Arizona Mineralization through Geologic History

Copper , Bisbee

Gold, Gold Basin, Mohave Co., AZ

It's not all copper!

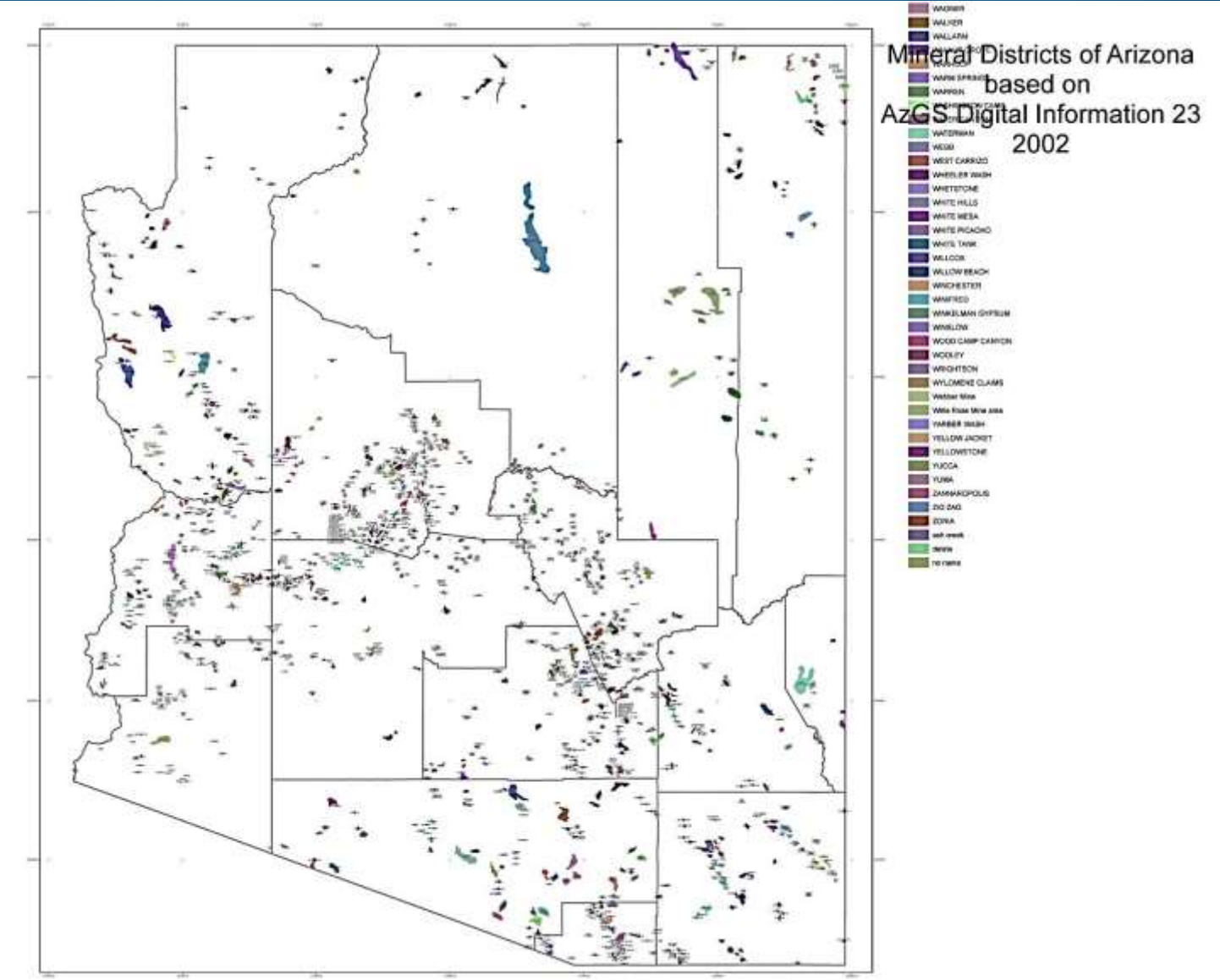
by Jan C. Rasmussen
Consulting Geologist

Arizona Mining Districts

>800 districts/ subdistricts

Very rich mineral heritage

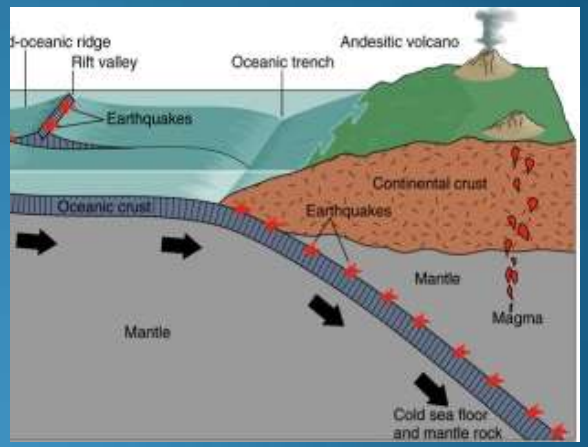
Copper deposits made only 3 times in AZ geologic history

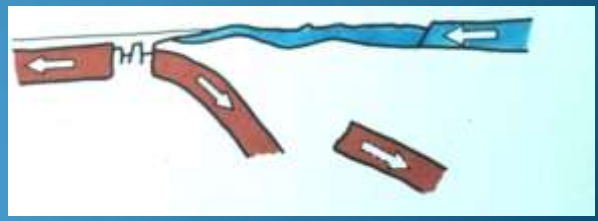


Arizona Mineralization through Geologic History

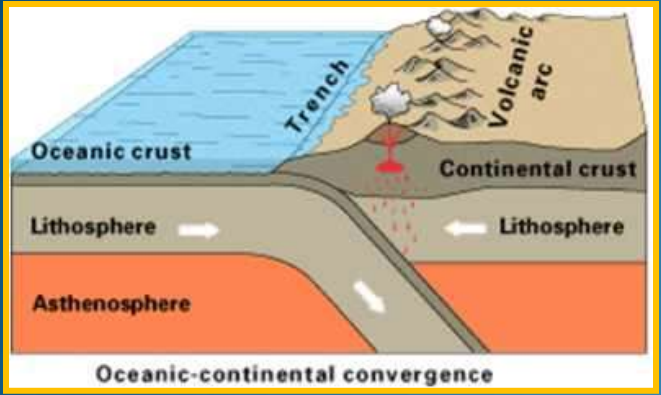
Mineralization related to mountain building episodes

- **Precambrian = orogenies added to fringes of continent**
- **Paleozoic = AZ on trailing edge - Eastern orogenies**
- **Mesozoic-Cenozoic = AZ on leading edge = Cordilleran orogeny – many metals**
- **Latest Cenozoic = subduction cutoff by San Andreas transform margin**





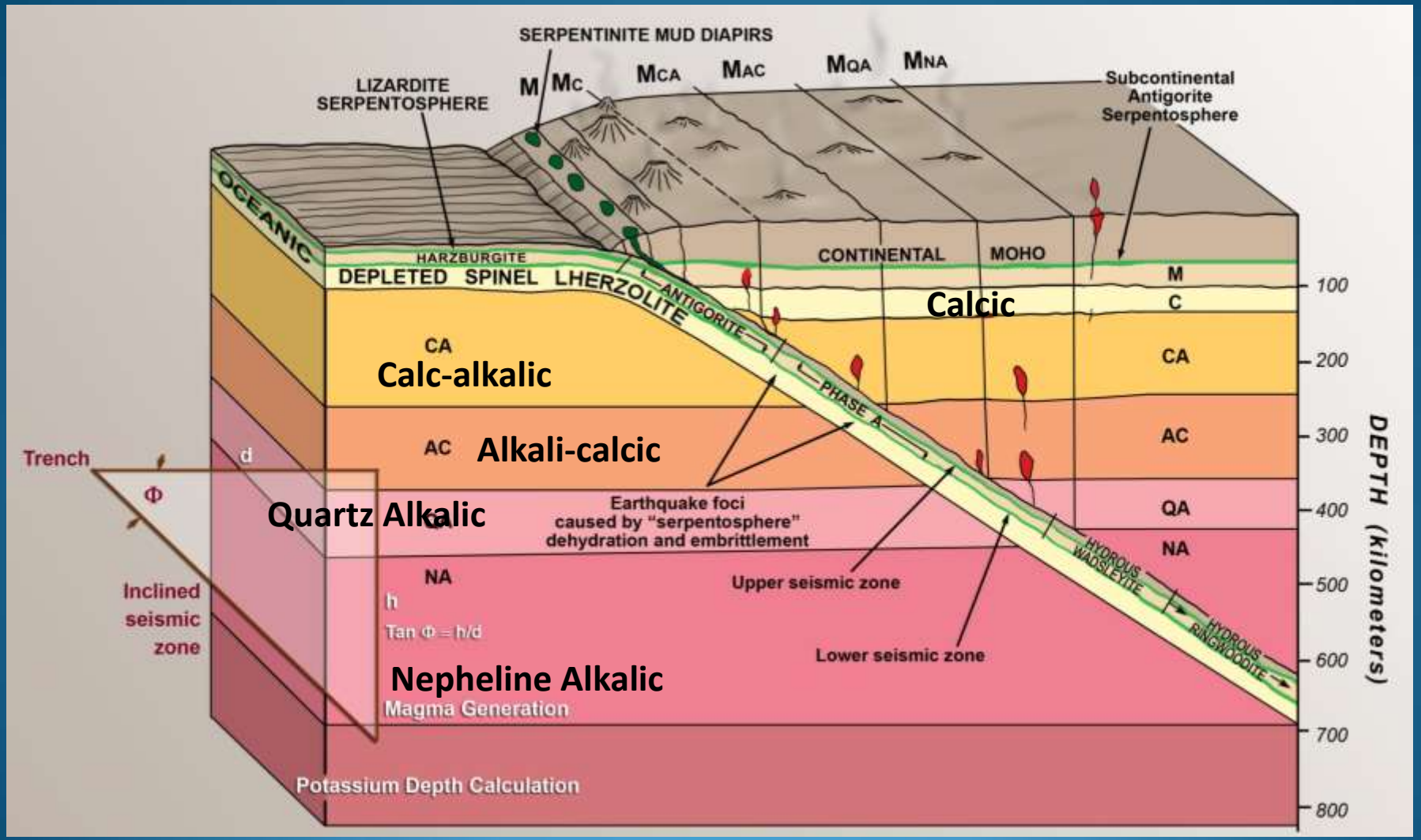
Orogenies in Arizona



Oceanic-continental convergence

Orogeny	Phase	Age (Ma)	Alkalinity	Resources	Mining districts
San Andreas	Basin & Range	13-0	M A	Sand, gravel, salt, zeolites, gypsum	San Francisco volcanic field, San Carlos olivine, Emerald Isle
Galiuro	Late)	18-13	M QA	Cu-Au-Ag in veins; epithermal Au-Ag veins	Oatman, Mammoth, Rowley
	Middle	28-18	M AC	Pb-Zn-Ag F veins, replace.; epithermal	Silver (Red Cloud m.), Castle Dome, Stanley, Aravaipa
	Early	30-22	M CA	Au +/- Cu-W veins & disseminated	Little Harquahala, Kofa
	Earliest	38-28	-	Uranium, clay, exotic copper	Ajo Cornelia, Copper Butte (from Ray)
Laramide	Late	55-43	P C, CA	Au dissem. & qtz veins; W veins,	Oracle (Wilderness granite), Boriana, Las Guijas, Gold Basin, Copperstone
	Middle	65-55	M CA	large disseminated porphyry Cu systems, local skarns & veins, fringing Zn-Pb-Ag	Ajo, Ray, Christmas, San Manuel, Mineral Park, Pima, Bagdad, Silver Bell, Globe-Miami, Morenci, Superior
	Early	85-65	M AC	Pb-Zn-Ag veins & replacement deposits	Tombstone, Tyndall (Glove), Washington Camp, Salero
	Earliest	89-85	M QA	Cu-Au hydrothermal	Hillsboro, NM
Sevier		145-89		Sedimentary rocks	Bisbee Group sediments
Nevadan	Late	160-145	P		
	Middle	205-160	M QA	porphyry Cu-Au at Bisbee, Gleeson	Warren (Bisbee mine), Turquoise (Courtland-Gleeson)
	Early	230-205	M AC, A	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley
Alleghenian (Ouachita)		325-220	-	U in sed. rocks	Payson uranium
Acadian/ Caledonian		410-380	-	Limestone	
Taconic.		490-445	-		
Grenville		1200-900	M QA	Serpentine asbestos	Sierra Ancha uranium Chrysotile (Salt R. Canyon)
"Oracle/Ruin"		1440-1335	P C AC	Pegmatites & greisens – Be, Li, Ta-Nb, U & W	White Picacho, Tungstona, Four Peaks
Mazatzal		1750-1600	M C	Cu-Zn-Ag VMS	Old Dick (Bruce)
Yavapai		1800-1775	M C	Cu-Zn-Au VMS, Cu-Zn-Ag	Big Bug (Iron King), Verde (Jerome)
Penokean/ Hudsonian		2000-1800	M C	BIF (Banded iron formation)	Pikes Peak iron

Alkalinity in mantle layers



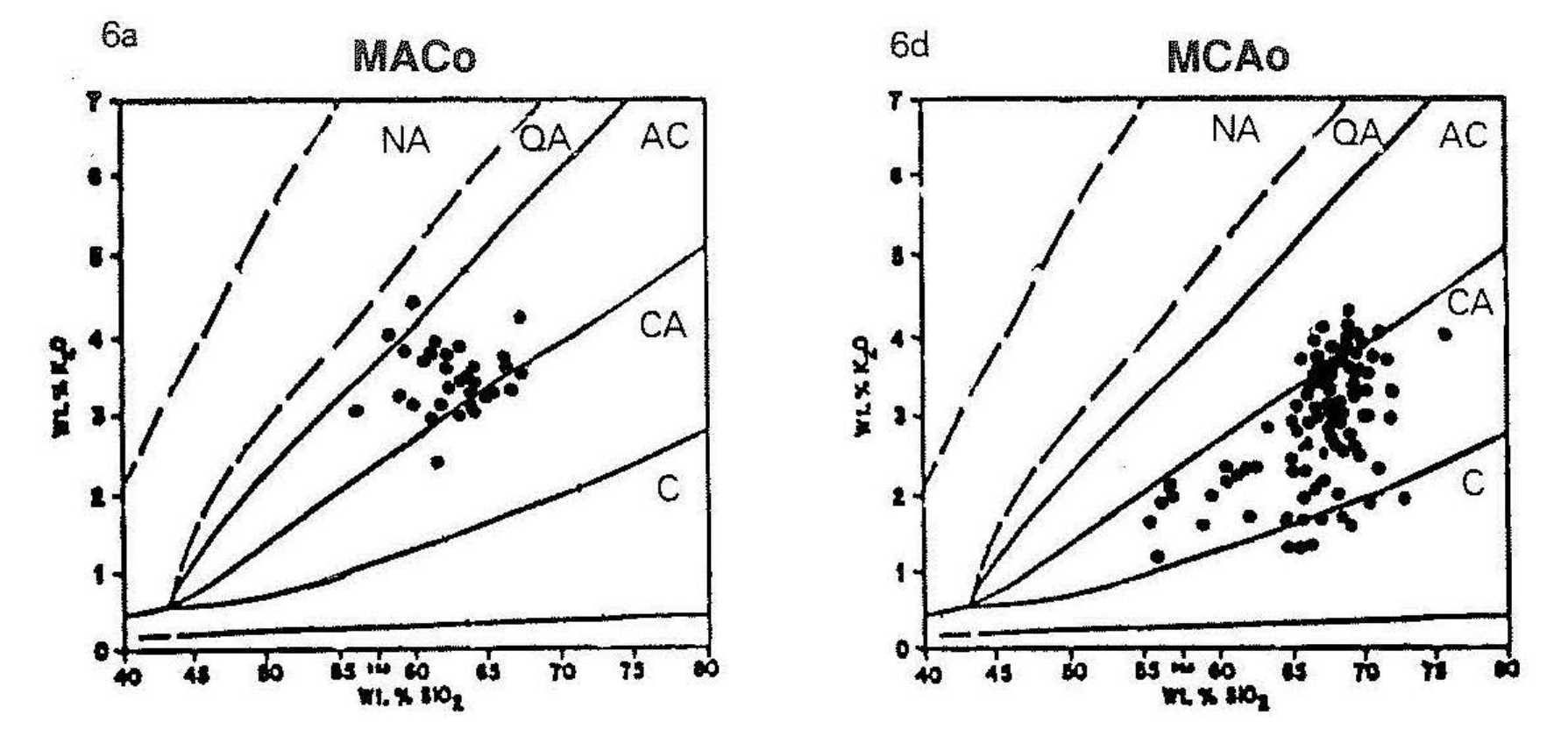
Source: S.B. Keith

Alkalinity in mantle layers

Alkalinity (Metaluminous)	Metals (oxidized)	Metals (reduced)
Calcic	Cu>Zn-Au-Ag	Au>Ag
Calc-alkalic	Cu* Zn-Pb-Ag>>Au-Mo-Mn	Au*
Alkali-calcic	Pb-Zn-Ag	Ag (Sn)
Quartz Alkalic	Cu-Au-Fe-U-LREE	Au-Cu-Ni-Co

Alkalinity (Peraluminous)	Metals (oxidized)	Metals (reduced)
Calcic	Au-Ag	Au>Ag
Calc-alkalic	W-Be-Pb-Zn-Ag	W-Pb-Zn-Ag
Alkali-calcic	U-W	Sn-W-Cu-U-Pb-Zn-Ag-Li-C

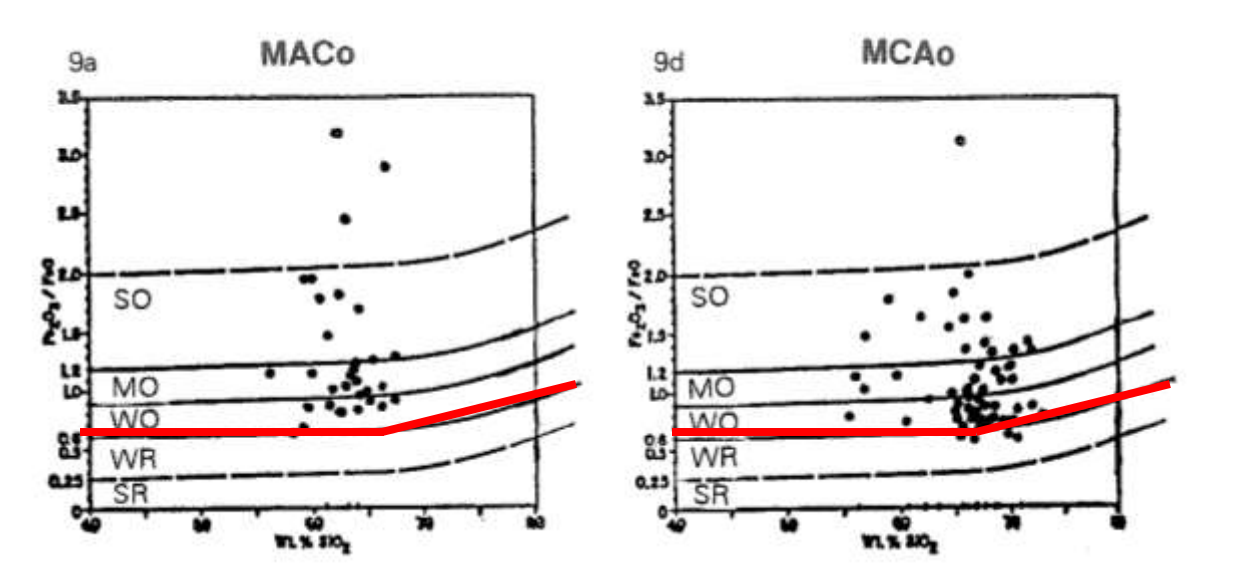
Alkalinity on K_2O vs. SiO_2 plots



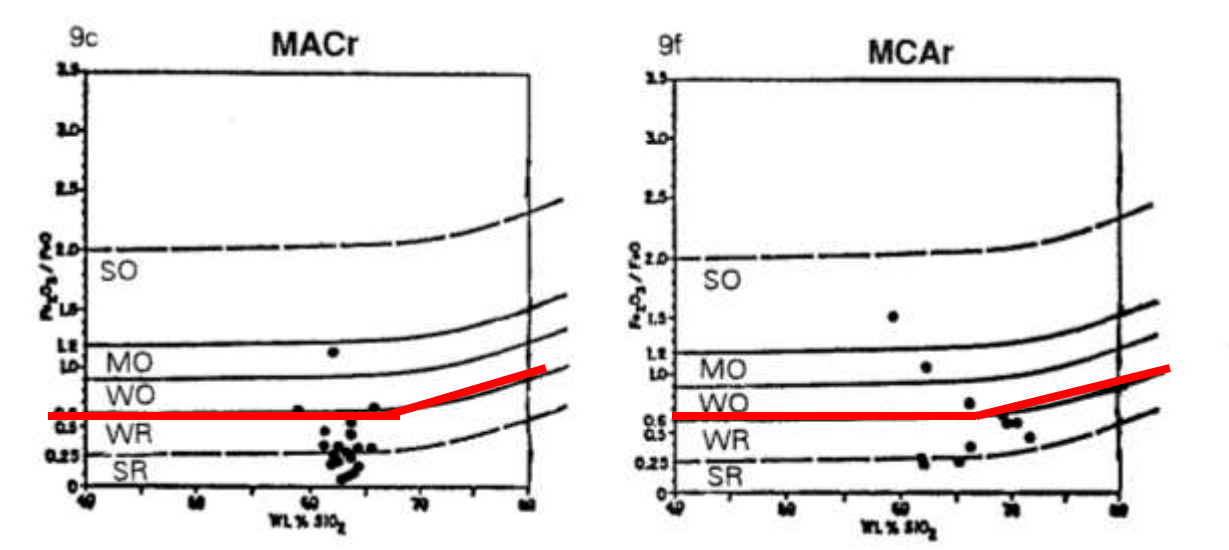
Alkali-calcic = MAC

Calc-alkalic = MCA

Oxidized and Reduced plots



Oxidized = base metals



Reduced = precious metals

Hudsonian/Mohave Orogeny (2 – 1.8 Ga)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Penokean/ Hudsonian		2000-1800	Middle Late Proterozoic	Schist, banded cherty iron formation	Metalum. Calcic	BIF (Banded iron formation)	Pikes Peak iron

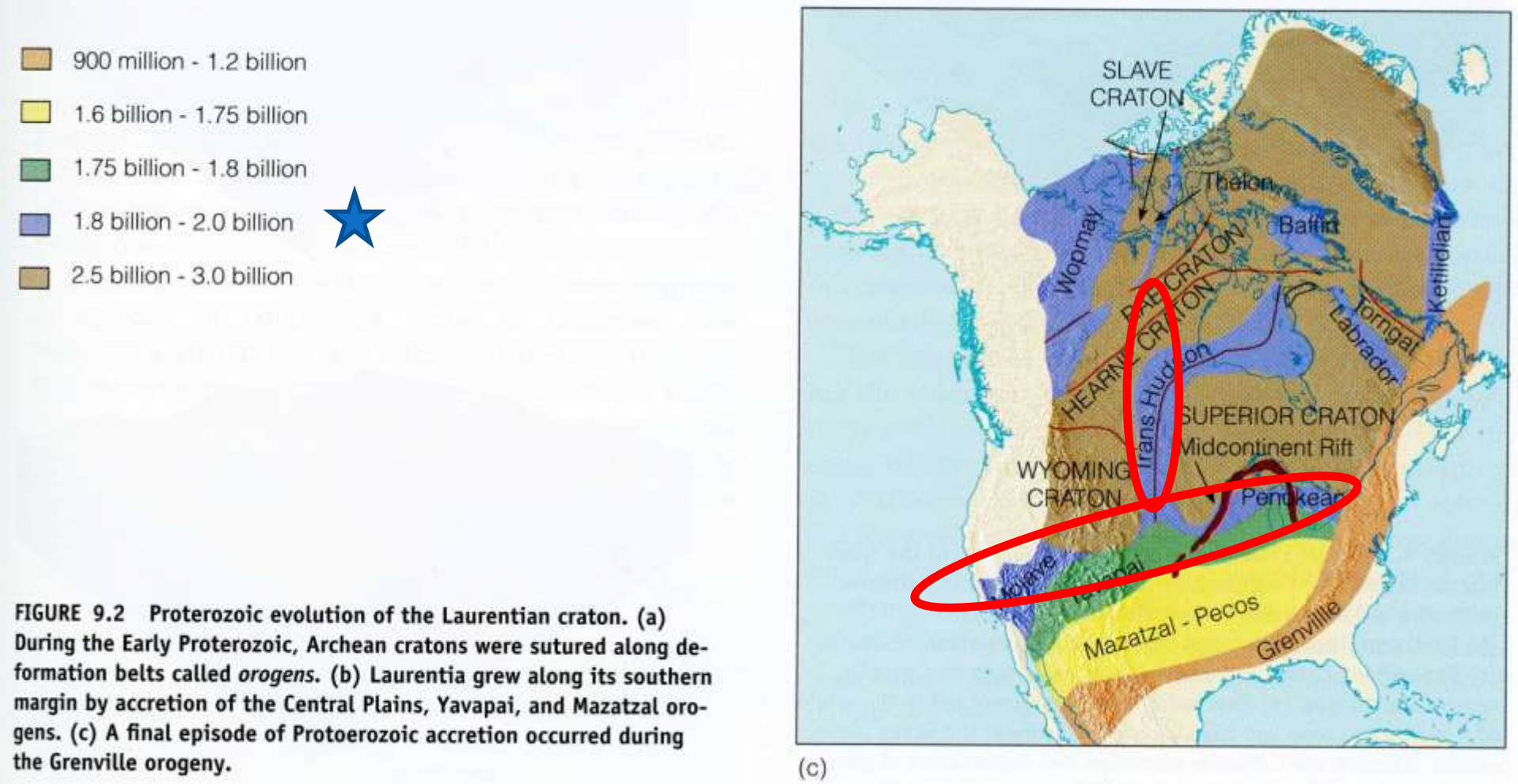


FIGURE 9.2 Proterozoic evolution of the Laurentian craton. (a) During the Early Proterozoic, Archean cratons were sutured along deformation belts called *orogens*. (b) Laurentia grew along its southern margin by accretion of the Central Plains, Yavapai, and Mazatzal orogens. (c) A final episode of Protoerozoic accretion occurred during the Grenville orogeny.

Mohave Orogeny – Pikes Peak BIF Banded Iron Formation

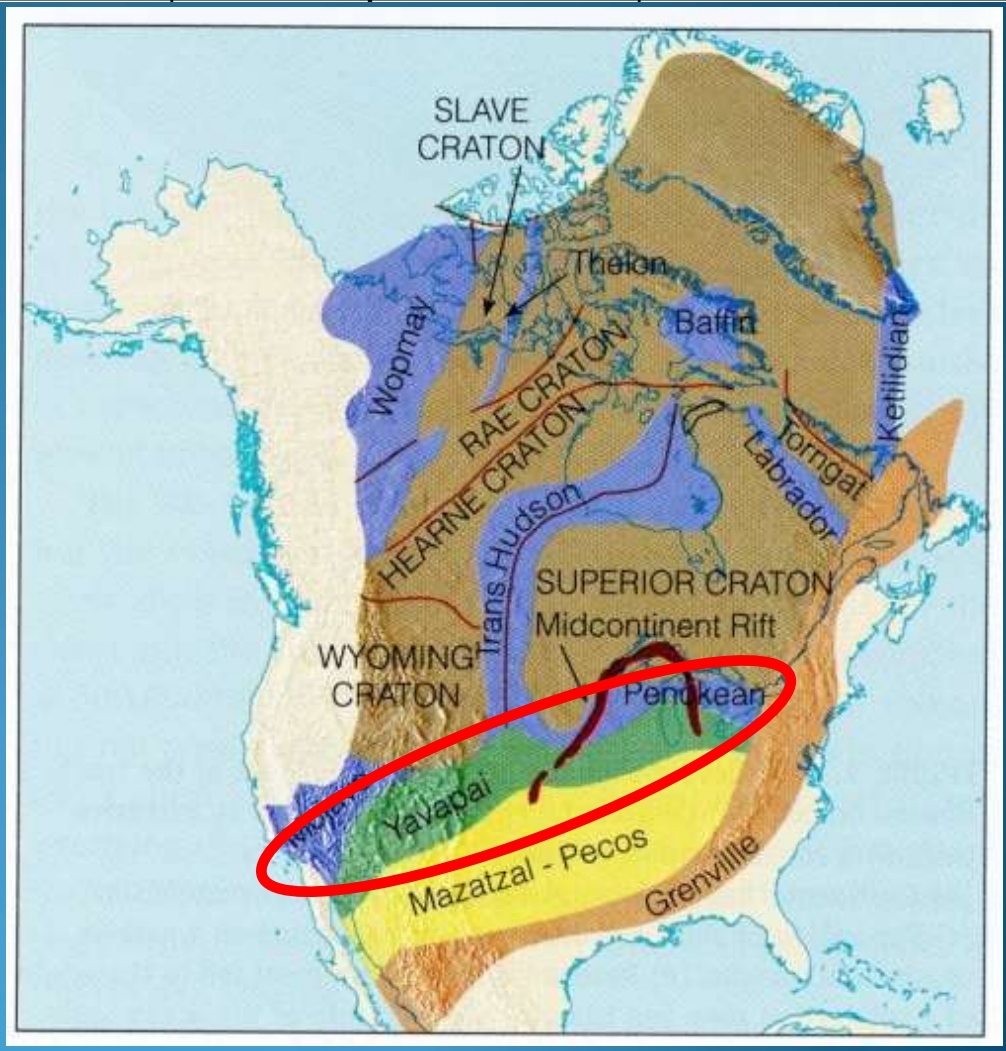
Hieroglyphic Mountains (Pikes Peak) Hematite-Magnetite Taconite, north-central Maricopa County - Iron Age, Pig Iron, and Bessemer

FIGURE 22. - Taconite-Like Hematite-Magnetite Iron Formation, Hieroglyphic Mountains, T 6 N, Rs 1 and 2 W, Maricopa County, Ariz. Note banded, laminated structure.

BIF (Jerome Historical museum) Paul Lindberg sample

Yavapai - Jerome VMS (1.8 – 1.775 Ga)

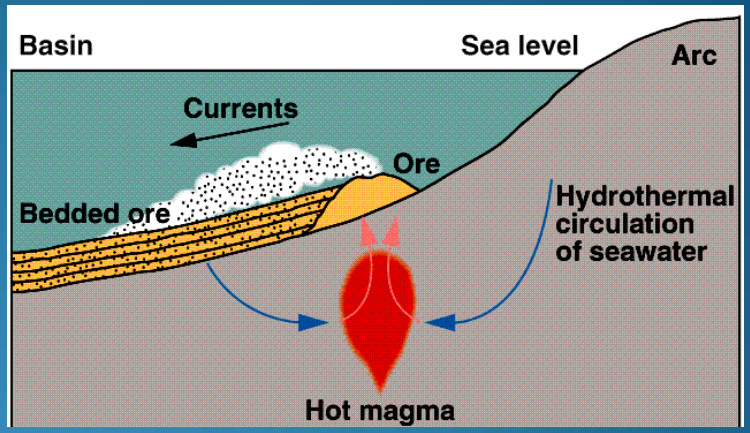
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Yavapai		1800-1775	Late Early Proterozoic	Andesite, schist, metarhyolite	Metalum. Calcic	Cu-Zn-Au VMS, Cu-Zn-Ag	Big Bug (Iron King), Verde (Jerome)



Yavapai - Jerome VMS (1800 – 1775 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Yavapai		1800-1775	Late Early Proterozoic	Andesite, schist, metarhyolite	Metalum. Calcic	Cu-Zn-Au VMS, Cu-Zn-Ag	Big Bug (Iron King), Verde (Jerome)

Black smoker, modern seafloor

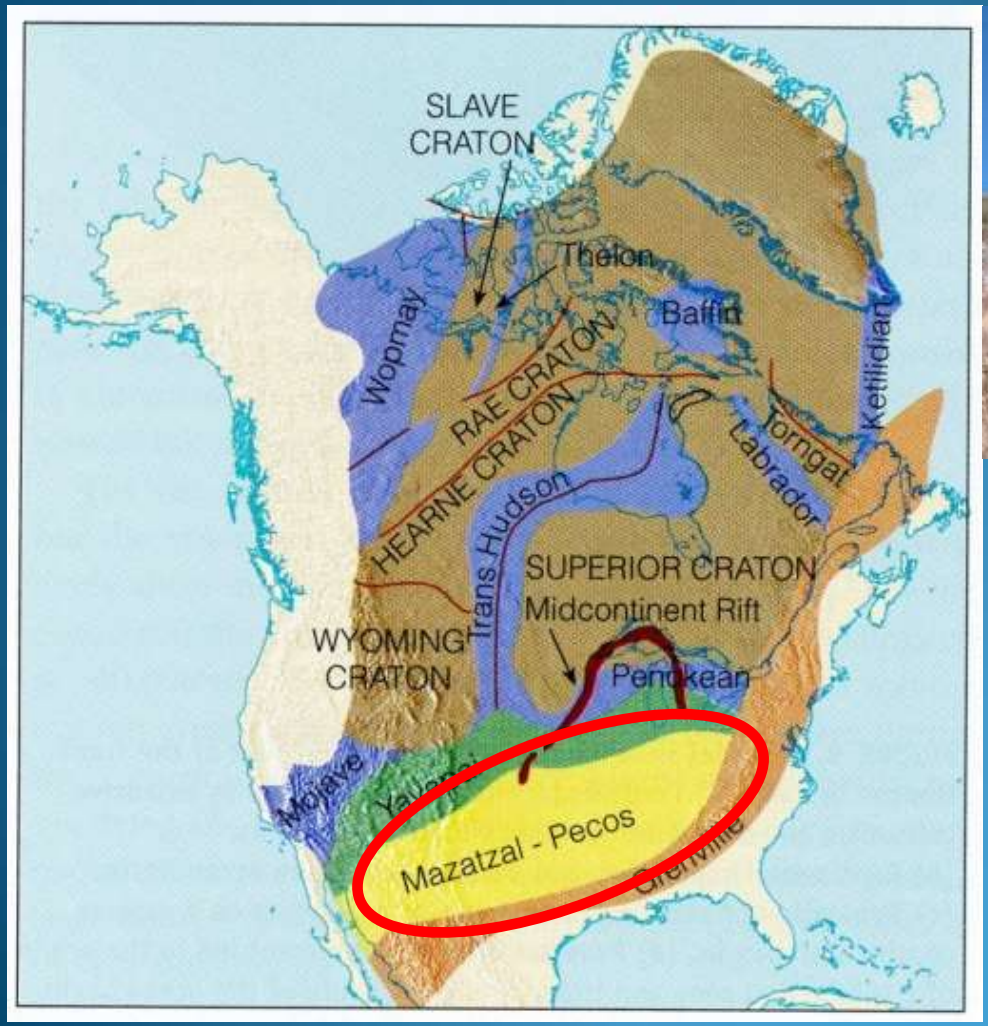


Deposition of Volcanogenic Massive Sulfide ore

Bornite, chalcopyrite
Copper iron sulfides
United Verde mine, Jerome, AZ
AzMMM sample

Mazatzal Orogeny (1.75-1.6 Ga)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Mazatzal		1750-1600	Late Early Proterozoic	Basalt & rhyolite metavolc., schist	Metalum. Calcic	Cu-Zn-Ag VMS	Old Dick (Bruce)



The Old Dick (Bruce) mine is a

- former underground Zn-Cu-Ag-Au-Pb-As-Co-Cd mine
- located 2¾ miles SSW of Bagdad.
- volcanogenic massive sulfide deposit

Oracle "anorogenic" Orogeny (1.44-1.335 Ga)

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

Euxenite, White Picacho pegmatites

Oracle Granite, Santa Catalina Mts.

Oracle "anorogenic" Orogeny (1.44-1.335 Ga)

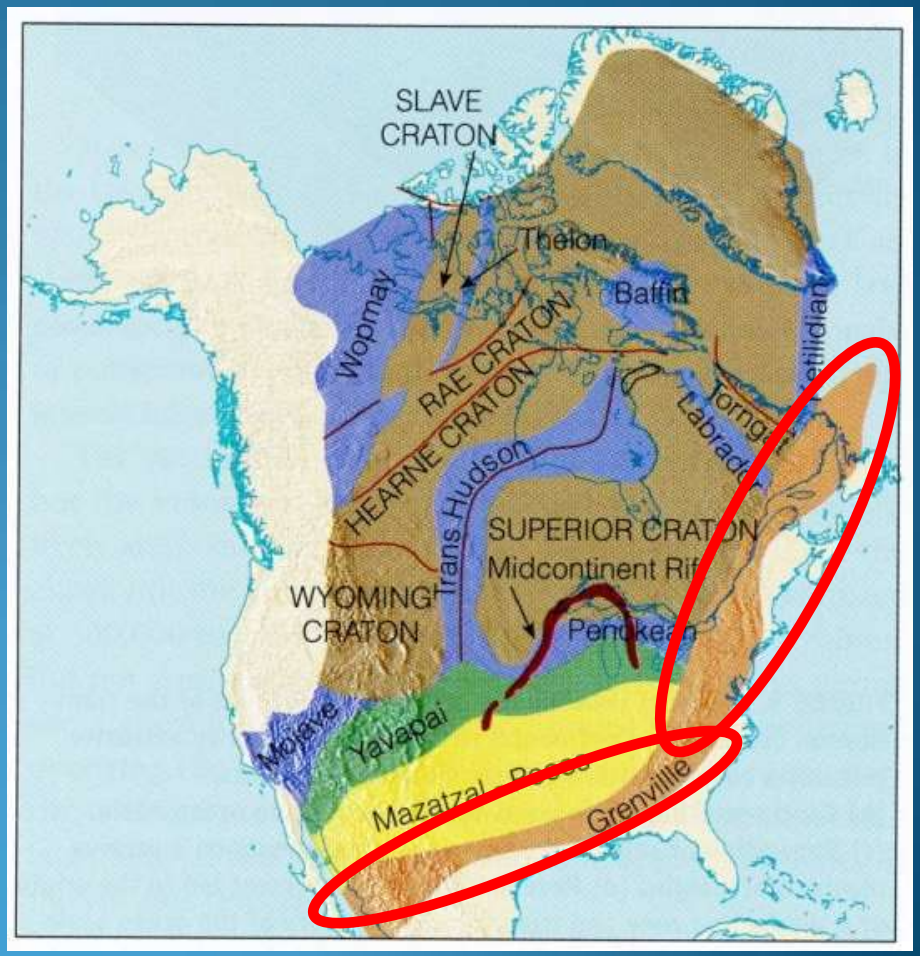
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
"Oracle/Ruin"		1440-1335	Middle Proterozoic	K-feldspar megacrystic or porphyritic granites	Peralum. Calc-alkalic, Alkali-calcic	Pegmatites & greisens – Be, Li, Ta-Nb, U & W	White Picacho, Tungstona, Four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

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

Grenville Orogeny (1200-900 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Grenville		1200-900	Late Middle Proterozoic – Early Late Proterozoic	basalt flows, diabase dikes	Metalum. Alkalic	Serpentine asbestos	Sierra Ancha uranium Chrysotile (Salt R. Canyon)

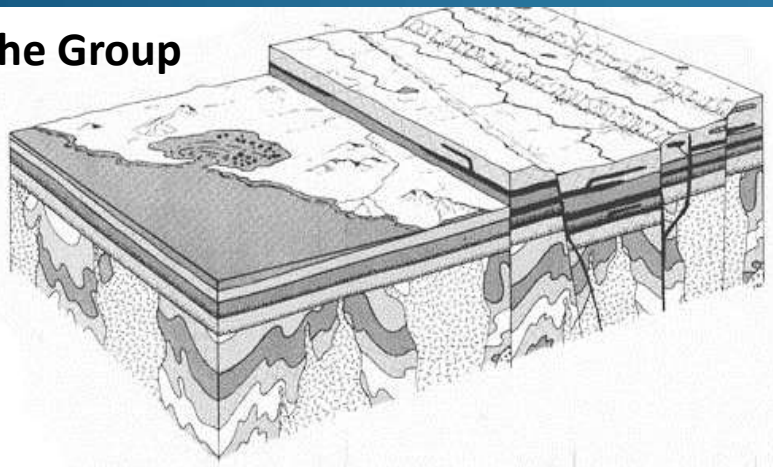
Grand Canyon Supergroup (Unkar Gp. (incl. Cardenas basalt - 1070 Ma Rb-Sr), Nankoweap Fm., Chuar Gp.)



Grenville Orogeny (1200-900 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Grenville		1200-900	Late Middle Proterozoic – Early Late Proterozoic	basalt flows, diabase dikes	Metalum. Alkalic	Serpentine asbestos	Sierra Ancha uranium Chrysotile (Salt R. Canyon)

Apache Group

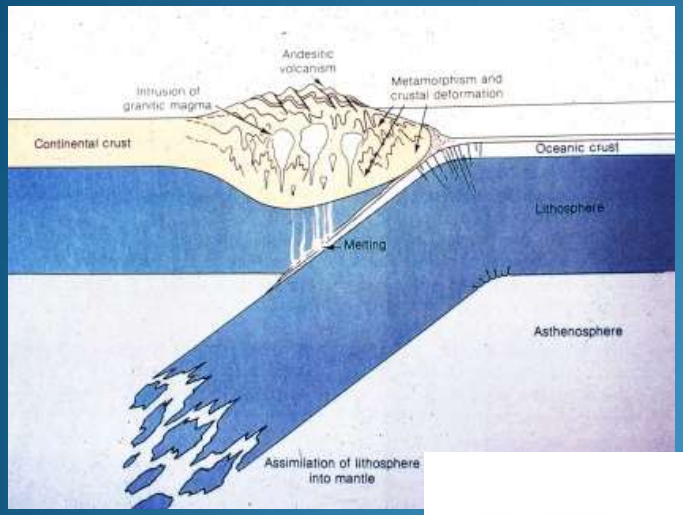


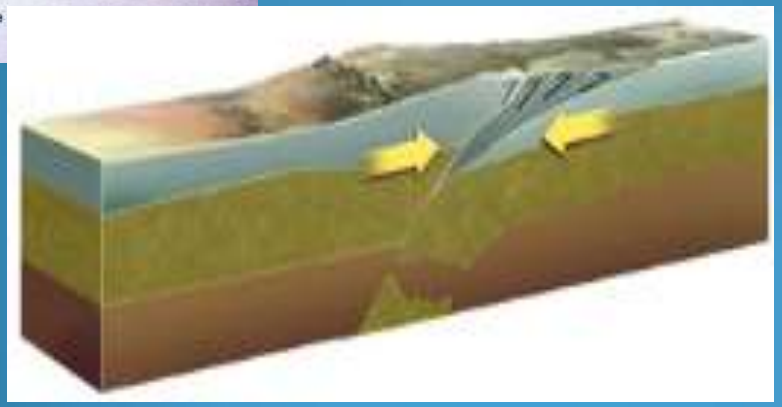
Diabase in Apache Gp. ,Tohono Chul Park, Tucson

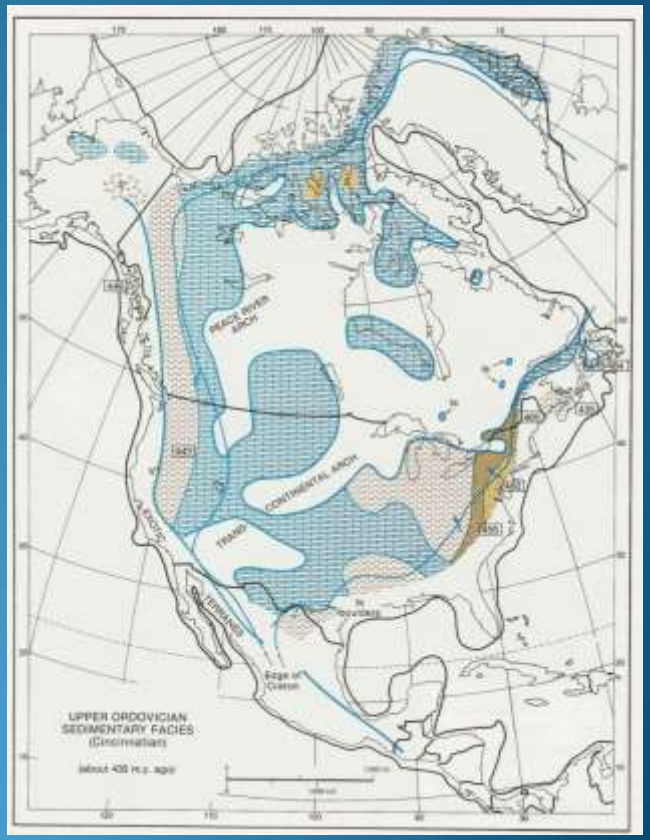
Serpentine asbestos, Apache Gp. , Sierra Anchas

Paleozoic Orogenies in Eastern U.S.

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
				rocks		copper	
Alleghenian (Ouachita)		325-220	Miss. – Triassic	None	-	U in sed. rocks	Payson uranium
Acadian/ Caledonian		410-380	Devonian	None	-	Limestone	
Taconic.		490-445	Cambrian – Ord.	None	-		





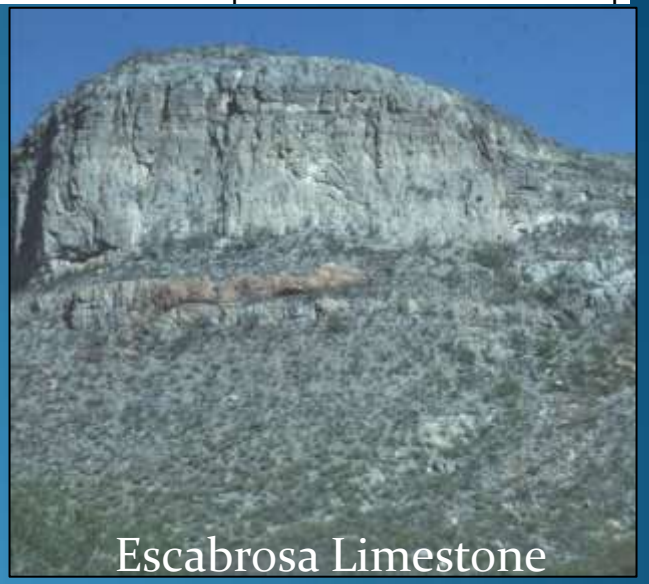


Lull - Mississippian Limestones in Arizona

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Alleghenian (Ouachita)		325-220	Miss. – Triassic	None	-	U in sed. rocks	Payson uranium
Acadian/ Caledonian		410-380	Devonian	None	-	Limestone	

Redwall Limestone

Rillito Cement plant

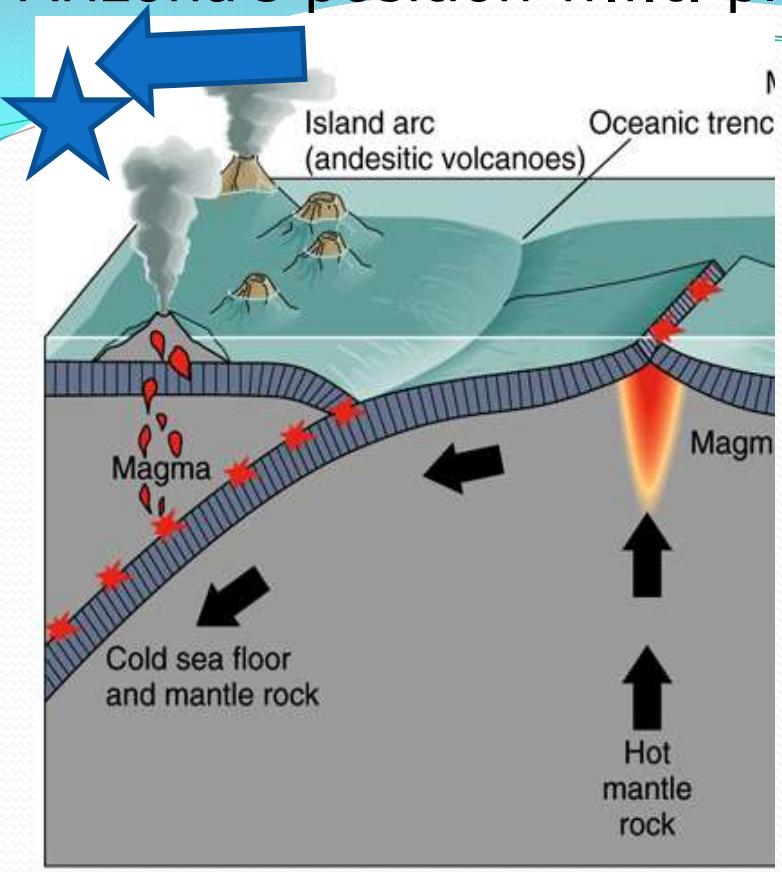


Escabrosa Limestone

Clarkdale Cement plant

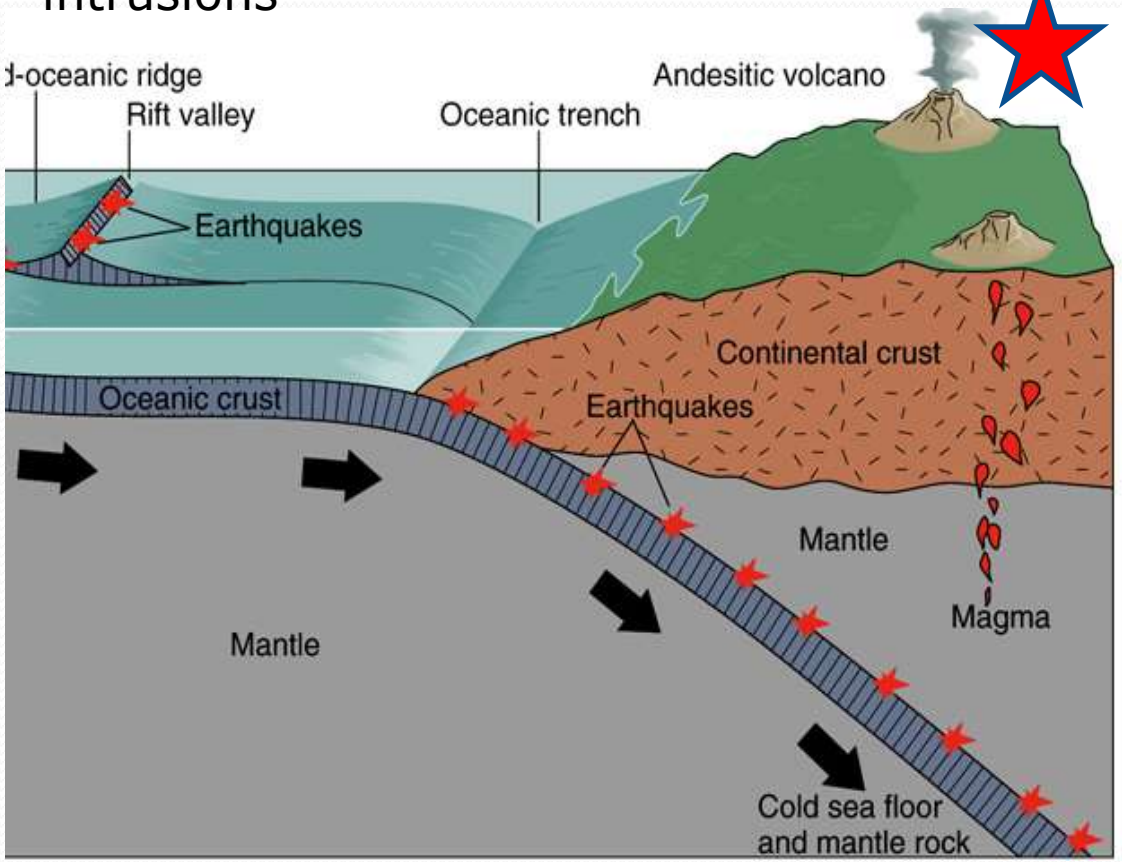
Sahuarita Marble

Arizona's position w.r.t. plate tectonics in Paleozoic vs. Mesozoic



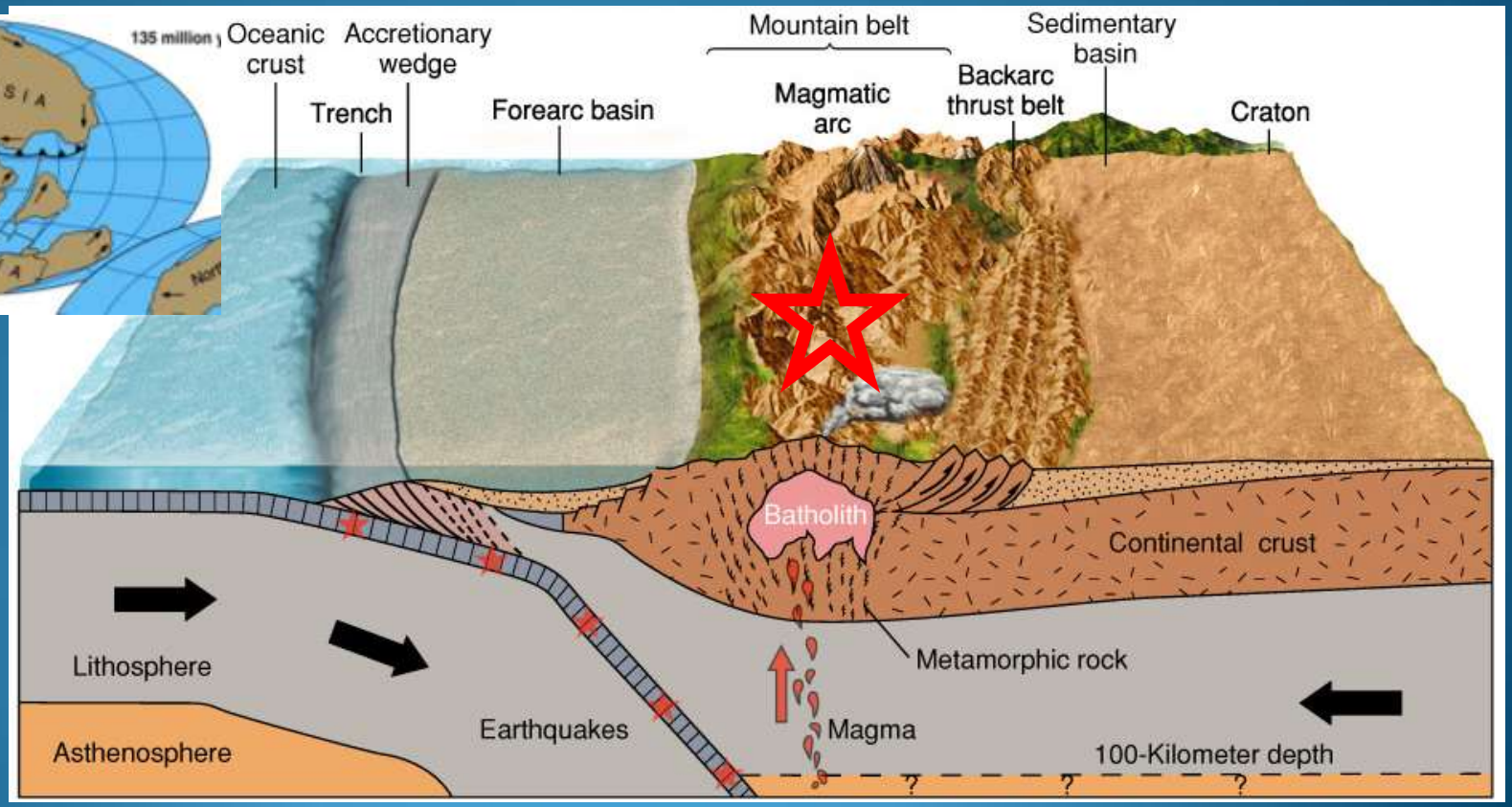
Paleozoic – Arizona was on trailing edge of N. American continent = calm seaways

Mesozoic – Arizona was on leading edge of N. American continent = mountain building, volcanoes, earthquakes, igneous intrusions



Nevadan Orogeny (230-145 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Nevadan	Late	160-145	Late Jurassic	volcanics			
	Middle	205-160	Late & Middle Jurassic	Canelo Hills volcanics; plutonic rocks	Metalum. Alkalic	porphyry Cu-Au at Bisbee, Gleeson	Warren (Bisbee mine), Turquoise (Courtland-Gleeson)
	Early	230-205	Late Triassic	Fluid flow thru sedimentary rocks	Metalum. Alkalic	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley



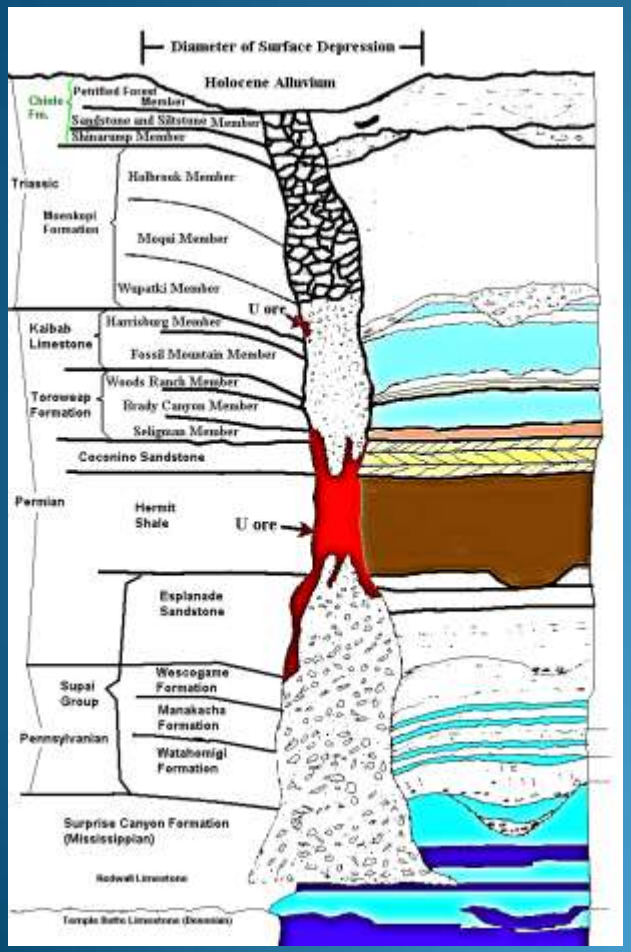
Early Nevadan Orogeny (230-205 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Nevadan	Early	230-205	Late Triassic	Fluid flow thru sedimentary rocks	Metalum. Alkalic	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley

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

Early Jurassic [Nevadan Orogeny] (230-200 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Early	230-205	Late Triassic	Fluid flow thru sedimentary rocks	Metalum. Alkalic	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley



Source: Wenrich

Breccia pipe in Grand Canyon

Early Jurassic [Nevadan Orogeny] (230-200 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Early	230-205	Late Triassic	Fluid flow thru sedimentary rocks	Metalum. Alkalic	Uranium, vanadium, copper	Orphan, Grandview, Monument Valley

Grandview mine; cyanotrichite on antlerite AzMMM specimen

Ridenour mine; tyuyamunite, Wenrich photo

Carnotite in petrified wood, Coconino Co. AzMMM specimen

Middle Nevadan - Warren m.d. (Bisbee)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Nevadan	Middle	205-160	Late & Middle Jurassic	Canelo Hills volcanics; plutonic rocks	Metalum. Alkalic	porphyry Cu-Au at Bisbee, Gleeson	Warren (Bisbee mine), Turquoise (Courtland-Gleeson)

Lavender Pit, Bisbee

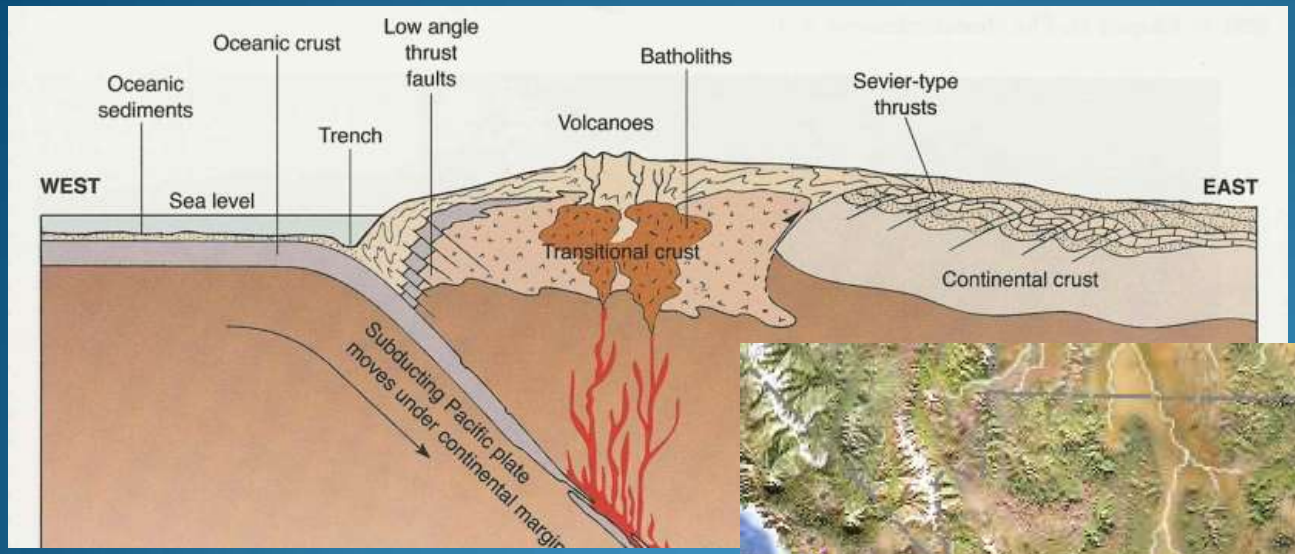
Warren district (Bisbee) secondary

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Nevadan	Middle	205-160	Late & Middle Jurassic	Canelo Hills volcanics; plutonic rocks	Metalum. Alkalic	porphyry Cu-Au at Bisbee, Gleeson	Warren (Bisbee mine), Turquoise (Courtland-Gleeson)

chalcocite

Sevier Orogeny (145-89 Ma)

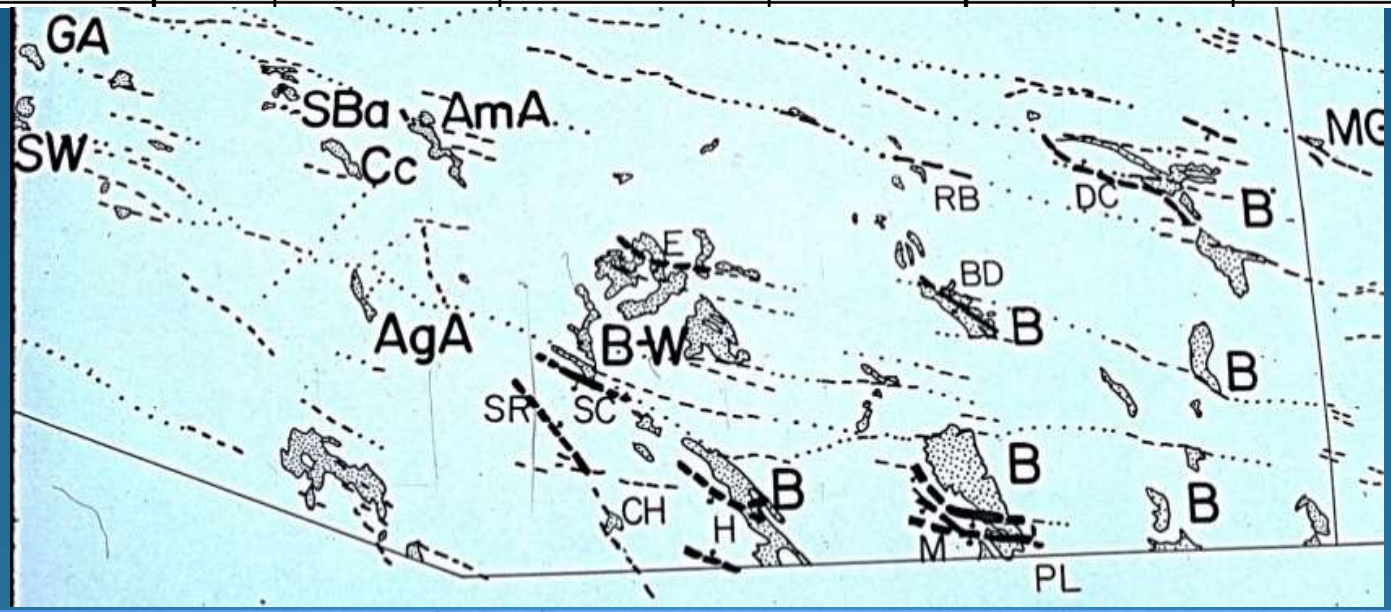
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Sevier		145-89	mid-Cretaceous			Sedimentary rocks	Bisbee Group sediments

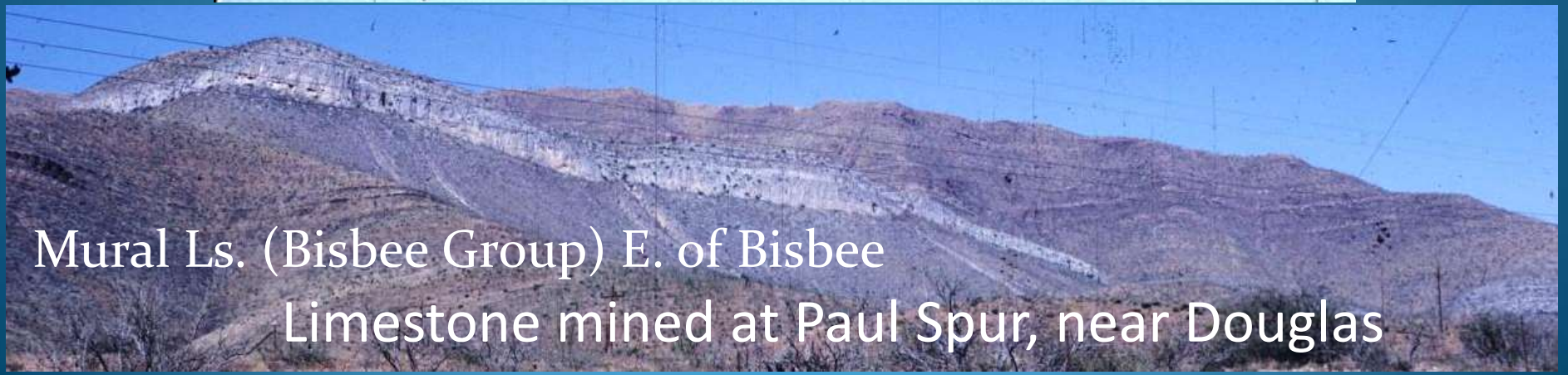


Constant dip subduction – magmatism mostly in California

Sevier Orogeny (145-89 Ma)

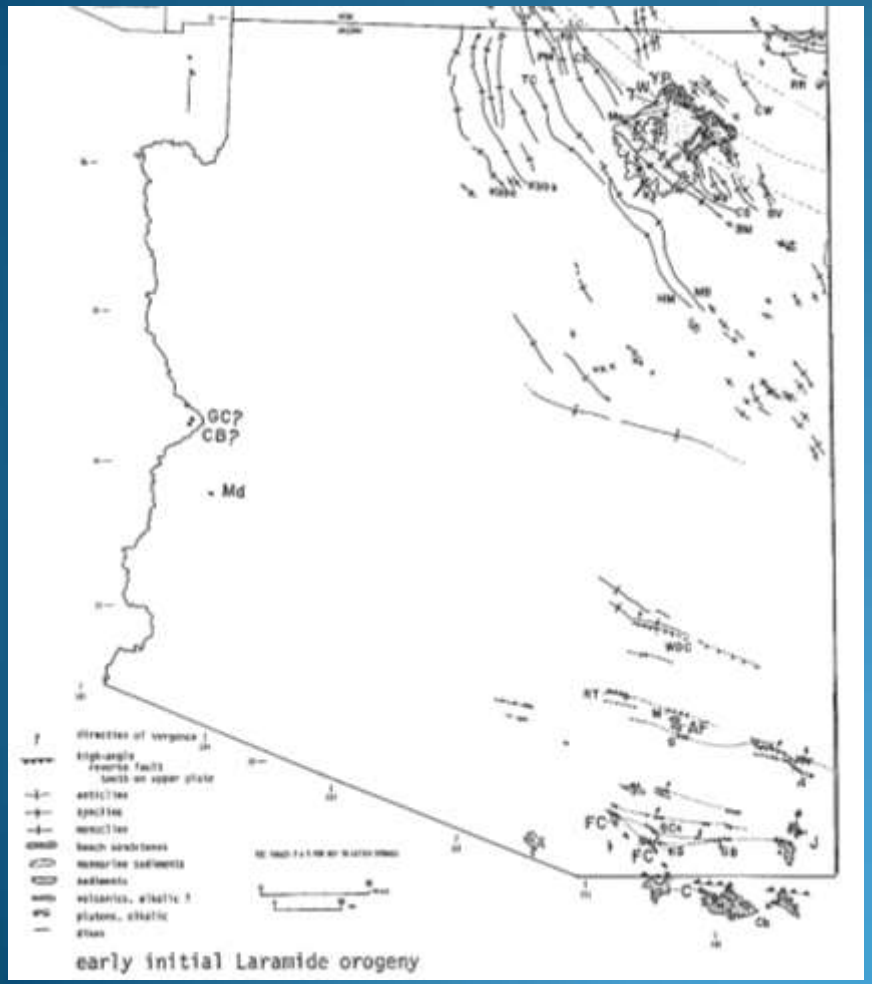
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Sevier		145-89	mid-Cretaceous			Sedimentary rocks	Bisbee Group sediments





Earliest Laramide -Hillsboro (89-85 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Earliest (Hillsboro)	89-85	mid-Cretaceous	Volcanics, small stocks	Metalum. Alkalic	Cu-Au hydrothermal	Hillsboro, NM

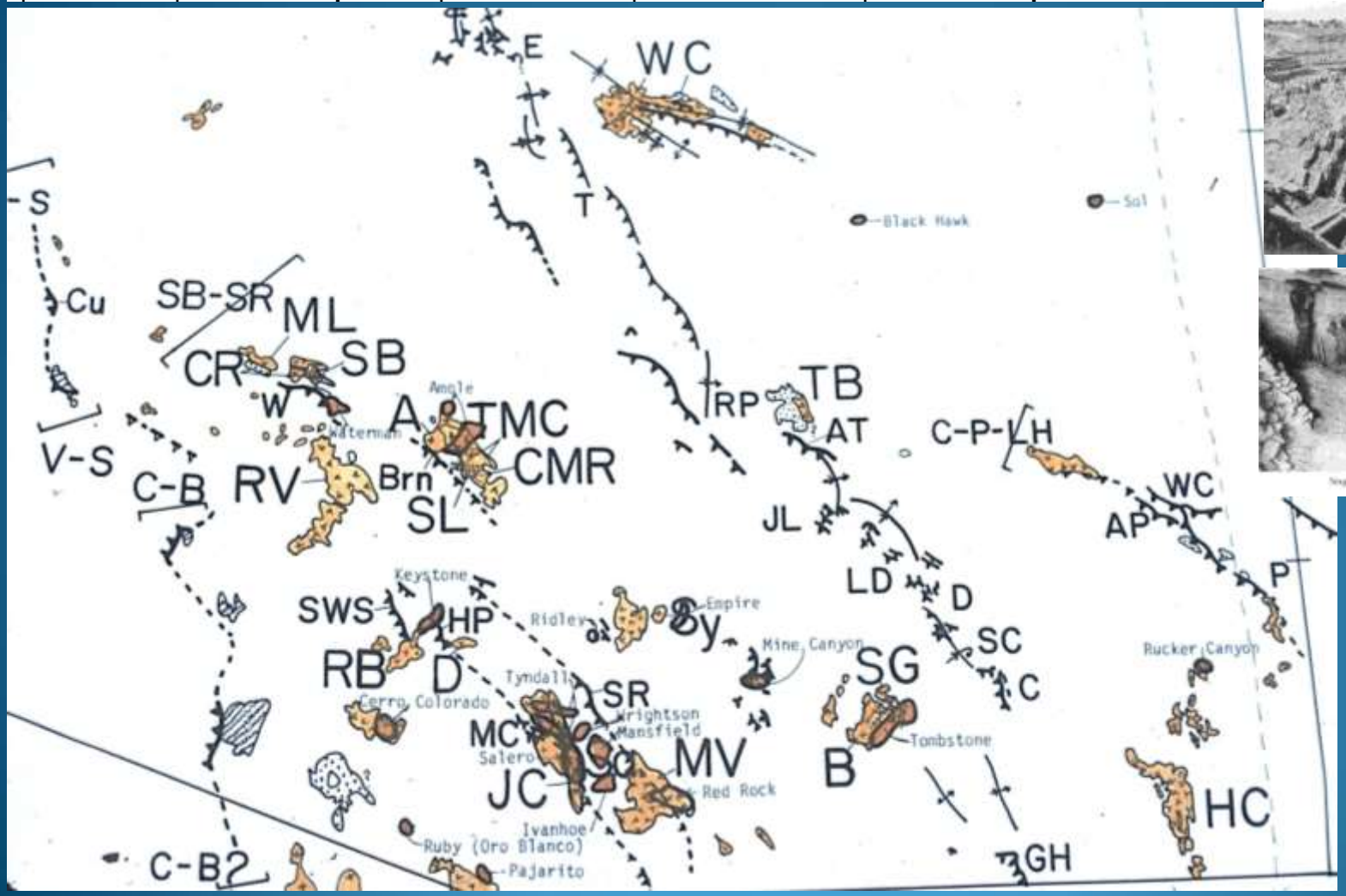


N Arizona – coal in Wepo Fm. at Black Mesa

Photo from Peabody Coal (Freeport-McMoran)

Early Laramide (Tombstone) (85-65 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Early (Tombstone)	85-65	Late Cretaceous	qtz. monz. porph. stocks; ash flows	Metalum. Alkali-calcic	Pb-Zn-Ag veins & replacement deposits	Tombstone, Tyndall (Glove), Washington Camp, Salero



Early Laramide (Tombstone) (85-65 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Early (Tombstone)	85-65	Late Cretaceous	qtz. monz. porph. stocks; ash flows	Metalum. Alkali-calcic	Pb-Zn-Ag veins & replacement deposits	Tombstone, Tyndall (Glove), Washington Camp, Salero

Mt. Pinatubo, Philippines, 1991

Glove mine wulfenite, Santa Rita Mts.

Tombstone Hills – Uncle Sam Tuff

Tombstone silver mines

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Early (Tombstone)	85-65	Late Cretaceous	qtz. monz. porph. stocks; ash flows	Metalum. Alkali-calcic	Pb-Zn-Ag veins & replacement deposits	Tombstone, Tyndall (Glove), Washington Camp, Salero

Alabandite MnS

Emmonsite, Empire m.

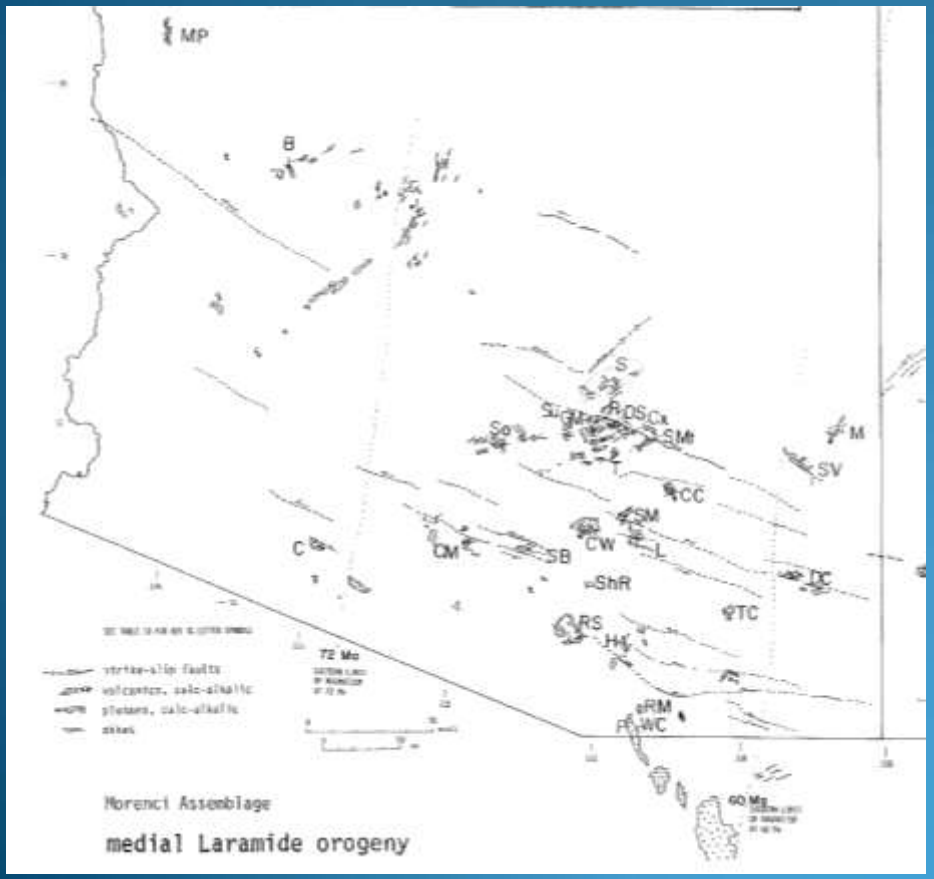
$Fe_2Te_3O_9.2H_2O$

Silver, Lucky Cuss m.

Chlorargyrite – John Betts photo & specimen MinDat.org AgCl

Middle Laramide - Morenci (65-55 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Laramide	Middle (Morenci)	65-55	Cretaceous-Tertiary	granodiorite - quartz monzonite porphyry stocks, NE to ENE-striking dike swarms	Metaluminous Calc-alkalic	large disseminated porphyry Cu systems, local skarns & veins, fringing Zn-Pb-Ag	Ajo, Ray, Christmas, San Manuel, Mineral Park, Pima, Bagdad, Silver Bell, Globe-Miami, Morenci, Superior



Laramide - Ray mine – porphyry Cu

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Laramide	Middle (Morenci)	65-55	Cretaceous-Tertiary	granodiorite - quartz monzonite porphyry stocks, NE to ENE-striking dike swarms	Metaluminous Calc-alkalic	large disseminated porphyry Cu systems, local skarns & veins, fringing Zn-Pb-Ag	Ajo, Ray, Christmas, San Manuel, Mineral Park, Pima, Bagdad, Silver Bell, Globe-Miami, Morenci, Superior

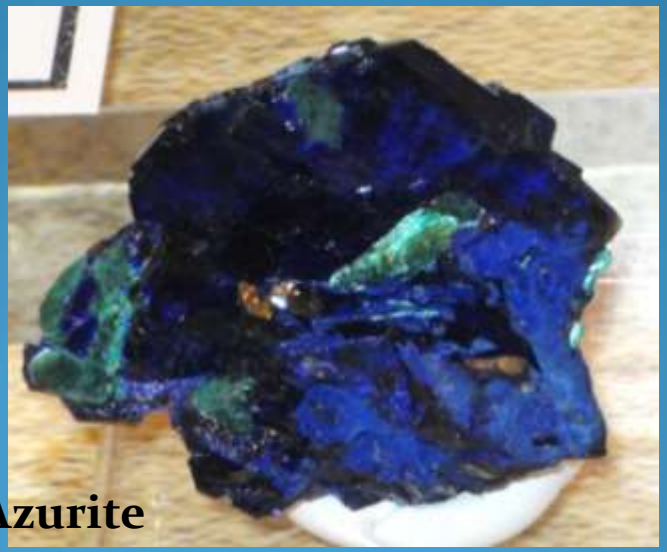
Ray shovel, haul truck
Dave Briggs photos

San Manuel Mine

Malachite

Quartz on Chrysocolla

Pyrite



Azurite

Outer Pb-Zn zones of Porphyry Copper deposits

Christmas mine

rosasite

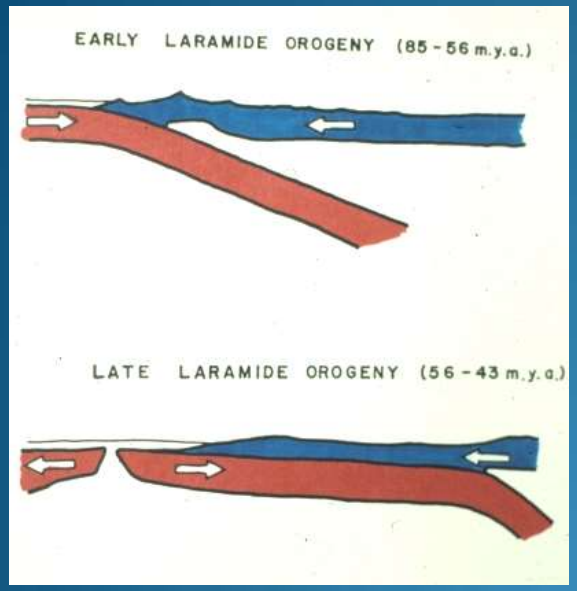
Copper on apophyllite

kinoite

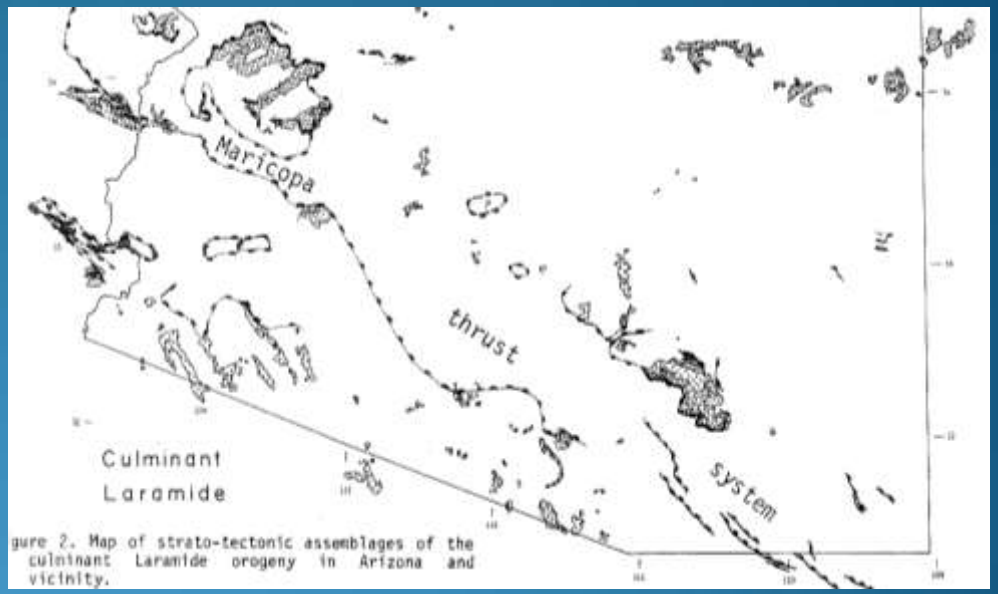
dioptase

Latest Laramide – Wilderness (55-43 Ma)

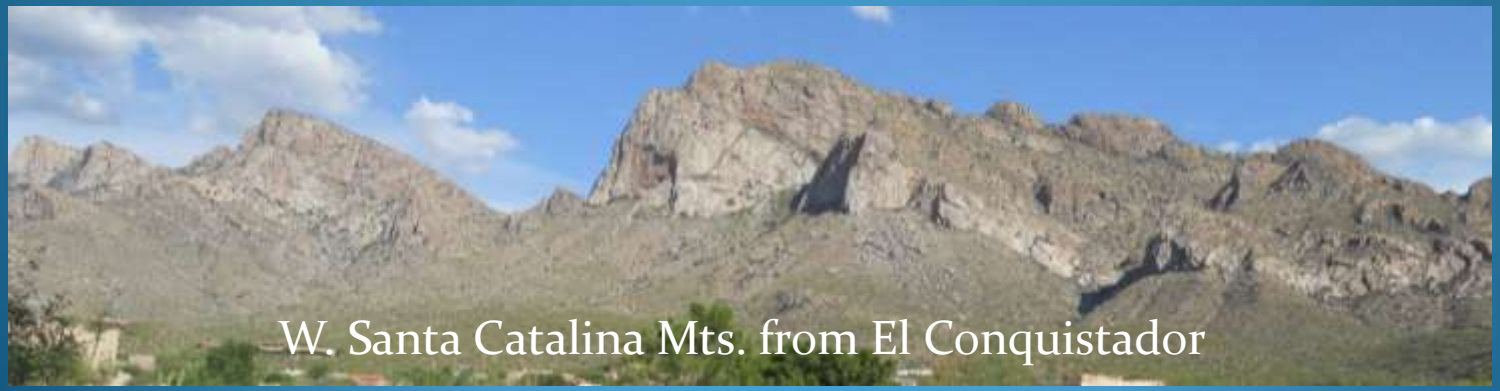
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Late (Wilderness)	55-43	Early Tertiary	2-mica, garnet-muscovite granitic stocks, sills, dikes	Peralum. Calcic, Calc-alkalic	Au dissem. & qtz veins; W veins,	Oracle (Wilderness granite), Boriana, Las Guijas, Gold Basin, Copperstone



Flat subduction



gure 2. Map of strato-tectonic assemblages of the culminant Laramide orogeny in Arizona and vicinity.


W. Santa Catalina Mts. from El Conquistador

Latest Laramide (Paleocene) mining districts

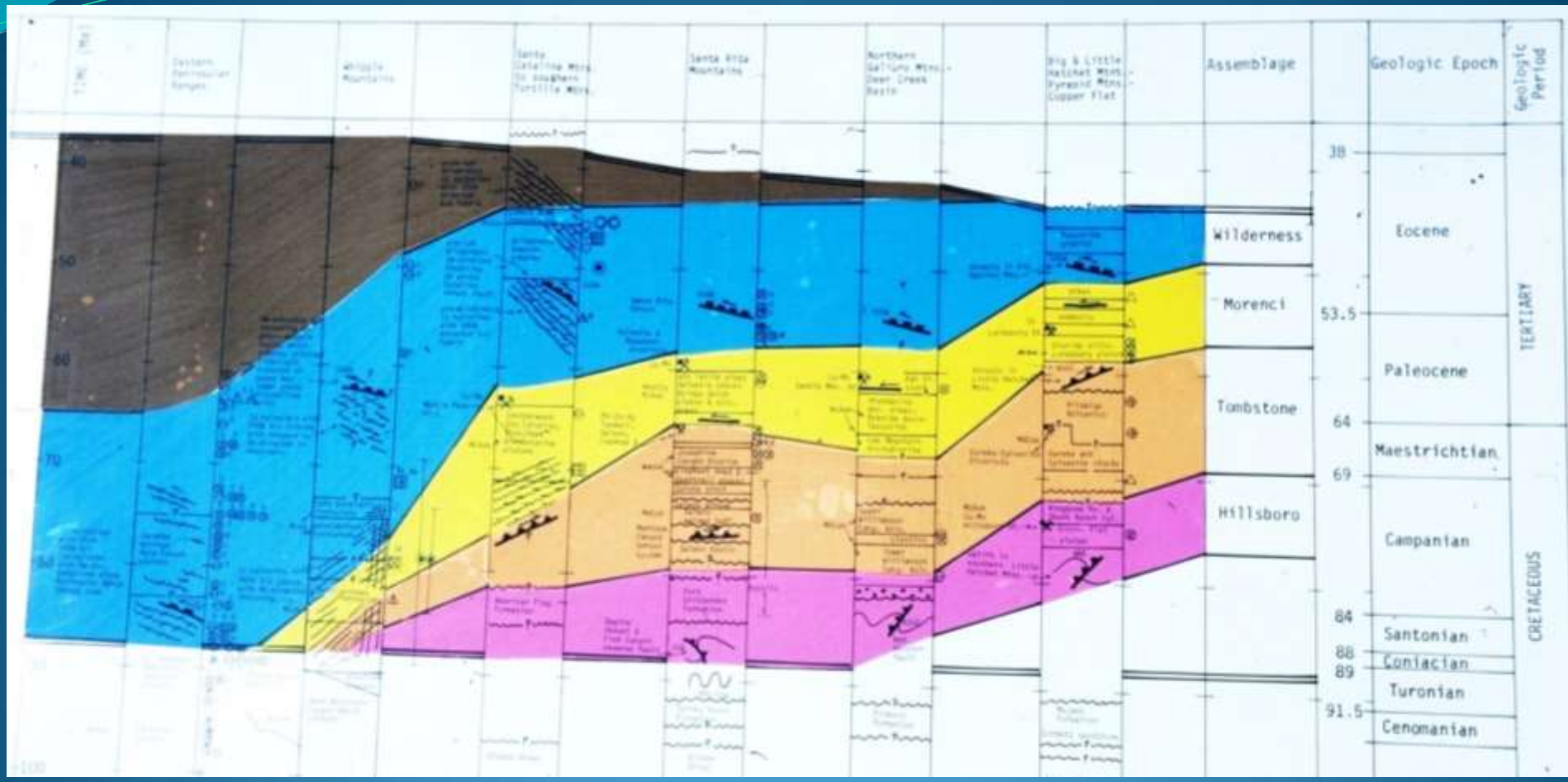
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Late (Wilderness)	55-43	Early Tertiary	2-mica, garnet-muscovite granitic stocks, sills, dikes	Peralum. Calcic, Calc-alkalic	Au dissem. & qtz veins; W veins,	Oracle (Wilderness granite), Boriana, Las Guijas, Gold Basin, Copperstone

Gold, Gold Basin, Mohave Co., AZ

Copperstone Gold mine, La Paz Co.

Gold, Las Guijas, Pima Co. AZ

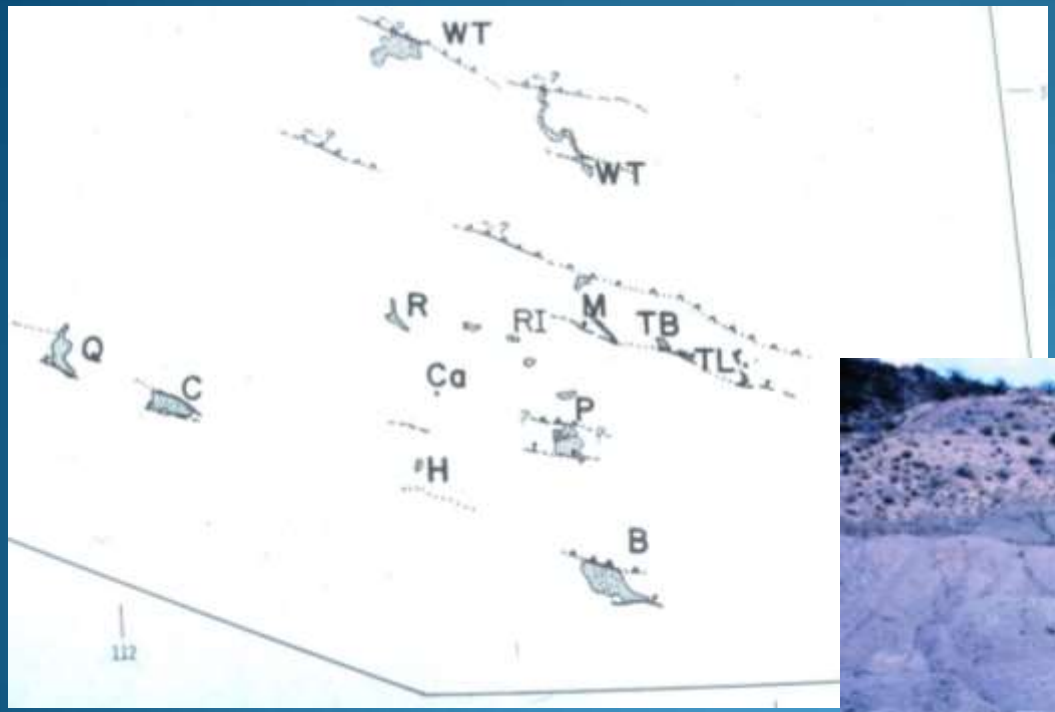
Laramide 'transgression' of magmatism



Eastward migrating magmatism of Metaluminous QA, AC, and CA, then Peraluminous

Early Galiuro – Mineta (38-28 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Earliest (Mineta)	38-28	Mid-Tertiary	mostly within 'volcanic gap"	-	Uranium, clay, exotic copper	Ajo Cornelia, Copper Butte (from Ray)



Pantano Clay, East Tucson - 1987

Middle Galiuro – Datil (28-18 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Galiuro	Middle (Datil)	28-18	Mid-Tertiary	alkali-calcic ignimbritic volcanics & plutons	Metaluminous Alkali-calcic	Pb-Zn-Ag F veins, replace.; epithermal	Silver (Red Cloud), Castle Dome, Stanley, Aravaipa

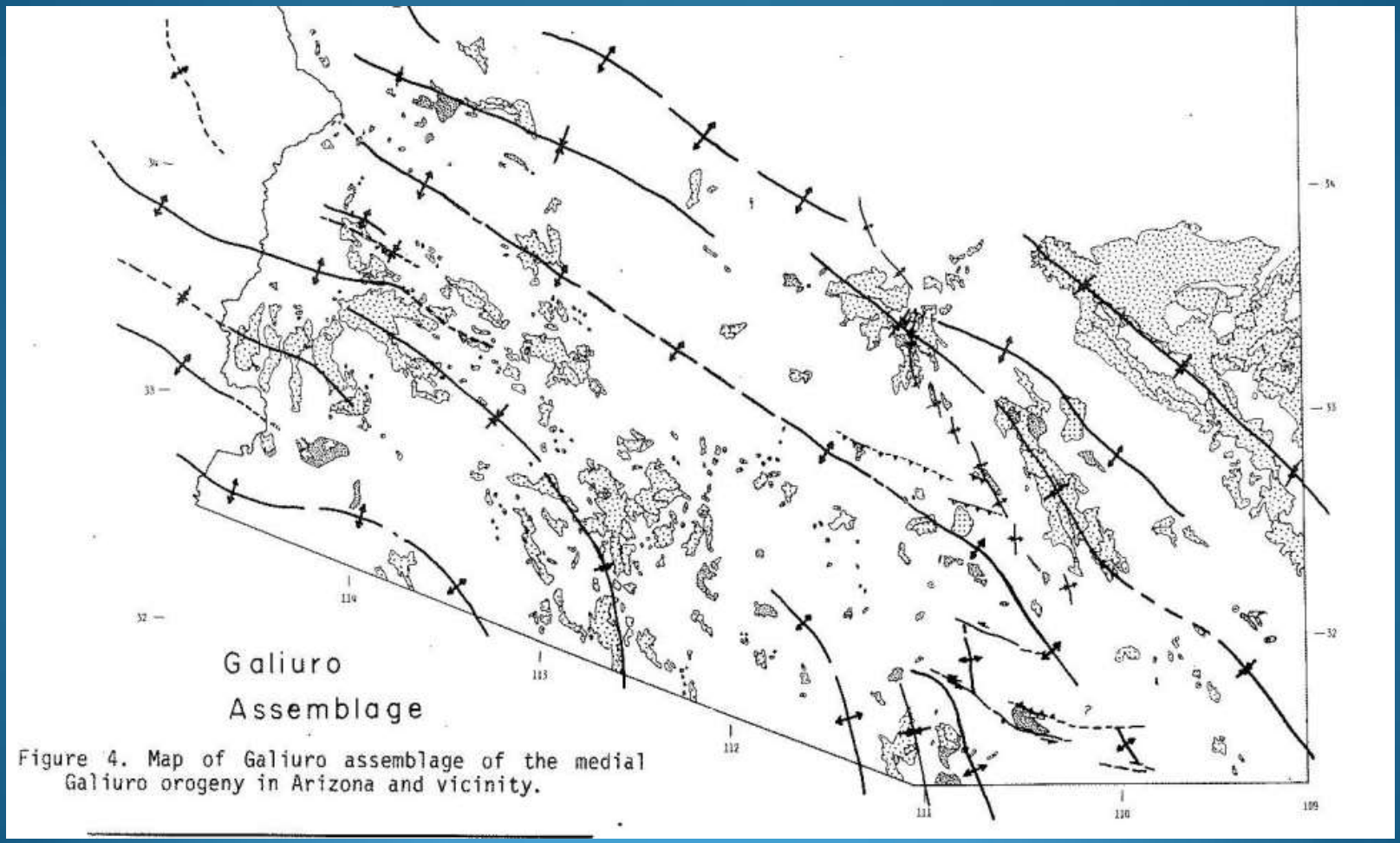


Figure 4. Map of Galiuro assemblage of the medial Galiuro orogeny in Arizona and vicinity.

Middle Galiuro – Datil (28-18 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
Galiuro	Middle (Datil)	28-18	Mid-Tertiary	alkali-calcic ignimbritic volcanics & plutons	Metaluminous Alkali-calcic	Pb-Zn-Ag F veins, replace.; epithermal	Silver (Red Cloud), Castle Dome, Stanley, Aravaipa

Chiricahua Mts. Ash flow tuffs

N. Tucson Mts.

Organ Pipe volcanics

Red Cloud Mine

Late Galiuro – Whipple (18-13 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Late (Whipple)	18-13	Late Tertiary	volcanics & local epizonal stocks	Metalum-inous Alkalic	Cu-Au-Ag in veins; epithermal Au-Ag veins	Oatman, Mammoth, Rowley,Swansea

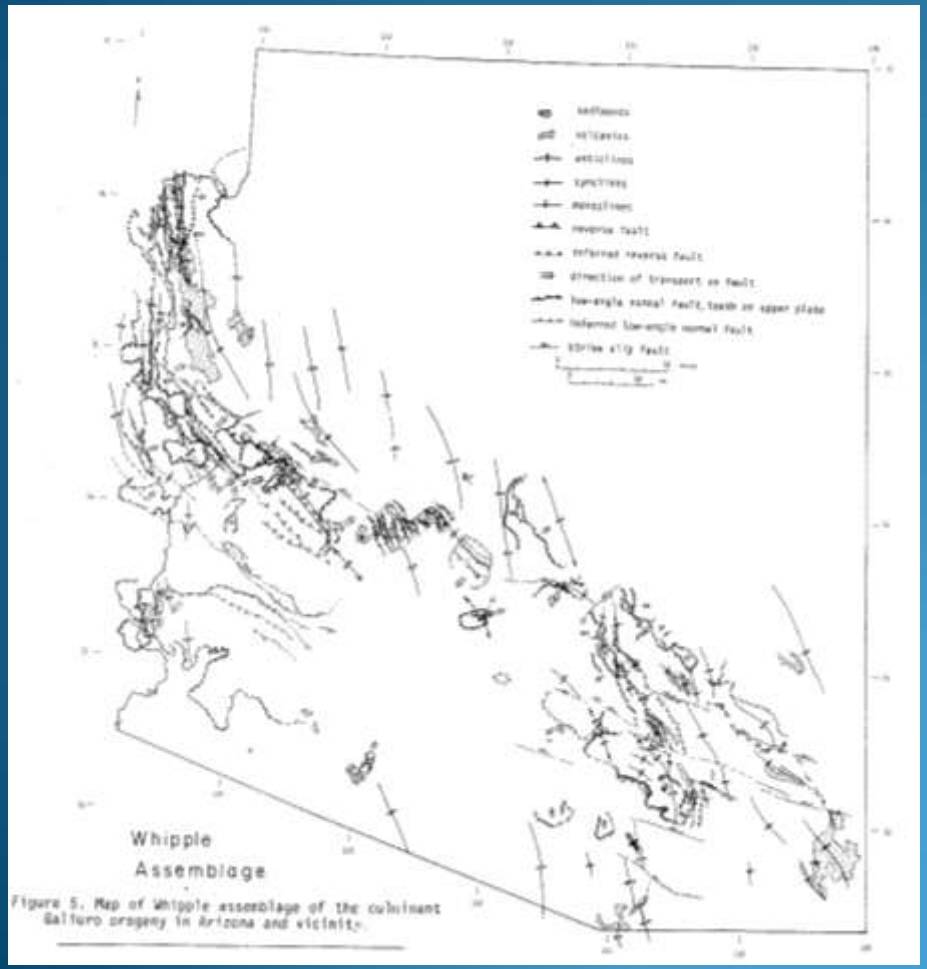


Figure 5. Map of Whipple assemblage of the culminant Galiuro orogeny in Arizona and vicinity.

Fluorite, Harquahala Mts.

Mammoth-St. Anthony mine (Tiger)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
	Late (Whipple)	18-13	Late Tertiary	volcanics & local epizonal stocks	Metalum-inous Alkalic	Cu-Au-Ag in veins; epithermal Au-Ag veins	Oatman, Mammoth, Rowley,Swansea

Aerial photo courtesy of BHP Billiton, 2006

Mid-Tertiary – Santa Catalinas - Tiger – Mammoth-St. Anthony mine

vanadinite

cerussite

diaboleite

boleite

dioptase

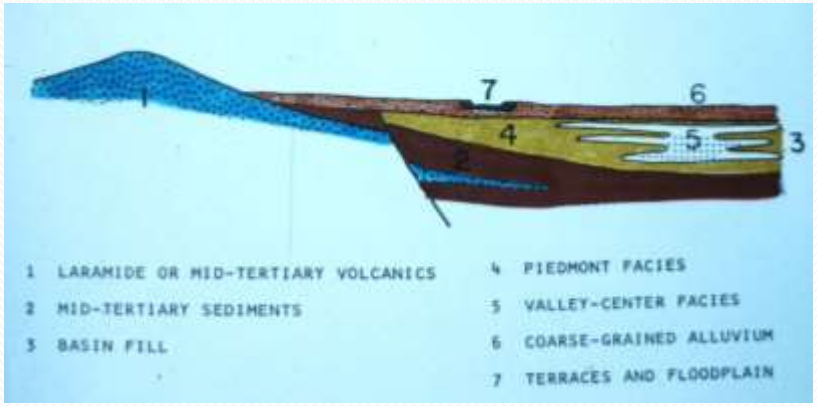
hemimorphite

caledonite

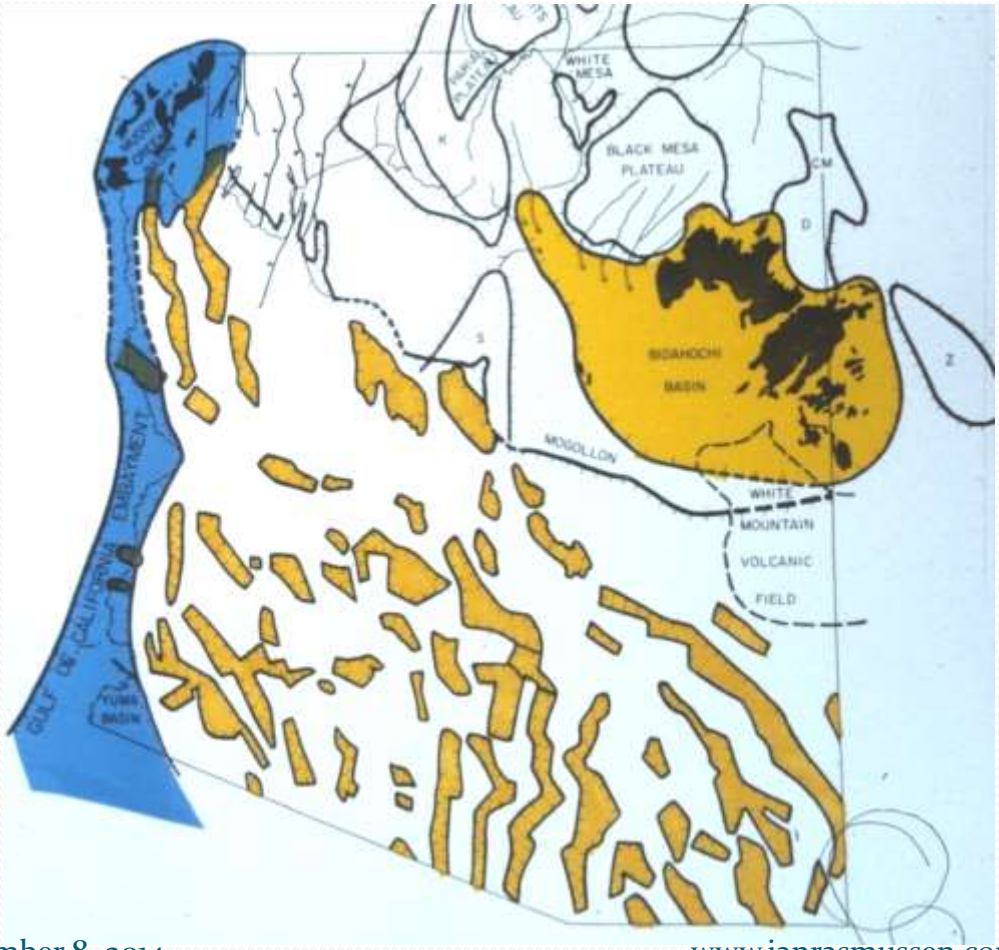
Basin & Range Disturbance (13-0 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
San Andreas	Basin & Range	13-0	Latest Tertiary	anhydrous basaltic volcanism	Metalum. Alkalic	Sand, gravel, salt, zeolites, gypsum	San Francisco volcanic field, San Carlos olivine, Emerald Isle exotic Cu

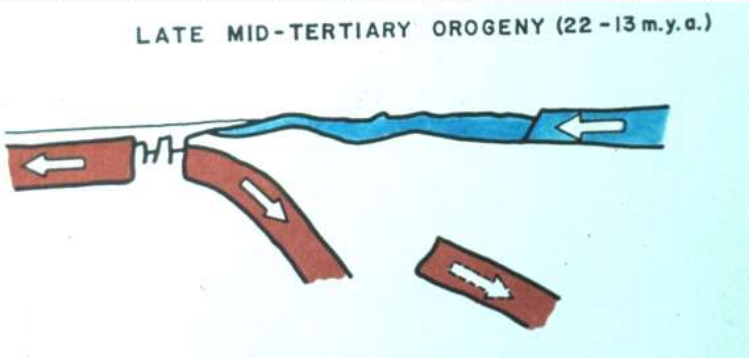
Valleys filled with sand, gravel, clay, gypsum, & salt

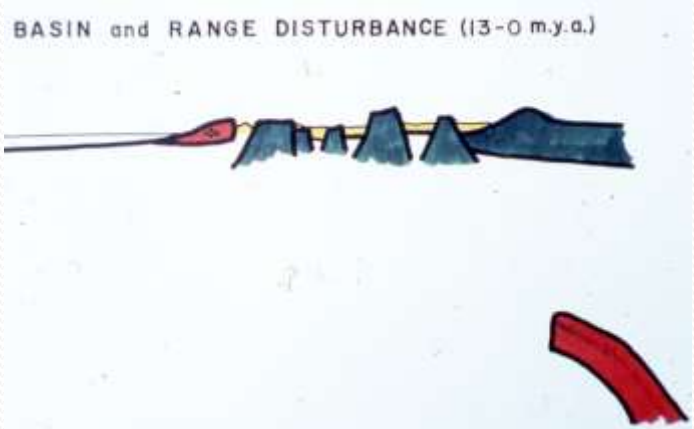



Willcox Playa



San Andreas fault cuts off eastward-subducting plate



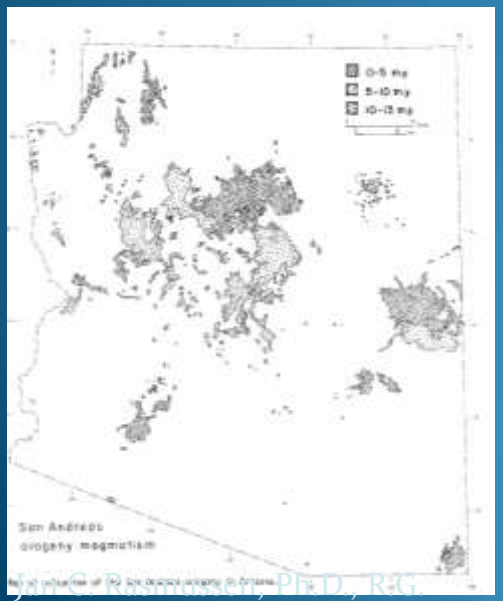


San Francisco Peaks, Flagstaff, AZ

San Andreas – Basin & Range (13-0 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Resources	Mining districts
San Andreas	Basin & Range	13-0	Latest Tertiary	anhydrous basaltic volcanism	Metalum. Alkalic	Sand, gravel, salt, zeolites, gypsum	San Francisco volcanic field, San Carlos olivine, Emerald Isle exotic Cu

cinders



San Francisco Peaks, Flagstaff

Industrial Minerals - Late Cenozoic

Sand & gravel

Kalamazoo Clay - 1987

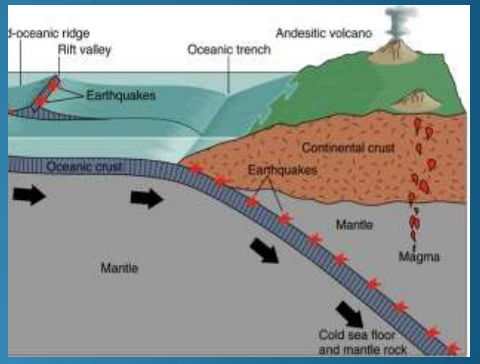
Gypsum rose

Arizona Mineralization through Geologic History

Mineralization is related to orogenic episodes

- **Precambrian = orogenies added to fringes of continent – many different metals in AZ**

- **Paleozoic = AZ on trailing edge - Eastern orogenies – AZ sediments, limestone**



- **Mesozoic-Cenozoic = AZ on leading edge – Cordilleran – many different metals in AZ**

- **Latest Cenozoic = subduction cutoff by San Andreas – industrial minerals, basalt**