Directory of Active Mines in Arizona: FY2020

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Cover Image: Top Right: High-wall at Silver Bell Copper Mine. Bottom Right: Whitecliffs Diatomite Mine. Bottom Left: Shovel loading a haul truck at Bagdad Copper Mine. Top Left: Underground mining loader with operator at mine dumps of Clementine mine. All photos available on Arizona Geological Survey Mining Data website.

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Preface

The purpose of this report is to support governmental entities undertaking planning decisions by providing on mineral resources and active mining operations that are essential to infrastructure development.

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 the there are additional mines not listed that are in an exploration, evaluation, or part-time development phase. Other mines where production is intermittent are not listed. The directory is compiled from a much larger database from the Arizona State Mine Inspector's Office. Staff and budget restrictions prevent the Arizona Geological Survey from visiting the operations listed. 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 difficult to recognize activity; and 2) some areas lack recent imagery, leading to the impression of no recent operations.

This work fulfills amended sections 9-461.05, 11-804, and 27-106 of the Arizona Revised Statutes, having went 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.

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https://arcg.is/1844Hi0

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 and 68% of domestic production in 2019 (U.S. Geological Survey, 2020). 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 2019, Arizona was ranked the 9th most attractive region in the world for mining and exploration by the Fraser Institute, which considered both geologic attractiveness and favorable government policies. Arizona consistently ranked in the top 20-30 regions through most of 2000-2015, and has been ranked as a top ten region for mineral resource investment since 2016 (Table 1).

Commodities and Active Mines/Projects

In FY 2020, there were 401 active, full-time mines or development projects in the state of Arizona (Plate 1). Each mine extracts a specific product that have been categorized into 44 discrete products. 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:

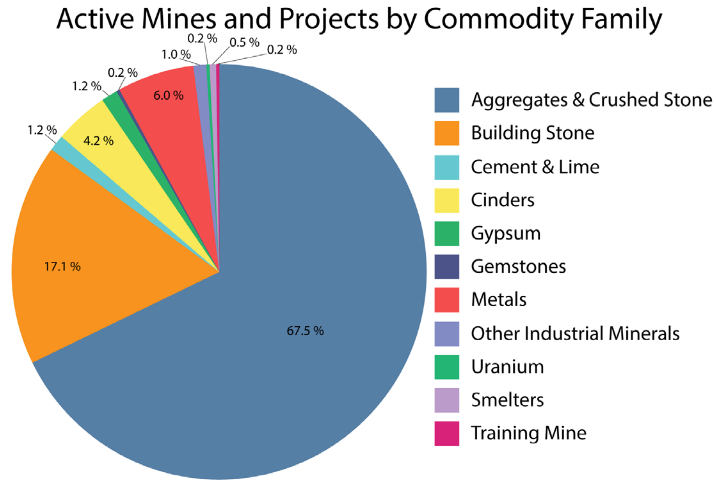

Figure 1. Active Mines and Projects by Commodity Family

- Aggregates & Crushed Stone: Aggregates are variably sized crushed earth materials used in construction and infrastructure. They are crushed by natural processes (e.g., particle size reduction via flow in fluvial [river] systems) and/or by anthropogenic processes (crushing via machinery). Aggregates provide bulk and strength to mixed materials and

Table 1. Arizona's Ranking in Investment Attractiveness[1], 2001-2019

Year(s)	Rank	Number of Considered Regions	Source
2019	9	76	Stedman et al. (2019)
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 jurisdiction based on policy factors (e.g., regulations, taxation levels, infrastructure), and the geologic attractiveness or mineral potential.

Table 2. Classification Scheme

Commodity Family	Commodity Type	Product
Aggregates and Crushed Stone	Sand and Gravel	Aggregates
		Asphalt
		Gold / Silica Sand
		Sand and Gravel
		Soil and Sand
		Stucco Sand
	Concrete	Concrete
		Pozzolan
		Ready Mix
Building Stone	Decorative Stone	Decorative Rock
		Decorative Stone
		Granite / Decorative Stone
	Dimension Stone	Building Stone
		Stone, Dimension
	Flagstone	Flagstone
	Limestone and Marble	Limestone
		Marble
	Sandstone	Sandstone
	Rip / Rap	Rip / Rap
Cement and Lime	Cement and 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 and Silver
		Silver
	Iron	Iron and Gold
		Iron
	Lead-Zinc-Silver	Lead / Zinc / Silver
Other Industrial Minerals	Clay	Clay
	Industrial Sand	Sand, Industrial
	Perlite	Perlite
	Pumice	Pumice
	Salt	Salt
	Zeolites	Chabazite Clay
		Zeolite - Chabazite
Uranium	Uranium	Uranium
Training Mine	Training Mine	Training Mine
Smelter	Smelter	Smelter

used in a 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 used placed along shorelines, 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 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 in a magma chamber 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, 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). Coal mining in Arizona ceased in late 2019 with to the closure of the Navajo Generating Station and the Kayenta coal mine.
- Gypsum: Gypsum, calcium sulfate dihydrate ($CaSO4 \cdot 2H2O$), is an evaporite mineral that often accumulate in basins or salt flats under arid conditions. Gypsum has multiple uses, from carving due to its soft properties (called alabaster in that context), utilized for cement, fertlizers, and fillers in

toothpaste and paint, and most commonly as plasterboard and rendering walls and ceilings (Evans, 1993);

- Gemstones: Currently includes a significant producer 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. 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 medical 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: 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).

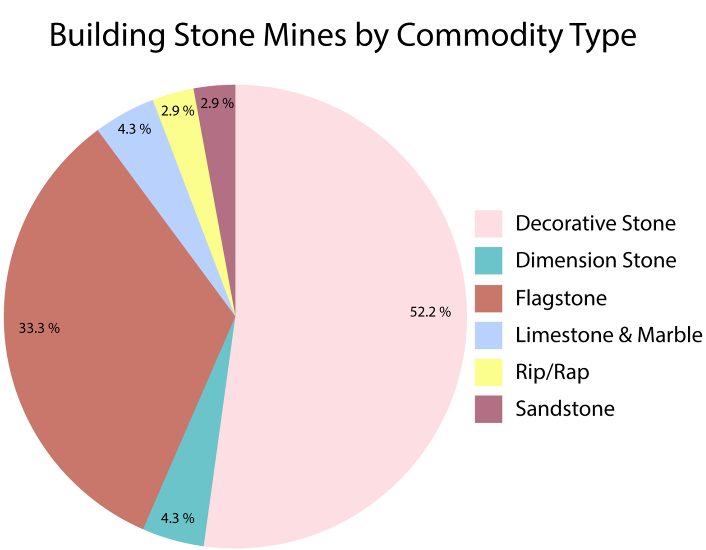

Figure 2. Building Stone Mining Operations by Commodity Type

- Training Mine: The San Xavier Underground Mining Laboratory operated by the Department of Mining and Geological Engineering at the University of Arizona for research and training students.
- 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.

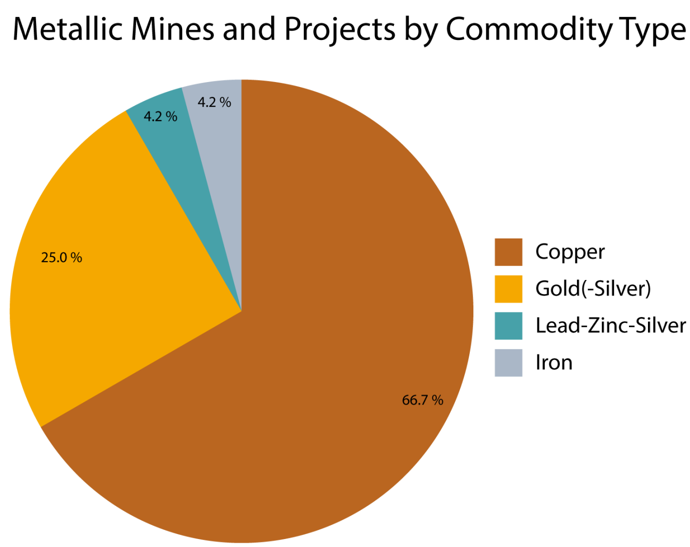

Figure 3. Metallic Mining Operations by Commodity Type

Complete data for each mine is listed in the appendix Table A1. 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/1844Hi0.

Facilities that supplied aggregates and crushed stone constitute two-thirds of the mining facilities in the state with 272 out of 401 active mines or quarries (Fig. 1). Of the aggregate and crushed stone facilities, 18 sites have asphalt hot plans, 45 have concrete batch plants, and 22 have both an asphalt hot plant and concrete batch plant. The second largest commodity family is building stone, where the all but ~85% of production (59 of 69 quarries) produces either decorative stone or flagstone (Fig. 2). Metallic mining in Arizona remains dominated by copper with 16 of 24 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.

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