CONTROLS OF REE MINERAL DEPOSITS IN THE GALLINAS MOUNTAINS (GALLINAS DISTRICT), CENTRAL NEW MEXICO, USA

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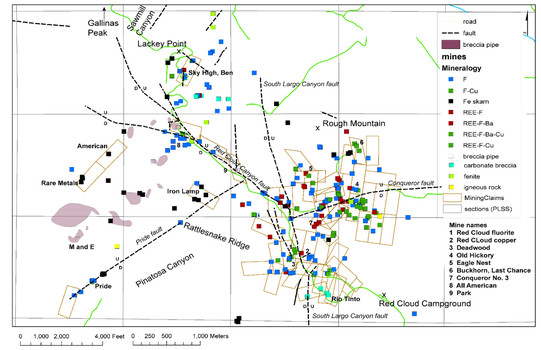
ABSTRACT

Many rare earth elements (REE) deposits are found in North American Cordilleran igneous belt, a zone of Cenozoic alkaline igneous rocks and associated mineral deposits that extends from Canada, western U.S., including New Mexico, and into eastern Mexico. This zone has been explored and exploited for numerous types of mineral deposits. The Gallinas Mountains is one such district with established REE potential, where a small amount of bastnäsite was recovered during fluorite processing from 1954-1956 and 1980. In addition, Pb, Cu, Zn, Ag, Au, and Fe have been produced. Host rocks include Proterozoic granite and gneiss, overlain by Permian sedimentary rocks that are intruded by 38.5-24.4 Ma rhyolite, trachyte, and syenite laccoliths, sills and dikes. Seven types of mineral deposits are found in the district, distinguished by mineralogy, chemistry, form, and host rocks: (1) Fe skarn-contact replacement deposits, (2) hydrothermal breccia and fissure veins, (3) F replacements/disseminations, (4) magmatic, intrusive breccia pipes, (5) carbonate breccias, (6) hypogene oxidation, and (7) supergene oxidation. The hydrothermal breccia and fissure veins are controlled by minor faults, fractures and bedding planes, and subdivided according to mineralogy and chemistry. The intrusive breccia pipes form a 2 km-NE-trending belt and locally host REE-F and F veins and anomalously high Au (<222 ppb). Fe skarn-contact replacement deposits consist of hematite and magnetite, with local elevated REE, replacing limestone and sandstone. Carbonate breccias/veins are found near limestone and gypsum beds and many contain F, local Au (<178 ppb), and variable amounts of REE. Different alteration styles are associated with the intrusions and mineral deposits. The origin of the mineralizing fluids is uncertain but geochemical analyses, mineralogy, texture, and field relationships are consistent with previous conclusions that the REE deposits are derived from magmatic-hydrothermal fluids from either an alkaline magma, such as the trachyte and syenite exposed in the area or from a deep-seated, **buried** carbonatite. New mapping reveals that many of the magmatic intrusive breccia pipes were emplaced along the margins of syenite intrusions, suggesting a connection between fluids associated with the intrusions and breccia pipe formation.

CONTROLS OF MINERAL DEPOSITS IN THE GALLINAS MOUNTAINS

Type of Mineral Deposit	Mineralogy	Form	Host rocks	Comments
Iron (Fe) skarn and contact-metasomatic deposits (including iron veins)	Hematite, magnetite, calcite, with local fluorite, amphiboles, K-feldspar, and bastnäsite	Replacement bodies and hematite veins near the contact with trachyte or syenite sills and laccoliths	limestone, sandstone, syenite, trachyte, rhyolite	Accounts for all of the iron production. Locally contains elevated REE
Hydrothermal breccia and fissure veins	Purple fluorite and pink to white barite with numerous additional minerals, including local bastnäsite	Purple breccia veins with granite, sandstone, limestone, syenite, and trachyte clasts. Along fractures and minor faults, with thin (<1 cm wide) banded veins or veinlets cutting the breccia. Entire mineralized zone can be up to 18 m wide	Sandstone, limestone, trachyte, syenite, granite	Fluorite cements the breccia, with local fissure veins along fractures and cutting the breccia. Accounts for all of the Cu, Ag, Pb, Zn, F, and REE production
Fluorite replacements/ disseminations	Fluorite	Disseminated, replacements, and thin veinlets (<mm wide) of fluorite, with few additional minerals	Sandstone, trachyte, syenite, granite	Many are near hydrothermal breccia and fissure veins, and trachyte dikes
Intrusive breccia pipes (Au-rich, hydrothermal breccia pipes vs non-mineralized pipes)	Local disseminated fluorite and veins of REE-F, F and Au in magmatic breccia.	Elliptical pipe-like magmatic, intrusive bodies in a NE-trending belt (approximately 2 km long)	Intruded sandstone and trachyte	Matrix-supported and consist of angular to subrounded fragments
Carbonate breccias and veins (high REE and low REE)	Calcite breccias and veins with additional minerals	Near trachyte and syenite intrusive contacts with limestone, gypsum and limey sandstone. Many contain F, local Au, and variable REE	Limestone, gypsum, limey sandstone	Some carbonate breccias are overprinted by travertine (i.e. spring) deposits
Hypogene oxidation	Oxidation of primary minerals, generally sulfides			Primarily late stage oxidation of late hydrothermal fluids
Supergene oxidation	Oxidation of primary minerals, generally sulfides			Primarily weathering of the mineral deposits

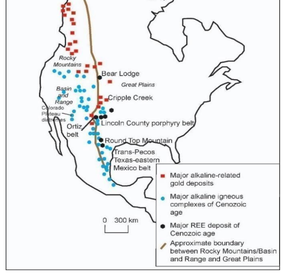


- Measurements of bedding in the Gallinas Mountains is consistent with doming resulting from a concealed, subsurface intrusion
- Doming is also caused by the intrusion of sills and laccoliths
- Major faults are not mineralized with the exception of the Pride, Conqueror and Buckhorn faults
- The Pride and Conqueror faults are normal faults and are mineralized, although none of these deposits have any production

PURPOSE

- Compile and interpret available published and unpublished data from the Gallinas Mountains
- Deliver a new 1:24,000-scale geologic map and present detailed map sections of mineralized and altered areas
- Describe the geochemistry, geochronology, mineral-resource potential, and origin of the mineral deposits and alteration in the Gallinas Mountains
- Relate the Gallinas Mountains district to other REE mineral deposits in New Mexico and elsewhere

INTRODUCTION

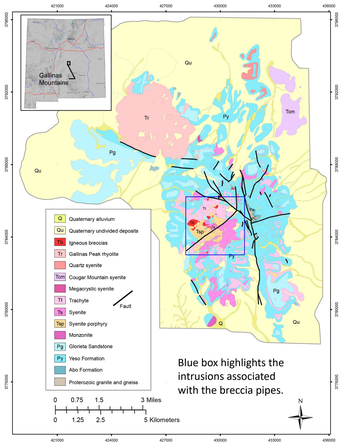


Tertiary alkaline igneous-related REE deposits in New Mexico

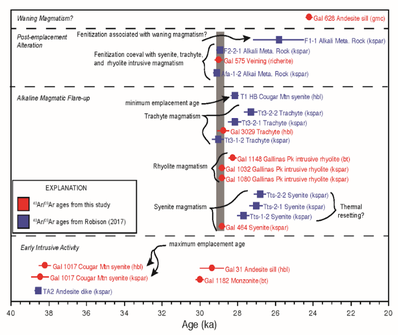
- Part of a belt of alkaline-igneous rocks
- Extends along the eastern edge of the Rocky Mountains and Basin and Range Provinces
- From Alaska and British Columbia southward into New Mexico, Trans-Pecos Texas, and Eastern Mexico
- These alkaline rocks contain relatively large quantities of important commodities such as, gold, fluorine, zirconium, rare earth elements (REE), tellurium, gallium, and other critical minerals

Extent of the North American Cordilleran alkaline-igneous belt (Woolley, 1987; Mutschler et al., 1991; McLemore, 1996, 2018).

GEOLOGIC SETTING



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

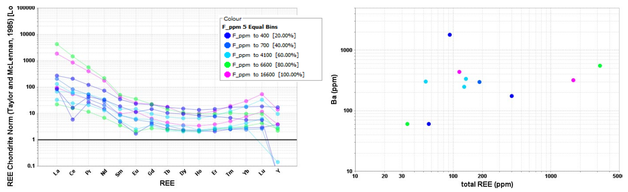


Argon dating results

- Early magmatic activity (38.5 to 29.3 Ma)
- Alkaline intrusive flare-up (28.8 to 28.0 Ma)
- Alteration and implied younger intrusions (25.8 to 24.4 Ma)

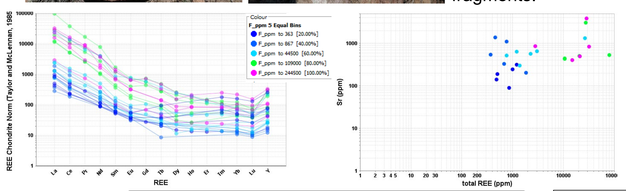
Fe skarn-contact metasomatic replacement deposits

Left—Iron skarn at the American mine (NMLI0003). Right—Iron vein cutting trachyte at the American mine (Gal102c).



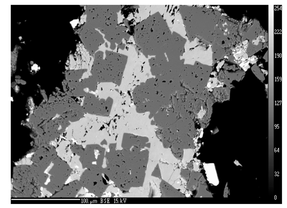
Magmatic intrusive breccia pipes (Tibx)

Magmatic intrusive breccia pipes (Tibx) on Rattlesnake Ridge (left Gal228c, right Gal231a). Note the different breccia fragments.

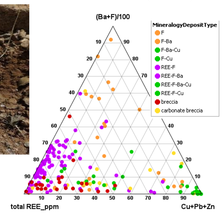


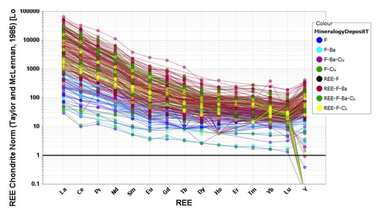
Hydrothermal breccia and fissure vein deposits (Tv)

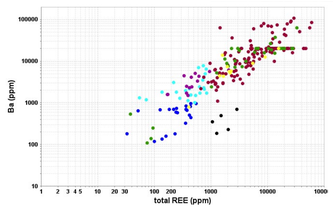
Mineralogy Deposit Type	Predominant mineralogy	Chemistry
F	Mostly fluorite of varying amounts with little or no other hydrothermal minerals	Presence of fluorite
F-Ba	Predominantly fluorite and barite, locally significant calcite	>1000 ppm Ba
F-Ba-Cu	Predominantly fluorite with significant barite and copper oxides, other sulfide and carbonate minerals may be present	>1000 ppm Ba, >1000 ppm Cu
F-Cu	Predominantly fluorite with significant copper minerals	>1000 ppm Cu
REE-F	Predominantly fluorite with REE minerals	>1000 ppm total REE
REE-F-Ba	Predominantly fluorite with REE minerals and barite	>1000 ppm Ba, >1000 ppm total REE
REE-F-Ba-Cu	Predominantly fluorite with REE minerals and barite and copper minerals	>1000 ppm Ba, >1000 ppm Cu, >1000 ppm total REE
REE-F-Cu	Predominantly fluorite with REE minerals and copper minerals, other sulfide and carbonate minerals may be present	>1000 ppm Cu, >1000 ppm total REE

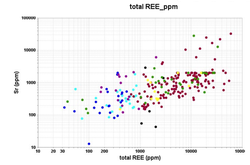


Fluorite (gray cubes) intergrown with strontianite (white). Bright white rectangles are bastnäsite (Gal7).









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MINERAL-RESOURCE POTENTIAL

- Most exposed outcrops of hydrothermal breccia and fissure veins in the Gallinas Mountains appear small, although samples as high as 8% total REE are found in some hydrothermal breccias/fissure veins and magmatic intrusive breccia pipes
- Hydrothermal breccia and vein deposits in the Gallinas Mountains are too low grade to be economic for Au, U, Th, and Nb in today's market
- Further drilling and subsurface sampling is suggested
- In 1991-1992, USBM calculated an inferred resource of 537,000 short tons with a grade of 2.95% total REE

CONCLUSIONS

- Major faults (based on length and displacement) are not mineralized with the exception of the Pride, Conqueror. and Buckhorn faults
- REE breccia and vein deposits are mostly along minor faults with small displacements and short lengths, and fracture zones
- Positive correlation between TREE, F, Ba, and Sr
- Dikes south of Rough Mountain also control some of the REE breccia and vein deposits
- Most precious and base metal sulfide deposits are associated with REE-F deposits
- A combination of thin section petrography and whole-rock geochemistry indicates that geochemical reactions with 1-2 stages of barite-fluorite-calcite veins may control REE distribution followed by precipitation of later bastnäsite-fluorite veins
- REE deposits are derived from magmatic-hydrothermal fluids from either an alkaline magma, such as the trachyte and syenite exposed in the area or from a deep-seated, buried carbonatite
- Many of the magmatic intrusive breccia pipes were emplaced along the margins of syenite intrusions, suggesting a connection between fluids associated with the intrusions and breccia pipe formation