Directory of Active Mines in Arizona: FY 2019

C.A. Richardson[1], L. Swartzbaugh[2], T. Evans[2], F.M. Conway[1]

[1]Arizona Geological Survey, [2] Arizona State Mine Inspector's Office

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Corresponding author: carichardson@email.arizona.edu

Arizona Geological Survey, University of Arizona, 1955 East Sixth Street, P.O. Box 210184, Tucson, Arizona 85721-0184
Arizona State Mine Inspector's Office, 1700 West Washington Street, Suite 400, Phoenix, Arizona 85007-2805

Preface

For the purpose of this directory, an active mine is defined as a mine in continuous operation, either in production or under full-time development for production. It is acknowledged that there are additional deposits not listed that are in an exploration, evaluation, or part-time development phase, or where production is intermittent are not listed.

The directory is compiled from a much larger database from the Arizona State Mine Inspector's Office. The operations listed were not visited by Arizona Geological Survey staff. The locations were checked using available aerial imagery to confirm location information and mining activity, with two caveats: 1) resolution of imagery varies across the state to some degree, making it challenging to recognize recent activity; and 2) some areas lack recent imagery, making it impossible to detect recent operations.

This work fulfills recently amended sections 9-461.05, 11-804, and 27-106 of the Arizona Revised Statutes, which go into effect on August 13, 2019 following Governor Ducey signing H.B. 2453 into law on May 13, 2019.

Acknowledgements

This work is a collaborative effort between the Arizona Geological Survey and the Arizona State Mine Inspector's Office. We wish to thank all those involved for their cooperation with the compilation of this information.

Arizona's mineral resources

Arizona has long been known for its 5 C's of cattle, cotton, citrus, climate, and copper. The abundance of the red metal has led Arizona to be the leading producer of mined copper in the United States, accounting for >60% of copper produced since 1970 (U.S. Geological Survey, 2019). While copper is often the first result when considering Arizona and mining, the minerals industry of Arizona exploits a diverse group of metallic and industrial deposits.

In 2018, Arizona was ranked the 8th most attractive region in the world for mining and exploration by the Fraser Institute, which considered both geologic attractiveness and favorable government policies (Stedman and Green, 2019). Arizona consistently ranked in the top 20-30 regions through most of 2000-2015, but has been ranked as a top ten region for mineral resource investment since 2016 (Table 1).

Table 1. Arizona's Ranking in Investment Attractiveness[1], 2001-2018

Year	Rank	Number of Considered Regions	Source
2018	8	83	Stedman and Green (2018)
2017	9	91	"
2016	7	104	"
2015	17	109	"
2014	13	122	"
2013	20	112	Wilson et al. (2013)
2012-2013	28	96	"
2011-2012	29	93	"
2010-2011	25	79	"
2009-2010	25	72	"
2008-2009	27	71	McMahon and Cervantes (2009)
2007-2008	14	68	"
2006-2007	19	65	"
2005-2006	8	64	"
2004-2005	11	64	McMahon and Lymer (2005)
2003-2004	30	53	"
2002-2003	11	47	"
2001-2002	4	45	Fredricksen (2004)

[1]Defined by the Frasier Institute as a composite index that considers the attractiveness of a jurisdication based on policy factors (e.g., regulations, taxation levels, infrastructure), and the geologic attractiveness or mineral potential.

Purpose and future work

The purpose of this report is to support governmental entities undertaking planning decisions by providing information on mineral resources that essential to infrastructure development. The current version of this annual report only includes information on active mines; however, future productions of this annual report will include information on mineral resource potential for different geologic resources. While evaluations of potential for undiscovered mineral deposits are inherently speculative, consideration of future economic mineral potential should be considered before planning decisions are made that can be difficult or impossible to reverse.

Mineral commodities & active mines

In FY 2019, there were 380 active, full-time mines or development projects in the state of Arizona (Plate 1). Mine products have been categorized into 43 discrete categories (as defined by Hart, 2018). These products can be grouped based on shared characteristics into commodity types, and then into larger commodity families by their end use (Fig. 1; Table 2). The commodity families are defined as:

- Aggregates & Crushed Stone: Aggregates are variably-sized crushed earth materials used in construction and infrastructure. They are shaped by natural processes (e.g., particle size reduction via bedload transport in fluvial [river] systems) and/or by anthropogenic processes (crushing via machinery). Aggregates provide bulk and strength to mixed materials and have many end-use applications from asphalt for roads, concrete when mixed with cement that make buildings, canals, and tunnels, and gravel that lines hiking trails and drive ways;

- Building Stones: Building stone includes cut stone that is used for construction of buildings, as well as aesthetic stone veneers, stone slabs used for landscaping, and rip/rap (or rock armor) where large boulders are deployed along shorelines, riverbanks, bridge abutments, and other structures to prevent erosion;

- Cement & Lime: Cement is the binding agent used to join other materials (such as aggregates) together into concrete. Lime is one of the historically most prevalent binding agents used in cement production. It is produced by the heating of limestone (calcium

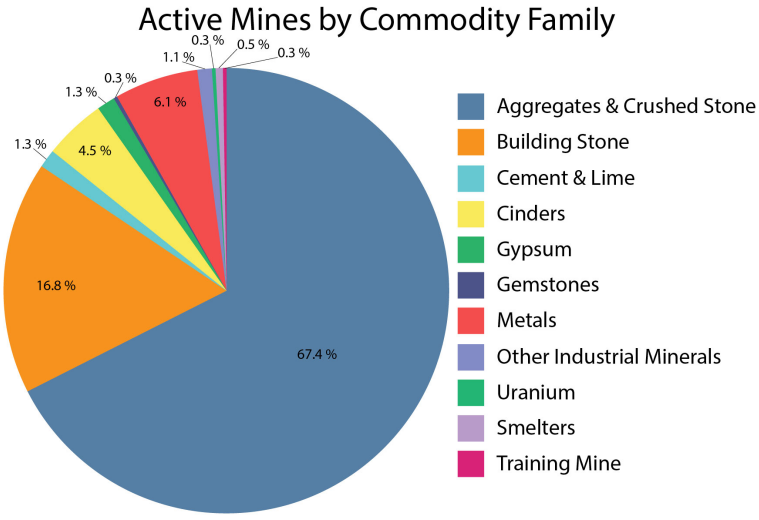

Figure 1. Active Mines by Commodity Family

carbonate) to create quicklime (calcium oxide), with the possible addition of other agents to such as dehydrated clays. Quicklime is then mixed with water to produce slaked lime (calcium hydroxide) which when mixed with aggregates creates concrete (Manning, 1995);

- Cinders: Cinders are volcanic fragments that have been fragmented at high temperature. Cinders are vesicular, meaning they have abundant cavities that were gas-filled bubbles at the time of eruption. They are commonly found in northern Arizona where they are associated with geologically recent volcanoes known as cinder cones (Bezy, 2003). They have multiple uses including use on icy roads to improve traction, landscaping, and potting soil mixtures due to the pore space allowing better connectivity for watering and root development;

- Coal: Coal is the product of burial and compaction (diagenesis) of large accumulations of organic remains of plant material (peat) that drives off hydrogen and oxygen and increases the total carbon content within coal. There is one major coal field at Black Mesa in northeastern Arizona, two smaller fields at Pinedale and Deer Creek in east-central Arizona, and several smaller occurrences (Peirce et al., 1970);

- Gypsum: Gypsum, calcium sulfate dihydrate ($CaSO4{\cdot}2H2O$), is an evaporite mineral that often accumulates in basins or salt flats under arid conditions. Gypsum has multiple uses, from carving due to its soft properties (called alabaster in that context), to cement, fertilizers, and fillers in toothpaste and paint, and most commonly as plasterboard and rendering walls and ceilings (Evans, 1993);

- Gemstones: Includes significant production of turquoise, a secondary mineral from the weathering and oxidation of pre-existing copper minerals, for jewelry;

- Metals: This includes all mines extracting metallic ore or advanced-stage development projects (deposit that are likely to go into production in the near future). The uses of metal are diverse, from infrastructure with copper interconnecting our electrical systems and lead being mixed with other metals to produce alloys with unique properties, to the medical field with gold fillings in dentistry;

- Other Industrial Minerals: This includes all other industrial minerals that may only be mined at one or a few sites. Examples include perlite (used for lightweight, thermal or acoustic insulation), zeolites (used for catalysts, pet litter, odor control, and environmental remediation), and pumice (used as an abrasive in polishing and the production of the worn look in stone-washed jeans);

- Uranium: Economic uranium deposits in Arizona are associated with vertical, pipe-shaped bodies of highly fractured rock (called breccia pipes) that collapsed into voids created by the dissolution of underlying rock due to groundwater flow. Uranium is soluble in oxidized fluids, such as shallow groundwater, and insoluble in reduced fluids, such as organic- / sulfide-rich brines, and the mixing of those two fluids in the highly fractured breccia pipe results in the precipitation of uranium as the mineral uraninite, UO2 (Spencer and Wenrich, 2011);

- Training Mine: An underground mining laboratory operated by the Department of Mining and Geological Engineering at the University of Arizona for research and training students; and

- Smelter: Smelters are facilities where metal concentrates are shipped to recover the contained metal. For copper, the metal concentrates are heated via a multi-step process to separate the copper in a copper sulfide (e.g., chalcopyrite: CuFeS2) from the other elements in the original metal concentrate. There are only three copper smelters in the United States, with two of them located in the towns of Hayden and Miami.

Complete data for each mine is listed in the appendix Table 1A. Plate 1 shows the distribution of active mines across the entire state, while Plates 2-7 show more detailed maps focusing in on multiple counties. The data is also available via an interactive ArcOnline map at https://arcg.is/1KX5nH and as a .kmz file to import into Google Earth.

Facilities that supplied aggregates and crushed stone constitute two-thirds of the mining facilities in the state with 256 out of 380 active mines or quarries (Fig. 1). Of the aggregate and crushed stone facilities, 17 sites have asphalt hot plants, 39 have concrete batch plants, and 23 have both an asphalt hot plant and concrete batch plant. The second largest commodity family is building stone, where 84% of production (53 of 63 quarries) is either decorative stone or flagstone (Fig. 2). Metallic mining in Arizona remains dominated by copper with 14 of 22 active mines or advanced stage development projects focused on copper, though several operations (albeit smaller in size relative to some of the porphyry copper mines) focus on gold (-silver) and other base metals (Fig. 3). The majority of the other commodity families are primarily one or two products, with less variability within them.

Table 2. Classification Scheme

Commodity Family	Commodity Type	Product
Aggregates & Crushed Stone	Sand & Gravel	Aggregates
		Asphalt
		Gold / Silica Sand
		Sand & Gravel
		Soil and Sand
		Stucco Sand
	Concrete	Concrete
		Ready Mix
Building Stones	Decorative Stone	Decorative Rock
		Decorative Stone
		Granite/Decorative Stone
	Dimension Stone	Building Stone
		Stone, Dimension
	Flagstone	Flagstone
	Limestone & Marble	Limestone
		Marble
	Sandstone	Sandstone
	Rip/Rap	Rip/Rap
Cement & Lime	Cement & Lime	Cement/Lime
		Lime
Cinders	Cinders	Cinders
Coal	Coal	Coal
Gypsum	Gypsum	Gypsum
Gemstones	Gemstones	Gemstones
		Wulfenite Crystals
Metals	Copper	Copper
	Gold(-Silver)	Gold
		Gold / Silver / Zinc
		Gold & Silver
		Silver
	Iron	Iron & Gold
		Iron Ore
	Lead-Zinc-Silver	Lead / Zinc / Silver
Other Industrial Minerals	Clay	Clay
	Industrial Sand	Sand, Industrial
	Perlite	Perlite

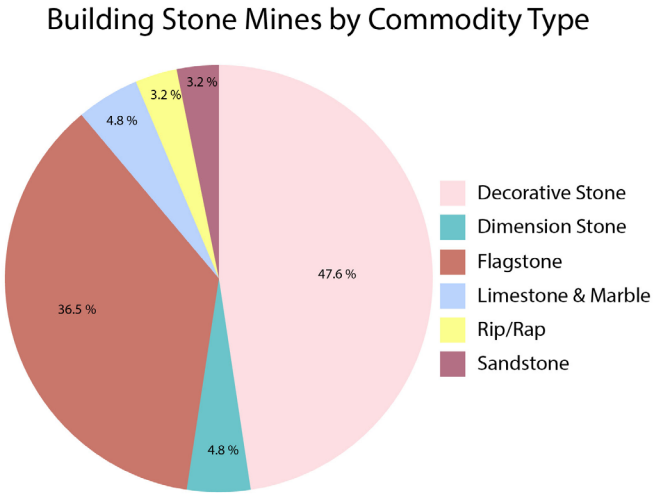

Figure 2. Building Stone Mines by Commodity Type

Continuing Work

This product is the first in an ongoing, annual production between the Arizona Geological Survey and the Arizona State Mine Inspector's Office. We welcome feedback on the accuracy and completeness of the information contained in this report in preparation of future updates.

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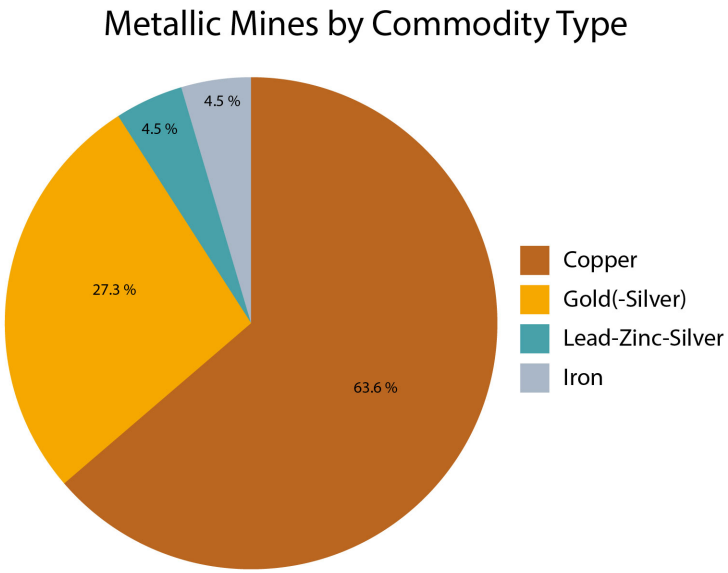


Figure 3. Metallic Mines by Commodity Family

Plates

Plate 1. Active Mines of Arizona

Plate 2. Active Mines - Maricopa, Gila, and Pinal County

Plate 3. Active Mines - Santa Cruz and Pima County

Plate 4. Active Mines - Mohave, Yavapai, and Coconino County

Plate 5. Active Mines - Graham, Greenlee, and Cochise County

Plate 6. Active Mines - Navajo and Apache County

Plate 7. Active Mines - La Paz and Yuma County

Appendix Table 1A

Active mine data MS Excel file. http://repository.azgs.az.gov/uri_gin/azgs/dlio/1916.

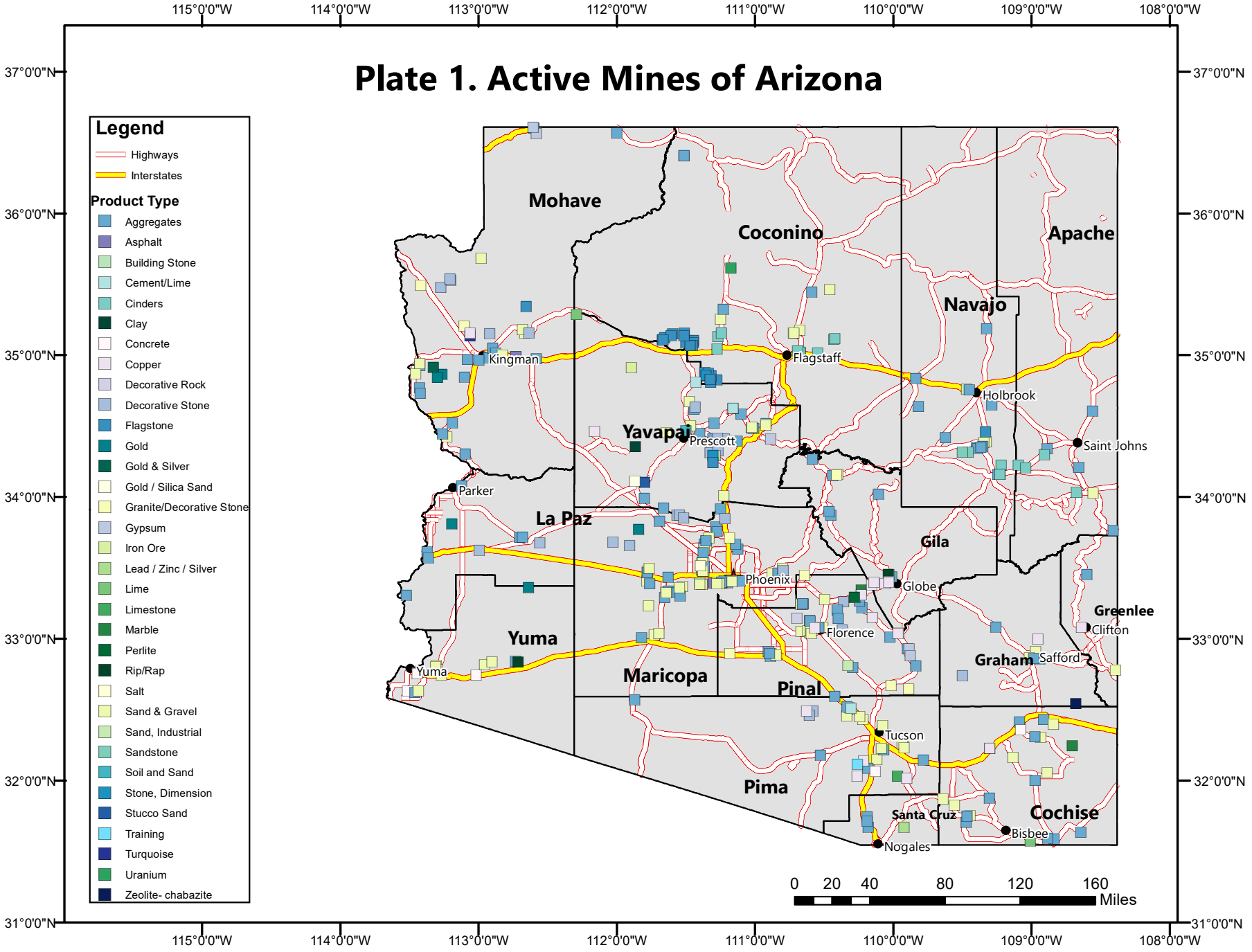
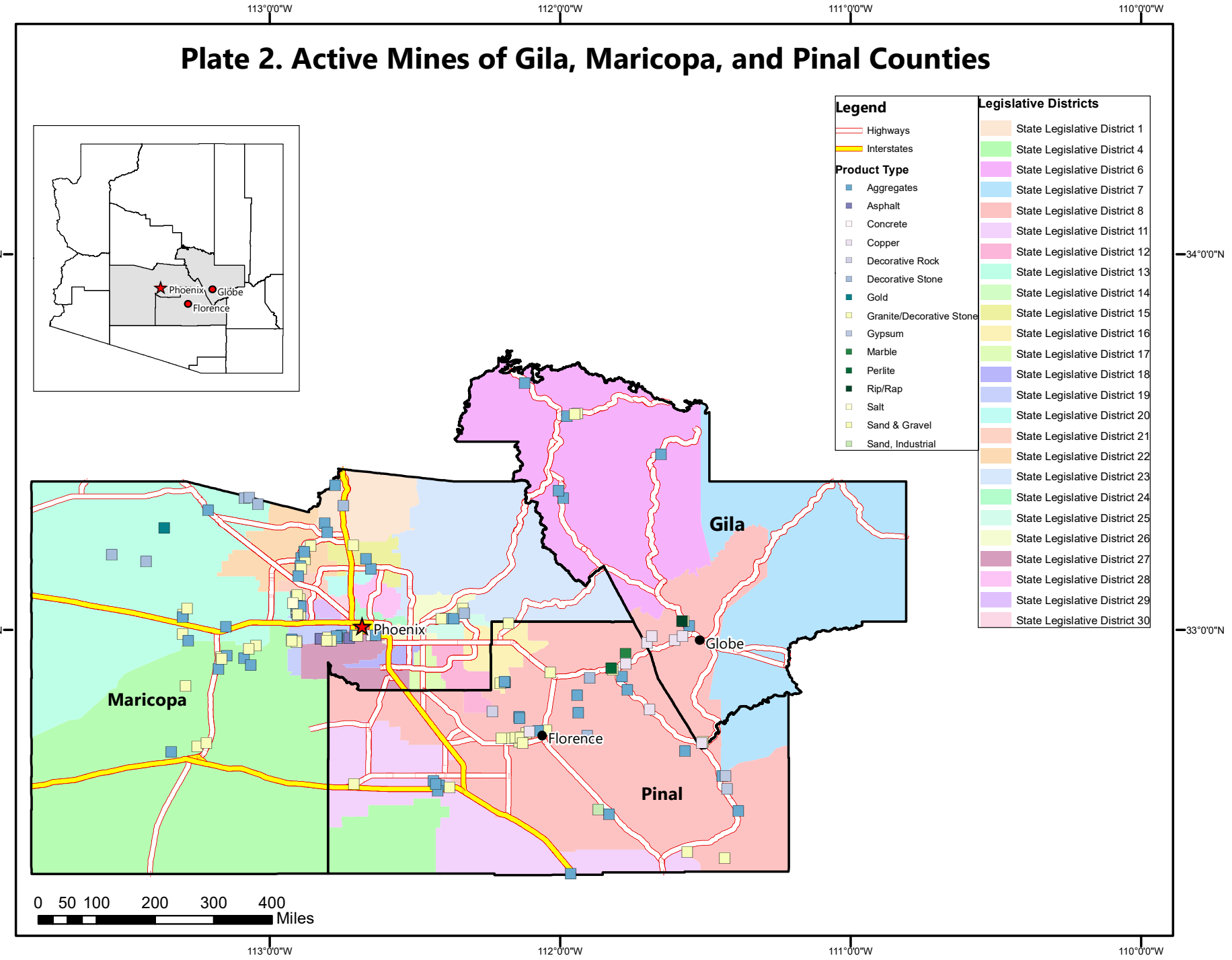


Plate 1. Active Mines of Arizona
Legend
Highways
Interstates
Product Type
Aggregates
Asphalt
Building Stone
Cement/Lime
Cinders
Clay
Concrete
Copper
Decorative Rock
Decorative Stone
Flagstone
Gold
Gold & Silver
Gold / Silica Sand
Granite/Decorative Stone
Gypsum
Iron Ore
Lead / Zinc / Silver
Lime
Limestone
Marble
Perlite
Rip/Rap
Salt
Sand & Gravel
Sand, Industrial
Sandstone
Soil and Sand
Stone, Dimension
Stucco Sand
Training
Turquoise
Uranium
Zeolite- chabazite
115°0'0"W
114°0'0"W
113°0'0"W
112°0'0"W
111°0'0"W
110°0'0"W
109°0'0"W
108°0'0"W
37°0'0"N
36°0'0"N
35°0'0"N
34°0'0"N
33°0'0"N
32°0'0"N
31°0'0"N
Mohave
Coconino
Apache
Navajo
Yavapai
La Paz
Gila
Yuma
Maricopa
Pinal
Pima
Greenlee
Graham
Cochise
Kingman
Flagstaff
Holbrook
Prescott
Saint Johns
Parker
Phoenix
Globe
Florence
Clifton
Safford
Yuma
Tucson
Santa Cruz
Bisbee
Nogales
0 20 40 80 120 160
Miles

Plate 2. Active Mines of Gila, Maricopa, and Pinal Counties



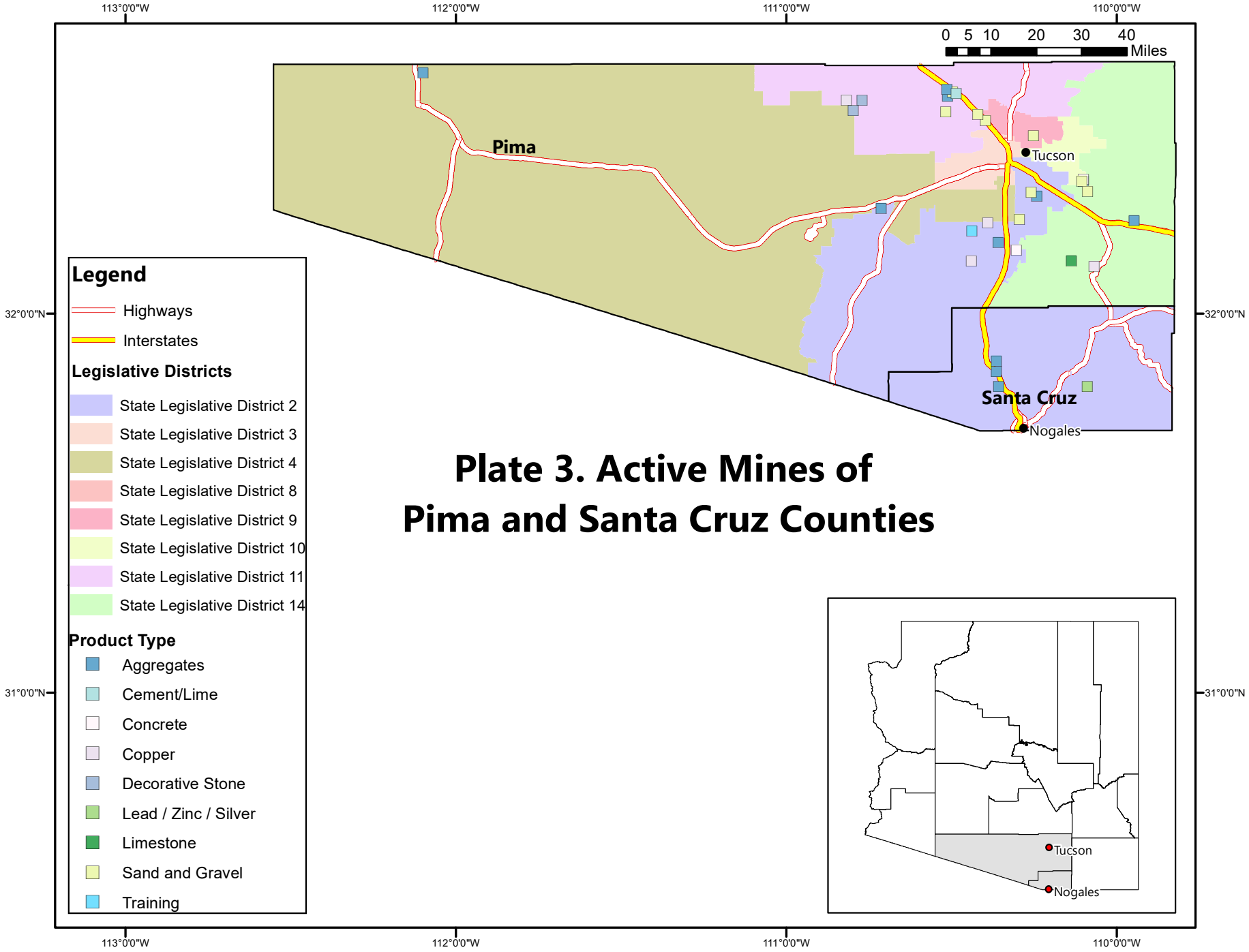


Plate 3. Active Mines of Pima and Santa Cruz Counties

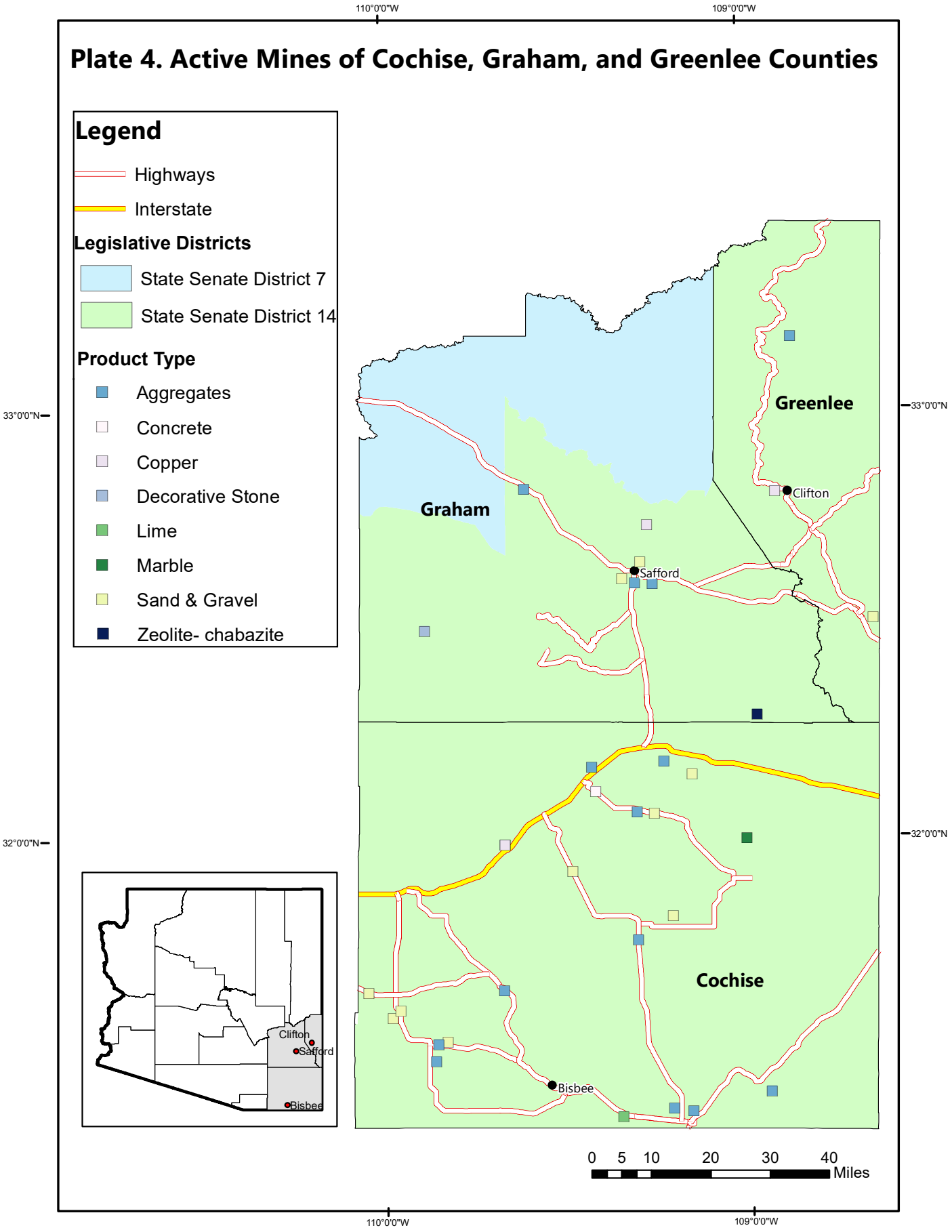


Plate 4. Active Mines of Cochise, Graham, and Greenlee Counties
Legend
Highways
Interstate
Legislative Districts
State Senate District 7
State Senate District 14
Product Type
Aggregates
Concrete
Copper
Decorative Stone
Lime
Marble
Sand & Gravel
Zeolite- chabazite
110°0'0"W
109°0'0"W
33°0'0"N
32°0'0"N
Greenlee
Graham
Cochise
Clifton
Safford
Bisbee
0 5 10 20 30 40
Miles

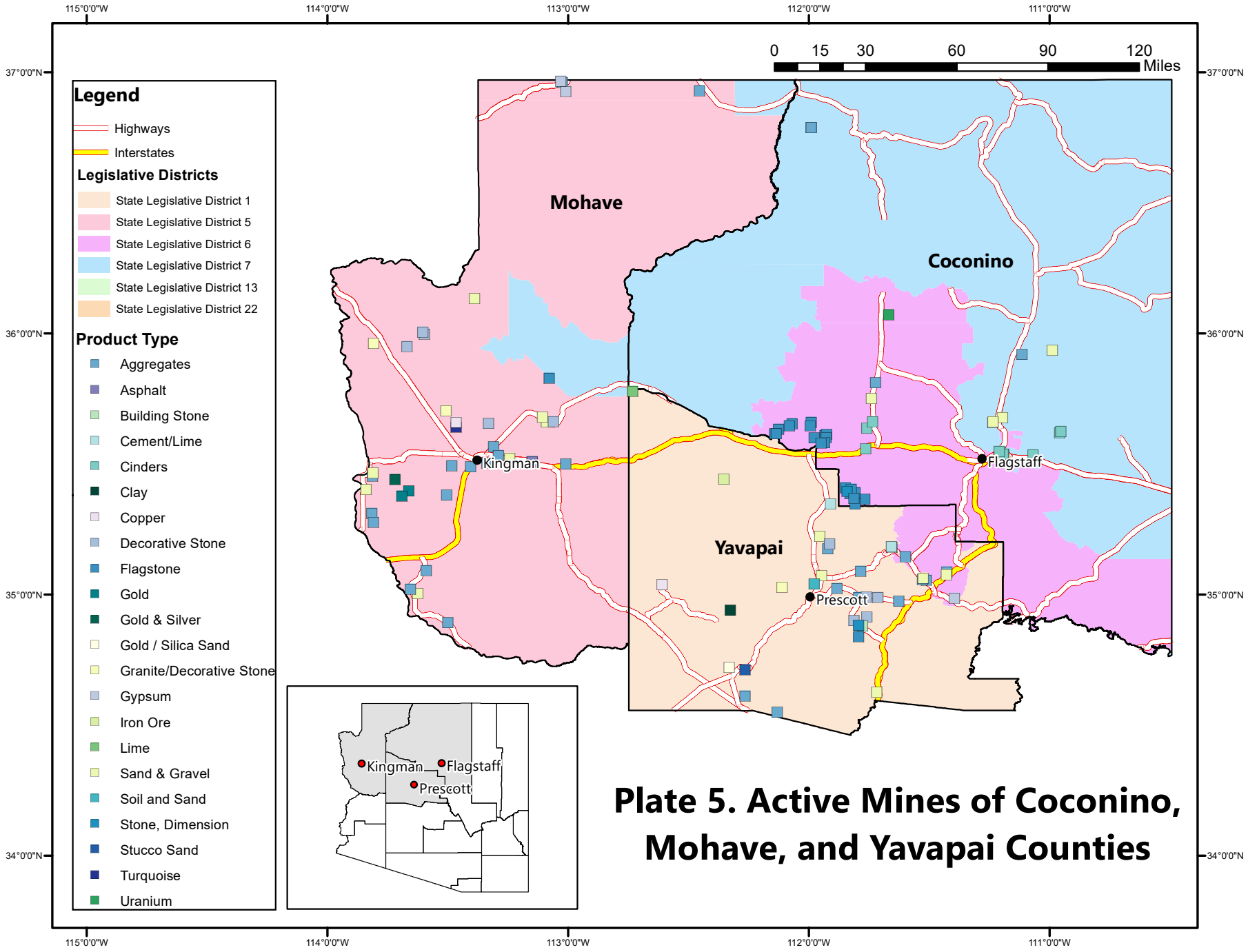
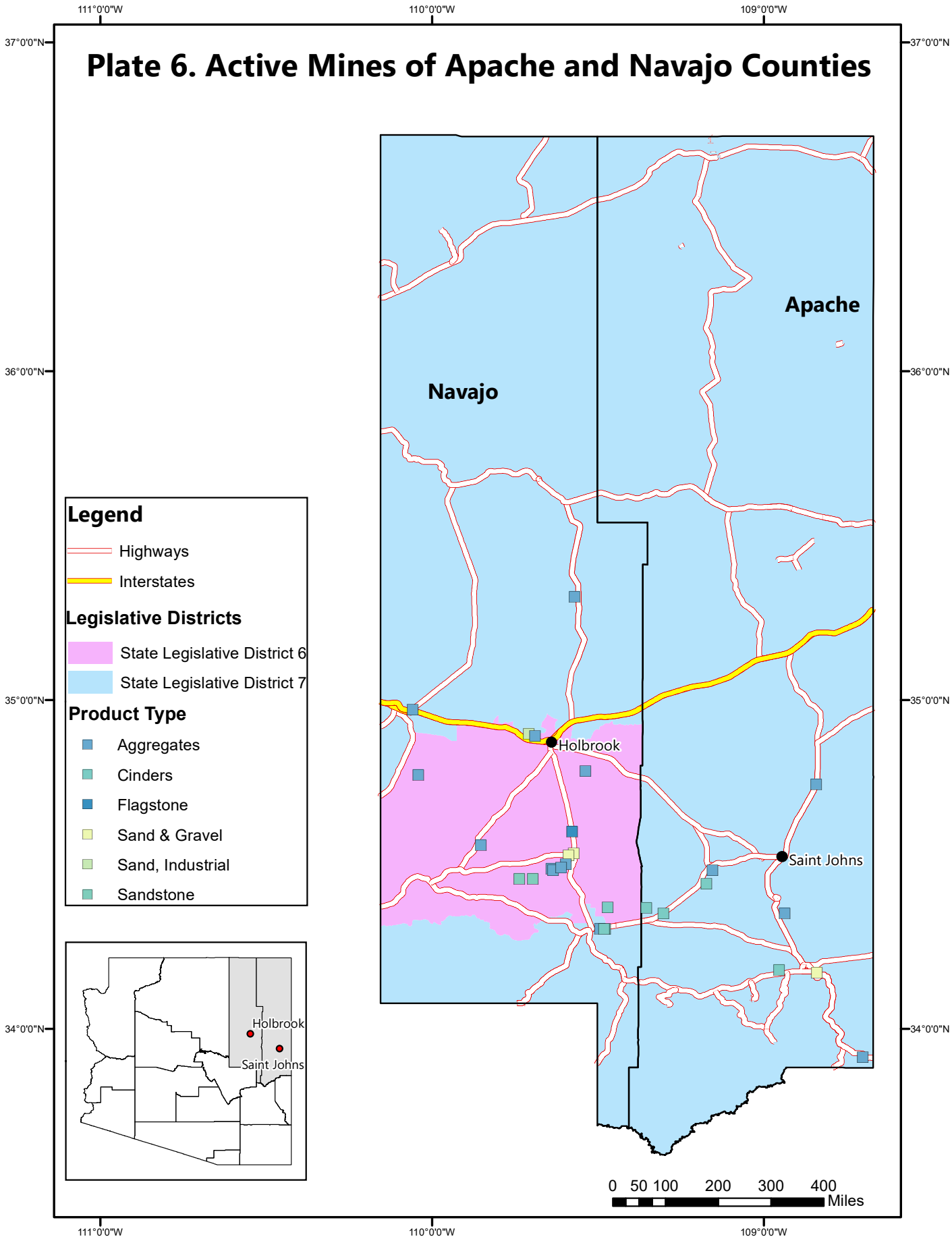

115°0'0"W
114°0'0"W
113°0'0"W
112°0'0"W
111°0'0"W
37°0'0"N
36°0'0"N
35°0'0"N
34°0'0"N
0 15 30 60 90 120
Miles
Legend
Highways
Interstates
Legislative Districts
State Legislative District 1
State Legislative District 5
State Legislative District 6
State Legislative District 7
State Legislative District 13
State Legislative District 22
Product Type
Aggregates
Asphalt
Building Stone
Cement/Lime
Cinders
Clay
Copper
Decorative Stone
Flagstone
Gold
Gold & Silver
Gold / Silica Sand
Granite/Decorative Stone
Gypsum
Iron Ore
Lime
Sand & Gravel
Soil and Sand
Stone, Dimension
Stucco Sand
Turquoise
Uranium
Mohave
Coconino
Yavapai
Kingman
Flagstaff
Prescott
Kingman
Flagstaff
Prescott
Plate 5. Active Mines of Coconino, Mohave, and Yavapai Counties

Plate 6. Active Mines of Apache and Navajo Counties



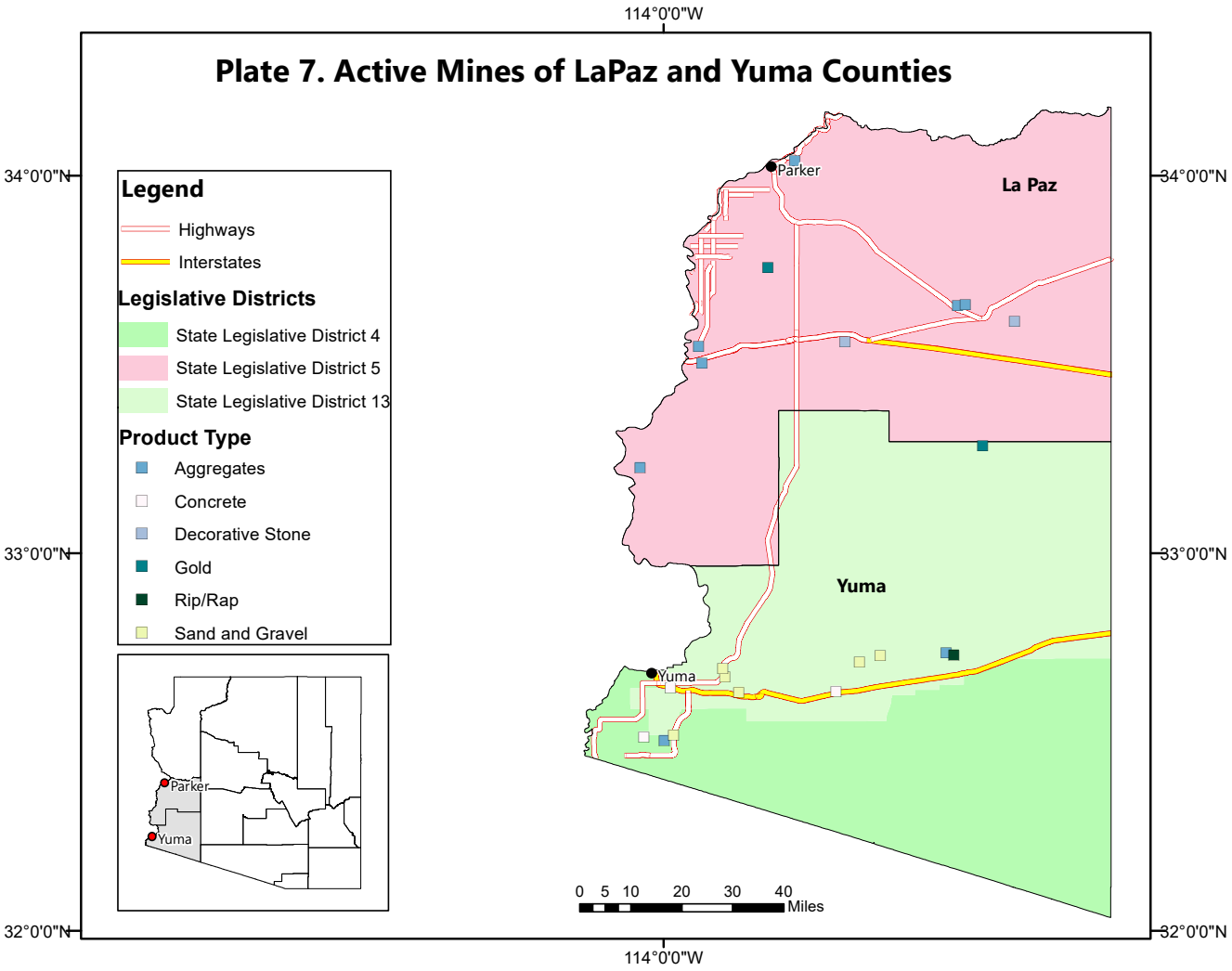


Plate 7. Active Mines of LaPaz and Yuma Counties
114°0'0"W
34°0'0"N
33°0'0"N
32°0'0"N
Legend
Highways
Interstates
Legislative Districts
State Legislative District 4
State Legislative District 5
State Legislative District 13
Product Type
Aggregates
Concrete
Decorative Stone
Gold
Rip/Rap
Sand and Gravel
Parker
Yuma
La Paz
Yuma
0 5 10 20 30 40
Miles