Annotated Bibliography of Rare Earth Elements Deposits and Occurrences in New Mexico

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This document is an annotated bibliography of rare earth element occurrences and deposits located throughout New Mexico. Many of the references include information on the location, geology, production history, and economic potential of the deposits when available, while the rest focus on describing the geochemistry of certain areas. Most of the references were found by conducting keyword searches of various databases including, but not limited to, Google Scholar, GeoScienceWorld, and Elsevier. Other references were located by searching the archives at the New Mexico Bureau of Geology and Mineral Resources and the library at the New Mexico Institute for Mining and Technology. All of the references were cited and stored in an application called Endnote.

(1944). "Bastnaesite at Corona, New Mexico." American Mineralogist 29(3-4): 157.

This short article mentions the tentative identification of the mineral bastnaesite found in the Red Cloud fluorite deposit located in Corona, New Mexico. The article also describes some of the optical and identification properties of the mineral, and mentions how it will be checked by a quantitative chemical analysis.

(1950). "Experienced prospectors lead search for uranium in New Mexico." New Mexico Miner and Prospector 12(5).

This very short article describes a few officially reported occurrences of uranium throughout New Mexico that might warrant further exploration. The Organ mining district of Dona Ana County was reported to contain euxenite, of which specific amounts or concentrations were not specified.

(1951). "New Mexico." Engineering and Mining Journal 152(11): 140.

This very short, one-paragraph article mentions how William Heim is operating a mill designed to produce thorium and cerium by processing bastnaesite. He receives the shipments from the Gallinas Mountains, where the deposits are associated with high-grade fluorspar ore.

(1952). "Companies join with Heim to develop bastnaesite." Engineering and Mining Journal 153(1): 108-108.

This short paragraph describes that the Lindsay Light and Chemical Company of Chicago joined with Heim, who discovered the rare-earth deposits in the Gallinas district, to collect and process the bastnaesite in the area. The article also mentions that the deposit contains 14 rare-earths and associates of the REEs.

(1981). Geological survey research, fiscal year 1981. Professional Paper.

There is a lot of information in this publication. However, there is a very specific piece of information related to Laughlin Peak. Page 37 states that there are a number of rare earth veins found on the southwest flank of Laughlin Peak with rare earth content ranging from 147 to 19,030 ppm. H.M. Staatz conducted this research but I was unable to find the original source.

Adams, J. W. and M. H. Staatz (1965). Mineral and water resources of New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology. 87: 1-444.

This bulletin details the mineral and water resources throughout New Mexico, which includes information on thorium and REE. It is an excellent resource for combining the research up to that point on REE, and it goes through each mining district or area where they can be found.

Allen, M. S. and E. E. Foord (1991). Geological, geochemical, and isotopic characteristics of the Lincoln County porphyry belt, New Mexico: Implications for regional tectonics and mineral deposits. NMGS Fall Field Conference. New Mexico: 91-113.

The authors wanted to better understand the Lincoln County porphyry belt (LCPB) by obtaining radiometric age determinations, geochemical data, and isotopic data. They used this data to infer the petrogenesis of related rocks as

well as the mineralogy of those rocks. This required data collection on REE, and while specific concentrations were not reported, the report contains normalized graphs of REE. The observed patterns led the authors to state that the Gallinas Mountains and Capitan pluton have high REE abundance, and they speculate that bodies that underwent similar processes could contain higher REE amounts.

Allen, M. S. and V. McLemore (1991). The geology and petrogenesis of the Capitan Pluton, New Mexico. NMGS Fall Field Conference. New Mexico: 115-127.

The authors of this article wanted to understand the textural and compositional variations found within the Capitan pluton as well as determine how it was generated. They also wanted to explain the textural zoning within the pluton, which the authors accomplished by conducting a literature search and by taking personal samples that were then analyzed for their mineralogical compositions. The geochemical data is reported in a table, which includes REE compositions. This data is also important for determining the geologic conditions that created the pluton, and suggests that higher REE concentrations can be found in similar environments.

Amato, J. M., et al. (2011). "Syntectonic 1.46 Ga magmatism and rapid cooling of gneiss dome in the southern Mazatzal Province, Burro Mountains, New Mexico." Bulletin of the Geological Society of America 123(9/10): 1720-1744.

This experiment examined large granitic plutons in the Burro Mountains in order to determine the age of the area as well as how the geologic expression relates to metamorphism and deformation. The authors collected monazite crystals and used that to determine the age, as well as took other samples that required a report of the geochemical data, which is tabulated within the article. While this article did not focus on specific occurrences of REE, it does show that REE can occur in this area as well as gives a baseline amount that can help further the understanding of the potential of the Burro Mountains.

Anderson, E. C. (1956). Mining in the southern part of the Sangre de Christo Mountains. NMGS Fall Field Conference. New Mexico. Southeastern Sangre de Cristo Mountains: 139-142.

This paper describes the various mining districts and mines located in the Sangre de Christo Mountains, and when applicable, includes information on mineral resources, production history, and potential deposits. For the Tecolote district in the Ribera area, the author mentions the production of monazite in addition with columbite, tantalite, and beryl from the Old Priest Mine.

Anderson, E. C. (1957). The metal resources of New Mexico and their economic features through 1954. Bulletin, New Mexico Institute of Mining and Technology: 1-188.

The purpose of this article was to gather information on New Mexico's various mining districts and compile information such as important minerals, active mines, and mining histories for many of those districts. Parts of this report mentions REEs and their production.

Armstrong, A. K., et al. (1995). "Comparison of hydrothermal alteration of carboniferous carbonate and siliclastic rocks in the Valles caldera with outcrops from the Socorro caldera, New Mexico." Journal of Volcanology and Geothermal Research 67: 207-220.

The authors of this article wanted to compare the hydrothermal alteration and mineralization of the carbonate rocks found in the Valles and Socorro calderas. They did this by analyzing the geologic settings, recording the mineralogy of the collected core samples, and by describing the lithology of the two areas. Even though specific REE concentrations are not mentioned in this report, the authors stated that REE bearing minerals were precipitated in the mineralized systems, that a sample of the carbonate rocks contained an unknown REE bearing mineral, and that the calderas formed rare-earth bearing jasperoids.

Audetat, A. and T. Pettke (2003). "The magmatic-hydrothermal evolution of two barren granites: A melt and fluid inclusion study of the Rito del Medio and Canada Pinabete plutons in northern New Mexico (USA)." Geochimica et Cosmochimica Acta 67(1): 97-121.

The authors of this report studied barren granite systems of the Tertiary Questa Caldera to further the understanding of the magmatic-hydrothermal evolution of this area in order to relate those findings to similar areas as an attempt to explain the apparent mineralogy and geological features. Because of that, this study required comprehensive mineral analyses that included REE, which are tabulated within the report. The authors reported chevkinite occurring as an accessory mineral.

Audetat, A., et al. (2008). "The composition of magmatic-hydrothermal fluids in barren and mineralized intrusions." Economic Geology 103(5): 877-908.

This study attempted to determine if there are fundamental differences in magmatic hydrothermal fluids when comparing barren system to mineralized systems. The study combined field work and literature research for the following New Mexico localities: Central Mining district, Rito del Medio pluton, Capitan pluton, and Mina Tiro Estrella prospect. This source gives research on the controls of REE creation and desired environments to maximize the concentrations.

Banks, D. A., et al. (1994). "REE composition of an aqueous magmatic fluid: A fluid inclusion study from the Capitan Pluton, New Mexico, U.S.A." Chemical Geology 113(3-4): 259-272.

This study analyzed the REE content of fluid inclusions collected from the Capitan Pluton to better understand fluid inclusions in relation to the transportation and exchange of REE. They mentioned that the area contains minor amounts of titanite and allanite, and how they are enriched in REE, as well as mentioned that the samples were enriched in LREE. The specific concentrations of the REE for each sample are tabulated within the report.

Barker, F. (1958). Precambrian and Tertiary geology of Las Tablas quadrangle, New Mexico. Bulletin, New Mexico Institute of Mining and Technology: 1-120.

The author of this report analyzes and describes the Precambrian and Tertiary geology, structural geology, stratigraphy, and the formation and features of different rocks, along with basic information on mineral deposits, of the Las Tablas quadrangle located in Rio Arriba County. He also comments on the regional metamorphism and geologic history. On page 63, the author mentions that the pegmatites on the La Jarita Mesa have fractures filled with a variety of

minerals including samarskite, as well as cites Jahns (1946) regarding the formation of those pegmatites.

Bartsch-Winkler, S. and A. J. Donatich (1995). Mineral and energy resources of the Roswell Resource area, east-central New Mexico. Bulletin, USGS: 1-145.

This document is a wide-ranging report that covers everything from energy resources within the Roswell Resource area, to information on geophysical data and sediment composition. This document also contains a lot of information about rare earth deposits, where to find them, potential areas where they could be located, and even some compositional amounts. The Capitan and Gallinas Mountains are mentioned as key sources along with the Red Cloud mine.

Bauer, P. W. (1987). Precambrian geology of the Picuris Range, north-central New Mexico. Earth and Environmental Science, New Mexico Institute of Mining and Technology. Doctor of Philosophy: 283.

The purpose of this thesis was to characterize the Precambrian geologic history of the Picuris Range and fit it into a regional framework for northern New Mexico, as well as to understand the physical forces involved in the tectonism of the area. The author met these purposes by detailed mapping, structural analyses, and date determinations using U-Pb zircon geochronology. On pages 179 and 219, the author cites Codding (1983) and mentions that the upper pink portion of the felsic schist at Pilar contains unspecified anomalously high concentrations of REEs.

Berger, M. Geology and mineralization of the Pajarita Mountain layered peralkaline syenitic pluton-hosted REE-Zr prospect, Mescalero Apache Reservation, New Mexico. Geology and Geological Engineering, Colorado School of Mines. Master of Science: 84.

The author of this thesis wanted to “assess the roles and types of magmatic processes that led to the REE enrichment in the Pajarito Mountain pluton” as well as relate the petrographic and geochemical signatures of the area so that they can be used as a method to recognize similar processes in other areas. The author accomplished this by acknowledging previous work, and analyzing the geology, mineralogy, and geochemistry of the areas. In relation to REEs, the author mentions the presence of eudialyte, samarskite, cerite, bastnaesite, allanite, and monazite within the area, which hosts potentially economic resources of REE according to the author. The document also includes tables of REE concentrations.

Bingler, E. C. (1968). Geology and mineral resources of Rio Arriba County, New Mexico. Bulletin, New Mexico Institute of Mining and Technology. 91: 1-175.

This article focuses on the geology and mineral resources of Rio Arriba County, and goes into detail about those resources for many of the county's mining districts and important locations. The report describes the REE found in the Petaca district and while the report did not mention concentrations, it did uphold that REE bearing minerals samarskite and monazite were common accessory minerals that been produced from a few of the mines.

Bosze, S. and J. Rakovan (2002). "Surface-structure-controlled sectoral zoning of the rare earth elements in fluorite from Long Lake, New York, and Bingham, New Mexico, USA." Geochimica et Cosmochimica Acta 66(6): 997-1009.

These authors examined fluorite samples taken from Bingham and Long Lake, and attempted to correlate concentrations found to sectoral zoning of those specific crystals. The report includes the mines the samples were taken from and concentrations of REE, even though those concentrations appear too small for our purposes.

Bove, D. J., et al. (1995). "The evolution of the Eagle Peak volcano-a distinctive phase of Middle Miocene volcanism in the western Mogollon-Datil volcanic field, New Mexico." Journal of Volcanology and Geothermal Research 69: 159-168.

In this study, the authors wished to determine the petrogenesis, magma source, and evolution of the Eagle Peak volcano. They used major-oxide, trace element, and isotope geochemistry to accomplish this, which caused them to also analyze the REE composition within their sample area. The REE in ppm are reported in a table and a few of the samples were enriched in light rare earth elements when compared to the others.

Boyd, F. S., et al. (1953). Recent investigations of radioactive occurrences in Sierra, Dona Ana, and Hidalgo Counties, New Mexico. NMGS Fall Field Conference. New Mexico: 141-142.

This paper briefly described radioactive occurrences in a variety of geologic settings in Sierra, Dona Ana, and Hidalgo Counties. In relation to REE, the authors mention pegmatite dikes located near Lordsburg, New Mexico that contain unspecified amounts of samarskite and euxenite.

Brookins, D. G. (1979). Uranium deposits of the Grants, New Mexico Mineral Belt (II), University of New Mexico: 1-411.

The authors of this study conducted and analyzed geochemical data of the samples collected from the Grants Mineral Belt in order to relate that to the mode of ore formation, as well as to determine if that mode of formation can be used as an exploration tool. This meant that the authors reported on the REE of the samples collected that showed a slight enrichment in the LREE.

Brookins, D. G. (1982). "Uranium and thorium abundances, whole rock chemistry and trace element chemistry, Zuni Mountains, New Mexico." The Mountain Geologist 19(3): 83-90.

The authors of this article studied the uranium and thorium content of rocks and drill core samples collected from the Zuni Mountains in order to determine if the mineralization in that area has any relationship to the uranium mineralization of the nearby Grants Mineral Belt. Although the authors collected multiple samples for a variety of settings, they only analyzed one sample for each location for REE. The data, which is tabulated in the report, caused them to conclude that the observed trends are characteristic of New Mexican granite and that there was evidence of local REE migration and transport.

Brookins, D. G., et al. (1977). Trace elements as possible prospecting tools for uranium in the southern San Juan Basin. NMGS Fall Field Conference. New Mexico: 264-269.

The purpose of this paper was to compare trace element data collected from whole rock and barren samples to determine if there is a way to predict the concentration of selected elements if they were transported to an ore-bearing sight. To do this, the authors collected and analyzed many mineral samples and tabulated the trace element concentrations, which included REE. While the results show generally low concentrations, the authors mention that there was an enrichment of REE scattered through all three of the testing sample types including the ore zone, the bleached zone, and the outcrop.

Brookins, D. G. and A. Majumdar (1982). The Sandia granite-- Single or multiple plutons? NMGS Fall Field Conference. New Mexico: 221-223.

The authors of this paper wanted to determine if the Sandia granite can be split into a northern and southern portion as other authors have suggested, which they did by conducting a literature search as well as by collecting and analyzing samples from the area. There is a table of trace elements reported that include REEs for this area.

Brookins, D. G. and C. E. Rautman (1978). A study of silicic plutonic rocks in the Zuni and Florida Mountains to evaluate the possible occurrence of disseminated uranium and thorium deposits. Open-file report: 1-47.

The authors wanted to analyze the thorium and uranium potential of the Zuni Mountains, which they did by determining the composition and trace elements of surface and drill core samples. They tabulated the data within the report, which included tables and graphs of the REE abundance within the area.

Broxton, D., et al. (2007). Pliocene volcanic rocks of the Tshicoma Formation, east-central Jemez volcanic field: chemistry, petrography, and age constraints. NMGS Fall Field Conference. New Mexico: 284-295.

The authors of this paper wanted to constrain and describe the depositional history of the Pliocene Piuyu Formation, which they did by studying and describing the age, mineral assemblage, chemistry, and geology of the Tschicoma Formation. Even though this paper did not focus on REE, it does contain a table of major and trace element data which includes concentrations, although small, of REE.

Burt, D. M., et al. (1980). Uranium mineralization in fluorine-enriched volcanic rocks, Department of Geology Arizona State University: 1-494.

The author of this article studied the mineralogy, chemistry, history, and magmatic evolution of the Taylor Creek Rhyolite. Within the article, he mentions that the rhyolite is enriched in HREE, Hf, Cs, and Yb when compared to the average granites, as well as includes a table of REE concentrations for certain samples.

Campbell, A. R., et al. (1995). "Geochemistry of Th-U-REE mineralizing magmatic fluids, Capitan Mountains, New Mexico." Economic Geology 90: 1271-1287.

This study did not focus much on the Th, U, REE content of the Capitan Mountains. Instead, it attempted to determine how the well-documented REE veins were made through both physical and chemical methods.

Castor, S. B. (2008). "Rare earth deposits of North America." Resource Geology 58(4): 337-347.

This article is a very broad overview of REE deposits in certain areas of America. It focuses less on amounts and more on the general areas of known or mined deposits. For New Mexico, this includes the Pajarito and Gallinas Mountains.

Castor, S. B. and J. B. Hedrick (2006). Rare earth elements, Society for Mining, Metallurgy, and Exploration.

This article describes the history, genesis, mining and production, and economic considerations of the REEs and their associated minerals. However, the bulk of the document describes the types of deposits that contain REEs, and mentions the Pajarito Mountain deposit and the Gallinas Mountains briefly by name.

Cavosie, A. J., et al. (2016). "Nanoscale deformation twinning in xenotime, a new shocked mineral, from the Santa Fe impact structure (New Mexico, USA)." Geology 44(10): 803-806.

The authors of this article wanted to observe and study the effects of impact-related deformation in geologic structures in order to find additional constraints on impact conditions. They did this by finding and collecting xenotime from a shatter-cone found in granite near Santa Fe in the Sangre de Christo Mountain

Range and by observing the twinning present in those grains. While this study does not focus on REE or concentrations, it does recognize the presence of REE minerals in the area.

Chenoweth, W. L. (1974). Uranium in the Petaca, Ojo Caliente, and Bromide districts, Rio Arriba County, New Mexico. NMGS Fall Field Conference. New Mexico: 315.

In this article, the author describes uranium and rare earth deposits in the Petaca, Ojo Caliente, and Bromide districts in Rio Arriba County. His descriptions include a discussion of the history, economic quality, and occurrence for minerals such as samarskite, uraninite, and monazite. For all districts, the author stated that the minerals were of low and uneconomic grade, as well as the deposits were rather small and erratically distributed.

Chenoweth, W. L. (1979). Uranium in the Santa Fe area, New Mexico. NMGS Fall Field Conference. New Mexico: 261-264.

This paper describes uranium deposits found around Santa Fe and by association, rare earth elements. The author mentions the presence of samarskite and monazite found within the Rincon Range and mentions that the Guy No. 1 mine produced more than 227 kg of uranium and REE between 1930 and 1945.

Clippinger, D. M. (1949). Barite in New Mexico. Circular. New Mexico, New Mexico Institute of Mining and Technology: 1-28.

The purpose of this report was to combine all mentions and known sources of barite within New Mexico into one document and give information on geologic setting, location, grade, and market price. Even though this article focuses mainly on barite and barite's economic applications, REE are known to occur with barite. There is exactly one reference to any sort of REE element, and it was bastnaesite.

Condie, K. C. (1978). "Geochemistry of Proterozoic granitic plutons from New Mexico, U.S.A." Chemical Geology 21(1-2): 131-149.

The author of this study analyzed the geochemistry of 38 granitic plutons scattered throughout New Mexico and recorded the samples' major and trace element concentrations including REEs. She then relates that data to offer explanations on origin, magma composition, and age. Tables of the major and trace element analyses are included within the report, and are organized by potassium and rare earth concentrations for different groups.

Condie, K. C., et al. (2004). "Distribution of high field strength and rare earth elements in mantle and lower crustal xenoliths from the Southwestern United States: The role of grain-boundary phases." Geochimica et Cosmochimica Acta 68(19): 3919-3942.

The above people examined spinel lherzolite and harzburgite xenoliths collected from various areas in the southwestern United States in order to determine the effect secondary processes have in controlling incompatible element distribution. Their results report REE as weight percentage in a table for locations involving The Thumb, Rio Puerco volcanic field, Elephant Butte, Kilbourne Hole, and Potrillo maar.

Constantopoulos, J. (2007). "Geochemistry of the Bonito Lake stock, Lincoln County, New Mexico: Petrogenesis and hydrothermal alteration." Rocky Mountain Geology 42(2): 137-155.

This author studied the Bonito Lake stock, which is a plutonic body that intrudes the Oglicene Sierra Blanca Volcanics, in order to understand the petrogenesis and alteration of the stock. He reported enrichment in that area of the LREEs, and tabulated REE concentrations for the many samples he collected.

Crook, J. C. and V. W. Lueth (2014). A geological and geochemical study of a sedimentary-hosted turquoise deposit at the Iron Mask mine, Orogrande, New Mexico. NMGS Fall Field Conference: 227-233.

The authors of this article studied the turquoise deposits located in the Iron Mask mine of the Orogrande district in order to determine the setting, history of formation, and geochemistry of the samples collected. The authors noticed that the shale hosting the turquoise deposits contained xenotime and included XRD and microprobe analysis information in the supplemental data.

Daniel, C. G. and J. M. Pyle (2006). "Monazite–xenotime thermochronometry and Al2SiO5 reaction textures in the Picuris Range, northern New Mexico, USA: New evidence for a 1450–1400 Ma orogenic event." Journal of Petrology 47(1): 97-118.

The purpose of this study was to determine the timing and temperature of the triple point metamorphism in the aluminosilicate rocks located within the Picuris range. A majority of the data came from studying monazite and using the temperature and growth of monazite to relate it to the triple point. Tables of microprobe analysis results are located within the document, which contains information on the presence of certain REE. While this article does not focus on specific monazite occurrences and amounts, it is a document that records that the Picuris range does contain amounts of REE.

Davis, J. M. and C. J. Hawkesworth (1995). "Geochemical and tectonic transitions in the evolution of the Mogollon-Datil Volcanic Field, New Mexico, U.S.A." Chemical Geology 119: 31-53.

The people who conducted this study wanted to determine the timing and shift from lithospheric-derviced magmas to asthenospheric-derived magmas in the Mogollon-Datil Volcanic Field. Within this article, there is a table that reports magma composition, which includes an analysis of REE.

DeMark, R. S. (1980). "The Red Cloud Mines, Gallinas Mountains, New Mexico." The Mineralogical Record 11(2): 69-72.

The author of this article described the location, basic geology, and mineral deposits of the Red Cloud mines located in the Gallinas Mountains. For the mineral deposits, the author mentioned size, relative amount, and identifying factors for the notable minerals found in and around the mines. In relation to REEs, he mentioned bastnaesite and how it is abundant in the area and ranges from 1 to 10 mm in size.

DeMark, R. S. (1984). "Minerals of Point of Rocks New Mexico." The Mineralogical Record 15(3): 149-156.

The author of this article described the location and basic geology of Point of Rocks before going into some detail on the minerals that can be found in the area. He describes relative abundance, location, mineral associations, and identification properties for the minerals located in this area. In relation to REEs, he mentions that eudialyte is common in small crystals scattered throughout the quarry.

DeMark, R. S. (1989). "Micromounting in New Mexico." The Mineralogical Record 20: 57-64.

This article describes a series of localities and mines scattered throughout New Mexico that might be of some interest to the micromounter. Each stop, of which there are 28, has a description of the mineralogy, identifying factors of specific minerals, and relative amount of the noteworthy and collectable minerals present. In relation to REEs, the Mina Tiro Estrella claim contains allanite, and the Red Cloud mines contain bastnaesite.

DeMent, J. and D. H.C. (1947). Handbook of uranium minerals. Oregon, Mineralogist Publishing Company.

This small book briefly describes the occurrence of uranium minerals, how to detect them, their uses, and prospecting. The authors mentioned New Mexico and how samarskite is found "2.5 miles southwest of the village of Petaca" as well as in the Fridlund dike. In addition, the authors said that monazite occurs in the Petaca district.

Dow, V. T. and J. V. Batty (1961). Reconnaissance of titaniferous sandstone deposits of Utah, Wyoming, New Mexico, and Colorado. Report of Investigations.

This report describes the location, geology, and basic mineralogy of titaniferous sandstones in various states in order to establish a baseline of economic viability. While this study did not specifically focus on REE, titaniferous sandstones do contain minerals such as monazite and elements like yttrium, cerium, and neodymium. This article provides a preliminary investigation of tonnage, grade, location, and size of various deposits around New Mexico.

Dunbar, N. W., et al. (1996). "Physical, chemical, and mineralogical evidence for magmatic fluid migration within the Capitan pluton, southeastern New Mexico." Bulletin of the Geological Society of America 108(3): 318-333.

In this article, the authors wanted to explain the generation of porous zones within the Capitan Pluton using physical, chemical, and mineralogy data in order to offer possible alternative explanations on why the zones exist. The authors related this to the REE bearing ore deposits and offered explanations on why this certain area is enriched in REE enough to be considered economically viable.

Dungan, M. A., et al. (1986). "Open system magmatic evolution of the Taos Plateau volcanic field, northern New Mexico; the petrology and geochemistry of the Servilleta Basalt." Journal of Geophysical Research 91(B6): 5999-6028.

This article describes the mineralogy, petrology, and genesis of the Servilleta Basalt located in the Taos Plateau volcanic field. This required a chemical analysis of many samples collected from the area, which included a report on the concentrations of REEs and is tabulated within the report.

Ellinger, S. T. and J. C. Cepeda (1991). A geochemical survey of ferrous and selected base metals in the eastern half of the Capitan Mountains, Lincoln County, New Mexico. NMGS Fall Field Conference. New Mexico. Geology of the Sierra Blanca, Sacramento, and Capitan Ranges, New Mexico: 299-304.

The authors of this study evaluated the mineral resource potential of the eastern Capitan Mountains as well as examined the ferrous and base metal chemical anomalies in relation to their economic potential. The authors found that certain areas including Saw Mill Canyon, Sunset Peak, and the eastern Capitan Mountains contain REEs with anomalous concentrations. This data caused the authors to believe that the source could be from bastnaesite that might be located throughout the areas, as well as speculated that REEs could be found in the granite and in alluvial concentrations.

Elston, W. E. (1970). Volcano-tectonic controls of ore deposits, southwestern New Mexico. NMGS Fall Field Conference. New Mexico. Tyrone, Big Hatchet Mountain, Florida Mountains Region: 147-153.

The author of this article wanted to prove that hypogene mineral deposits are related to volcano-tectonic structures, and show that identifying those volcano-tectonic structures could serve as a good exploration tool. While this article did not focus on REEs, their minerals, or concentrations, the author mentioned that “a few pegmatites in the Gold Hills have traces of rare earths.”

Ennis, D. J., et al. (2000). "The effects of K-metasomatism on the mineralogy and geochemistry of silicic ignimbrites near Socorro, New Mexico." Chemical Geology 167(3-4): 285-312.

The purpose of this article was to determine the effect K-metasomatism has in relation to altering the mineral assemblage of the upper Lemitar and Hells Mesa Tuffs. REE concentrations are reported in a few tables scattered around the report, and the data showed that there was REE enrichment in the Hells Mesa Tuff.

Eppinger, R. G. (1988). Trace element and rare earth element variation in fluorites collected from skarn and epithermal mineral deposits in the Sierra Cuchillo area, south-central New Mexico. Open-file report, USGS: 1-108.

This study wanted to determine if fluorites collected from variable deposits within the same area have different chemical and physical properties that can be used as a classification scheme for further exploration. Three fluorite deposits from the Sierra Cuchillo area were analyzed for major and minor elements, which includes REE. The results are tabulated in the back of the document.

Eppinger, R. G. and L. G. Closs (1990). "Variation of trace elements and rare earth elements in fluorite: A possible tool for exploration." Economic Geology 85: 1896-1907.

This study wanted to determine if fluorite compositions can be used for mineral exploration within the same province that the samples were collected from, as well as determine if the chemical signatures are similar or different when collected from the same province. The study area included parts of the Sierra Cuchillo, Black Range, and Caballo Mountains and described the geology, history, and fluorite-bearing mineral deposits. After collecting 28 samples, the authors analyzed the mineralogical compositions of the fluorite, which included REE, and reported the findings in a table that is in the document. While the

authors noticed wide-ranging compositions, they said that generally the LREE elements were more enriched than the HREE.

Ericksen, G. E., et al. (1970). Mineral resources of the Black Range Primitive Area, Grant, Sierra, and Catron Counties, New Mexico. Bulletin: 1-162.

The purpose of this article was to determine the mineral resources of the Black Range Primitive area by describing the mineralogy, geochemistry, and geology of the area by mapping, collecting, and analyzing samples. In relation to REEs, the article mentions on page 79 that “An unusual type of rare-earth mineralization, which may warrant further study occurs near Bald Hill” located in the Kingston mining district. Below that, the document contains concentrations of selected elements including yttrium and lanthanum.

Evans, G. C. (1963). Geology and sedimentation along the lower Rio Salado in New Mexico. NMGS Fall Field Conference. New Mexico: 209-216.

This paper studied the relationship between the sand dunes and the Rio Salado drainage area in order to help determine the history of the area. The author mapped the area, as well as studied the stratigraphy, structure, and described the basic mineralogical compositions of some sand deposits. He mentioned that the sample contained monazite, but did not give concentrations or any relative size when compared to the presence of the other elements or minerals present.

Feigenson, M. D. (1986). "Continental alkali basalts as mixtures of kimberlite and depleted mantle: evidence from Kilbourne Hole maar, New Mexico." Geophysical Research Letters 13(9): 965-968.

The main purpose of this experiment was to test a model of how alkali basalts mix with depleted mantle and kimberlite mantle. This experiment required an analysis of REE, and while it was not a focus, amounts were still reported in a table.

Fieldman, D. W. (1977). Initial geologic report on the Arroyo Uranium Prospect, Socorro County, New Mexico: 1-33.

Foord, E. E. (1991). "Rare-earth arsenates and rare-earth minerals from the Black Range tin district, Sierra and Catron Counties, New Mexico." New Mexico Geology 13(2): 38-41.

This abstract focusses on the REE bearing minerals located within the Black Range tin district and briefly describes their structure and geologic history and setting. The article mentions REE bearing minerals such as titanite, gasparite, chernovite, and chevkinite by name, as well as gives general locations to each occurrence. However, the author does state that the REE bearing minerals occur in minute amounts and makes no mention of economic potential or history or possible future of mining exploits for REE bearing minerals.

Foord, E. E. and C. H. Maxwell (1989). "Mineralogy of the Black Range tin district, Sierra and Catron Counties, New Mexico." New Mexico Geology 11(2): 37-43.

This abstract described the mineralogy of the Black Range tin district, and mentions the presence of HREE and LREE at Willow Springs Draw. The author also indicates that gasparite, chernovite, and chevkinite can be found within this district, specifically at Willow Springs Draw and Squaw Creek.

Frempong, K. B., et al. (2013). "Cambrian-ordovician rare earth element (REE)-bearing episyenites in the Caballo and Burro Mountains, southern New Mexico, insights into a metasomatic origin." New Mexico Geological Society Annual Spring Meeting-Abstracts. 2019, from https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=65.

This website abstract describes the mineralogy, geologic setting, and possible sources of formation of the episyenites located in the Caballo and Burro Mountains. It mentions how these episyenites contain REE, and gives some known concentrations of the REE.

Gardner, J. N., et al. (2007). Geology of the Cerro del Medio moat rhyolite center, Valles Caldera, New Mexico. NMGS Fall Field Conference. New Mexico: 367-372.

The authors of this study wanted to add to the information and data available on the Cerro del Medio dome and flow complex as well as show the complex geology and characterize the volcanic activity that created it. In addition to studying the tectonics, history, age, and general geology, the authors collected samples of the area and reported the concentrations of major and minor elements in ppm in a table within the document. Even though this study did not focus specifically on REE concentrations, REE element concentrations were reported in small amounts in this area as the table shows.

Gillerman, E. (1964). Mineral deposits of Western Grant County, New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology. 83: 1-241.

Like the title suggests, this Bulletin describes the mineral deposits of western Grant County. Western Grant County includes Gold Hill and the White Signal district, which have been considered for REE and mentioned in other articles collected within this bibliography. This report does not go into much detail about the rare earths found within these areas, but it does add valuable research and correlating evidence.

Gillerman, E. (1970). Mineral deposits and structural pattern of the Big Burro Mountains, New Mexico. NMGS Fall Field Conference. Tyrone, Big Hatchet Mountain, Florida Mountains Region: 115-121.

The author of this article analyzed the mineral deposits of the Big Burro Mountains, and related that information to the observed structural patterns to determine the similarities and trends between the two qualities. The article contains a singular mention of rare earth elements and how they are characteristic of early pegmatitic mineralization and are concentrated on the north, south, and southwest fringes of the Big Burro Mountains.

Glass, J. J. and R. G. Smalley (1945). "Bastnaesite." American Mineralogist 30: 601-615.

This article describes bastnaesite found in the Gallinas Mountains and compares it to other deposits of bastnaesite found in America and Sweden. It details geologic setting, location, physical and optical properties of the bastnaesite samples, and mineral occurances. It also shows qualitatively that lanthanum and cerium are the major constituents of bastnaesite.

Goff, F., et al. (2014). Geochemistry and geochronology of intrusive and volcanic rocks of the Three Rivers stock, Sierra Blanca, New Mexico. NMGS Fall Field Conference: 183-196.

The authors of this paper studied the geochemistry and ages of samples collected from the Three Rivers stock to show that "the intrusive complexis the root of an uplifted and eroded caldera." The report contains a table of major and minor trace elements, which include REEs. It shows and correlates with other data that the REE content in this area is low even though REE are often enriched in syenitic and alkalic rocks such as the ones analyzed for this report.

Griswold, G. B. (1959). Mineral deposits of Lincoln County, New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology. 67: 123.

This bulletin describes the mineral resources of Lincoln County and goes into detail about the different mines and what those mines produced, including the Gallinas district. The Gallinas district is known for its REE concentrations, and the author describes a few of them as well as details the mining history behind REE production, especially in relation to bastnaesite. The report also mentions where REE have been found and describes previous explotation or lack of exploting those sources.

Griswold, G. B. (1964). Mineral resources of Lincoln County. NMGS Fall Field Conference. New Mexico: 148-151.

This paper gives a very brief overview of the mineral deposits and their mining history and location in Lincoln County. The author mentions the fluorite-bastnaesite veins in the Gallinas Mountains and desrcibes the geologic setting and appearance of the bastnaesite within that area.

Hansley, P. L. and J. J. Fitzpatrick (1989). "Compositional and crystallographic data on REE-bearing coffinite from the Grants uranium region, northwestern New Mexico." American Mineralogist 74(1-2): 263-2701.

This study focused on studying the geochemistry and crystallography of coffinite samples from the Morrison Formation. The interesting thing to note about this study is that it showed that REE can substitute easily into coffinite samples because of the nature of the structure of coffinite. This study showed that coffinite can easily have REE substitutions, meaning this mineral can be a potential source of REE. However, the issue with this is finding large enough samples that can be considered economically viable considering that even in the report, the author states that REE amounts were not included in the quantitative analysis scheme; this was because small crystals of coffinite were sampled.

Hanson, T. (1989). "Mina Tiro Estrella." The Mineralogical Record 20: 51-53.

This brief article describes the location, history, geology, and mineralogy of the Mina Tiro Estrella claim located in Lincoln County. It mentions the presence of allanite, its association, descriptive qualities, and relative size and abudance.

Hanson, T. and B. Thompson (1991). "The Smokey Bear quartz claims." The Mineralogical Record 22: 359-366.

This article describes the history, mineralogy, and geology of the Smokey Bear quartz deposit located in the White Mountains Wilderness. It mentions the presence of allanite similar to the allanite the Mina Tiro Estrella claim, Capitan claim, and the Capitan Mountains, and states that only a few traces remain.

Harvey, J., et al. (2015). "The effects of melt depletion and metasomatism on highly siderophile and strongly chalcophile elements: S–Se–Te–Re–PGE systematics of peridotite xenoliths from Kilbourne Hole, New Mexico." Geochimica et Cosmochimica Acta 166: 210-233.

This experiment attempted to understand the abundances of HSE and abundances of chalcophile elements in the Primitive Upper mantle by studying metasomatism in peridotite xenoliths found in Kilbourne Hole. Part of this experiment required REE analysis, and once again, the study upheld low concentrations of REE and REE depletion within the peridotites.

Harvey, J., et al. (2012). "Deciphering the trace element characteristics in Kilbourne Hole Peridotite Xenoliths: Melt–rock interaction and metasomatism beneath the Rio Grande Rift, SW USA." Journal of Petrology 53(8): 1709-1742.

The authors wanted to understand the processes that effected the composition of Kilbourne Hole including by analyzing the sequence of melt depletion, melt-

rock interaction, and metasomatic events. The compositional analysis included REE, although the data and table of results seem to support the fact that REE are depleted within Kilbourne Hole. This supports other research conducted in this area, and shows that it is likely not a viably economic source.

Hedlund, D. C. (1985). Geology, mines, and prospects of the Tyrone stock and vicinity, Grant County, New Mexico. Open-file report: 1-31.

The purpose of this report was to describe the faulting, age, mineralogy, and geology of the Tyrone area located in the Big and Little Burro Mountains. The document also indentifies and defines the various mines in the area, including information on name, location, and production, In relation to REEs, the document contains tables of the geochemistry of the samples, as well as mentions that the Blue Jay mine has anomalously high values of REEs at 350 ppm.

Hedlund, D. C., et al. Mineral resource potential of the Sandia Mountain Wilderness, Bernalillo and Sandoval Counties, New Mexico. Miscellaneous Field Studies: 1-16.

The purpose of this article was to determine and describe the mineral resource potential of the Sandia Mountain wilderness by analyzing the geology and geochemistry of the area. Scattered throughout the report are mentions of anomalous concentrations of REEs including elements such as yttrium and lanthanum located throughout the wilderness area.

Heinrich, C. A. and A. A. Levinson (1953). "Studies in the mica group; mineralogy of the rose muscovites." American Mineralogist 38(1-2): 25-49.

The authors of this article describe the mineralogy, mineral assemblage, basic structure and composition of rose muscovites from a variety of areas both within the Unites States and without. They did this in an attempt to determine the chemical controls on the observed color. Within the article, the authors mention that REE-bearing minerals such as monazite and samarskite occur as accessory minerals with the rose muscovite at the Pittlite pegmatites and within the pegmatites of the Petaca district.

Heinrich, E. W. (1958). "Economic geology of the rare-earth elements." The Mining Magazine 98: 265-273.

The author of this article described the economic uses, mineralogy, and deposit types with examples of the REE and the REE-bearing minerals. The article briefly mentions that the Gallinas Mountains contain bastnaesite associated with barite, quartz, and iron oxide minerals.

Heinrich, E. W., et al. (1960). "Relationships between geology and composition of some pegmatitic monazites." Geochimica et Cosmochimica Acta 19: 222-231.

The authors of this article analyzed fourteen monazite samples from different areas in the western United States in order to determine cerium sub-group content as well as yttrium and thorium. The resutls in weight percent are reported within the article for all of the samples, which include monazite specimens collected from the Petaca district and Elk Mountain. The authors also attempted to relate the patterns and mineralogical data to samples collected in the same area as well as to other pegmatite districts; in other words, they used the data to observe any similarities and distinctions between sample and location.

Hess, F. L. (1925). "The natural history of the pegmatites." Engineering and Mining Journal Press 120(8): 289-298.

The author of this article combined personal research and the research conducted by others in an attempt to explain the genesis of pegmatites as well as their form and mineral assemblages. He relied on describing the mineral assemblages, crystal habits, and form in order to propose theories on the pegmatite evolution. In relation to REE in New Mexico, there is a singular mention of the Fridlund pegmatite containing "a good many small masses of a radioactive rare earth mineral not yet analyzed."

Hess, F. L. and R. C. Wells (1930). "Samarskite from Petaca, New Mexico." American Journal of Science 19(5th series): 17-26.

The authors of this article analyzed samarskite collected from the Fridlund claim located in Petaca, New Mexico in order to determine age, formula, and relate those findings to a proposed theory on pegmatite genesis. The article contains calculations of the weight percent of oxides found within the piece of samarskite including REE such as cerium, yttrium, lanthanum, and erbium, and descriptions of the occurrence of samarskite throughout the claim. The author notes a variety of sizes ranging from small grains to masses akin to one's fist, as well as the presence of monazite in the same area.

Hill, G. T. (1994). Geochemistry of southwestern New Mexico fluorite deposits; possible base and precious metals exploration significance. Earth and Environmental Science. Socorro, New Mexico, New Mexico Institute of Mining and Technology. Master of science.

The author of this thesis analyzed samples collected from multiple, known fluorite deposits located throughout the southwestern portion of New Mexico in order to try to find a trend between the origin of the fluorite and if that knowledge can be applied as an exploration tool for determining additional areas of mineralization. Sample areas included the Caballo Mountains, the Lemitar Mountains, the Capitan Mountains, and the Hansonburg district where the author described the geology of each location and the major and trace element data of those samples. The appendices in the back of the thesis give the trace element data for his samples, which includes REE, as well as pages 47 and above focus on the REE composition of the fluorite samples and the various observed trends.

Hill, G. T., et al. (2000). "Geochemistry of southwestern New Mexico fluorite occurences implications for precious metals exploration in fluorite-bearing systems." Journal of Geochemical Exploration 68: 1-20.

The authors of this paper collected multiple samples of fluorite deposits scattered throughout southwestern New Mexico and attempted to determine a few of the controls on fluorite genesis and how those controls affect the geochemistry. All of the results required REE analysis, and the results are present in a table within the report.

Hitzman, M. W. and R. K. Valenta (2006). "Uranium in Iron Oxide-Copper-Gold (Iocg) Systems." Economic Geology 100(8): 1657-1661.

Horning, R. R., et al. (2003). Geology and petrogenesis of magmatic veins at El Porticito volcanic vent, Catron County. NMGS Fall Field Conference. New Mexico: 139-154.

The authors of this paper wanted to understand the generation of host and vein magmas at El Porticito and Tejana Mesa, which they attempted by analyzing new age data and by reporting on the structure and chemical composition of the geology of those areas. The report includes an analysis and table of major and trace elements, which includes REE concentrations. While this paper did not focus on REE concentrations specifically, it adds to the data and knowledge of REE within New Mexico.

Hughes, J. M., et al. (1991). "Rare-earth-element ordering and structural variations in natural rare-earth-bearing apatites." American Mineralogist 76: 1165-1173.

The authors of this study analyzed samples of apatite collected from multiple areas, including Pajarito, New Mexico. They specifically studied the sample’s individual crystal structure and chemical composition in order to determine the ordering of the REE in the crystal structure. The REE composition of a sample of apatite is recorded in a table within the article.

Jackson, D. D. and G. Christiansen (1993). International strategic minerals inventory summary report- Rare-earth oxides. Circular: 1-68.

This report focused on describing the important, mineralogy, and location of economically considerable deposits of REE bearing oxides throughout the United States and the world. It does not focus on specific concentrations or specific areas, but it does give a good baseline of known deposits throughout the world as a pontential for future consideration, exploration, or mining. In relation to New Mexico, the report focusses on the Gallinas Mountains and Pajarito specifically. The article tabulates information on location, host rock, commodities produced, and year of discovery.

Jahns, R. H. (1946). Mica deposits of the Petaca district Rio Arriba County, New Mexico with brief descriptions of the Ojo Calienta district, Rio Arriba County, and the Elk Mountain district, San Miguel County. Bulletin. New Mexico, New Mexico Institute of Mining and Technology. 25: 1-294.

This bulletin is dedicated to describing mica deposits with the Petaca district of Rio Arriba County. The report is organized by groups and then individual deposits within that group, which includes any mining data when applicable or available. The author states that large masses that contain monazite along with a few other minerals have been found in the following deposits: Globe, Fridlund, and North Star deposits. Samarskute has been found in the Fridlund and Kiawa deposits as well as in Lonesome mine. Upon reading this document, I found that many of the deposits have minor amounts of samarskite and monazite, and a few others such as the Kiawa deposit and the Hoyt-Steward mine contain higher concentrations than what is found elsewhere.

Jahns, R. H. (1953). "The genesis of pegmatites II. Quantitative analysis of lithium-bearing pegmatite, Mora County, New Mexico." American Mineralogist 38(11-12): 1078-1112.

The purpose of this journal article was to determine and describe the geologic setting, mineralogy, and formation of the Pidlite dike located in the Sangre de Christo Mountains. While the author did not determine exact compositions, he did show that pegmatites consistently have REE often in the form of monazite, and showed monazite can be found in the Pidlite pegmatite and Harding pegmatite. He also gave a brief description of location and physical appearance of the monazite in the pegmatite.

Jahns, R. H. (1974). Structural and petrogenetic relationships of pegmatites in the Petaca district, New Mexico. NMGS Fall Field Conference. New Mexico: 371-375.

This article is a very broad, qualitative piece of writing that contains information such as geologic setting, characteristics, and origins of the Petaca pegmatites. There is no quantitative data within this article, but it does mention how the pegmatites have yielded amounts of monazite and samarskite. In other words, it mentions that the pegmatites contain concentrations of REE, but does not give any amounts.

Jones, F. A. (1915). The mineral resources of New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology.

The purpose of this report was to begin describing in a very broad, general overview the mining history, mineral resources, and mineral districts of New Mexico. The report briefly mentions that samarskite was found in the Petaca district, as well as monazite might be in the Chama River sands. The mentions are highlighted and the page numbers are recorded within this citation.

Just, E. (1937). Geology and economic features of the pegmatites of Taos and Rio Arriba Counties, New Mexico. Bulletin, New Mexico School of Mines. 13.

The author of this report wanted to make a systematic report on pre-Cambrian rocks, mostly pegmatites, found in Taos and Rio Arriba County. He focuses on the Picuris and Petaca districts, and details geography, geology, and the history and production of the various mines found within those areas. For some of these mines and areas, the report mentions amounts of samarskite and monazite and their history of production, economic quality, and general abundance when the information is available. I have highlighted the individual mentions of REE or minerals, as well as recorded relevant page numbers in the note section and important areas or mines in the keywords section of this resource. However a piece of information to note is that on page 60, the author states that REE minerals should not be considered as a basis for exploitation.

Klich, I. (1983). Precambrian geology of the Elk Mountain - Spring Mountain area, San Miguel County, New Mexico. Earth and Environmental Science, New Mexico Institute of Mining and Technology. Masters: 171.

The purpose of this thesis was to map and describe the geology, mineralogy, geochemistry, metamorphism, and geologic history of the Elk Mountain-Spring Mountain area with particular emphasis placed on the Precambrian rocks. The author accomplished this by conducting detailed mapping, geochemical analyses, and petrography in the area and with collected samples. The geochemical analyses include REE compositions, with a few of the samples showing LREE enrichment, though the author cites Lane (1980) about how Elk Mountain contains low potential for REE resources.

Knowles, C. S., et al. Geology and mineral deposits of the Gallinas Mountains (Gallinas district), Lincoln County, New Mexico; preliminary report. Preliminary report: 1-2.

This publication examines the mineral potential and geology of the Gallinas Mountains. It states the geology of the area, describes the types of deposits found, and judges the important of the area based off known and collected data.

Leventhal, J. S. (1990). Geochemistry of Mariano Lake-Lake Valley Cores, McKinley County, New Mexico. Bulletin: 1-60.

The US Geological Society, working in conjuction with the Bureau of Indian Affairs, wanted to better understand the relationship between the stratigraphy of the host rock and uranium mineralization in the Upper Jurassic Morrison Formation located in McKinley County. The Society drilled 8 cores and took a total of 280 samples to analyze for geochemistry including the trace elements. Results showed that the cores did contain minor amounts of rare-earth elements including lanthanum, cerium, and ytterbium.

Li, M., et al. (2018). "Aeromagnetic and spectral expressions of rare earth element deposits in Gallinas Mountains area, Central New Mexico, USA." Interpretation 6(4): T937-T949.

The authors of this article used the bastnaesite concentrations found in the Gallinas Mountains to explore various geophysical expressions of REE deposits. They conducted the experiment by using the multispectral band-ratio method and 2D subsurface structure inversion to explore the surface mineral recognition and to determine the depth of the ore distribution. While this study did not focus on REE minerals and concentrations specifically, it does give an overview of the geology of the Gallinas Mountains as well as recognize the existence and extent of the deposits.

Li, Y., et al. (2007). "Grenville-age A-type and related magmatism in southern Laurentia, Texas and New Mexico, U.S.A." Lithos 97(1-2): 58-87.

A majority of this experiment focused on Texas but some samples were taken from xenoliths from Potrillo maar, which is located on the southeastern border between New Mexico and Mexico. The authors wanted to take data on the Grenville-age plutons considering not much data has been collected on their distribution and compositional ranges. This required an elemental analysis that included REE, but they seem to be considered trace elements in the area studied and not economically viable. Of course, more research would need to be

conducted to correlate and confirm those results considering this is, so far, the only Potrillo maar study

Lindline, J., et al. (2011). The late Oligocene Cieneguilla basanites, Santa Fe County: Records of early Rio Grande rift magmatism. NMGS Fall Field Conference. New Mexico: 235-250.

The authors conducted a petrographic study of the Cieneguilla basanite in order to better understand the early Rio Grande rift magmatic processes. The authors studied the geologic setting, the history, and the petrographic characteristics to accomplish this, which including reporting on the major and trace element compositions of the area from the collected samples. While this study did not focus on REE, it shows the REE content of the Cieneguilla basanites and shows that the basanites are enriched in LREE when compared to HREE. Considering this was the first petrographic study completed in the area, this study could serve as a good baseline for determining the REE content and economic viability of the area.

Loeffler, B. M., et al. (1988). "Neogene rhyolites of the northern Jemez volcanic field." Journal of Geophysical Research 93(B6): 6157-6167.

The authors of this article studied select, whole rocks located within the Jemez volcanic field in order to determine the geochemistry, history, and age of the rocks and surrounding areas. The geochemistry analysis included detection of REEs, where the REE concentrations are tabulated within the article.

Long, K. R., et al. (2010). The principal rare earth elements deposits of the United States-A summary of domestic deposits and a global perspective. Scientific Investigations Report. U. S. D. o. t. Interior and U. S. G. Survey. Reston, Virginia, USGS. 5220: 96.

For every major rare earth element occurrence documented within New Mexico, this article combines much of the research and defines location, deposit type, and status of the deposit.

Lovering, T. G. (1952). Radioactive deposits in New Mexico. Bulletin, United States Geological Survey

U.S. Atomic Energy Comission: 315-390.

This report summarized the information available on radioactive occurances within New Mexico before 1952 and included data such as geology, origin, and specific mines when applicable. Considering REE and uranium often occur together, this article mentioned certain REE bearing minerals including samarskite and monazite. I have gone through and higlighted all relevant mentions of REE bearing minerals as well as recorded important pages and locations within this reference. Just as a note, on page 382, the author states that the pegmatites near the Petaca district do not contain sufficient quantities of thorium

Lovering, T. G. and A. V. Heyl (1989). Mineral belts in western Sierra County, New Mexico, suggested by mining districts, geology, and geochemical anomalies. Bulletin: 1-58.

The purpose of this report was to combine different sources into a comprehensive report on the mineral deposits located in the mineral belts in western Sierra County, as well as comment on areas that show potential for exploration. The authors accomplished this by describing the geology, location, mineral deposits, mining history, and geochemistry of various districts and certain areas. In the Phillipsburg and Grafton districts, the author mentions anamolous concentrations of cerium, lanthanum, and neodymium, sporadic high concentrations of lanthanum on the north end of the Sierra Cuchillo Mountains, and anamolous concentrations of neodymium and yttrium in Quartz Hill. The Hot Springs district also contains concentrations of lanthanum and yttrium, and additional areas of note include the Salado Mountains, the Hillsboro district, and Taylor Creek.

Lumpkin, G. R. and B. C. Chakoumakos (1988). "Chemistry and radiation effects of thorite-group minerals from the Harding pegmatite, Taos County, New Mexico." American Mineralogist 73: 1405-1419.

The authors of this studied collected samples of thorites from the Harding pegmatite and analyzed the chemical composition of those samples. They then related this data to internal structure, substitution methods, and paragenesis of the thorites. Within the article, they reported the microprobe analysis data in multiple tables, as well as stated that REEs were enriched in many of the samples collected.

Maldonado, F., et al. (2006). "Geology, geochronology, and geochemistry of basaltic flows of the Cat Hills, Cat Mesa, Wind Mesa, Cerro Verde, and Mesita Negra, central New Mexico." Canadian Journal of Earth Sciences 43(9): 1237-1387.

The authors attempted to determine the origins of the basaltic flows by looking at the geochronology, geochemistry, and geology of the specified areas. Their research includes compositional analyses REE found in those areas. While the composition is too low to be economically important, it does help us understand where REE can not be found

Mariano, A. N. and A. Mariano (2012). "Rare earth mining and exploration in North America." Elements 8(5): 369-376.

This magazine article describes select deposits of REE-bearing minerals scattered throughout the United States. It includes a map of those deposits, which mentions the Gallinas Mountains, Parajito Mountains, and the Harding Mine by name, as well as a table that describes the dominate mineralogy. The other half of the article describes the production history and REE amounts when applicable for certain areas, but does not mention the Gallinas Mountains and Harding Mine by name. In relation to the Pajarito Mountains, the authors say that eudialyte mineralization with "significant tonnage" occurs in the area.

McKee, C. (1988). Geochemistry and tectonic setting of some Proterozoic rocks in the Pedernal Hills and Manzano Mountains, New Mexico. New Mexico, New Mexico Institute of Mining and Technology. Master of Science in geology: 362.

The author of this thesis studied the geochemistry and petrography of rock samples collected from the Pedernal Hills and Manzano Mountains in order to produce and explain theories on tectonic affinities and magma models. In addition to describing the geology of the areas, the author collected samples and analyzed them for their main and trace elements, which included REE. Tables of REE for both areas are scattered throughout the report, as well as chondrite normalized plots of REE. The page numbers where this data can be found are reported below excluding the appendices.

McLemore, V. (1980). Geology of the Precambrian rocks of the Lemitar Mountains, Socorro Count, New Mexico. Earth and Environmental Science, New Mexico Institute of Mining and Technology. Master of Science: 206.

The purpose of this thesis was to determine the history and describe the Precambrian rocks and sediments exposed in the Lemitar Mountains. The author accomplished this by conducting geochemical analyses, mapping, and petrography studies, where the results were interpretted and used to describe aspects such as sedimentary environment, magmatism, and tectonic setting. In relation to REEs, the author mentions the presence of bastnaesite in a few of the samples and the carbonatite dikes, and speculates that those areas might have high REE concentrations because of that mineral.

McLemore, V. (1982). Geology and geochemistry of Ordovician carbonatite dikes in the Lemitar Mountains, Socorro County, New Mexico. Open-file report: 1-115.

The purpose of this report was to analyze and better understand the carbonatite dikes located in the Lemitar Mountains, which was accomplished by mapping, describing the geologic setting and geologic history, petrography studies, geochemical calculations, and age calculations. In relation to REEs, the author mentions that the carbonatites are enriched but are likely of low potential though more analyses are needed to determine the potential adequately, and that bastnaesite is located in one of the dikes.

McLemore, V. (1987). "Geology and regional implications of carbonatites in the Lemitar Mountains, central New Mexico." Journal of Geology 95(2): 255-270.

The author of this study analyzed the geologic setting, petrology, and geochemistry of carbonatites located in the Lemitar Mountains. She then related this data to other areas with carbonatites, such as southern Colorado, as well as offered possible explanations on genesis. In relation to REEs, the author showed that the LREE are enriched compared to the HREE, but mentioned that the area shows depletion of REE in rodbergs which is unusual. In addition, she noted that monazite appears rarely in the collected samples and tabulated the geochemistry of the samples with the document.

McLemore, V. (1995). Mineral resources of the southern Sangre de Cristo Mountains, Santa Fe and San Miguel Counties, New Mexico. NMGS Fall Field Conference. New Mexico. Geology of the Santa Fe Region: 155-160.

The author of this article gave an overview of the mineral resources and the mining history and production of various districts located within the Sangre de Christo Mountains. She states that “pegmatites in the El Porvenir, Elk Mountain, Nambe, Tecolote, and Rociada districts were worked for mica, beryl, uranium, rare-earth elements, and tantalum.” This data is reported in tables 2 and 3 of the document in more detail.

McLemore, V. (2005). Mineral resources of the Wild Horse Mesa area, northern Burro Mountains, Grant County, New Mexico. Open-file report, New Mexico Institute of Mining and Technology: 1-46.

The purpose of this report was to describe and analyze the mineral resources of the Wild Horse Mesa area located in the northern Burro Mountains. The author accomplished this by describing previous studies, the geology, and the mineral resources of the area, as well as by mapping and taking samples of certain features in order to determine its geochemistry. In regards to REEs, the Wild Horse Mesa countains REE-Th-U veins located in alkaline rocks centralized along fault and shear zones that are spotty and discontinuous with variable grade. REE-bearing minerals such as monazite, bastnaesite, and eudialyte have been reported from the area, but the author believes the area to be of low mineral resource potential.

McLemore, V. (2010). Beryllium resources in New Mexico and adjacent areas. Open-file report, New Mexico Institute of Mining and Technology: 1-105.

The author of this report compiled literature on beryllium resources, described the noteworthy deposits of beryllium in New Mexico and surrounding areas, ananlyzed potential deposits using NURE geochemical stream data, and defined the geologic and tectonic settings of those areas. Considering beryllium and REEs occur together often, there are mentions of REEs scattered throughout the document. Mora, Rociada, Burro Mountains, Gold Hill, Elk Mountain, La Cueva, Laughlin Peak, Gallinas Mountains, Capitan, and White Signal districts contain minor amount of REEs, and REE-bearing minerals. The Caballo Mountains, Cornudas Mountains, and Wind Mountain also contain REEs and REE-bearing minerals. The Gallinas district specifically has bastnaesite, the Cornudas

Mountains contain monazite, and the Gold Hill, White Signal, and Burro Mountains districts contain euxenite, samarskite, and allanite.

McLemore, V. (2010). Geology, mineral resources, and geoarchaeology of the Montoyo Butte Quadrangle, including the Ojo Caliente No. 2 mining district, Socorro County, New Mexico. Open-file report, New Mexico Institute of Mining and Technology: 1-106.

The purpose of this report was to describe the geology, geochemistry, mineral resources, geoarchaeology, and lithologies in the Montoya Butte quadrangle. In relation to REEs, on page 65, the author mentions anomalous concentrations of REEs were found associated with a few mining districts in the San Mateo Mountains as well as with the Turkey Springs Tuff. Table one within the document also contains information regarding mining districts, mineral resources, which includes REEs when applicable, and production.

McLemore, V. (2015). Mineral deposits associated with tertiary alkaline igneous rocks in New Mexcio. SME Annual Meeting. Denver, Colorado: 1-9.

The author of this article gave a broad overview of the tertiary alkaline igneous rocks located throughout New Mexico, and gave information on age, formation, geology, history, minerals, and mineral resource potential. In relation to REEs, the author stated that these types of rocks often include relative large quantities of REEs and gave examples including the Gallinas Mountains, Laughlin Peak, and the Cornudas Mountains.

McLemore, V., et al. (2001). Mineral-resource assessment of Luna County, New Mexico. Open-file report, New Mexico Institute of Mining and Technology: 153.

The purpose of this article was to describe the basic geology, mineral resources, and mining history and production of Luna County. The authors accomplished this by compiling unpublished and published literature and research, as well as by collecting and analyzing samples of the focus area. In relation to REEs, the report mentions that the Florida Mountains have a C level of certainty in relation to mineral resource potential because the NURE data has anomalous concentrations, but no REE-bearing veins had been found at the time of publication.

McLemore, V., et al. Geology and geochemistry of the Redrock granite and anorthosite xenoliths (Proterozoic) in the northern Burro Mountains, Grant Ciunty, New Mexico, USA. Bulletin of the Geological Society of Finland. 74: 7-52.

The authors of this article described the lithology, mineralogy, and geochemistry of the Redrock Granite located within the northern Burro Mountains. In addition to mentioning the presence of monazite within the granite, the article contains tabulated concentrations of REE elements, and show minor enrichment in HREE for the alkali feldspar granite.

McLemore, V. and A. Robison (2016). Exploration of beach-placer heavy mineral deposits in the San Juan Basin in New Mexico. SME Annual Meeting. Phoenix, Az: 1-10.

The author of this article explored the geology and geochemistry of the heavy mineral beach-placer sandstone deposits located in the San Juan Basin. In addition to describing the geology, she collected samples and analyzed their elemental compositions knowing that such deposits have historically contained anomalous concentrations of REEs. The author showed that the areas studied do contain locally high concentrations of REEs, but believed that the areas would not be mined in the near future because of low tonnage.

McLemore, V., et al. (1996). Mining history and mineral resources of the Mimbres Resource Area, Dona Ana, Luna, Hidalgo, and Grant Counties, New Mexico. Open-file report: 1-251.

The purpose of this report was to describe the geology and mineral resources of the Mimbres Resrouce Area, which includes Dona Ana, Hidalgo, Luna, and Grant Counties. The document is organized by describing the mineral districts, deposits, and mines for each county, as well as includes tables with information on districts, deposit type, year discovered, years of production, and the products of the district. Within the Gila Fluorspar district, the Clum mine averaged 7.4% rare-earth oxides in the two samples analyzed. The Gold Hill district contains REE-bearing minerals including allanite, euxenite, samarskite, and cyrtolite in the Burro Mountains granite and the pegmatites in the northern section of the district. In the White Signal district, deposits of REE and REE-bearing minerals are reported to occurr that are similar to the Gold Hill district deposits.

McLemore, V. T. Radioactive occurances in veins and igneous and metamorphic rocks of New Mexico with annotated bibliography. Open-file report, New Mexico Institute of Mining and Technology: 1-267.

This is a very broad, general overview of promising areas within New Mexico for uranium occurances. While the focus of this report is not REE, it does mention certain REE occurances considering uranium, thorium, and REE often occur together. After combing through the report, I have noted areas with REE potential in the keywords, highlighted any mention of REE within the article that include keywords such as rare, thorium, samarskite, monazite, and bastnaesite, and have supplied the relevant pages below. I will mention that a few of the highlights have to deal with the qualitative description of REE content within granites.

McLemore, V. T. (1980). "Carbonatites in the Lemitar Mountains, Socorro County, New Mexico." New Mexico Geology 2(4): 49-52.

This article described the geology, chemical compositions, and history of the carbonatite dikes located in the Lemitar Mountains. While there was no REE analysis at the time of the publication of this paper, the author mentioned how carbonatite dikes have a higher possibility of containing REE than other geologic settings, as well as briefly mentioned the identification of bastnaesite in a portion of one of the sections.

McLemore, V. T. (1983). Carbonatites in the Lemitar and Chupadera Mountains, Socorro County, New Mexico. NMGS Fall Field Conference. Socorro Region II, New Mexico Geological Society: 235-240.

This article discusses the geologic setting, mineralogy, petrology, and geology of carbonatites found in the Lemitar and Chupadera Mountains. Considering carbonatites are a known source for high concentrations of REE, this article does put forth some REE data on the collected carbonatites. A few of the findings are reported in a table, but the author upheld that some of the samples analyzed were enriched in REE and that the carbonatites in these areas could be economically viable.

McLemore, V. T. (1983). Uranium and thorium occurrences in New Mexico: Distribution, geology, production, and resources, with selected bibliography. Open-file report. New Mexico, New Mexico Institute of Mining and Technology: 1-964.

This report is a detailed and comprehensive document of all the thorium and uranium occurrences within New Mexico, which includes REE by association of mineralogical occurrences. It organizes uranium and thorium deposits by geologic setting before going into more detail on where to find deposits within the counties and districts. However, the most relevant information is included in the appendix, which organizes each mine by county and includes information such as exact location, production, mineralogical deposits, and geologic setting when applicable. I have gone through and highlighted all mentions of REE, as well as recorded page numbers and keywords within this citation.

McLemore, V. T. (1986). Geology, geochemistry, and mineralization of syenites in the Red Hills, southern Caballo Mountains, Sierra County, New Mexico--Preliminary observations. NMGS Fall Field Conference. New Mexico: 151-159.

This article focuses specifically on the syenites in the Red Hills and describes their geology, mineral composition, and economic potential. While this article did not focus on REE or even mention them that much, it does show that the Red Hills in the Caballo Mountains have anonamously high amounts of thorium, ytrrium, and uranium. Considering thorium often occurs with REE and since yttrium is REE, this article lays a potential area to study further in relation to REE. However, a thing to note is that the thorium and uranium concentrations were declared uneconomic because of low grade and small size.

McLemore, V. T. (1990). "Background and perspectives on the Pajarito Mountain yttrium-zirconium deposit, Mescalero Apache Indian Reservation, Otero County, New Mexico." New Mexico Geology 12(2): 1.

This brief article described the significance of the Pajarito eudialyte deposit as well as mentioned the history and future potential of the area. It mentions that the eudialyte contains yttrium and that Molycorp is interested in the area.

McLemore, V. T. (1990). "Rare-earth minerals of New Mexico." New Mexico Geology 12(2): 30-33.

This abstract briefly mentions various REE deposits found within New Mexico as well as gives a list of minerals believed to carry REE. The author does not give specific concentrations or occurrences, but mentions Laughlin Peak, the Harding Pegmatite, the Lemitar Mountains, and the Gallinas Mountains as potential sources.

McLemore, V. T. (2010). Distribution, origin, and mineral resource potential of Late Cretaceous heavy mineral, beach-placer sandstone deposits. NMGS Fall Field Conference. New Mexico: 197-212.

The purpose of this report was to describe the history, geologic setting, mineralogy, and economic potential of the various beach-placer sandstone deposits scattered throughout New Mexico, which are known for having having higher than normal concentrations of REE. The authow showed that many of the deposits including the Gallup deposit, Miguel Creek Dome, Toadlena, and the Standing Rock deposit consitently contain monazite. However, many of the deposits could be difficult or uneconomic to mine because of low grade, low tonnage, high degree of cementation, and large distance between processing plants. The author does state that if the demand rises enough, it could make these deposits appear promising, as well as states that REE could be recovered as by-products of the other potential resources found. Further studies to understand the full potential, age, and history of the San Juan Basin deposits was recommended.

McLemore, V. T. (2010). Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico; Preliminary report. Open-file report. New Mexico, New Mexico Institute of Mining and Technology: 1-92.

This is an incredibly detailed report on the geology and mineralogy of the Gallinas Mountains. The author combined personal research and the research of others in order to create a comprehensive, very specific document that stated the geology of the area, the deposit types that hold the most potential for REEs, specific mines that have produced REE or at the very least noted them, and relates the economic potential of this area to other deposits within New Mexico and the United States.

McLemore, V. T. (2011). Geology and mineral resources in the Hopewell and Bromide No. 2 districts, northern Tusas Mountains, Rio Arriba County, New Mexico. NMGS Fall Field Conference. New Mexico: 379-388.

As the title suggests, this paper describes and analyzes the geology and mineralogy of the northern Tusas Mountains with special emphasis on the Hopewell and Bromide No. 2 districts. It combined reconaissance missions conducted by the leading author as well as a combination of published and unpublished data that has been updated in order to describe geology, mineralogy, geochemistry, and mining history of the targetted areas. In relation to REE, the article mentions that the area contains U-Th-REE veins of three distinct types that need additional research and analysis in order to determine the mineral resource potential and economic viability of those veins.

McLemore, V. T. (2011). "Rare earth elements for emerging technologies." Earth Matters 11(2): 1-5.

This newsletter gives a broad report on various information about REE including where they are found in New Mexico, current and future production, why REE are important to society, and various logistical and health concerns that arise from REE mining and production. In regards to location, the article mentions the Gallinas, Cornudas, Caballo, Pajarito, and Burro Mountains, as well as Apache Warm Springs and the San Juan Basin.

McLemore, V. T. (2012). Geology and mineral resources in the Ojo Calienta No. 2 mining district, Socorro County, New Mexico. NMGS Fall Field Conference. New Mexico: 547-558.

Ths paper describes the history, geologic setting, mineral deposits, age, and economic potential of those mineral deposits located within the Ojo Caliente No.2 mining district. While this report does not mention specific REE concentrations located within this district, the author notes that low concentrations do exist and more might be found within the beryllium found within the district and areas around it. The author recommends further studies in order to determine that, however.

McLemore, V. T. (2012). Rare earth elements deposits in New Mexico. 48th Annual Forum on the Geology of Industrial Minerals. Scottsdale, Arizona, Arizona Geological Survey: 1-16.

This paper focusses primarily on stating the importance of REE, why New Mexico could be considered for mining such deposits, and gives general information about where to find REE in environments and where a few of those environments exist within the state. At the end of this article, there is a table of mining districts in New Mexico that contain REE.

McLemore, V. T. (2013). Geology and mineral resources in the Zuni Mountains mining district, Cibola County, New Mexico: Revisted. NMGS Fall Field Conference. New Mexico: 131-142.

The purpose of this paper was to analyze the mineral resources of the Zuni Mountains mining district by describing the individual deposits, mining history, geochemistry, and geologic setting of the area. The area contains REE-Th-U metasomatic bodies that the author collected samples from, analyzed for their REE content, tabulated the results, and concluded that the deposits found within episyenites are of low economic potential because of low grade and small size.

McLemore, V. T. (2013). "Rare earth element (REE) potential and origin of episyenites in the Caballo, Burro, and Zuni Mountains, southern New Mexico." Abstracts with Programs 45. Retrieved 06 September, 2019, from https://gsa.confex.com/gsa/2013AM/webprogram/Paper232800.html.

Even though this is only an abstract, this article mentions a potential source of REE in episyenites found in southeastern New Mexico. Based off the small amount of data shown, it seems like something that should be researched further considering its preliminary potential.

McLemore, V. T. (2014). Geochemistry of four rare earth elements (REE) deposits in New Mexico. International Applied Geochemistry Symposium. Phoenix, Arizona: 15.

The author of this article compiled research on the REE deposits on the Gallinas Mountains, Laughlin Peak, Capitan Mountains, and Cornudas Mountains using both published and unpublished research. Using this research, she summarized

and compared the ages, geology, and geochemistry between the four areas. Even though the article did not focus on specific concentrations, the report does contain chondrite-normalized reports and relative amounts with the recommendation that the Gallinas Mountains display the best potential.

McLemore, V. T. (2015). Geology and mineral resources of the Laughlin Peak mining district, Colfax County, New Mexico. NMGS Fall Field Conference. New Mexico, New Mexico Geological Society: 277-288.

The purpose of this report was to describe the history of mining in the Laughlin Peak district, to describe the geology, mineralogy, and geochemistry of that area, and to summarize and help determine the mineral resource potential of that area. After drawing upon personal research and the research of others, the author concluded that the Laughlin Peak mining district has possible potential for thorium, REE, and gold production but upholds the fact that further research needs to be conducted in order to fully determine and understand the resources the Laughlin Peak mining district contains. The article mentions specific concentrations for select commoditities as well as the geologic setting they can be found in including hydrothermal veins, carbonatites, and breccia pipe deposits.

McLemore, V. T. (2016). Episyenites in the Sevilleta National Wildlife Refuge, Socorro County, New Mexico: preliminary results. NMGS Fall Field Conference. New Mexico: 255-262.

The author studied the episyenites located in the Sevilleta National Wildlife Refuge in order to determine the economic viability of the episyenites considering other areas throughout New Mexico have episyenites that contain important amounts of uranium, throium, and REE. After describing the geology of the area as well as mapping and sampling, the author determined that the episyenites have no economic potential after evaluating the REE content of the collected samples. However, the author does state that the episyenites could have potential at depth, but the area is removed from mineral entry.

McLemore, V. T. (2017). Heavy mineral, beach-placer sandstone deposits at Apache Mesa, Jicarilla Apache Reservation, Rio Arriba County, New Mexico. NMGS Fall Field Conference. New Mexico: 123-132.

The author of this article examined the potential mineral resources of the beach-placer sandstone deposits in the Apache Mesa by describing the geology of the area, mapping the area, and analyzing collected drill samples using an electron microprobe. Using this data, the author concluded that the total REE concentration was 522 ppm, and recommended no further investigation considering the data showed an area of small and low grade that would have been uneconomic in the market at the time the article was written.

McLemore, V. T. (2017). "Update of industrial minerals and rocks of New Mexico." Mineral Engineering 69(6): 49-56.

This article gives a broad overview of various, industrial minerals found within New Mexico and their localities and production amounts when available. This includes REE and mentions the Cornudas, Gallinas and Capitan Mountains by name along with a few other areas. While this article does not give very specific information on mines or amounts, it does mentions areas that are being considered for REE.

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).

This report focused on REE deposits associated with Great Plain Margin (GPM) deposits within parts of New Mexico and Mexico. It took the three GPM mining districts and broke them into geochronology, location, and mineralogy for each of those specific locations. For each location, the paper describes what type of feature or environment contains the REE, preliminary concentrations, and recommends future exploration or multiple studies to fully understand the potential of those areas.

McLemore, V. T., et al. (2016). Mineral resource assessment of heavy mineral, beach placer sandstone deposits at Apache Mesa, Jicarilla Apache Reservation, Rio Arriba County, New Mexico. Open-file report. New Mexico, New Mexico Institute of Mining and Technology: 1-61.

The study conducted in this article analyzed beach-placer sandstone deposits on Point Lookout Sandstone on the Jicarilla Apache Reservation in order to determine if that area is economically viable for titanium, zircon, and REE. After considering tonnage, grade, size, mineralogy, and geology of the samples, the authors concluded that the sandstone deposit is too small and of too low of a grade to be considered as an economic resource as of 2016. This article is useful because it tells us where to not mine, which remains important information on where to find REE within New Mexico.

McLemore, V. T., et al. (1986). A preliminary resource-potential of western Rio Arriba County, northwestern New Mexico. Open-file report. New Mexico, New Mexico Institute of Mining and Technology: 1-157.

This report assessed the mineral resource potential of Rio Arriba County, and classified the economic potential for certain areas and deposits. The report looked at previous literature as well as data on geophysical, geochemical, and geological findings along with personal studies to determine the economic quality before classifying into high, moderate, low, or unknown. In relation to REEs, the report mentions that monazite can be found in beach placer deposits such as in the San Juan Basin, along with anomalously high concentrations of rare-earth elements in general. After considering various factors such as low-grade, low-quality, and the state of development, the authors stated that " the resource potential is moderate and the development potential is low."

McLemore, V. T., et al. (1986). A Preliminary mineral-resource potential of Cibola County, northwestern New Mexico. Open-file report: 1-438.

The purpose of this report was to summarize data found and collected on Cibola County. The authors combined published and unpublished work, and geophysical, geochemical, and mineralogical data regarding Cibola County in order to present the mineral resource potential of those areas. The report includes mining history, geology, and mineral occurrence for a variety of types and deposits. In regards to REE minerals and deposits, many of the areas were deemed sub-economic to uneconomic, or the authors recommended further studies in order to fully understand the nature of the deposit.

McLemore, V. T., et al. (2014). Geology and mineral deposits of the Orogrande mining district, Jicarilla Mountains, Otero County, New Mexico. NMGS Fall Field Conference. New Mexico: 247-259.

This paper summarized the mining history, geochemistry, geology, mineral resources, and formation of mineral deposits located within the Orogrande mining district, which includes the Jarilla Mountains. The authors analyzed bibliographic sources, published and unpuiblished data, and conducted field work in order to add to the information known about this area as well as determine the mineral resource potential for certain elements and deposits. This analysis included REE that has concentrations tabulated in the appendix and based off additional data, caused the authors to recommend no further exploration in the district for REE at the time of the report's publication because of low potential and concentrations.

McLemore, V. T., et al. (2014). Geology and mineral resources of the Nogal-Bonito mining district, Lincoln County, New Mexico. NMGS Fall Field Conference. New Mexico: 235-246.

The purpose of this paper was to describe the history, mineral deposits, geologic setting, age, and mining history of the Nogal-Bonito mining district located within Lincoln County, New Mexico. In relation to REEs, the authors state the status of potential concentrations and mining of REE is unknown, but seems promising considering the similar geology of this area compared to the geology of known high REE concentrated areas including the Capitan Mountains and Gallinas Mountains within the same county. In addition, another area that was considered was the Three Rivers stock, which has potential considering the presence of fluorite and elevated REE concentrations reported in a previous study. For both cases, the authors recommended further studies to fully determine the presence or lack of REE in the area.

McLemore, V. T. and J. R. Gullinger (1993). Geology and mineral resources in the Cornudas Mountains, Otero County, New Mexico and Hudspeth County, Texas. NMGS Fall Field Conference. New Mexico: 145-153.

This article describes a very broad, general study that focuses on the geology and mineral resources of the Cornudas Mountains. Mostly the authors synthesized and combined previous studies conducted on this area in order to describe the geology, compare it to other areas within New Mexico, and speculate on the economic potential of the various mineral deposits. Some studies have analyzed REE concentrations in the area, which are tabulated within the article, but the authors state that more studies need to be conducted in order to fully understand the economic potential of REE deposits.

McLemore, V. T. and G. Hoffman (2005). Mineral deposits in Rio Arriba County, New Mexico. NMGS Fall Field Conference. New Mexico: 445-456.

The purpose of this paper was to describe the geology, geochemistry, and mineralogy of certain mining districts and generalized deposits within Rio Arriba County. In relation to REEs, the author mentioned the presence of REE in the Hopewell, Bromide No.2, Petaca, and Ojo Caliente districts, as well as in black sandstone deposits and pegmatites found within the county. However, the article upheld the fact that many of the deposits are small, scattered, and of low grade, which means production or economic viability seems unlikely.

McLemore, V. T., et al. (1996). "Petrology and mineral resources of the Wind Mountain laccolith, Cornudas Mountains, New Mexico and Texas." The Canadian Mineralogist 34: 335-347.

The authors of this article examined the petrology, mineralogy, and economic history of the Wind Mountain Laccolith. REE were a part of that analysis, although the amounts found seem to be slightly conflicting. A study conducted by Chess Draw found few REE in their sampling areas, but different, higher numbers were reported by McLemore in separate study with as much as 1235 ppm Ce, which is noteworthy. The article also upheld that the Cornudas Mountains remain to be exploited for economic resources even though the potential is there.

McLemore, V. T. and C. McKee (1988). Geochemistry of the Burro Mountains syenites and adjacent Proterozoic granite and gneiss and the relationship to a Cambrian-Ordovician alkalic magmatic event in New Mexico and southern California. NMGS Annual Fall Field Conference. New Mexico: 89-98.

This study attempted to understand the syenites found in the Burro Mountains by gathering geologic, mineralogical, and geochemical data from selected samples. The samples analyzed REE elements among the major elements, and reported the results in a table found within the report. After reviewing data, the authors believe that the syenites are potentially uneconomical because of the sporadic nature and low grade of REE deposits despite the enrichment in Y, Nb, and other REE. However, they also recommend additional studies to further understand this area considering very little of it has been explored at depth.

McLemore, V. T. and K. E. Mullen (2004). Mineral resources in Taos County, New Mexico. NMGS Fall Field Conference. New Mexico: 383-390.

This paper describes the broad and general history, geology, and mineral production of the ten deposits of the nine mining districts all located within Taos County. This paper does not contain many specifics, but it does mention that mineralized zones found within the Costilla granite in the La Cueva district have high concentrations of REE that are currently uneconomic at the time of the paper's publication because of low grade, low demand, and overall small sizes.

McLemore, V. T., et al. (1999). "Geochemistry of the Copper Flat porphyry and associated deposits in the HIillsboro mining district, Sierra County, New Mexico, USA." Journal of Geochemical Exploration 67: 167-168.

The purpose of this study was to refine the understanding of the mineralization of the Hillsboro district using new geochemical, geochronological, and geological data in association with data from previous studies. In particular, this experiment focused on the Copper Flat porphyry and included tabulated data on REE content. The values reported seem too small to be considered economically viable, but this document adds to the understanding of the Copper Flat porphyry and correlates with other data collected.

McLemore, V. T., et al. (1988). "Rare-earth elements in New Mexico." New Mexico Geology 10(2): 33-38.

This article details the known REE deposits within New Mexico by organizing the occurrences into specific geologic setting and the REE bearing minerals found there. It details the basic geology of the area, as well as gives examples of research done by others and concentrations when applicable.

McLemore, V. T., et al. (1988). REE, niobium, and thorium districts and occurrences in New Mexico. Open-file report. New Mexico, New Mexico Bureau of Mines and Mineral Resources: 1-28.

This article gives a broad, general overview of known REE, niobium, and thorium occurrences in New Mexico. The article breaks up the occurrences by location and type, and tabulates information including mineralogy, environment, and a geologic description of each area, while the rest of the article goes into detail about a few of those select areas with data on elemental concentrations and production history.

McLemore, V. T., et al. (2012). Intermittent Proterozoic plutonic magmatism and Neoproterozoic cooling history in the Caballo Mountains, Sierra County, New Mexico: Preliminary results. NMGS Fall Field Conference. New Mexico: 235-248.

In this report, the authors presented prelimary results and observations on the Caballo Mountains in order to summarize the area's geology and potential mineral resources. The study particular focused on the episyenites that intruded in various areas and rock types including the Longbottom Canyon pluton, Palomas Gap, Apache Gap, and Red Hills. Episyenites historically contain REE-U-Th elements, and while the authors studied those episyenites and found promising results, they uphold that more, extensive research needs to be conducted on that area before it can be determined economically viable or not.

McLemore, V. T., et al. (1984). Preliminary report on the geology and mineral resource potential of the northern Rio Puerco Resource Area in Sandoval and Bernalillo Counties and adjacent parts of McKinley, Cibola, and Santa Fe Counties, New Mexico. Open-file report: 1-874.

The purpose of this report was to summarize data found and collected on the northern Rio Puerco Resource Area (RPRA). The authors combined published and unpublished work, and geophysical, geochemical, and mineralogical data regarding Sandoval and Bernalillo Counties in order to present the mineral resource potential of those areas. The report includes mining history, geology, and mineral occurrence for a variety of types and deposits. In regards to REE minerals and deposits, many of the areas were deemed sub-economic to uneconomic, or the authors recommended further studies in order to fully understand the nature of the deposit.

McLemore, V. T., et al. (2018). Characterization and origin of episyenites in the southern Caballo Mountains, Sierra County, NM. NMGS Fall Field Conference. New Mexico: 207-216.

This study wanted to further the understanding of the tectonic setting, geologic characteristics, and mineral resource potential of the syenites found in the Caballo Mountain. To do this, the authors described the geology, conducted field investigations, age mapped, and analyzed samples using an electron microprobe. Using this data, the authors concluded that the Caballo Mountain has the potential for REE but further analysis needs to be done because large concentrations of HREE were found only in some of the samples. Many of the remaining areas were determined to be too small and of too low grade to be considered as economically viable.

McLemore, V. T. and M. Zimmerer (2009). Magmatic activity and mineralization along the Capitan, Santa Rita, and Morenci lineaments in the Chupadera Mesa area, central New Mexico. NMGS Fall Field Conference. New Mexico. Geology of the Chupadera Mesa: 375-386.

The purpose of this paper was to discuss the mineralogy, geology, magmatic history and activity, and economic potential of various deposits in the Capitan, Santa Rita, and Morencia lineaments located in the Chupadera Mesa area of New Mexico. By combining a variety of research including published data, published data, and field studies, the authors concluded that the Capitan Pluton, which contains REE-Th-U-Au veins, has uneconomic concentrations. However, the document does mention that additional deposits of REE-Th-U-Au could be located throughout the Chudadera Mesa with ongoing investigations.

Mclennan, S. M., et al. (1995). "Early Proterozoic crustal evolution: Geochemical and Nd-Pb isotopic evidence from metasedimentary rocks, southwestern North America." Geochimica et Cosmochimica Acta 59(6): 1153-1177.

According to the introduction, the major purposes of this study included to determine the chemical evolution of the continental crust, to explore the sedimentary history of the rocks, and to analyze the history of the complex sedimentary sequences. The majority of this study focused on the Hondo Group found in northern New Mexico, though some samples came from Colorado, and included REE abundance analyses. The authors tabulated their data within the report and showed that there were some samples that had high REE abundances.

Michelfelder, G. S. and N. J. McMillan (2012). Geochemistry, origin, and U-Pb zircon ages of the Sierra Cuchillo laccolith, Sierra County, New Mexico. NMGS Fall Field Conference. New Mexico: 249-260.

The purpose of this paper was to better constrain the age of the Sierro Cuchillo laccolith as well as describe the magmatic history and how the laccolith correlates to the surrounding areas. While this study did not focus on REE, it did require major and trace element data analysis, which includes a table of REE. The concentrations appear to be low, but it does display the presence of REE in those sample areas.

Migdisov, A. A. and A. E. Williams-Jones (2014). "Hydrothermal transport and deposition of the rare earth elements by fluorine-bearing aqueous liquids." Mineralium Deposita 49(8): 987-997.

The authors of this study wanted to better understand and help determine the nature of REE transport and mineral deposition in fluorine-bearing saline hydrothermal fluids. They used samples collected from the Capitan Mountains, and while the authors did not focus on concentrations of the REE or relative amounts, this article does present a good study on understanding the conditions that allow for REE deposition in saline hydrothermal fluids.

Miller, W. R. Geochemical anomalies in the vicinity of the Three Rivers Area, Otero Co., New Mexico. Open-file report: 1-14.

The purpose of this report was to investigate and determine the REE and Au mineralization resource potential in the Caballo Resource Area located in Otero and Sierra Counties. The authors described the geology, mining history, and collected stream water and stream samples to analyze the elemental composition of each. The observed anomalous concentrations of REE and Au led the authors to conclude that there is evidence for moderate REE and gold mineralization of the area. However, they recommend further studies and drilling to fully confirm the presence or lack of mineralizaton.

Miller, W. R., et al. Environmental geochemistry and mineral resource potential of the Three Rivers area and the geology of the Three Rivers Petroglyph Site, Otero County, New Mexico. Open-file report: 1-36.

The authors of this study conducted geological and geochemical studies of the areas surrounding the Three Rivers Petroglyph Site located in northeastern Otero County. In addition to mentioning the Gallinas district and its bastnaesite, as well stating that thorium and rare earth veins occur throughout the BPM area, the authors showed that the Three Rivers Area contains anomalous concentrations of certain rare earth elements. Because of this, they recommended further studies to better determine the potential, but at the time of the study believed that the area contained moderate potential as shown by the surrounding areas and water samples collected.

Modreski, P. J., et al. (1990). Mineral resources of the Chamisa, Empedrado, and La Lena WIderness Study Areas, Sandoval and McKinley Counties, New Mexico. Bulletin: 1-38.

The purpose of this report was to analyze the mineral resource potential in the wilderness areas of the Chamisa, Empedrado, and La Lena Wilderness Areas, which are located in Sandoval and McKinley Counties. In between the Empedrado and La Lena study areas, there is a small beach-placer titaniferous sandstone deposit containing rare earths of small size and low concentrations. Because of this, the area is believed to have low mineral resource potential with a certainty level of C.

Moench, R. H. and M. E. Lane Mineral resource potential of the Pecos Wilderness, Santa Fe, San Miguel, Mora, Rio Arriba, and Taos Counties, New Mexico.

The purpose of this report was to determine and described the mineral resource potential of the Pecos Wildnerness located throughout a few counties in New Mexico. The document described the geology, mining history and production, and geochemistry of the area. While the document did not mention rare-earth potential under the 'assessment of mineral resources' section, a few of the areas contain unknown potential for niobium and thorium with one of those areas containing "high abudances of yttrium."

Moench, R. H., et al. (1980). Mineral resources of the Pecos Wildnerness and adjacent areas, Santa Fe, San Miguel, Mora, Rio Arriba, and Taos Counties, New Mexico. Open-file report: 1-115.

The purpose of this study was to determine the mineral resource potential of the Pecos Wilderness Area, which the authors did by mapping, collecting and analyzing samples for their geochemistry, by interpreting aeromagnetic data, and by looking at the mining history and production of the area. The results that a few of the pegmatites and some granites in the study area contain at least trace amounts of REEs of low economic interest at the time of publication.

Moench, R. H. and J. S. Schlee (1967). Geology and uranium deposits of the Laguna district, New Mexico. Professional Paper: 1-117.

This detailed and all-encompassing document describes almost everything that there is to know about the Laguna district. The report details geology, geochemistry, location, history, and origins of many of the areas, mines, and deposits located within the district. Even though the report focused on uranium and its relationship to the geologic setting, the authors briefly mentioned REEs. In particular, it focuses on the Woodrow deposit and how it “is of particular interest because it contains cerium, dysprosium, erbium, gadolinium, lanthanum, neodymium, yttrium, and ytterbium.” The authors also mention the Sandy mine and how it contains a large variety of REEs, as well as report those results relative to uranium concentrations

Moore, S. J., et al. (2013). "Origins of yttrium and rare earth element distributions in metamorphic garnet." Journal of Metamorphic Geology 31(6): 663-689.

The authors explored the variable concentrations of REE in garnets collected from the Picuris Mountains in New Mexico and how that relates to differing origins and degrees of mobility. While this study did not focus on total REE concentrations, it is interesting to note that garnet can contain such amounts of REE, and occur in New Mexico

Muench, O. B. (1948). "A few interesting minerals of San Miguel County, New Mexico." New Mexico Miner and Prospector 10(1): 28-30.

This article lists a variety of minerals located within San Miguel County and the respective mining districts those minerals can be found in. At the end of the article, the author described a select number of minerals and their uses, including monazite. According to the article, monazite can be found near Elk

Mountain, which is east of the Willow Creek district, and southwest of Las Vegas.

Muench, O. B. (1950). "Recent analyses for age by lead ratios." Bulletin of the Geological Society of America 61: 129-132.

The purpose of this article was to analyze the age of monazite collected from a variety of areas using the lead to uranium ratio. One of the analyses included monazite collected from the Bull Creek area near Las Vegas, New Mexico.

Nelson, W. J., et al. (2012). Geology of the Fra Cristobal Mountains, New Mexico. NMGS Fall Field Conference. New Mexico: 195-210.

This paper details the geology, statigraphy, and mineral resources of the various formations and units within the Fra Cristobal Mountains. It mentions that there are episyenite deposits within the Fra Cristobal Mountains that are similar to the REE bearing episyenites of the Caballo Mountains. The authors recommend that those episyenites should be analyzed for their REE and Nb potential considering that had not been done before the time of the paper's publication.

Norman, D. I., et al. (1989). "Analysis of trace elements including rare earth elements in fluid inclusion liquids." Economic Geology 54: 162-166.

In order to understand the mobility of elements within a hydrothermal system, the authors took samples of fluid inclusion liquids within the Copper Flat deposit. They analyzed the mineralogy of these samples, which included noting REE amounts, and tabulated the results. After analyzing the results, the authors offered explanations as to why the minerals and amounts show up as they do, considering factors such as salinity of the liquid and chlorine. In association with the paper conducted by Maher and others, this is additional data to add to REE in New Mexico to influence economically viable sources.

Northrop, S. A. (1996). Minerals of New Mexico, University of New Mexico Press.

This book describes all of the known occurrences of any mineral in New Mexico and includes the mineral's abundance when applicable. It then lists all of the mining districts by county, and notes the minerals found in each. REE bearing minerals include bastnaesite, samarskite, xenotime, euxenite, chevkinite, monazite, allanite, brannerite, fergusonite, mosandrite, yttrotantalite, ancylite, brockite, cerianite, eudialyte, aeschynite, betafite, chernovite, agardite, purochlore, and gadolinite.

Nutt, C. J., et al. Geology and mineral resources of the Cornudas Mountains, New Mexico. Open-file report: 1-47.

The purpose of this report was to analyze and determine the potential for undiscovered mineral resources located in the Cornudas Mountains, including Alamo Mountain and Wind Mountain. The authors accomplished this by describing the geology, mineralogy, geochemistry, and geophysics of the area as well as by analyzing previous reports and studies conducted in the area. The authors mentioned how the area had been explored for REEs in the 1950s because of the presence of rare minerals, and how a few of those studies concluded little to no REE potential. Considering this information and the geology of the area, the report mentions that the potential for undiscovered deposits is low to moderate.

Olin, P. H. and J. A. Wolff (2010). "Rare earth and high field strength element partitioning between iron-rich clinopyroxenes and felsic liquids." Contributions to Mineralogy and Petrology 160(5): 761-775.

In this study, the authors showed that Fe-rich pyroxenes in magmatic systems have higher heavy REE concentrations than Mg-rich clinopyroxenes subjected to similar environments. While three areas were analyzed to collect the necessary data, only one of those areas was in New Mexico. REE concentrations were tabulated and reported within the article. The concentrations seem low, but this data does add to other data collected within the same area.

Orris, G. J. and R. I. Grauch (2002). Rare earth element mines, deposits, and occurrences. Open-file report. Arizona, USGS: 1-174.

The USGS worked in conjuction with the University of Arizona Center for Mineral Resources to compile a document that contains data on REE mines, occurrences, and deposits for areas both within and outside of the United States by reviewing literature published by that time. Within this document, I have

highlighted all mentions of New Mexico and will list page numbers and locations in the notes and keyword section.

Overstreet, W. C. (1967). The geologic occurrence of monazite. Professional Paper: 1-327.

This professional paper describes the geologic occurrences of monazite throughout the United States of America as well as the world. Its research is based off the literature of others, and describes the type of area reported deposits can be found in including crystalline rocks, fossil placers, and surficial deposits. When applicable, the author described the location of the deposit, the type, its basic geology, and thorium concentrations. While REE concentrations were never mentioned for the New Mexico section, monazite is an important mineral for REE and this report describes potential locations. For New Mexico, I have highlighted the relevant information, as well as recorded page numbers and locations in the fields above and below.

Page, L. R. (1950). "Uranium in pegmatites." Economic Geology 45: 12-34.

This article is a review of uranium and REE bearing minerals in various pegmatite districts across the United States and select places throughout the world. The article details geology, associated minerals, and setting. While it does not go into specifics or is very detailed towards concentration, the article mentions the Petaca district multiple times as a source of uranium and REE within New Mexico.

Perhac, R. M. (1954). Notes on the mineral deposits of the Gallinas Mountains, New Mexico. NMGS Fall Field Conference: 152-154.

This article gives a brief overview of the types of mineral deposits found in the Gallinas district. It focusses on the fluorite-copper deposits and the iron deposits, and mentions REE considering REE are often found with fluorite deposits. The important research of note given in this article is found in table 1. Samples were taken from various mines and among the analyzed minerals, bastnaesite is included. Although vague, it is valuable because it gives us a baseline measurement of bastnaesite deposits found within other mines, information that has been lacking up to this point. Bastnaesite has concentrations above trace amounts in the Red Cloud fluorite mine and the Congress mine.

Perhac, R. M. (1970). Geology and mineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology: 1-51.

The purpose of this article was to describe the geology, petrology, mineralogy, history, and mineral deposits of the Gallinas Mountains. Considering the types of minerals found in this area, the author described bastnaesite quite often, along with iron and ore deposits.

Perhac, R. M. and E. W. Heinrich (1964). "Fluorite-bastnaesite deposits of the Gallinas Mountains, New Mexico and bastnaesite paragenesis." Economic Geology 59: 226-239.

The purpose of this paper was to describe the characteristics, paragenesis, and history of the fluorite-bastnaesite deposit within the Gallinas Mountains. Because of this, this document is a valuable resource for understanding more in regards to the bastnaesite concentrations found in this area, why they occurred, and how researchers can apply those specific environments elsewhere for potential mineralization. Other important information includes that the Red Cloud Fluorite Mine has been the most important mine for bastnaesite production, many of the deposits occur within the Red Cloud district, and a majority of the deposits are found in Yeso sandstones and siltstones. The report also describes various mineralogical and optical properties of the bastnaesite, which could be important for future recognition.

Phillips, R. S. (1990). "Mineralogy and geochemistry of the veins in the Capitan Mountains, central New Mexico." New Mexico Geology 12(2): 30-33.

This abstract described the mineral deposits and veins located within the Capitan Mountains. The author mentions the REE quartz veins and the REE-thorium-uranium quartz veins, but does not give information of specific concentrations. Instead, the abstract tended to focus more on describing the mineral occurrences and offering possible explanations as to the formation of these veins. Once again, it is only an abstract and is not a complete article.

Phillips, R. S., et al. (1991). Th-U-REE quartz/fluorite veins, Capitan Pluton, New Mexico: Evidence for a magmatic/hydrothermal origin. NMGS Fall Field Conference. New Mexico: 129-136.

Rather than focus on REE specifically and display data on occurrence and amounts, the people conducting this study wanted to understand the history and the processes behind what created the mineralized veins within the Capitan Pluton. Their fluid inclusion and geochemical data showed that the anomalously high REE amounts was caused by the cracking outer shell of the Capitan Pluton that was then injected with high temperature and high salinity magmatic fluids.

Phillips, R. S. and V. McLemore (1991). Geology of the mineralization and associated alteration in the Capitan Mountains, Lincoln County, New Mexico. NMGS Fall Field Conference. New Mexico: 291-298.

The purpose of this paper was to describe the diverse mineral occurances within the Capitan pluton, the access to and history of those mineral sources, and the petrogenesis of the Capitan pluton. The authors accomplished this by conducting personal studies and geochemical analyses of samples collected from the area and by combining the previous reports accomplished by others. Based off the date of this report, the authors concluded that the Capitan Mountains could be an important resource for REE, thorium, and uranium, but upholds the fact that little data has been conducted in this area and more needs to be done before a definite conclusion can be reached. However, there is some preliminary geochemical data collected from this area that reports REE in ppm that could be useful for our purposes.

Potter, L. S. (1996). "Chemical variation along strike in feldspathoidal rocks of the eastern alkalic belt. Trans-Pecos Magmatic Province, Texas and New Mexico." The Canadian Mineralogist 34: 241-246.

The author of this article wanted to understand a portion of the Trans-Pecos Magmatic Province (TPMP) and why there are only sight chemical and mineralogical variations along the mountain range, even though the range was not sourced from the same magmatic province. Because of this, the author studied the geologic setting, petrology, tectonic history, and mineralogy, which required an analysis of the elements found within the samples such as REE. Considering this study included the extreme eastern end of the Cornudas Mountains, the results reported could serve as good correlating data for previous research conducted. It is important to note that the REE composition of those specific samples and perhaps the general area seem too low to be of economic interest.

Rakovan, J. and F. Partey (2009). Mineralization of the Hansoburg Mining district, Bingham, New Mexico. NMGS Fall Field Conference. New Mexico. Geology of the Chupadera Mesa: 387-398.

This paper focused on the mineralogy, history, geology, and geochemistry of the Hansonburg Mining district by combining literature and field studies. While this most of this paper was a broad overview of the district, the authors conducted a specific study where they took 86 fluorite samples from the district and analyzed the REE content in order to determine controls on colors through trace elements. In this instance, color of the fluorite is associated with the paragenic sequence of the fluorite, which means color enabled the authors to figure out the paragenic sequences and conclude that there is potential for two mineralization events in the district. In relation to REE, while the paper did not mention specific concentrations, the authors found a range of REE from 7 ppm to 37 ppm but did not specify the specific elements.

Register, M. E. and D. G. Brookins (1979). Geochronologic and rare-earth study of the Embudo granite and related rocks. NMGS Fall Field Conference, NMGS: 155-158.

The author wanted to add to the studies already conducted on Embudo Granite located in the Picuris Range by determinig the granite's crystallization sequence and the REE composition. Granites tend to have low REE concentrations as a general rule and this particular area of granite do not seem to be an exception to that general observation. The author reported a small enrichment in light REE, but in amounts too small to be considered economically.

Reid, M. R., et al. (1989). "Contribution of metapelitic sediments to the composition, heat production, and seismic velocity of the lower crust of southern New Mexico, U.S.A." Earth and Planetary Science Letters 95(3-4): 367-381.

These authors collected and studied granulite xenoliths erupted at Kilbourne Hole in order to try and understand crustal composition, the nature of the heat flow, and seismic velocities. While REE were not the focus of this experiment,

the authors did report on their concentrations for each sample taken, as well as mentioned that monazite could occur locally in the xenoliths.

Riggins, A. M. (2014). Origin of the REE-bearing episyenites in the Caballo and Burro Mountains, New Mexico. Department of Earth and Environmental Science. New Mexico, New Mexico Institute of Mining and Technology. Master of science: 149.

The author of this thesis studied the episyenites in the Caballo Mountains in order to determine their origin, age, and associated magmatic processes. She described the mineralogy and geology of the location, as well as analyzed samples for their geochemistry and age to learn about the different processes that made the episyenites. She reported all of her data, including REE amounts and anylses in the various appendices.

Robertson, J. M. (1976). Mining districts of northeastern New Mexico. NMGS Fall Field Conference. New Mexico: 257-262.

This paper gives a broad overview of selected mining districts and mines located within northern New Mexico. For the mentioned mines and districts, the author detailed location, history, mineralogy, and production. He mentions that the Pidlite pegmatite mine produced rare-earth minerals along with the Guy No. 1 deposit and the Old Priest Mine in the past.

Rothrock, H. E., et al. (1946). Fluorospar resources of New Mexico. Bulletin. New Mexico, New Mexico Institute of Mining and Technology: 1-233.

The purpose of this report was to describe the fluorspar deposits throughout New Mexico by breaking New Mexico into its different counties, mining prospects, and specific mines. Even though this article focused mainly on fluorspar, REE occur often with fluorspar deposits, mostly bastnaesite. I have gone through and highlighted all mentions of bastnaesite, as well as recorded the areas bastnaesite was found in in the keywords section and the relevant page numbers in the notes section of this citation.

Schrader, F. C., et al. (1917). Useful minerals of the United States. Bulletin: 1-412.

This bulletin is a compiled list of important industrial and mining minerals throughout the United States. It is organized by state with a list of minerals and where to find them below. For New Mexico, the only REE mention is monazite where, according to the document, it can be found in the black sands of Shandon in Sierra County.

Schreck, P., et al. (2005). "Multi-metal contaminated stream sediment in the Mansfeld mining district: metal provenance and source detection." Geochemistry: Exploration, Environment, Analysis 5(1): 51-57.

Schreiner, R. A. (1989). Preliminary investigation of the rare-earth-element-bearing-veins, breccia and carbonatites in the Laughlin Peak area, Colfax County, New Mexico. Open-file report. Colorado, Intermountain Field Operations Center, Denver, Colorado.

The purpose of this study was to determine and evaluate the REE resources in Laughlin Peak area. Samples were taken from veins, intrusive breccias, and carbonatites from a variety of areas and then analyzed for their REE contents. The author upheld the fact that REE concentration is high within this area, but individual concentrations depend on the type and location within that area, meaning the concentrations can be highly variable. All of the results are reported in an appendix in the back. The data collected also correlates with data taken by Staatz in a previous study,

Schreiner, R. A. (1991). Mineral investigation of the rare-earth-element-bearing deposits, Red Cloud Mining District, Gallinas Mountains, Lincoln County, New Mexico. Open-file report. Colorado, Intermountain Field Operations Center, Denver, Colorado: 1-189.

The people who conducted this study wanted to investigate and explore REE deposits within the Red Cloud Mining District. They collected samples from a variety of mines, deposits, breccias, and carbonatites within the district and reported the results within the paper. Some of the results are mentioned in the "research notes" of this citation, but the general conclusion reached by the researchers was that this district does contain high amounts of REE in certain areas, but some of those areas are either too low of grade, or need more

research in order to quantify it with more accuracy. However, the author did state that intrusive breccia pipes within the M and E No.13 prospect have the most potential for REE.

Segerstrom, K., et al. (1979). Mineral resources of the White Mountain Wilderness and adjacent areas, Lincoln County, New Mexico. Bulletin: 1-135.

The purpose of this report was to identify and describe mineral resources of the White Mountain Wilderness by describing the geology, mineralogy, and geochemistry of the area. The document mentions the presence of REEs as being characteristic of the Three Rivers stock and how anomalous concentrations were found at and near the head of Indian Creek. The area also contains xenotime, which taken with the higher than average concentrations, recommends a potential study area for REE as well as additional elements such as molybdenum. The report contains tables of the geochemistry of the samples taken

Sherer, R. L. (1990). "Pajarito yttrium-zirconium deposit, Otero County, New Mexico." New Mexico Geology 12(2).

This very brief and short article describes the Pajarito yttrium-zirconium deposit around Pajarito Mountain. It mentions how Molycorp obtained prospecting permits from the Mescalero Apache tribe and determined the deposit to have high grade yttrium deposits, but it ends at that. This current status of this deposit and possible mining is uncertain and uinknown at this point in time, and this article does little except put forth another possible resource.

Slack, J. F., et al. (2009). "Seafloor-hydrothermal Si-Fe-Mn exhalites in the Pecos greenstone belt, New Mexico, and the redox state of ca. 1720 Ma deep seawater." Geosphere 5(3): 302-314.

In order to understand the redox state of the late Paleoproterozoic deep seawater, the authors took mineralogical and geochemical data from Jones Hill. The REE reported for this area are trace elements and very low in their concentrations, but this research still adds to the knowledge of REE found within New Mexico and their abundances.

Spilde, M. N., et al. (2016). Rare-element pegmatites of the Petaca district, New Mexico. Eugene E. Foord Pegmatite Symposium. Golden, Colorado 107-109.

The authors of this abstract focused specifically on the rare-earth bearing pegmatites located within the Petaca district. It mentions that the accessory minerals include monazite, REE oxides, samarskite, and xenotime, as well as gives details and identifying factors for a few of those minerals. While this abstract does not give concentrations of REEs specifically, it does identify a majority of the known REE bearing minerals in that area.

Spilde, M. N., et al. (2011). Rare earth bearing-minerals of the Petaca district, Rio Arriba County, New Mexico. NMGS Fall Field Conference: 389-398.

The authors conducted this study in order to analyze the concentration and distribution of REE within various areas of the Petaca district in order to understand the generation of pegmatites, confirm reports conducted by other people, and to identify new REE not previously detected. Samples were taken from multiple mines, analyzed, and the results are reported within the article. The authors confirmed several new minerals and after analysis, noted that there were high concentrations of Nb and Y in the accessory minerals of this area.

Staatz, M. H. (1974). "Thorium veins in the United States." Economic Geology 69: 494-507.

This article mentions thirteen thorium-bearing veins by name distributed throughout the United States including the New Mexican localities of Laughlin Peak, Capitan Montains, and Gold Hill district. While this article does not mention specific concentrations of thorium and the REE known to occur together with thorium by mineral assemblage and association, it mentions a few of the minerals found within the thirteen areas and describes the geologic settings, structural features, and general mineralogy of the thorium veins.

Staatz, M. H. (1985). Geology and description of thorium and rare-earth veins in the Laughlin Peak area, Colfax County, New Mexico. Professional Paper.

This paper describes the work Staatz did on determining the thorium and REE concentrations in various areas in and around Laughlin Peak. He studied 29 veins carrying REE and thorium, and reported the concentrations in ppm. Some of the concentrations are very promising, especially with the yttrium-group REE.

Staatz, M. H., et al. (1965). Thorium-bearing microcline-rich rocks in the southern Caballo Mountains, Sierra County, New Mexico. Professional Paper: D1-D230.

The purpose of this report was for the authors to conduct a study in order to better understand the radioactive syenite dikes in the southern portion of the Caballo Mountains. However, their research caused themt to conclude that what were considered to be syenite dikes are actually metasomatic bodies composed of mostly microline. In order to determine this, the authors had to take samples of the area and determine the mineralogical composition of those samples. Considering these areas were abnormally radioactive, REE along with thorium and uranium were included in the sample. After analysis, the authors determined that the Ce-group elements are not abudant, ytrrium-group elements were sparse to non-existent, and economic interest seems unlikely.

Stix, J. and M. P. Gorton (1990). "Changes in silicic melt structure between the two bandelier caldera-forming eruptions, New Mexico, USA: Evidence from zirconium and light rare earth elements." Journal of Petrology 31(6): 1261-1283.

The authors of this study wanted to determine the controls and parameters that temperature, bulk composition, and volatile content have on the REE concentrations of the magma of the study area. Because of this, the authors studied the Cerro Toledo rhyolite located in the Valled Caldera and tabulated iron, zirconium, and REE concetrations as well as analyzed what the concentrations indicated about the area. In addition, the authors noted the presence of allanite and chevkinite in the Cerro Toledo Rhyolite.

Stix, J. and M. P. Gorton (1990). "Variations in trace element coefficients in the Cerro Toledo Rhyolite, Jemez Mountains, New Mexico: Effects of composition, temperature, and volatiles." Geochimica et Cosmochimica Acta 54(10): 2697-2708.

The authors of this studied analyzed the trace element partition coefficients of samples of plagioclase and sanidine collected from the Cerro Toledo Rhyolite. They did this in order to differentiate bteween the effects magma composition and crystal structure have on the sanidine coefficients. They reported the REE

composition of the samples, as well as recognized minor amounts of allanite and chevkinite within the samples they collected.

Tschanz, C. M. (1958). Radioactive phonolite and associated thorium-rare earth-niobium veins in the Laughlin Peak area, Chico Hills, Colfax County, New Mexico. Trace Elements Investigations Report: 1-4.

I could only find the abstract of this article, so this serves as a placeholder because multiple databases I searched mentioned this study specifically and I looked for it multiple times before I realized I already had. It mentions the veins containing REE, niobium, and thorium within Laughlin Peak and how the amounts have the potential to be considered as commercial sources.

Tschanz, C. M., et al. (1954). The copper and uranium deposits of the Coyote district, Mora County, New Mexico. Trace Elements Investigations Report: 1-72.

This report describes the geology, mineralogy, and structure of the various formations within the Coyote district in relation to the uranium and copper deposits. Even though REEs are only mentioned in passing, the authors noticed that REE tend to occur more with the uranium samples and the sandstones had higher concentrations of REE. After noting the occurrences, the authors attempted to explain why those concentrations existed and applied it to the overall geology of the specific area.

Tschanz, C. M., et al. (1958). Copper and uranium deposits of the Coyoto district, Mora County, New Mexico: 1-64.

The purpose of this study was to determine the presence, or lack thereof, of a large reserve of low-grade copper ore from which uranium can be obtained as a byproduct, as indicated by copper-bearing carbonaceous shale noted in previous studies of the Coyote district. To determine this, the authors analyzed the geology, stratigraphy, geochemistry, structure, and mineral deposits of the area, as well as the relationships between copper and uranium deposits. In relation to REEs, the authors that REEs are concentrated more heavily in the uranium-bearing samples rather than the copper ones, have higher than average content in the uraniferous sandstone of the district, and offer explanations on the genesis and history of the rare earths in the area.

Van Allen, B. R. and D. L. Emmons (1986). "Carbonatite dikes of the Chupadera Mountains, Socorro County, New Mexico." New Mexico Geology 8(2): 25-40.

The authors of this article described the geology, mineralogy, geochemistry, and history of carbonatite dikes located within the Chupadera Mountains. They mention that the area has an enrichment in REEs, as well as report some of the geochemical results in a table that describes the mean and average of select elements for the samples they studied. In addition, as a side note, the authors briefly mention the Caloso Formation and how it contains no detectible REEs.

Vance, Z. (2013). Mineralogy, geochemistry, and genesis of the hydrothermal REE-fluorite-Ag-Pb-Cu ore deposits of the Gallinas Mountains, New Mexico. Earth and Environmental Science. New Mexico, New Mexico Institute of Mining and Technology. Master of Science: 209.

The author of this thesis conducted this study in order to determine and constrain the relationship between REE and sulfide mineralization, as well as see if a carbonatite influences that process in regards to mineralization and hydrothermal fluid generation. In addition, the author analyzed the genesis of the bastnaesite-fluorite deposits and the history of the hydrothermal fluids responsible for the mineralogy. To do this, the author described the geology, mineralogy, and geochemistry of the area and samples, and reported his work throughout the thesis and the appendices at the end.

Verplanck, P. L., et al. (1999). "The chemical and isotopic differentiation of an epizonal magma body: Organ Needle Pluton, New Mexico." Journal of Petrology 40(4): 653-378.

The authors wanted to understand the origin and evolution of the magmas that created the Organ Needle Pluton, which they did by collecting samples, obtaining trace element data, and analyzed the surrounding areas using geochemical data. Their results are reported in a series of tables that include REE abundances, which we can look at to see if Organ Needle Pluton or the surrounding areas are possible candidates for future research. The REE abundances fluctuated depending on the sample and location, and few seemed to contain large deposits.

Wallace, C. J. and K. C. Maher (2019). "Phyllic alteration and the implications of fluid composition at the Copper Flat hydrothermal System, New Mexico, USA." Ore Geology Reviews 104: 273-293.

The authors took various samples from the Copper Flat system in Hillsboro, New Mexico to study the extent of phyllic observation. This experiment required elemental analysis to determine alteration minerals both major and minor, which included REEs. The authors reported an enrichment in REEs and tabulated their abundance within the report

Walters, A., et al. (2010). Rare earth elements, British Geological Survey: 1-44.

This article gave a broad overview of REE, the type of deposits they commonly show up in, areas of economic interest, environmental implications, and processing and producing REEs. The article mentions the Gallinas Mountains and the hydrothermal veins located there, as well as contains a map of areas of important REE deposits, which includes Pajarito Mountain and the Gallinas Mountains.

Wells, R. C. (1928). "Note on the J. Lawrence Smith method for the analysis of samarskite." Journal of the American Chemical Society 50: 1017-1022.

The author of this article commented on and analyzed the J. Lawrence Smith method for decomposing samarskite using hydrofluoric acid. While a majority of this article focusses more on that analysis instead of the samarskite itself, the author mentioned that the sample was collected near Petaca, New Mexico.

Williams, M. L., et al. (1999). "Age mapping and dating monazite on the electron microprobe: Deconvoluting multistage tectonic histories." Geology 27(11): 1023-1026.

The authors of this article wanted to determine of age mapping of monazite crystals could serve as an accurate technique for dating the age and tectonic activity of the area. They collected samples from the Tusas Mountains and from an area in Norway, and looked as qualities such as zoning and using electron microprobe mapping. While this study does not report concentrations or occurrence levels of that monazite within the Tusas Mountains, it does recognize that monazite exists in that area.

Williams, S. A. (1978). Mineralization at Granite Gap, Hidalgo County, New Mexico. NMGS Fall Field Conference: 329-330.

This small paper details the mineralogical information of Granite Gap found in Hidalgo County. It briefly mentions that monazite is an accessory mineral in the area, but does not give any data on concentrations or occurrence.

Williams-Jones, A. E., et al. (2012). "Hydrothermal Mobilisation of the Rare Earth Elements - a Tale of "Ceria" and "Yttria"." Elements 8(5): 355-360.

This article gives a short history of hydrothermal mobilization before briefly talking about key deposits found throughout the world. It mentions the Gallinas Mountains and Capitan Pluton by name, and although it does not give REE concentrations, it supports data and has some valuable references.

Williams-Jones, A. E., et al. (1997). "Hydrothermal REE-fluorite mineralization in the Gallinas Mountains, New Mexico, USA." Mineral Deposits Papunen: 687-690.

The purpose of this study was to determine the nature of the fluids responsible for the formation of the fluorite-REE deposits located within the Gallinas Mountains and use that data to develop a genetic model for that mineralization. In relation to REE, the author mentioned the minor presence of bastnaesite and xenotime in the Pinatosa deposit, and the presence of bastnaesite in the Red Cloud mining district. When applicable, the authors then describe the appearance and relative amount of those rare earth-bearing minerals.

Williams-Jones, A. E., et al. (2000). "The genesis of hydrothermal fluorite-REE deposits in the Gallinas Mountains, New Mexico." Economic Geology 95(95): 327-342.

While this article does not focus on specific concentrations of REE in the Gallinas Mountains, it contains important research for finding REE deposits in similar environments and supports the Red Cloud Mining District as a legitimate and economically important REE source.

WoldeGabriel, G., et al. (1999). "Effects of shallow basaltic intrusion into pyroclastic deposits, Grants Ridge, New Mexico, USA." Journal of Volcanology and Geothermal Research 92: 389-411.

The purpose of this experiment was to determine the effects of shallow magmatic intrusions had on the host rocks in Grants Ridge. The researches accomplished this in part by taking samples of the surrounding areas and determining their major and trace element compositions, which included REE. There is a table in the report that gives REE in ppm that we can analyze to determine if this area has the potential to be of interest for our purposes

Wolff, J. A. and F. C. Ramos (2014). "Processes in caldera-forming high-silica rhyolite magma: Rb-Sr and Pb isotope systematics of the Otowi Member of the Bandelier Tuff, Valles Caldera, New Mexico, USA." Journal of Petrology 55(2): 241-458.

The authors wanted to understand the origins of the elemental and isotopic variations in the Otowi Member of the Bandelier Tuff, which caused them to take samples of the surrounding elements and analyze their chemical components, including REE. REE were not an essential part of the experiment, so little information is known and not tabulated in the article. The article did note that concentrations are high for the MREE and HREE.

Woodward, L. A. (1991). Tectono-metallogenic maps of mining districts in the Lincoln County porphry belt New Mexico. NMGS Fall Field Conference. New Mexico. Geology of the sierra Blanca, Sacramento, and Capitan Ranges, New Mexico: 283-290.

The author of this article analyzed tecto-metallogenic maps and literature regarding multiple mining districts located within the Capitan Mountains to determine the tectonics of the area, the structure of the rocks, and the mineralogy for each of the districts. In relation to REEs, he mentioned the production of bastnaesite in Lincoln County and that lanthanum, cerium, and yttrium are found within the allanite of the Capitan Mountains district.

Wright, L. A. (1948). "The Globe pegmatite, Rio Arriba County, New Mexico." American Journal of Science 246: 665-688.

This article describes the mineralogy, structure, and basic paragenesis of the Globe pegmatite located within the Petaca district. The author mentions that monazite is a common mineral within the area, while samarskite is a rare accessory mineral. She then goes on to describe their relative sizes, mineral assemblages, habits, and appearances along with all of the other minerals she noticed in her studies.

Young, R. W. and O. B. Muench (1953). "The chemical analysis of an euxenite for age determination." American Journal of Science 251: 784-788.

The authors of this article wanted to analyze a sample of euxenite taken from Bull Ckreek, which is located near Pecos, New Mexico, in order to determine an age using the lead content. While the authors determined an age, it was highly variable considering the small amount of lead present. However, this article does mention that minerals such as euxenite, samarskite, and monazite occur around Willow Creek, and reported the rare-earth oxide content of their sample as 13.96%.

Zadra, J. B., et al. (1952). Concentration of bastnaesite and other ores. Report of Investigations: 1-15.

The article describes the concentration of REE in samples of bastnaesite or fluorspar collected from either Mountain Pass, California or the Zuni Mountains in New Mexico. The concentrations are tabulated within the report along with a detailed analysis of how the concentrations were determined

Zech, R. S., et al. (1994). Heavy-mineral placer deposits of the Ute Mountain Ute Indian Reservation, southwestern Colorado and northwestern New Mexico. Bulletin: 1-52.

The report focused on the analysis of various samples of heavy mineral placer deposits collected from Ute Mountains in order to determine their subsurface extent. While some of the samples were taken from Colorado, a good portion of them were collected from New Mexico and analyzed for their mineralogical components, which included REE. The REE compositions are reported in the appendix near the end of the paper, and could be valuable to look at for our purposes in order to determien econimic viability. These samples are located on

an Indian reservation, which could make it difficult, but some of the concentrations reported seem promising, especially for cerium.

Zelenka, B. R. (1984). Distribution and interpretation of granitic uranium occurrences in the Vermejo Park Ranch, north central New Mexico. Fairbanks, Alaska, University of Alaska. Master of Science: 184.

With this thesis, the author wanted to describe the geology, mineralogy, formation, and economic potential of the uranium occurrences located within the Costilla massif on the Vermejo Park Ranch. To do this, the author did a comprehensive analysis on the regional geology, observed metamorphism, and mineralogical studies on the uranium present as well as trace elements including REE. There are multiple tables within the report that display the concentrations for the samples analyzed, and based off the information gathered, the author determined that the area does have economic potential for uranium deposits.

Zumlot, T., et al. (2009). "Geochemical mapping of New Mexico, USA, using stream sediment data." Environmental Geology 58(7): 20.

The author used stream sediment data collected during the national uranium resource evaluation and used that data to identify geochemical signatures and to determine the source of the various elements found. Even though this study does not focus on REE concentrations found in any particular area of New Mexico, it is interesting to note that the author determined the following based off the data: there are strong, localized clusters of REE in the Organ Mountains, Boot Heel, San Andres Mountain, and El Capital Mountains; common REE elements are found in certain felsic igneous rocks and pegmatites.