MINERAL DEPOSITS ASSOCIATED WITH TERTIARY ALKALINE IGNEOUS ROCKS IN NEW MEXICO

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ABSTRACT

Lindgren (1933) was one of the first geologists who noted that a belt of alkaline-igneous rocks extends from Alaska and British Columbia southward into New Mexico, Trans-Pecos Texas, and eastern Mexico and that these rocks contain relatively large quantities of gold, fluorine, zirconium, rare earth elements (REE), and other elements. Since then, the North American Cordilleran alkaline-igneous belt has been explored and exploited for numerous types of mineral deposits, especially gold. In New Mexico, the belt extends from the Sangre de Cristo Mountains near Raton, southward to the Cornudas Mountains, in the northern Trans-Pecos alkaline belt. Significant mineral production in New Mexico, especially gold, has come from deposits found within this belt. The New Mexico deposits have been referred to as Great Plains Margin deposits (GPM), Au-Ag-Te veins, Th-REE veins, alkaline-igneous related gold deposits, porphyry gold deposits, and Rocky Mountain gold province. Mid-Tertiary alkaline to subalkaline igneous rocks are found associated with mineral deposits in these districts and, in New Mexico, consist of seven deposit types: (1) polymetallic epithermal/mesothermal veins, (2) gold-bearing breccias/quartz veins (tellurium), (3) copper-gold/gold/molybdenum porphyries, (4) copper, lead/zinc, and gold skarns and carbonate-hosted deposits, (5) iron skarns and replacement bodies, (6) gold placers, and (7) Th-REE epithermal veins. Some of New Mexico's largest gold and REE deposits are found within this belt. The Elizabethtown-Baldy district, Colfax County has produced an estimated 14,649,984 g Au. In the Old Placers district, Ortiz Mountains, the Carache Canyon breccia deposit is estimated to contain reserves of 11.7 million metric tons of 1.6 g/t Au and the Lukas Canyon skarn deposit is estimated to contain reserves of 13 million metric tons of 0.9 g/t Au. Production from this district is estimated at 13,996,800 g Au. Gold values in alkaline-igneous deposits are generally higher than other deposits in New Mexico and have high gold/base-metal ratios and low silver/gold ratios, unlike other deposits in the state. Deposits of REE are found in several districts, but typically not with gold. In 1991-1992, U.S. Bureau of Mines (USBM) calculated an inferred resource of 0.487 million metric tons of total REE (grade of 2.95% total REE) in the Gallinas Mountains district and recent drilling has occurred in the Cornudas Mountains looking for REE. The origin of these deposits is not well understood, but a compilation of new and past data, including new dates and isotopic and chemical analyses of igneous rocks and associated mineral deposits, allows for a better understanding of the origin of these deposits. The diversity of igneous rocks and associated mineral deposits along the boundary of the Great Plains with the Southern Rocky Mountain and Basin and Range provinces suggests that this region is characterized by highly fractionated and differentiated, multiple pulses of magmas. Both upper mantle and lower crustal source rocks may be involved, along with local hot spots. Deep-seated fracture systems or crustal lineaments probably channeled the magmas and hydrothermal fluids. Once magmas and metal-rich fluids reached shallow levels, local structures and wall rock compositions determined distribution of and final style of intrusions and resulting mineral deposits.

INTRODUCTION

The Rocky Mountain alkaline belt is a north-south belt of alkaline-igneous rocks and crustal thickening, roughly coinciding with the Great Plains physiographic margin with the Basin and Range (Rio Grande rift) and Rocky Mountains physiographic provinces. This belt is associated with relatively large quantities of gold, copper, fluorite, rare earth elements (REE), uranium, and other elements and continues northward into Canada and southward into Mexico (Fig. 1; Mutschler et al., 1985, 1991; Bonham, 1988; Thompson, 1991a; Richards, 1995; McLemore, 1996; Kelley and Luddington, 2002). The alkaline-igneous related mineral deposits in New Mexico have been referred to as Great Plains Margin (GPM) deposits by North and McLemore (1986, 1988) and McLemore (1996, 2001). Alternative classifications by other workers include Au-Ag-Te veins (Cox and Bagby, 1986; Bliss et al., 1992; Kelley et al., 1998), alkalic-gold or alkaline-igneous related gold deposits (Fulp and Woodward, 1991a; Thompson, 1991a, b; Bonham, 1988; Mutschler et al., 1985, 1991; Richards, 1995), porphyry gold deposits, and the North American Cordilleran belt of alkaline igneous rocks (Woolley, 1987; Mutschler et al., 1991). The purposes of this presentation are to (1) summarize the geology, geochemistry, and mineral production of alkaline-igneous related mineral deposits in New Mexico, (2) discuss the age and formation of these deposits, (3) evaluate compiled data, and (4) comment on the future economic potential of mineral deposits in New Mexico.

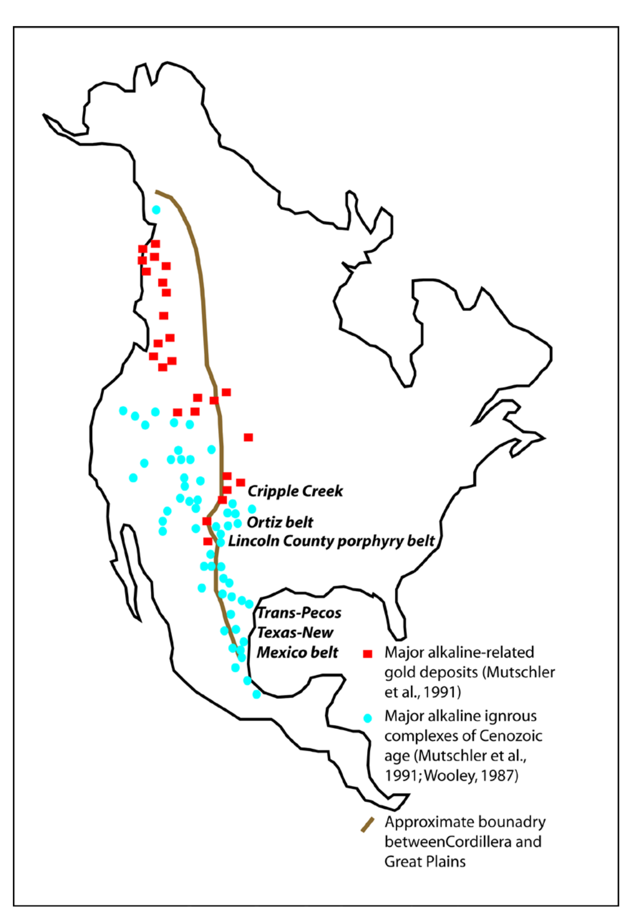

FIGURE 1—Extent of the Rocky Mountain alkaline belt (Woolley, 1987; Mutschler et al., 1991; McLemore, 1996).

DEPOSITS IN NEW MEXICO

Types of Alkaline-related Deposits

- Polymetallic epithermal/mesothermal veins (Au, Ag, Cu, W, Te?)
- Au-bearing breccias/quartz veins (W, Te?)
- Cu-Au, Au and Mo porphyry deposits
- Cu, Pb/Zn, and Au skarns and carbonate-hosted deposits (W, Te?)
- Fe skarns and replacement bodies (with some Au)
- Au placers
- Th-REE (with some U, Nb) epithermal veins

TABLE 1—Alkaline-igneous mining districts in New Mexico. Names of districts are after File and Northrop (1966) wherever practical, but many former districts have been combined and new districts added. The district number refers to the New Mexico Mines Database district number (McLemore et al., 2005a, b). Districts are shown in Figure 2.

District Id	Name	Associated Volcanic Field	Type of deposit	Selected elements	Age Ma	veins	breccia pipes	porphyry	other skarns	Fe skarns	REE veins	placers	Selected References
DIS237	Questa	Latir	porphyry Mo	Mo, Be	22.7-28.5	x	x	x					McLemore (2009), McLemore et al. (2009), Zimmerer and McIntosh (2012)
DIS238	Red River	Latir	veins	Au, Ag, Cu, Be, Te	24.9	x						x	Roberts et al. (1990), Zimmerer and McIntosh (2012)
DIS018	Cimarroncito	Cimarron porphyry	veins, placer	Au, Ag	29.1	x						x	Lindgren et al. (1910), Kish et al. (1990)
DIS019	Elizabethtown-Baldy	Cimarron porphyry	veins, skarns, placer	Au, Ag, W, Te	29.1	x			x	x		x	Lindgren et al. (1910), Kish et al. (1990)
DIS020	Laughlin Peak	Laughlin Peak-Chico Hills	REE-Th-U veins	REE, Th, U	22.8-32.3	x	x				x		Stroud (1997), Staatz (1985), Potter (1988)
DIS180	Cerrillos	Ortiz porphyry belt	veins, porphyry	Au, Ag, Cu	28.9	x		x					Giles (1991), Maynard (2014)
DIS186	New Placers	Ortiz porphyry belt	veins, skarns, placer	Au, Ag, Cu, Te	33.7-33.9	x			x			x	Sauer (1994), Maynard (2014)
DIS187	Old Placers	Ortiz porphyry belt	veins, skarns, placer	Au, Ag, Cu, W, Te	29.6-43.2	x	x	x	x			x	Kay (1986), Maynard (2014)
DIS091	Capitan Mountains	Lincoln County porphyry belt	REE-Th-U veins	REE, Th, U, Fe, Be	28.3	x				x	x		McLemore and Phillips (1991), Campbell et al. (1995), Rawling (2011)
DIS092	Gallinas Mountains	Lincoln County porphyry belt	REE-Th-U veins	REE, Th, U, Te	29.2	x	x			x	x		Perhac (1970), McLemore (2010), Vance (2013)
DIS093	Jicarilla	Lincoln County porphyry belt	veins, iron skarn	Au, Ag, Fe	39.45-40.72	x				x		x	McLemore et al. (2014a)
DIS098	Tecolote Iron	Lincoln County porphyry belt	iron skarn	Fe						x			Rawson (1957)
DIS099	White Oaks	Lincoln County porphyry belt	veins, iron skarn	Au, Ag, W, Te		x				x		x	Grainger (1974), Rawling and Koning (2011)
DIS271	Duran	Lincoln County porphyry belt	iron skarn	Fe						x			McLemore (1984)
DIS095	Nogal-Bonito	Lincoln County porphyry belt, Sierra Blanca	veins, porphyry Mo, placer	Au, Ag, Cu, Mo, Fe, Te, REE(?)	26-33	x	x	x		x	?	x	Rawling (2004, 2011), McLemore et al. (2014a), Goff et al. (2011, 2014)
DIS096	Schelerville	Lincoln County porphyry belt, Sierra Blanca	veins	Au, Ag	26-33	x							Goff et al. (2014), Kelley et al. (2014)
DIS132	Three Rivers	Lincoln County porphyry belt, Sierra Blanca	veins, iron skarn	Fe (Au, Ag, REE?)	26-33	x				x			Goff et al. (2014), Kelley et al. (2014), McLemore (2014)
DIS216	Jones Camp	Chuadera Mesa (Magdalena radial dike swarm)	iron skarn	Fe (Au)	28.88					x			Chamberlin et al. (2009)
DIS241	Chupadera Mesa	Chudaera Mesa dikes	iron skarn	Fe (Au)						x			McLemore (1984)
DIS129	Orogrande	Jarilla plutons	veins, skarns, porphyry Cu-Mo, placer	Cu, Au, Ag, Fe, Te	45.6-41.4	x		x	x	x		x	North (1982), McLemore et al. (2014b)
DIS030	Organ Mountains	Organ (Mogollon-Datil)	veins, skarns, porphyry Cu-Mo	Cu, Pb, Zn, Au, Ag, Te, Be	36.0-36.45	x		x	x				Lueth and McLemore (1998), Zimmerer and McIntosh (2013)
DIS128	Cornudas Mountains	Trans-Pecos volcanic field	REE-Th-U veins	REE, Th, U, Be	36.3	x	x				x		McLemore et al. (1996), New Mexico Bureau of Mines and Mineral Resources et al. (1998)
DIS255	Hueco Mountains	Trans-Pecos volcanic field	skarn	Fe, REE, Th, U	34.5-34.7					x	?		McLemore (2002)

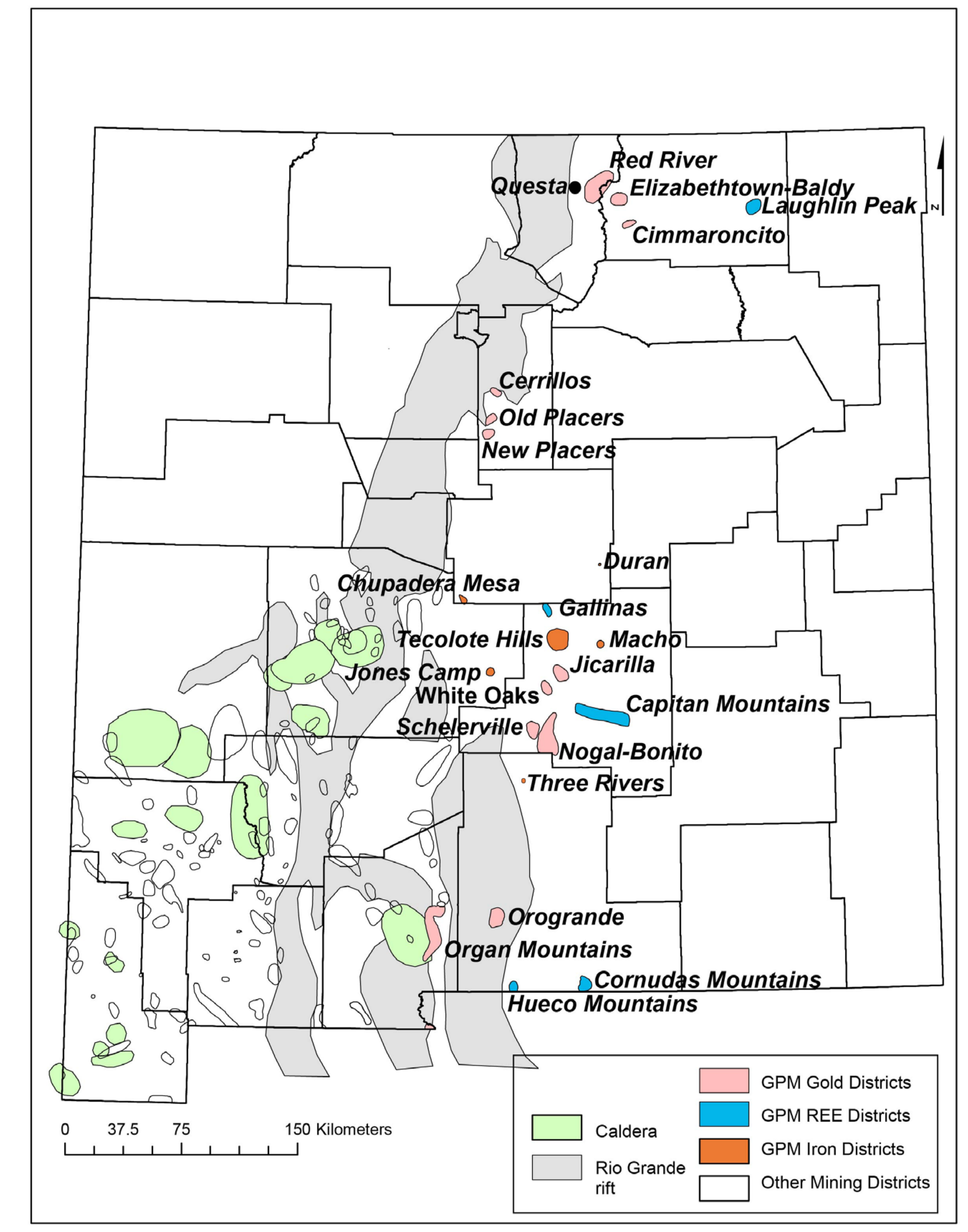

FIGURE 2—Alkaline-related mining districts in New Mexico (Chapin et al., 1978, 2004; McLemore, 2001; Sims et al., 2002; McLemore et al., 2005a).

PRODUCTION

TABLE 2—Reported and estimated base and precious metals production by district. — no reported production. * estimated, ** includes placer production. W withheld or not available. From U.S. Geological Survey (1902-1927), U.S. Bureau of Mines Mineral Yearbooks (1927-1990), Johnson (1972), McLemore (2001), and NMBMG unpublished information.

District Id	County	District	Period of Production	Ore (Short Tons)	Copper (Pounds)	Gold (Troy Ounces)	Silver (Troy Ounces)	Lead (Pounds)	Zinc (Pounds)	Iron (Short Tons)
DIS018	Colfax	Cimmaroncito*	1896-1940	—	W	100	1,000	—	—	
DIS019	Colfax	Elizabethtown-Baldy**	1904-1952	200,582	329,231	234,469	26,136	5,287	—	
DIS019	Colfax	Elizabethtown-Baldy**	1866-1968	—	—	471,400	—	—	—	
DIS030	Dona Ana	Organ Mountains*	1849-1961	—	4,636,000	11,500	820,000	25,000,000	1,700,000	
DIS092	Lincoln	Gallinas Mountains	1909-1955	5,367	385,418	7	23,723	1,797,838	17,344	11,540
DIS093	Lincoln	Jicarilla**	1912-1957	53,307	4,201,474	22,857	37,561	2,665	—	8,000
DIS095	Lincoln	Nogal-Bonito	1932-1955	1,626	100	1,858	2,501	7,750	—	
DIS095	Lincoln	Nogal-Bonito*	1868-1965	—		17,000	20,000			
DIS096	Lincoln	Schelerville		—	W	W	W	W	—	
DIS099	Lincoln	White Oaks**	1933-1951	2,679	450	1,432	1,044	12,200	—	
DIS099	Lincoln	White Oaks*	1850-1942	—	1,000	163,500	1,100			
DIS129	Otero	Orogrande**	1904-1966	133,819	5,695,066	15,849	45,477	157,661	—	222,948
DIS129	Otero	Orogrande*	1879-1966 (Fe until 2012)	—	5,700,000	16,500	50,000	158,000		456,765
DIS180	Santa Fe	Cerrillos	1907-1957	27,670	229,395	2,594	28,030	1,583,440	1,897,527	
DIS186	Santa Fe	New Placers	1904-1959	272,129	14,874,003	19,979	307,175	3,679,008	4,046,955	
DIS186	Santa Fe	New Placers*	1839-1968	—	17,000,000	117,000	308,000			
DIS187	Santa Fe	Old Placers	1907-1940	291	1,570	228	157	5,100	—	
DIS187	Santa Fe	Old Placers*	1828-1986	—	2,000	450,000	1,000	6,000		
	Santa Fe	Cunningham Hill	1979-1986	6,000,000		250,000				
DIS238	Taos	Red River	1907-1956	2,373	17,000	207	5,107	—	—	
DIS238	Taos	Red River*	1902-1956		17,000	365	8,051			

Geochemistry

TABLE 4—Summary of fluid inclusion and stable isotope data

Name	Temperature degrees C	Salinities	δD per mil	δ18O per mil	δ34S per mil	Conclusion	Reference
Questa	550		–138 to –110 (phlogopite)	2.8 to 5.7 for phlogopite, 6.8 to 10.3 for quartz		little or no meteoric fluids	Ross et al. (2002)
Questa	62-560	0-63 eq wt% NaCl + KCl + CaCl2	-89 to -63	3.8-7.4	0.4-2.3, 1.6-2.5, and 6.6-10.0	evolved magmatic-hydrothermal fluid	Rowe (2012)
Capitan	600	84 eq wt% NaCl + KCl	-54 to -80	7.1 to 8		magmatic fluids	Campbell et al. (1995)
Nogal	230-540	6-50 eq wt% NaCl		0.9 3.9 gold, -2.6 2.3 Ag-Pb-Zn	-1.7 0.8	Au magmatic-meteoric fluid,Ag-Pb-Zn meteoric fluids	Campbell et al. (1991), Douglass and Campbell (1994, 1995)
Gallinas	400	15 eq wt% NaCl				meteoric fluid, with REE magmatic	Williams-Jones et al. (2000)
Gallinas	200-310			15.0 to 23.8	-21.1 to 1.5, 9.6 to 13.3	hydrothermal	Vance (2013)
Cunningham Hill, Ortiz	324-445 (quartz, scheelite)	>40 eq wt% NaCl					Kay (1986)
Carache Canyon, Ortiz	275->400	25-46 eq wt% NaCl					Schutz (1995)
Organ	178->300	0-6 eq wt% NaCl					Lueth (1998)

TABLE 5—Summary of Sr isotope data

District id	Name	Sr isotopes	Sr reference
DIS237	Questa	0.7076-0.7069	Laughlin et al. (1969)
DIS019	Elizabethtown-Baldy	0.70617	Kish et al. (1990)
DIS020	Laughlin Peak	0.7044, 0.7039-0.7060	Potter et al. (1991)
DIS091	Capitan Mountains	0.70801	Allen and Foord (1991)
DIS092	Gallinas Mountains	0.7061	Allen and Foord (1991)
DIS093	Jicarilla	0.70565-0.70578	Allen and Foord (1991)
DIS098	Tecolote Iron	0.70490-0.70513	Allen and Foord (1991)
DIS099	White Oaks	0.70673	Allen and Foord (1991)
DIS095	Nogal-Bonito	0.7067	Allen and Foord (1991)
DIS216	Jones Camp	0.70715	Allen and Foord (1991)
DIS030	Organ Mountains	0.7085 to 0.7060	Verplanck et al. (1999)
DIS128	Cornudas Mountains	0.7041	Barker et al. (1977)

RESOURCES

TABLE 3—Alkaline-related gold deposits in New Mexico with reported, historic (non 43-101 compliant) resources

Mine Id	Name of deposit	Tons of ore	Au grade (ppm)	Ag grade (ppm)	Cu grade %	Mo grade %	Year of estimate	Reference
NMLI0068	Vera Cruz	207,450 (assured)	4.5				1938	Ryberg (1991)
		435,000 (probable)	3.9					
		934,000 (possible)	3.9					
NMLI0207	Great Western	3,600,000	18.7				1992	NMBGMR file data
NMLI0271	Parsons	44,000	16.1				1991	Thompson (1991a, b)
NMLI0121	Rialto	30 million short tons				0.05-0.18%	1978	(Hollister, 1978)
NMLI0008	Bonito	1.7 million short tons	1.6	16.1			1989	NMBGMR file data
NMSF0116	Carache Canyon	11.7 million metric tons	1.58				2012	10K (http://www.sec.gov/Archives/edgar/data/851726/000106299313004849/form10k.htm)
NMSF0117	Lucas Canyon	13 million metric tons	0.91		0.142		2012	10K (http://www.sec.gov/Archives/edgar/data/851726/000106299313004849/form10k.htm)
	Florencio	3,000,000	0.65				?	Maynard (2014)

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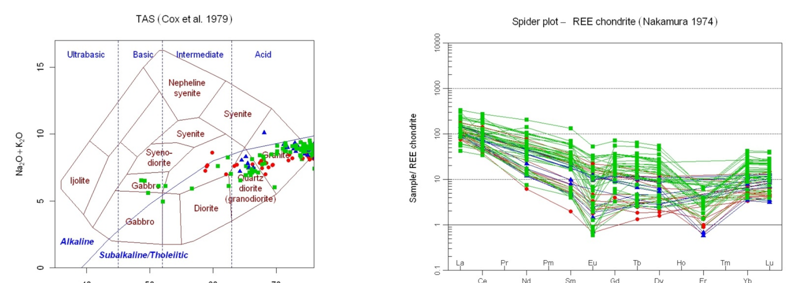
DESCRIPTION OF DEPOSITS IN NEW MEXICO

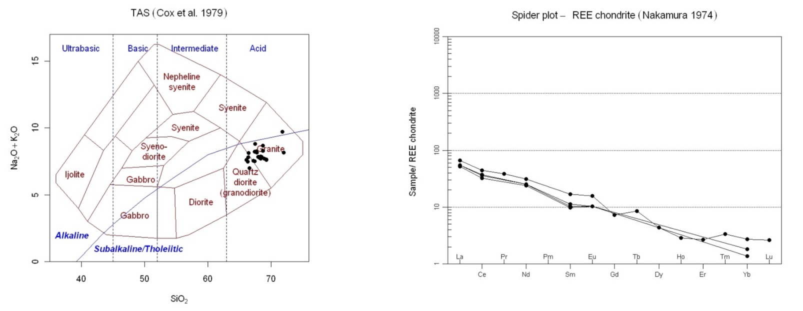
Questa, Red River districts
- Caldera volcanism 22.7-28.5 Ma and intrusions 19.3-25.4 Ma (Zimmerer and McIntosh, 2012)
- Calc-alkaline to slightly alkaline, metaluminous to peraluminous intrusions
- Light REE-enriched patterns with Eu anomaly
- WPG (within-plate granites) to VAG (volcanic arc granites), active continental margins to within plate volcanic zones (Pearce et al., 1984; Schandl and Gordon, 2002)
- Extensive alteration, including acid-sulfate (advanced argillic)
- Questa production (porphyry Mo)
  - from 1919-1958 0.375 million tons of >4% MoS_2
  - from Goat Hill orebody from 1983-2000 21.11 million tons of 0.31% MoS_2
  - from D-orebody in 2001-2014 unknown
- Mo reserves remaining (Questa mine closed in June 2014)
- Au and Ag in Red River district, but no Au or Ag from Questa



TAS and REE chondrite-normalized plots for the Questa rocks (data compiled from various sources). Red circles are Rio Hondo pluton, blue triangles Red River intrusions, green squares other intrusions.

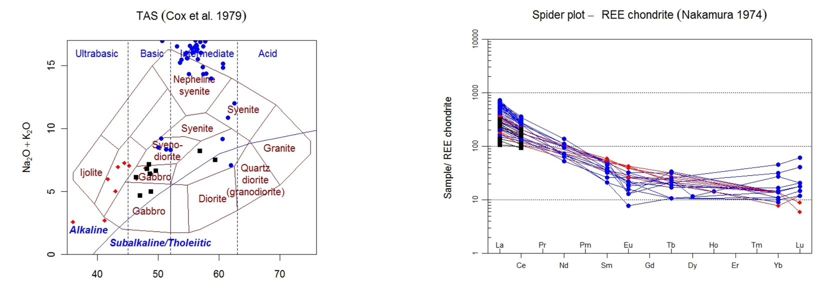
Vein from E-facies crosscutting MHBX matrix; bleached or QSP altered clasts.

Elizabethtown-Baldy, Cimarroncito districts
- Associated with Cimarron pluton (Palisades sill), trachydacite to rhyolite
- Calc-alkalic to slightly alkaline, metaluminous to peraluminous
- Low TREE, light REE-enriched patterns with no Eu anomaly
- Quartz-pyrite veins (some chalcopyrite, galena), Fe (with Au) skarns
- 2nd largest alkaline-related district in NM in Au production, but much of gold production was from placer gold deposits
- Part of Philmont Boy Scout Ranch, withdrawn from mineral entry



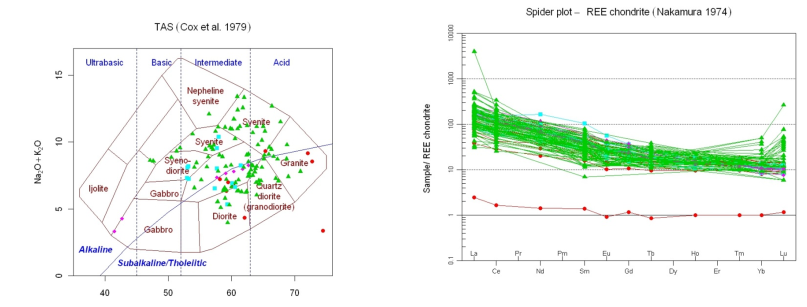
TAS and REE chondrite-normalized plots for the Palisades Sill, Cimarron pluton (data from Kish et al., 1990).

Laughlin Peak district
- Older Laughlin Peak-Chico Hills volcanic complex (22.8 Ma) overprinted by younger Raton-Clayton volcanic field (3.5-9 Ma, Stroud, 1997)
- Consists of variety of intrusive and extrusive lithologies including phonolite, lamprophyre, carbonatite
- Alkaline, metaluminous to peraluminous to peralkaline
- Light REE-enriched patterns with no Eu anomaly
- A-type, WPG, active continental margins zone (Pearce et al., 1984; Whalen et al., 1987; Schandl and Gordon, 2002)
- Carbonatite contains <1.6% TREE, breccias and veins contain <165 ppb Au (Schreiner, 1991; NMBGMR unpublished data)



TAS and REE chondrite-normalized plots for the Laughlin Peak-Chico Hills volcanic complex (data from Potter, 1988; Schreiner, 1992). Black squares are basalts, red diamonds lamprophyres, blue circles phonolite and trachyte.

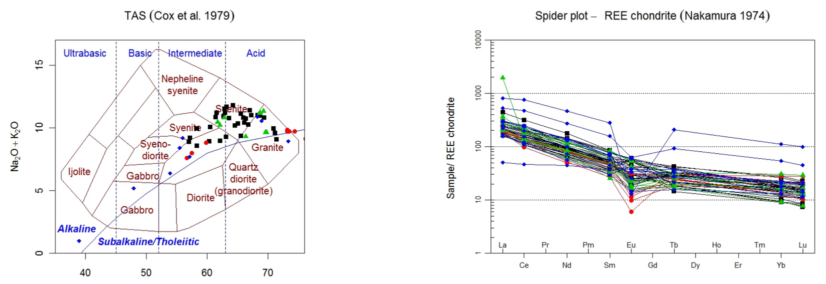
Ortiz porphyry belt (Old Placers, New Placers, Cerrillos districts)
- Early calc-alkaline (34.29-35.79 Ma) and younger slightly alkaline (31.68-33.27 Ma) phases (Maynard, 2014)
- Five intrusive centers: La Cienega (north), Cerrillos Hills (Cerrillos district), Ortiz Mountains (Old Placers district), San Pedro Mountains (New Placers district), and South Mountain
- Calc-alkalic to alkaline, metaluminous to peraluminous rocks (Shand, 1943; Cox et al., 1979; Frost et al., 2001)
- WPG to VAG, active continental margins to within plate volcanic zones (Pearce et al., 1984; Schandl and Gordon, 2002)
- Formed during the transition at the end of subduction (continental arc) and beginning of extension (Rio Grande rift) (Sauer, 1993)
- Mineralization (31.56-32.2 Ma) is along the Tijeras-Cañoncito fault system (Maynard, 2014)
- Old Placers is the largest alkaline-related district in gold production in NM, but much of gold production was from placer gold deposits
- See Table 3 for reserves



TAS and REE chondrite-normalized plots for the Ortiz porphyry belt (data from Coles, 1986; Sauer, 1994; Maynard, 2014). Green triangles are from Ortiz Mountains (Old Placers district), red circles San Pedro Mountains (New Placers district), turquoise squares Cerrillos district, pink diamond La Cienega.

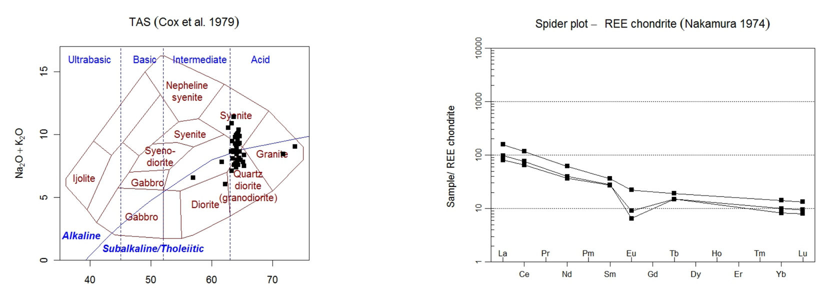
Ortiz open pit in 1984, New Placers district

Organ Mountains district
- Organ caldera
- Alkaline, metaluminous to peraluminous
- WPG to VAG, active continental margins to within plate volcanic zones (Pearce et al., 1984; Schandl and Gordon, 2002)
- Light REE-enriched patterns with negative Eu anomaly
- Magmas generated from shallow crustal sources by in situ differentiation (Zimmerer and McIntosh, 2013)
- Zoned district (Lueth and McLemore, 1998)
- Te minerals found in base-metal skarns and veins and Au-bearing quartz veins and breccias (Lueth, 1998)
- Porphyry copper deposit at depth (never developed; Newcomer and Giordano, 1986)



TAS and REE chondrite-normalized plots for the Organ caldera rocks (data from Verplanck et al., 1999). Black squares are syenite, red circles granite/monzodiorite, blue diamonds mafic xenoliths and felsic dikes, green triangles granites from Ash and Blair Canyons.

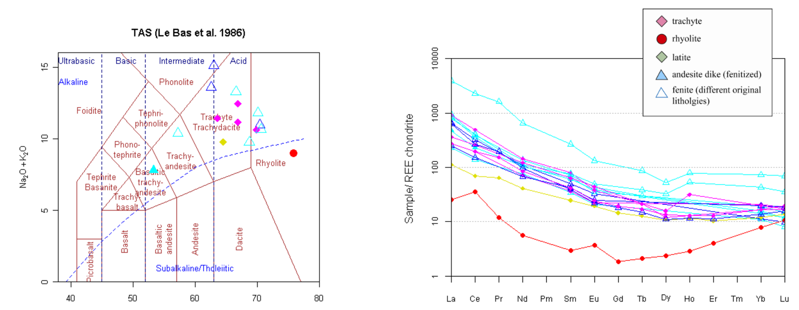
Orogrande district
- Correlates to older pulse of the LCPB
- Monzonite to quartz monzonite to granodiorite to syenodiorite
- Calc-alkaline to alkaline, metaluminous to peraluminous
- VAG to WPG (Pearce et al., 1984)
- Light REE-enriched patterns with no to slight negative Eu anomaly



TAS and REE chondrite-normalized plots for the Orogrande rocks (McLemore et al., 2014b).

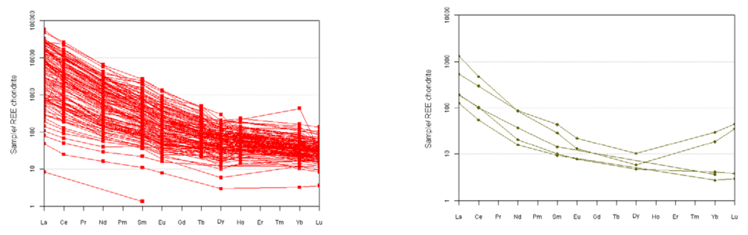
Lincoln County Porphyry Belt (LCPB)
- Two pulses of igneous activity, older 30-38 Ma and younger pulse 26-30 Ma (Allen and Foord, 1991)

Gallinas Mountains district (early pulse at 29.2 Ma)
- Metaluminous to peraluminous, alkaline rocks
- A-type, WPG (Pearce et al., 1984; Whalen et al., 1987)
- Light REE-enriched chondrite-normalized REE patterns
- Crustal source
- Zoned mineralization, REE-Cu-F veins and breccias, REE-bearing Fe skarns (McLemore, 2010)
- Fenites contain light REE enriched chondrite-normalized REE patterns (Schreiner, 1993)
- Highest Au (1707 ppb) found in breccias (Schreiner, 1993; McLemore, 2014)

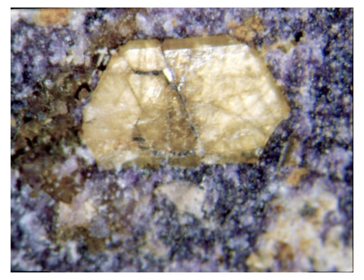


TAS and REE plots for the Gallinas Mountains rocks (McLemore, 2010).

Breccia with REE-Cu-F veins at Red Cloud mine, Gallinas Mountains district

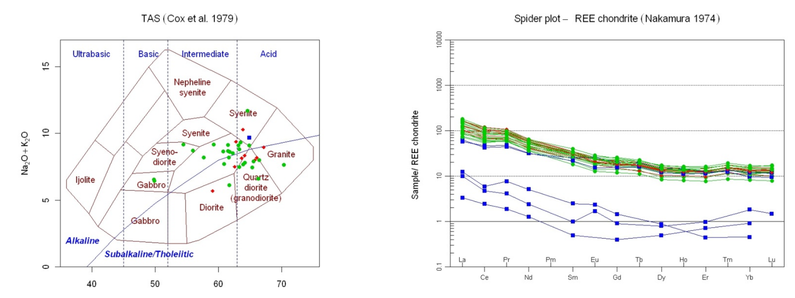


Veins (red) and Fe skarns (gray) from Gallinas Mountains district (McLemore, 2010).



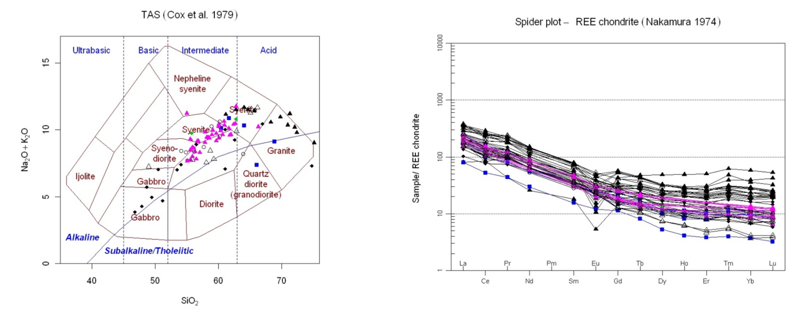
Bastnäsite in the Red Cloud deposit, Gallinas Mountains district (length is ~8 mm)

Jicarilla district (older pulse at 39.45-40.72 Ma)
- Alkaline to calc-alkaline, metaluminous to peraluminous
- I or S type granites, VAG, active continental margin (Pearce et al., 1984; Whalen et al., 1987; Schandl and Gordon, 2002)
- Slightly enriched-light REE chondrite-normalized patterns, with no Eu anomaly
- Au veins and Au placers



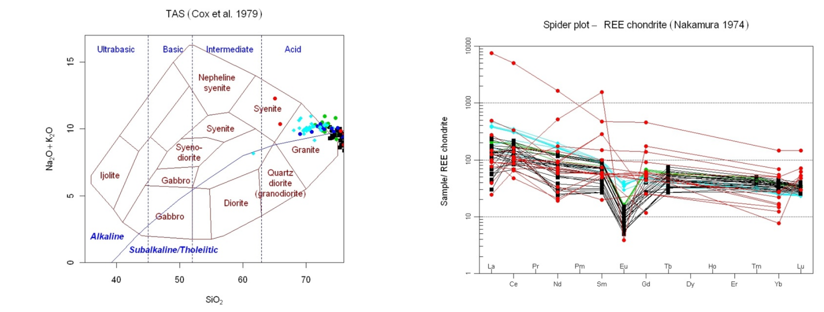
TAS and REE chondrite-normalized plots for the Jicarilla rocks (unpublished data). Blue squares are mineralized samples, green circles are monzonites, red diamonds are altered rocks.

Nogal-Bonito district (26-33 Ma)
- Alkaline to slightly calc-alkaline, metaluminous to slightly peraluminous to slightly peralkaline
- A-type (some I and S), WPA to VAG, active continental margins to within plate volcanic zones (Pearce et al., 1984; Whalen et al., 1987; Schandl and Gordon, 2002)
- Light-REE-enriched, chondrite-normalized patterns
- Sri 0.7038 to 0.7045 and suggest a deep crustal or upper mantle source
- Sulfur isotopes range from -3.1 to -0.3 per mil and also suggest a mantle-magmatic source
- Zoned district and alteration (Goff et al., 2011)
- See Table 3 for reserves



TAS and REE chondrite-normalized plots for the Nogal-Bonito volcanic rocks (data compiled by McLemore, et al., 2014a from other sources). Pink triangles are Nogal Bonito stock, black triangles are Three Rivers stock, black diamonds volcanic rocks, green diamonds Nogal Peak stock, Rialto syenite blue squares, open triangles other intrusions.

Capitan Mountains district (younger pulse 28.3 Ma)
- Zoned Capitan pluton
- Calc-alkaline to alkaline, metaluminous to peraluminous to peralkaline
- I-type to A-type, WPG, within plate volcanic zones to active continental margins (Pearce et al., 1984; Whalen et al., 1987; Schandl and Gordon, 2002)
- Light REE-enriched patterns with Eu anomaly
- Lower crust source
- Change from Laramide northeast compression to Tertiary east-west extension
- Th-REE veins derived from magmatic-hydrothermal fluids, low Au



TAS and REE chondrite-normalized plots for the Capitan pluton (data from Allen and McLemore, 1991). Turquoise diamonds are porphyry granite, green circles aplite, black squares granophyre, red circles veins.

CONCLUSIONS

- Generally early calc-alkaline followed by younger alkaline volcanism
- Small- to medium-sized volcanic fields or porphyry systems, ages 22 to 46 Ma (Table 1)
- Typically emplaced as multiple, compositionally diverse magmas, with periodic eruptions of varying volumes and wall rock assimilation
- Low Sr isotopes, low La/Nb, Zr/Nb suggests primitive mantle magma sources (Table 5)
- Volcanic systems formed during the transition at the end of Laramide subduction (continental arc) and beginning of extension (Rio Grande rift) (Sauer, 1993; McLemore, 1996; Kelley and Luddington, 2002)
  - Waning of Laramide compression ~43-37 Ma and rifting/extension began at ~33-36 Ma (McMillan et al., 2000; Chapin, 2012)
  - Different melt regimes exist for Laramide compression and younger rifting/extension: Laramide magmas are derived from the mantle to lower crust, and shifts to intracrustal melting of heterogeneous sources (McMillan et al., 2000; Anthony, 2005)
- Complex, generally older magmatic-hydrothermal breccia pipes and porphyry deposits to generally younger, hydrothermal veins and skarns, involving mixing and cooling of magmatic meteoric waters and leaching from host rocks (Table 4)
- Structural control
- General paragenesis early base-metal veins followed by gold veins or Th-REE veins, Fe skarns and replacements found in most districts, with high concentrations of gold and/or REE
- Style of mineralization in New Mexico differs from Colorado: Te is found in most of the Colorado districts, but most New Mexico districts have W with little or no Te, except for a few districts (Kelly and Ludington, 2002; this report)
  - Note that Te could be found in specific zones within New Mexico deposits
- Gold values in alkaline-igneous deposits are generally higher than other deposits in New Mexico and have high gold/base-metal ratios and low silver/gold ratios than other districts (North and McLemore, 1988; McLemore, 1996)
- Deposits of REE are found in several districts, but typically not with gold deposits (Table 1)
- Mineral potential
  - See Table 2 for known Au historic resources
  - Mo resources remain at Questa and Nogal-Bonito districts
  - REE potential in the Laughlin Peak, Gallinas Mountains, and Cornudas Mountains districts
  - Te potential in the Organ Mountains district

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