PETROGENESIS OF IGNEOUS ROCKS IN THE EMINENCE KNOBS REGION: SOUTHWESTERN ST. FRANCOIS MOUNTAINS, MISSOURI

Meszaros, Nicholas[1], Mills, James G.[1]

[1]Department of Geosciences, DePauw University, 602 South College Ave., Greencastle, Indiana 46135 Contact: nmeszaros_2018@depauw.edu

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ABSTRACT:

Recent USGS 7.5 minute quadrangle mapping in the Eminence Knobs region of southeastern Missouri has identified the location of approximately 13 Mesoproterozoic (1.6-1.3 bya) volcanic and plutonic units that comprise the southwest portion of the tectonically enigmatic St. Francois Mountains granite-rhyolite province. Representative samples of 10 of the most prominent units were collected for petrographic and geochemical analysis: Ygh (informally named here as the Ruble, Mill Spring, and Big Spring granites), Ycl, Ycu, Yltm, Ymm, Yrm, Ysc, Yscr, Ysi, and Ysm. Petrography of the rhyolitic units indicates that these rocks were predominantly lava flows (Ycl, Ycu, Yltm, Ymm, Yrm, Ysc, Yscr, Ysi, and Ysm). Two interbedded air-fall and poorly-welded ash-flow units in Ycl were encountered during field work (additional air fall and ash flow deposits within some of these units are noted on USGS maps but were not located during this field study). Ysi lavas contain up to 2% secondary fluorite; other units may only have a trace of fluorite, if any at all. The Ruble and Mill Spring plutons are Alkali Feldspar Granites and the Big Spring pluton is a true Granite (IUGS classification). All granites are leucocratic and subsolvus; the Mill Spring granite contains a trace of pyrite and the Ruble granite contains a trace of primary fluorite. Geochemically, the igneous rocks of this region have a weak anorogenic affinity based on a Ga/Al vs. Zr plot (Whalen et al., 1987). Tectonic discrimination plots using Nb, Rb, Ta, and Yb are ambiguous in delineating the specific tectonic setting. All units are ferroan and peraluminous (ASI>1) except for the Ruble Granite which is slightly metaluminous (ASI = 0.9421) (Frost et al., 2001). All units except Ycl, have La/Lu ratios of 4-5 (Ycl: 1.5–8) which in part, is used here to suggest that the units in the region are cogenetic. Except for the Mill Spring granite, all units have uniform patterns on Spider plots and REE diagrams (all are depleted in Eu, Sr, P, and Ti indicating fractionation of feldspar, apatite, and ilmenite. Depleted Ba, K, and Rb in the Mill Spring Granite indicates potential enhanced feldspar fractionation as compared to the Ruble and Big Spring granites. Based on REE and Spider plots, all granites are inferred to be either comagmatic or cogenetic with the volcanic units in the Eminence Knobs region.

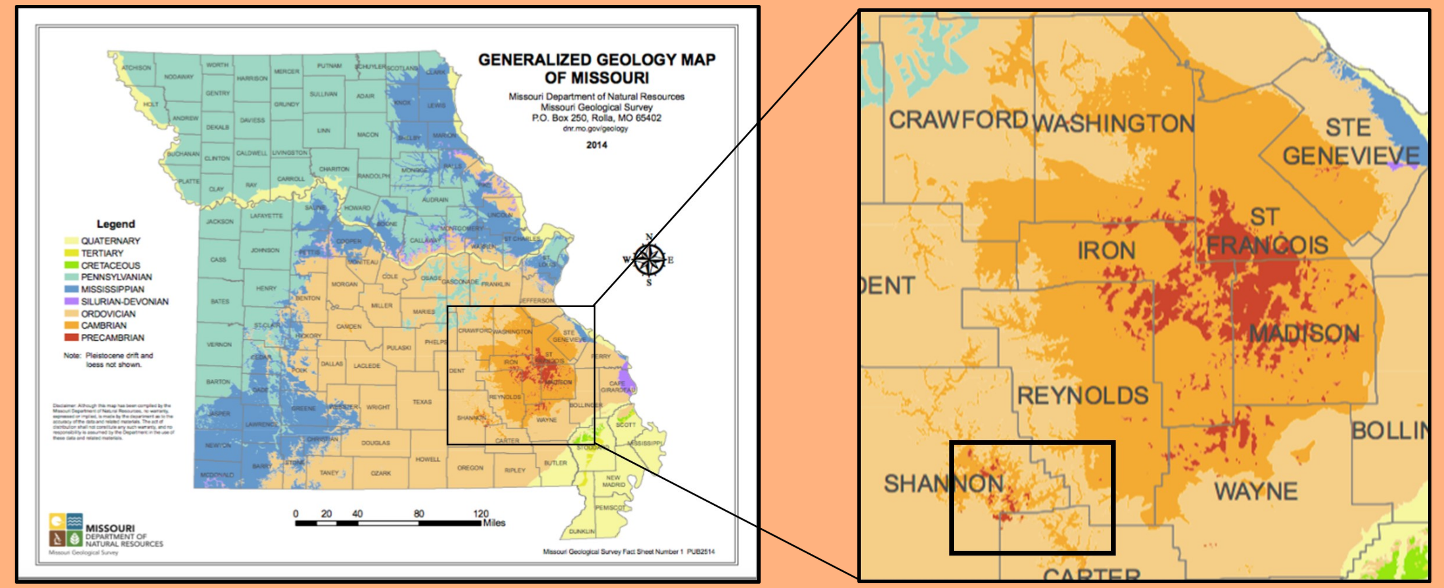

Figure 1: Geologic maps of Missouri compiled by the Missouri Department of Natural Resources (2014). Areas in red indicate Precambrian igneous rocks of the St. Francois Mountains. The black box on the map on the right indicates the area of study.

GEOLOGIC BACKGROUND:

Granites and rhyolites are the dominant rock types in the St. Francois Mountains. These rocks are the remnants of a Mesoproterozoic caldera complex located along the Laurentian margin of the supercontinent Columbia. The St. Francois Mountains are part of the Eastern Granite-Rhyolite Province (EGR), one of the basement terranes associated with the assemblage of Laurentia during the Precambrian. U/Pb and Sm/Nd isotopes bracket the age of the granites and rhyolites in the EGR range from 1.5 -1.3 Ga (Bickford et al. 2014). The EGR originated from the accretion of juvenile exotic terranes (1.6-1.5 Gya) onto Laurentia that would later melt and evolve into the high silica granites and rhyolites that characterize both the EGR and St. Francois Mountains (Mengue et al. 2002). The granitic rocks of the St. Francois Mountains are chemically classified as A-type (anorogenic) granitoids (Kisvarsanyi and Kisvarsanyi 1990; Bickford et al. 2014; Mengue et al. 2002). The implications of this classification in regards to tectonic setting is ambiguous. Walker et al. (2002) suggested subduction-related genesis for the granites and rhyolites; whereas Kisvarsanyi (1980) argued that hot spot magmatism is the most likely tectonic setting. More recent evaluations suggest a hybrid model of active margin back-arc spreading (Bickford et al. 2014), (Mengue et al. 2002), with back-arc magmatism occurring as a result of slab pull back of the subducting oceanic crust (Slagstad et al. 2009). The area of focus in this study is the Eminence Knobs region, located southwest of the main St. Francois Mountains complex (Fig. 1). The plutonic and volcanic units here are relatively unexplored; however, preliminary assessments disagree on whether the volcanic units are primarily lava flows (Fisher 1969) or ash-flows (Lowell et al. 2010).

KEY QUESTIONS:

1) Determine the setting in which these rocks formed, (i.e. what plate tectonic processes led to the formation of the calderas and their eruptive products).
2) Investigate what types (volcanic and plutonic) of igneous rocks are present in the southwestern St. Francois Mountains.
3) Explore the relationship between the volcanic and plutonic rocks of the region (i.e. did the rocks form cogenetically (from the same process) or comagmatically (from the same magma source)).

METHODS:

- Using the geologic maps of Weary et al. (2014) and Pratt et al. (1979) a representative suite of 32 samples were collected from 14 localities. Multiple samples were collected from a locality if there was lithological variance.
- 22 samples were analyzed for major and trace elements using ICP-MS at ALS Global in Reno, Nevada.
- Petrographic modal and textural analyses were conducted on 27 samples at DePauw University. 1000 and 500 point counts were performed on plutonic and volcanic rocks respectively.

UNITS SAMPLED:

Ruble Granite **(Ygh)**
Big Spring Granite **(Ygh)**
Mill Spring Granite **(Ygh)**
Lower Unit of Coot Mtn. **(Ycl)**
Upper Unit of Coot Mtn. **(Ycu)**
Rhyolite of Sutton Creek **(Ysc)**
Rhyolite of Shut-In Mtn. **(Ysi)**
Rhyolite of Storeys Creek **(Yscr)**
Rhyolite of Stegall Mtn. **(Ysm)**
Rhyolite of Little Thorny Mtn. **(Yltm)**
Rhyolite of Mule Mtn. **(Ymm)**
Rhyolite of Russell Mtn. **(Yrm)**

PETROGRAPHIC ANALYSIS:

All of the plutonic rocks formed under subsolvus (water-rich) conditions, whereas the volcanic rocks formed under hypersolvus (water-poor) conditions. Figures 2-4 show notable features of the plutonic rocks. Figures 5-7 show examples of common volcanic textures observed in thin section. We interpret the volcanic rocks to be primarily lava flows; however, ash flow and air fall units are present. Figure 7 shows disseminated fluorite in a lava flow. Fluorite was common in this suite of rocks, occurring as a secondary phase in volcanic rocks, and as a primary phase in the Ruble Granite.

PLUTONIC

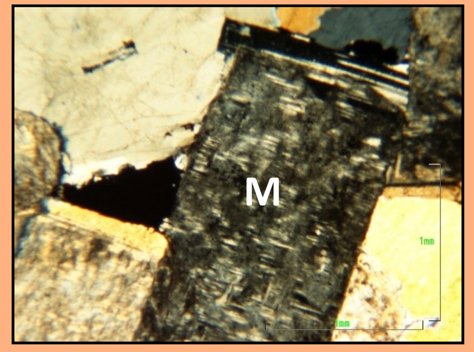

Figure 2: A feldspar crystal that is potentially Mesoperthite (M). SEM analysis is required to confirm. Cross polarized light, Mag. 40x.

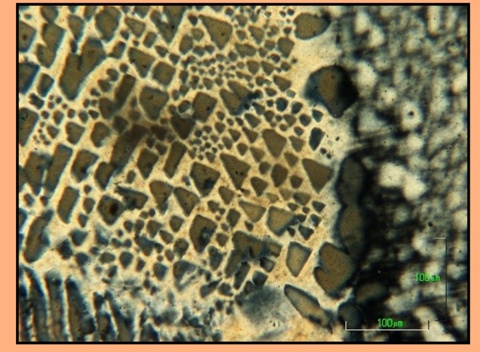

Figure 3: Micrographic texture of the Mill Spring Granite. Uncommon in the Ruble Granite. Cross polarized light, Mag. 200x.

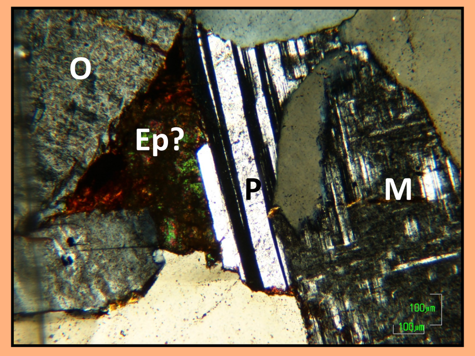

Figure 4: Plagioclase (P), microcline (M), orthoclase (O), and epidote (Mz) in the subsolvus Ruble Granite. Cross polarized light, Mag. 100x.

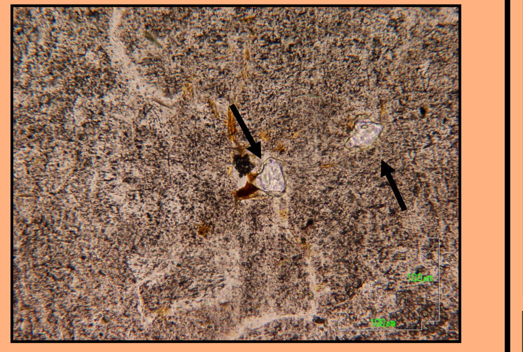

Figure 5: Primary fluorite in the Ruble Granite. Plane polarized light, Mag. 200x.

VOLCANIC

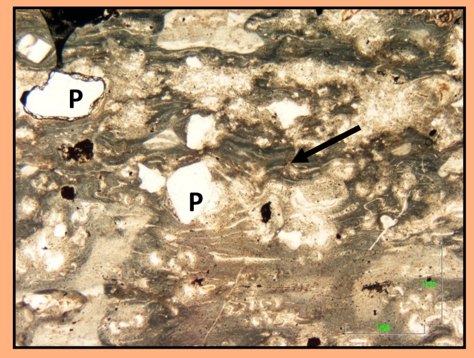

Figure 6: Flow bands (arrow) and large phenocrysts (P) in a lava flow from Slater Knob. Plane polarized light, Mag. 20x.

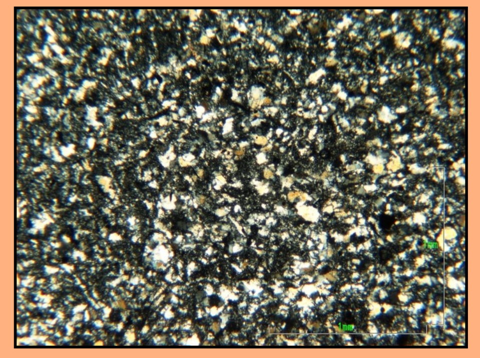

Figure 7: Granophyric matrix of devitrified glass shards of an air-fall sample from Slater Knob. Plane polarized light. Mag. 40x.

Figure 8: Devitrified glass shards (arrow), phenocrysts (P), and a xenolith (X) in a Slater Knob ash-flow. Plane polarized light. Mag. 20x.

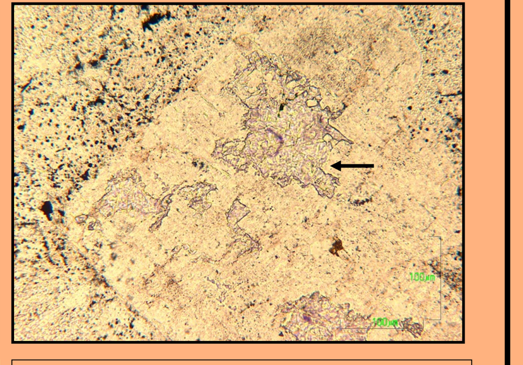

Figure 9: Secondary fluorite (arrow) within a feldspar host. Photomicrograph of Ysi collected from Pole Bridge Hollow. Plane polarized light. Mag. 200x.

Sample	Unit	Location	Or	Sa	Mc	Total K-	Pl	Qtz	Hbl	Chl	Ep	Zrn	Mnz	Hem	Opq	Unk
16SF-18-1	Ruble Granite	37.16257°N 90.92989°W	61.2	0	0	61.2	4.8	30.3	1.3	0.9	0.3	0.0	0.2	0.0	1.0	0.0
16SF-19-1	Big Spring Granite	36.97128°N 90.97730°W	44.5	0	0	44.5	18.6	32.5	0.0	0.0	0.0	0.1	0.0	0.3	3.5	0.5
16SF-19-2	Mill Spring Granite	37.00824°N 90.60915°W	57.5	0	0	57.5	1.1	36.2	0.4	1.5	0.0	0.1	0.0	0.0	2.5	0.7

Table 1: Results of 1000 point count modal analyses performed on plutonic samples. Grains that are potentially mesoperthite were counted as either orthoclase or plagioclase depending on the degree of albite twinning in the individual grain.

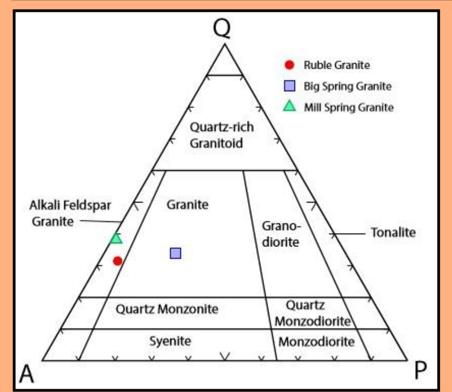

Figure 10: IUGS classification of plutonic samples. A= total alkali feldspars, Q= quartz, P= plagioclase.

GEOCHEMICAL ANALYSIS:

All of the rocks sampled can be classified as ferroan, peraluminous to slightly metaluminous, A-type granitoids with slight I&S type affinities (Fig. 11). Tectonic discrimination is highly ambiguous (Fig. 12) and most units are cogenetic as indicated by La/Lu ratios of 4-5 (Ycl: 1.5-8.0) (Figs. 13 and 14). Figure 15 is a Spider diagram of just the granites of the region which shows that Mill Spring Granite is depleted in Ba, Rb, and K relative to the other granites.

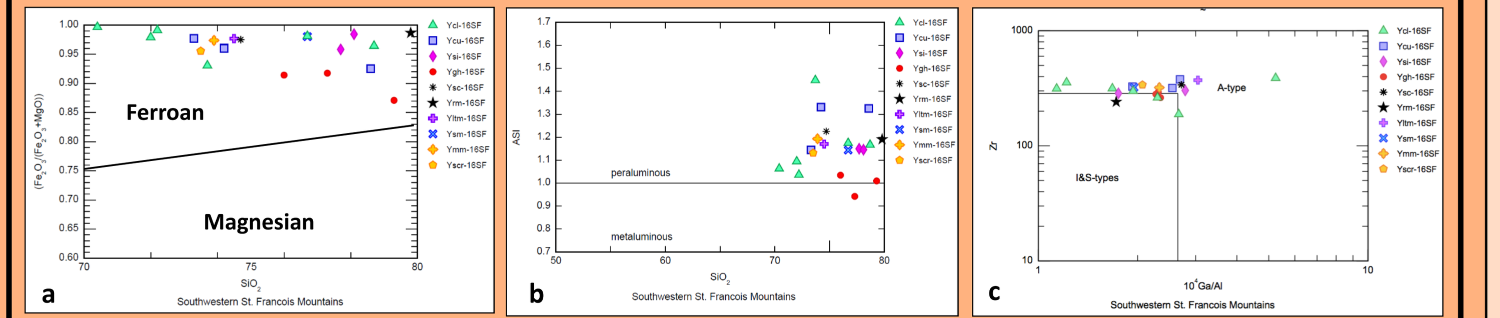

Figure 11: a) Fe-number diagram from Frost et al. (2001). b) Aluminum Saturation Index (ASI) plot from Frost et al. (2001) that classifies granitic rocks based on their calculated ASI value from the following equation: ASI= Al /(Ca - 1.67P + Na + K). c) Granitic classification based on inferred tectonic setting from Whalen et al. (1987).

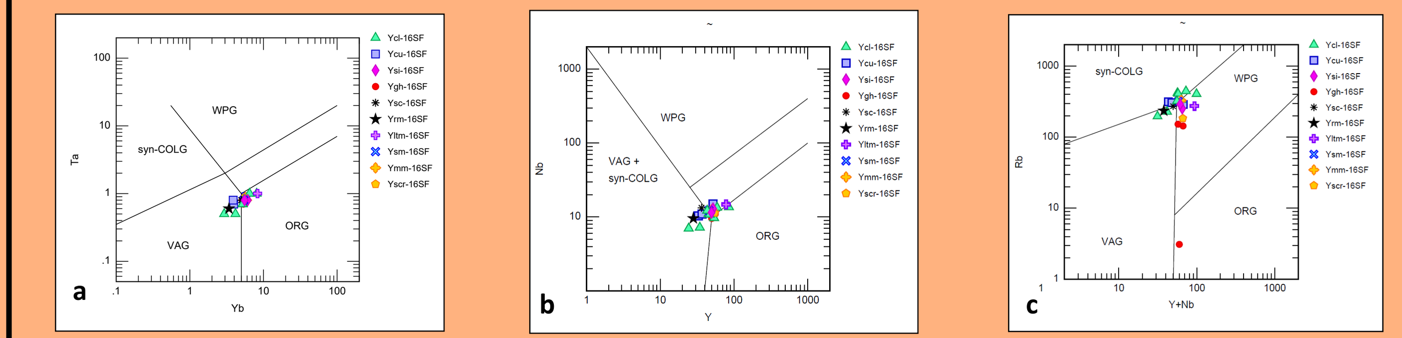

Figure 12: (a-c) Various tectonic discrimination diagrams from Pearce et al. (1984).

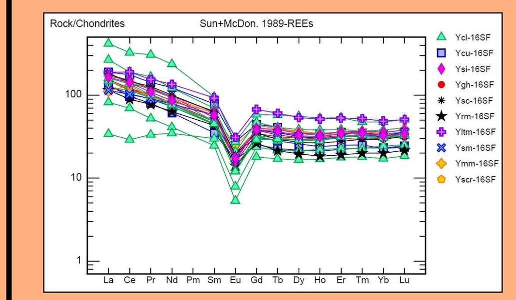

Figure 13: REE diagram of all analyzed samples. Eu anomaly indicates plagioclase fractionation. The La-Lu ranges from 4-5 for most units; however, Ycl (green triangles) ranges from 1.5-8.

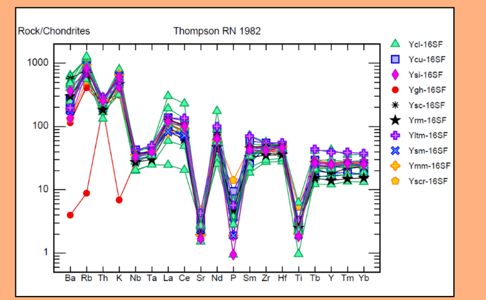

Figure 14: Spider diagram of all analyzed samples. Note the P, Sr, and Ti anomalies indicative of fractionation of apatite, feldspar, and ilmenite.

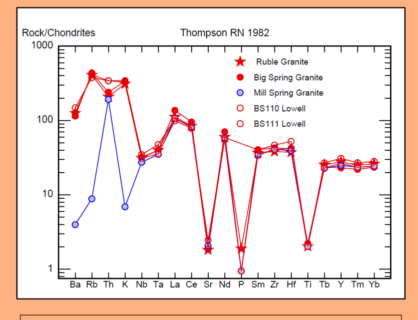

Figure 15: Spider diagram of the plutonic rocks of the study area plus analyses of the Big Spring Granite from Lowell et al. (2010). Note the variability of Ba, K, and Rb concentrations in the Mill Spring Granite (blue) relative to the other granites of the region.

CONCLUSIONS:

- The volcanic rocks of the region are primarily rhyolite lava flows, whereas the plutonic rocks are peraluminous ferroan A-type granites based on the granitoid classifications of Frost et al. (2001) and Whalen et al. (1987).
- The Mill Spring Granite is not as enriched in Ba, K, and Rb as the other granites of the region (Figures 14 and 15), and may represent a magma chamber from an additional caldera lacking surface exposures of its erupted products, or a non-erupted pluton. Alternatively, the Mill Spring Granite's relative depletion in Ba, K, and Rb may be due to its parental magma being less contaminated by crustal sources through partial melting and assimilation in comparison to the other plutonic units of the region.
- La/Lu ratios of 4-5 suggest that the igneous rocks are mostly cogenetic. Ysm, Ysi, Ycu, and a couple samples of Ycl may be comagmatic with the plutonic rocks; however, those units were more enriched in alkalis than their granite counterparts.
- Eu and Sr anomalies (Figures 13 and 14) are indicative of plagioclase fractionation, the Ti anomaly is indicative of ilmenite fractionation, and the P anomaly is indicative of apatite fractionation.
- The igneous rocks all have a weak A-type tectonic signature that we interpret to be anorogenic; however, no clear tectonic setting can be determined using any of the discrimination diagrams of Pearce et al. (1984) (Figure 12).
- The Lower Unit of Coot Mountain (Ycl), and in particular Ycl at Slater Knob, is geochemically and texturally diverse and should be redefined into several units. At Slater Knob there are clearly lava flows, an air fall, and an ash flow all with variable trace element concentrations in both Spider and REE diagrams (See Ycl Figures 13 and 14, as well as Figures 16 and 17 below).

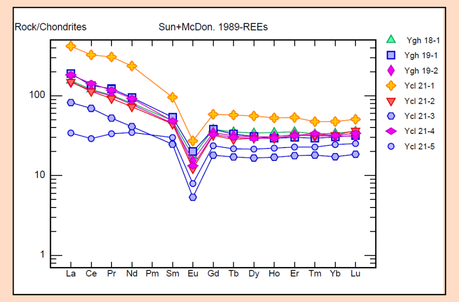

Figure 16: An REE diagram from Sun and McDonald (1989) plotting both the plutonic units sampled (Ygh) and the five volcanic units of Slater Knob (Ycl).

Figure 17: Slater Knob. Located east of Eminence, MO along Highway 106.

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An excellent exposure of the Mill Spring Granite in an old quarry.

Rocky Falls State Park: An exposure of the Rhyolite of Shut-In Mountain.

The Ruble Granite deep in the woods.