Geothermobarometry of the Garnet Schist near Keystone, South Dakota

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Petrology 422

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Geothermobarometry

- **Geothermobarometry**: is the calculation of equilibrium temperatures and pressures from the measured distribution of elements between coexisting phases

- **Geothermometry**: the evaluation of the temperature at which a rock formed.
- **Geobarometry**: The evaluation of the pressure

- (Winter, 2010)

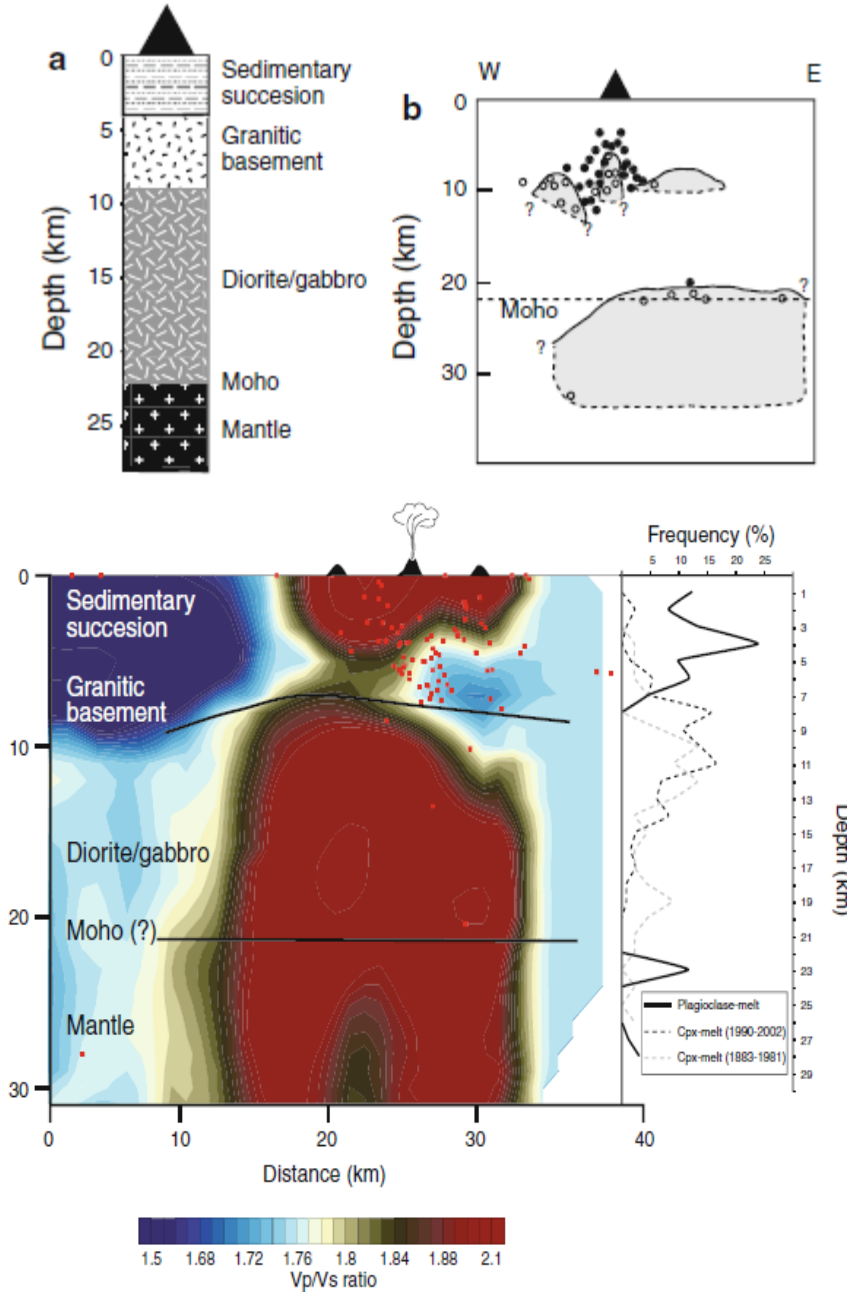
Krakatoa Volcanic Complex

How it can be helpful.

Anak Krakatoa study published in September 2011, by Börje Dahren examined the magma chamber feed the Krakatau Volcanic Complex using Geothermobarometry and seismic data.

Used Olivine, Clinopyroxene, and Plagioclase compositions

(Dahren, 2011)

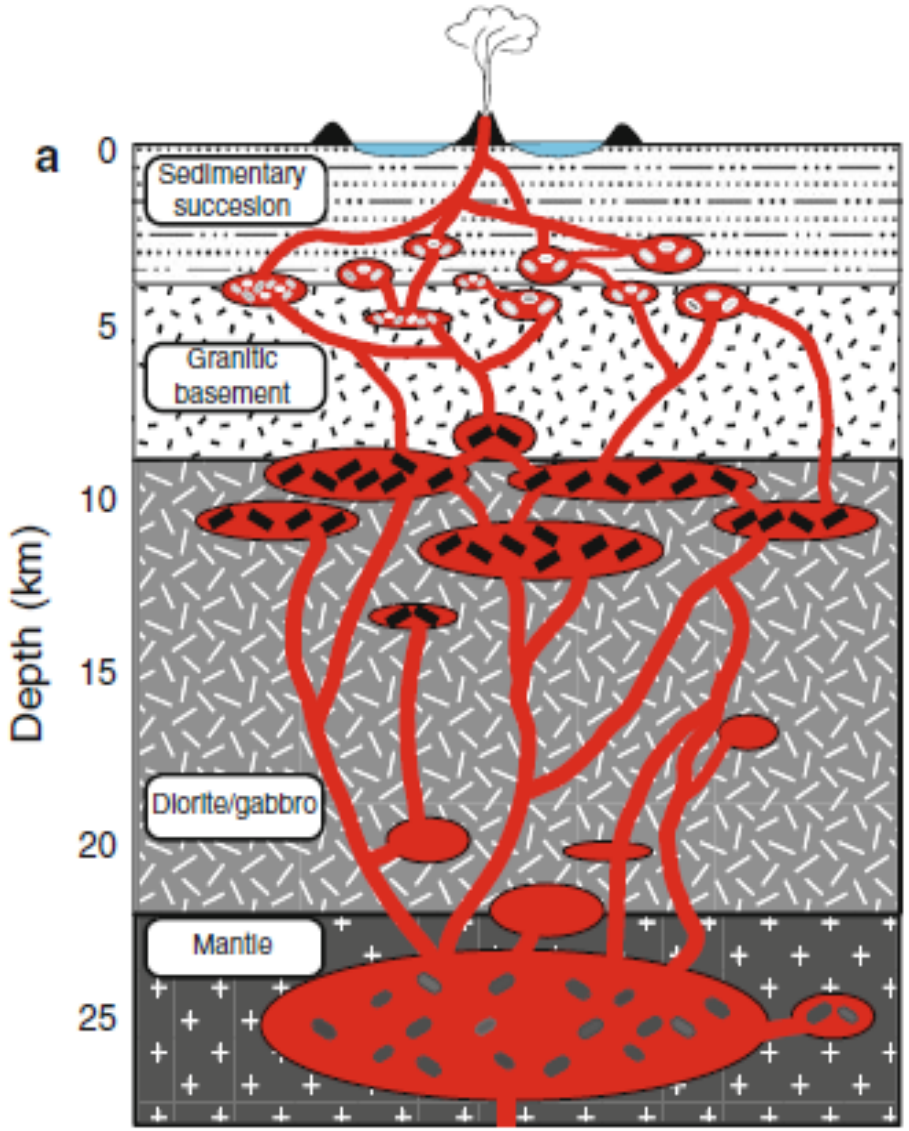


Krakatoa Volcanic Complex

New map for the magma chamber feeding the volcano complex.

Study demonstrated that Geothermobarmetry was able to determine deep magma storage zones that were undetected by seismic surveys

(Dahren, 2011)



Geology of the Black Hills Region of South Dakota

The Black Hills are an elliptically domed area 125 miles by 65 miles.

The purple is an exposure of Precambrian granite of the region that caused to the uplift in the region and now is eroded away and exposed. (Trimble, 1980)

The outer shell of the dome is Paleozoic and Mesozoic sedimentary rocks (USGS, 2014)

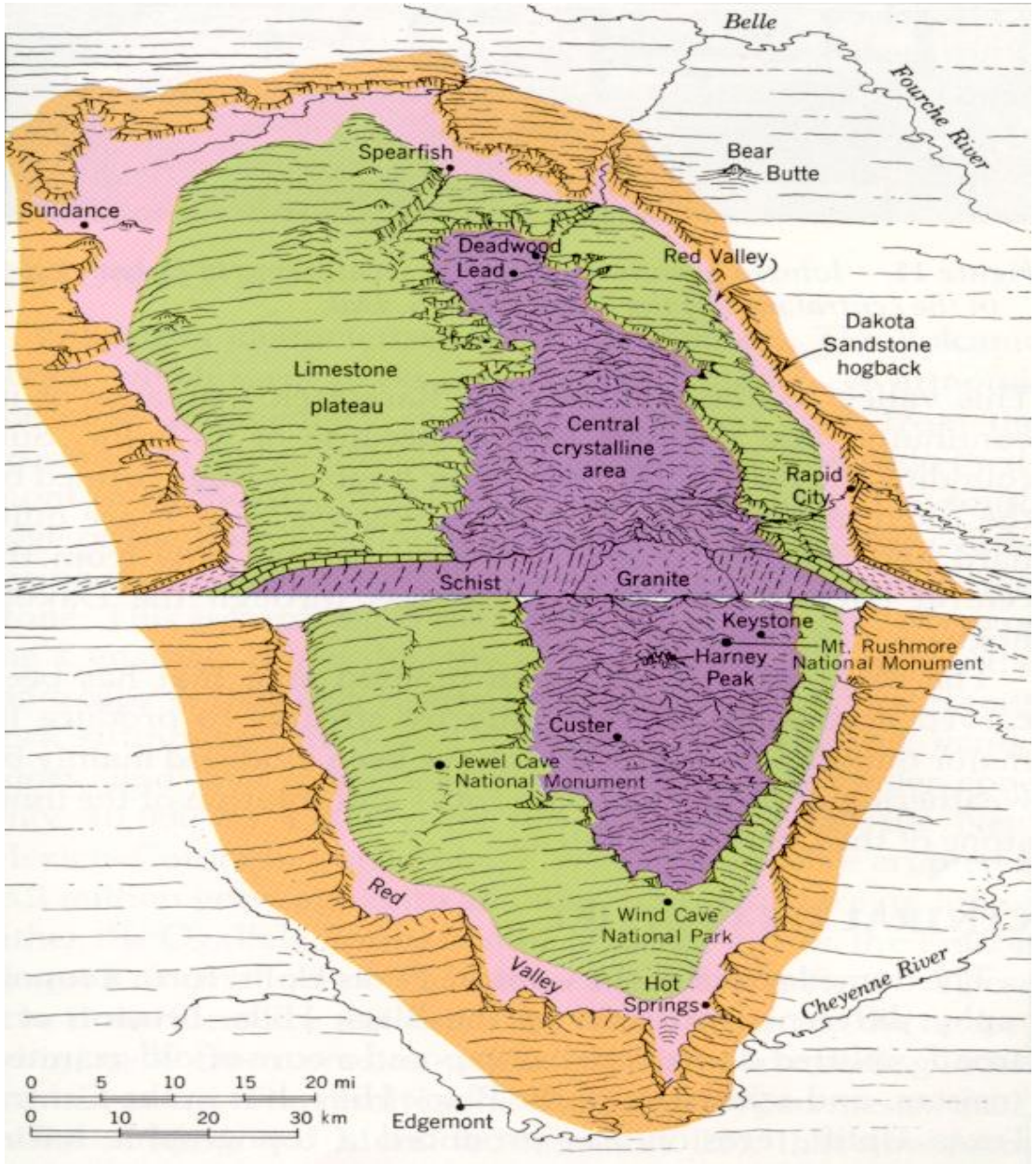


Image from Trimble, 1980)

Methods

S.E.M.

By using the Scanning Electron Microscopy, which uses electrons in a beam to interact with the sample and it knocks electrons in the samples valence shell and projects them back to the objective. This is called Backscattered electrons. This technique was used to get a better reading of the sample.

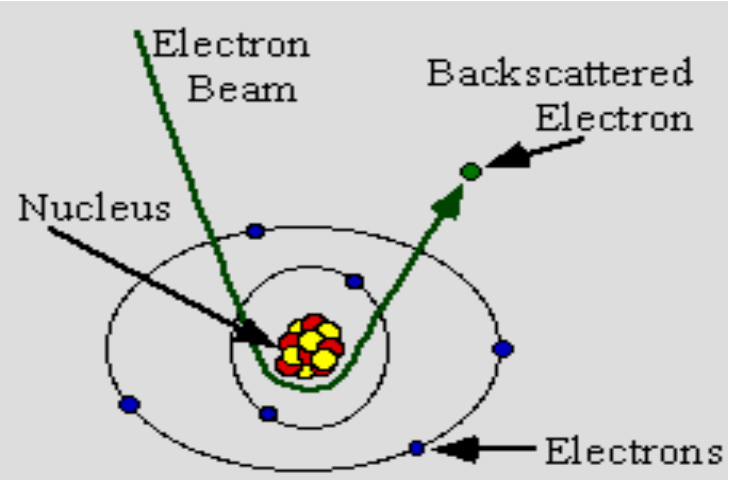


Image from http://
bsclarified.wordpress.com

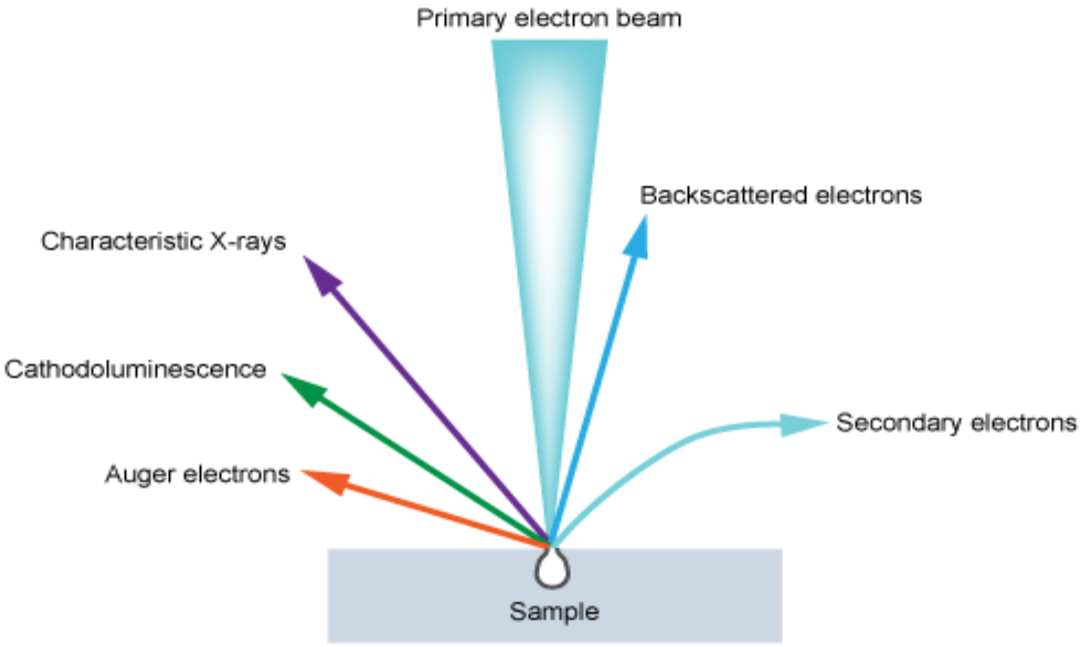


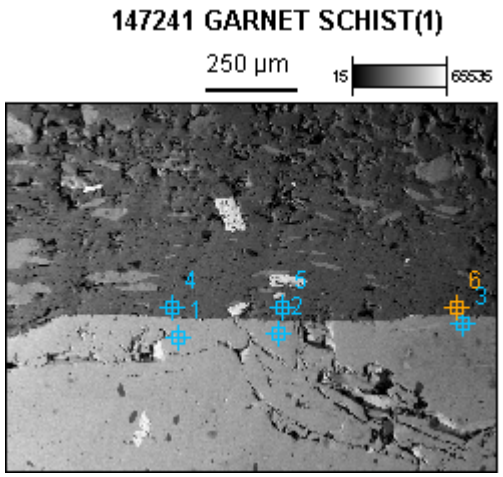
Image from http://
www.ammrf.org.au

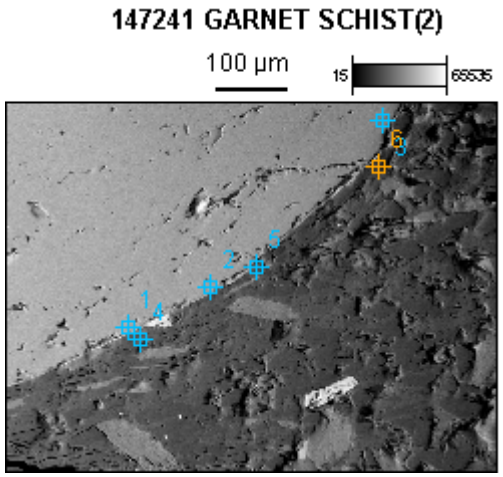
Methods

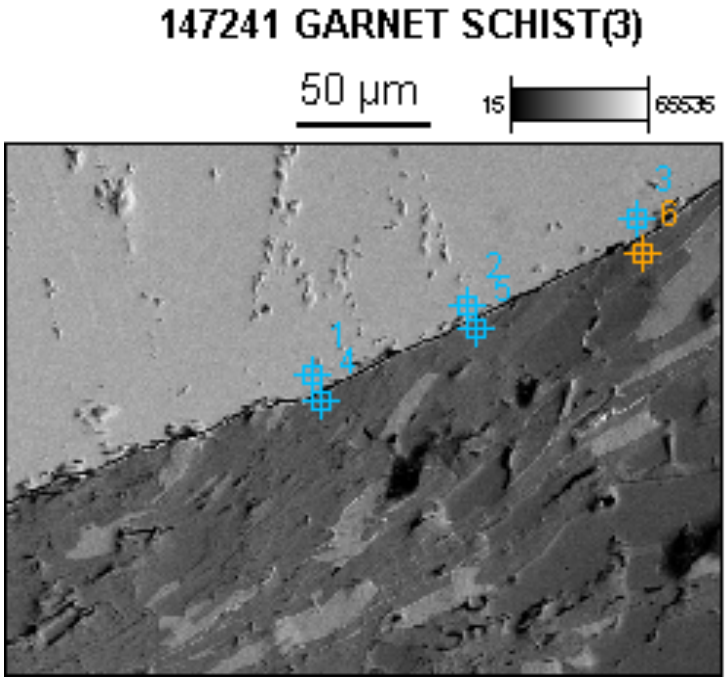
In order to get the best reading to calculate the geothermobaromtry of the two equilibrium phases, it is important to gather readings of Garnet and Biotite in contact.

This is an assumption of geothermobaromaty that if two minerals are in contact, then the two formed at the same time and are in equilibrium.

Took 18 readings from three different Garnet-Biotite contact points, making sure every site received over 1,500 counts of data.





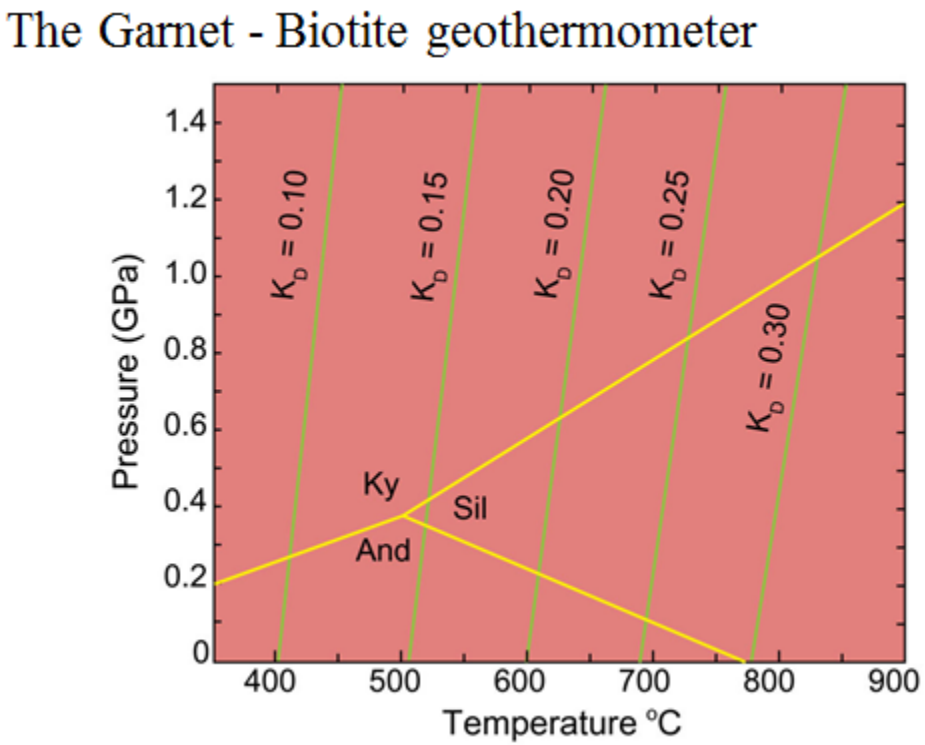


Methods

One of the first geothermometrys discovered was the Fe-Mg exchange between Garnet-Biotite

Kd = (Mg/Fe)Gt / (Mg/Fe)Bt

Kd equals the ratio of Magnesium to Iron in Garnet divided by the ratio of Magnesium to Iron in Biotite.



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

Winter, 2010

Results

Formula based on 12 oxygen's inc. Fe2/Fe3 Garnet									
Garnet	1	2	3	4	5	6	7	8	9
Si	4.021	2.940	2.893	2.604	2.521	2.579	2.594	2.611	2.590
Al	0.297	2.265	2.378	1.962	1.898	1.865	1.950	1.905	1.924
Fe	2.691	2.307	2.192	3.395	3.557	3.532	3.376	3.458	3.451
Mg	0.353	0.271	0.372	0.168	0.158	0.149	0.185	0.147	0.151
Ca	0.185	0.144	0.083	0.107	0.156	0.135	0.137	0.116	0.130

Formula based on 12 oxygen's inc. Fe2/Fe3 Biotite									
Si	5.735	5.787	5.723	5.688	5.619	5.694	5.749	5.666	5.631
Al iv	2.265	2.213	2.277	2.312	2.381	2.306	2.251	2.334	2.369
Al vi	3.817	3.888	3.784	3.539	3.503	3.463	3.540	3.520	3.551
Ti	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.000	0.000	0.228	0.335	0.301	0.274	0.207	0.228	0.232
Mg	0.000	0.000	0.000	0.030	0.070	0.022	0.000	0.041	0.055
Na	0.916	0.786	0.850	0.637	0.654	0.627	0.671	0.799	0.629
K	1.748	1.762	1.619	2.329	2.476	2.698	2.547	2.439	2.511

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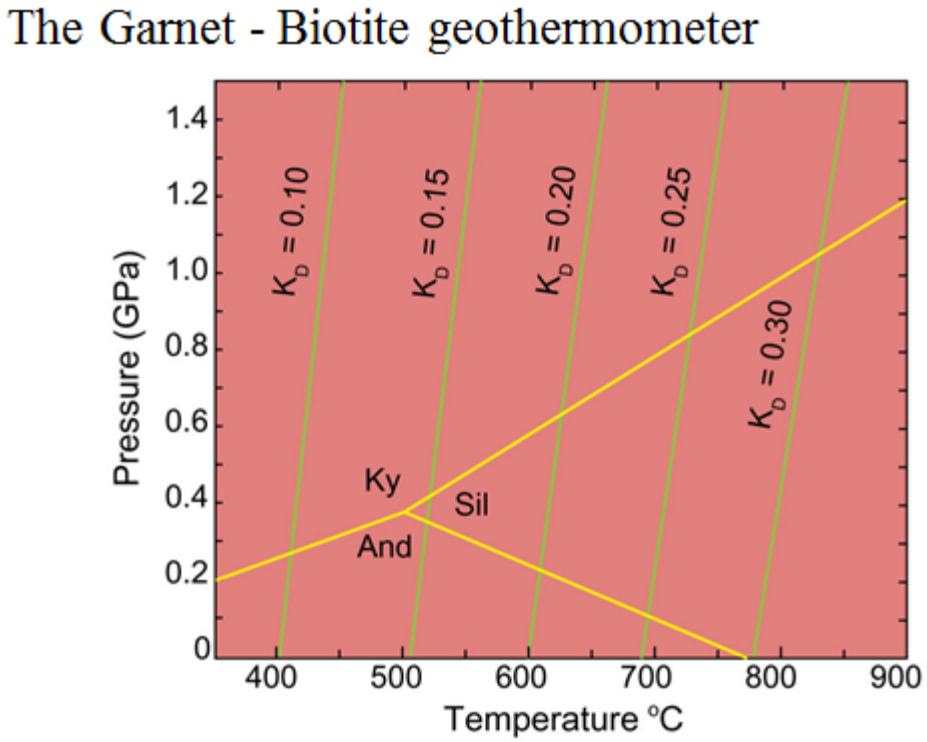
Results

Average K_D value = 0.310

$\ln K_D$ = -1.171

Found Temperature at 0.2GPa, 0.7GPa and 1.4 GPa

1 Gigapascal = 1000 Megapascals



Winter, 2010

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

Results

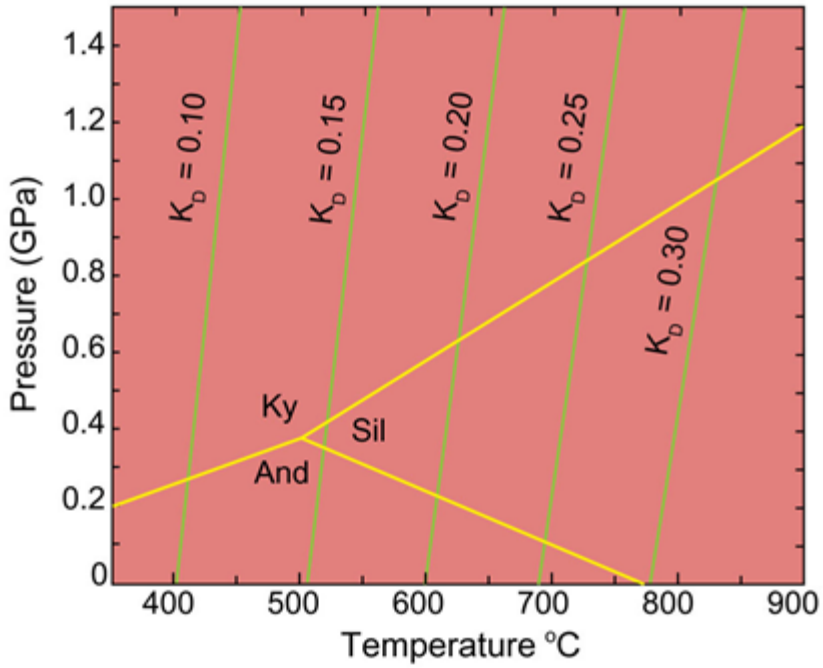
Temperature at 0.2 GPa = 1244°C

Temperature at 0.7 GPa = 1280°C

Temperature at 1.4 GPa = 1330°C

Way to high.

The Garnet - Biotite geothermometer



Winter, 2010

Conclusion

- Possible sources for error.
- The assumption of geothermobaromaty that if two minerals are in contact, then the two formed at the same time and are in equilibrium.
- Microscopy is not able to distinguish between Fe2+ and Fe3+.
- User Error

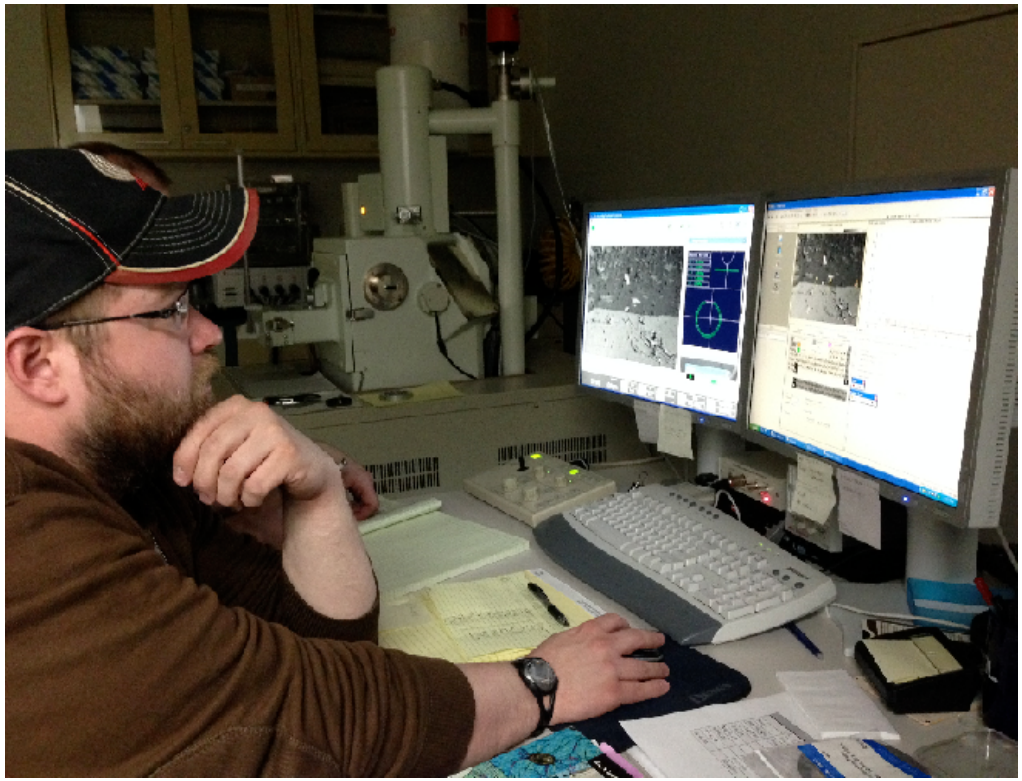


Image by Dr. Eidukat

Referances

- Winter, J., 2010. Principals of Igneous and Metamorphic Petrology. Pearson Education Inc., Upper Saddle River, New Jersey.
- Dahren, B., Troll, V., Andersson, U., Chadwick, J., Gardner, M., Jaxbulatov, K., Koulakov, I., 2012. Magma plumbing beneath Anak Krakatoa volcano, Indonesia: evidance for multiple storage regions: Contrib Mineral Petrol 163, 631-651.
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