Characterization and Origin of the REE-bearing Magmatic-Hydrothermal Breccia Pipes in the Gallinas Mountains, Lincoln County, New Mexico

Stellah Cherotich[1], Virginia T. McLemore[2]

[1]Department of Mineral Engineering, New Mexico Institute of Mining and Technology,[2]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM 87801 virginia.mclemore@nmt.edu

ABSTRACT

Breccia pipes are a common host of many precious metals, base metal and rare earth elements (REE) mineral deposits because they provide conduits for fluid flow and open spaces for mineral precipitation, hence are a focus area for exploration. The Gallinas Mountains district in Lincoln County, New Mexico produced copper, lead, silver, fluorite, iron, REE (as Bastnäsite) and gold from 1902 to 1980, but no production has been reported from the breccia pipes. However, some magmatic-hydrothermal breccia pipes in the Gallinas Mountains host high concentrations of fluorite-REE and gold. Previous studies have described the occurrence of REE in breccia pipes, but the controls for their transportation and deposition are still unclear. The purpose of this research is to characterize the magmatic-hydrothermal breccia pipes in order to understand the geochemical and physical conditions of deposition of REE and gold in the breccia pipes found in the Gallinas Mountains.

A total of 66 samples were subjected to various analysis. Chemically, the breccia pipes exhibit light REE-enriched chondrite-normalized patterns, some host high concentrations of REE (8% TREE) and Au (175 ppb), carbonates rich hydrothermal fluids and fluorite overprint the breccia pipes causing precipitation and mineralization along the breccia pipes edges.

INTRODUCTION

The rare earth elements (REE) are the 15 lanthanides on the periodic table, plus scandium and yttrium. These elements have the same ionic radius, similar chemical properties and can easily substitute for each other.

There is high demand for REE because of their unique magnetic, phosphorescent, physical and catalytic properties that make them useful, when mixed or alloyed in small quantities with some other commonly available metals, at a reduced overall cost in terms of energy consumption, efficiency, durability, speed, thermal stability hence their wide application (figure 1).

REE are found to occur in various deposits types. These deposits are divided into two classifications, the ones formed initially through the magmatic, hydrothermal and/or metamorphic process listed as primary(for example carbonatites and alkaline igneous rocks emplaced into extensional settings) and the secondary deposits formed through erosion and weathering processes.

Other common target areas for REE explorations are breccia pipes. These vertical pipe-like columns of broken rocks, provide a porous column, which forms conduits and open spaces for minerals precipitation (figure 2).

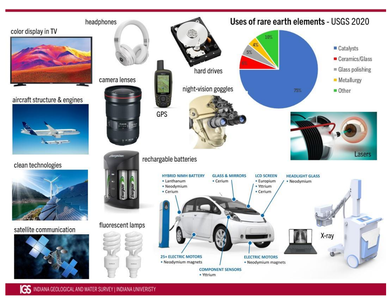

Figure 1: Some applications of REE in various sectors as listed by Clifford,2022.

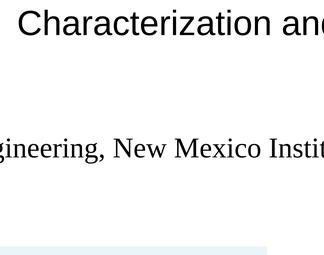

Figure 2: Schematic representation of various breccia pipes and veins (modified from Corbett, 2018). The light green circle shows the location of the breccia pipes studied in this project.

PURPOSE

- Examine the magmatic-hydrothermal breccia pipes in the Gallinas Mountains in order to understand the geochemical and physical conditions of deposition of the REE and gold.
- Evaluate the economic potential for REE and gold.

PROJECT AREA AND GEOLOGY

- The Gallinas Mountains are located in Cibola National Forest, Lincoln County, New Mexico.
- It is one of several mining districts that form part of the North American Cordilleran alkaline-igneous belt extending from Alaska and British Colombia southwards into Mexico (Fig. 3; from McLemore et al., 2021) .
- Production of Cu, Pb, Ag, Au ,F, Fe, and REE's (as bastnäsite) from 1902-1980.

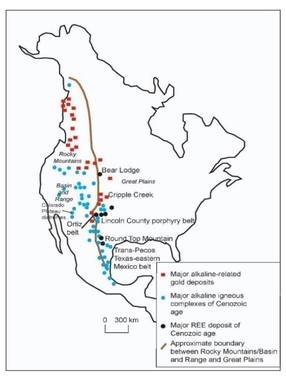

Figure 3: Simplified map showing the extent of the North American-Cordilleran alkaline igneous belt (modified from Mutschler et al., 1991; McLemore, 1996, 2015, 2018).

GEOLOGY

- The oldest rocks in Gallinas Mountains are the altered Proterozoic gneisses and granites. These rocks are overlain by quartz sandstones, shales, arkoses, and limestons of the Abo, Yeso, and the Glorieta, formations (McLemore et al., 2021). A simplified geologic map is in figure 4.
- A northwest-trending fault (Red Cloud fault) divides the area into two areas, west area with approximately 20 exposed magmatic-hydrothermal breccia pipes and veins and the west area with no exposed breccia pipes, only veins.
- The area is further offset by two additional faults, the Conqueror fault and the Pride fault as shown in figure 5.

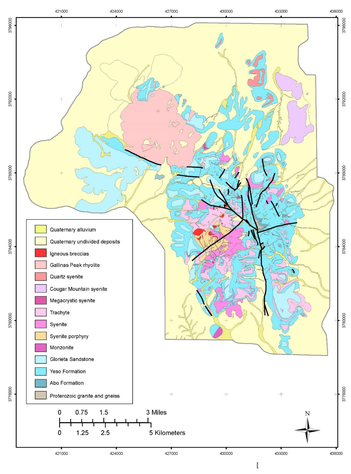

Figure 4: Geologic map of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico based upon new mapping for this study. McLemore et al. (2020), (with incorporation of published maps (Kelley et al., 1946; Kelley, 1949, 1971; Perhac, 1961, 1970; Woodward and Fulp, 1991; 32 Schreiner, 1993). The thick black lines are major faults. The numbers along the edge are UTM units, zone 13, NAD83.

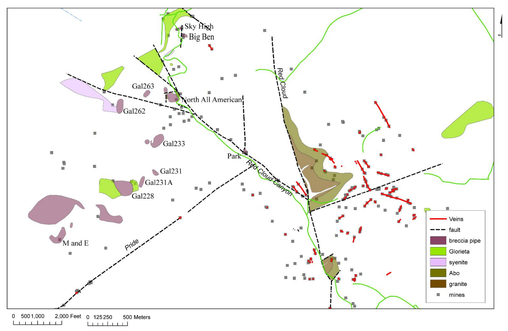

Figure 5: The conqueror and the pride fault, most pipes are north of the Pride fault. The magmatic-hydrothermal breccia pipes are shown as maroon polygons. The breccia pipes form a northeast-trending belt from McLemore et al. (2020).

METHODOLOGY

Petrography, mineralogy, and chemistry analysis were done through;

- Hand description .
- Microscopic examination.
- Chemical analysis.

RESULTS AND DISCUSSION

- Most of the breccia pipes are brown to tan gray in color, matrix supported with fragments of granite, sandstone, limestone, trachyte, and syenite.
- A significant number of these breccia pipes are altered and weathered, consisting of secondary hematite and local calcite, fluorite and quartz.
- Breccia pipes are magmatic and intruded into the host rocks and, subsequently, hydrothermal fluids precipitated fluorite-REE along the edges of some breccia pipes, gold is disseminated in the breccia matrix.
- The breccia pipes are enriched in light REE in chondrite-normalized patterns.
- Some breccia pipes contain as much as 8% total REE and 175 ppb Au.

GEOCHEMISTRY

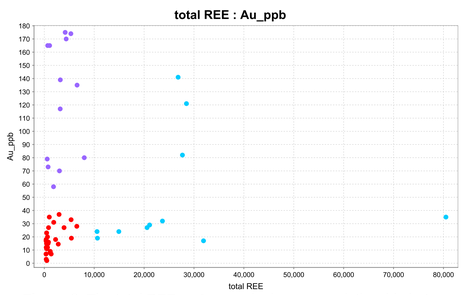

Figure 6: The total REE vs Au graph shows no relationship between the concentrations of Au and REE, samples with high REE concentrations are low in Au and vice versa ,the red circle shows sample with low Au and REE concentration, this are the unmineralized breccia samples.

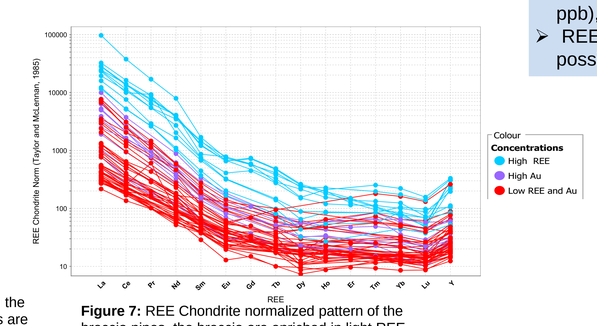

Figure 7: REE Chondrite normalized pattern of the breccia pipes, the breccia are enriched in light REE.

PETROGRAPHIC ANALYSIS

Group 1:Unmineralized, magmatic breccia pipe

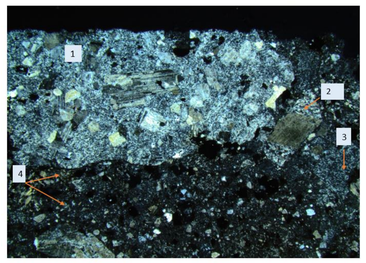

Figure 8: Gal 4909 thin section with Various rock fragments clusters syenite (1), trachyte(2), sandstone (3) and granite (4) cemented by a fine matrix.

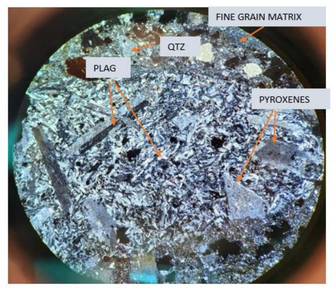

Figure 9: Gal 4909,mineral composition and texture of the unmineralized group one breccia.

Figure 10: Hand sample of Gal 4909.

Group 2: Elevated in gold concentration (50-175 ppb)

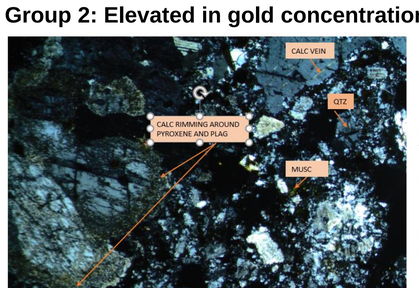

Figure 11: Gal 4903: hydrothermal fluids enter the system and start altering the rock as shown by the rimming on the plagioclase (plag) and pyroxene by calcite (calc) and calcite veins cutting through quartz (qtz) grains, trace amount of muscovite (musc) can be seen along with hematite.

Figure 12: A hand sample of Gal 4901, vugs and veins filled with hematite forms in the fine grain rock fragments that cement the breccia and around the coarse grained rocks.

Group 3: Elevated REE-F (1-8% TREE)

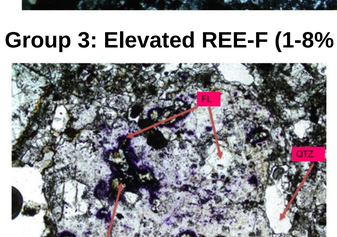

Figure 13: Purple fluorite forming around bastnäsite (bsn) in Gal 4907, bastnäsite formed as inclusion in this sample filled with fluorite (fl) and quartz (qtz), an example of group 3 samples, which are highly altered and contain high concentrations of REE.

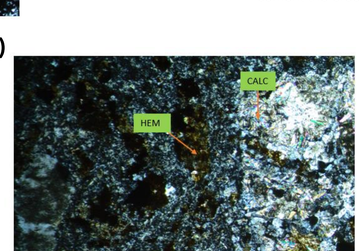

Figure 14: Gal 4911: the sample has been altered and the magmatic minerals have been replaced by calcite (calc), hematite (hem) and REE bearing minerals.

Figure 15: Gal 4911 hand sample with visible fluids pathways/vugs, this sample is filled with hematite and calcite.

Sequence of events at Gallinas Mountain

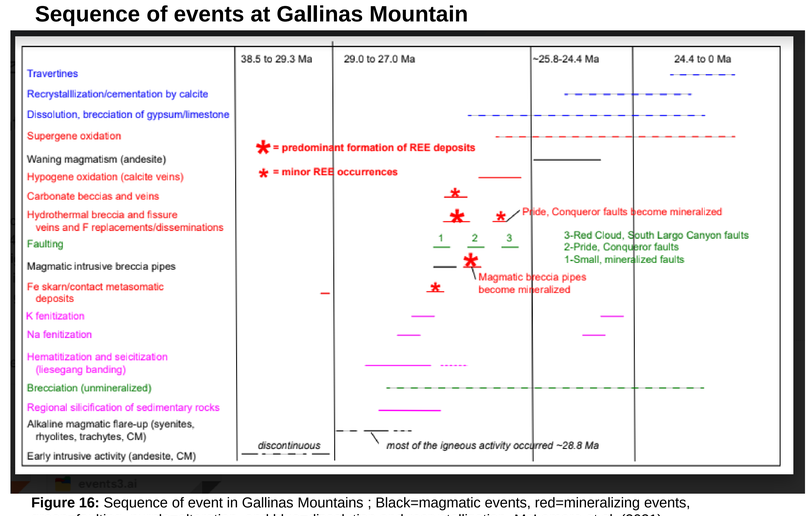

Figure 16: Sequence of event in Gallinas Mountains ; Black=magmatic events, red=mineralizing events, green=faulting, purple=alteration, and blue=dissolution and recrystallization, McLemore et al. (2021).

PRELIMNARY CONCLUSIONS

- The breccia pipe sample can be classified into 3 groups
  - First group is least altered and not mineralized, with original magmatic minerals.
  - The second group is the slightly altered materials which depicts the introduction of hydrothermal fluids into the system, these samples have elevated gold concentrations.
  - The last group is highly altered, highly mineralized, with high concentrations of REE and fluorite samples that contain REE- bearing minerals like bastnäsite and zircon.
- Chemically, the breccia pipes exhibit light REE-enriched chondrite-normalized patterns.
- Some breccia pipes have high REE (8% TREE) and Au (175 ppb), but are not currently economically viable.
- REE is superimposed on breccia pipes--later event, gold possibly primary with the breccia pipe.

ACKNOWLEDGEMENTS

- This study was partially funded by the U.S. Geological Survey Earth MRI (Mapping Resources Initiative) Cooperative Agreement No. G19AC00258, WAIME (SME) and NMGS (New Mexico Geological Society)
- Thanks to my Thesis Committee members, the Bureau economic geology group and Minerals Engineering students for their continuous support and motivation.
- Special gratitude to Russ Schreiner for his prior research in this area which form the basis for this study

REFERENCES

1. Clifford.(2022).Rare Earth Elements. *Indiana Journal of Earth Sciences*, 4: https://igws.indiana.edu/outreach/news/research/REE
2. Corbett, 2018, short course manual, Chapter 4; Breccia, single page 18 (2-18): https://corbettgeology.com/wp-content/uploads/2018/02/Chapter-4-Breccias-single-page18-2-18_-interactive.pdf
3. Kelley, V.C., 1949, Geology and economics of New Mexico iron ore deposits: University of New Mexico, Publications in Geology, no. 2, 246 p.
4. Kelley, V.C., 1971, Geology of the Pecos country, southeastern New Mexico: New Mexico Bureau Mines Mineral Resources, Memoir 24, 75 p.
5. Kelley, V.C., Rothrock, H.E., and Smalley, R.G., 1946, Geology and mineral deposits of the Gallinas district, Lincoln County, New Mexico: U.S. Geological Survey, Strategic Minerals Investigation Preliminary Map 3-211, scale 1:62, 50.
6. Mutschler, F.E., Mooney, T.C., and Johnson, D.C., 1991, Precious metal deposits related to alkaline igneous rocks-a space-time trip through the Cordillera: Mining Engineering, v. 43, p. 304-309.
7. McLemore, V.T., 1991b, Gallinas Mountains mining district, New Mexico: New Mexico Geological Society, Guidebook 42, p. 62-63.
8. McLemore, V.T., 1996, Great Plains Margin (alkalic-related) gold deposits in New Mexico; in Cyner, A.R. and Fahey, P.L. (eds.), Geology and ore deposits of the American Cordillera: Geological Society of Nevada Symposium Proceedings, Reno/Sparks, Nevada, April 1995, p. 935-950.
9. McLemore, V.T., Kelley, S. Zimmerer, M. Owen, E. Haft, E. Cantrell ,T. Gysi, A. Cherotich, S. Trivitt, A, 2021, Geology and Mineral Deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico, Open-file Report 617, 164p., https://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=617
10. Schreiner, R.A., 1993, Mineral investigation of the rare-earth-element-bearing deposits, Red Cloud Mining district, Gallinas Mountains, Lincoln County, New Mexico: U.S. Bureau of Mines, MLA 99-93, 189 p.