Magmatic Crystallization of Sulfides in the Ellicott City Granodiorite

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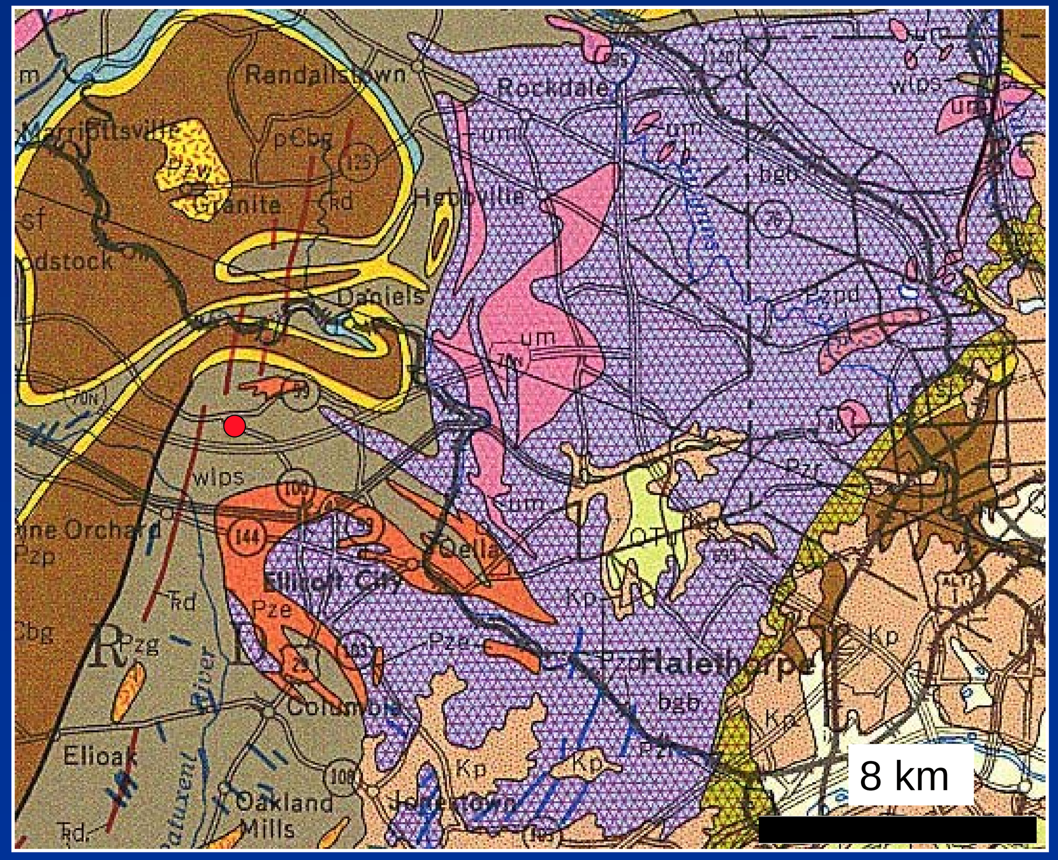
Abstract

The Ellicott City granodiorite is an epidote-bearing pluton containing sulfide minerals observable in outcrop. The granodiorite is c. 460 Ma old and formed during the Taconic Orogeny. Epidote in the granodiorite is of magmatic origin (Mario, 1985). Pressure estimates for an epidote-bearing granitoid place the crystallization pressure of epidote at 0.6-0.8 GPa (Zen and Hammarstrom, 1984). This corresponds to 25-30 km under the earth's surface.

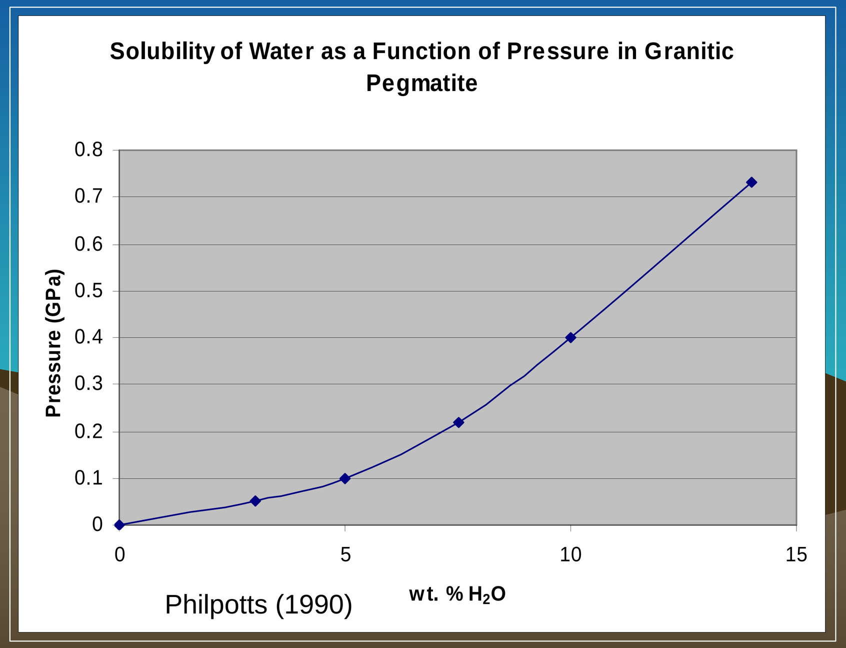
At these pressures a magmatic vapor phase is unlikely to form (Philpotts, 1990). If sulfides had crystallized from the magma prior to exsolution of a vapor phase, the sulfides may contain high chalcophile element abundances. However, sulfide phases can be susceptible to a magmatic ore-fluid, which could strip the chalcophile elements from the sulfides. The magmatic origin of sulfides is established from petrographic analyses of polished thin sections. I identified two sulfide phases in the ECG using the electron probe microanalyzer: pyrite and chalcopyrite. Trace elements such as Mn, As, Te, Ag, and Pb were measured in these sulfides by LA-ICP-MS. Similar analyses were made on pyrites in a latite from the Golden Sunlight gold mine, MT. Trace element abundances in the ECG sulfides are heterogeneous, with the exception of Ag. ECG sulfide trace element abundances are low compared to pyrite from the gold deposit. Low abundances can be a consequence of an initially defecient magma in chalcophile elements prior sulfide crystallization. Also, chalcophile elements may have been stripped from sulfides by a late stage magmatic fluid.



- Ellicott City Grandodiorite (orange) intruded during Taconic Orogeny
- Samples taken from outcrop on MD highway 144 (red dot)

Exsolution of a magmatic vapor phase in ECG?

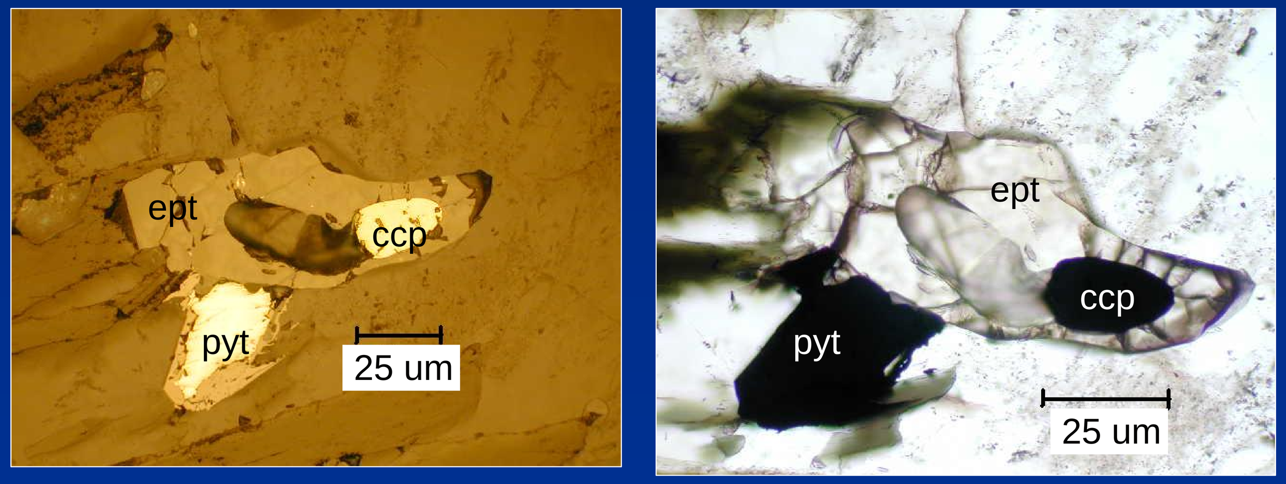
- ECG has magmatic epidote, therefore crystallized at 0.6-0.8 GPa
- At these pressures, 12-15 wt. % H_2O is required for exsolution of a magmatic vapor phase (see below)
- Therefore, a vapor phase did not exsolve prior to, or during crystallization of epidote and sulfide phases (see petrography)



Pyrite and Chalcopyrite Relationships

- Pyrite with intergrown biotites, quartz and thin oxide rims
- Chalcopyrite with thick oxide rims
- Found both pyrite and chalcopyrite in epidote and hornblende
- Crystallization sequence: allanite, plagioclase, chalcopyrite, pyrite, epidote, hornblende, biotite, K-feldspar, quartz, muscovite

- Pyrite surrounded by thin iron oxide in reflected light (left) and transmitted light (right)



- Chalcopyrite in epidote and pyrite surrounded by iron oxide in reflected light (left) and transmitted light (right)

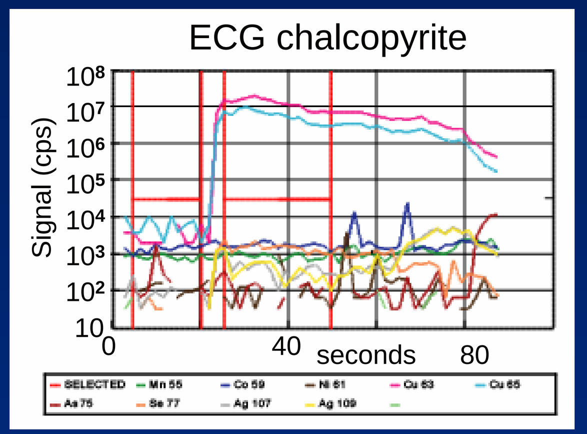
Electron Probe Microanalyzer Data

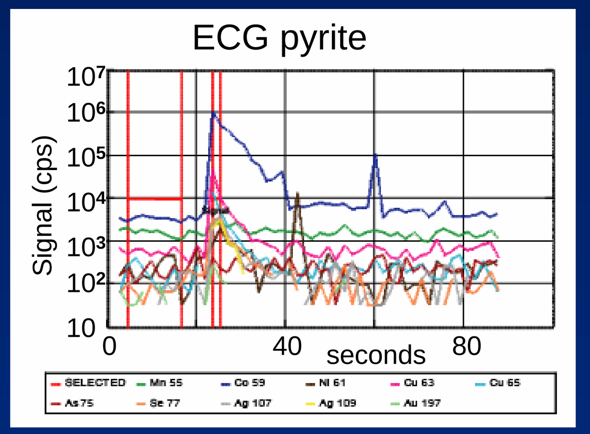
- used to determine chemistry
- measure concentration of an element to be used as an internal standard for the LA-ICPMS
- Fe and S homogeneous in pyrite and chalcopyrite
- Cu heterogenous in pyrite

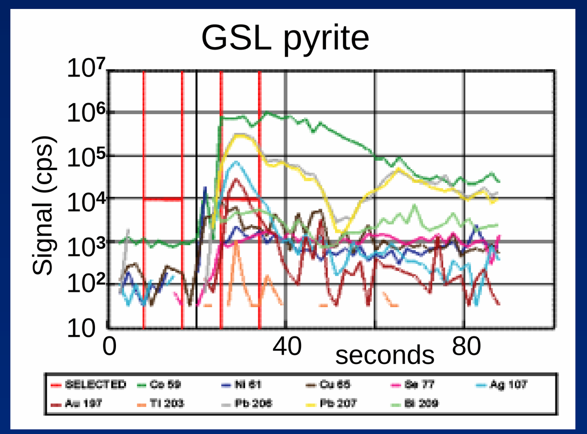
ECG pyrite	Fe	S	Cu
EC52-1 Grain 1	45.94	53.25	0.01
EC52-1 Grain 2	45.16	51.68	0.01
EC52-1 Grain 4	46.97	53.07	b.d.
EC52-1 Grain 5	47.07	51.81	b.d.
EC52-2b Grain 1	45.62	52.49	0.04
EC52-2b Grain 2	45.20	52.70	0.03
EC52-2b Grain 3	45.16	52.30	0.05
Average	45.87	52.47	0.02
1 sigma	0.77	0.55	0.02
% RSD	1.68	1.04	92.58
GSL pyrite			
GSL-01 Grain 1	46.69	53.11	0.06
GSL-01 Grain 3	45.00	50.65	0.11
GSL-01 Grain 4	46.47	52.99	0.06
GSL-01 Grain 6	46.97	52.98	0.03
Average	46.28	52.44	0.07
1 sigma	0.76	1.03	0.03
% RSD	1.65	1.96	44.19

ECG ccp	Fe	S	Cu
EC52-1 Grain 1	28.94	33.35	37.60
EC52-1 Grain 2	28.62	33.28	38.11
EC52-1 Grain 3	29.85	34.29	36.68
Average	29.14	33.64	37.46
1 sigma	0.64	0.57	0.72
% RSD	2.19	1.69	1.93

- LA-ICP-MS data show low abundances of trace elements in the ECG compared to a Au deposit at Golden Sunlight mine
- Chalcophile element abundances in the ECG sulfides are heterogeneous, with the exception of Ag



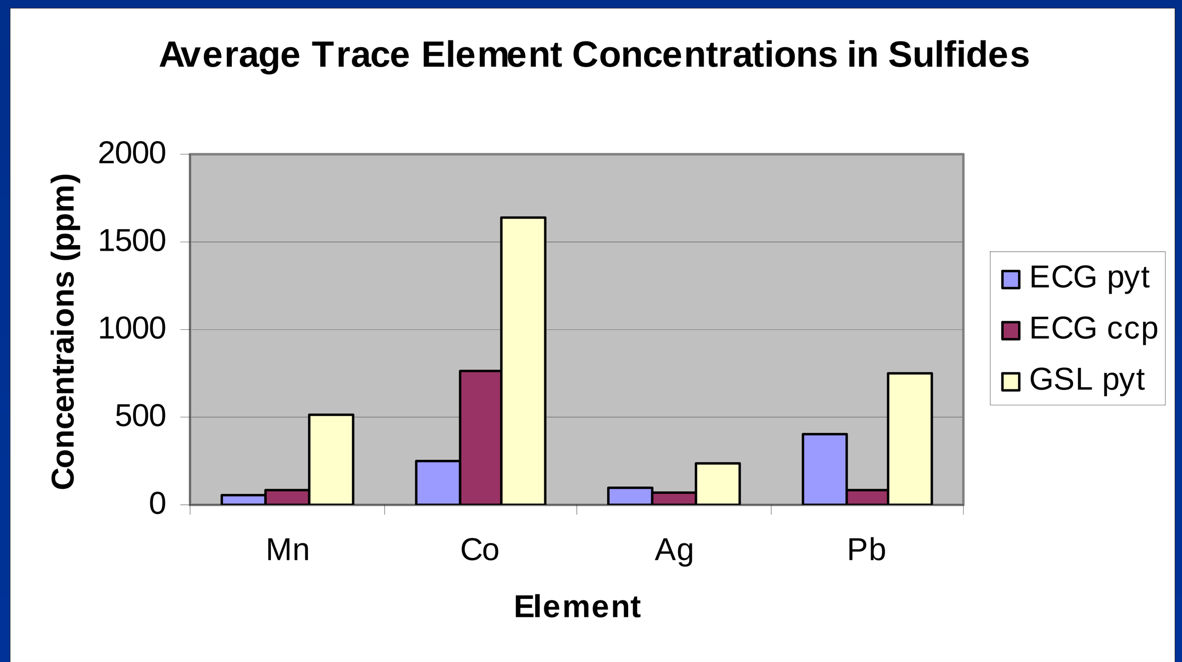




- High abundances of Ag, Au and Pb are seen in the GSL spectrum compared to the ECG spectra

Low concentrations in ECG can be a result of:

- Stripping of chalcophile elements from sulfides by a late-stage magmatic fluid (Keith et. al, (1991).
- The ECG magma was initially deficient in chalcophile elements.



Conclusions

The Ellicott City granodiorite contains magmatic epidote, which crystallized at pressures of 0.6-0.8 GPa. Two sulfides, pyrite and chalcopyrite, are also observed in the rock. Petrographic analysis show that pyrite and chalcopyrite occur as inclusions in epidote and only chalcopyrite in hornblende. Thus, the sulfides are magmatic and crystallized at the same time as epidote and hornblende (i.e., at high pressures). Elemental abundances of chalcophile elements are low in the ECG sulfides compared to the Au deposit. Low abundances of these trace elements can be explained two ways. The first, the initial ECG magma was deficient in chalcophile elements. Second, a late stage magmatic fluid may have stripped chalcophile elements from the sulfides.

References

Keith, J.D., et al. "The Role of Magmatic Sulfides and Mafic Alkaline Magmas in the Bingham and Tintic Mining Districts, Utah." Journal of Petrology 38 (1997). 1679-1690.

Zen, E-an, and Hammarstrom, Jane. "Magmatic epidote and its petrologic significance." Geology 12 (1984). 515-518.