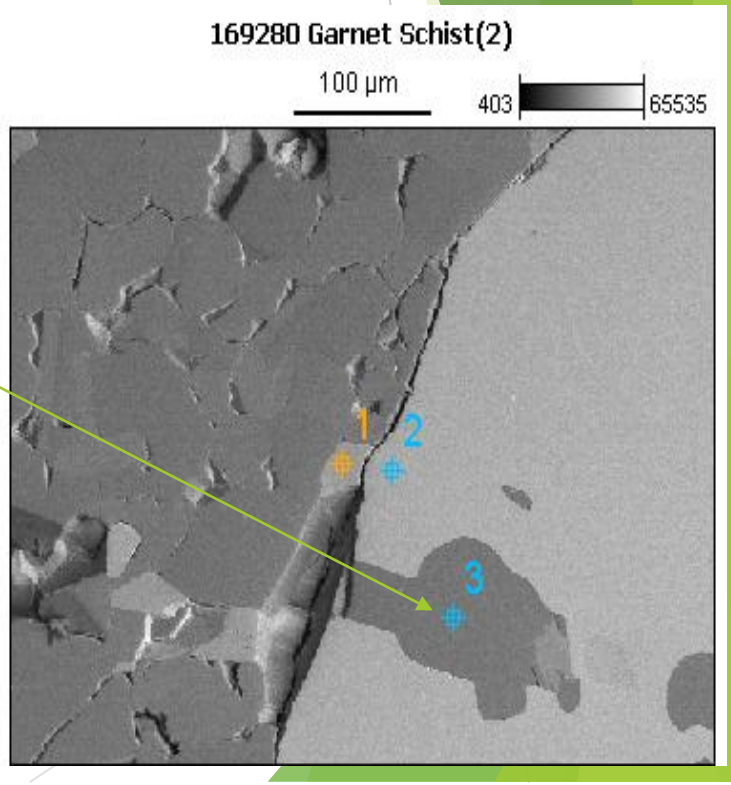
- Spessartine- $Mn_3Al_2Si_3O_{12}$
- Almandine- $Fe_3Al_2Si_3O_{12}$
- Ca free garnets



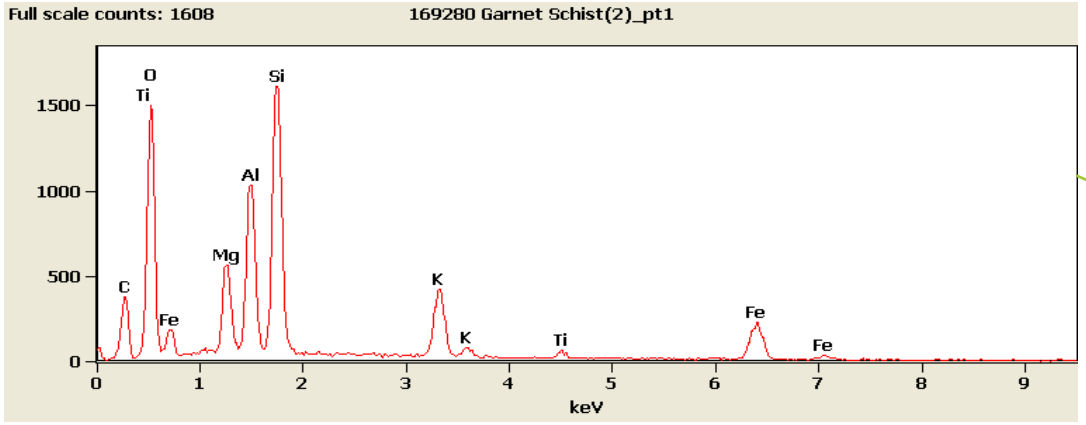
Quartz Inclusions

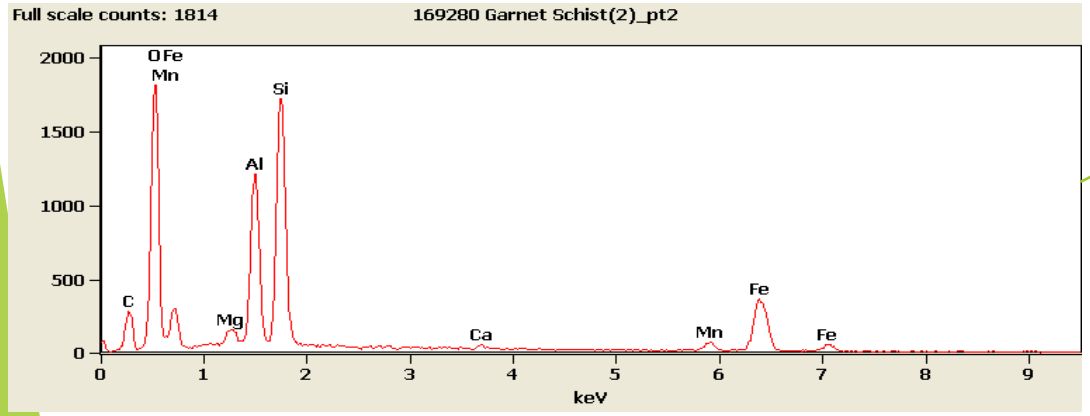
- Garnets contained quartz inclusions
- C peak is from carbon coating

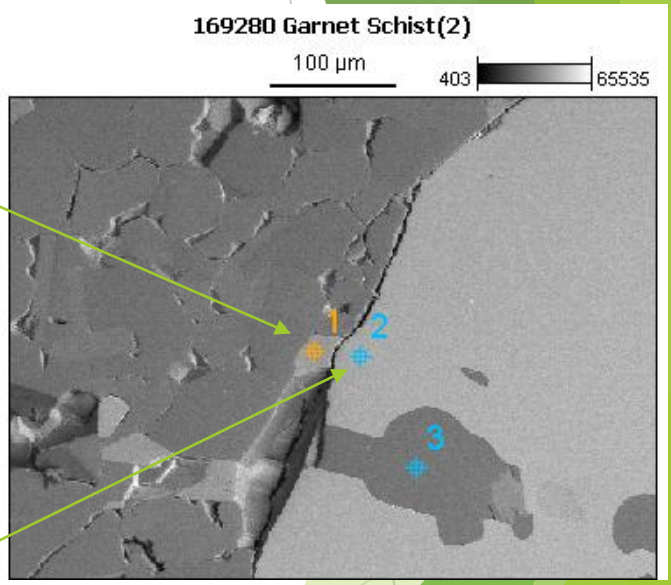




SEM DATA







Magnification: 270
Voltage: 15kV

SEM DATA

Atom %

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
169280 Garnet Schist(2)_pt1	57.50	5.05	9.18	15.44	4.81		0.52		7.49
169280 Garnet Schist(2)_pt2	56.13	1.09	11.11	17.03		0.35		1.57	12.71
169280 Garnet Schist(2)_pt3	63.73			36.27					

Calculations

Utilizing the images, peaks, and Atom % chemical data, I could then do some calculations:

$$\frac{(Mg/Fe)^{Garnet}}{(Mg/Fe)^{Biotite}} = K_D$$

Ratio of the Ratios of Mg/Fe in the Garnet and Biotite

Insert desired approximate pressure for P, I used 400kbars

Related to pressure

Enthalpy, heat transfer

Converts answer from K to C

$$T(^{\circ}C) = \frac{52,090 + 2.494P(MPa)}{19.506 - 12.943 \ln K_D} - 273$$

Enthalpy and Entropy are related in Gibbs Free Energy

Entropy, randomness

Result of above calculation K_D

(Winter, 2010)

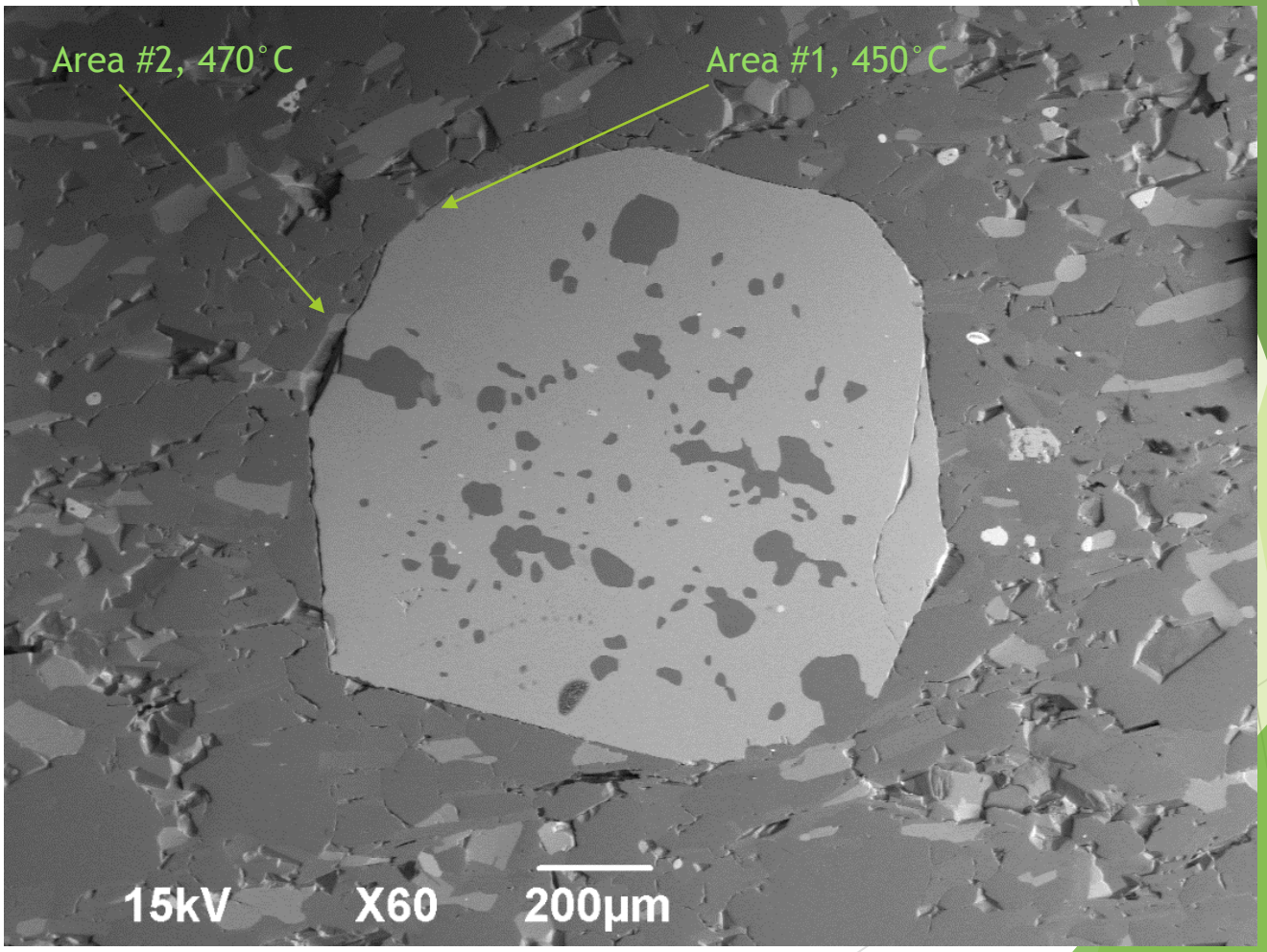
Calculations

- For our purposes the only variables we will worry about are K_D, and P
- K_D is the result of our Mg/Fe ratio equation, and P is an estimate of pressure, 400kbars is a good average pressure
- The other numbers remain the same in THIS thermometer, and P should be kept constant in each analysis

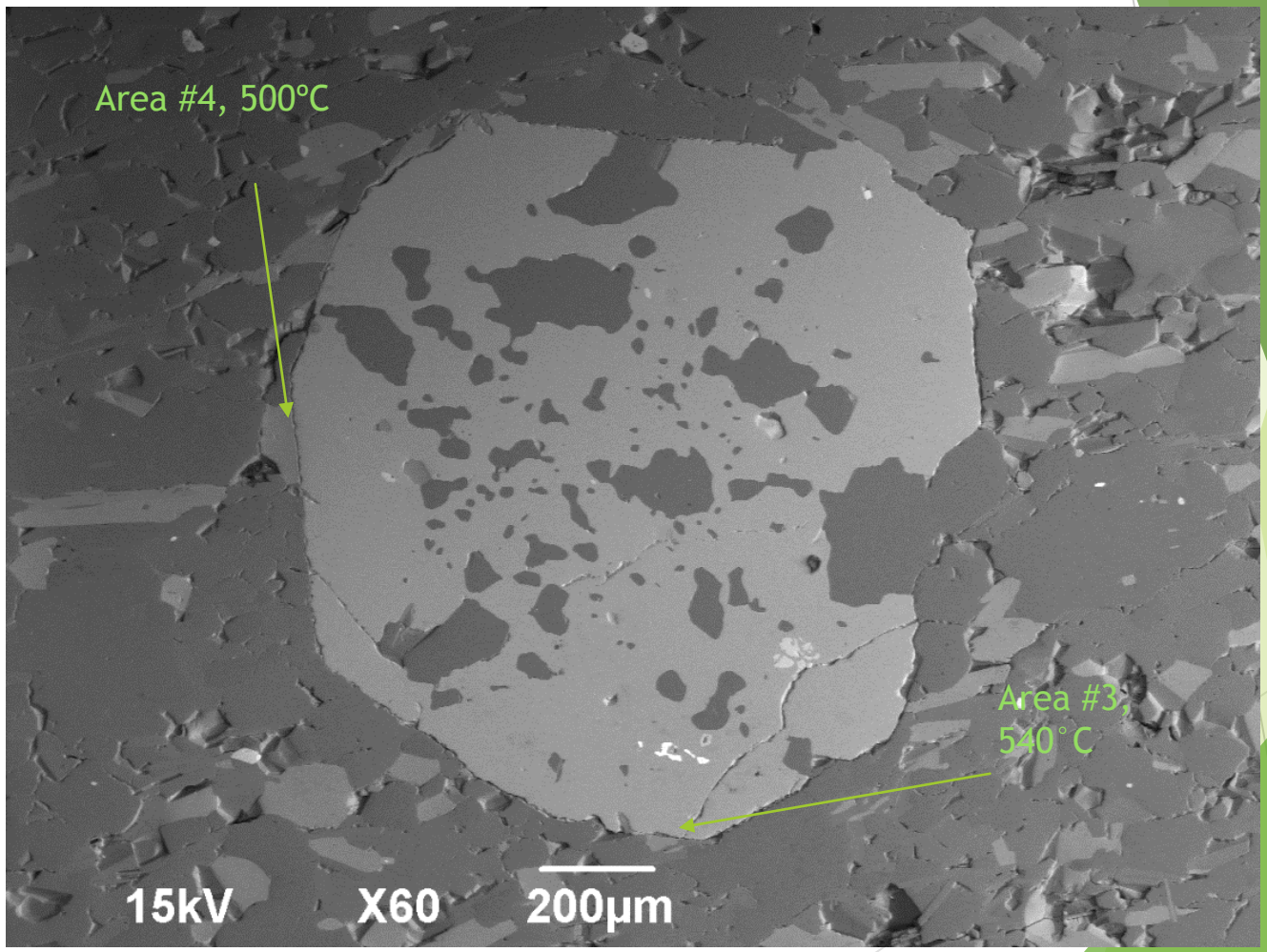
$$T(^{\circ}C) = \frac{52,090 + 2.494P(MPa)}{19.506 - 12.943 \ln K_D} - 273$$

- It should be noted that if one were to first perform a barometry analysis, then that value could be input for P, but different mineral assemblages are needed

Results

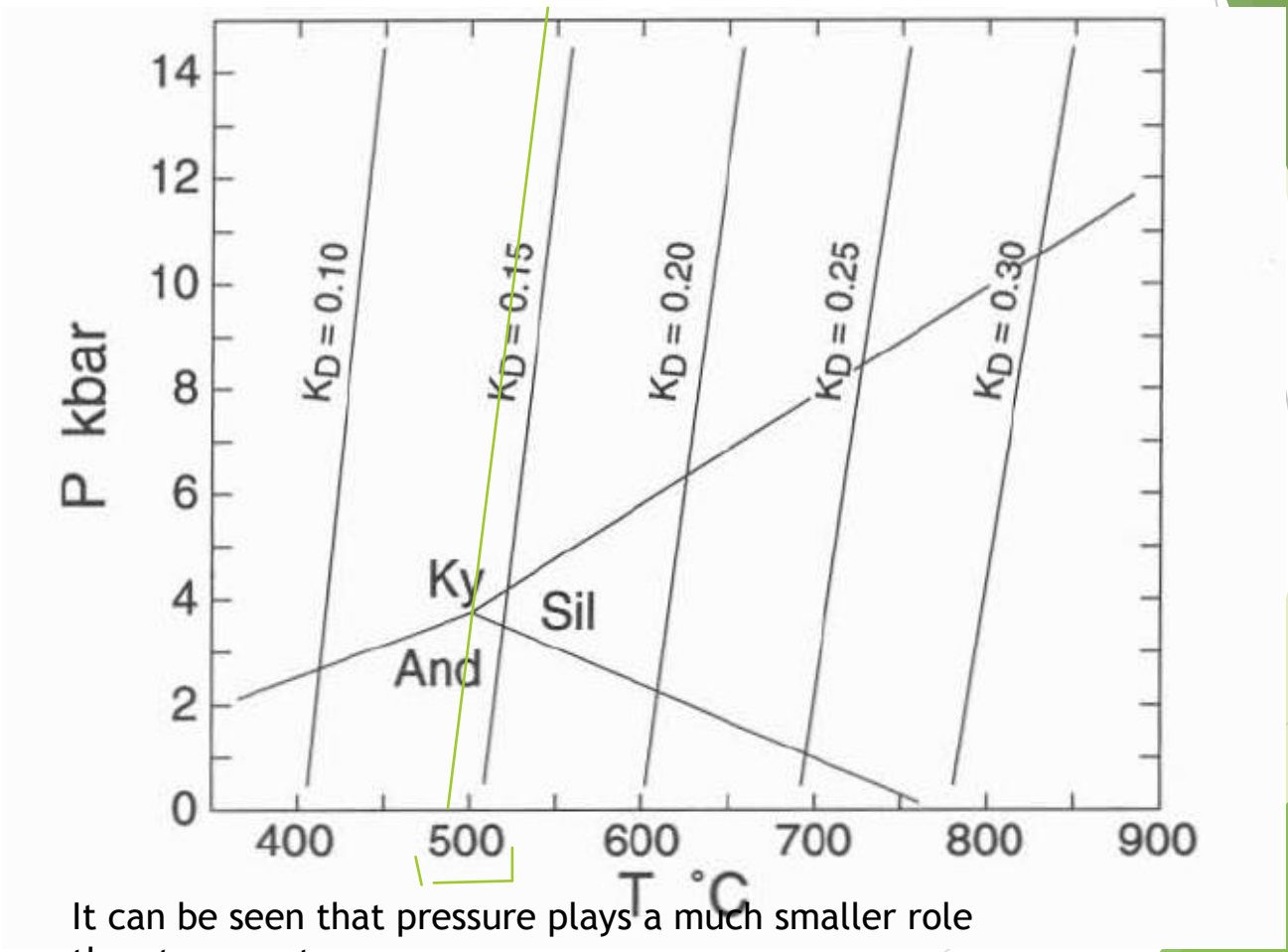


Results



Results

- 490°C average of the four Garnet-Biotite pairs analyzed
- Deviation of 17, 40, 50, and 8 degrees respectively
- These results are backed by Garnet being a moderate metamorphic index mineral



It can be seen that pressure plays a much smaller role than temperature

(Winter, 2010)

Acknowledgments

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