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CHARACTERIZATION AND ORIGIN OF THE REE-BEARING MAGMATIC-HYDROTHERMAL BRECCIA PIPES IN THE GALLINAS MOUNTAINS, NM

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ABSTRACT

Breccia pipes are vertical pipe-like columns of rocks that provide conduits for fluid flow and open spaces for mineral precipitation, hence are focus areas for exploration. In the Gallinas Mountains, Lincoln County, New Mexico, there is recorded production of Cu, Pb, Ag, F, Fe, REE (as bastnäsite), and Au from 1902 to 1980, but no production reported from the breccia pipes. Previous studies described the occurrence of REE in breccia pipes, but their transportation and deposition controls are still unclear. The aim 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.

There are more than 20 exposed breccia pipes that form a NE-trending belt about 3–5 kilometers, mostly gray-brown and consist of angular- to sub-rounded rock fragments, some host high concentrations of REE (80,500 ppm total REE) and Au (175 ppb). Preliminary studies suggest they are magmatic and intruded into the host rock and, subsequently, hydrothermal fluids precipitated F-REE and Au along the edges of some breccia pipes. More studies are underway to test this hypothesis.

INTRODUCTION

The rare earth elements (REE) comprise the 15 lanthanides on the periodic table, plus scandium and yttrium. Currently there is a high demand for REE in the USA and over the world because of their wide range of applications as key ingredients in achieving the highly desired clean energy and in the manufacture of high tech products like electric cars. They are listed as critical minerals because of their wide applications and their supply is prone to disruption.

REE can form in a variety of mineral deposits including breccia pipes. These vertical pipe-like columns of broken rocks, provide a porous column, which forms conduits and open spaces for minerals precipitation. Corbett (3) classified breccia pipes into various categories according to their mode of occurrence including dissolution, phreatomagmatic, eruption, dilation, hydrothermal collapse, magmatic hydrothermal injection breccia fluidized and crackle breccia injection (Figure 1).

In the Gallinas Mountains, there are four different types of breccia's including; magmatic intrusive breccia pipes, tectonic fault breccia, brecciated country rock and brecciated hydrothermal vein deposits as described in Table 1 (see APPENDIX). For this paper, we will focus on the magmatic-hydrothermal breccia pipes from the region circled in Figure 1.

Figure 2 below shows the geographic distribution and location of the breccia pipes in the Gallinas Mountains.

PURPOSE

The purpose of this research is to 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 and assess the economic potential for REE and gold**.**

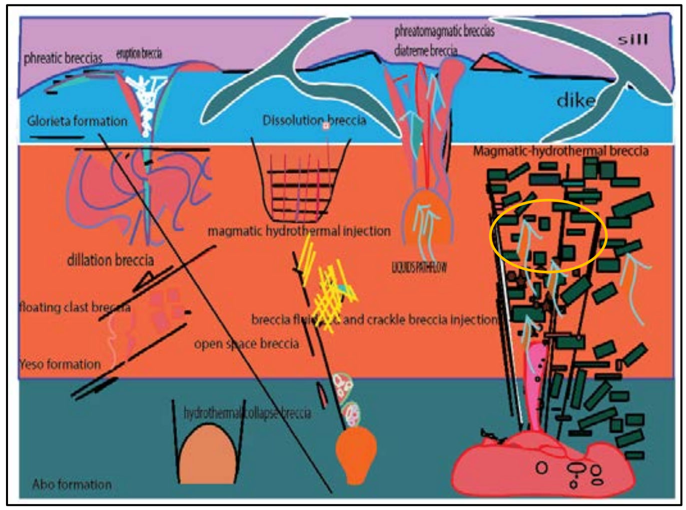


Figure 1. Schematic representation of various breccia pipes and veins (modified from 3). The orange circle shows the location of the breccia pipes studied in this project. These samples are highly fractured and altered.

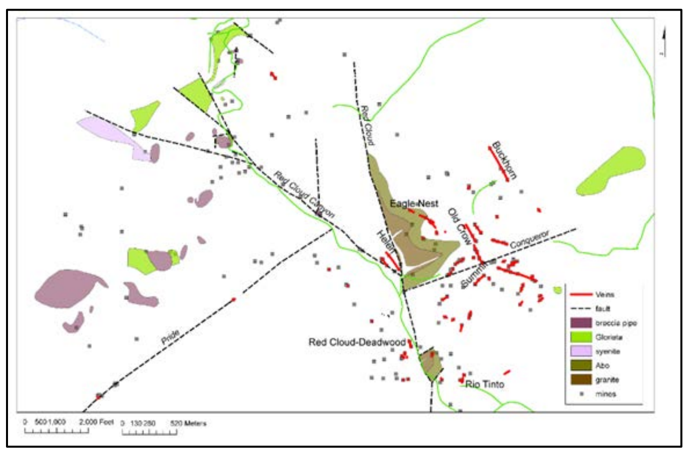


Figure 2. The magmatic-hydrothermal breccia pipes are shown as maroon polygons. Most pipes are north of the Pride fault (15).

LOCATION 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 Eastern New Mexico (Fig. 3; from16).

The Gallinas Mountains district contains hydrothermal REE-fluorite hydrothermal breccia veins hosted in Permian sedimentary rocks and Tertiary trachyte/syenite that are found spatially related to faults, fracture zones, and magmatic-hydrothermal breccia pipes, as shown in Figure 4. The northwest trending Red Cloud fault (normal fault) divides the district into two areas, one that contains over 10 magmatic-hydrothermal breccia pipes, and an area where there are no exposed breccia pipes. The Red Cloud Canyon fault (northwest-trending) and the Pride fault (east-northeast trending) form the fault block that contains the breccia pipes.

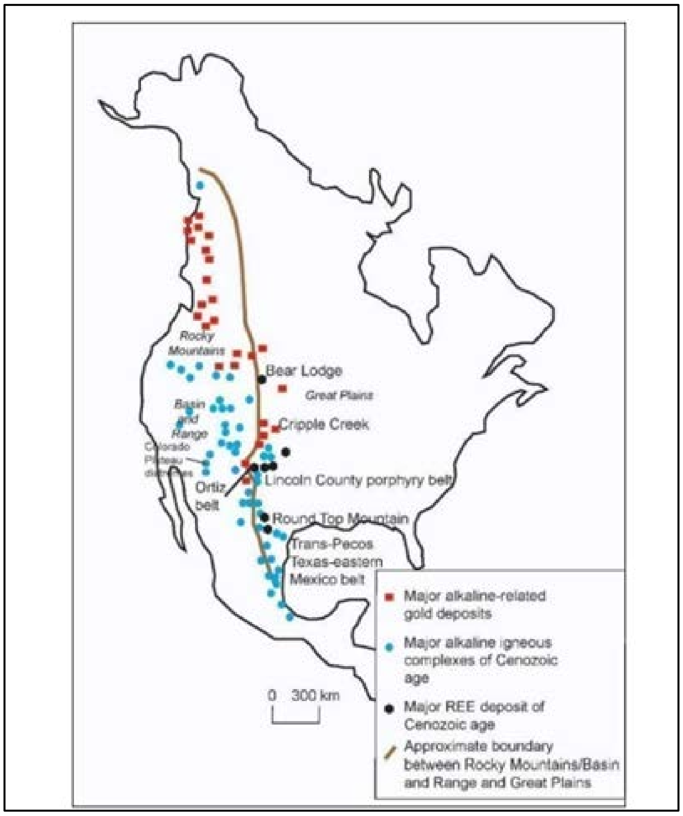


Figure 3. Simplified map showing the extent of the North American Cordilleran alkaline-igneous belt (modified from 9, 11, 15, and 16)

The breccia pipes intrude Permian sedimentary rocks of the Abo, Yeso, and Glorieta Formations and Oligocene trachyte/syenite dikes and sills. The Abo Formation consists of arkosic conglomerates, arkose, siltstone, and shale uncomfortably overlying Proterozoic granite. Unconformably overlying the Abo Formation is the Yeso Formation, which consists of thinly bedded sandstone, siltstone, shale, limestone, and dolomite and is often mottled tan to orange. The Glorieta Formation is a tan to light grey locally cross-bedded quartz sandstone that overlies the Yeso rocks. Up to 75 meters thick, the Glorieta Formation caps many of the mesas and ridges in the district.

METHODS

Methods are described in McLemore (15) and include;

- ✓ Hand description and petrographic analysis
- ✓ Geochemical analysis
- ✓ Electron microscope studies

RESULTS AND DISCUSSION

Most of the breccia pipes are matrix-supported with a groundmass of feldspar and quartz, along with small crystals of other minerals and rock fragments (Fig. 5, 6). Some breccias have a groundmass of hydrothermal minerals such as calcite, fluorite, and barite (Fig. 7). A significant number of these breccia pipes are altered and weathered, consisting of secondary hematite and local calcite, quartz, and fluorite. Some rock fragments are silicified around their edges and other fragments are surrounded and cut by fluorite-REE veins. Fluorite and hematite occurs as halos or near each other throughout these samples. Paragenetically, fluorite precipitated first, overprinting the breccia matrix, followed by hematite.

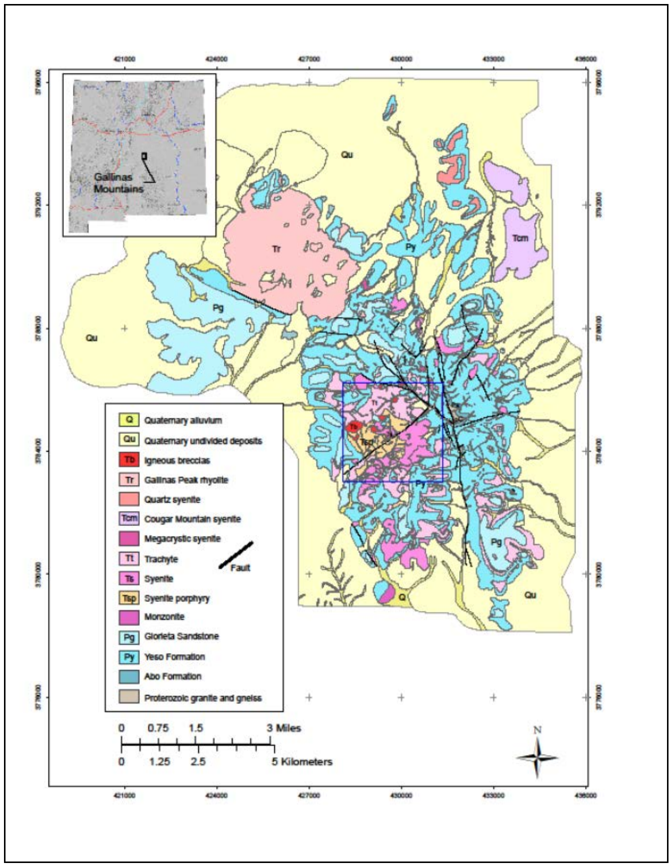


Figure 4. Geologic map of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico based upon new mapping (from 15). The thick black lines are major faults. The numbers along the edge are UTM units, zone 13, NAD83. The blue box is the location of the magmatic-hydrothermal intrusive breccia pipes shown in Figure 2.

Sample GAL3045 has anomalously high concentrations of total REE (80,494.02 ppm) (Fig. 7). The hydrothermal fluorite-bastnäsite veins overprints the breccia pipe matrix. This is an example of later fluids hosted by the porous breccia pipe.

Chemically, the breccia pipes exhibit light REE-enriched chondrite-normalized patterns (Fig. 8). A weak correlation between REE, Au, and base metals with regards to fluorite indicates three different mineralization types (Fig. 8, 9, 10), Type 1 is characterized by low total REE, fluorite, base metals and Au. Type 2 has a positive correction between total REE, Au, fluorite and base metals; this zone has higher concentrations of REE and the other elements. Type 3 has higher concentration of REE and fluorite with a decrease in concentration of base metal and Au. The highest values noted for total REE=80,500 ppm, Au=175 ppb, and Pb+Zn+Cu =7968 ppm.

PRELIMINARY CONCLUSIONS

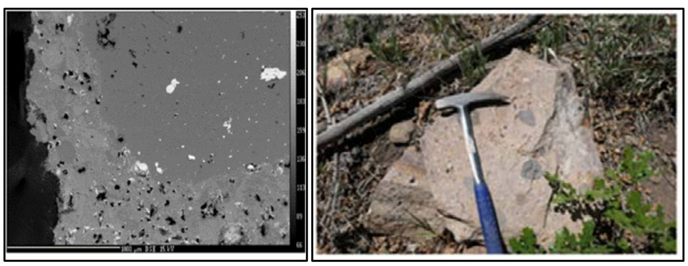
Some breccia pipes have REE-fluorite veins along the edges of the breccia pipes, overprinting the matrix.

There are 3 different mineralization types in this breccia pipes that require further analysis.

The breccia pipes can host significant amounts of REE. Au is mostly in the matrix and has a weak correlation between REE and Au.

Most breccia pipes are uneconomic, but can host later economic concentrations of REE.

Figure 5. Hematite altered breccia pipe with matrix supported breccia fragments (GAL370).



a) b)

Figure 6a & 6b. Back scattered electron photomicrograph of a typical matrix from magmatic intrusive breccia pipe showing K-spar replacing albite (K-fenitization). The fine-grained matrix consists of primary albite (GAL252-01) with a field photo.

Figure 7. Hydrothermal hematite-fluorite-calcite breccia showing euhedral purple cubes of fluorite and hematite pseudomorphs after pyrite (GAL3044C).

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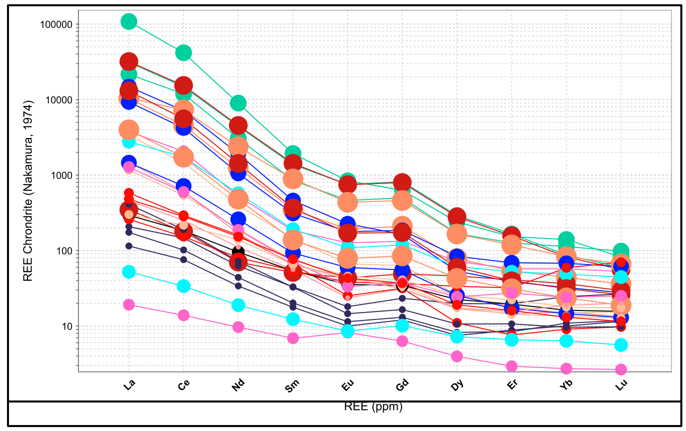

Figure 8. Chondrite-normalized REE (16), some breccia pipes are enriched in light rare earth elements.

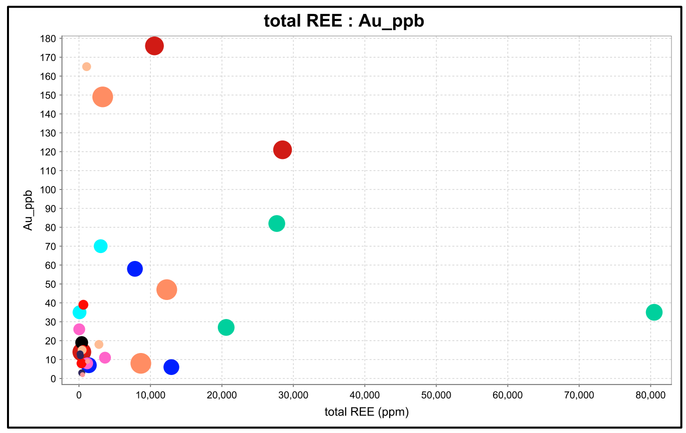

Figure 9. There is no distinct relationship between total REE, fluorite and Au in their distribution and occurrence as shown in this plot.

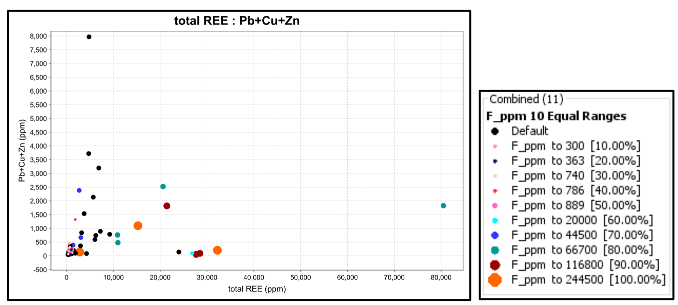

Figure 10. A scatter plot of the base metals and total REE shows three different types of F-REE mineralization.

REFERENCES

1. Allen, M.S. and Foord, E.E., 1991, Geological, geochemical and isotopic characteristics of the Lincoln County porphyry belt, New Mexico: implications for regional tectonics and mineral deposits: New Mexico Geological Society, Guidebook 42, p. 97-113.

2. Berger, V.I., Singer, D.A., and Orris, G.J., 2009, Carbonatites of the world, explored deposits of Nb and REE; database and grade and tonnage models: U.S. Geological Survey Open-File Report 2009-1139, 17 p. and database.

3. 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

4. File, L., and Northrop, S.A., 1966, County Township, and range locations of New Mexico's mining districts: New Mexico Bureau of Mines and Mineral Resources, Circular 84, 66 p.

5. Kelley, K.D. and Spry, P.G., 2016, Critical Elements in Alkaline Igneous Rock-Related Epithermal Gold Deposits: Chapter 9 In Rare Earth and Critical Elements in Ore Deposits;

6. Kelley, V.C., 1949, Geology and economics of New Mexico iron ore deposits: University of New Mexico, Publications in Geology, no. 2, 246 p.

7. Kelley, V.C., 1971, Geology of the Pecos country, southeastern New Mexico: New Mexico Bureau Mines Mineral Resources, Memoir 24, 75 p.

8. 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.

9. 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.

10. McLemore, V.T., 1991b, Gallinas Mountains mining district, New Mexico: New Mexico Geological Society, Guidebook 42, p. 62-63.

11. 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.

12. McLemore, Virginia T., 2010a, Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance counties, New Mexico: Preliminary report, New Mexico Bureau of Geology Mineral Resources, Open-file Report.

13. McLemore, V.T., 2010b, Use of the New Mexico Mines Database and ArcMap in Uranium Reclamation Studies: Society of Mining, Metallurgy and Exploration Annual Convention, Phoenix, Feb 2010, Preprint 10-125

14. McLemore, V.T., 2011, Rare earth elements for emerging technologies: New Mexico Earth Matters,summer,4p. http://geoinfo.nmt.edu/publications/periodicals/earthmatters/11/EM11n2.pdf

15. McLemore, V.T., 2015a, Mineral deposits associated with Tertiary alkaline igneous rocks in New Mexico: Society for Mining, Metallurgy, and Exploration, 2015 Annual meeting preprint, 13 p.

16. McLemore, V.T., 2018, Rare Earth Elements (REE) Deposits Associated with Great Plain Margin Deposits (Alkaline-Related), Southwestern United States and Eastern Mexico: Resources,7(1),8;44p.,doi:10.3390/resources7010008; http://www.mdpi.com/2079-9276/7/1/8 link http://www.mdpi.com/2079-9276/7/1/8

17. McLemore, V.T., Kelley, S., Zimmerer, M.J., Owen, E., Haft, E., Cantrell, T., Gysi, A., Haley, D., Cherotich, S., and Trivett, A., 2021, Geology and mineral resources of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico: New Mexico Bureau of Geology and Minerals Resources, Open-file Report 617, 164 p., https://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=617

18. Nakamura, N., 1974, Determination of REE, Ba, Fe, Mg, Na and K in carbonaceous and ordinary chondrites: Geochemical et Cosmochemical Acta, v. 38, p. 757-775.

19. Perhac, R.M., 1961, Geology and mineral deposits of the Gallinas Mountains, New Mexico: Unpublished Ph.D. thesis, Ann Arbor, University of Michigan, 224 p.

20. Sillitoe, R.H. 1985, Ore-related breccia's in volcano plutonic arcs: Economic Geology, v. 80, p. 1467-1515.

APPENDIX

Table 1. Classification and descriptions of various breccia pipes found in Gallinas Mountain (from 15).

Breccia type	Geometry/Dimensions	Clast/Matrix/Cement types	Features	Distributions	Crosscutting relationship
Magmatic-hydrothermal intrusive breccia pipes	The contacts are mostly concealed, but the pipes appear to be roughly elliptical to circular in geometry	Mostly matrix-supported with a groundmass of feldspar and quartz, along with small crystals of other minerals and fragments with few partially clast supported	Are gray to brown and consist of angular to sub rounded fragments of granite, granitic gneiss, sandstone, shale, limestone, trachyte, and syenite that are as much as 1 m in diameter	Intrude the Yeso Formation, Glorieta Sandstone, trachyte, and syenite units, forming a northeast-trending belt, approximately 3–5 kilometers long in a fault block northwest of the Pride fault	Many of the igneous breccia pipes in Pinatosa Canyon and along Rattlesnake Ridge were emplaced along the margins of syenite intrusions
Tectonic fault breccia	Linear along faults	They are clast supported with multiple lithologies and large blocks of host lithologies with a matrix of rock flour	There is no mineralization except minor calcite or quartz and no fluorite or fenitization present. Slickensides are common.	They are structurally controlled and found along major faults s (i.e. Red Cloud Canyon and South Largo Canyon faults)	Youngest crosscutting older rocks
Brecciated country rock	Irregular contact zones at the intrusive contacts of breccia pipes and trachyte/syenite	Matrix supported	The fragments are irregular in shape and cemented by quartz, amorphous silica, and hematite.	Yeso and Glorieta sandstones are brecciated and recemented by silica cement adjacent to the igneous dikes, sills, and intrusive breccia deposits	Veins of fine calcite and hematite busticate the original cement of the host rock
Brecciated hydrothermal vein deposits	linear, veins and fillings along faults and fractures zones	cemented by fluorite	Fluorite, barite, and quartz are the major minerals in these deposits. Early barite and fluorite, followed by bastnäsite are typically brecciated, broken and partially replaced by other minerals. These veins deposits account for all of the Cu, Pb, Zn, Ag, Au, fluorite, and bastnäsite production in the Gallinas Mountains	Locally found at the intersections of minor faults and fracture zones.	These are thin banded veins, or veinlets in sandstone, limestone, syenite, and trachyte controlled by minor faults, fractures, and bedding planes