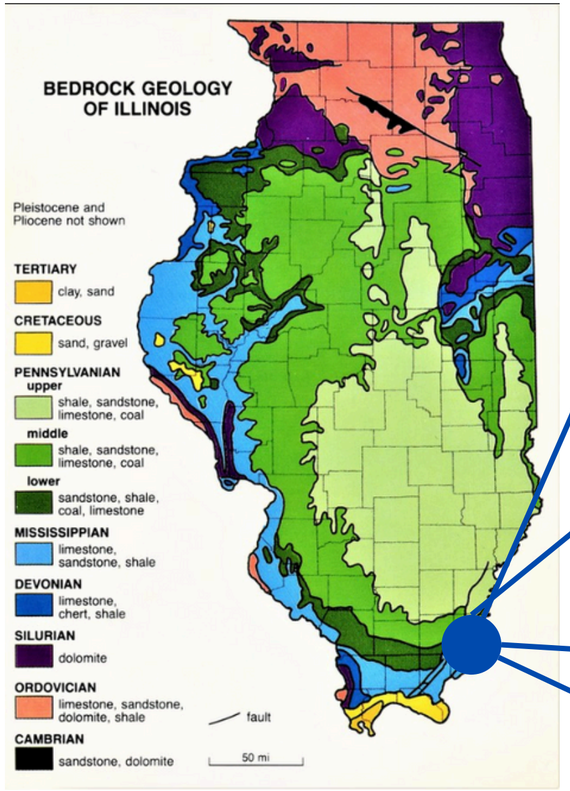
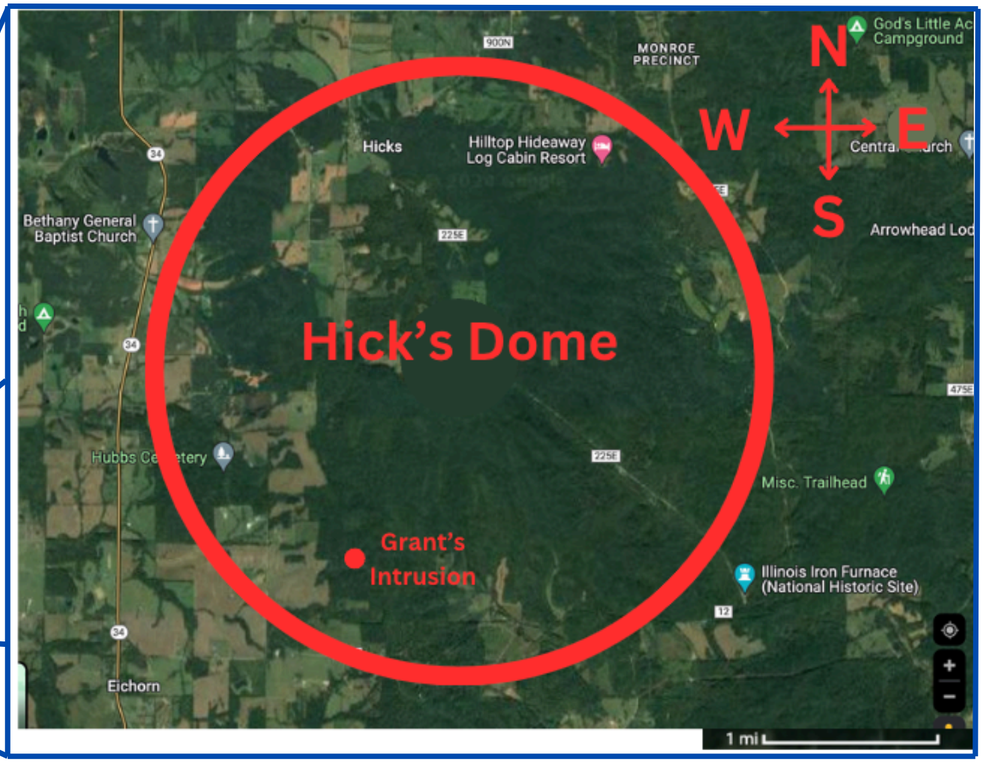
Petrological and Geochemical Analysis of the Grant Intrusive Breccia within Hick's Dome, Hardin County, Illinois





By: Aaron Beirl, Dr. Daniel Hummer, and Dr. Harvey Henson

Southern Illinois University Carbondale - School of Earth System's and Sustainability

04/23/2024

Background Information on Grant Intrusive

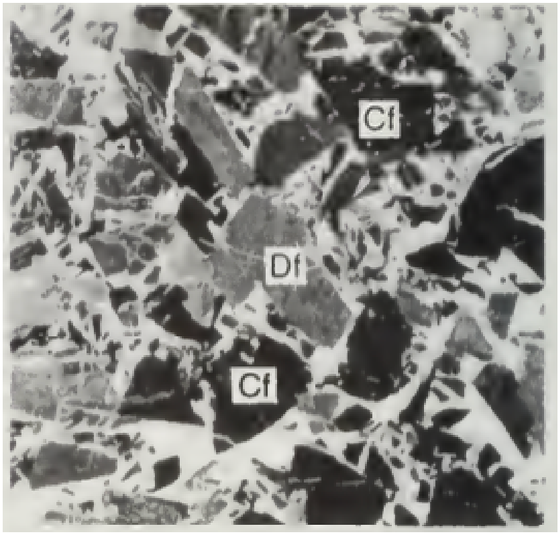
- Part of the Hicks Dome crypto-volcanic structure
  - Explosive emplacement but cooled rapidly
  - Initial magma temperatures >550°C, reheated up to 300°C
  - Formed in multiple events? *(Reynolds et al. 1997)*

- Contain's amalgamations of alkaline, carbonatitic, and ultramafic gabbros
  - Elevated concentrations of iron (Fe), magnesium (Mg), calcium (Ca), and potassium (K)

- Classified as a lamprophyric dike / shatter breccia

- Ore deposits are hypothesized to contain concentrations of titanium (Ti), barium (Ba), and thorium (Th), as well as rare earth elements (REE's), such as yttrium (Yt) and scandium (Sc)

Shatter Breccia



Cf = Carbonaceous Shale
Df = Dolomite Fragments
(Bradbury and Baxter, 1992)

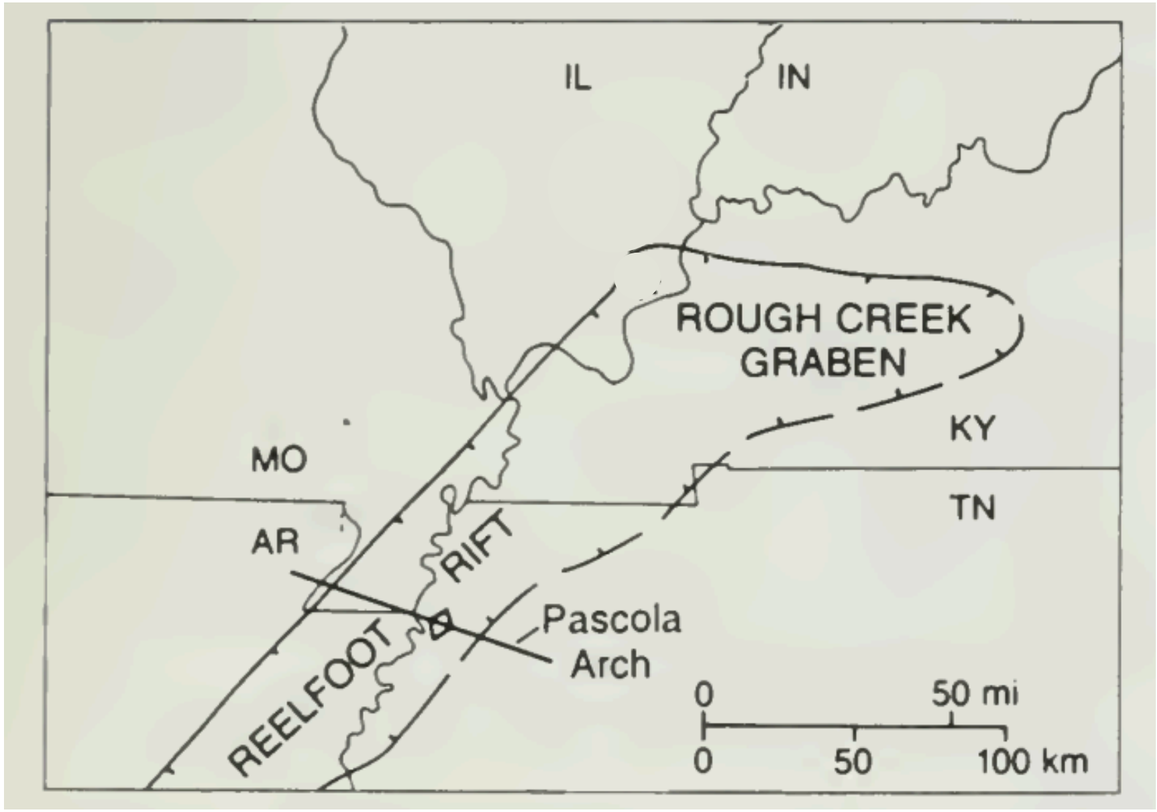
(Bradbury and Baxter, 1992)

Timeline of Events

1. PЄ -> Є(~1Ga)

a. Breakup of Rodina fomed the Reelfoot Rift and Rough Creek Graben

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

(Reynolds et al. 1997)

Timeline of Events

1. PЄ -> Є(~1Ga)

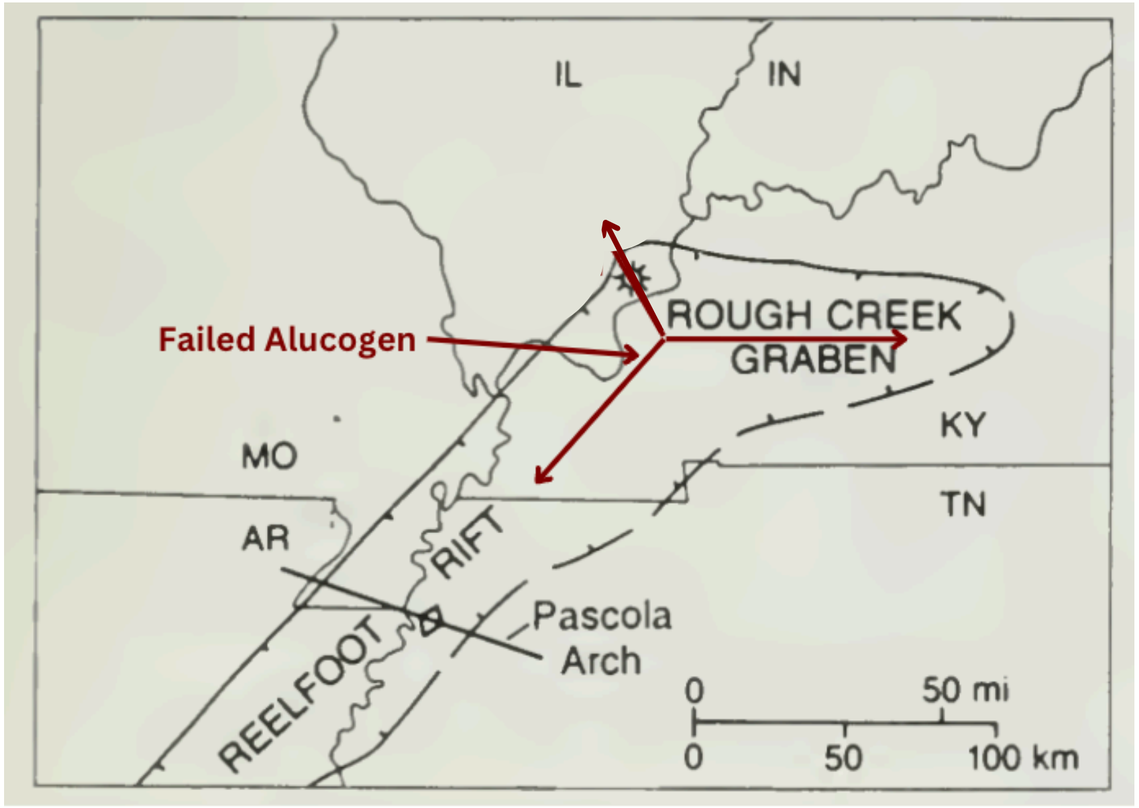
a. Breakup of Rodina fomed the Reelfoot Rift and Rough Creek Graben

↓

2. Late Pa ->Early PR (~290 mya)

a. North American plate is deformed by the breakup of Pangea

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

(Reynolds et al. 1997)

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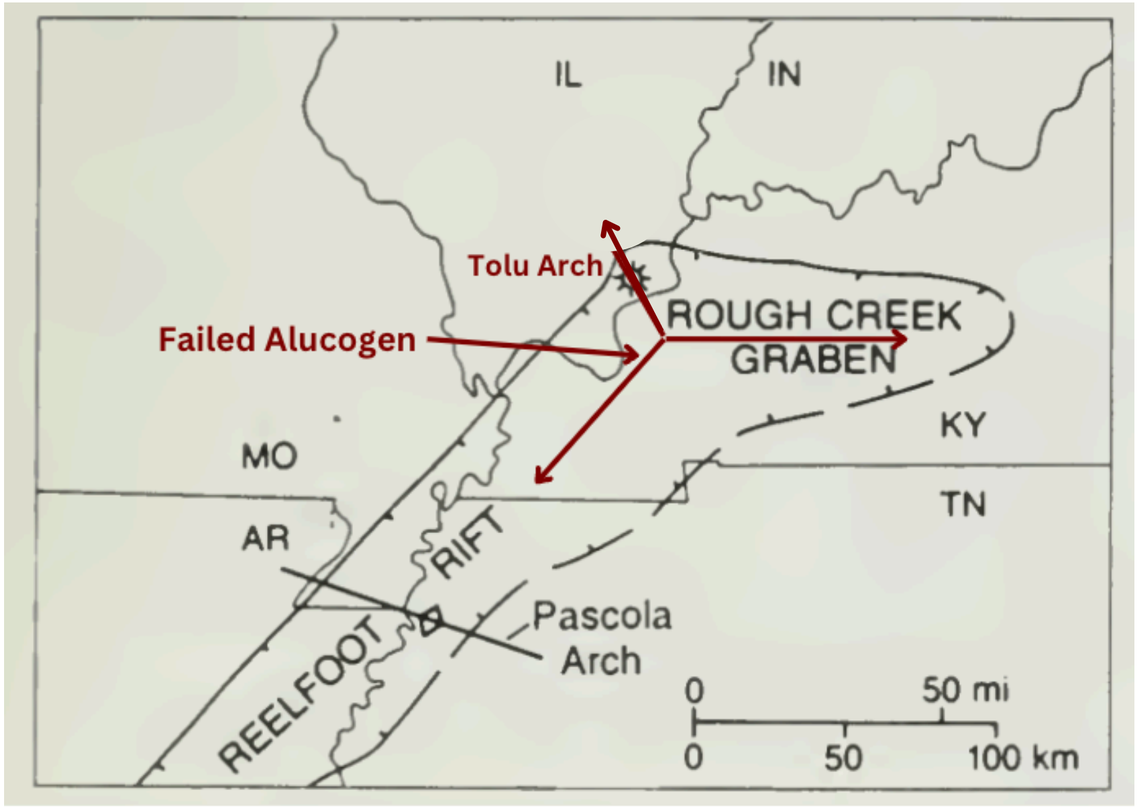
a. North American plate is deformed by the breakup of Pangea

b. Tolu Arch forms

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

(Reynolds et al. 1997)

Timeline of Events

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a. North American plate is deformed by the breakup of Pangea

b. Tolu Arch forms

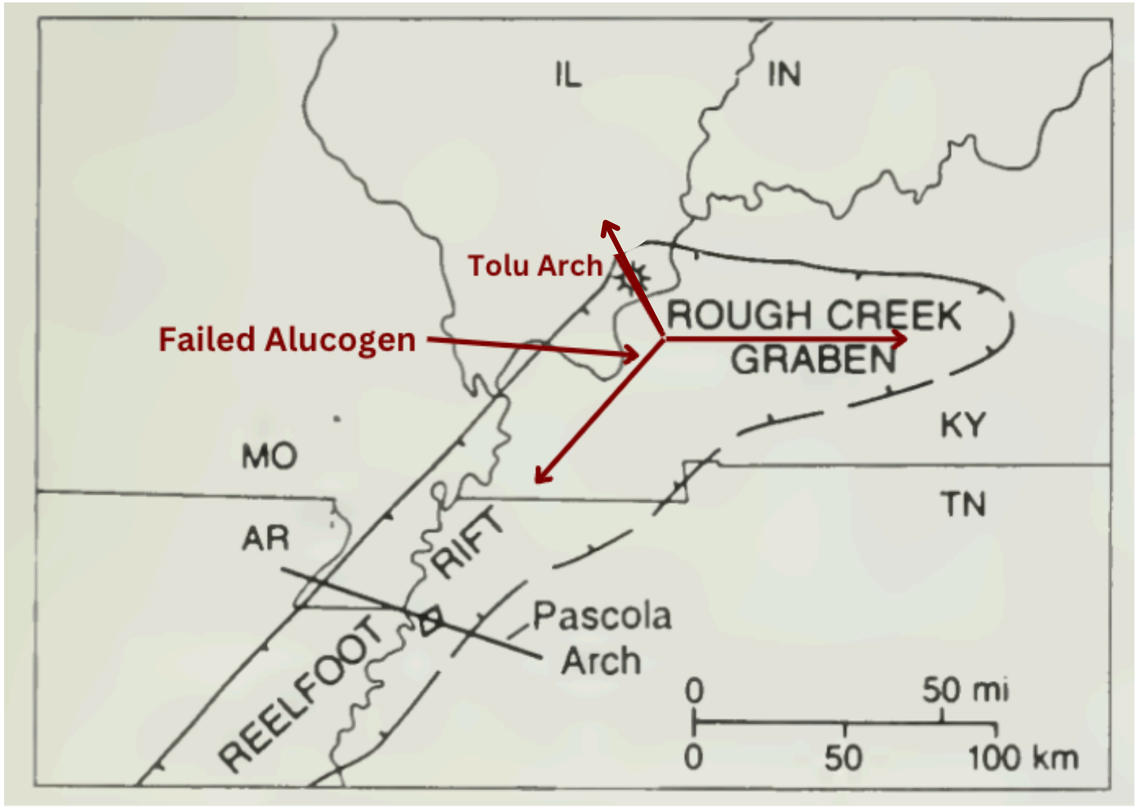
↓

3. Middle PR (~272 mya)

a. Grant Intrusive (G.I.) form's

(Reynolds et al. 1997)

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

Timeline of Events

1. PЄ -> Є(~1Ga)

a. Breakup of Rodina fomed the Reelfoot Rift and Rough Creek Graben

↓

2. Late Pa ->Early PR (~290 mya)

a. North American plate is deformed by the breakup of Pangea

b. Tolu Arch forms

↓

3. Middle PR (~272 mya)

a. Grant Intrusive (G.I.) form's

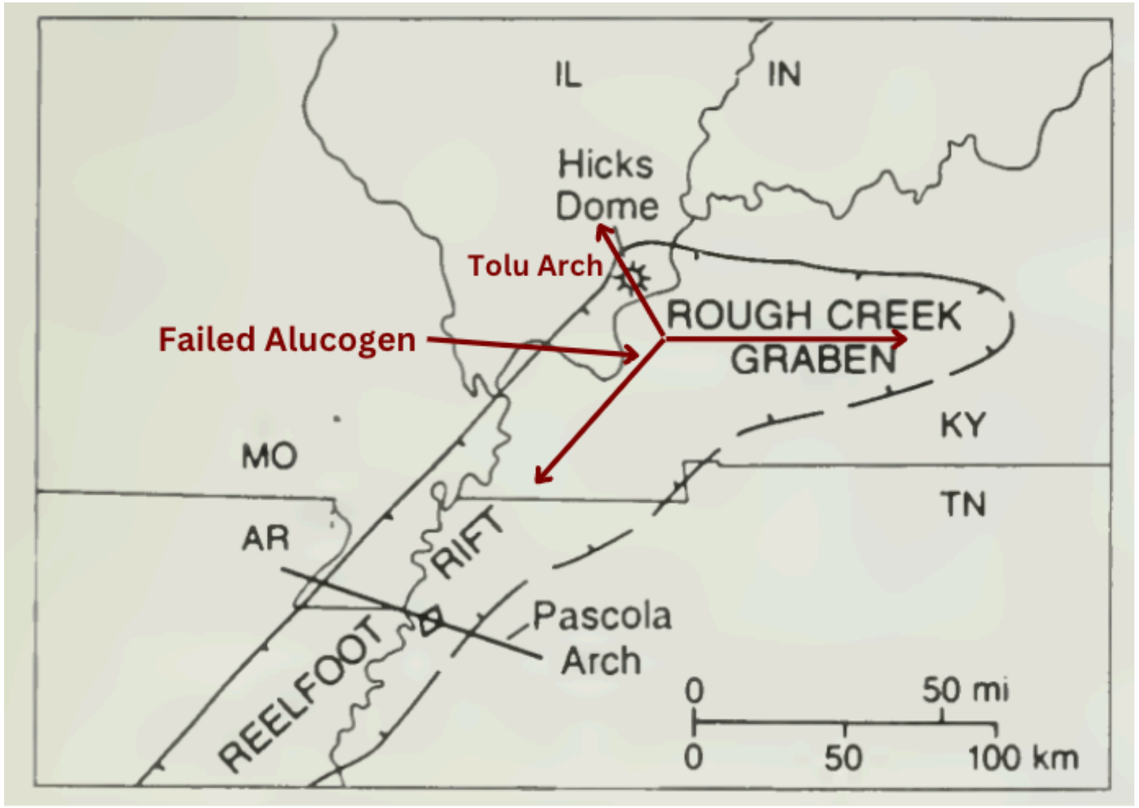
↓

4. Middle PR (~270 mya)

a. Hicks Dome intrudes

(Reynolds et al. 1997)

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

Timeline of Events

1. PЄ -> Є(~1Ga)

a. Breakup of Rodina fomed the Reelfoot Rift and Rough Creek Graben

↓

2. Late Pa ->Early PR (~290 mya)

a. North American plate is deformed by the breakup of Pangea

b. Tolu Arch forms

↓

3. Middle PR (~272 mya)

a. Grant Intrusive (G.I.) form's

↓

4. Middle PR (~270 mya)

a. Hicks Dome Intrudes

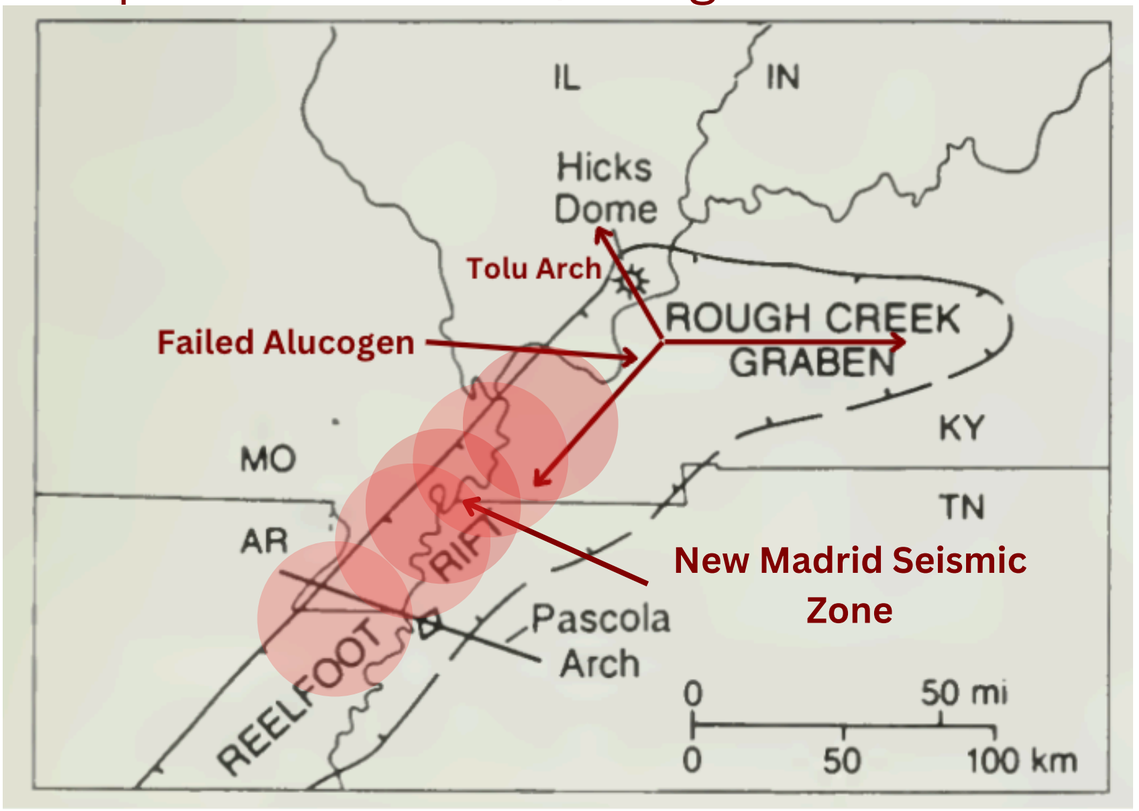
↓

5. Late JP -> Early K (~145 mya)

a. New Madrid Fault System forms above dormant Reelfoot Rift

(Reynolds et al. 1997)

Map of Reelfoot Rift / Rough Creek Graben



(Bradbury & Baxter, 1992)

Grant Intrusive Dating

- *Reynold's et. al.* was able to date G.I. to 272 +/- 0.7 ma using ^{40}Ar / ^{39}Ar dating on riebeckite and phlogopite

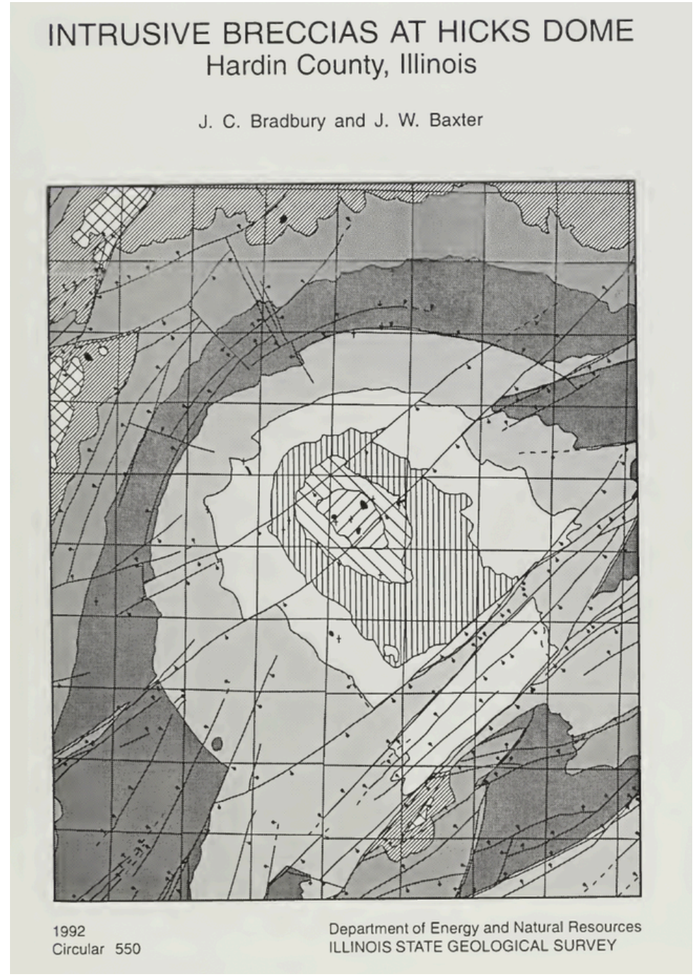
- Indications:
  - G.I. is potentially older than Hicks Dome (270 mya +/- 1.0 ma)
  - H.D. age derived from K-Ar dating by *(Bradbury and Baxter, 1992)*

G.I. Amphibole

G.I. Biotite

Limitations of Study

- Not a lot of literature of Hicks Dome, let alone Grant Intrusive
  - Only two studies have focused on characterizing Grant's Intrusive (Bradbury and Baxter, 1992) and (Reynolds et al., 1997)
  - No cross sections or diagrams to illustrate the subsurface
  - Lot's of uncertainty / disagreement between hypothesis


INTRUSIVE BRECCIAS AT HICKS DOME
Hardin County, Illinois

J. C. Bradbury and J. W. Baxter

1992
Circular 550

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

Paleomagnetic and $^{40}Ar/^{39}Ar$ Results from the Grant Intrusive Breccia and Comparison to the Permian Downeys Bluff Sill—Evidence for Permian Igneous Activity at Hicks Dome, Southern Illinois Basin

By Richard L. Reynolds, Martin B. Goldhaber, *and* Lawrence W. Snee

EVOLUTION OF SEDIMENTARY BASINS—ILLINOIS BASIN
Jennie L. Ridgley, *Project Coordinator*

U.S. GEOLOGICAL SURVEY BULLETIN 2094–G

A multidisciplinary approach to research studies of sedimentary rocks and their constituents and the evolution of sedimentary basins, both ancient and modern

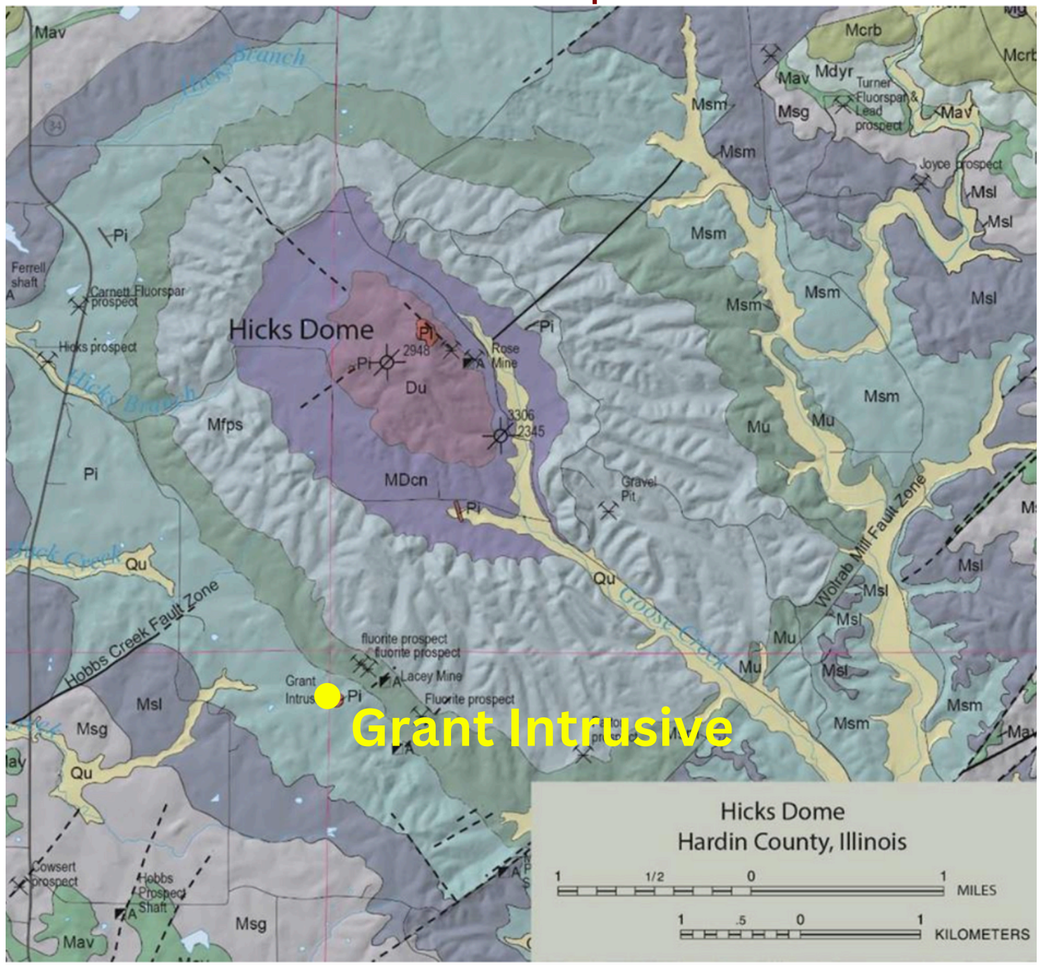
Project Hypothesis

- What are the concentrations of Ti, Ba, Th, and REE's within Grant Intrusive?
    - What are the ore minerals harboring these critical elements of interests?
    - What inferences can we make about ore zone localities within and around the intrusion?

Project Goals

- 1. Identify minerals hosting critical material elements

Crater Explorer

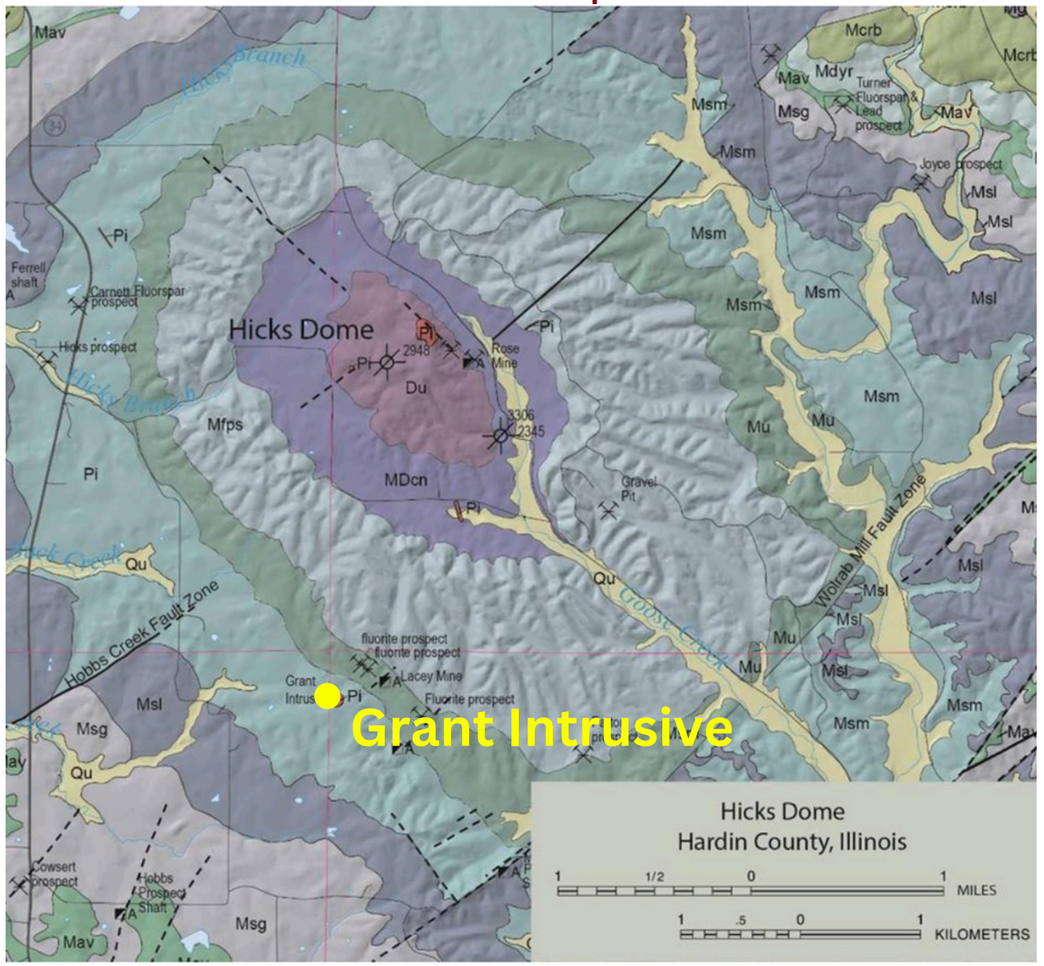


(Charles O'Day)

Project Goals

- 1. Identify minerals hosting critical material elements
- 2. Map igneous bodies within the subsurface

Crater Explorer

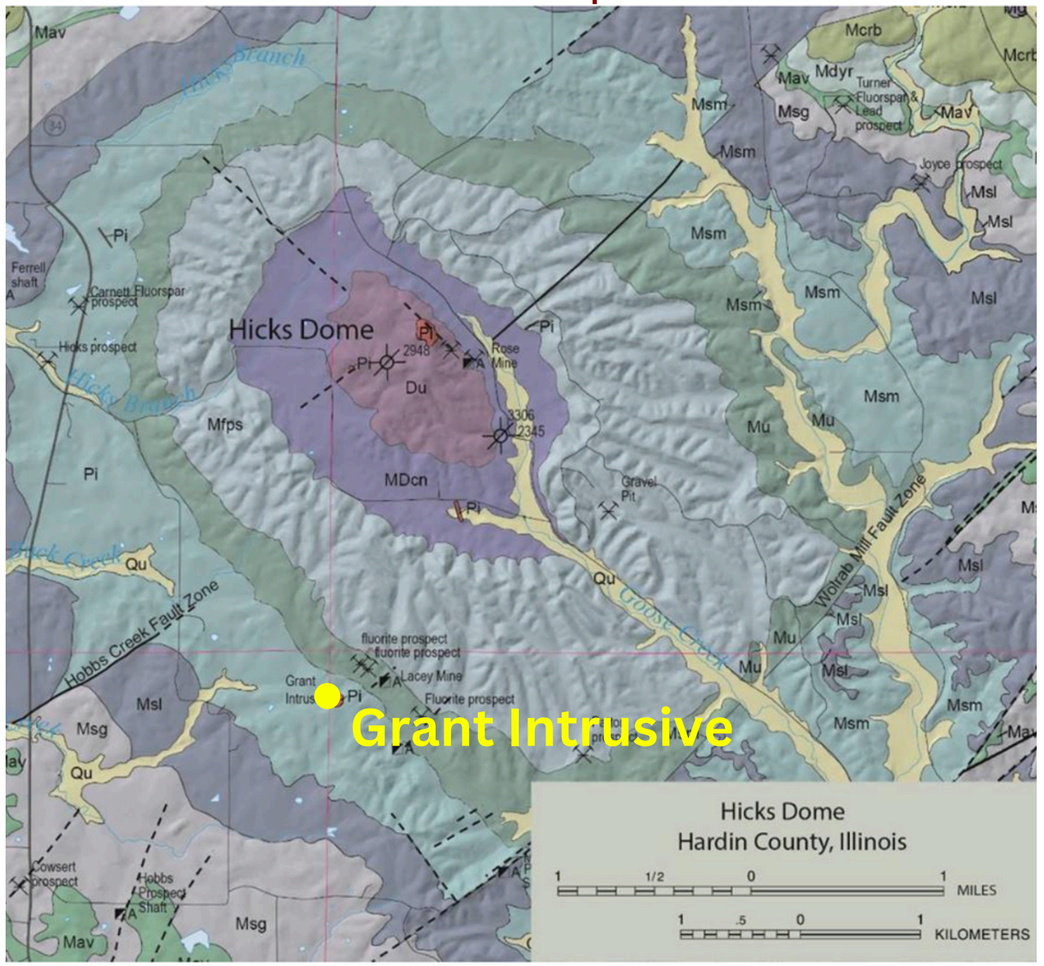


(Charles O'Day)

Project Goals

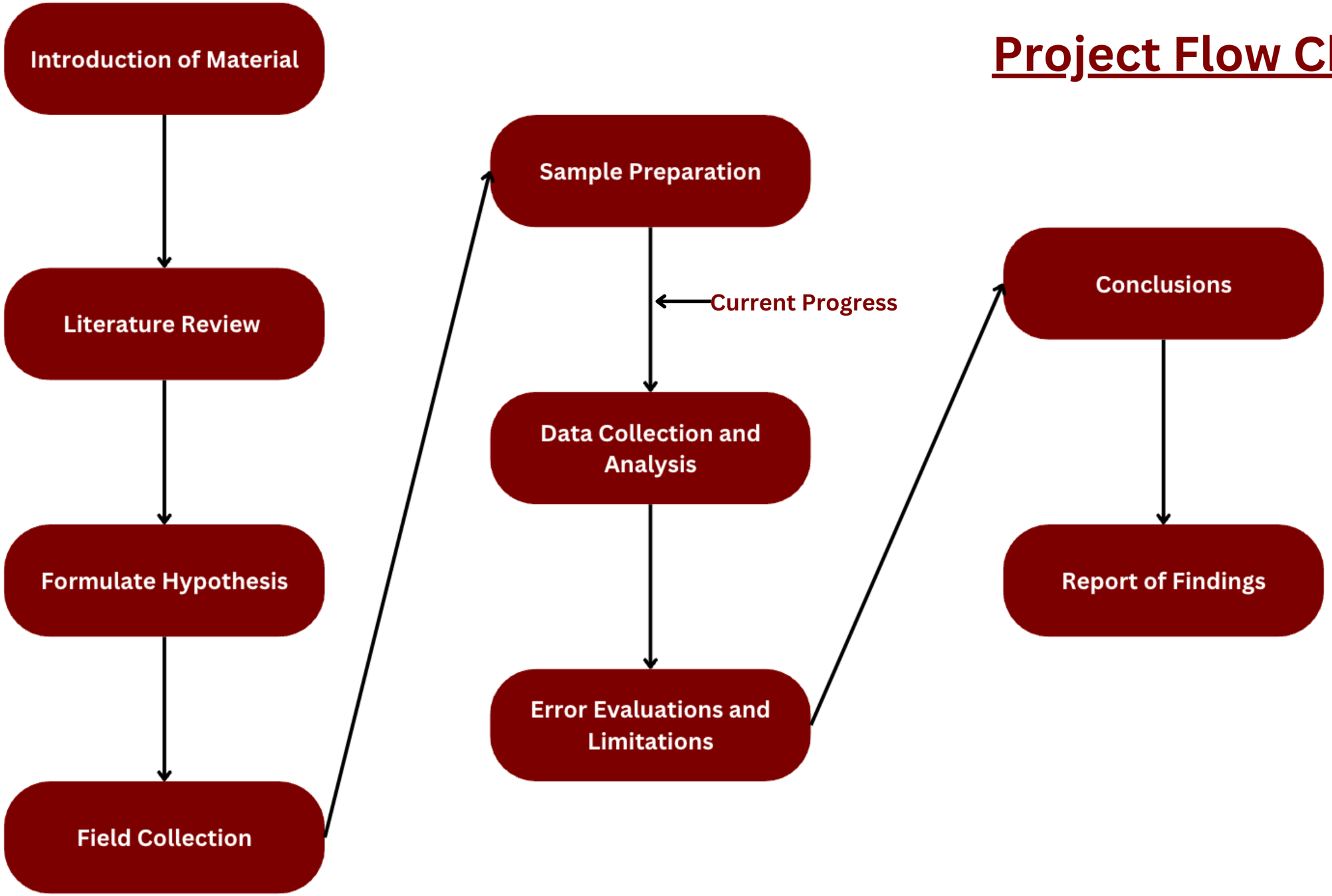
- 1. Identify minerals hosting critical material elements
- 2. Map igneous bodies within the subsurface
- 3. Infer economic ore concentrations

Crater Explorer



(Charles O'Day)

Project Flow Chart

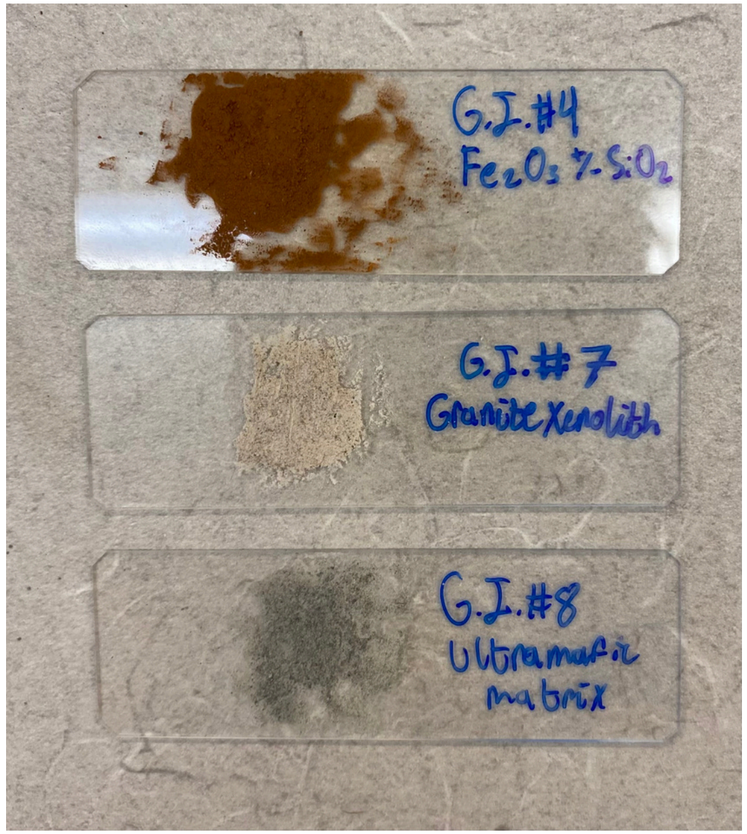


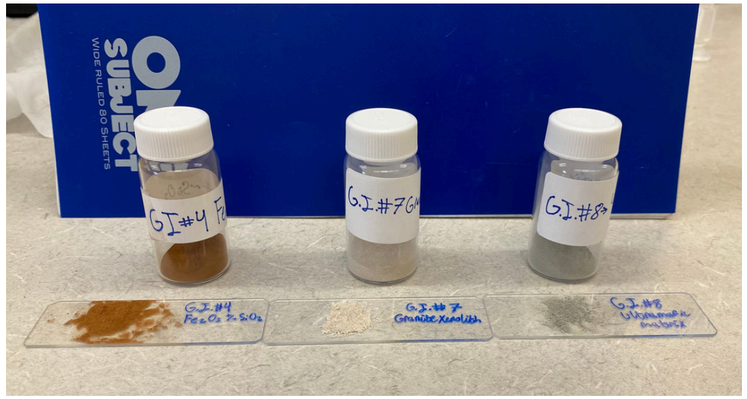
Samples Utilized

G.I. #4 Fe_2O_3 +/- SiO_2

G.I. #7 Granite Xenolith

G.I. #8 Ultramafic Matrix





Rock samples provided by the Illinois State Geological Survey (ISGS)

Methodologies

Current Methods:

- Scanning Electron Microscope (SEM) with Electron Dispersive Spectroscopy (EDS)
  - To identify critical elemets
- X-Ray Diffraction (XRD)
  - To confirm mineral identities

FEI Quanta FEG450 SEM with EDS

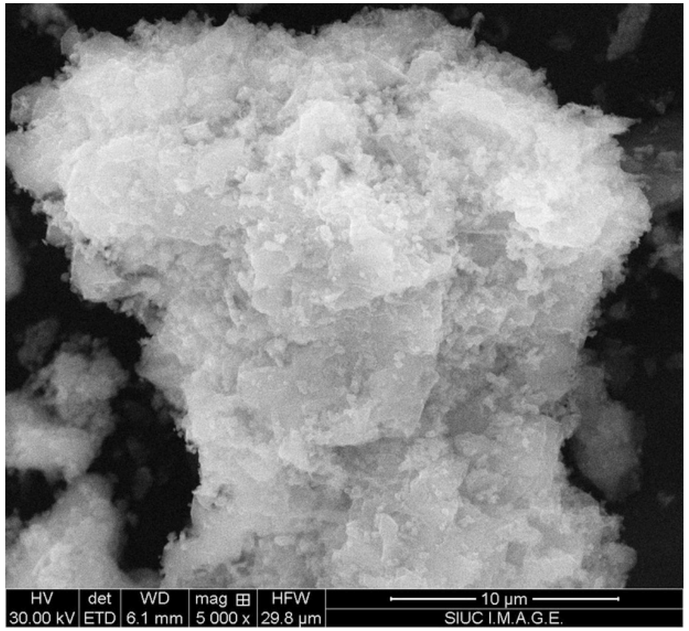
Future Methods:

- Vulcan 3D Modeling Software + Magnetic Anomaly Measurements
  - Model and map ore localities
- X-Ray Fluorescence (XRF)
  - To determine bulk geochemistry and ore grade

Rigaku Ultima 4 XRD

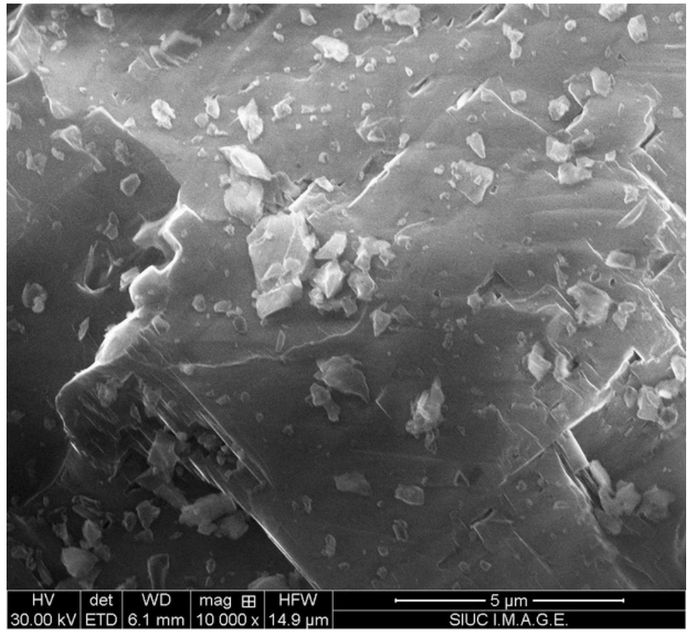
Scanning Electron Microscope (SEM)

G.I. #4 Fe_2O_3 +/- SiO_2



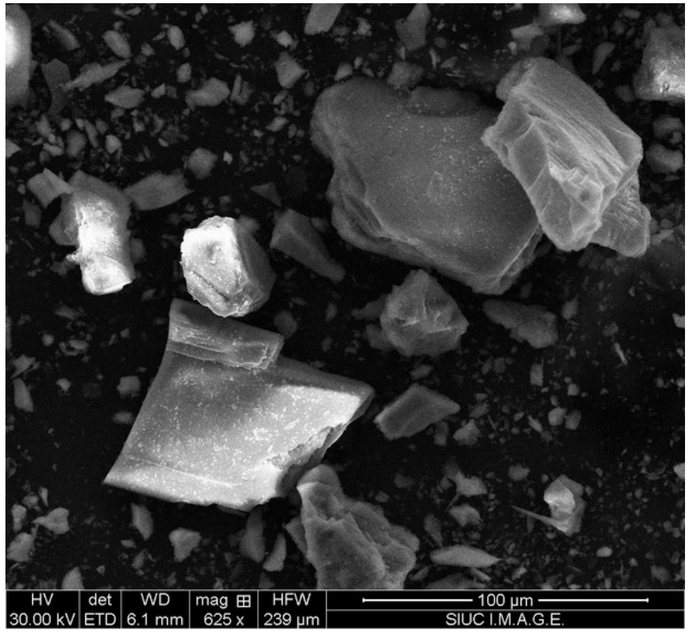
- Gritty and amorphous
- Clay like material

G.I. #7 Granite Xenolith



- Clearly defined orthorhombic cleavage planes
- Most likely plagioclase feldspar

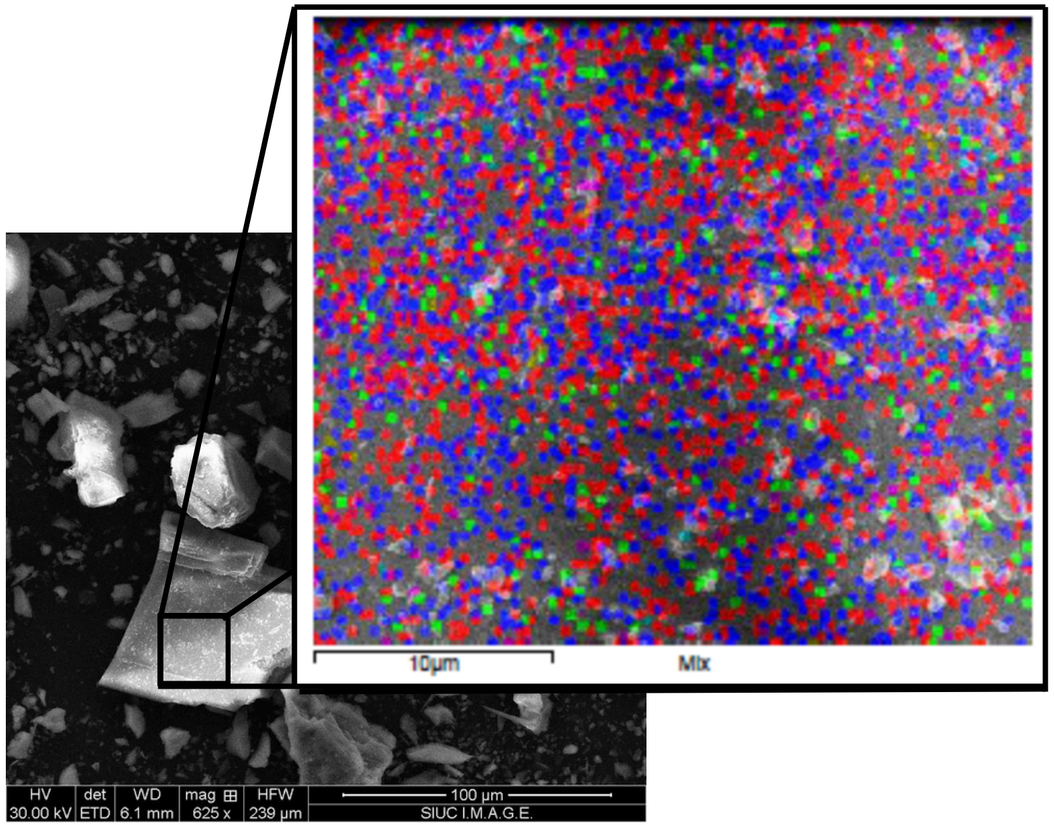
G.I. #8 Ultramafic Matrix



- Platy grains
- Most likely forms of amphibole and / or biotite

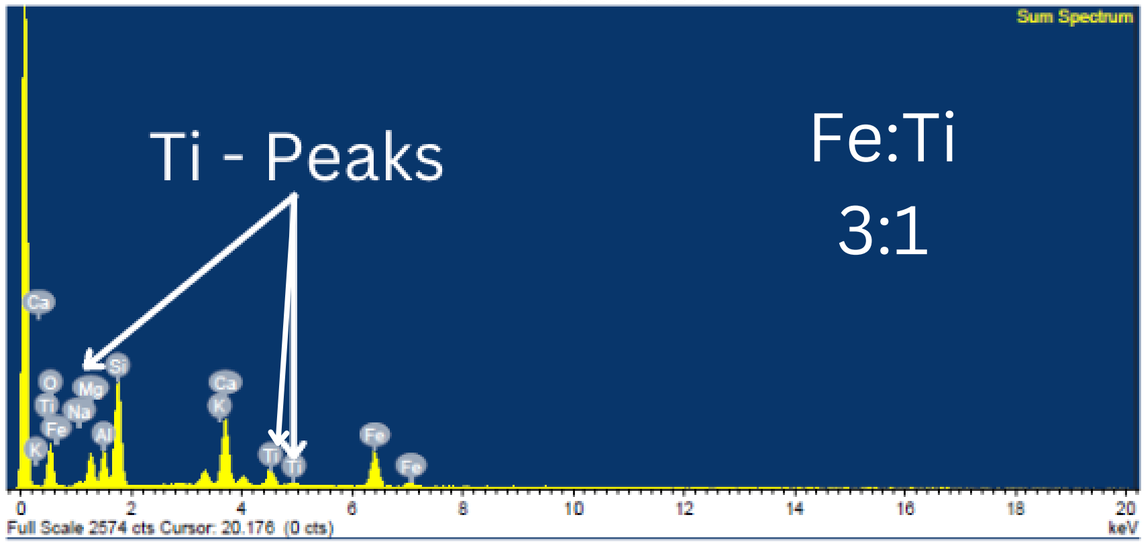
Scanning Electron Microscope with Electron Dispersive Spectroscopy (SEM-EDS)

G.I. #8 Ultramafic Matrix



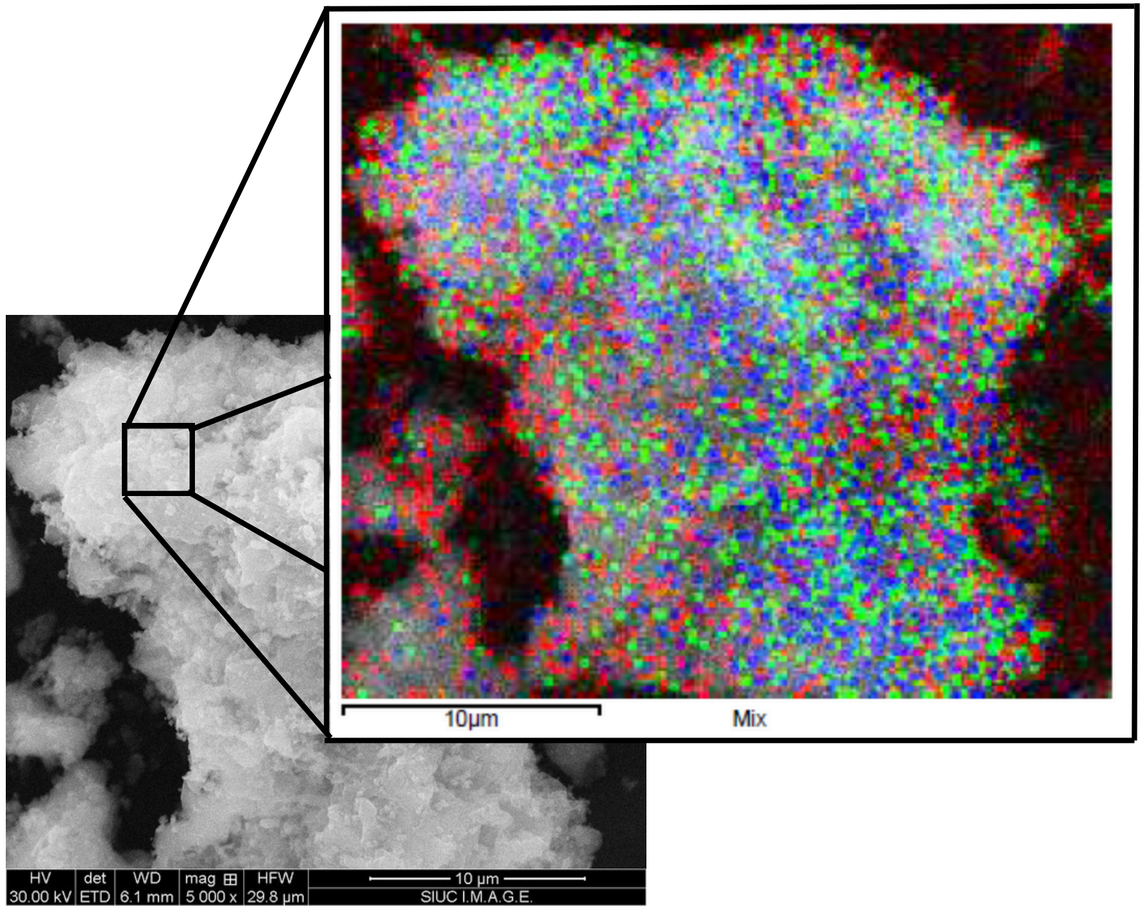
Element	App Conc.	Intensity Corn.	Weig...	Weig... Sigma	Atomi...
O K	78.25	0.5088	47.42	1.24	64.47
Na K	2.20	0.4421	1.54	0.28	1.45
Mg K	10.34	0.4471	7.13	0.35	6.38
Al K	9.46	0.4968	5.87	0.31	4.74
Si K	30.07	0.5600	16.56	0.49	12.82
K K	5.58	0.9573	1.80	0.13	1.00
Ca K	25.63	0.9275	8.52	0.28	4.62
Ti K	6.86	0.7806	2.71	0.16	1.23
Fe K	23.00	0.8386	8.46	0.32	3.29

Total: 100.00



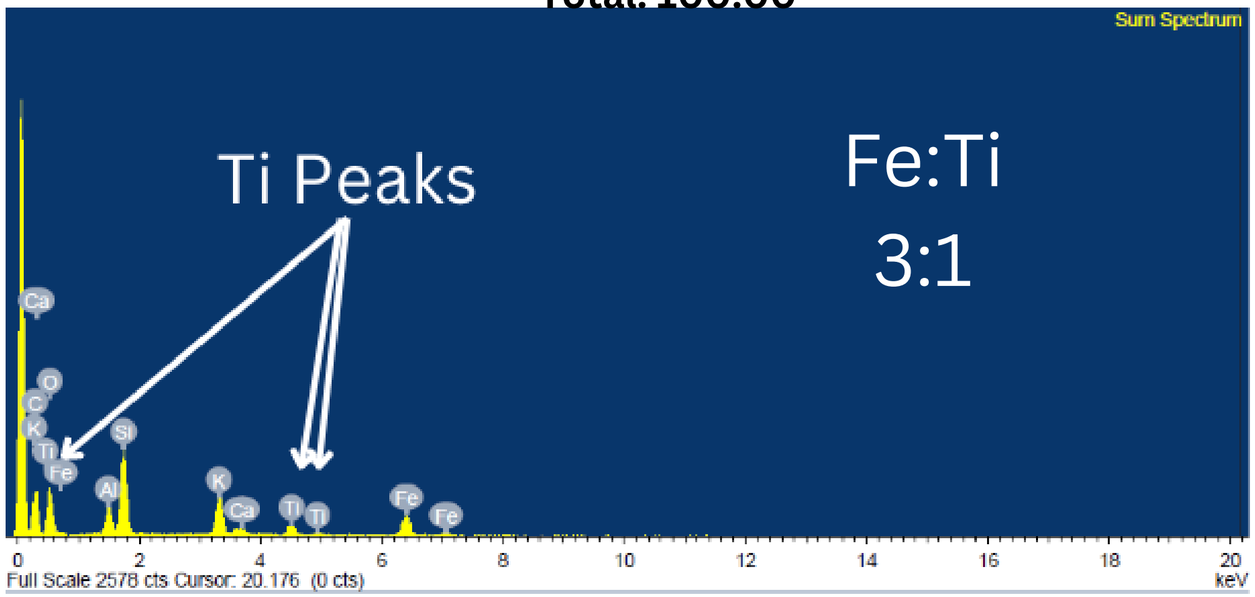
Scanning Electron Microscope with Electron Dispersive Spectroscopy (SEM-EDS)

G.I. #4 Fe_2O_3 +/- SiO_2



Element	App Conc.	Intensity Corrn.	Weig...	Weig... Sigma	Atomi...
C K	242.24	0.6279	46.79	7.14	57.45
O K	114.70	0.3481	39.96	5.45	36.84
Al K	9.91	0.6470	1.86	0.27	1.02
Si K	31.78	0.7426	5.19	0.71	2.73
K K	20.42	1.0484	2.36	0.33	0.89
Ca K	2.62	0.9795	0.32	0.07	0.12
Ti K	6.18	0.8299	0.90	0.14	0.28
Fe K	17.84	0.8286	2.61	0.37	0.69

Total: 100.00

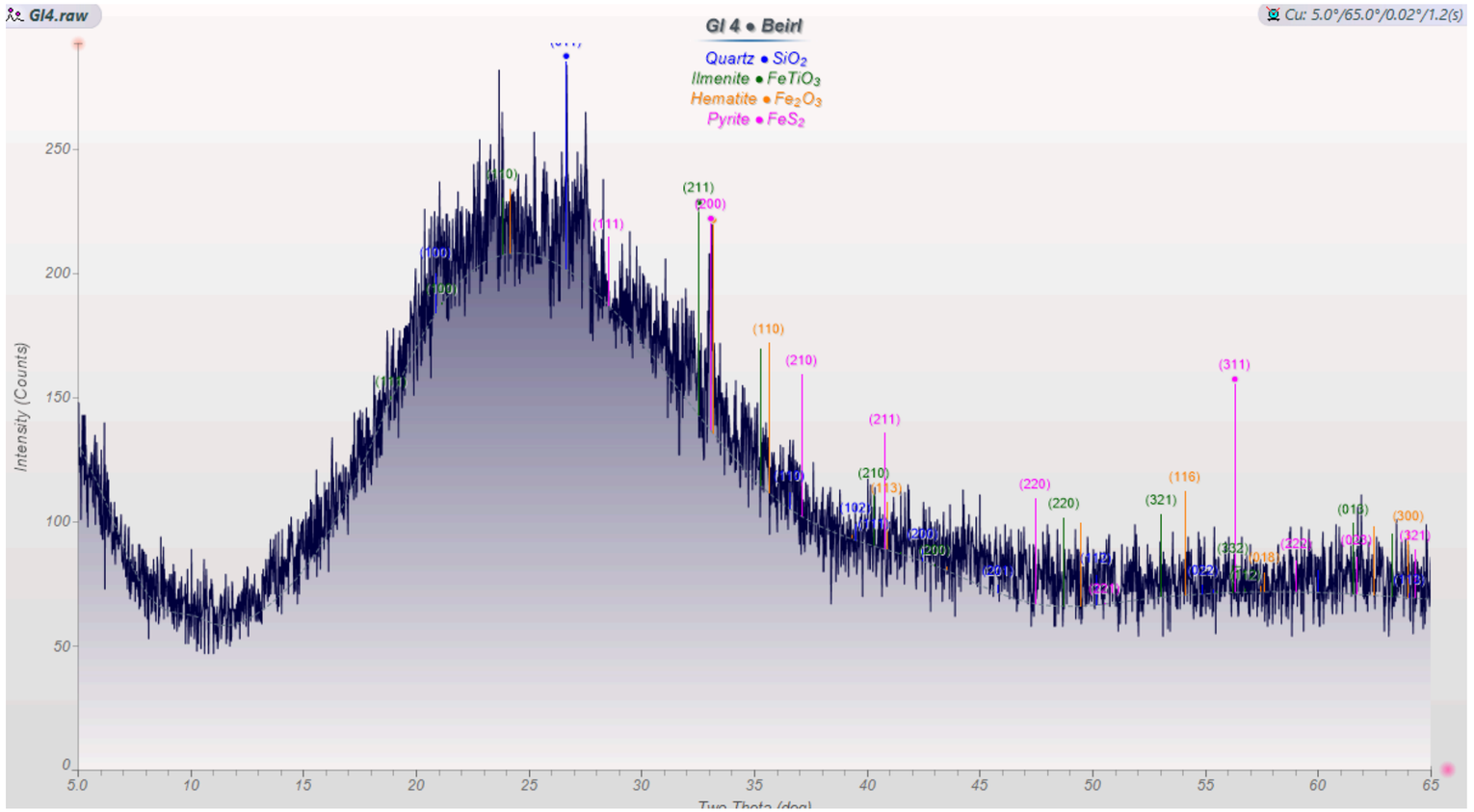


X-Ray Diffraction (XRD)

G.I. #4 Fe_2O_3 +/- SiO_2

Potentially Identified:

- Quartz SiO_2
- Ilmenite $FeTiO_3$
- Hematite Fe_2O_3
- Pyrite FeS_2



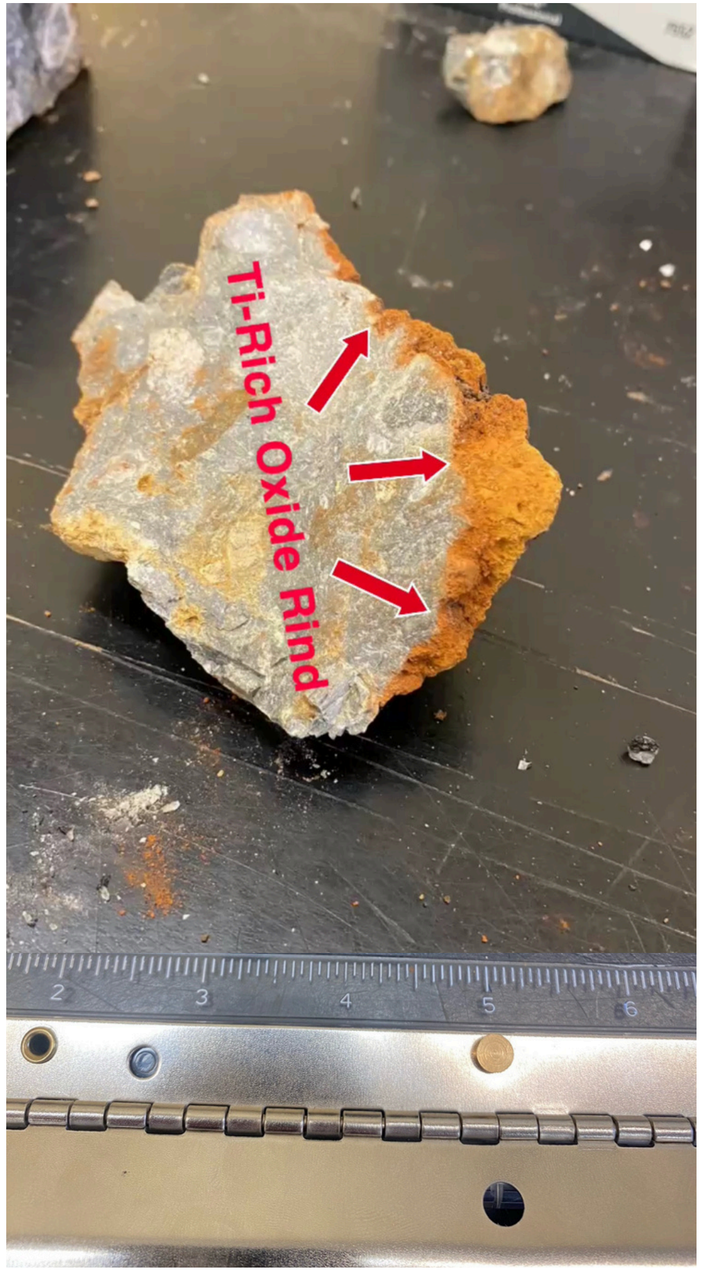
- Lots of amorphous material and background interference
- Low confidence level

Data Processed in MDI Jade ® Software version: 8.9

Results

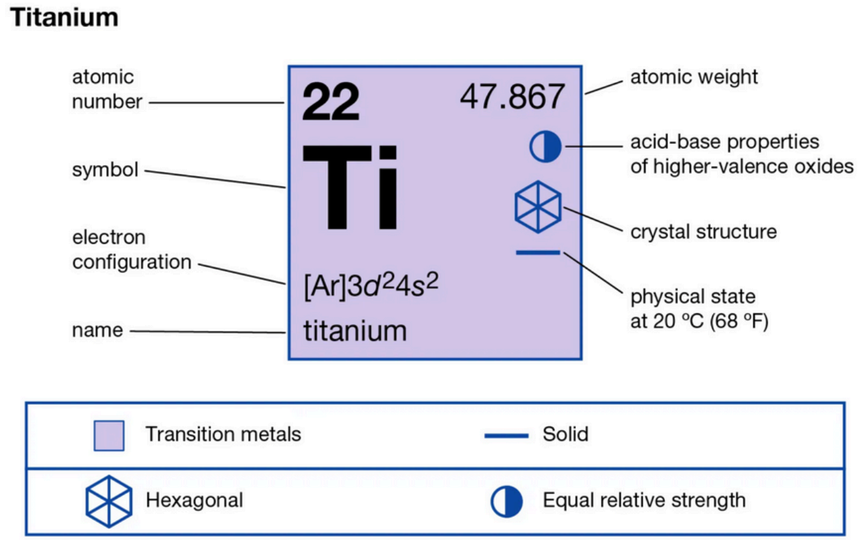
- *Reynolds et. al.'s* petrographic analysis confirmed the presence of magnetite Fe_3O_4 coated with ilmenite $FeTiO_3$
  - Suggested that Ti- saturation occurred after initial magma placement, during rapid cooling

- Our current results indicate Ti-saturation not just in the ultramafic material, but in the weathering rinds as well



Current Conclusions

- Based on the differences in the:
  - magma compositions
  - ages of igneous bodies
  - mineralogical occurrence of Ti



(© Encylcopedædia Britannica, INC)

- Grant Intrusive Is:
  - *Potentially* older than Hicks Dome
  - Formed from more than one enrichment episode
  - Very well preserved
  - A *potentially* economic source for Ti in addition to REE's and other critical metals

References

1. Bradbury, J. C., & Baxter, J. W. (1992). INTRUSIVE BRECCIAS AT HICKS DOME Hardin County, Illinois . file:///Users/aaronbeirl/Downloads/intrusivebreccia550brad.pdf
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Acknowledgments

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- Director of Earth System's and Sustainability: Dr. Justin Schoof
  - Provided up to $500 in funding to present
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