Geological History of the St. Francois Mountains

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Abstract

The St. Francois Mountains have an ancient igneous terrain with valuable Precambrian crustal records necessary for understanding geological history. One characteristic of this region is domination by the formation of felsic magmatic rocks, rhyolite, welded tuff, and coarse-grained granite during a major pulse of anorogenic, intraplate magmatism that is over time associated with the midcontinent Granite-Rhyolite Province within the age of 1.47–1.38 Ga. Another important aspect that stands out is that geothermal and isotopic evidence indicate that the formation involved extensive crustal melting within the continent, as evidenced by accessory features such as hydrothermal veins, xenoliths, and iron ore deposits. The Cambrian sediments across the Great Unconformity overlie the basement rocks in the region, but this period shows many years of missing records. The exposure is a direct result of long-term erosion, which played a significant role in removing the sedimentary cover, exposing the Precambrian basement. It makes the St. Francois Mountains a significant part of the continental crust of the ancient Laurentian craton, as is evident today.

Keywords: magmatic rocks, tectonic, St. Francois Mountains, intrusion,

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Some of North America's earliest exposed surface crust is in the St. Francois Mountains, and the Mesoproterozoic rocks of the St. Francois area contain an important record of early continental development. During this period (1.47 to 1.38 Ga), the region underwent significant transformation by massive magmatic intrusions that produced large volumes of rhyolite, granitic rocks, and ash-flow tuffs. This anorogenic magmatism did not occur at a plate boundary, and data indicate that it is due to deep crustal melting in a tectonically stable continental interior. It is part of the larger Midcontinent Granite-Rhyolite Province in Laurentia, and so studying the area helps understand the development of the North American craton over time. Erosion and uplift of the Ozarks have brought these igneous rocks to the surface, where they now lie under a thick layer of Cambrian sediments. In this study, the aim is to investigate the petrology, geochemistry, and tectonic setting of the rocks to reconstruct the entire magmatic history of the region during the Mesoproterozoic.

The Magmatic of St. Francois Mtns

Phase 1: Early Felsic Volcanism

The magmatic history of the St. Francois Mountains began with the intrusion of felsic magma into the crust through fractures that slowly rose over time, forming lava flows and volcanic domes, giving rise to the rhyolite and rhyolite porphyry found in this phase. The rocks have been rapidly cooled at the surface and are fine-grained; some are porphyritic, with larger crystals embedded in a finer-grained matrix. Biotite, alkali feldspar, and quartz are always present, confirming a highly differentiated silica-saturated melt source (Wracher, 1976). This flow of heat from a deep mantle source rose into the continental block’s mantle, leading to partial melting of the lower crust and early volcanic activity.

Phase 2: Explosive Caldera Volcanism

The second phase is the period of explosive Caldera volcanism, which occurred when magmatic pressure rose, leading to the filling of shallow crustal chambers with volatile-rich magma and triggering an abrupt shift from effusive lava flows to explosive eruptions. The single-stage collapse of the caldera ejected large amounts of pyroclastic material at high speed, including ash flows, welded tuffs, and volcanic breccia, which cover the surrounding landscape and accumulated as sheets several meters thick and layered across the region and are clearly distinct from the Phase 1 rhyolites due to their fragmented, welded texture.

Phase 3: Post-Volcanic Granitic Intrusion

As the deep heat source subsided, magmatic activity migrated into the slowly consolidating continental crust, and surface volcanism waned over an extended period. A large body of unmelted material began to cool at depth, forming coarse-grained granite and granophyre below. It produces a phaneritic texture, characterized by visible (non- "microscopic") crystals (medium-sized, in the range of 4 mm to 3.0 cm), and contains abundant crystals of quartz, alkali feldspar, and hornblende. The granite is well dated at 1,804 ± 19 Ma by Van Schmus et al. (2007), placing it in the Mesoproterozoic magmatic time frame. As volcanic activity ceased and intrusive activity began, the magmatic system matured, with hotter magma leading to more melt crystallizing in place within the rock system. Figure 1 shows a map of the Mesoproterozoic igneous rocks, including the mafic intrusive rock unit (See Appendix A). The map highlights the mafic intrusive units within the broader igneous terrane.

Phase 4: Late Mafic Injection and Mafic–Felsic Interaction

A final phase began when mafic magma was added to the cooling felsic system, providing compositional input to an already felsic-dominated terrane. This mafic–felsic interaction is more evident in the Silvermine Granite, a subvolcanic ring pluton in eastern Missouri that occurred around 1.48 Ga. A partial melt of the granitic with hot mafic magma that, if mixed at all, was crystallized rather quickly and formed rounded, pillow-like enclaves. Kisvarsanyi et al. (1980) highlighted that during this late stage, the terrain was predominantly alkaline-silicic and never mafic, which had remained subordinate in the magmatic system. Figure 2 (a) shows pillow-shaped hybrid enclaves, and Figure 2(b) shows the hybrid granite (See Appendix B). Both show evidence of mafic magma intrusion into a partially solidified felsic host.

Chronological Framework

Magmatic activity in the St. Francois Mountains involved a sequence of activity that is of Mesoproterozoic age, ranging from about 1.50 to 1.38 Ga. The rhyolite sequences are the earliest to be erupted at 1.48–1.47 Ga, and the zircon U-Pb ages support formation at the onset of volcanism (du Bray et al., 2021). Isotopic data have allowed us to correlate the ash-flow tuffs directly with the explosive caldera stage, and these deposits closely precede more ash-flow tuffs at about 1.47 Ga. These intrusions are post-volcanic (1.47-1.45 Ga), as shown by U-Pb dating. Mafic rocks age from 1.48 to 1.45 Ga (du Bray et al., 2021) and their ages overlap with the felsic units, thus providing evidence of coeval mafic–felsic magmatic activity. Mafic dikes are the latest intrusions, cutting across all the earlier ones and the last manifestation of Proterozoic magmatic activity.

Magmatic System Characteristics

The St. Francois magmatic system drew from two regions: the lower continental crust and the underlying mantle. Over time, partial melting of the lower crust, driven by mantle heat, produced intermediate- to felsic magmas that percolated up through the system (Lowell &

Young, 1999). Fractional crystallization as these melts rose increased the silica content of the remaining melt, concentrating high silica rhyolite into the last little amounts. As the caldera collapsed, it ejected large amounts of high-silica magma, forming the thick ash-flow tuffs recorded throughout the area. The granitic plutons represent areas of residual magma that did not erupt but cooled slowly at considerable depth, and they document a fully differentiated magmatic system.

Tectonic Setting

The geologic environment in which the St. Francois Mountains formed was intraplate, or one within a continental interior with no nearby plate boundary. Intraplate magmatism is not driven by subduction, rifting, or continental collision, but rather by deep-lithosphere thermal anomalies. The magmatism is further classified as anorogenic because no compressional or collisional tectonic unifying forces were active during the emplacement of these magmas. The region is part of the stable Laurentian crustal block, which was well consolidated and stabilized by 1.5 Ga. Even though stable, a subcontinental thermal anomaly led to melting at lower depths and provided a general crustal magmatic activity that has persisted over time in the cratonic interior. The St. Francois Mountains are part of the Midcontinent Granite-Rhyolite Province, which documents a regional phase of anorogenic magmatism in the central part of Laurentia.

Regional Context

This Precambrian cratonic block is the bedrock of North America, and the St. Francois Mountains are deeply embedded within it. The craton of Laurentia formed through the continual accretion of Precambrian igneous terranes, and the St. Francois basement is one of the best-preserved exposed parts of the Laurentian craton. The region is part of the Midcontinent Granite-Rhyolite Province of central Laurentia, which underlies much of the subsurface of central North

America. Records a widespread episode of felsic magmatism from 1.48Ga to 1.38Ga, best exposed and preserved in the St. Francois Mountains. To the north of the eastern portion of the Granite-Rhyolite Province is the Central Plains Orogen, and between these are the alkali-feldspar granite belt, spanning about 125 km in width to the West (du Bray et al., 2021). Figure 3 shows a sample of the extent of the Precambrian rock outcrops (See Appendix C). It shows evidence of the existing relationship between the St. Francois terrane and the basement rocks.

Special Rocks and Relationships

As the magmatic system cooled, mineral-bearing fluids circulated through fractures, forming hydrothermal veins and iron ore deposits. The quartz, sulfides, magnetite, and hematite contained these fluids in the host rock, and the presence of titanite rims in the Sabula pluton supports a magmatic-hydrothermal phase (du Bray et al., 2021). Hydrothermal veins are important because they record late-stage magmatic fluid paths and because the iron ore packages in these veins have direct economic and metallogenic significance. Xenoliths are pieces of pre-existing rock captured by rising magma, and their presence provides information on the assimilation of crust during magma ascent to the surface in the lithosphere.

Conclusion

During this period (1.48 to 1.38 Ga), there was a significant phase of intraplate magmatism that led to the development of a thick felsic crust, characterized by the formation of granite, rhyolite, and tuff (the St. Francois terrane). These rocks were protected from later deformation and metamorphism by the stable Laurentian craton, with other portions of Missouri having basement rocks covered by thick sedimentary sequences. The Precambrian basement rocks exposed here are largely due to the uplift of the Ozark Dome, which crushed the above material into folds. Eroded in the Great Unconformity are hundreds of millions of years, and the direct exposure of the Precambrian igneous basement below the Cambrian sedimentary layer indicates this erosion. These conditions are responsible for the limited exposure of basement rocks in the St. Francois Mountains and make this region a unique indicator of the Mesoproterozoic history of the East versus the West.

References

du Bray E. A., E. A., Aleinikoff, J. N., Day, W. C., Neymark, L. A., and Burgess, S. D. 2021, Petrology and Geochronology of 1.48 to 1.45 Ga Igneous Rocks in the St. Francois Mountains Terrane, Southeast Missouri, Professional Paper 1866, 88 p. 1-100, doi:10.3133/pp1866.

Kisvarsanyi, E. B., 1980, Granitic ring complexes and Precambrian hot-spot activity in the St. Francois terrane, Midcontinent region, United States, Geology, vol. 8, p. 43-47, doi:10.1130/0091-7613(1980)8<43:GRCAPH>2.0.CO;2

Kisvarsanyi, E. B., Hebrank, A. W., and Ryan, R. F., 1980, Guidebook to the geology and ore deposits of the St. Francois Mountains, Missouri (No. NP-2904121), Missouri Dept. of Natural Resources, Rolla (USA), Div. of Geology and Land Survey.

Lowell, G. R., and Young, G. J., 1999, interaction between coeval mafic and felsic melts in the St. Francois Terrane of Missouri, USA, Precambrian Research, 95, p. 69-88, doi:10.1016/S0301-9268(98)00127-2

Van Schmus, W. R., Schneider, D. A., Holm, D. K., Dodson, S., and Nelson, B. K. 2007, New insights into the southern margin of the Archean–Proterozoic boundary in the north-central United States based on U–Pb, Sm–Nd, and Ar–Ar geochronology, Precambrian Research, vol. 157, p. 80-105, doi:10.1016/j.precamres.2007.02.011

Walker, J. A., Pippin, C. G., Cameron, B. I., and Patino, L., 2002, Tectonic insights provided by Mesoproterozoic mafic rocks of the St. Francois Mountains, southeastern Missouri, Precambrian Research, vol. 117, p. 251-268., doi:10.1016/S0301-9268(02)00091-8

Wracher, D. A., 1976, Geology of the pilot knob magnetite deposit, Southeast Missouri: In studies in Precambrian geology of Missouri: Missouri Division of Geology and Land Survey, Report of Investigations no. 61, p. 155-161.

Appendix A

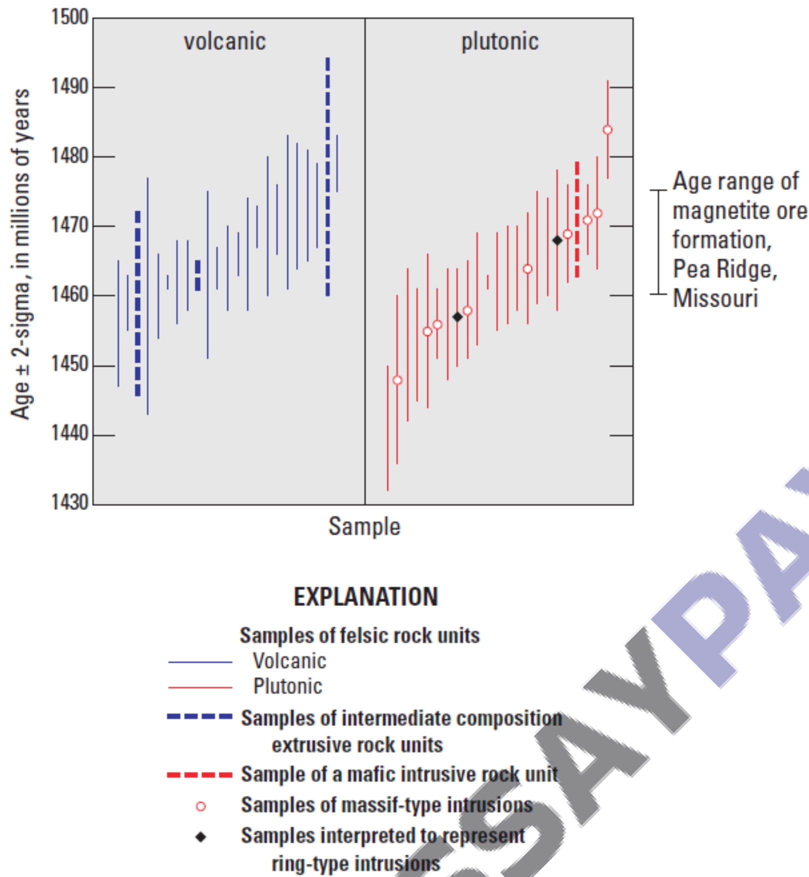


Figure 2. A map showing the Mesoproterozoic igneous rocks, including the mafic intrusive rock unit. From du Bray et al., 2021, U.S. Geological Survey Professional Paper 1866, 88 p. 46. https://doi.org/10.3133/pp1866

Appendix B

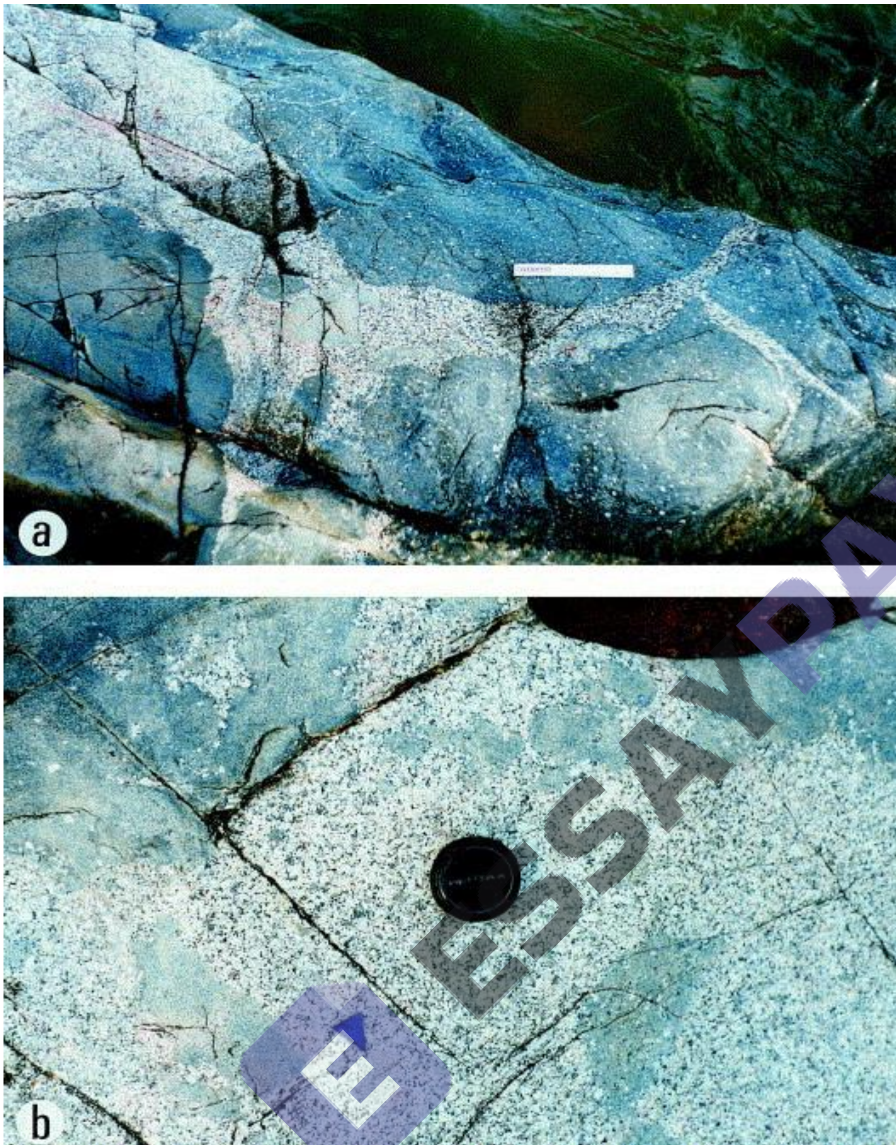
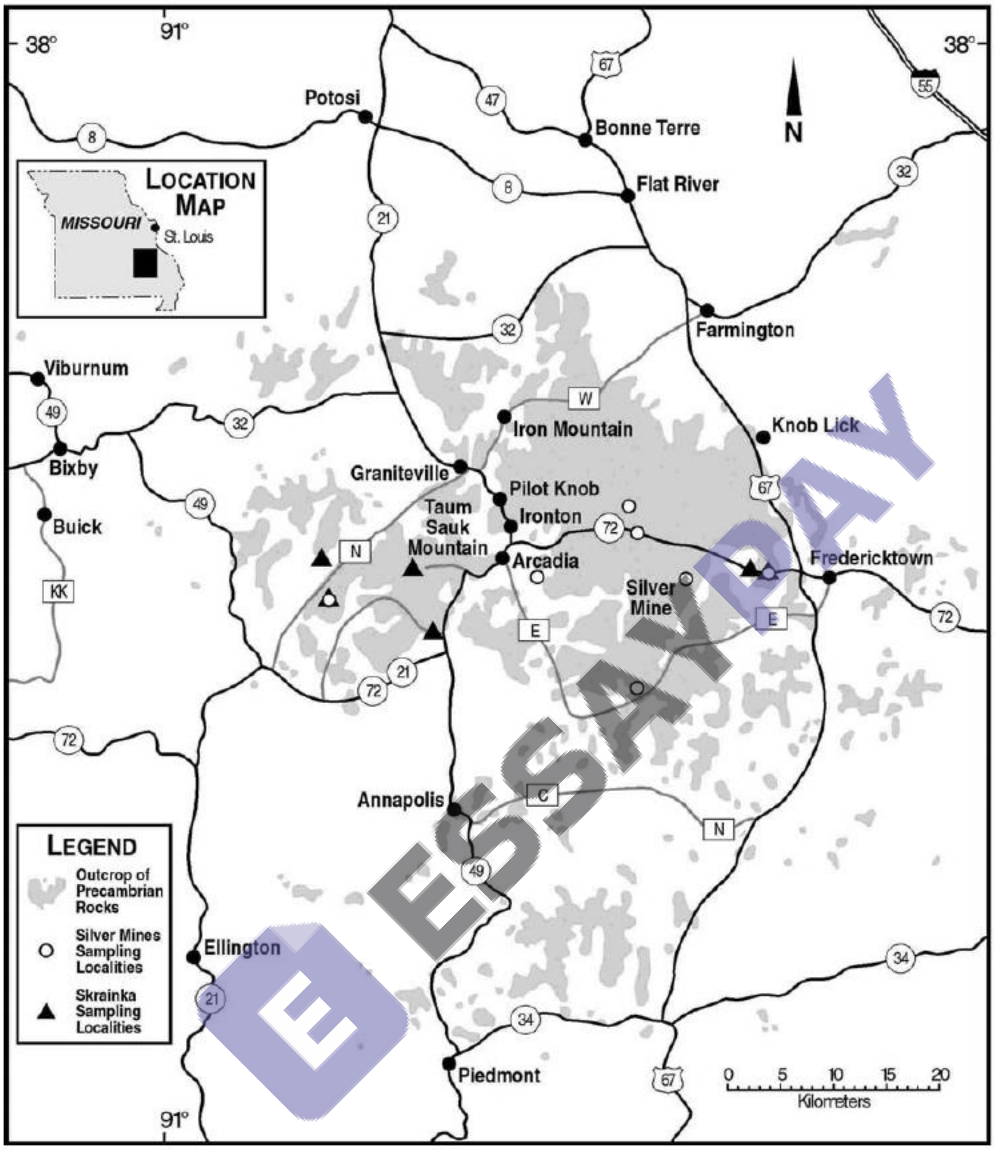


Figure 3. A Typical pillow-shaped hybrid enclave *and* Hybrid granite. From Lowell, G. R., and Young, G. J., 1999, interaction between coeval mafic and felsic melts in the St. Francois Terrane of Missouri, USA, Precambrian Research, 95, p. 74. https://doi.org/10.1016/S0301-9268(98)00127-2

Appendix C



A sample of the extent of the Precambrian rock outcrops. From Walker, J. A., Pippin, C. G., Cameron, B. I., and Patino, L., 2002, Tectonic insights provided by Mesoproterozoic mafic rocks of the St. Francois Mountains, southeastern Missouri, Precambrian Research, vol. 117, p. 253, doi:10.1016/S0301-9268(02)00091-8