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POTENTIAL LITHIUM RESOURCES IN NEW MEXICO

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ABSTRACT

Critical minerals are mineral resources that are essential to our economy and whose supply may be disrupted; many critical minerals are 100% imported into the U.S. Lithium is a critical mineral used in many industrial products, such as lubricating grease, glass fabrication and glazes for ceramics, health products, and batteries for cars, cellphones, and other devices. In addition, lithium is alloyed with copper and aluminum to fabricate lighter components in airplane frames. Several hundred short tons of spodumene ore were produced from pegmatites in New Mexico since 1920. Most of this production, which represents nearly 10% of the total U.S. lithium production between 1920 and 1950, came from the Harding mine, Picuris mining district, Taos County. Several lithium-bearing pegmatite dikes are found in Precambrian rocks in the Sangre de Cristo Range, Mora and San Miguel Counties that have potential for lithium resources. Future potential for lithium in New Mexico is in modern and ancient playa lakes, especially in the Estancia Lake in Torrance County, Lordsburg playa in Hidalgo County, and the Popotosa Formation in Socorro County. These playa deposits have nearby rhyolites that could be a source for lithium.

INTRODUCTION

Lithium is a critical mineral used in many industrial products, such as lubricating grease, glass fabrication, glazes for ceramics, synthetic rubbers, special concretes, health products, and batteries for cars, cellphones, and other devices. In addition, lithium is alloyed with copper and aluminum to fabricate lighter components in airplane frames (Bradley and Jaskula, 2014). Lithium is important as a catalyst in manufacturing. Newly developed lithium-ion batteries promise to increase driving ranges of electric automobiles, thereby reducing auto emissions from gasoline-driven automobiles (Goonan, 2012). Lithium-ion batteries also will be used to store renewable energy from solar and wind farms.

A critical mineral, which is defined by U.S. Presidential Executive Order No. 13817 (2017) as "*a mineral (1) identified to be a nonfuel mineral or mineral material essential to the economic and national security of the United States, (2) from a supply chain that is vulnerable to disruption, and (3) that serves an essential function in the manufacturing of a product, the absence of which would have substantial consequences for the U.S. economy or national security*". Critical minerals are mineral resources that are mostly imported into the U.S., are essential to our economy, and whose supply may be disrupted (Committee on Critical Mineral Impacts of the U.S. Economy, 2008; Schulz et al., 2017). Disruptions in supply chains can arise for any number of reasons, including natural disasters, labor strife, trade disputes, resource nationalism, conflict, and so on. In order to make alternative energy sources, such as solar power and wind farms, effective, we need rechargeable long-term storage lithium-ion batteries. As countries prioritize the transition to renewable energy sources, lithium demand is expected to increase (Jaskula, 2018).

Lithium is the lightest of the metals and is a highly reactive metal that does not occur naturally in its elemental form (Bradley and Jaskula, 2014). Instead, it occurs predominantly as the hardrock minerals spodumene ($LiAlSi_2O_6$), petalite ($LiAlSi_4O_{10}$), and lepidolite ($KLi_2Al(Si_4O_{10})(F,OH)_2$), or in lithium-rich clay minerals, or dissolved lithium chloride (LiCl) (Kesler et al., 2012).

There are three basic types of economic lithium deposits: 1) peralkaline and peraluminous pegmatites and associated metasomaticic rocks, 2) volcanic clays, generally containing Li-rich hectorite, and 3) brine and hydrothermal (geothermal) deposits, including salar evaporates, continental playa lakes, and oil field and geothermal brines (Kesler et al., 2012; Bowell et al., 2020). In addition, some manganese deposits contain high concentrations of lithium and lithium is also found in seawater. Historically, most lithium in the world, including in New Mexico, was mined from pegmatites (i.e., igneous rocks with large interlocking crystals) and, today, lithium production from pegmatites accounts for approximately one fourth of the world's lithium production (Bradley et al., 2017a). Currently, Australia exports the majority of pegmatite-sourced lithium (Goonan, 2012; Bradley et al., 2017b). Economic pegmatite deposits typically contain 110-943 kilotons of 0.5-1.2% Li (Bowell et al., 2020). The average concentration of lithium in the earth's crust is approximately 20 ppm (Bradley and Jaskula, 2014). Most of the economic pegmatites are classified as lithium-cesium-tantalum (LCT) pegmatites (Brady et al., 2017a).

However today, most lithium production comes from solars, subsurface brines, and playa lakes located in closed-basins, where lithium exists primarily as soluble lithium chloride (Asher-Bolinder, 1991b; Goonan, 2012). In arid regions, subsurface brines are pumped into a series of surface ponds, where water evaporates, concentrating lithium chloride (Bradley et al., 2017b). The lithium chloride is then treated with sodium carbonate to form lithium carbonate (Li_2CO_3) (Goonan, 2012). Economic brine deposits typically contain 41-6,300 kilotons of 0.01-0.2% Li and economic Li-clay deposits typically contain 209-845 kilotons of 0.17-.024% Li (Bowell et al., 2020). Near-by rhyolites are suspected sources of lithium (Bradley et al., 2013, 2017a; https://www.usgs.gov/media/images/lithium-brine-and-clay-conceptual-model).

Closed-basin brine deposits contain an estimated 58% of the world's lithium resources (Bradley et al., 2017b). Countries that export significant amounts of lithium from brines or playa lakes are Chile, Argentina, China, and Australia (Goonan, 2012). The only location of lithium production currently active in the United States is a brine operation at Clayton, Nevada (Jaskula, 2019). Geothermal waters and oilfield brines also are known to contain locally high concentrations of lithium (Bradley et al., 2017), resources that are not currently exploited. Lithium also occurs in clay minerals, such as hectorite, a member of the smectite clay mineral family (Bradley et al., 2017). Known methods for extracting lithium from clays are not yet economically viable.

The purposes of this report are to 1) summarize the resource potential for lithium in New Mexico, 2) update an earlier compilation by McLemore and Austin (2017), and 3) suggest areas in the state for future lithium exploration. For the purposes of this report, a lithium occurrence is defined as 1) production of lithium minerals, 2) whole-rock chemical analysis of approximately 100 ppm total lithium (Tourtelot and Meier, 1976) or 3) lithium-bearing minerals found in sufficient quantities to be considered a potential mineral resource.

LITHIUM IN NEW MEXICO

Lithium is found in New Mexico in all three types of deposits: 1) pegmatites, 2) volcanic clays, and 3) brine, hydrothermal (geothermal), and playa deposits (Fig. 1).

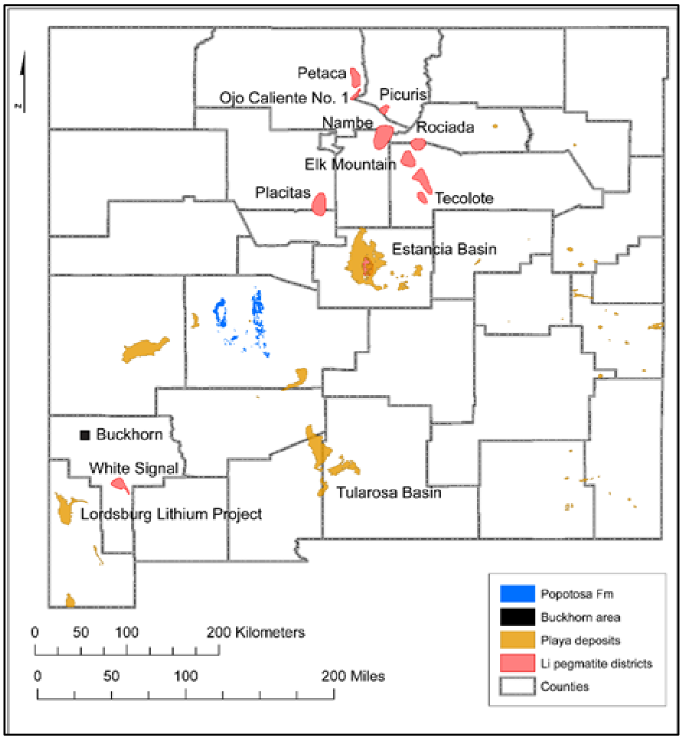

Figure 1. Areas in New Mexico that contain potential lithium deposits (modified from McLemore and Austin, 2017). Summary of pegmatite districts is in McLemore (2017).

Pegmatites

Pegmatites are coarse-grained igneous rocks, lenses, or veins with granitic composition, contains essential quartz and feldspar, and represent the last and most hydrous phase of crystallizing magmas (Page and Page, 2000; Ercit, 2005; McLemore and Lueth, 2017; Brady et al., 2017a). Complex pegmatites include prominent mineralogical and/or textural zones. Pegmatites can contain a variety of economic minerals, including, mica, quartz, feldspar, and minerals containing lithium, cesium, tantalum, niobium, REE, rubidium, yttrium, scandium, uranium, thorium, tin, boron, beryllium and others. LCT (lithium cesium tantalum) pegmatites are a compositionally defined class of complex granitic pegmatites that contain lithium, cesium, and tantalum minerals (lithium in spodumene, petalite, and lepidolite; cesium in pollucite; and tantalum in columbite-tantalite).

Most of the pegmatites found in New Mexico are associated with the Late Proterozoic granite plutonism of 1450–1400 Ma, although some possibly may be as young as 1100-1200 Ma. The pegmatites in New Mexico vary in size, but are typically several hundred meters long and several tens of meters wide. Simple pegmatites consist of feldspar, quartz, and mica, whereas complex pegmatites are mineralogically and texturally zoned, and consist of a variety of rare minerals. Several commodities have been produced from complex pegmatites in New Mexico in the past; including mica, quartz, feldspar, beryl, lithium, uranium, thorium, REE, niobium, tantalum, tungsten, and gem stones (McLemore and Austin, 2017). At least 75 pegmatites in New Mexico contain lithium, REE, niobium, and thoium. Additional commodities occur in pegmatites that could be recovered, including antimony, rubidium, and molybdenum (Jahns, 1946; McLemore et al., 1988a, b; McLemore and Chenoweth, 2017; McLemore, 2020).

Two major lithium-bearing minerals in pegmatites are spodumene and lepidolite. More than 13,000 short tons of lepidolite ore and several hundred short tons of spodumene ore have been produced from pegmatites in New Mexico since 1920. Most of this production, which represents nearly 10% of the total U.S. production between 1920 and 1950, came from the Harding mine (Picuris district, Taos County). A small amount came from the Pidlite mine (Rociada district, San Miguel County).

The Harding mine was discovered in 1910, but mining did not start production until 1920 for lepidolite. Operations ceased in 1930 after the production of more than 12,000 short tons of lepidolite ore averaging 3.5% Li_2O (Schilling, 1960). The Harding pegmatite is a tabular body that dips gently to the southwest, is more than 100 m wide, extends 1000 m down dip, and averages 15-16 m thick. It is complexly zoned and contains a quartz-microcline-muscovite-albite-beryl wall zone; a zone of massive quartz below the hanging-wall zone, which grades downward into a thick zone of quartz and spodumene that contains some beryl; and a core of coarse-grained spodumene, microcline, and quartz with varying quantities of albite, muscovite, lepidolite, and tantalum minerals. Although the pegmatite may have been symmetrically zoned, many of the original lithologic units in the lower half have been obscured by the formation of late replacement albite and mica (Jahns, 1951).

Several lithium-bearing pegmatite dikes in Precambrian gneiss and schist are exposed in an area at least 3.4 km long on the east slope of the Sangre de Cristo Range near the headwaters of Sparks and Maestas Creeks in Mora and San Miguel Counties (Jahns, 1953). One of the largest of these bodies was mined by the Hayden Mining Co. at the Pidlite mine in 1946–1947. The pegmatite is a discoidal lens that contains a border zone of albite-quartz-muscovite-perthite pegmatites with accessory apatite, beryl, fluorite, spessartite, and tourmaline; a wall zone of coarse-grained perthite-quartz-albite-muscovite pegmatite; an intermediate zone of quartz-perthite; and a core of massive quartz. Cleavelandite, muscovite, and lepidolite occur in replacement bodies.

No production of lithium minerals in New Mexico has been reported since 1950. Recent exploration for lithium has occurred in New Mexico pegmatites and possible nearby placer deposits derived from pegmatite districts in the Petaca, Ojo Caliente No. 1, and Rociada districts in northern New Mexico (Fig. 1). Typically minerals containing these rare commodities are scattered discontinuously throughout the pegmatite, thereby hampering economic recovery.

Volcanic clays

Lithium is found in ancient closed basins in the form of high-lithium clays, hectorite, montimorillonite, and bentonite (Asher-Bolinder, 1991a, b). In New Mexico, lithium-rich volcanic tuffs in the Popotosa Formation contain lithium values as high as 3800 ppm Li (Brenner-Tourtelot and Machette, 1979: Asher-Bolinder, 1982, 1991a). However, no lithium has been produced from these deposits. The Popotosa Formation represents early basin fill of the Rio Grande rift and consists of intertonguing fanglomerates, alluvium, and playa deposits. The playa facies is best exposed between the Lemitar and Ladron Mountains north of Socorro. Lithium also can be found in surface and subsurface brines associated with these clay deposits (Asher-Bolinder, 1991b). Lithium is likely derived from alteration of the volcanic rocks in the Socorro and Lemitar Mountains (Asher-Bolinder, 1982).

Most of the basin fill in southwestern New Mexico is part of the Pliocene to Pleistocene Gila Conglomerate that correlates with the Santa Fe Group along the Rio Grande (Tourtelot and Meier, 1976). Most of the edges of the basins are conglomerate and sandstone, whereas the centers of the basins are gypsum, volcanic tuffaceous beds, diatomite, and thin fresh-water limestone and clay, deposited in lakes.

Lithium-bearing lacustrine deposits of clay, silt, chert, zeolite, and diatomite are found in the Gila Conglomerate in the Buckhorn area along Highway 180 west of Silver City, New Mexico (Fig. 1). Both zeolite and diatomite have been prospected. Zeolites were first discovered in the Buckhorn area in 1962 by T.H. Eyde during a zeolite exploration program for Union Carbide Corporation (Mumpton, 1984). Subsequent studies mapped the zeolitic volcanic tuffs, which cover approximately 11 km^2 in this part of the Mangas Basin (Olander, 1979; Eyde, 1982; Bowie et al., 1987; Sheppard and Gude, 1987; Gude and Sheppard, 1988). The Mangas Basin is a N-NW-trending graben characterized by alluvial fans and a shallow, closed basin called Lake Buckhorn (Mack and Stout, 2005).

The Buckhorn lacustrine rocks were deposited within Lake Buckhorn (Mack and Stout, 2005) and consist of 45 m of brown, gray, and red mudstone and siltstone with interbeds of limestone, chert, and volcanic ash-fall tuff. The marker tuff (Gude and Sheppard, 1988) is the principal zeolitic unit, multiple bedded, thin to thick bedded, and locally cross bedded. The paragenetic sequence (from early to late) is smectite, chabazite, clinoptilolite, erionite, and then analcime (Gude and Sheppard, 1988). Fluorite is common in many of the deposits (Shepard and Mumpton, 1984). Diatomite beds are found in the center of the lake, not far from the zeolitic beds (Mack and Stout, 2005). Chemical analyses of the Buckhorn deposit indicate values of 14 to 200 ppm Li (Tourtelot and Meier, 1976). Fluorite and zeolite are found with the lithium. Quaternary gravels commonly cover the zeolitic tuff along the badlands slopes.

Brine, hydrothermal (geothermal), and playa deposits

Brine and hydrothermal (geothermal) deposits in New Mexico are generally associated with modern playa lake beds (Fig. 1) and can contain high concentrations of lithium (Neupane and Wendt, 2017). Both types of deposits form together and are being examined for lithium potential.

Water samples near a playa lake in the northern Estancia Basin, Torrance County (Fig. 1), contain anomalously high lithium (as much as 624 ppb Li, McLemore, 2010), boron (as much as 5013 ppb B), uranium (as much as 344.7 ppb U), strontium (as much as 6091 ppb Sr), and magnesium (as much as 1320 ppm Mg). The Estancia Basin is a closed basin bounded on the east by the Pedernal Hills and on the west by the Sandia and Manzano Mountains.

The Lordsburg Lithium Project is in the Animas Valley in southwestern New Mexico, near the town of Lordsburg (Fig. 1, 2). The Animas Valley is a closed basin with a playa surface, bounded by the Pyamid Mountains to the east and Peloncillo Mountains to the west and comprises of clays, silts and highly saline brines. A nearby NURE (National Uranium Resource Evaluation) stream sediment sample contained 124 ppm Li and a water sample contained 4896 ppb Li (Fig. 2). Modern waters in the alkali flats are sodium-chloride-sulfate waters with TDS values exceeding 1000 mg/L (Hibbs et al., 2000). Local, active hot wells (Lightning Dock geothermal area) are along the eastern edge of the valley and has provided high regional heat flow to drive fluid movement. Structures provide fluid pathways and potentially form structures that create brine pool traps. The arid climate of southern New Mexico allows for brine formation, and geological age relationships demonstrate that sufficient accumulation time was available in this long-lived basin to develop sustainable brines. Many of the rhyolites found in the mountains surrounding the basin have been dated and geochemically analyzed by McIntosh and Bryan (2000); however, those analyses do not include lithium. Lordsburg Resources (Frank Bain) applied for state drilling exploration permits (http://www.emnrd.state.nm.us/MMD/MARP/documents/Application_LordsburgPlayaLithiumExploration_HI018EM.pdf). Hawkstone Mining Ltd. (http://hawkstonemining.com.au/lordsburg-lithium/) and Santa Fe Gold Corp. have mining claims in the area. The Buckhorn zeolite-fluorite prospect is to the north.

Other sources of lithium in New Mexico

High concentrations of lithium (0.02-2790 ug/L Li) have been reported from groundwater in the Ogallala aquifer in Texas (Hudak, 2016). Similar concentrations likely occur in the New Mexico portion of the aquifer.

Lithium concentrations are locally enriched in rhyolites and rhyolites are postulated as a source of lithium in New Mexico playa lakes and brines (Hofstra et al., 2013). In the Valles caldera, Jemez Mountains, Upper Bandelier rhyolite tuffs contain as much as 203 ppm Li (Dunbar and Hervig, 1992), whereas some volcanic breccias contain as much as 267 ppm Li (Higgins, 1988). Rhyolites from the Taylor Creek tin district in south-central New Mexico contain as much as 652 ppm Li (Webster and Duffield, 1994).

Oil field produced waters in New Mexico should be examined for potential lithium.

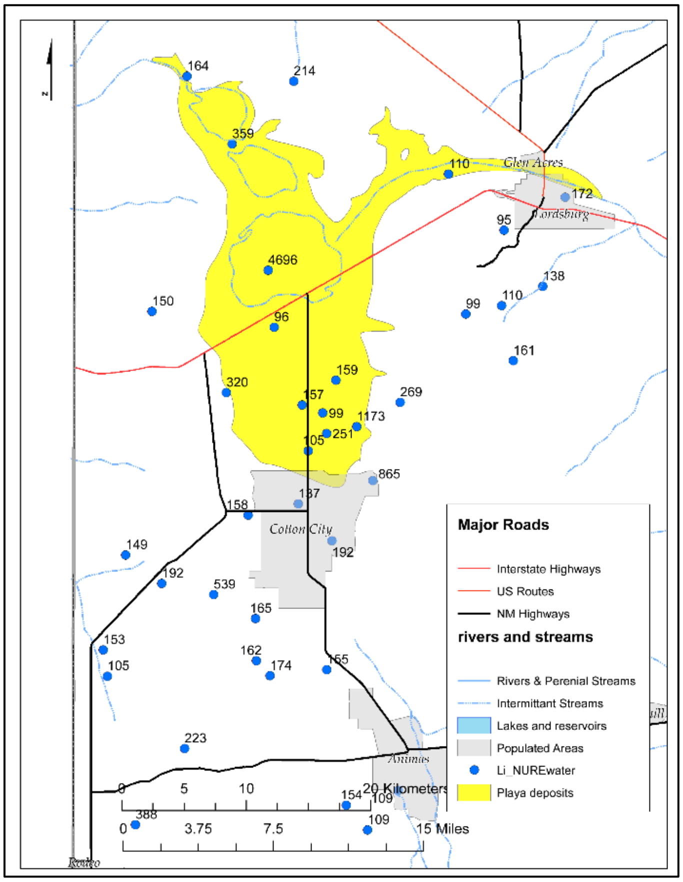

Figure 2. Water analyses (in parts per billion, ppb) from NURE data in the Lordsburg playa, Hidalgo County, New Mexico. Note the sample in the middle of the yellow playa, which is 4696 ppb.

SUMMARY

Although lithium is not currently being produced from New Mexico, significant production occurred from pegmatite deposits before 1950. Recent exploration for lithium has occurred in New Mexico pegmatites and possible nearby placer deposits in the Petaca, Ojo Caliente No. 1, and Rociada districts in northern New Mexico. Playa lake deposits and associated brines are currently being examined for lithium potential in the Lordsburg and Tularosa basins. The Estancia Basin also has some potential for lithium. Ancient playa deposits in the Popotosa Formation in the Socorro area and Gila Conglomerate in the Buckhorn areas were examined in the past for lithium and should also be re-examined for lithium potential.

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