Microscopic Studies of Ancient, Potentially Rift-Related Plutonic Igneous Rocks in Colorado

Isabella M. Niño and Dr. Richard Hanson

Department of Geological Sciences, Texas Christian University, Fort Worth, TX 76129

JOHN V. ROACH HONORS COLLEGE

Abstract

The regional geological framework of the area I am studying involves a possible major northwest-trending Cambrian to Ordovician rift zone with abundant igneous rocks in parts of Colorado. These igneous rocks may be related to large volumes of Cambrian igneous rocks located along the same trend in southern Oklahoma. My project focuses on plutonic igneous intrusions located in the Wet Mountains in the southern part of the Front Range and in the Powderhorn District farther west. The goal of this project is to discover whether the rocks in Colorado formed during the same major magmatic event as those in Oklahoma. I will be studying thin sections of rock samples from Colorado utilizing a petrographic microscope. I will describe and identify the main igneous minerals from the samples, some of which are rare. I will also study the igneous textures and alteration products in the samples. Geochemical studies in progress will build on these results and will allow detailed comparison with the southern Oklahoma igneous rocks.

Methods

Samples were collected in Colorado in 2022 and 2023. Microscopic studies of the igneous rocks were then studied in thin sections, including the identification of igneous minerals and their alteration products, as well as a description of igneous textures. I used a petrographic microscope in this work (Fig. 3). The microscope employs two polarizing filters, the polarizer and the analyzer. The polarizer is located beneath the stage of the microscope and allows light to vibrate in only one direction as it passes through the thin section. The analyzer is located above the objective lens and allows light vibrating 90 degrees from the polarizer to pass through it. As polarized light passes through the thin section it interacts with the minerals revealing their unique optical properties such as pleochroism and birefringence. These optical properties assist in identifying the minerals within a thin section. All thin sections used are 0.03 mm thick and 4.5 cm in length (Fig. 4).

Fig. 6. Example of a thin section (4.5 cm long)

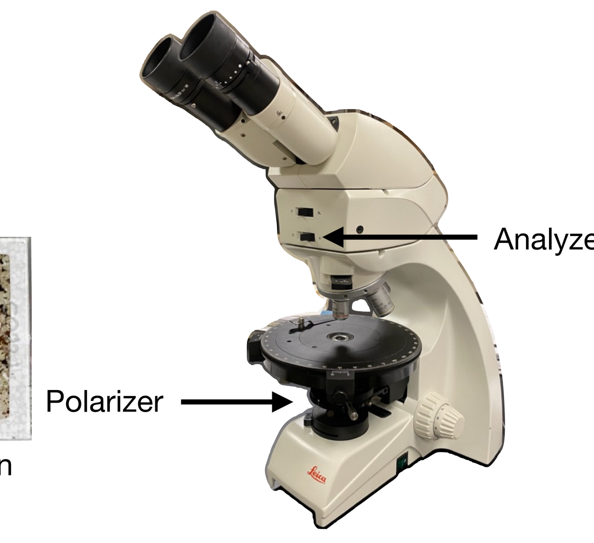


Fig. 7. Standard petrographic microscope using polarized light.

Conclusions

Cambrian to Ordovician plutonic igneous intrusions in parts of Colorado that are possibly related to the southern Oklahoma rift include a variety of igneous rock types. In the Wet Mountains, a sample of pyroxenite from the Gem Park Complex shows diopside that accumulated on the floor of a magma chamber. In the McClure Mountains Complex, both nepheline syenite (silica undersaturated) and syenite (silica saturated) rocks are present. We also have samples of cumulate pyroxenite and gabbro from the same complex. A sample from the Democrat Creek Complex shows a typical quartz syenite (silica oversaturated), indicating that these intrusive igneous rocks must have come from separate magma sources. Moving farther west, nepheline syenite from the Powderhorn Complex is very similar to nepheline syenite in the McClure Mountain Complex. Carbonatite from the central part of the Powderhorn Complex consists mostly of calcite, with minor amounts of unknown rare minerals (work is in progress to identify these). The samples show no evidence of significant alteration of the igneous textures or minerals, indicating that they all will be suitable for geochemical studies.

Geologic Background

Large volumes of Cambrian igneous rocks occur in southern Oklahoma and in adjacent parts of Texas, mostly in the subsurface (Hanson et al., 2013, Wall et al., 2021). These igneous rocks were emplaced in a major ancient rift zone as North America began to split apart (Fig. 1 and 2). It is speculated that abundant Cambrian to Ordovician igneous rocks in parts of Colorado located along the same trend may be a continuation of the same rift (Larson et al., 1985, Magnin et al., 2023). These igneous rocks occur in two main locations in Colorado, in the Wet Mountains and the Powderhorn Igneous Complex farther west (Van Gosen, 2009). In the Wet Mountains, three major plutonic intrusions are present, including the McClure Mountain Complex, the Gem Park Complex, and the Deer Creek Complex (Olson et al., 1977, Pivarunas and Meert, 2019). We are working on samples of mafic-ultramafic cumulate rocks, syenite, nepheline syenite, and ijolite (a fairly rare nepheline-pyroxene rock) from the McClure Mountain Complex. We also have samples of gabbro and quartz syenite from the Gem Park and Deer Creek Complexes. In the Powderhorn District, we have samples from the large Powderhorn Alkalic Complex, including nepheline syenite and carbonatite. The purpose of this project is to complete detailed microscopic work on these rocks which will be the foundation for geochemical work that is in progress.

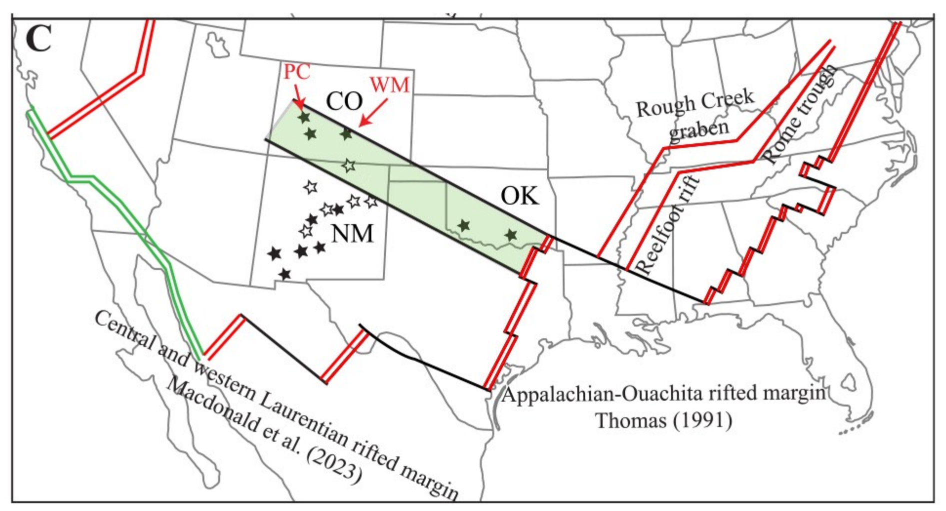


Fig.1. Figure depicts a northwest-trending Cambrian to Ordovician rift zone with abundant igneous rocks in parts of Colorado. These igneous rocks may be related to large volumes of Cambrian igneous rocks located along the same trend in southern Oklahoma. PC= Powderhorn Complex, WM= Wet Mountains, black stars= known Ediacaran-Ordovician intrusions, and white stars= inferred Ediacaran-Ordovician intrusions. Modified from Magnin et al. (2023).

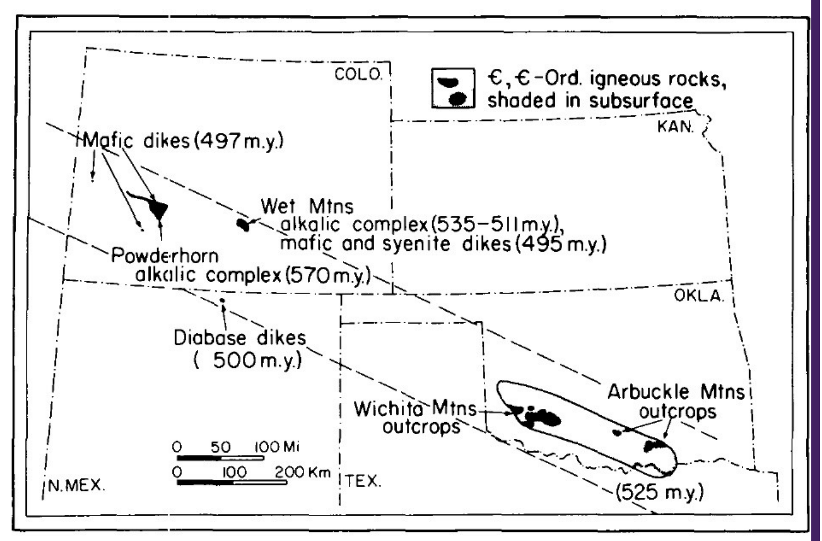


Fig. 2. Distribution of Cambrian-Ordovician igneous rocks in New Mexico, Colorado, and Oklahoma. Modified from Larson et al. (1985).

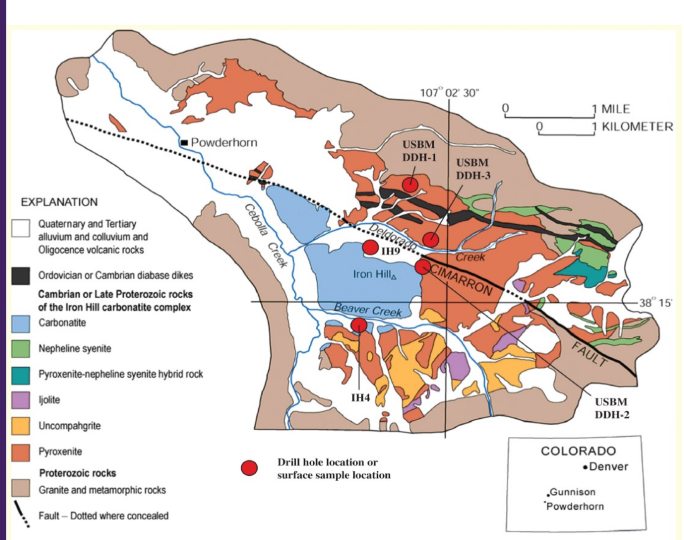


Fig. 3. Geologic map of the Powderhorn Complex. Modified from Van Gosen et al. (2009).

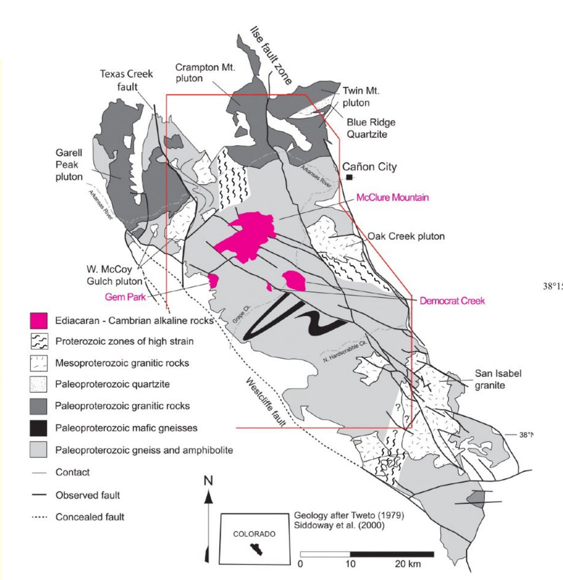


Fig. 4. General geology of the Wet Mountains with main plutonic intrusions highlighted. From Magnin et al. (2023).

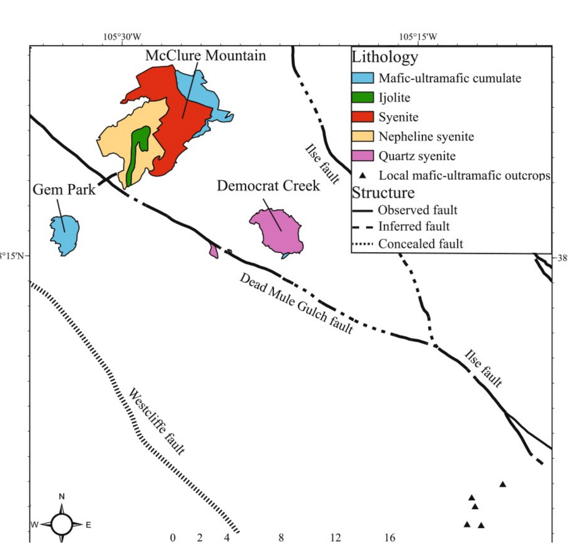


Fig. 5. Lithology of the main plutonic intrusions in the Wet Mountains. From Magnin et al. (2023).

References

Hanson, R, Puckett, R, Keller, G, Brueseke, M, Bulen, C, Mertzman, S, Finegan, S, McCleery, D.A., 2013, Intraplate magmatism related to opening of the southern Iapetus Ocean: Cambrian Wichita igneous province in the Southern Oklahoma rift zone: Lithos, v. 174, p. 57-70.

Larson, E E; Patterson, P E; Curtis, G; Drake, R; Mutschler, F E, 1985, Petrologic, paleomagnetic, and structural evidence of a Paleozoic rift system in Oklahoma, New Mexico, Colorado, and Utah: Geological Society of America Bulletin, Vol. 96, p.1364-1372.

Magnin, B P; Kuiper, Y D; Anderson, E, 2023, Ediacaran-Ordovician magmatism and REE mineralization in the Wet Mountains, Colorado, USA; implications for failed continental rifting: Tectonics, Vol. 42, Article e2022TC007674.

Olson, J C; Marvin, R F; Parker, R L; Mehnert, H H., 1977, Age and tectonic setting of lower Paleozoic alkalic and mafic rocks, carbonatites, and thorium veins in south-central Colorado: Journal of Research of the U. S. Geological Survey, v. 5, p. 673-687.

Pivarunas, A F; Meert, J, 2019,Protracted magmatism and magnetization around the McClure Mountain alkaline igneous complex: Lithosphere, v. 11, p. 590-602.

Van Gosen, B, 2009, The Iron Hill (Powderhorn) carbonatite complex, Gunnison County, Colorado; a potential source of several uncommon mineral resources: Open-File Report - U. S. Geological Survey, 2009-1005, 28 p.

Wall, C, Hanson, R, Schmitz, M, Price, J, Donovan, R, Boro, J, Eschberger, A, Toews, C, 2021, Integrating zircon trace-element geochemistry and high-precision U-Pb zircon geochronology to resolve the timing and petrogenesis of the late Ediacaran-Cambrian Wichita igneous province, Southern Oklahoma aulacogen, USA: Geology, v. 49, p. 268-272.

Thin Sections From Wet Mountains

Fig. 8. Cumulate pyroxenite from layered magic intrusion in McClure Mountain Complex. Pencil for scale.

Fig. 9. CO23-7 Photomicrograph of sample from above outcrop. Plane light. Width of view 4cm.

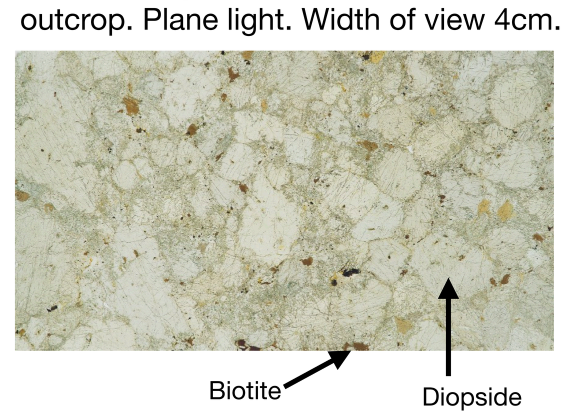


Fig. 10. CO23-7 Same view in crossed polars.

Fig. 11. CO23-10 Cumulate olivine gabbro from layered mafic intrusion in McClure Mountain Complex. Plane light. Width of view 4cm.

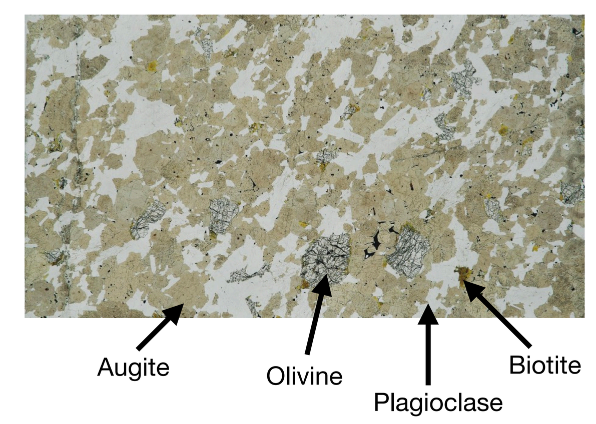


Fig. 12. CO23-10 Same view in crossed polars.

Fig. 13. CO22-1 Cumulate pyroxenite from the Gem Park Complex. Plane light. Width of view 2.5cm.

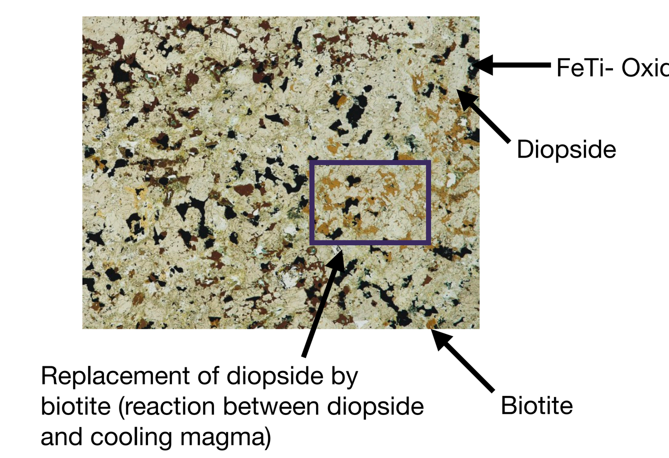


Fig. 14. CO22-5 Quartz syenite from Democrat Creek Complex. Crossed polars. Width view 1.3cm.

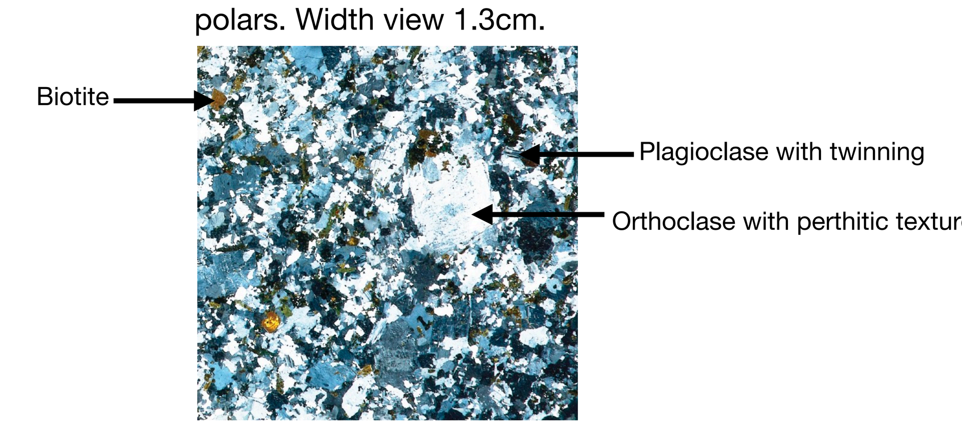


Fig. 15. Nepheline syenite from McClure Mountain Complex. Pencil for scale

Fig. 16. CO23-2 Photomicrograph of sample from above outcrop. Plane light. Width of view 4cm.

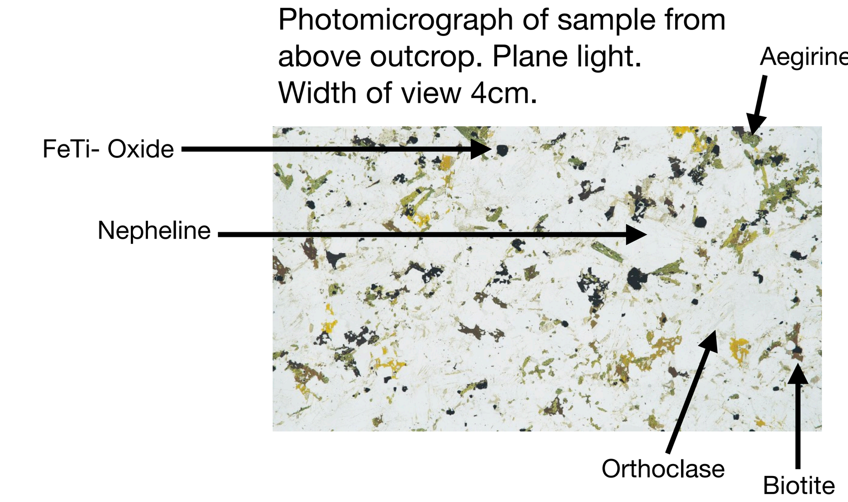


Fig. 17. CO23-2 Same view in crossed Polars.

Thin Sections From Powderhorn Complex

Fig.18 . View of Powderhorn Complex showing Iron Hill Carbonatite. From Van Gosen et al. (2009).

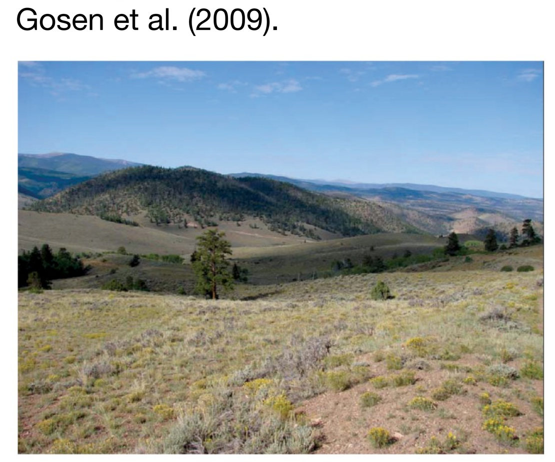


Fig. 19. CO22-14a2 Carbonatite from Powderhorn Complex. Consists mostly of igneous calcite. Crossed Polars. Width of view 4cm.

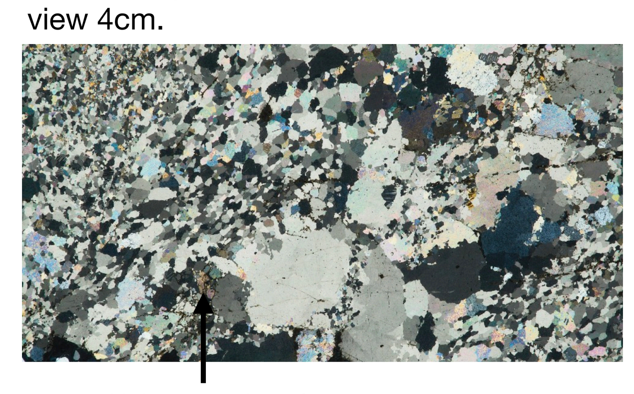
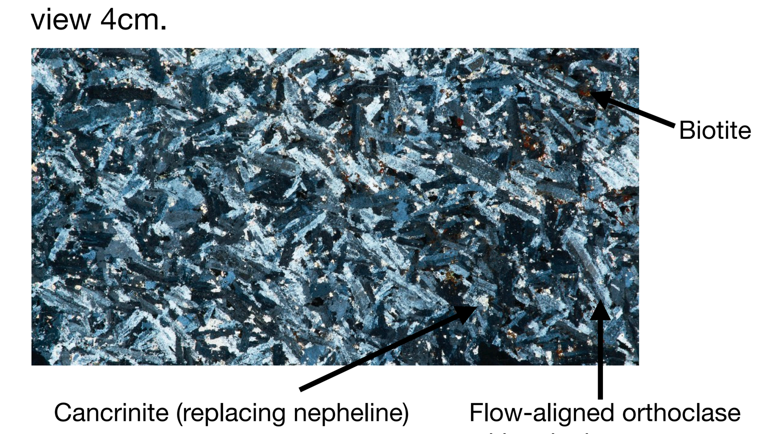


Fig. 20. CO22-12 Nepheline syenite from Powderhorn Complex. Crossed polars. Width of view 4cm.



Mineral Chemical Formulas

Olivine $(Mg,Fe)_2SiO_4$

Diopside $CaMgSi_2O_6$

Augite $Ca(Mg,Fe,Al)Si_2O_6$

Aegirine $NaFeSi_2O_6$

Biotite $K(Mg,Fe)_3(AlSi_3O_{10})(OH)_2$

Quartz SiO_2

Plagioclase Solid solution series between $NaAlSiO_3O_8$ and $CaAl_2Si_2O_8$

Orthoclase $KAlSi_3O_8$

Nepheline $NaAlSiO_4$

Cancrinite $Na_6Ca(CO)_3(AlSiO_4)_6 \cdot 2H_2O$