

Arizona Industrial Minerals through Geologic Time

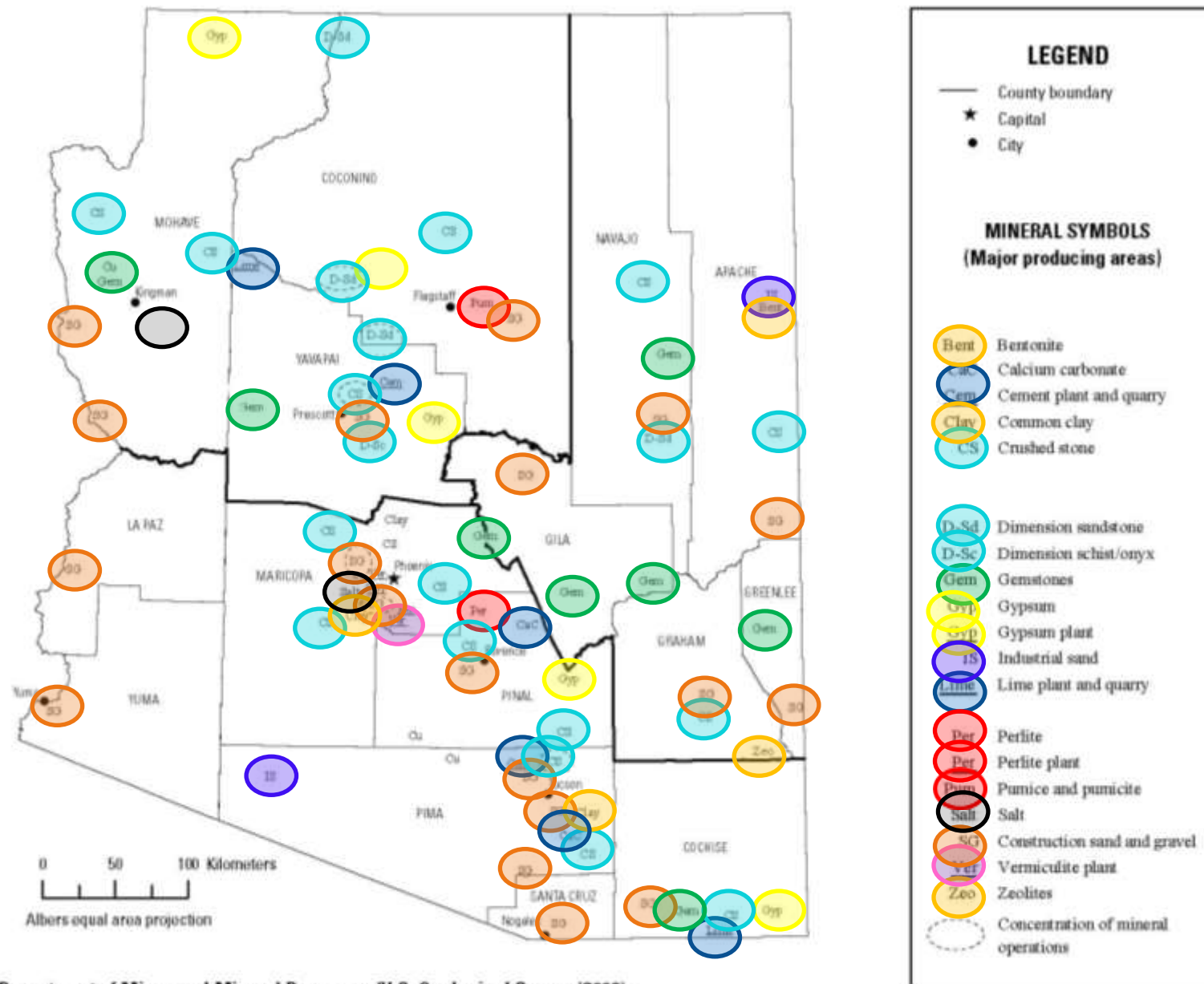


Mineral photos from the former Arizona Mining and Mineral Museum, closed in 2011 by the Arizona Historical Society.



Jan C. Rasmussen, Consulting Geologist, Ph.D., SME R.G.
and **Stanley B. Keith**, MagmaChem Exploration

Industrial Mineral Mines



Industrial Minerals in Precambrian & Paleozoic

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Industrial Minerals	Productive Mining areas/ Examples
Alleghenian (Ouachita)		325-220	Miss. – Triassic	Gypsum, Salt, Potash, Flagstone	Permian Holbrook salt, potash, gypsum; Coconino Ss. flagstone; cavities for gas storage in Supai evaporites; Moenkopi dimension stone
Lull between Acadian - Alleghenian		360-325	Mississippian	Limestone, Lime, Marble	Escabrosa & Redwall Ls. for cement
Acadian/ Caledonian		410-380	Devonian	Limestone for flux	Martin Fm.
Taconic.		490-445	Cambrian – Ord.	Quartzite for flux	Bolsa Quartzite
Grenville		1200-900	Late Middle Proterozoic – Early Late Proterozoic	Serpentine asbestos – Mescal Ls. altered by diabase; Dripping Spring Quartzite for flux	Chrysotile asbestos (Salt R. Canyon, Sierra Ancha Mts.); dimension stone
Oracle/Ruin		1440-1335	Middle Proterozoic	Silica, Feldspar & Mica from pegmatites; Beryl; Granite	White Picacho pegmatites; Four Peaks Amethyst; Buckeye Hills feldspar; granite dimension stone, crushed landscaping & clay
Mazatzal		1750-1600	Late Early Proterozoic	Silica, Granite	Mayer metarhyolite decorative facing stone; Payson granite road metal
Yavapai		1800-1775	Late Early Proterozoic	Silica, Granite, Schist	Crushed stone, BIF hematite for feed for cement plant
Penokean/ Hudsonian		2000-1800	Middle Late Proterozoic	Sparse localities – no production	

Industrial Min. – Mesozoic-Cenozoic

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Industrial Minerals	Productive Mining areas/ Examples
San Andreas	Basin & Range	5-0	Pliocene (5-2 Ma)	Sand, Gravel, Cinders, Peridot, Zeolites, Gypsum; Clay from altered latitic vitric ash, Hydrofrac sand reworked from Permian sand	San Francisco volcanic field cinders, San Carlos olivine; Bidahochi Fm. hydrofrac sand, Cheto bentonite clay
		13-5	Late Miocene (12-5 Ma)	Halite; Perlite; Cinders, Pumice, Perlite, Zeolite; Gypsum; Specialty Clay, Diatomite	Luke Salt, Red Lake halite; Bowie zeolite; San Pedro valley gypsum, diatomite, Burro Creek clay
Galiuro	Late (Whipple)	18-13	Middle & Late Miocene (16-12 Ma)	Fluorite, barite assoc. with gold veins; amethystine quartz	Oatman fluorite
	Middle (Datil)	28-18	Early Miocene (23-14 Ma)	Fluorite, barite assoc. with Pb-Zn-Ag F veins; gravel	Superior perlite; Sleeping Beauty turquoise from Castle Dome mine; Apache Leap Tuff building stone
	Early (South Mountain)	30-22	Late Oligocene (28-23 Ma)	Gravel	:
	Earliest (Mineta)	38-28	Early Oligocene (34-28 Ma)	Clay, Gravel	Pantano common clay for bricks
Laramide	Late (Wilderness)	55-43	Early Eocene (56-41 Ma)	Feldspar, Beryl, Mica; Gravel	
	Middle (Morenci)	65-55	Paleocene (66-56 Ma)	Metamorphism of limestone to marble; clay alteration on fringes of porphyry Cu	Clay at Kalamazoo (San Manuel); Sahuarita marble; Turquoise at Kingman, Castle Dome
	Early (Tombstone)	85-65	Late Cretaceous	Fluorite assoc. with Pb-Zn-Ag veins & replacement deposits	Kaolinitic shales Upper Cretaceous E AZ
	Earliest (Hillsboro)	89-85	mid-Cretaceous		
Sevier		145-89	Early & mid-Cretaceous	Limestone; Lime	Paul Spur Lime in Mural Ls. of Bisbee Group
Nevadan	Late	160-145	Late Jurassic		
	Middle	205-160	Early & Middle Jurassic	Turquoise; Sandstone for flux	Bisbee blue turquoise
	Early	230-205	Late Triassic	Gypsum, Petrified Wood	Chinle Fm. Petrified wood;

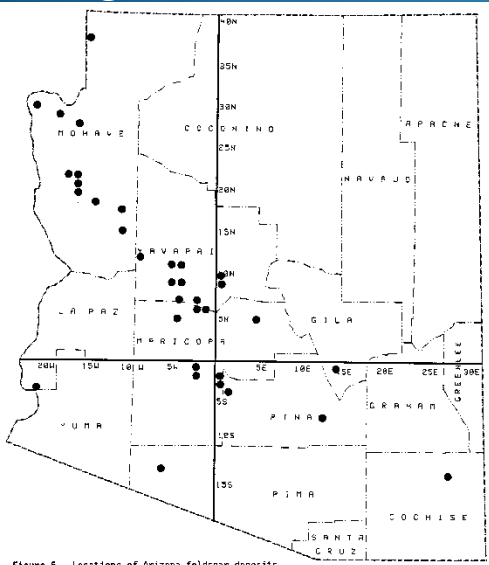
Pegmatite Minerals – 1400 Ma



Orthoclase feldspar,
Dragon

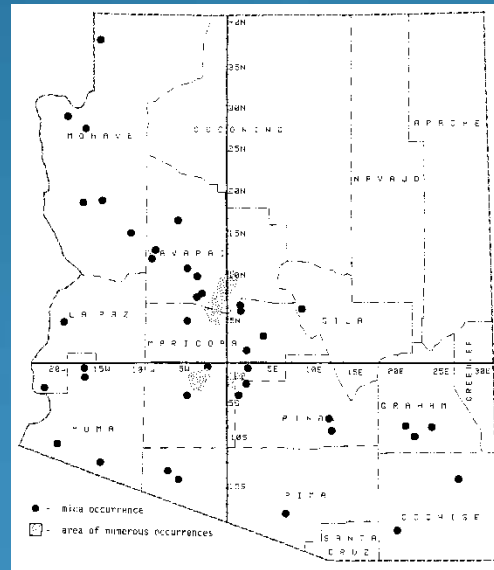


Cleveland Co., NC



Feldspar occurrences

Jan C. Rasmussen, Ph.D., R.G.



Mica occurrences

Operation Name	Company
Black Canyon Mica3	Azco Mica Inc.
February 22, 2016	

Gemstone – Amethyst - 1400 Ma

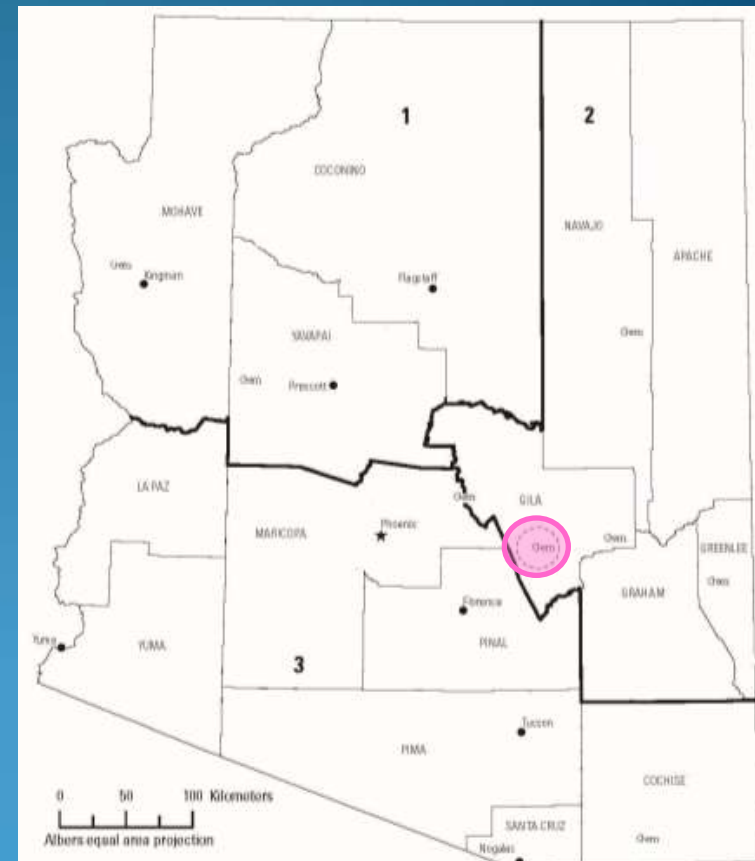
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
"Oracle/Ruin"		1440-1335	Middle Proterozoic	K-feldspar megacrystic or porphyritic granites	Peralum. Calc-alkalic, Alkali-calcic	Pegmatites & greisens – Be, Li, Ta-Nb, U & W	White Picacho, Tungstona, Four Peaks



Oracle Granite, Santa Catalina Mts.



Amethyst, Four Peaks mine, Mazatzal Mts., Maricopa Co.



Department of Mines and Mineral Resources/U.S. Geological Survey (2010–11).

Grenville Orogeny (1200-900 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Aluminum & Alkalinity	Resources	Mining districts
Grenville		1200-900	MQA	Serpentine asbestos, U, (Cu)	Sierra Ancha U, Chrysotile (Salt R. Canyon)

Apache Gp., serpentine asbestos

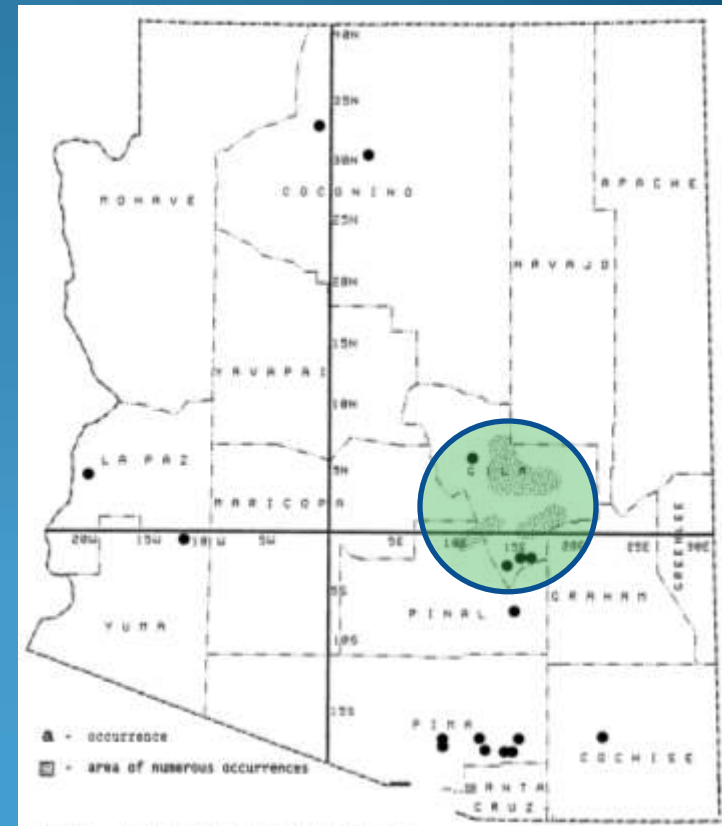


El Dorado mine, Gila Co.

Diabase in contact with Mescal Limestone made marble and serpentine asbestos

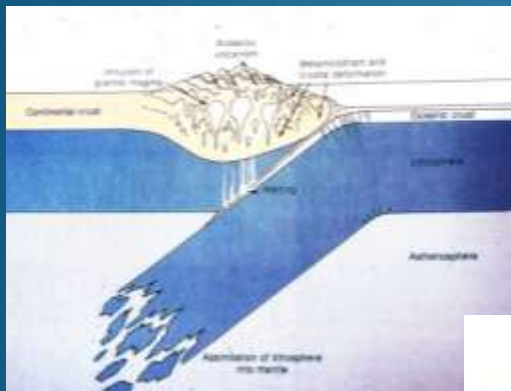


Diabase in Apache Gp

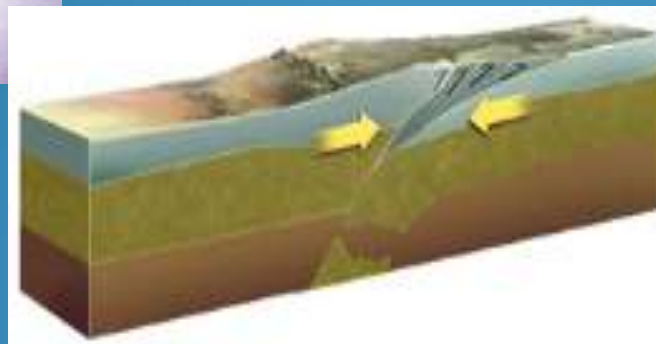


Paleozoic Orogenies in eastern U.S.

Orogeny	Orogenic Phase	Age (Ma)	Aluminum & Alkalinity	Resources	Mining districts
Alleghenian (Ouachita)		325-252	-	U, NaCl, K ₂ CO ₃	Payson uranium, Holbrook salt, potash
Lull between Acadian & Alleghenian		355-330		Limestone	Redwall Ls., Escabrosa Ls.
Acadian/ Caledonian/ Antler (NV)		410-370	-	UltraDeep Hydrocarbon?	Percha black shale
Taconic.		460-430	-		Hosts for later replacement

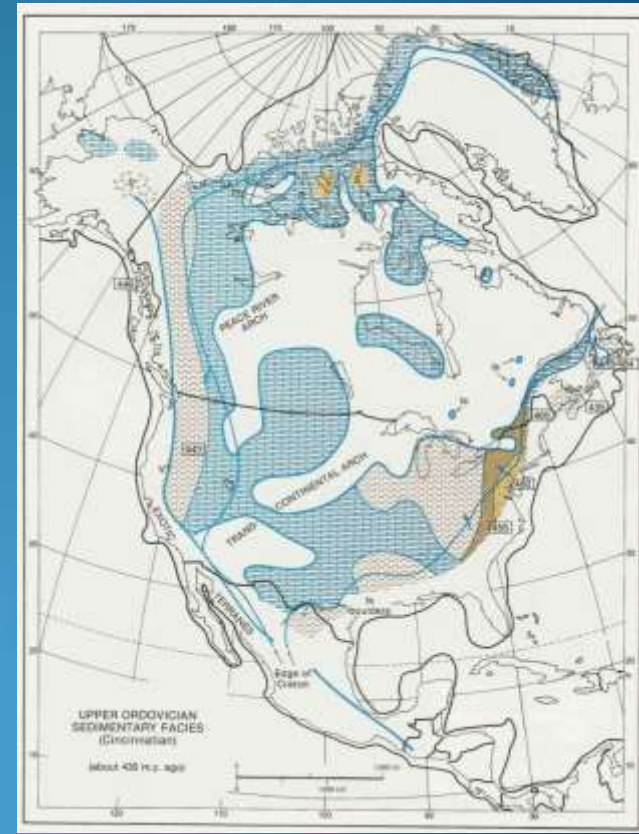


Arizona was on the western, trailing edge of North America



Collisions of eastern N.A. with Europe or Africa made large mountain ranges.

Arizona mostly had seas go in and out (transgression/regression).



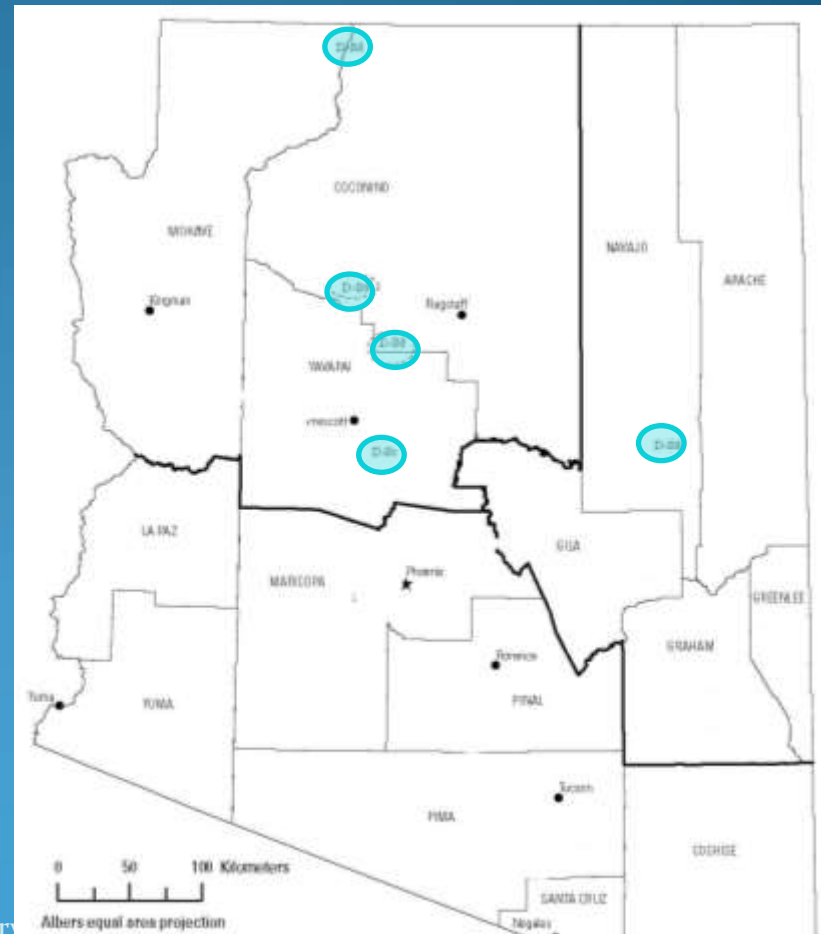
Dimension Stone



Mostly Coconino Ss
- Permian (~280
Ma) flagstone

Operation Name	Company Name
Apache Quarry	American Sandstone
Black Cat Quarries	American Sandstone
Blaser Stoneyard	American Sandstone
Coconino Quarries 1	American Sandstone
Cucamonga Quarry	American Sandstone
Geronimo Quarries	American Sandstone
Golden Buckskin Quarry	American Sandstone
Mills Quarries	American Sandstone
Red Bird Quarry	American Sandstone
Santa Cruz Quarry	American Sandstone
Trick Tank Quarry	American Sandstone
Yellow Horse Quarries	American Sandstone
New River Slate Quarry	Anasazi Stone
Rattlesnake Quarry	Anasazi Stone
Sidewinder Quarry	Anasazi Stone
Blue Bell Schist Quarry	Apache Stone
Brown Dog Quarry	Apache Stone
Echo Green Quarry	Apache Stone
Rainbow Schist Quarry	Apache Stone
Jagged Tooth Quarry	Arizona Aggregate Removers
Diamond 7 Oak Quarry	Drake Stone Products Inc.
Diamond 7 Quarry	Drake Stone Products Inc.
M C Canyon Quarry	Drake Stone Products Inc.
Rockhouse Quarry	Drake Stone Products Inc.
Antelope Quarry	Dunbar Stone Company Inc.
Blue Jay Quarry	Dunbar Stone Company Inc.
Hualapai Chocolate Quarry	Dunbar Stone Company Inc.
Red Bird Quarry	Dunbar Stone Company Inc.
Granite Pit	Fort McDowell Yavapai Materials

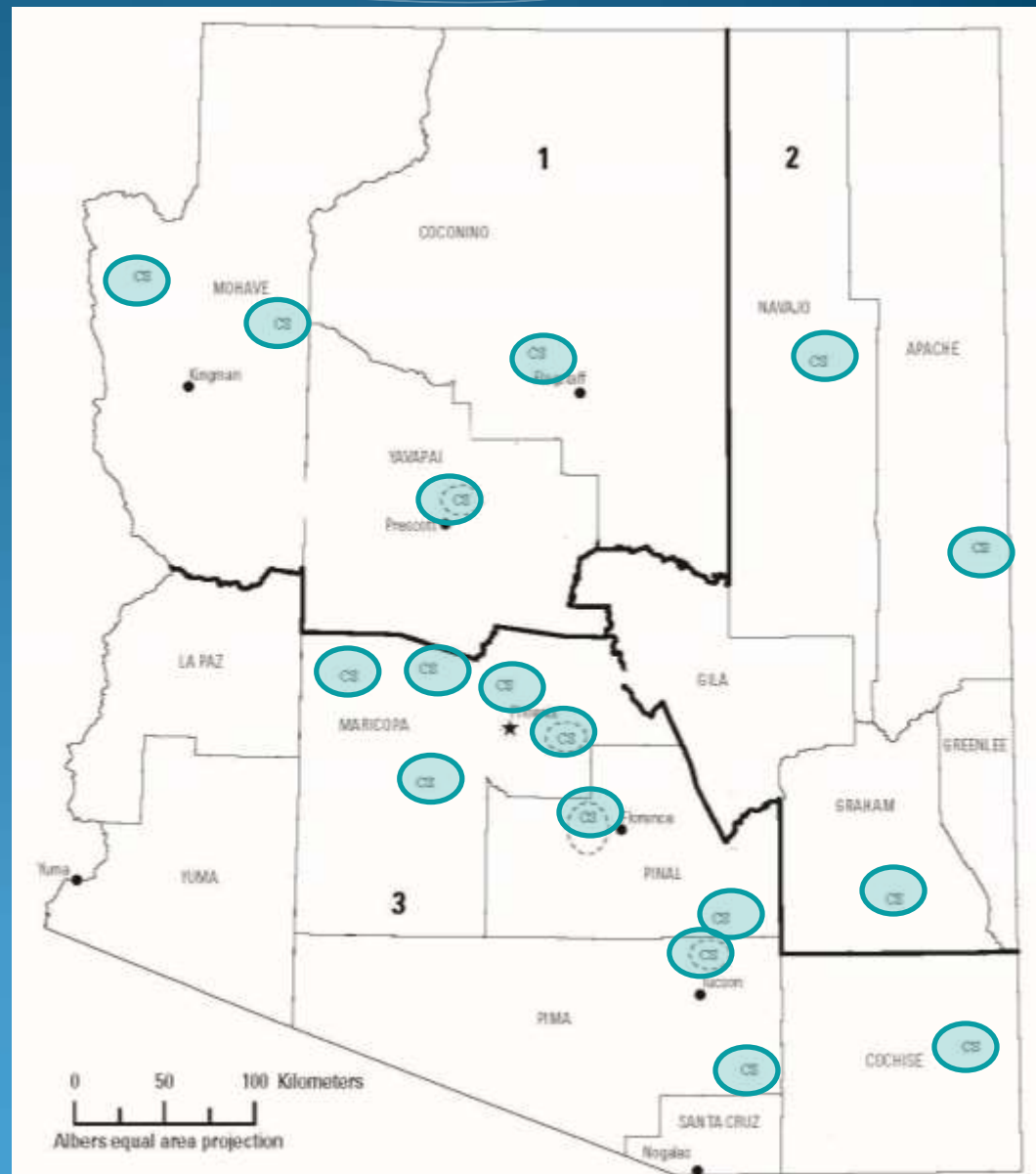
Operation Name	Company Name
Oak Quarry	Hammond Wholesale Flagstone
Oak Quarry	Harley Gray Stone Company
Partridge Quarry	Harley Gray Stone Company
Bacon and Beans Quarry	Horner Stone
Cucamonga Quarry	Horner Stone
Mary Ann Quarry	Horner Stone
Ferno/Oaky Quarry	Levin Stone Company Inc.
Levin Stone Plant	Levin Stone Company Inc.
Switchback Quarry	Mortimer Inc.
Rock Ridge Quarry	Rock Ridge Quarries LLC
Stone Yard and Plant	Silver Arrow Stone
Sweet Thing 1 and 2	Silver Arrow Stone
Crookton Quarry	Star Stone Quarries Inc.
Champagne Quarry	Stone World
Classic Oak	Stone World
Lizard Group Quarries	Stone World
Mayer Onyx	Stone World
Rattlesnake Canyon	Stone World
Sedona Red	Stone World
Copper Queen	Triple R Stone
Arizona Gold	White Mountain Sandstone Corp.
Buckskin Quarry	White Mountain Sandstone Corp.
Chocolate	White Mountain Sandstone Corp.
Shiraz	White Mountain Sandstone Corp.
Sierra Quarry	White Mountain Sandstone Corp.



Crushed Stone

Buckeye Hills Quarry	Kilauea Crushers Inc.
Estrella Quarry	Kilauea Crushers Inc.
Jomax Quarry	Kilauea Crushers Inc.
Picacho Quarry	Kilauea Crushers Inc.
MDI Pit (El Paso Pit)	Material Delivery Inc.
McCall Pit	McCall Construction
Redi Mix Detrital Pit	Meadow Valley Contractors Inc.
Redi Mix Detrital Pit	Meadow Valley Contractors Inc.
Mineral Park Pit	Mineral Park Decorative Rock
Rio Del Monte Mine	Murphy Landscaping & Excavating LLC
Casa Grande Quarry	Pioneer Sand Company
Navajo Quarry	Pioneer Sand Company
Picacho Quarry	Pioneer Sand Company
Prescott Valley Granite Pit	Prescott Valley Granite
Red Hills Quarry	Red Hills Mining LLC
Red Mountain Quarry	Red Mountain Mining Inc.
Congress Quarry	Rock Sources
Star Valley Granite Quarry	Star Valley Granite & Materials
Copper Chief	Sunset Marble Company LLC
Superstition Mountain Granite Pit	Superstition Mountain Stone Inc.
Treasure Chest Granite Quarry	Treasure Chest Granite Pit Inc.
Walker Butte Granite	Walker Butte Granite LLC
Riggs Pit	Willcox Rock & Sand Inc.

Hardluck (Bidahochi) Pit	Brimhall Sand Rock & Building Materials
New River Slate Quarry	Building Products Company
Red Lake Quarry	Crown Materials LLC
Belmont Pit (US Mine)	Custom Landscape Materials LLC
Little Hill Mine	Decorative Rock Sales LLC
Sacramento Mine	Dick Merritt Construction
Chevelon Pit	Dyna Rock & Sand
Eureka Rose	Eureka Mining
Reymert Mine	Gila Rock Products LLC
Barkley Pit	Granite Express LLC
Mineral Mountain	Granite Express LLC
Docie Pit	Granite Mountain Materials
Congress Pit	Jakes Granite Supplies LLC
Bonito Quarry	Kalamazoo Materials Inc.
Broccoli Raab	Kalamazoo Materials Inc.
Chloride Quarry	Kalamazoo Materials Inc.
New Superior	Kalamazoo Materials Inc.
Old Superior Quarry	Kalamazoo Materials Inc.
Valentine Quarry	Kalamazoo Materials Inc.
White Hills Pit	Kalamazoo Materials Inc.
Buckeye Hills Quarry	Kilauea Crushers Inc.
Estrella Quarry	Kilauea Crushers Inc.
Jomax Quarry	Kilauea Crushers Inc.
Picacho Quarry	Kilauea Crushers Inc.



Quartz / Sandstone / Flux



Quartz, Washington Camp,
Santa Cruz Co.

Sandstone



Operation Name	Company Name
Copper Hill	Kessen and Kessen
Bobbitt Silica	Smithco Enterprises Inc.

Limestone/ Lime ~ 350 Ma



Escabrosa Limestone



Rillito plant, Marana



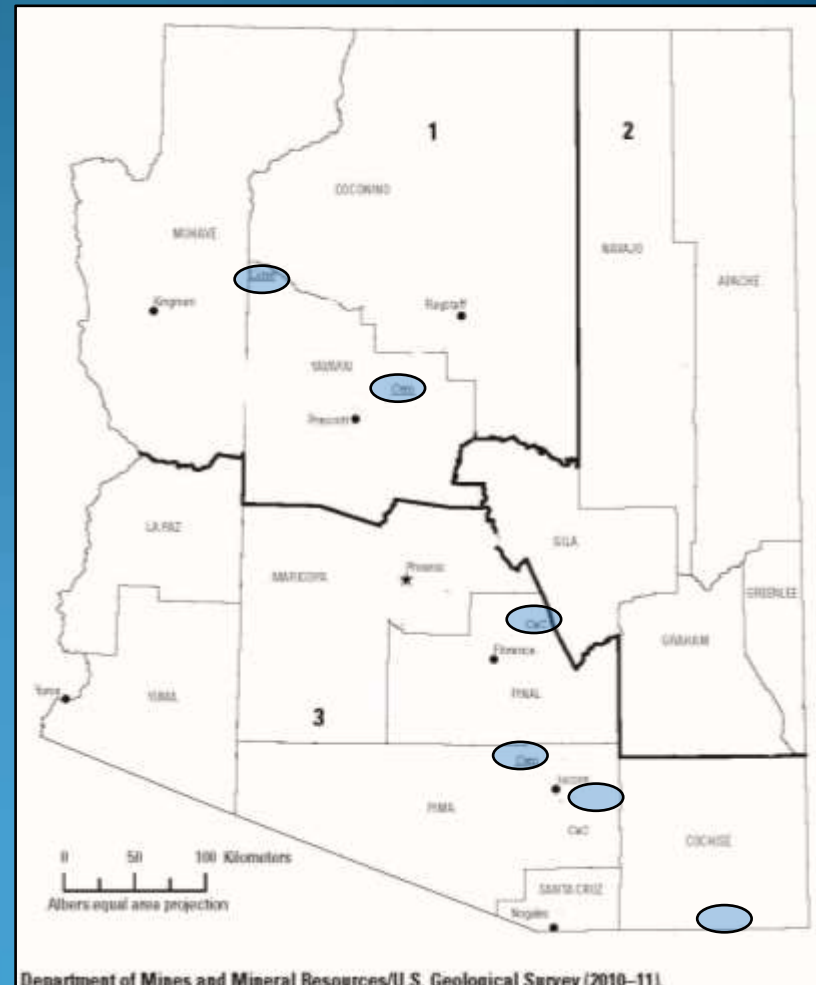
Limestone



Redwall Limestone



Clarkdale Cement plant



Cement/ Lime

Operation Name	Company Name
Rillito Plant	Arizona Portland Cement Co.
Twin Peaks Quarry	Arizona Portland Cement Co.
Cedar Glade Quarry	Drake Cement LLC
Clarkdale Quarry & Plant	Phoenix Cement Company



Hot Springs ~ Permian 252 Ma

Potash (sylvite & polyhalite), Salt, Gypsum

Halite, Salton Sea, CA



Sylvite, Carlsbad, NM



Polyhalite, Carlsbad, NM

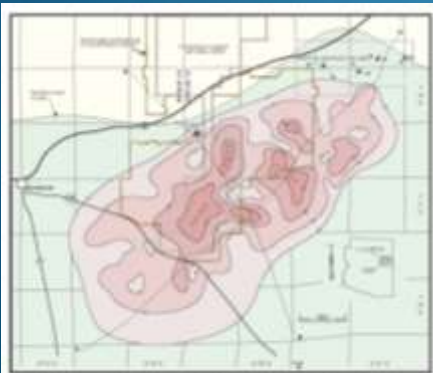
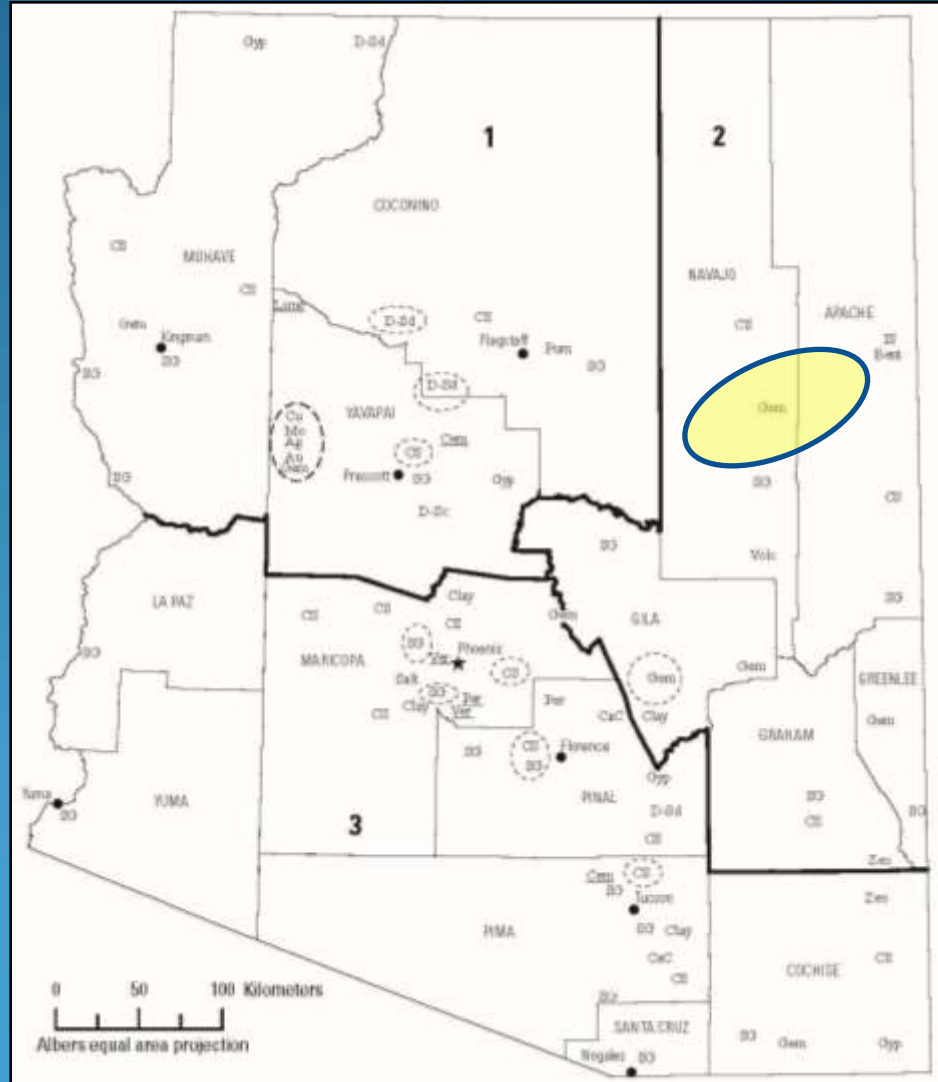


Figure 3. Map showing distribution of Permian hot springs in the Four Corners region, Arizona and New Mexico. Arrows indicate inferred flow directions. The red shaded areas indicate the locations of the springs. The map is based on data from the USGS and other sources.

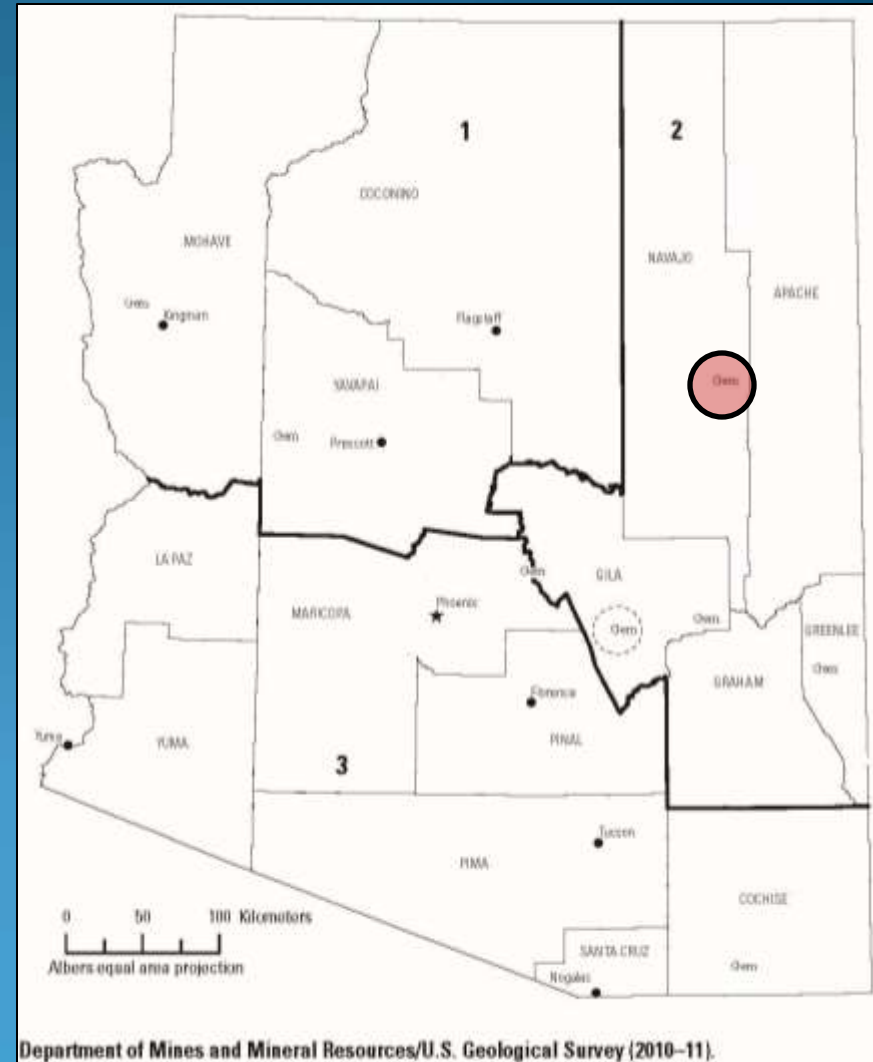


Gemstones – Petrified Wood

Triassic Chinle Fm. ~ 200 Ma



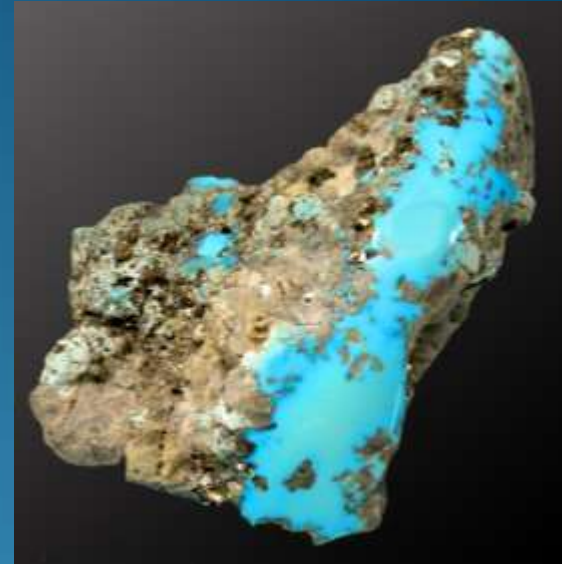
**Petrified Forest Member,
Chinle Fm., Petrified Forest
National Park**



Gemstones – Bisbee blue

Turquoise - 190 Ma – Nevadan orogeny

Lavender Pit, Bisbee

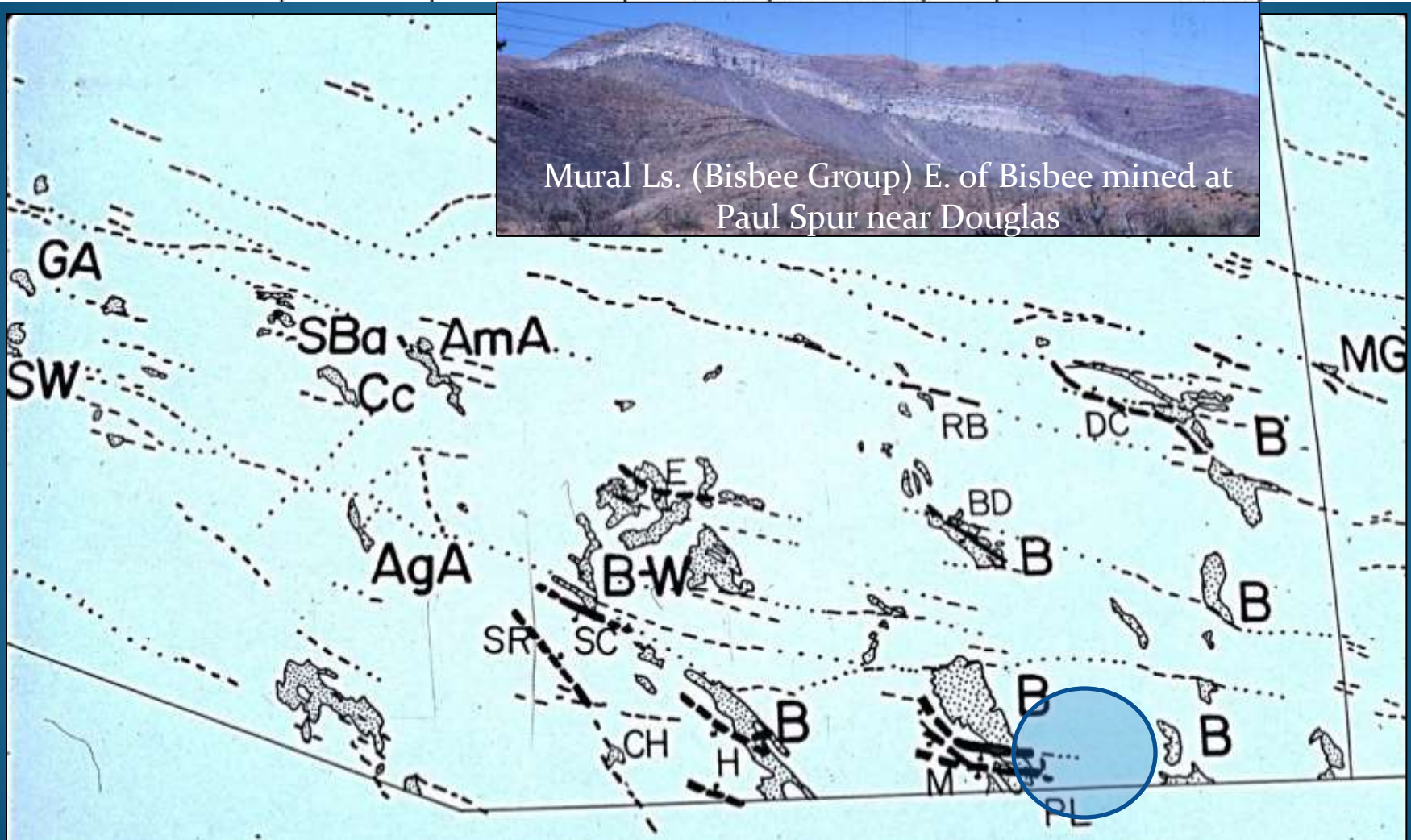


Bisbee 'blue' - turquoise

Sacramento Stock =
190 Ma MQA

Sevier sedimentation, faults (145-89 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Aluminum & Alkalinity	Resources	Mining districts
Sevier		145-89	-	Bisbee Group sedimentary rocks (113-100 Ma)	Limestone (Paul Spur near Bisbee)



Marble

– metamorphosed ~ 65 - 56 Ma – around contacts with Laramide intrusions



Marble, Dagoon

Operation Name	Company Name
Douglas Plant	Chemical Lime Company of Arizona
Nelson Quarry and Plant	Chemical Lime Company of Arizona
Cross Spear Marble Quarry	Cross Spear Marble Inc.
Santa Rita Quarry	Imerys
Queen Creek Limestone	Omya Arizona Inc.
Superior Marble	Superior Marble LLC



Dagoon Marble



Sahuarita Marble

Clay ~ mid-Tertiary 38-20 Ma



Pantano Clay, East Tucson

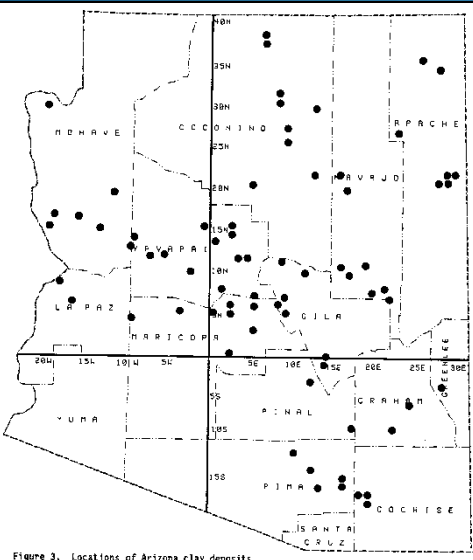
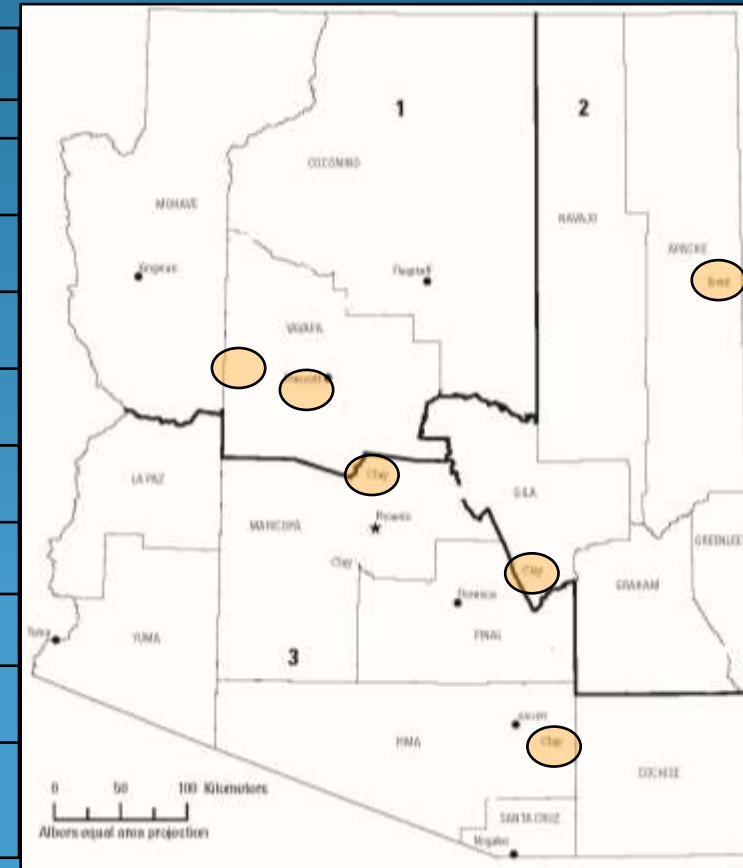


Hectorite

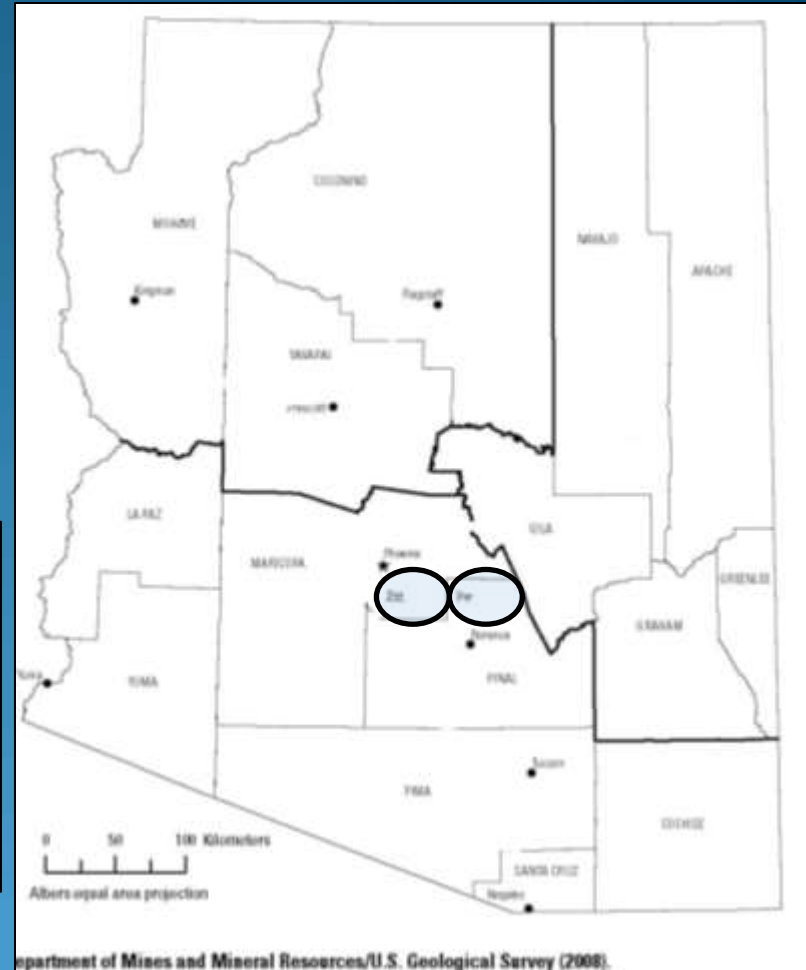
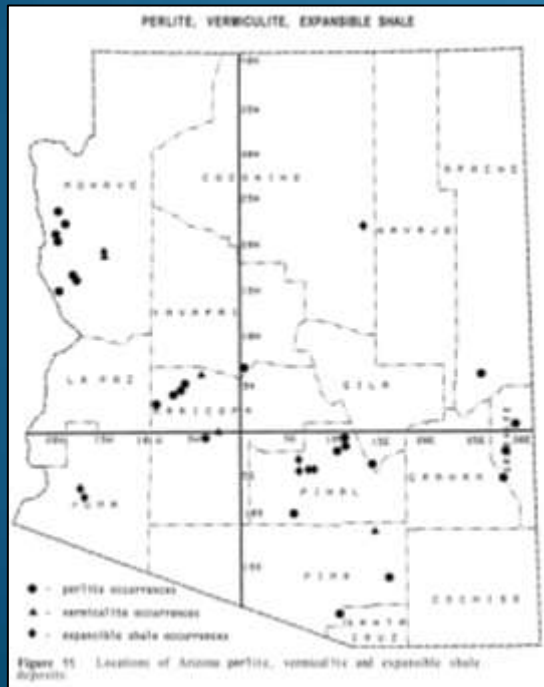
Lyle Hectorite
– photo from Ted Eyde



Operation Name	Company Name
Cheto #2	BASF Catalysts LLC
Dewey Ranch #2	Building Products Company
Rim Quarry	Building Products Company
Clay Mine Adobe Pit	Clay Mine Adobe Inc.
Pantano Clay Pit	Clinton - Campbell Contracting Inc.
Tolleson Pit	Clinton - Campbell Contracting Inc.
Weary Lode Mine	McKusick Mosaic
Burro Creek Clay	Nano Clays LLC
Old Pueblo Adobe Pit #1	Old Pueblo Adobe
Cheto Mine 1	Sud-Chemie Performance Packaging-Div/Sud-hemie



Perlite – Superior ~ 25 Ma



Operation Name

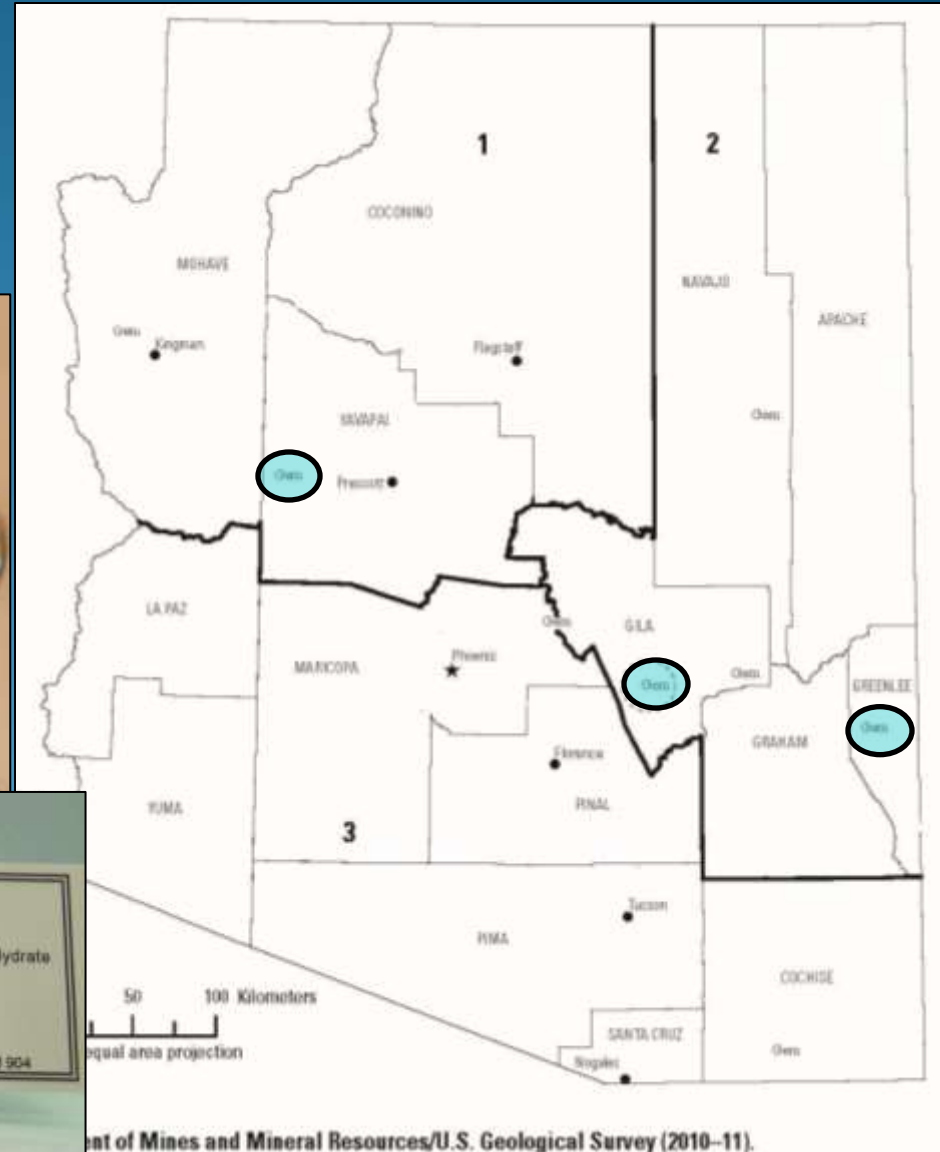
Company Name

Superior Perlite

Harborlite Corporation

Gemstones - Turquoise

Operation Name	Company Name
Morenci	Freeport McMoRan
Mineral Park	Kingman Turquoise Mining Co.
Sleeping Beauty Mine	Sleeping Beauty Turquoise

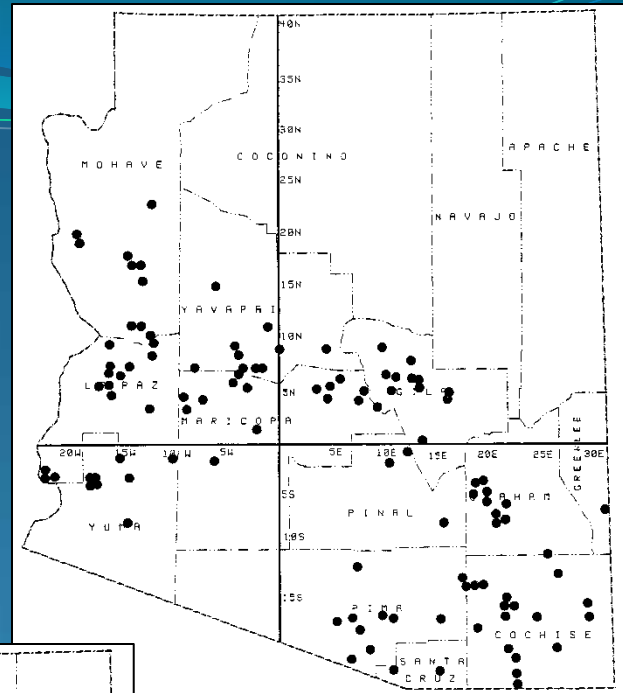


Fluorite ~ 18 Ma



Fluorite, Homestake mine,
Oatman

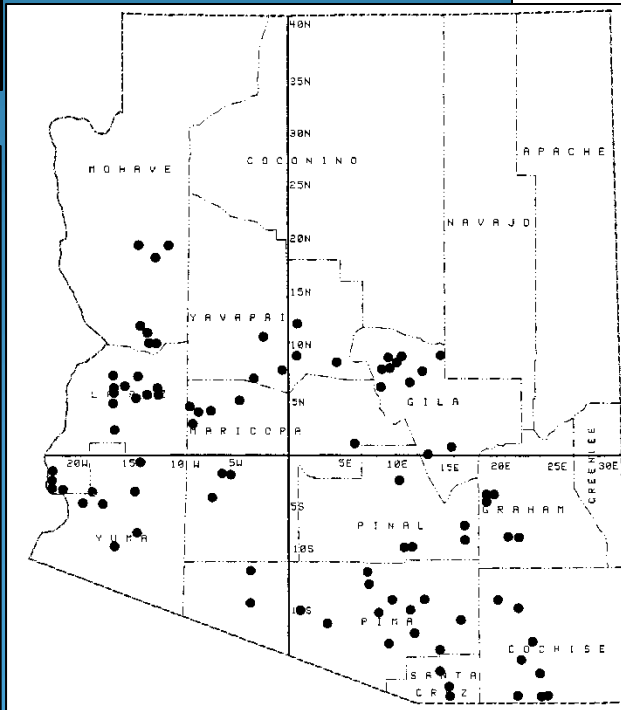
Associated with
lead-zinc-silver or
gold veins



Fluorspar
occurrences

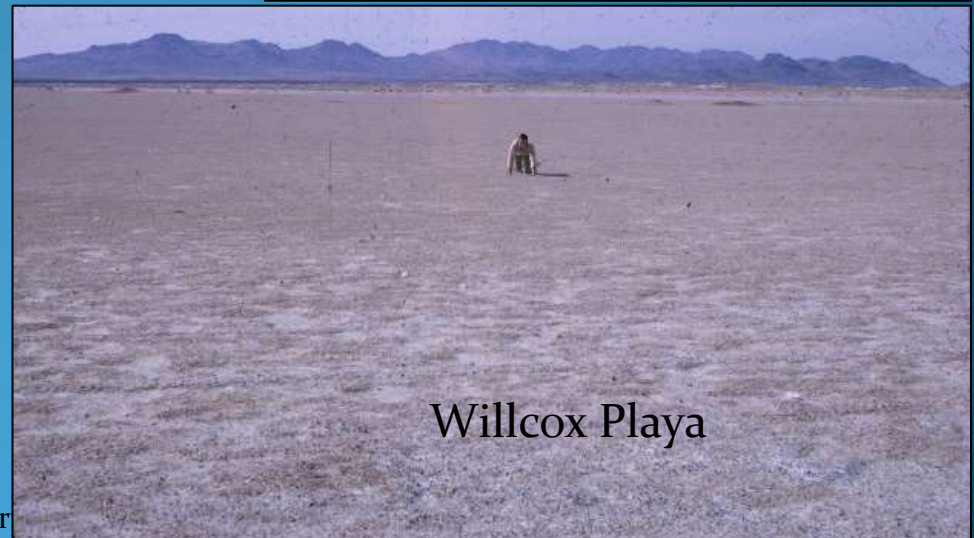
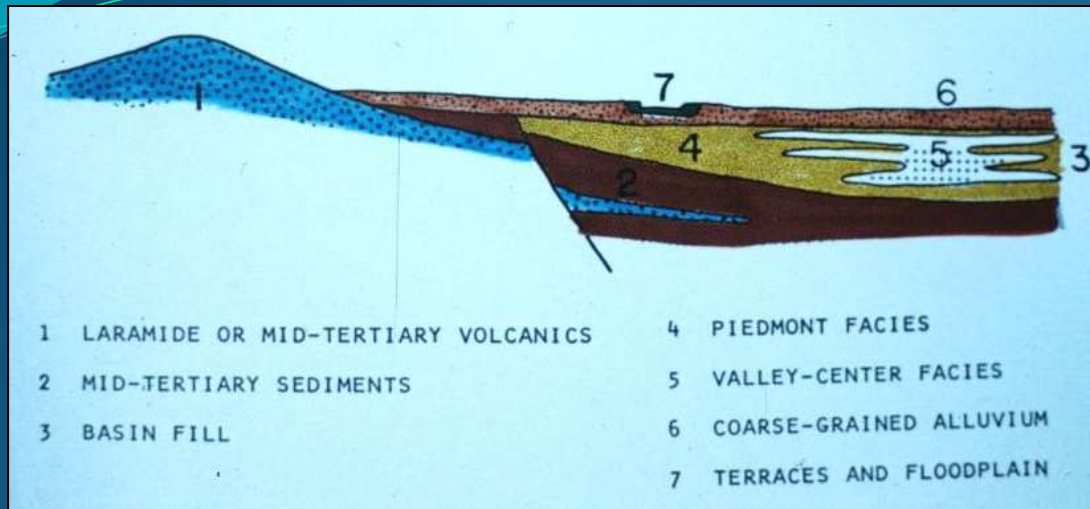


Barite



Barite
occurrences

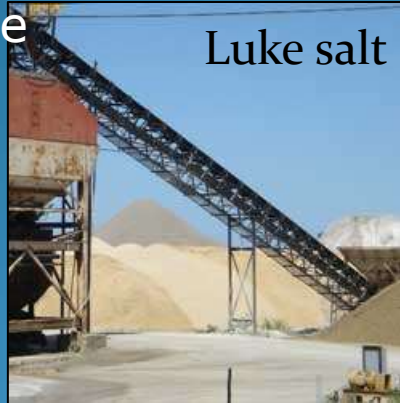
San Andreas (13-0 Ma) rifting - basins



Halite – Salt < 10 Ma

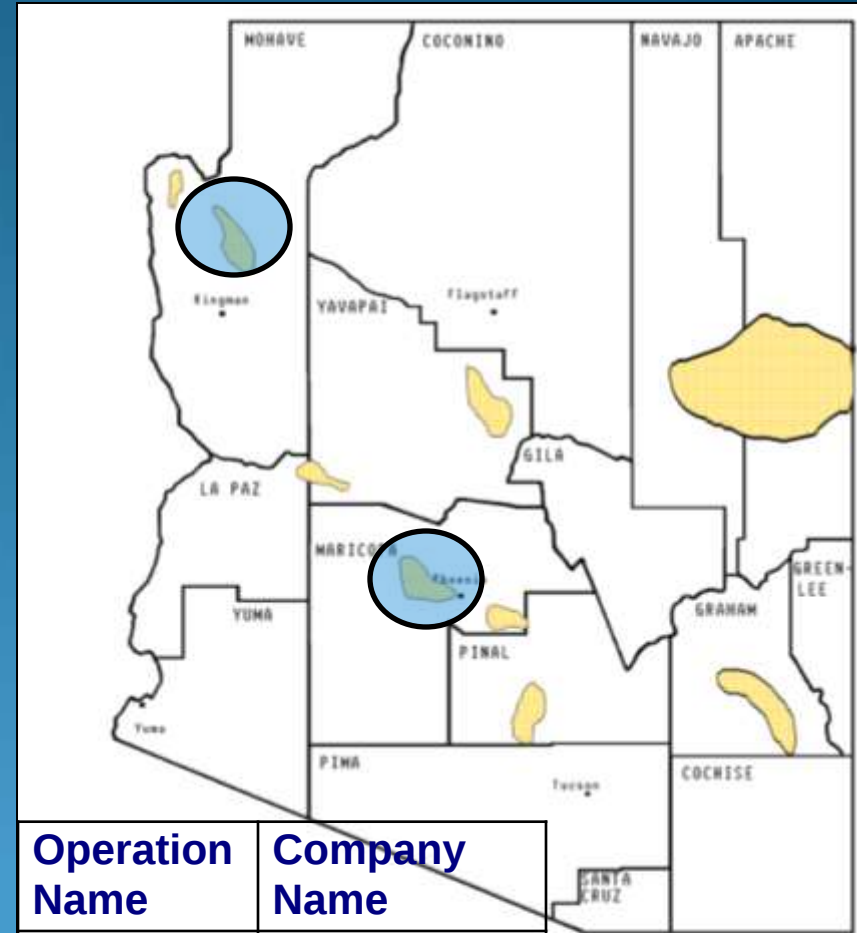


Glendale



Luke salt

Salt - Picacho Basin – UnoCal photo



**Operation
Name**

**Company
Name**

Luke Salt

Morton Salt

Map produced from Arizona Geological Survey data
in Circular 30, January 2002

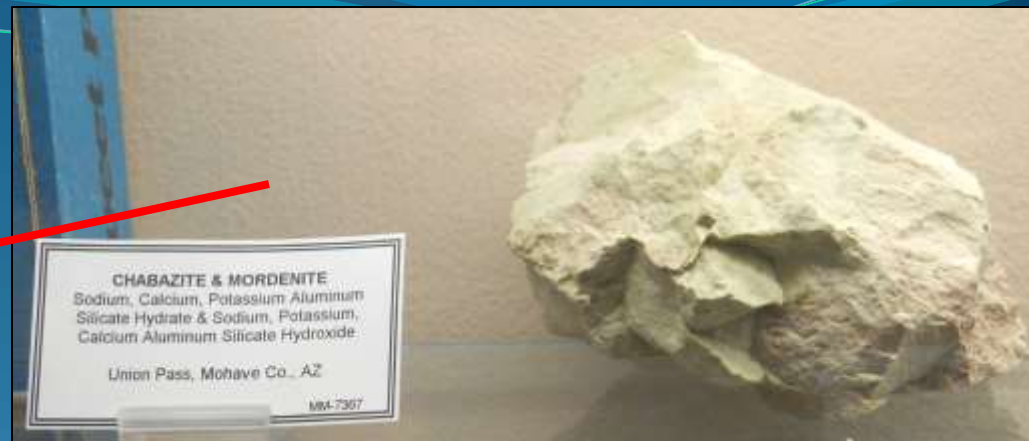
**Arizona's
HALITE Deposits**



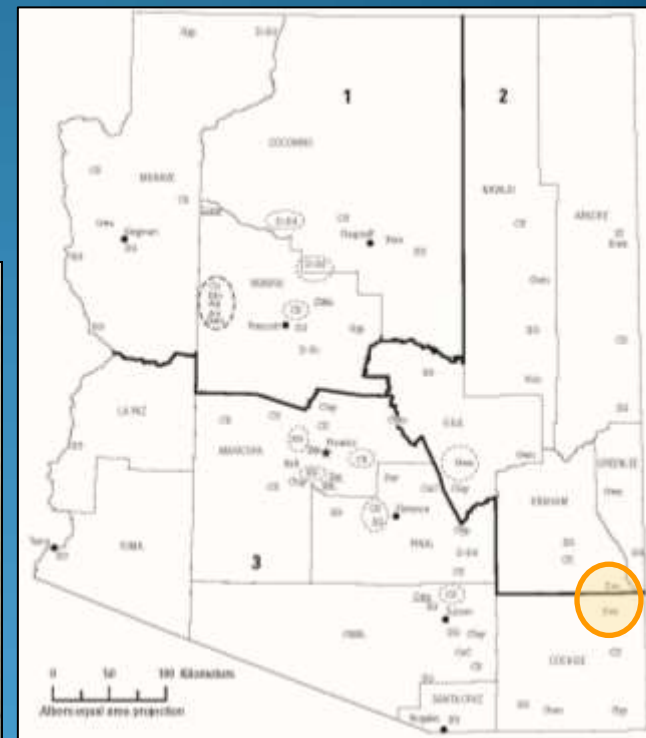
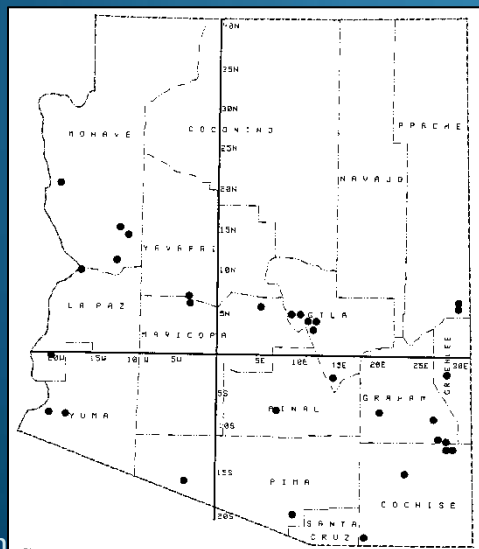
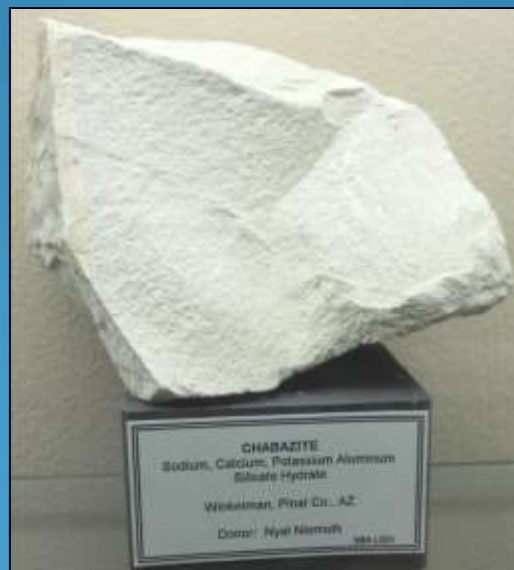
AREA OF NUMEROUS OCCURRENCES

Zeolite

Operation Name	Company Name
Bowie Chabazite	UOP
Union Pass Mordenite	UOP
Grace Chabazite	Zeox Mineral Materials Corp.



Chabazite, Winkelman



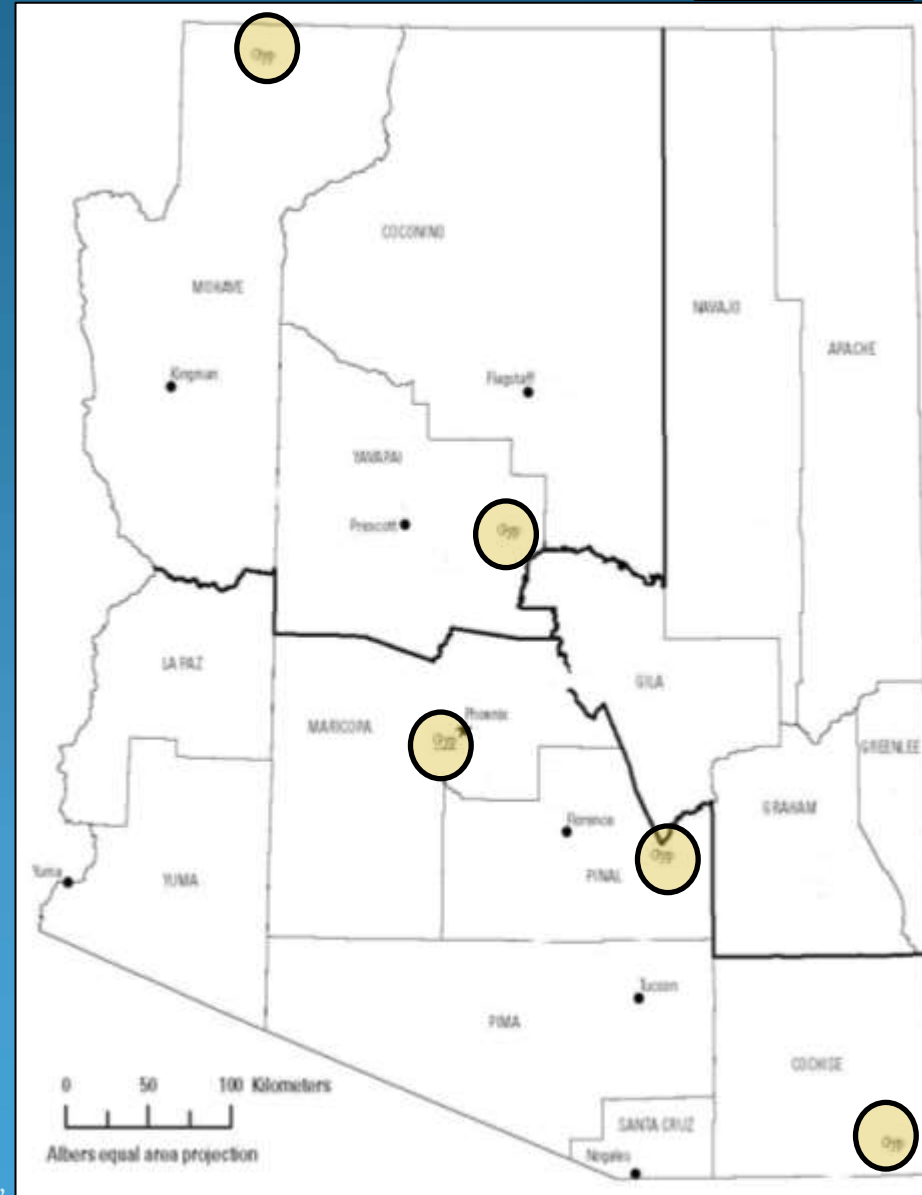
Gypsum

Roosevelt Lake

St. David



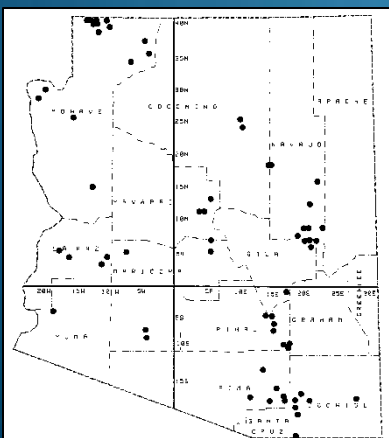
Operation Name	Company Name
Black Rock West	Georgia Pacific Corporation
White Eagle Gypsum	Kinder Custom Farm Work
Feldman Quarry	National Gypsum
Verde Gypsum Quarry	Phoenix Cement Company
White Cross Mine	Pinal Gypsum
Winkelman Quarry	Rinker Materials
Black Rock Mine	Western Mining and Minerals Inc.
Gypsum City Mine	Western Mining and Minerals Inc.



Gypsum, Mohave Co.

February 23,

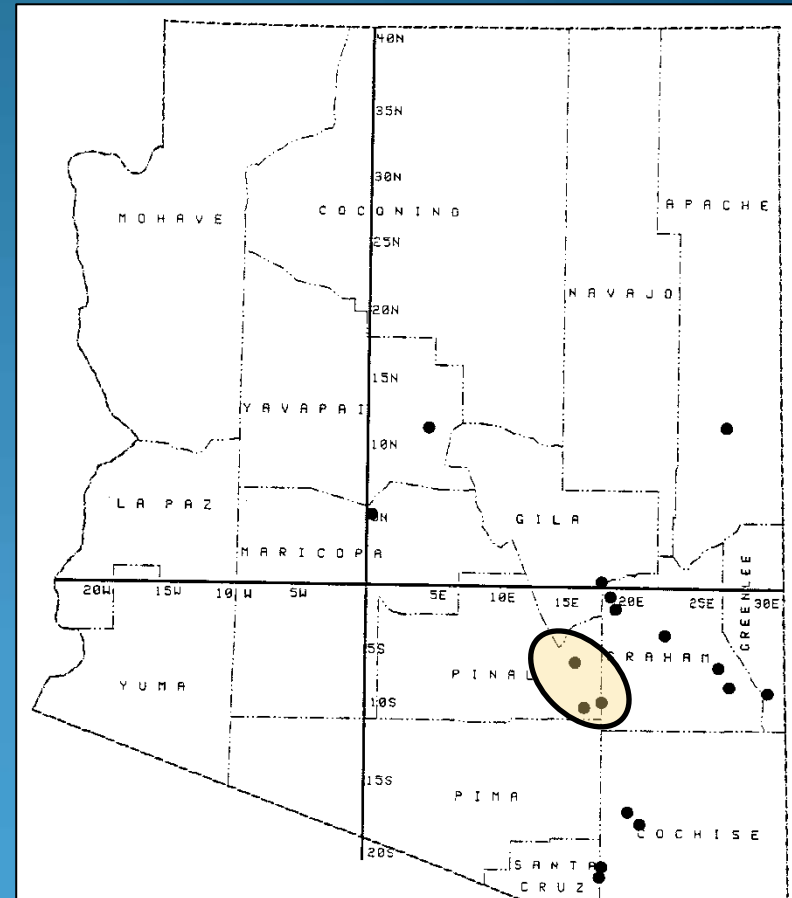
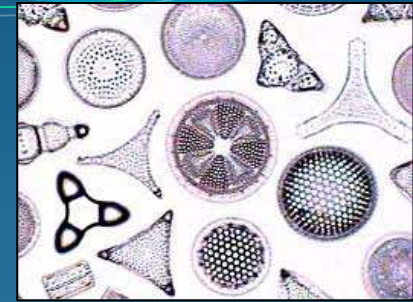
.G.



Diatomite



Mammoth, AZ



Pumice, Pumicite

Operation Name	Company Name
White Vulcan	Tufflite Inc.



Pumice Coconino Co

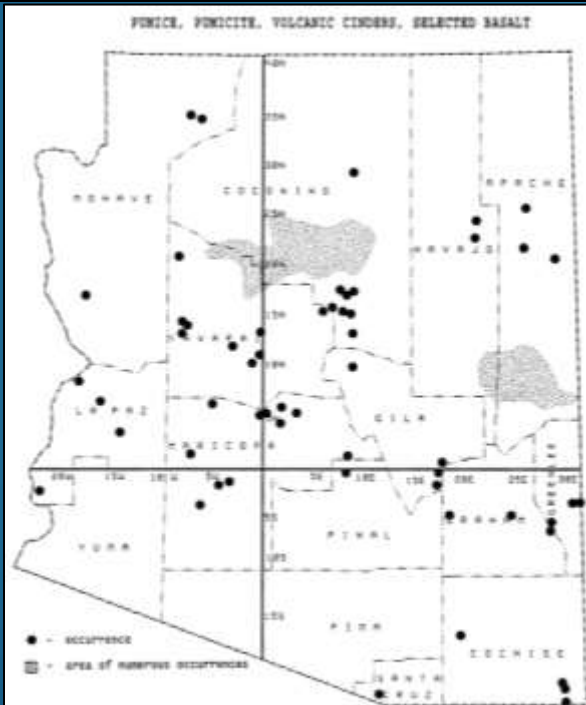
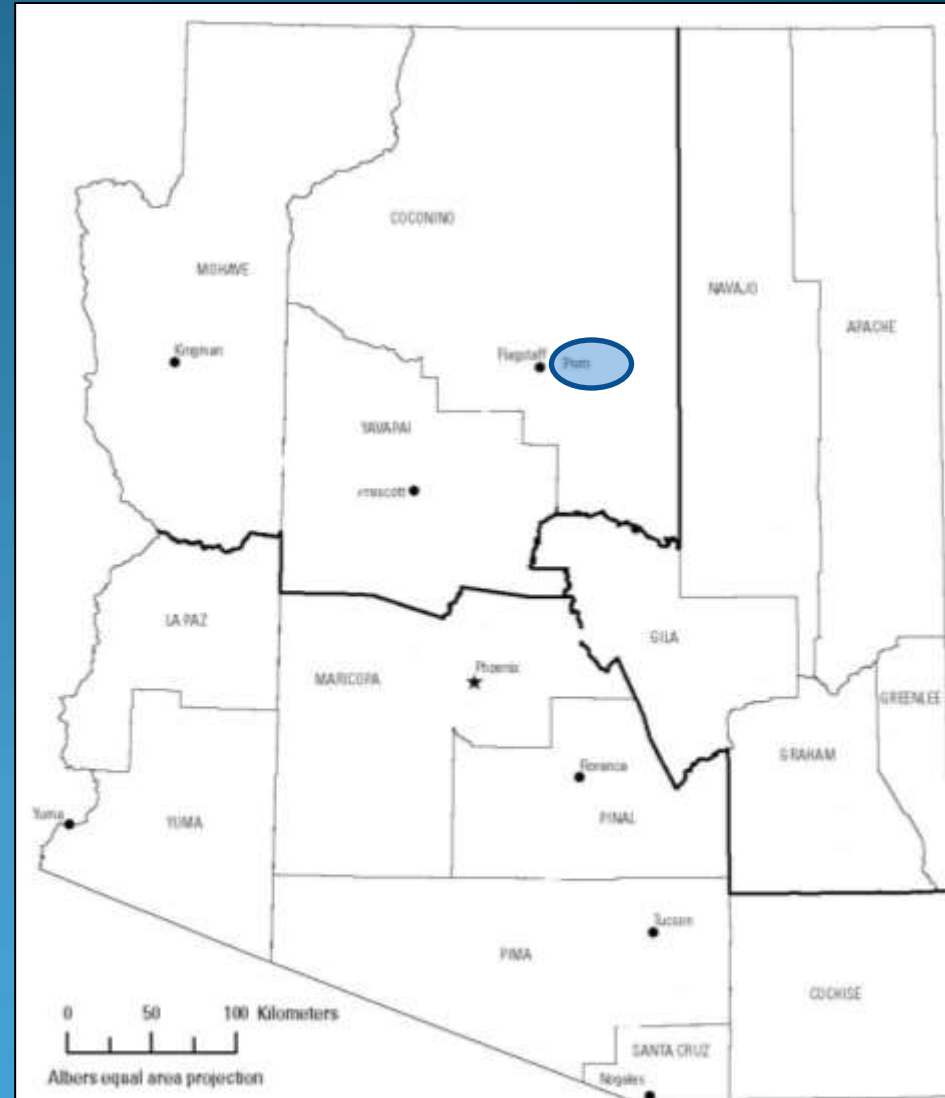


Figure 11. Locality of Arizona pumice, pumicite, volcanic cinders and selected basalt deposits.



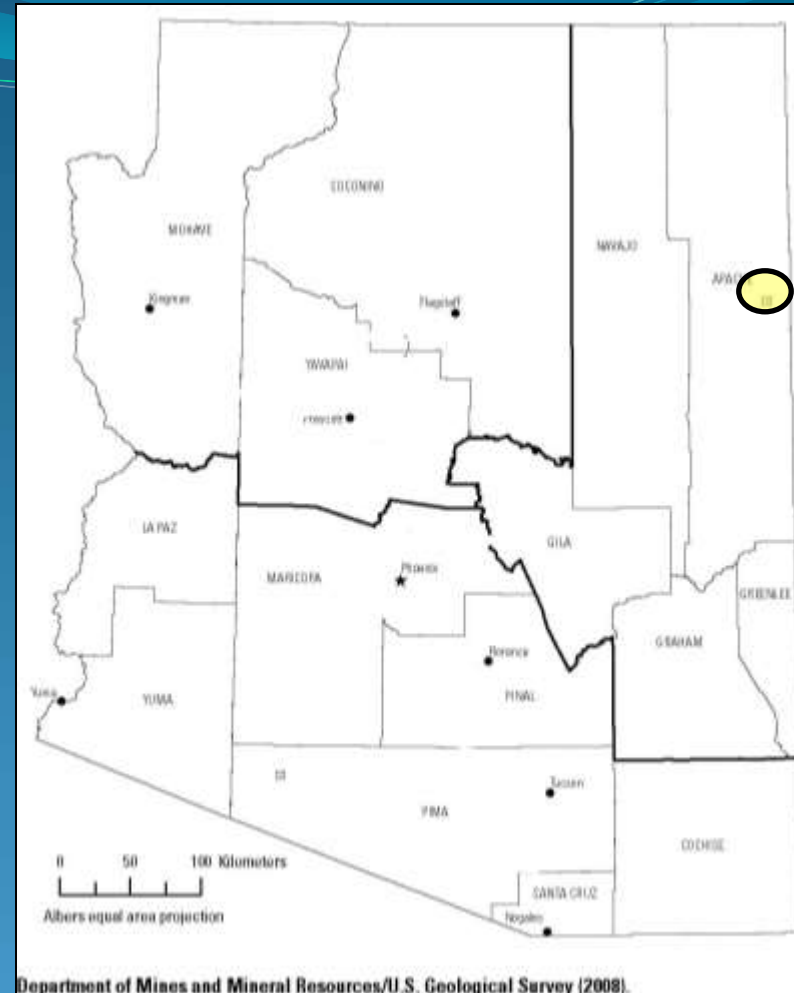
Hydrofrac Sand



Bidahochi Fm.
At White Cone



Sanders, AZ;
Sand reworked
from Permian
Coconino Ss.



Department of Mines and Mineral Resources/U.S. Geological Survey (2008).

Operation Name	Company Name
Houck Silica Sand Pit	Arizona Silica Sand Company
Ajo Plant and Slag Stockpile	Mineral Research & Recovery
WhiteCliffs	Nano Clays LLC
Fan Quarry	Wesco Minerals LLC
Wesco Plant	Wesco Minerals LLC

Cinders

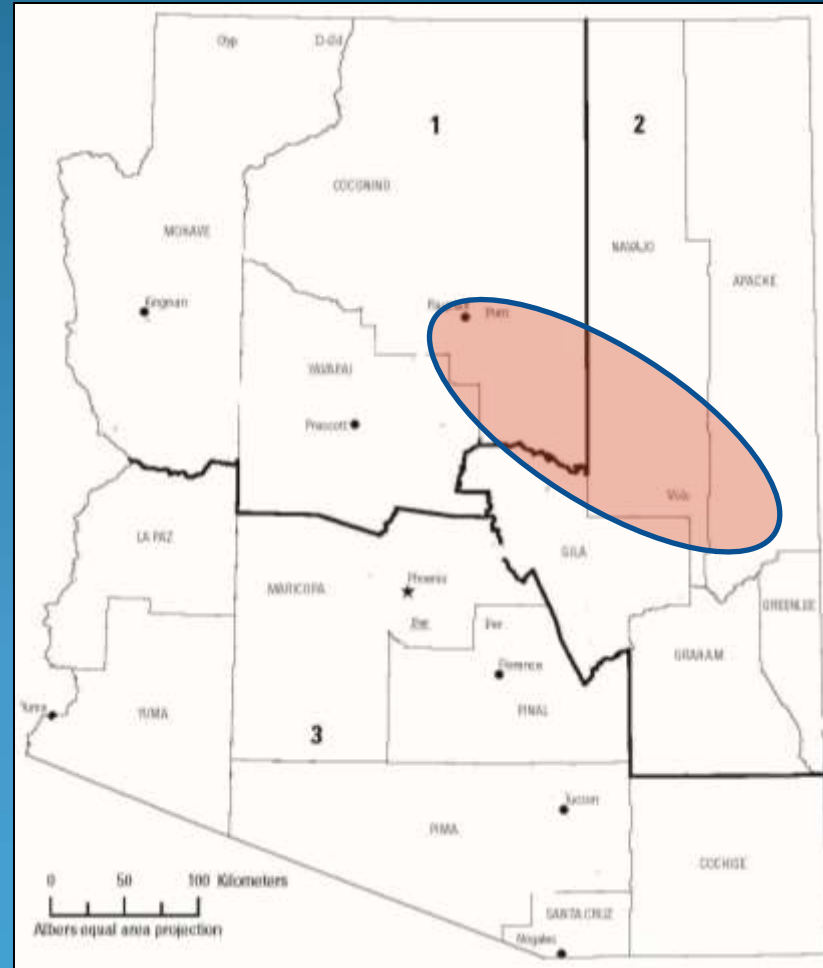


San Francisco Peaks

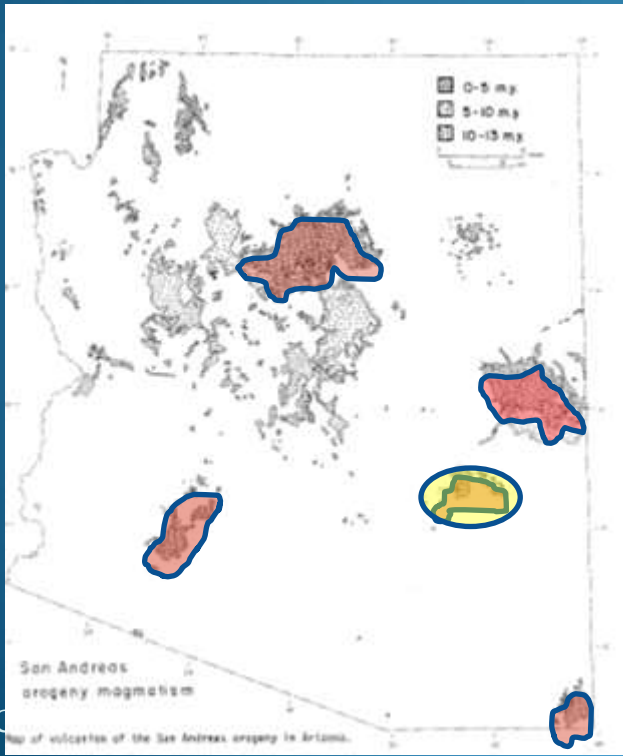


cinder

Operation Name	Company Name
Grantham Cinder Pit	Allen Grantham
Apple Pit	Arizona Pacific Materials LLC
Queen Creek Quarry	Arizona Pacific Materials LLC
Wildcat Hill Pit	Coconino Cinders
Old Perrin Pit	Espee Cinder Pit
Wildcat Hill aka Red Pit	Flagstaff Cinder Sales Inc.
County Line Pit	FNF Construction Inc.
Sheephill Plant	Glory Enterprises LLC
Miller Pit	Miller Mining
Owens Pit	Perkins Cinders Inc.
Dukes Peak	Red Rock Cinder Company
Darling Cinder Pit	Superlite Block



Gemstones – Olivine ~1-2 Ma

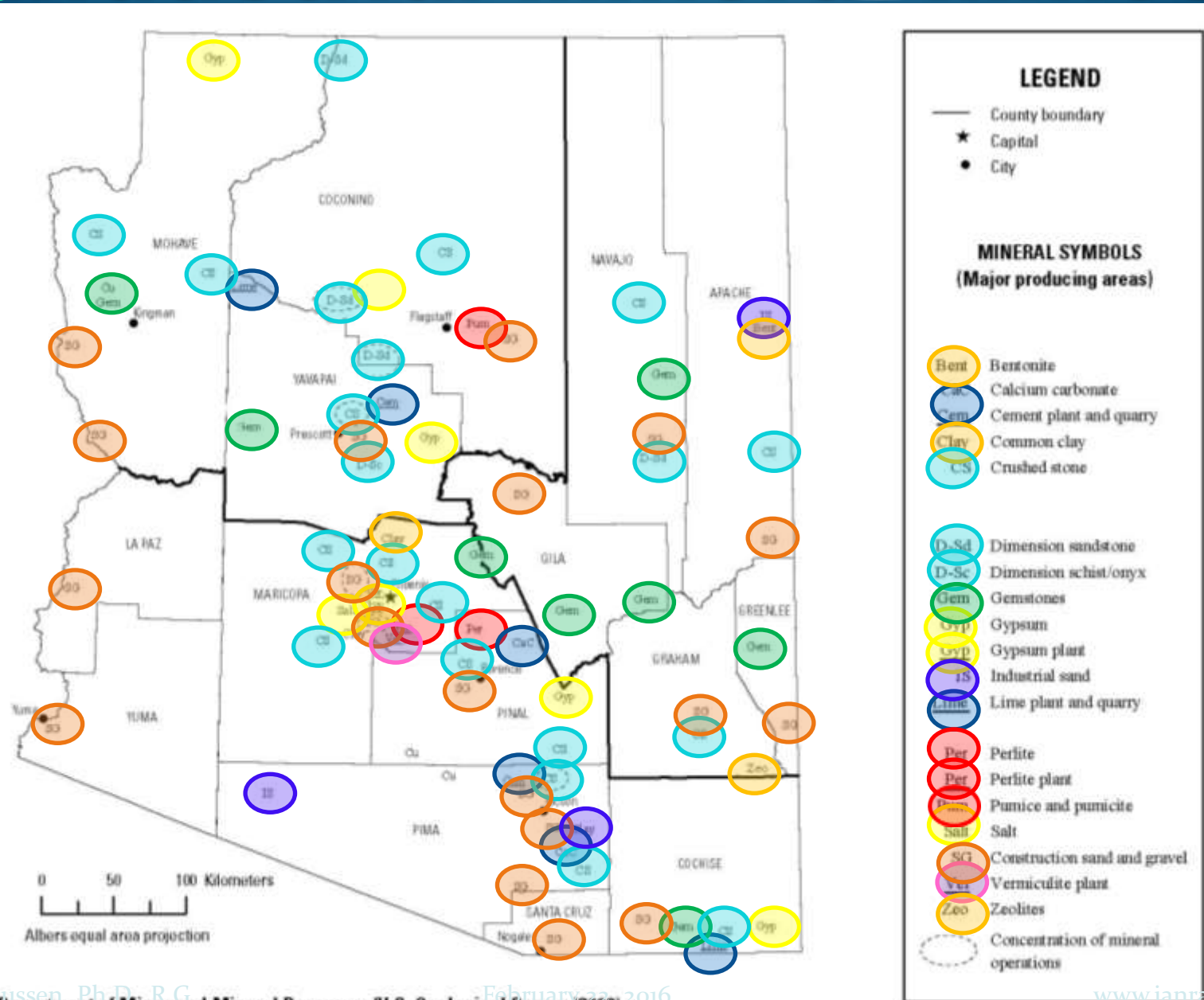


Olivine in basalt, San Carlos



[illegible]

Industrial Mineral Mines



Industrial Min. – Mesozoic-Cenozoic

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Industrial Minerals	Productive Mining areas/ Examples
San Andreas	Basin & Range	5-0	Pliocene (5-2 Ma)	Sand, Gravel, Cinders, Peridot, Zeolites, Gypsum; Clay from altered latitic vitric ash, Hydrofrac sand reworked from Permian sand	San Francisco volcanic field cinders, San Carlos olivine; Bidahochi Fm. hydrofrac sand, Cheto bentonite clay
		13-5	Late Miocene (12-5 Ma)	Halite; Perlite; Cinders, Pumice, Perlite, Zeolite; Gypsum; Specialty Clay, Diatomite	Luke Salt, Red Lake halite; Bowie zeolite; San Pedro valley gypsum, diatomite, Burro Creek clay
Galiuro	Late (Whipple)	18-13	Middle & Late Miocene (16-12 Ma)	Fluorite, barite assoc. with gold veins; amethystine quartz	Oatman fluorite
	Middle (Datil)	28-18	Early Miocene (23-14 Ma)	Fluorite, barite assoc. with Pb-Zn-Ag F veins; gravel	Superior perlite; Sleeping Beauty turquoise from Castle Dome mine; Apache Leap Tuff building stone
	Early (South Mountain)	30-22	Late Oligocene (28-23 Ma)	Gravel	:
	Earliest (Mineta)	38-28	Early Oligocene (34-28 Ma)	Clay, Gravel	Pantano common clay for bricks
Laramide	Late (Wilderness)	55-43	Early Eocene (56-41 Ma)	Feldspar, Beryl, Mica; Gravel	
	Middle (Morenci)	65-55	Paleocene (66-56 Ma)	Metamorphism of limestone to marble; clay alteration on fringes of porphyry Cu	Clay at Kalamazoo (San Manuel); Sahuarita marble; Turquoise at Kingman, Castle Dome
	Early (Tombstone)	85-65	Late Cretaceous	Fluorite assoc. with Pb-Zn-Ag veins & replacement deposits	Kaolinitic shales Upper Cretaceous E AZ
	Earliest (Hillsboro)	89-85	mid-Cretaceous		
Sevier		145-89	Early & mid-Cretaceous	Limestone; Lime	Paul Spur Lime in Mural Ls. of Bisbee Group
Nevadan	Late	160-145	Late Jurassic		
	Middle	205-160	Early & Middle Jurassic	Turquoise; Sandstone for flux	Bisbee blue turquoise
	Early	230-205	Late Triassic	Gypsum, Petrified Wood	Chinle Fm. Petrified wood;

Industrial Minerals in Precambrian & Paleozoic

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Industrial Minerals	Productive Mining areas/ Examples
Alleghenian (Ouachita)		325-220	Miss. – Triassic	Gypsum, Salt, Potash, Flagstone	Permian Holbrook salt, potash, gypsum; Coconino Ss. flagstone; cavities for gas storage in Supai evaporites; Moenkopi dimension stone
Lull between Acadian - Alleghenian		360-325	Mississippian	Limestone, Lime, Marble	Escabrosa & Redwall Ls. for cement
Acadian/ Caledonian		410-380	Devonian	Limestone for flux	Martin Fm.
Taconic.		490-445	Cambrian – Ord.	Quartzite for flux	Bolsa Quartzite
Grenville		1200-900	Late Middle Proterozoic – Early Late Proterozoic	Serpentine asbestos – Mescal Ls. altered by diabase; Dripping Spring Quartzite for flux	Chrysotile asbestos (Salt R. Canyon, Sierra Ancha Mts.); dimension stone
Oracle/Ruin		1440-1335	Middle Proterozoic	Silica, Feldspar & Mica from pegmatites; Beryl; Granite	White Picacho pegmatites; Four Peaks Amethyst; Buckeye Hills feldspar; granite dimension stone, crushed landscaping & clay
Mazatzal		1750-1600	Late Early Proterozoic	Silica, Granite	Mayer metarhyolite decorative facing stone; Payson granite road metal
Yavapai		1800-1775	Late Early Proterozoic	Silica, Granite, Schist	Crushed stone, BIF hematite for feed for cement plant
Penokean/ Hudsonian		2000-1800	Middle Late Proterozoic	Sparse localities – no production	