GARNET SCHIST OF THE BLACK HILLS

GARNET – BIOTITE GEOTHERMOMETER

DEVIN SAILER

LOCATION: KEYSTONE, SOUTH DAKOTA

- My samples were collected from just NW of Mount Rushmore National Monument
- 43 54’ 5” N, 103 25’ 47” W, Elevation: 4637 ft.

GEOLOGY OF THE BLACK HILLS

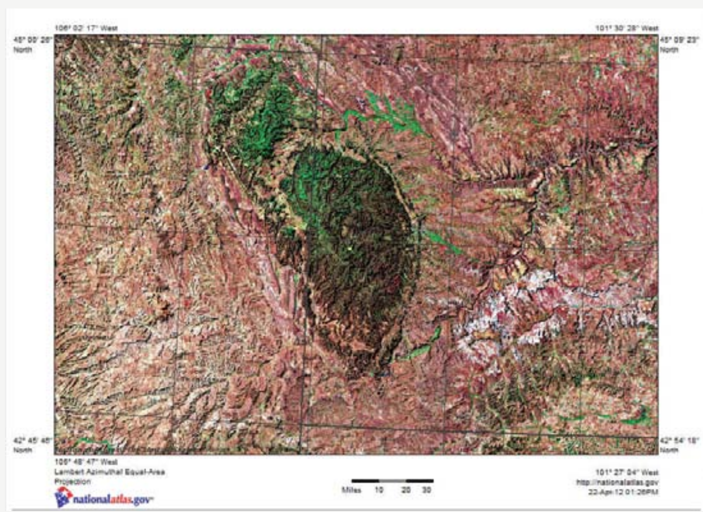
The Black Hills essentially form a concentric dome on the western edge of South Dakota. The core of the dome is largely composed of igneous rocks, such as granites and pegmatites. The next ring is a metamorphic zone created by the *Trans-Hudson Orogeny* approximately 2 billion years ago. The final ring is composed of sedimentary sandstones and limestones. The Deadwood Formation outcrops here and contains gold: leading to the area's popularity in the late 1870's. Also outcropping here is the Pahasapa Limestone, which is home to famous cave systems.

- Yellow (1.1-1.8 billion years old)

  - Igneous granites and pegmatites
- Red (~2 billion years old)

  - Wide variety of metamorphic rocks
- Blue

  - Sedimentary outcrops



GARNET SCHIST

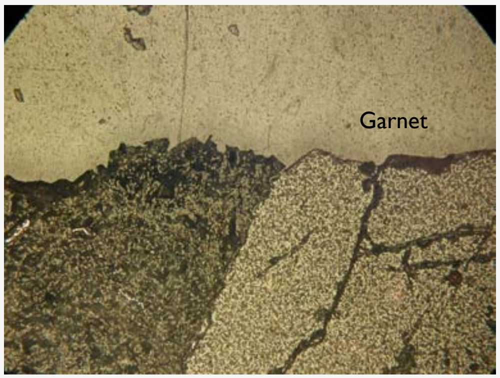
A medium grade metamorphic rock, containing abundant Garnets and Micas. Fine to medium grained and often foliated.

Composition:

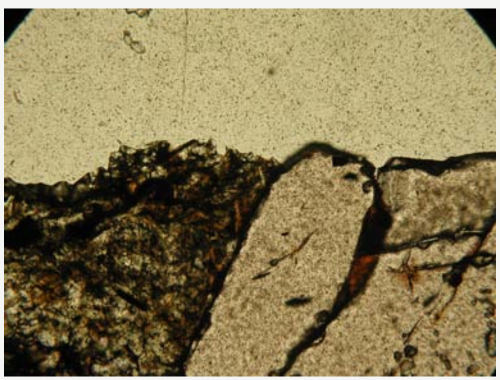
- Quartz
- Feldspars
- Micas
- Garnet
- Staurolite*

Schists are formed from the metamorphism of calcareous clay minerals and calcite rich rocks.

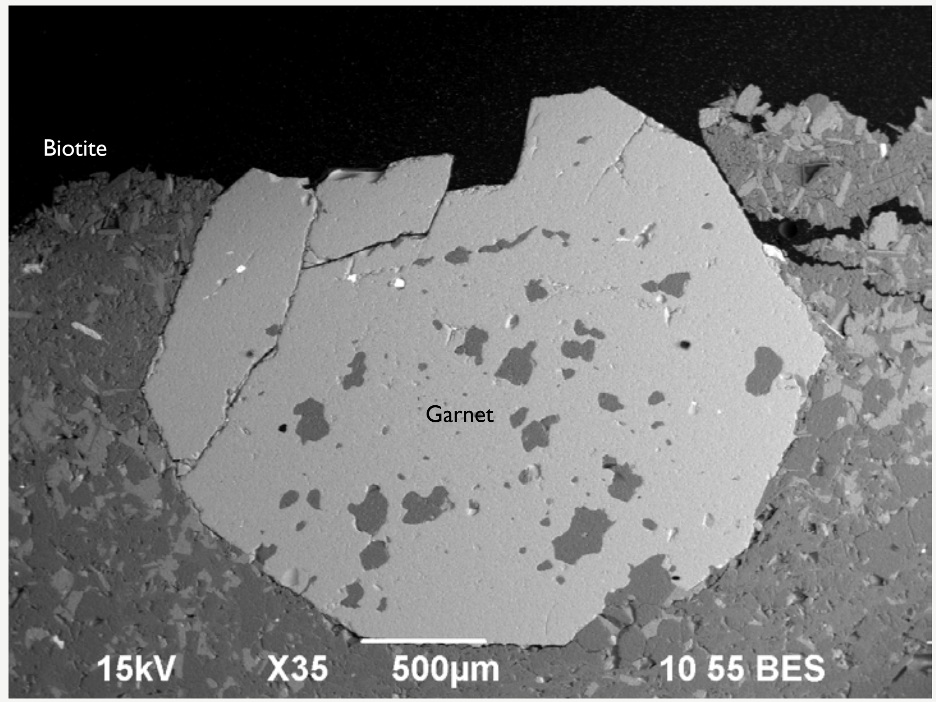
THIN SECTION



Biotite



~ 2.5 mm



SEM DATA

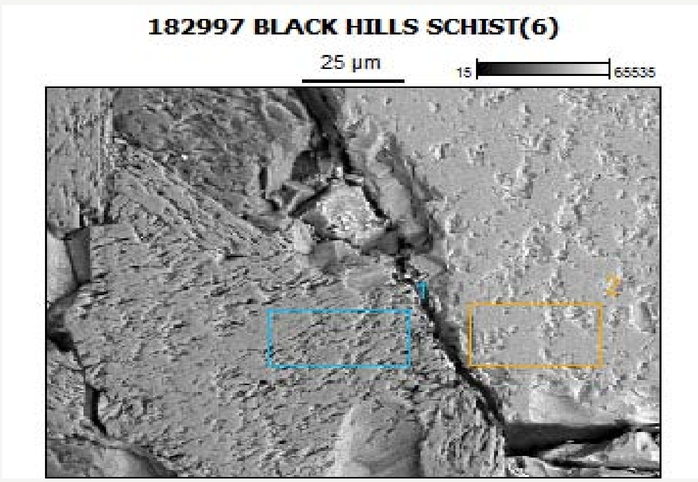
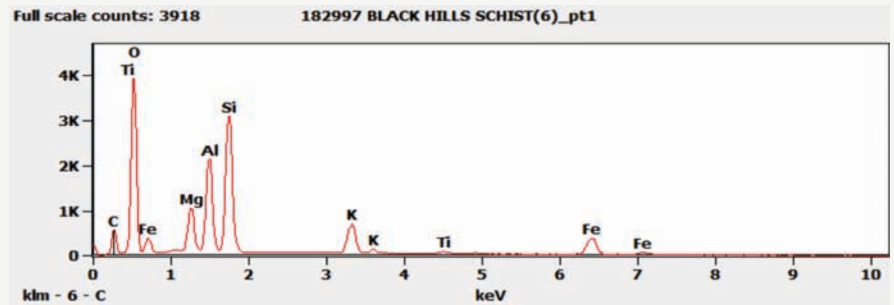
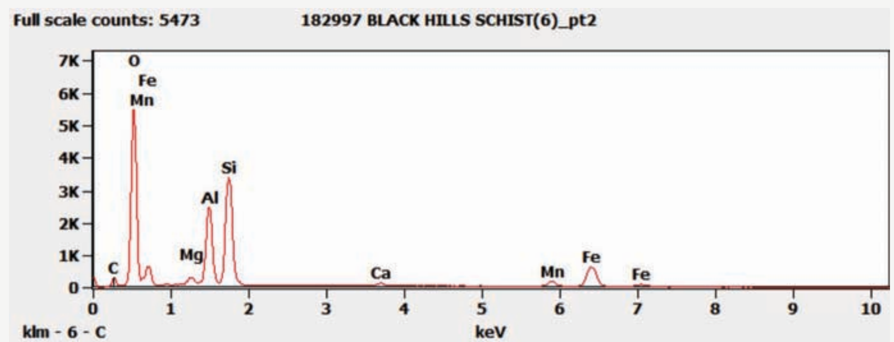


Image Name: 182997 BLACK HILLS SCHIST(6)
Image Resolution: 512 by 384
Image Pixel Size: 0.29 µm
Acc. Voltage: 15.0 kV
Magnification: 900





SEM DATA CONT.

Net Counts

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
182997 BLACK HILLS SCHIST(6)_pt1	24381	7646	17296	26671	7842		756		5316
182997 BLACK HILLS SCHIST(6)_pt2	33186	1454	19160	29681		847		2203	9271

Weight %

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
182997 BLACK HILLS SCHIST(6)_pt1	41.20	5.53	11.09	17.78	7.04		1.14		16.22
182997 BLACK HILLS SCHIST(6)_pt2	39.19	1.04	11.22	17.88		0.74		5.21	24.72

Weight % Error (+/- 3 Sigma)

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
182997 BLACK HILLS SCHIST(6)_pt1	±1.03	±0.20	±0.27	±0.48	±0.26		±0.22		±1.39
182997 BLACK HILLS SCHIST(6)_pt2	±0.84	±0.13	±0.25	±0.45		±0.14		±0.98	±1.57

Atom %

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
182997 BLACK HILLS SCHIST(6)_pt1	59.32	5.24	9.47	14.58	4.15		0.55		6.69
182997 BLACK HILLS SCHIST(6)_pt2	59.73	1.04	10.14	15.52		0.45		2.31	10.79

Atom % Error (+/- 3 Sigma)

	O-K	Mg-K	Al-K	Si-K	K-K	Ca-K	Ti-K	Mn-K	Fe-K
182997 BLACK HILLS SCHIST(6)_pt1	±1.49	±0.19	±0.23	±0.39	±0.15		±0.11		±0.57
182997 BLACK HILLS SCHIST(6)_pt2	±1.27	±0.14	±0.23	±0.39		±0.09		±0.43	±0.68

GEOTHERMOMETER CALCULATIONS

Given the equation in our textbook and data collected from the SEM I was able to carry out the following calculations:

Equation 30: $K_D = (X_{Mg}/X_{Fe})^{Grt}/(X_{Mg}/X_{Fe})^{Bt} = (Mg/Fe)^{Grt}/(Mg/Fe)^{Bt}$

Equation 36: $C = 52{,}090 + 2.494\ \boldsymbol{P(MPa)}/\ 19.506 - 24.943\ \ln(K_D)$

P(MPa) was assumed to be 500 Mpa

$K_D = (1.04/10.79)/(5.24/6.69)$

$= 0.123057114$

CALCULATIONS CONT.

With a calculated equilibrium value – take the natural log and then plug it into equation 36 from Winter.

$$\ln(0.123057114) = -2.09510669$$

$$C = (52{,}090 + 2.494(500)/19.506 - 24.943(-2.09510669)) - 273$$

$$C = 470.225$$

Given an assumed pressure of 500 MPa, my sample formed at a temperature of 470 C.

CONCLUSION

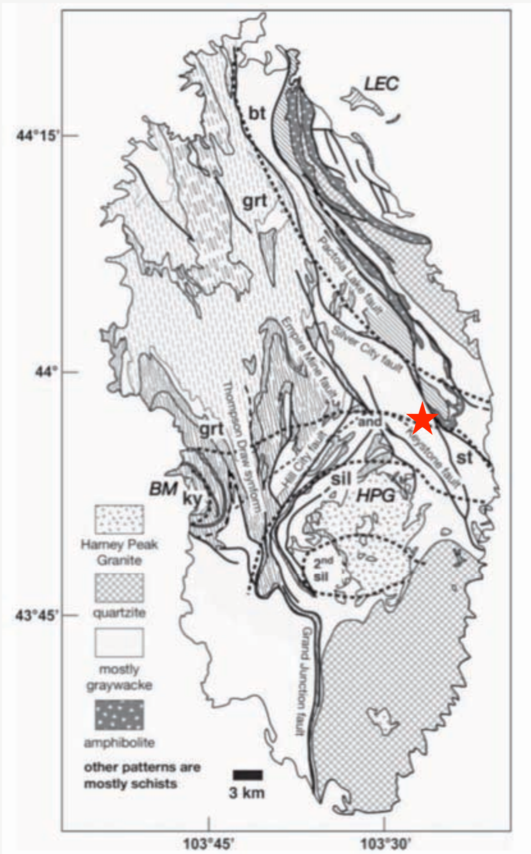


TABLE 2. Sample locations and calculated garnet-biotite equilibration temperatures

Sample*	Latitude	Longitude	TC† (4.5 kbar)	H&S‡ (4.5 kbar)
HP81-1	43.943	−103.387		
HP95-1 core	43.798	−103.697	521	543
HP95-1 rim	43.798	−103.697	530	552
HP98-1	43.957	−103.597		
HP112-1	43.900	−103.519		
HP118-1	43.800	−103.567		
HP121-1	43.806	−103.560		
HP124-1	43.811	−103.555		
HP137-1 core	43.932	−103.508	512	547
HP137-1 rim	43.932	−103.508	505	538
HP140-1-25 core	43.927	−103.498	542	550
HP140-1-25 rim	43.927	−103.498	516	534
HP140-1-26 core	43.927	−103.498		
HP140-1-26 rim	43.927	−103.498		
HP197-1	43.851	−103.636	552	581
HP208-1 core	43.930	−103.627	403	448
HP208-1 rim	43.930	−103.627	450	491
HP208-2	43.930	−103.627		
HP213-2	43.964	−103.629		
HP222-1	44.100	−103.650	384	426
HP224-6b	43.919	−103.442	540	560
HP227-1 core	44.137	−103.631	344	384
HP227-1 rim	44.137	−103.631	332	376
HP229-1	44.192	−103.760		
HL2	43.781	−103.575	566	593
HL3	43.812	−103.589	578	597
HL5	43.836	−103.436	501	525
HL6	43.884	−103.445	470	536
HL8	43.866	−103.651	482	496
HL9 core	43.919	−103.698	323	380
HL9 rim	43.919	−103.698	449	492
HL12	43.966	−103.553	374	412
HL12	43.966	−103.553	300	334
HL14 core	43.943	−103.497	491	517
HL14	43.943	−103.497	458	485
HL15A	43.912	−103.493	526	578
HL17	43.939	−103.429	458	488
HL19 core	43.964	−103.606	426	474
HL19 rim	43.964	−103.606	427	468
HL20 core	43.932	−103.654	368	407
HL20 rim	43.932	−103.654	454	467
HL22	43.913	−103.512	460	487
HL23 core	43.917	−103.661	347	373
HL23 rim	43.917	−103.661	501	516
HL24	43.906	−103.652		
HL25B	43.908	−103.506	525	547
HL27	43.786	−103.646	448	484
HL28	43.869	−103.598	520	544

- Star marks relative location of sample taken on map of surrounding geologic outcrops.
- Highlighted values on table, denote samples from similar latitudes and longitudes and their respective temperatures.

REFERENCES

- John D. Winter - *Igneous and Metamorphic Petrology*
- Helms and Labotka – *Black Hills: Metamorphism of Pelitic Schists*
- Nabelek et al – *Black Hills Metamorphism*
- In class lecture 19