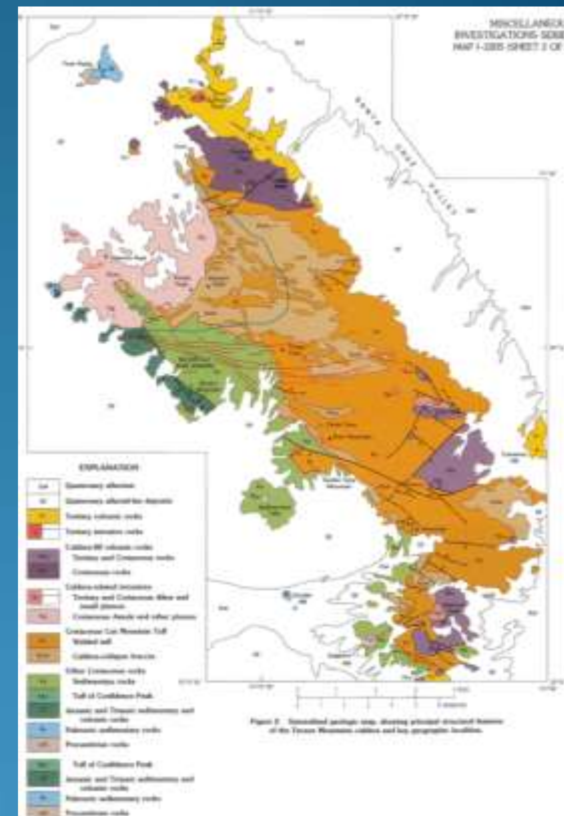
Geologic History of the Tucson Mountains

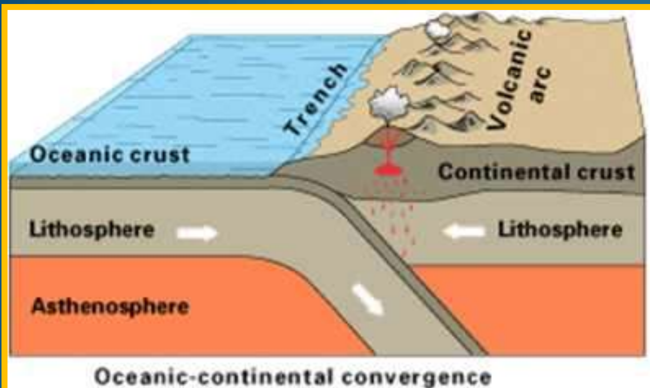

Vanadinite – Les & Paula Presmyck

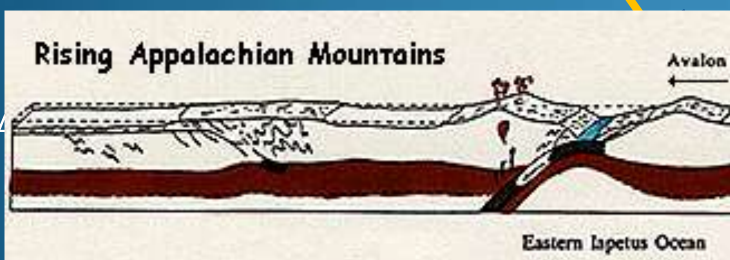

Wulfenite, photo - John Cesar, TGMS poster


Geologic maps & cross sections by Lipman, 1993

by Jan C. Rasmussen and Stanley B. Keith

Mountain Building Episodes in Tucson Mts.

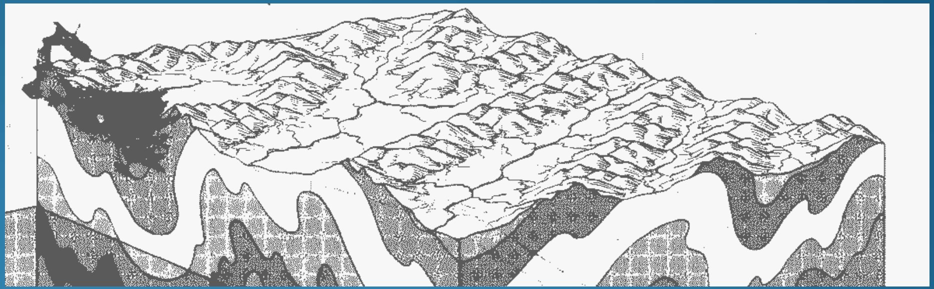




Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
San Andreas	Basin and Range	13-0	Latest Tertiary	Anhydrous basaltic volcanism		Tertiary-Quaternary alluvium; Recortado Tuff in Roskruge Mts	12.9 Ma
Galiuro	Late	18-13	Late Tertiary	Quartz alkalic volcanics; detachment faulting	MQA	None in Tucson Mts	
	Middle	28-18	Mid-Tertiary	Alkali-calcic ignimbritic volcanics & plutons	MAC	Safford Dacite & associated tuffs, Volcanics & tuffs of Tumamoc Hill	25.1 Ma Safford Peak dacite, 25.9 Ma Safford Tuff, 39.5 Ma basal Tsf1; 28.6-26.4 Ma Tumamoc basalts
	Earliest	39-28	Mid-Tertiary	Lake beds and possible erosion & secondary enrichment of Cu		Uranium sedimentary beds at Cardinal Avenue & Mission Rd.; Pantano Fm.	39.5 Ma basal Safford volcanic flow
Laramide	Late	55-40	Early Tertiary	Peraluminous 2-mica granites at great depths	PAC	None; Eocene erosion surface/unconformity below Safford Peak volcanics	43 Ma Wilderness Granite in Santa Catalina Mts
	Middle	65-55	Cretaceous-Tertiary	Porphyritic granodiorite stocks, dacites, andesites, tuffs	MCA	Tuff of Beehive Peak, porphyritic granodiorite of Sedimentary Hills & Saginaw Hill, S. Tucson Mts.	58.3 Ma Twin Hills dacite
	Early	80-65	Late Cretaceous	Granite & granodiorite stocks, rhyolite ash flows, dikes	MAC	Cat Mountain Tuff rhyolite; Amole Granite-granodiorite; Silver Lily dikes	73.1 Ma welded tuff Kcw, 72.3 Ma Silver Lily dikes; 73 Ma Amole Granite
	Earliest	85-75	Late Cretaceous	High K shoshonite, latite, and rhyolite lavas	MQA	Yuma Mine volcanics in N. Tucson Mts.: Ft. Crittenden ss. equivalent	Large hadrosaur dinosaur bones in sandstone
Sevier		145-89	mid-Cretaceous	None	-	Amole Arkose (Albian-Cenomanian)	100 Ma
Nevadan	Late	160-145	Late Jurassic	Volcanics		Andesite porphyry of Brown Mountain	159 Ma
	Middle	205-160	Late & Middle Jurassic	Volcanic and plutonic rocks		Recreation Redbeds	190 Ma?
Alleghenian		290-260	Permian	None	-	Naco Group (Concha & Rain Valley at Snyder Hill; Scherrer at Sus P.A.	
Ancestral Rocky Mts./ Ouachita		315-307	Middle Penn.	None	-	Horquilla at Sus P.A. and Twin Peaks	
Acadian (E coast) Antler (NV)		410-380	Devonian	None	-	Martin, Escabrosa at Twin Peaks, Rillito Cement mine; Sus PA	
Taconic (E coast)		470-440	Ordovician	None	-	Cambrian Bolsa, Abrigo at Twin Peaks	
Picuris		1440 - 1335	Meso-proterozoic	K-feldspar megacrystic or porphyritic granites	PCA, PAC, some M	Porphyritic Oracle Granite – Twin Peaks South side	~1440 Ma
Mazatzal		1750 - 1600	Paleo-proterozoic		MC	Pinal Schist – Twin Peaks West side	~1650 Ma

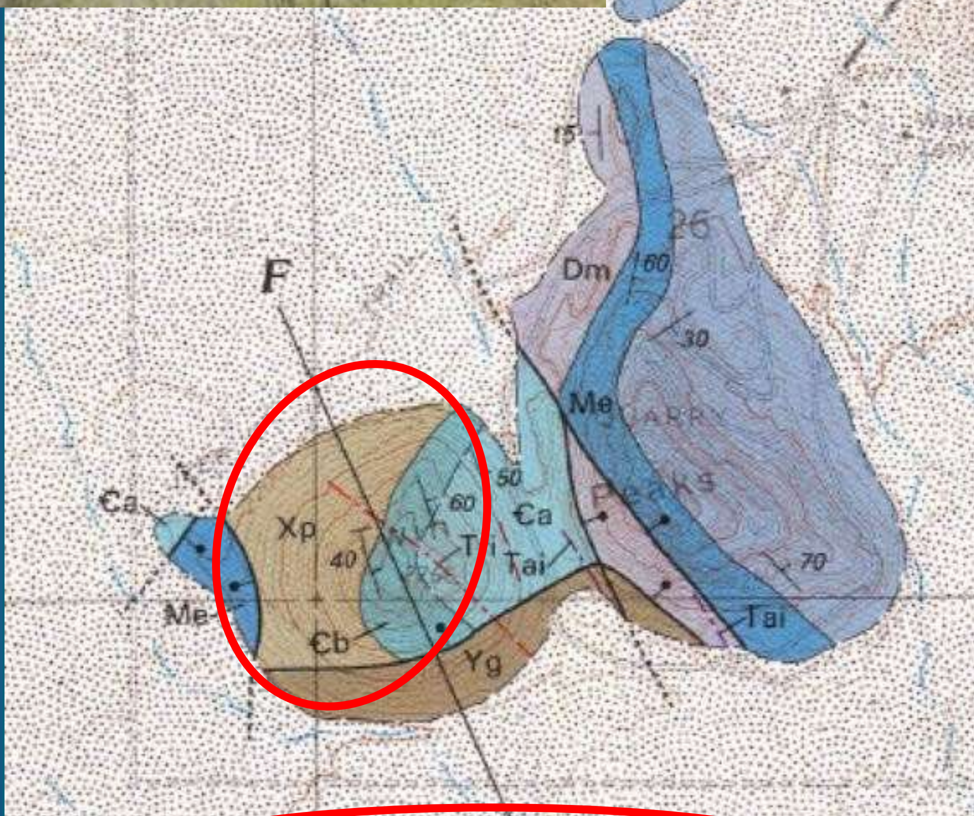
Mazatzal Orogeny (Paleoproterozoic) – Pinal Schist

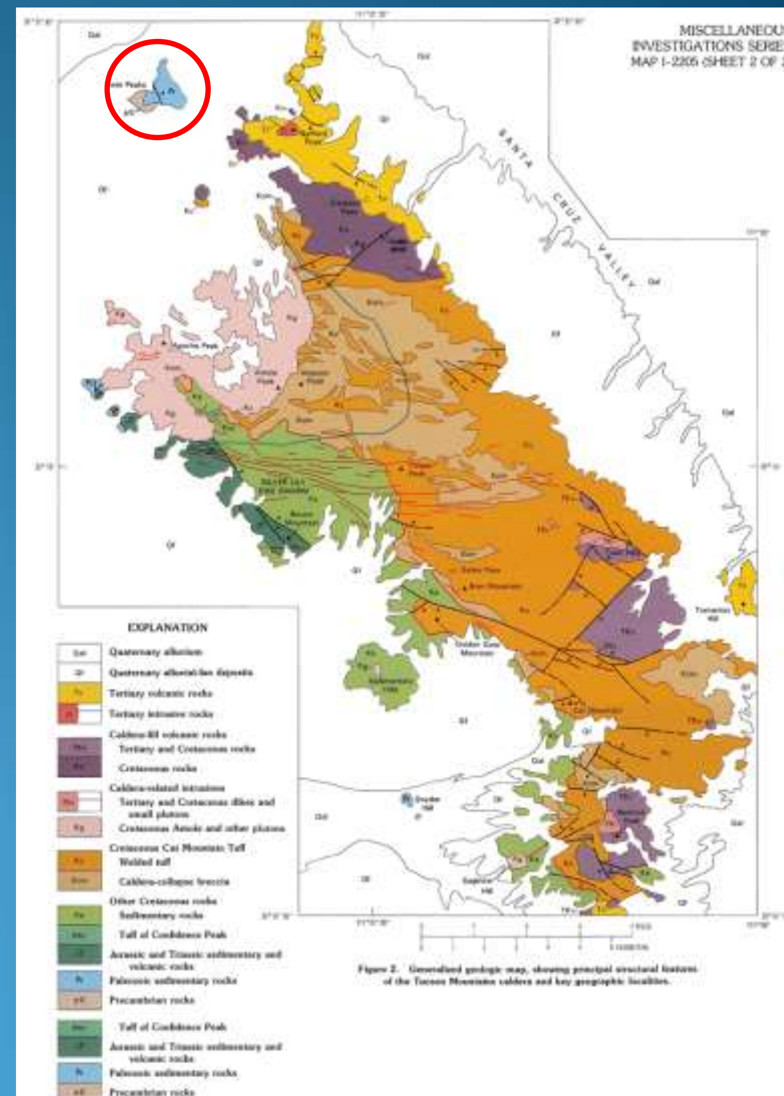
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Mazatzal		1695-1600	Late Paleo-proterozoic		MC	Pinal Schist – Twin Peaks West side	~1650 Ma



Mazatzal Orogeny (Paleoproterozoic) – Pinal Schist

fine-grained, gray-green, quartz-sericite schist



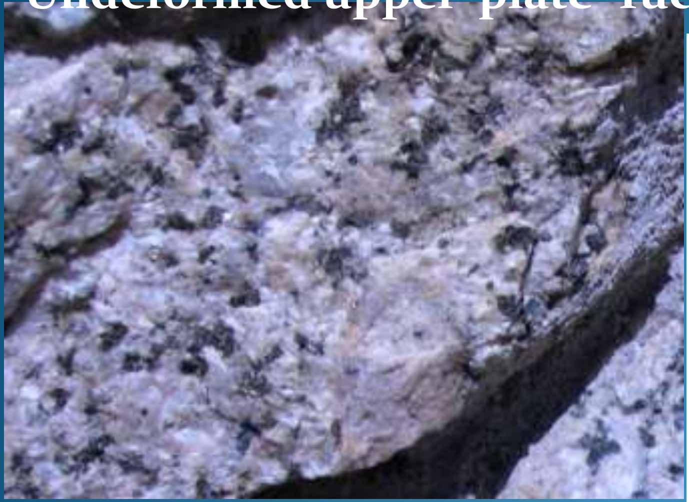


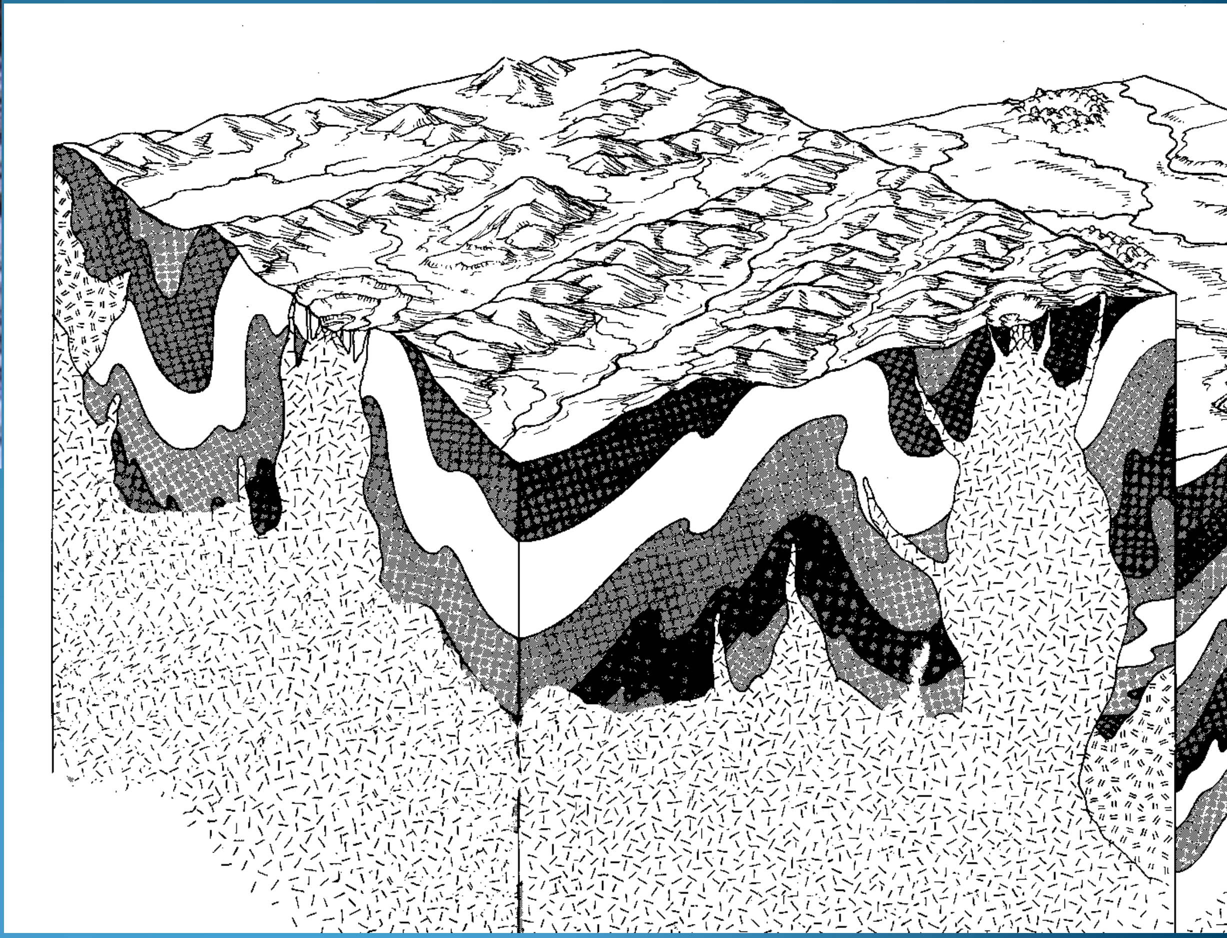
1695-1630 Ma – Pinal Schist - Xm

Picuris Orogeny (1.44-1.36 Ga)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Picuris		1440-1360	Middle Mesoproterozoic	K-feldspar megacrystic or porphyritic granites	PCA, PAC, some M	Porphyritic Oracle Granite – Twin Peaks South side	~1440 Ma

Undeformed upper plate Tucson Mts.

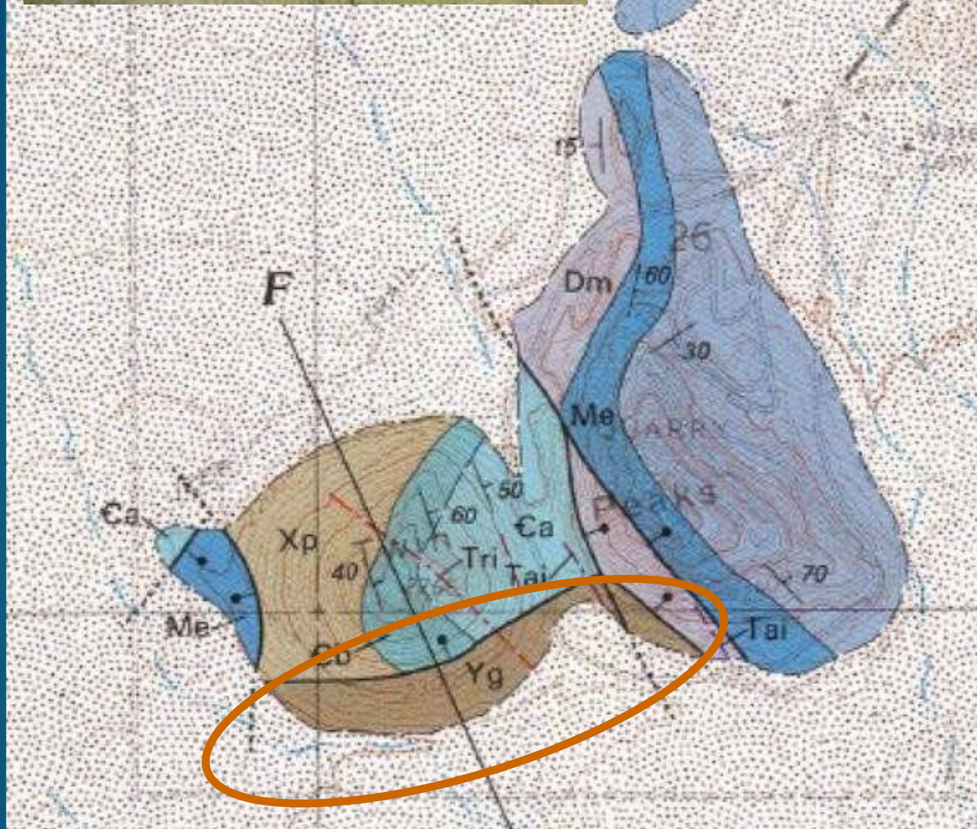




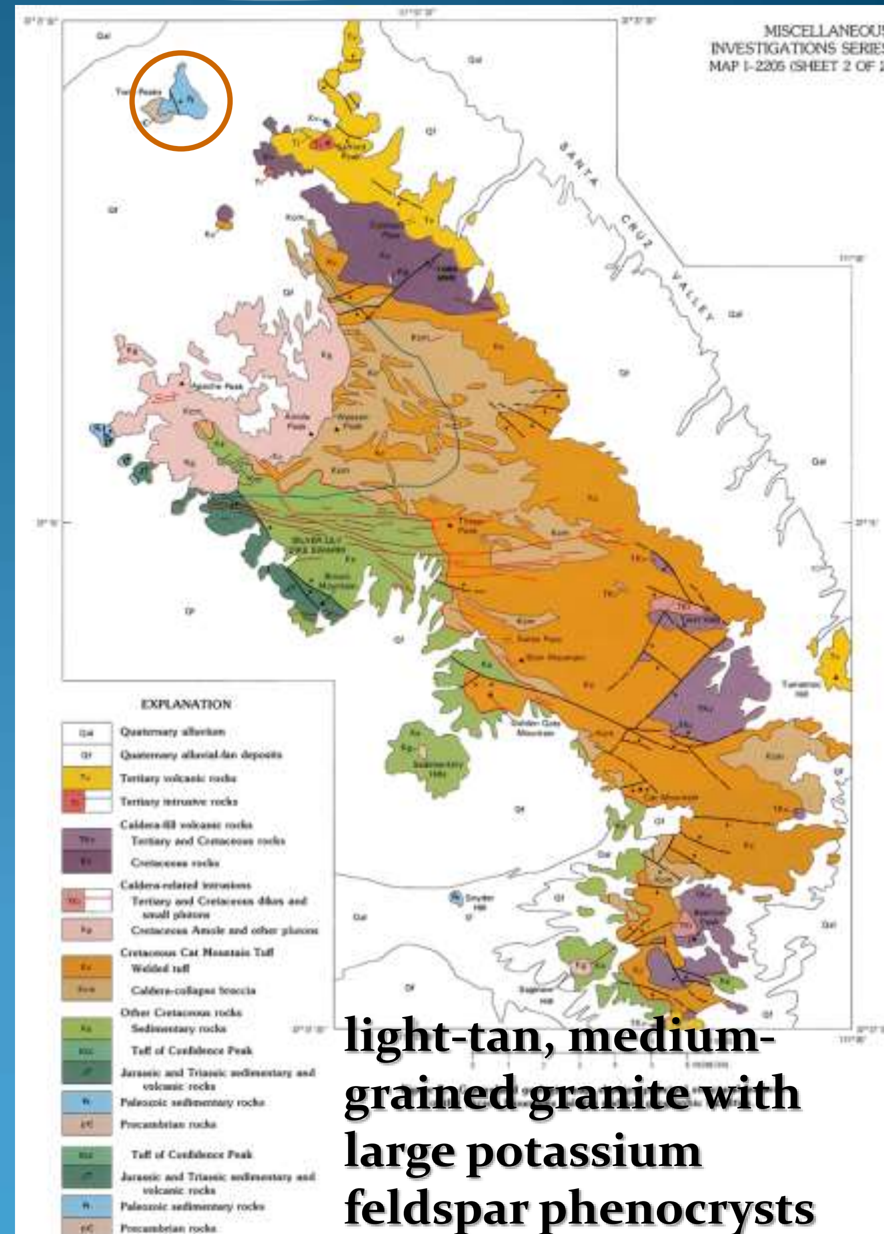
Oracle Granite

Deformed lower plate Catalina Mts.

Picuris Orogeny (Meso-proterozoic) Oracle Granite

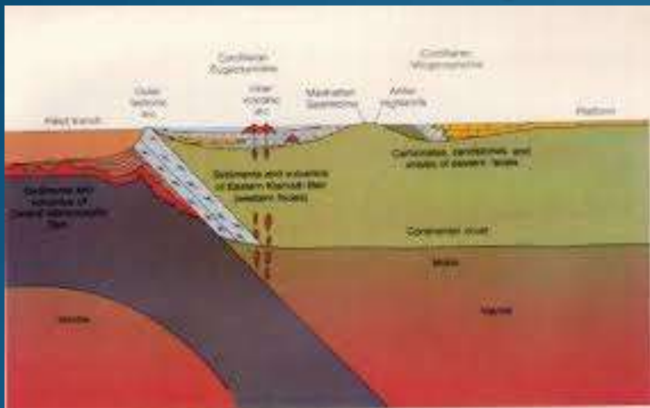


~1400 – 1450 Ma -
Oracle Granite - Yg

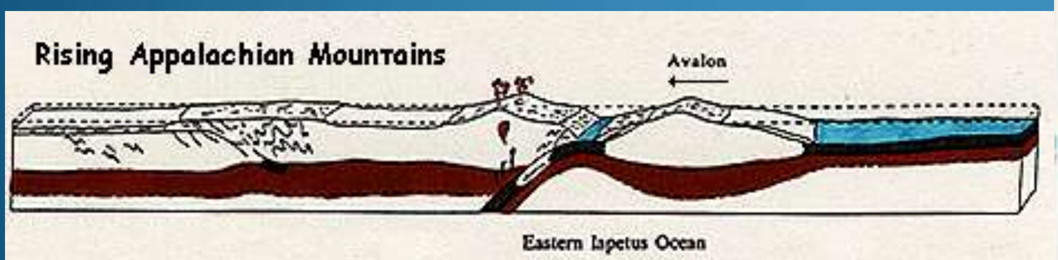


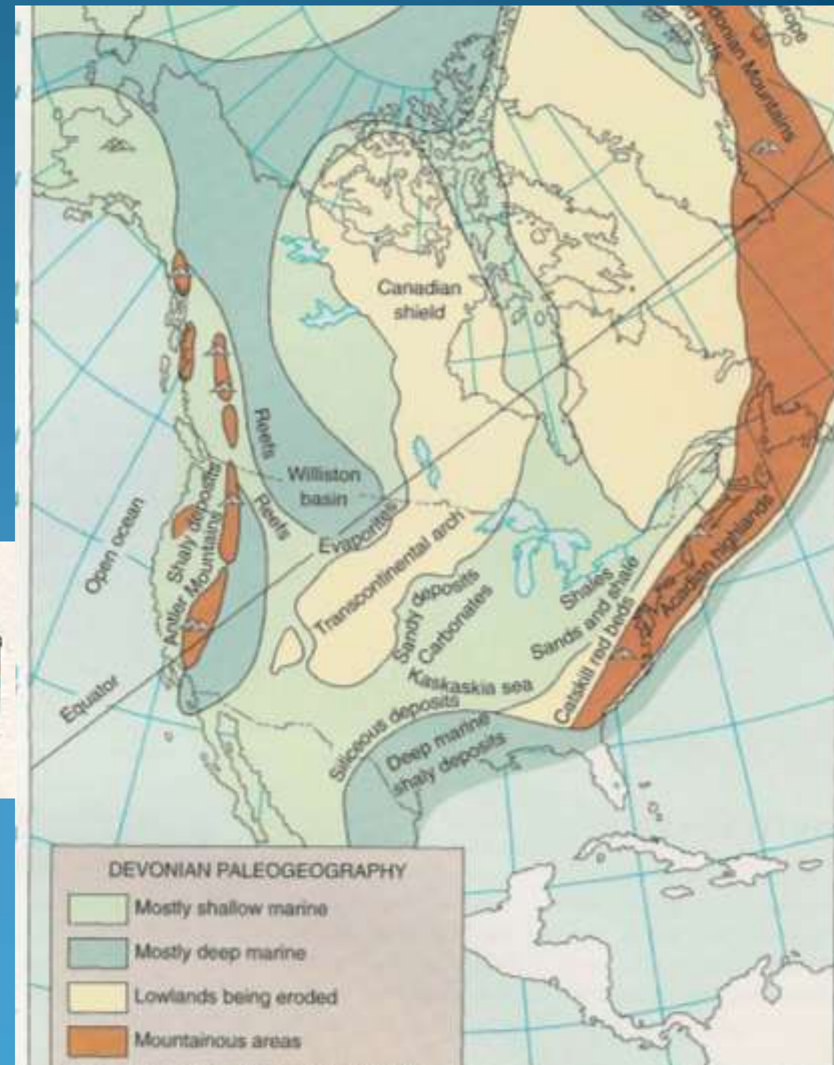
light-tan, medium-grained granite with large potassium feldspar phenocrysts

Paleozoic - mountain building along East coast; AZ mostly on trailing edge



Antler orogeny (CA & NV)

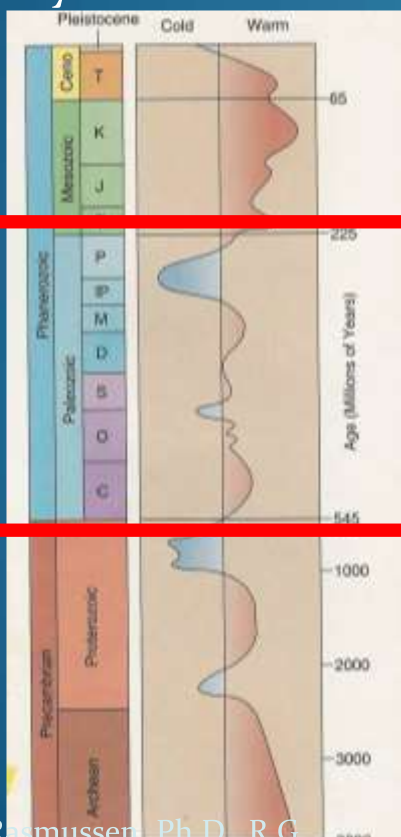


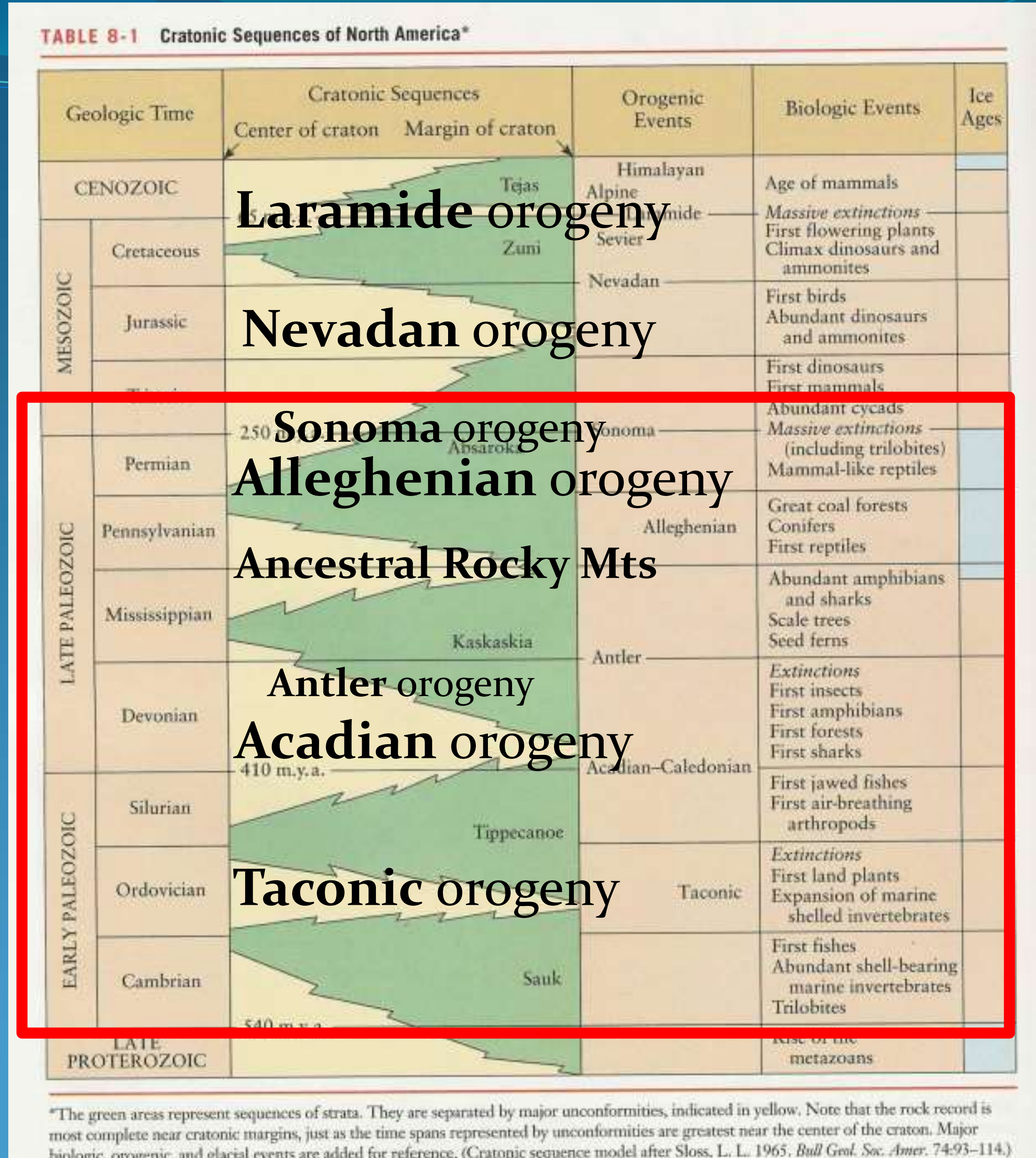


Seas go in, seas go out in AZ, depending on mountain building on east coast and volcanic activity on west coast.

Paleozoic cratonic sequences

Unconformity bounded, Island Arc collision with North America or continental assembly events





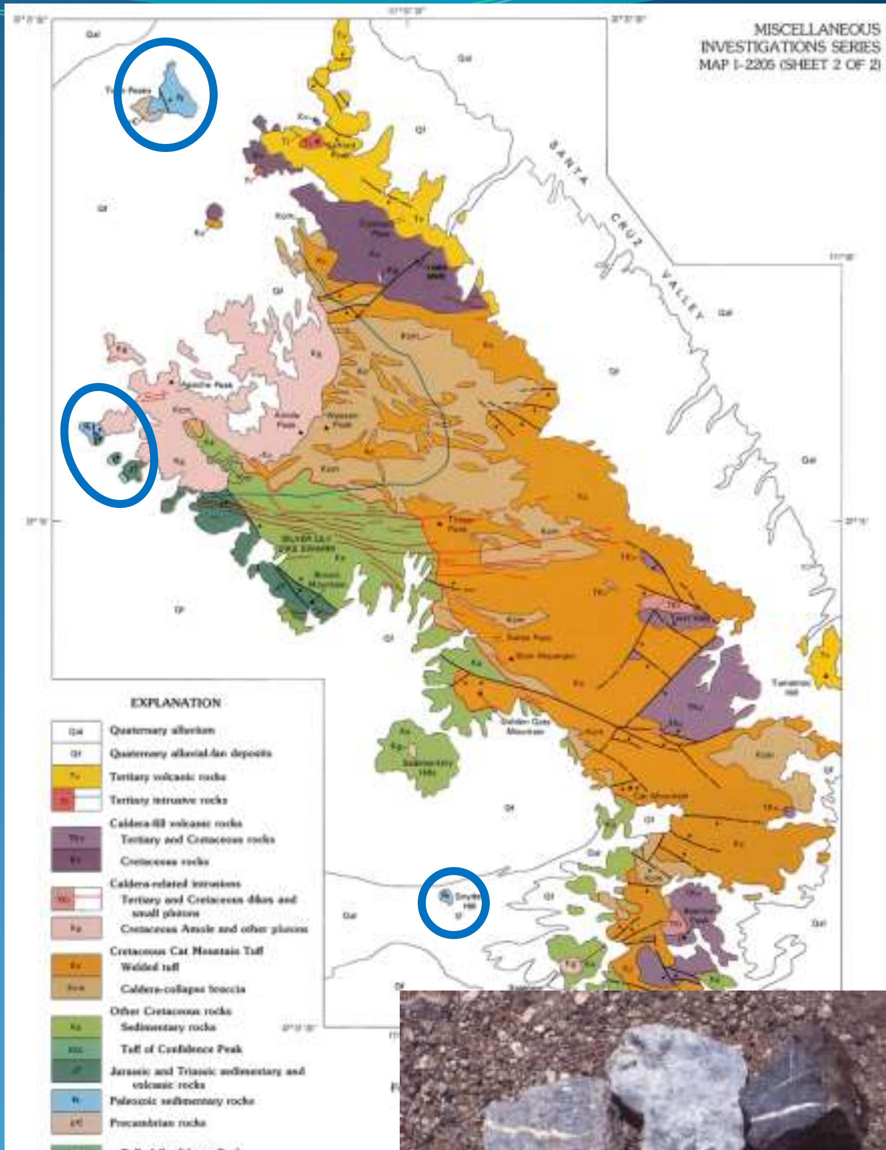
Paleozoic Sedimentary Rocks (541-252 Ma)

Twin Peaks

Sus Hills

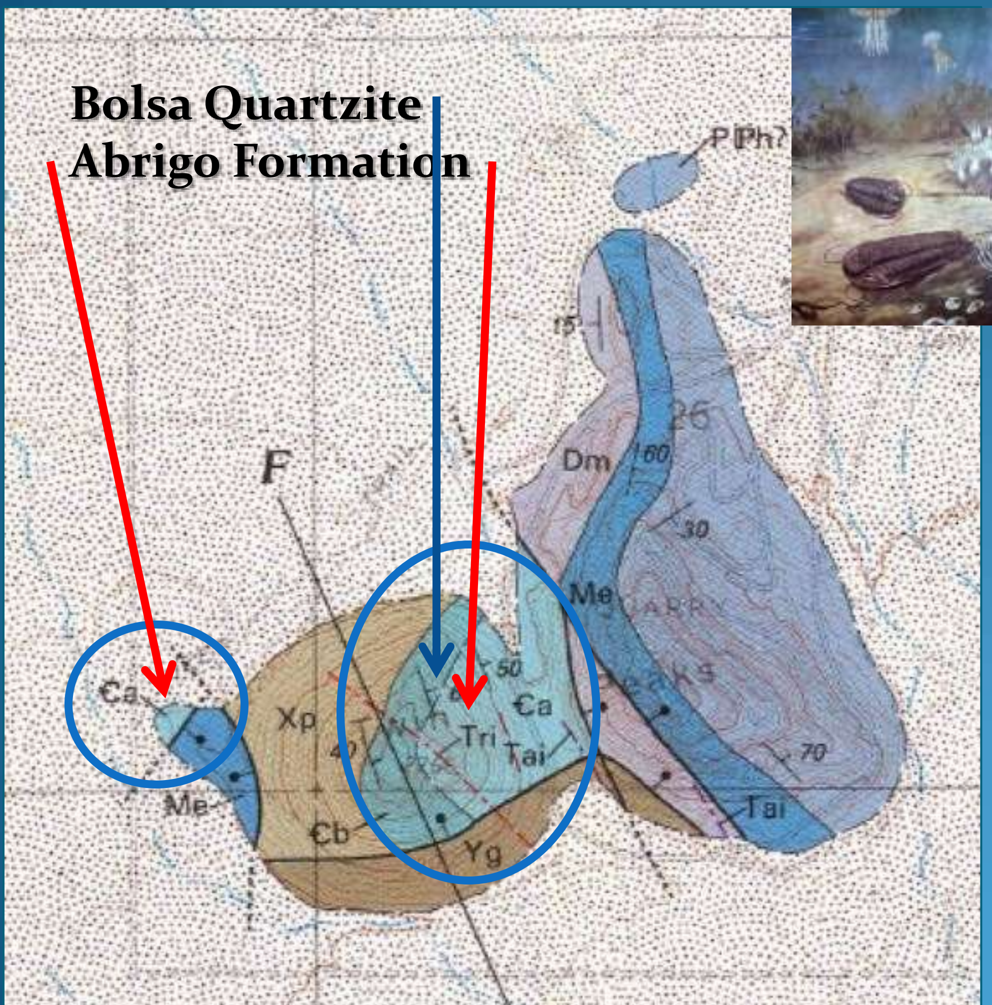
Snyder Hill

(Ma = million years ago)



Cambrian (500-485 Ma) rocks

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Taconic (E coast)		485-445	Ordovician	None	-	Bolsa, Abrigo at Twin Peaks	



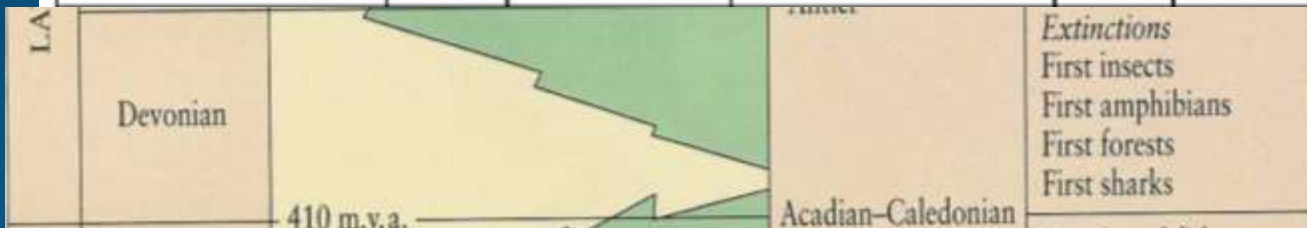
Twin Peaks
N Tucson
Mts.

Bolsa-tan qtzt
Abrigo- Sh, Ss

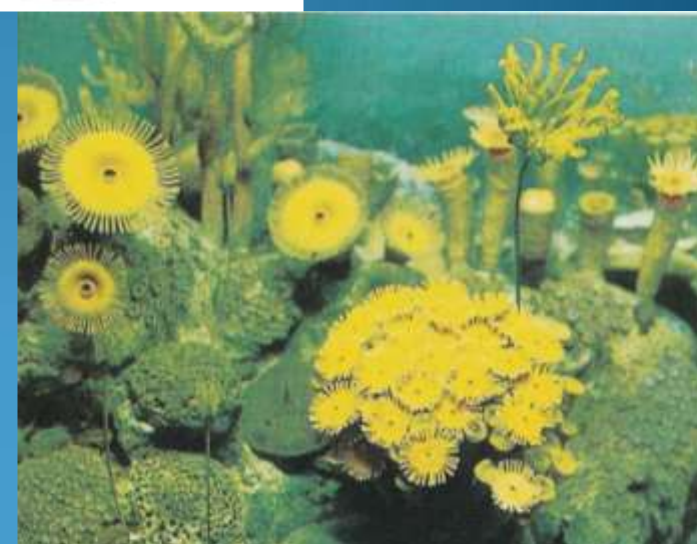
South Side W. Twin Peaks

Devonian (419-359 Ma) rocks – N. Tucson Mts.

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Acadian (E coast) Antler (NV)		410-380	Devonian	None	-	Martin, Escabrosa at Twin Peaks, Rillito Cement mine	



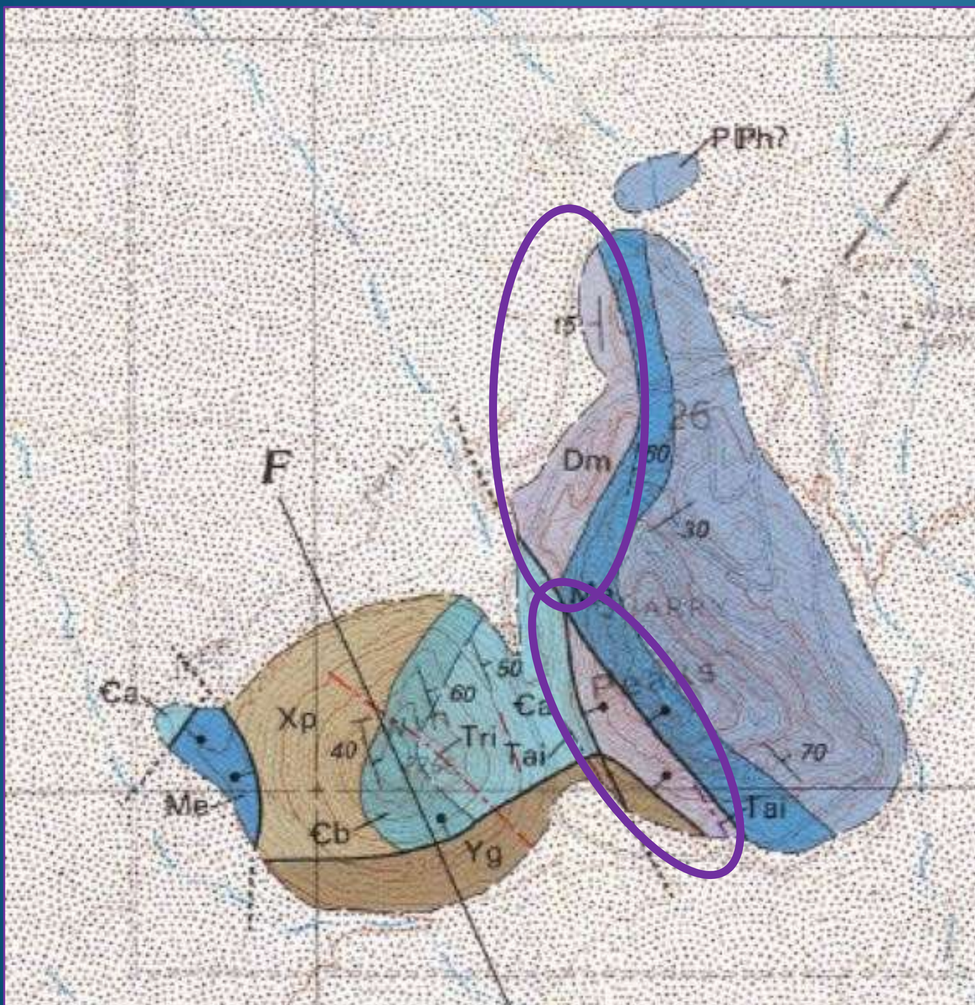
Schizophoria

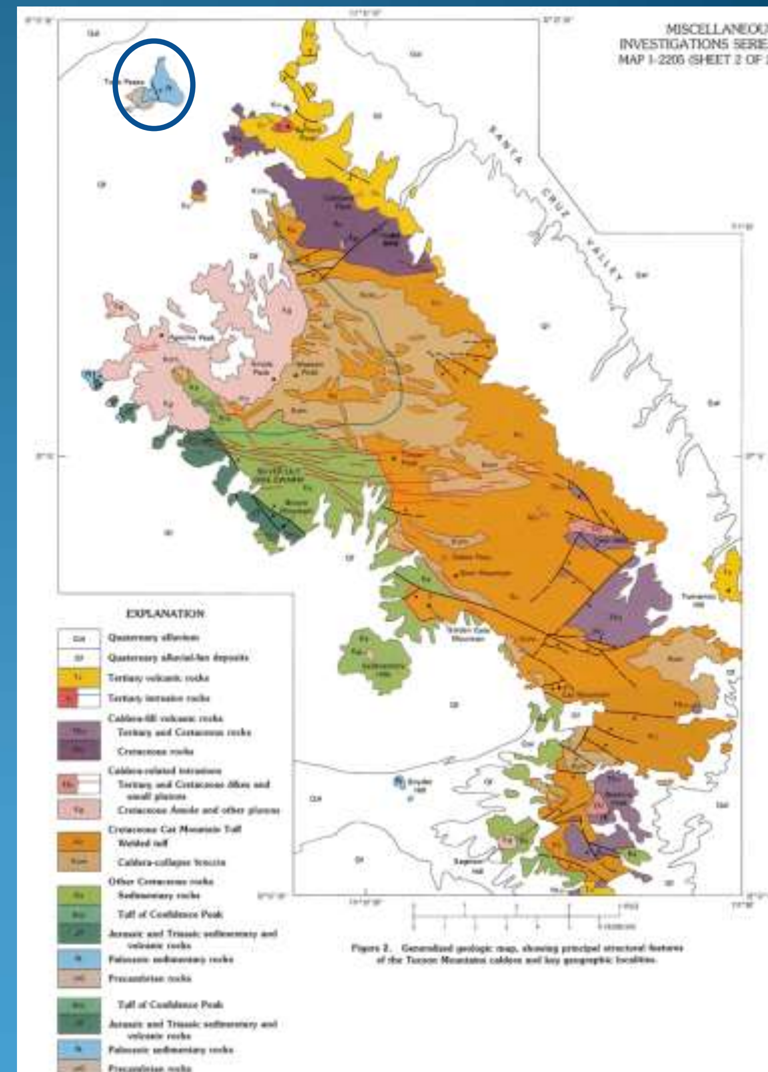


All paleogeographic paintings from Blakey & Ranney

Devonian (~419-359 Ma)
Martin Formation - N. Tucson Mts.

Martin – brown dolomite

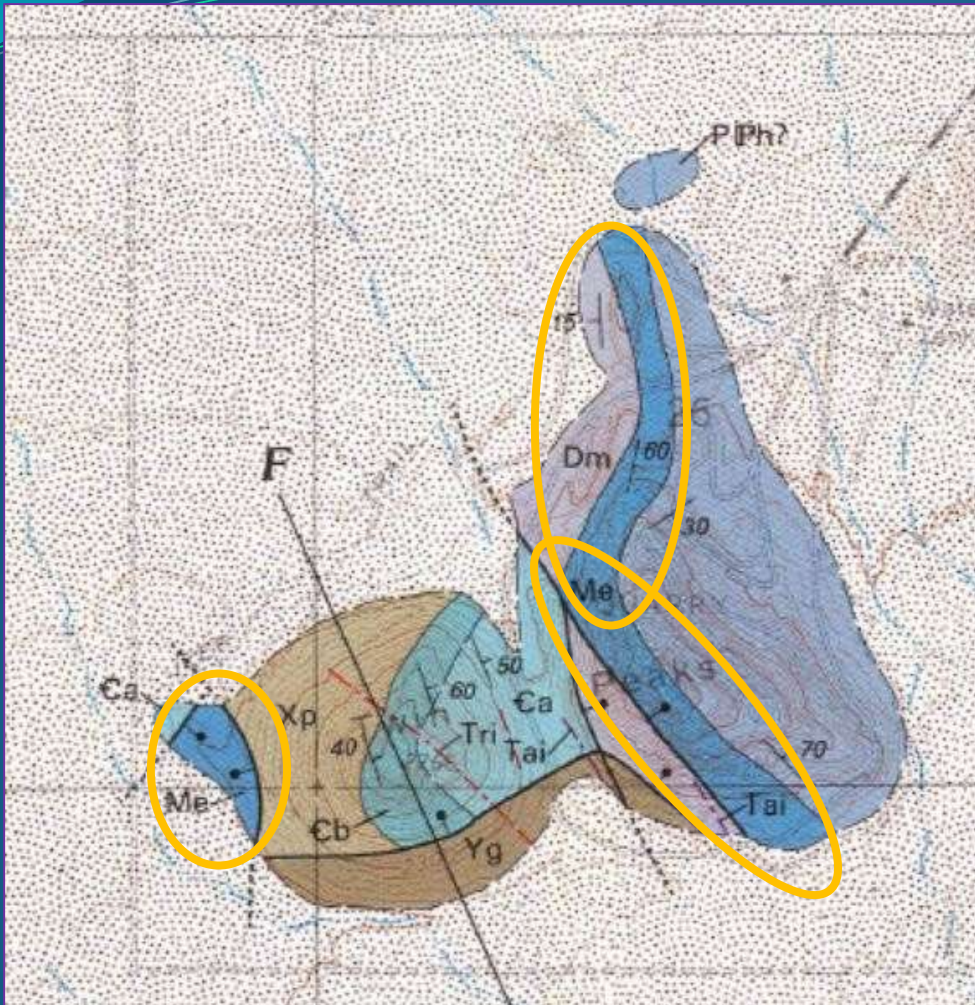


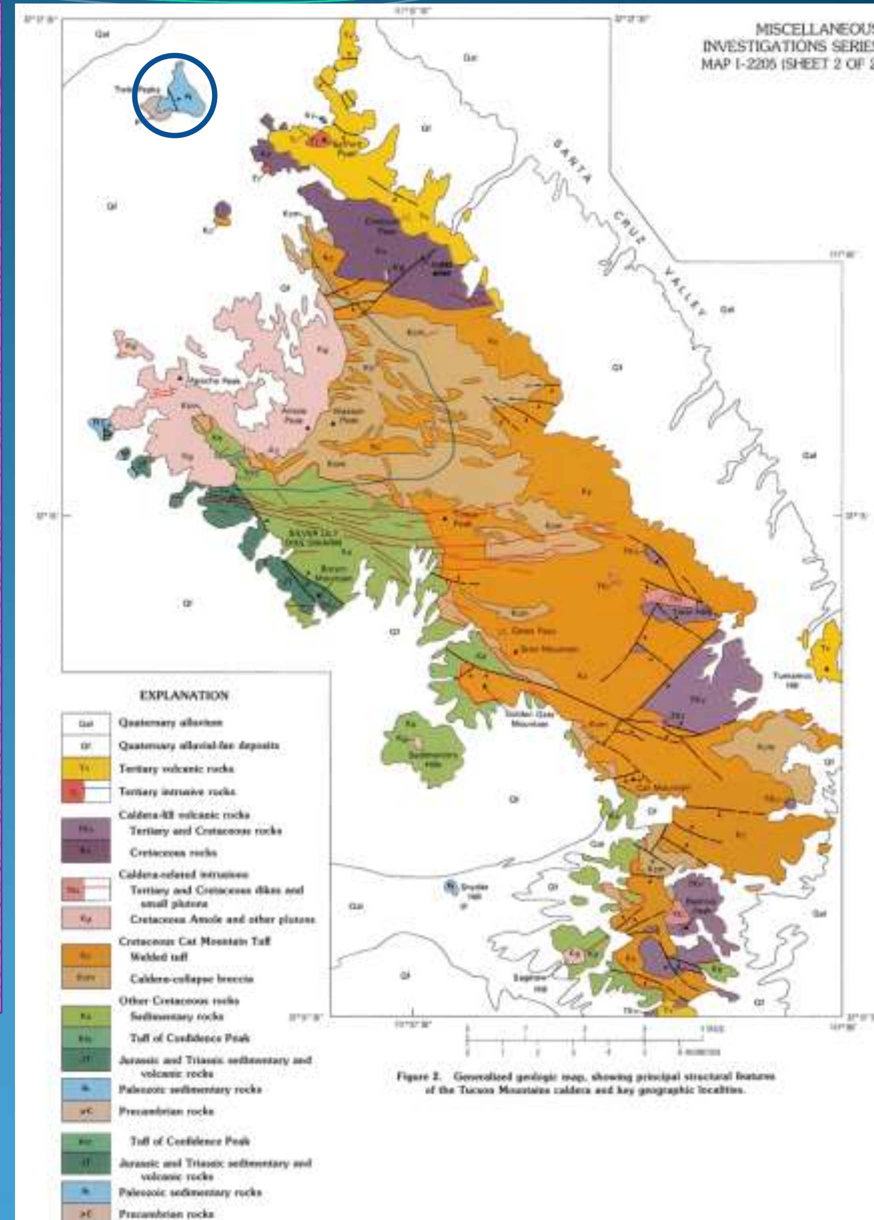


Lull - Mississippian – Escabrosa Limestone

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Ancestral Rocky Mts.		323-299	Pennsylvanian	None	-	Horquilla at Sus P.A., Twin Peaks	
Acadian (E coast) Antler (NV)		410-380	Devonian	None	-	Martin, Escabrosa at Twin Peaks, Rillito Cement mine	

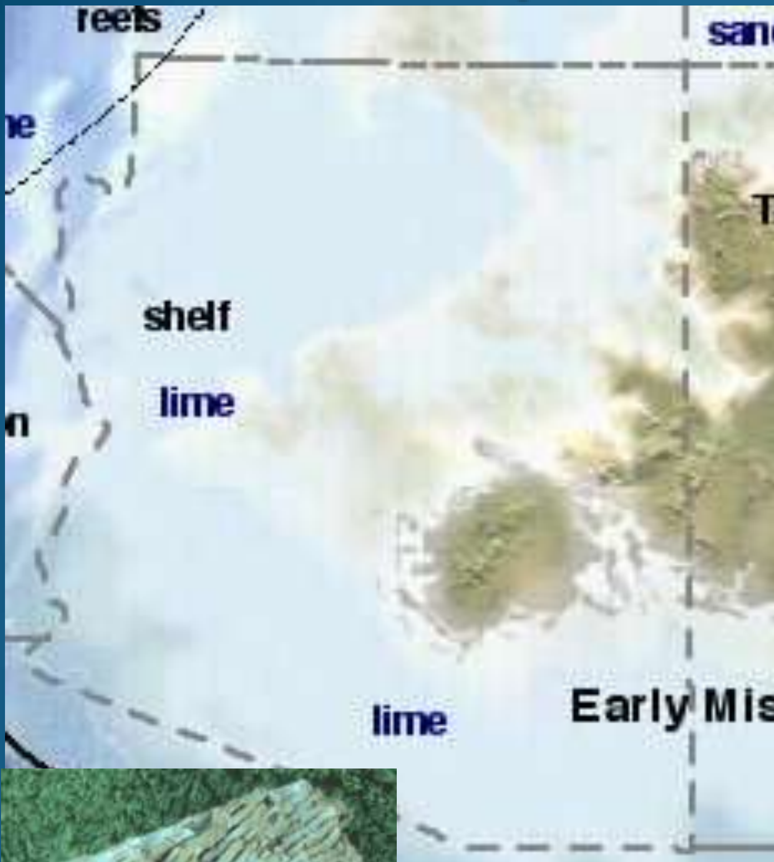
Mississippian – Escabrosa Limestone



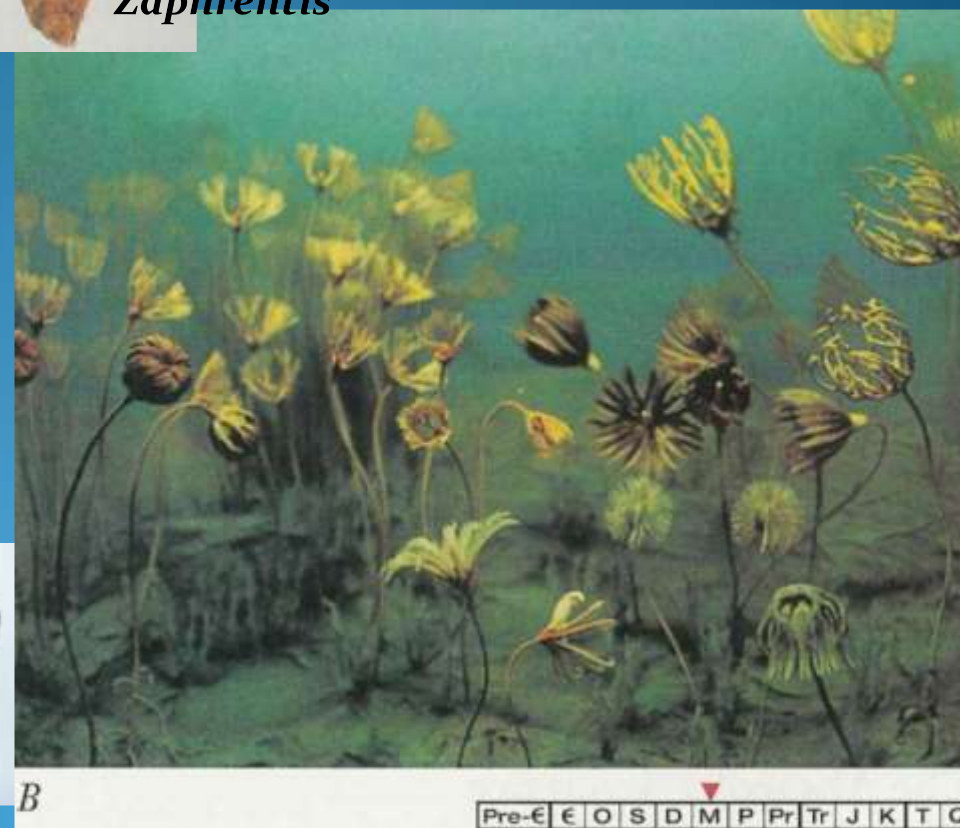


Light gray, coarse, cherty, crinoidal limestone

Mississippian - Escabrosa Limestone (359-~320 Ma)



Zaphrentis



***Syringopora* – colonial coral**

spirifer

Twin Peaks Limestone Quarry

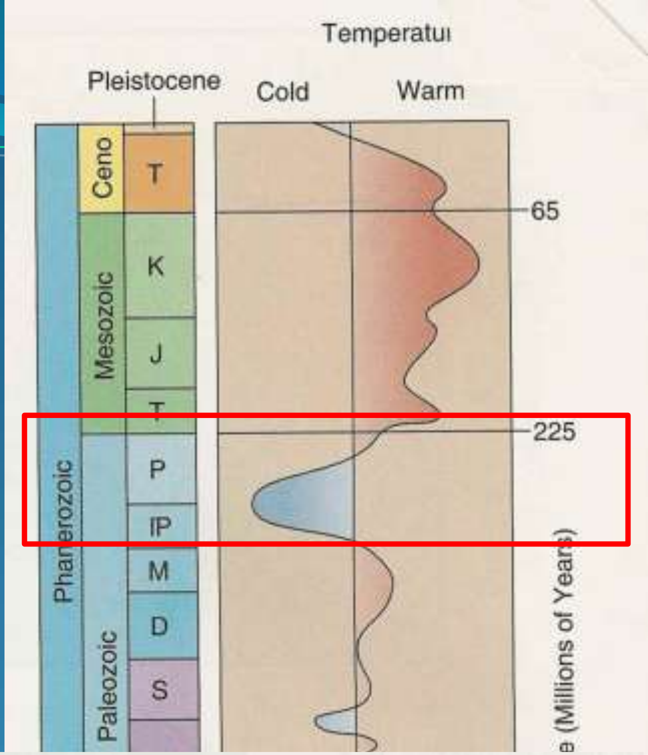
Portland Cement Plant at Rillito

Upper Paleozoic – Sus Picnic Area

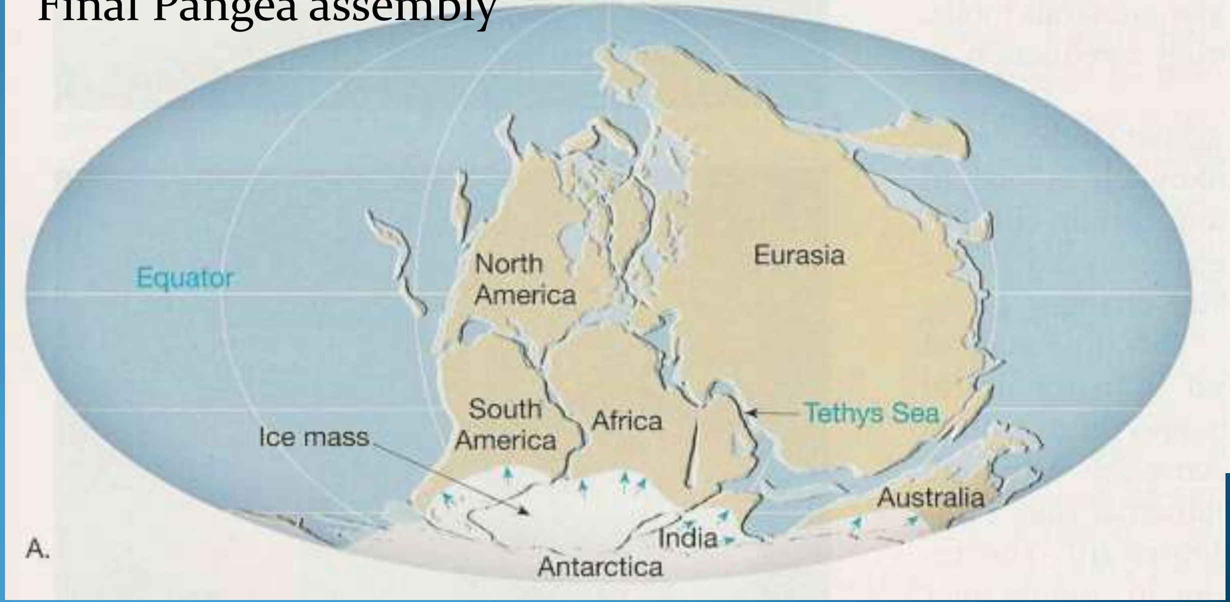
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Alleghenian (E coast)/ (Ouachita OK)		325-220	Permian-Triassic	None	-	Naco Group (Concha & Rain Valley at Snyder Hill	

Sus Hills, Paleozoic limestone – Escabrosa? metamorphosed to marble near Amole Granite intrusion

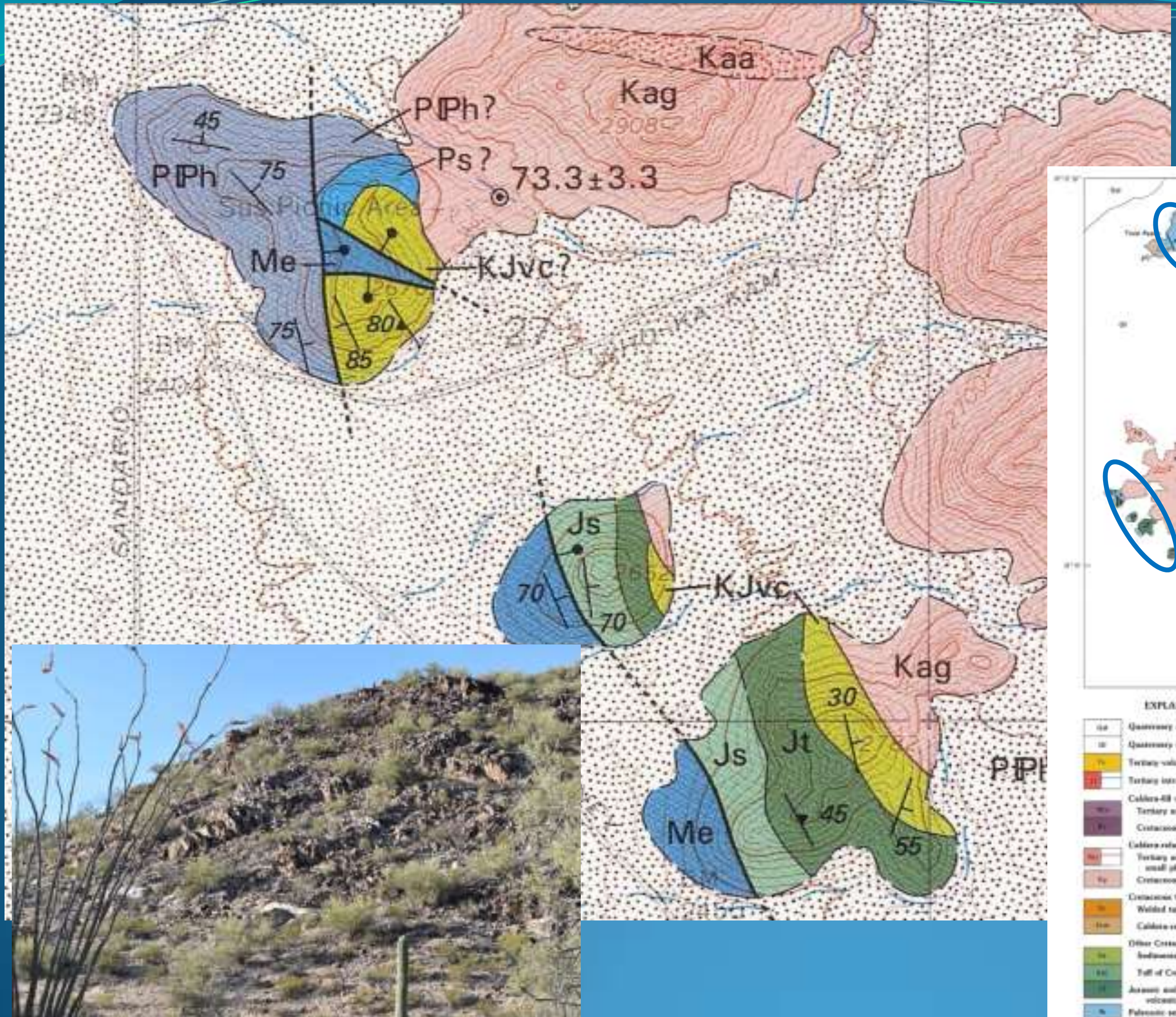
Pennsylvanian-Permian
(323 - 299 - 252 Ma)

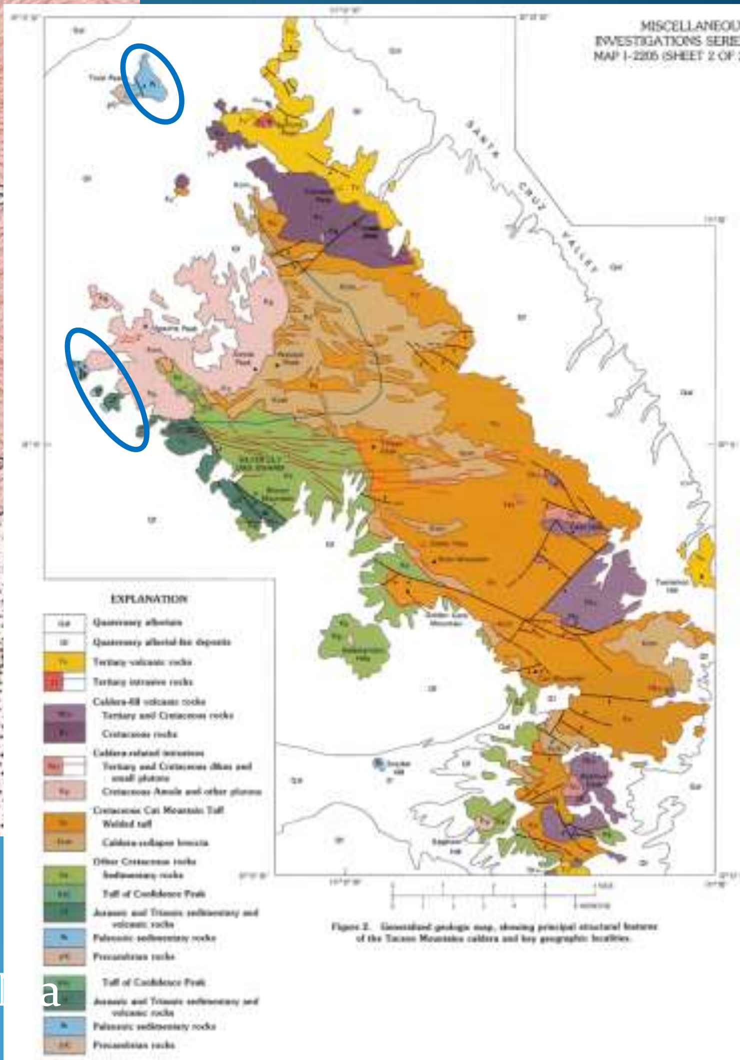


Final Pangea assembly



Late Paleozoic – NW Tucson Mts.

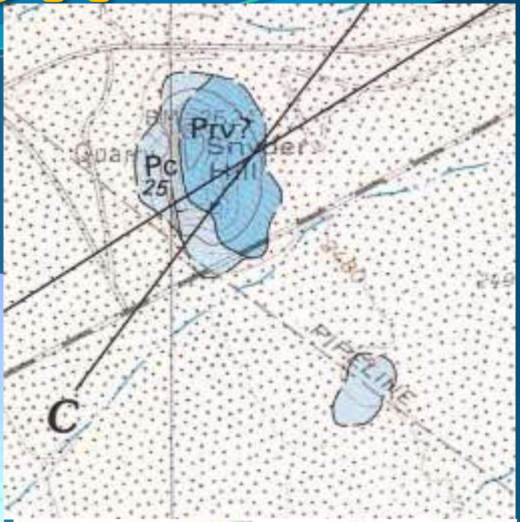




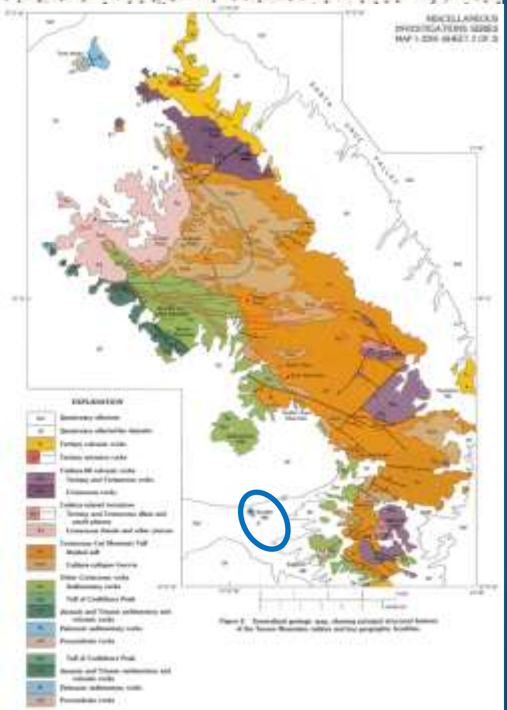
Pennsylvanian-Permian Horquilla Fm. - PPh – 359-252 Ma
Sus Hills – Sus Picnic Area

Late Paleozoic – Permian - SW Tucson Mts.

Composita



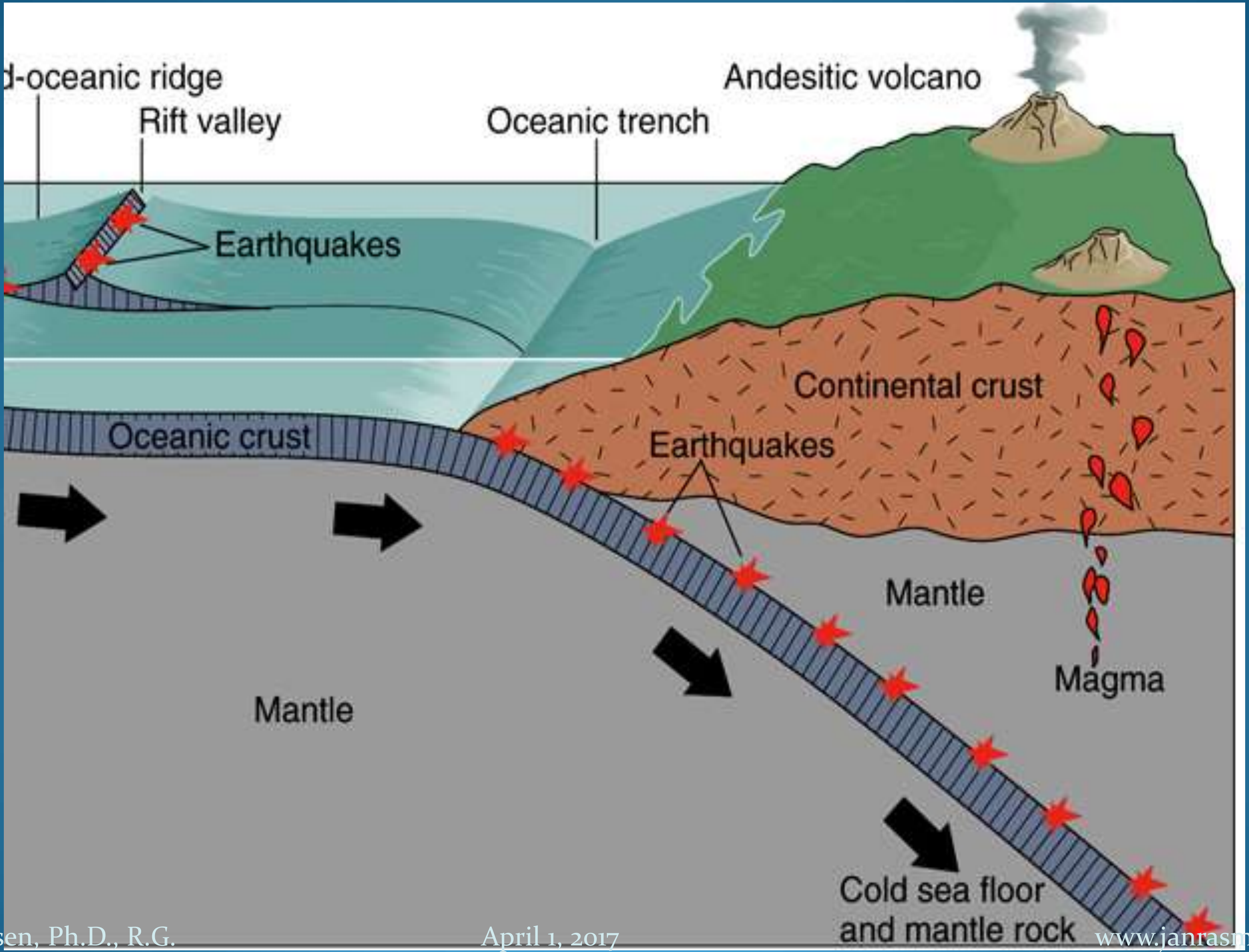
Snyder Hill – look NE



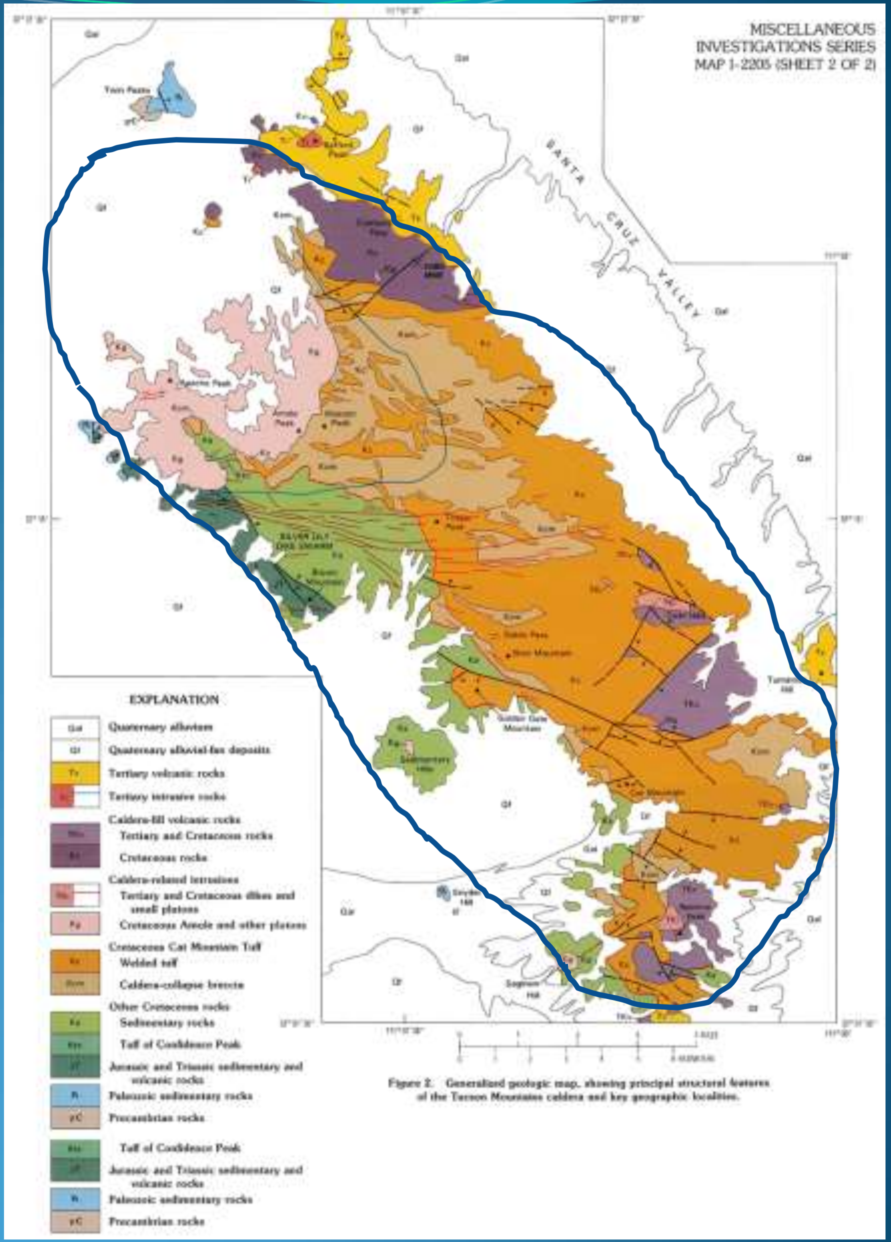
Snyder Hill, Permian Ls. – look W from Old Ajo Rd.

Arizona on Leading Edge of North American Plate in Mesozoic & Cenozoic

Mountain building, volcanoes, earthquakes, igneous intrusions



Mesozoic outcrops (252-66 Ma)



Triassic (252-201 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Nevadan	Middle	205-160	Late & Middle Jurassic	Canelo Hills volc.; plutonic rocks	MQA ?	Recreation Redbeds?	190 Ma?

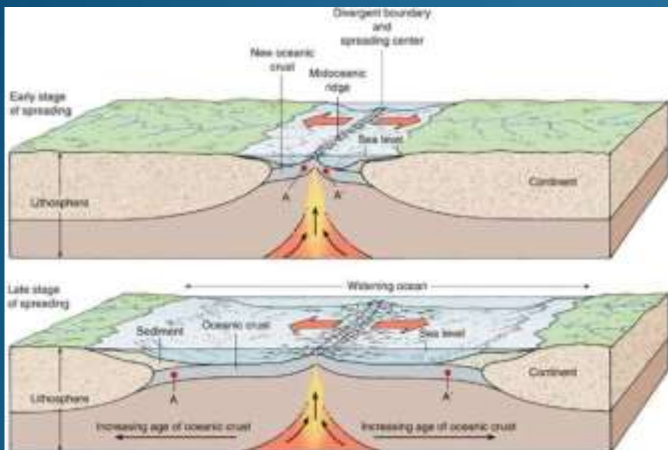
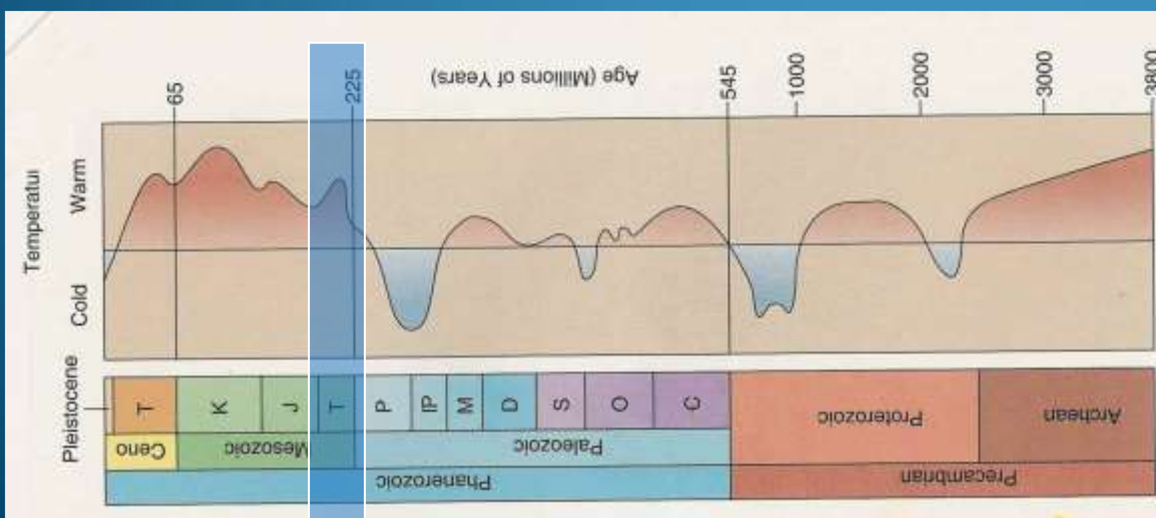
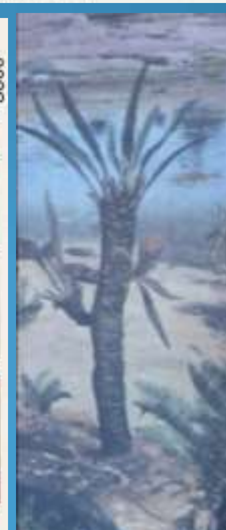
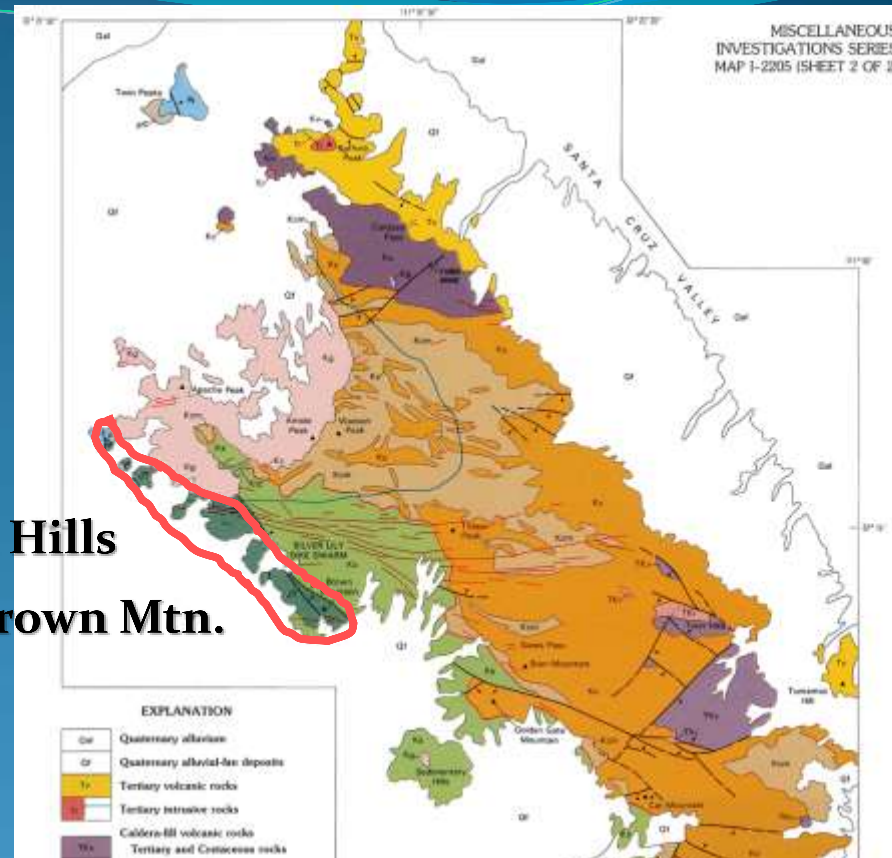


FIGURE 11-1 Paleogeographic reconstruction of the world about 180 million years ago, when the break-up of Pangea was beginning. (After Scotese, C. R. and McKerrow, W. S. 1990. Paleogeography and Biogeography, Geol. Soc. London Mem. 12:1-21.)





Triassic-Jurassic (252-145 Ma) – W. Tucson Mts.



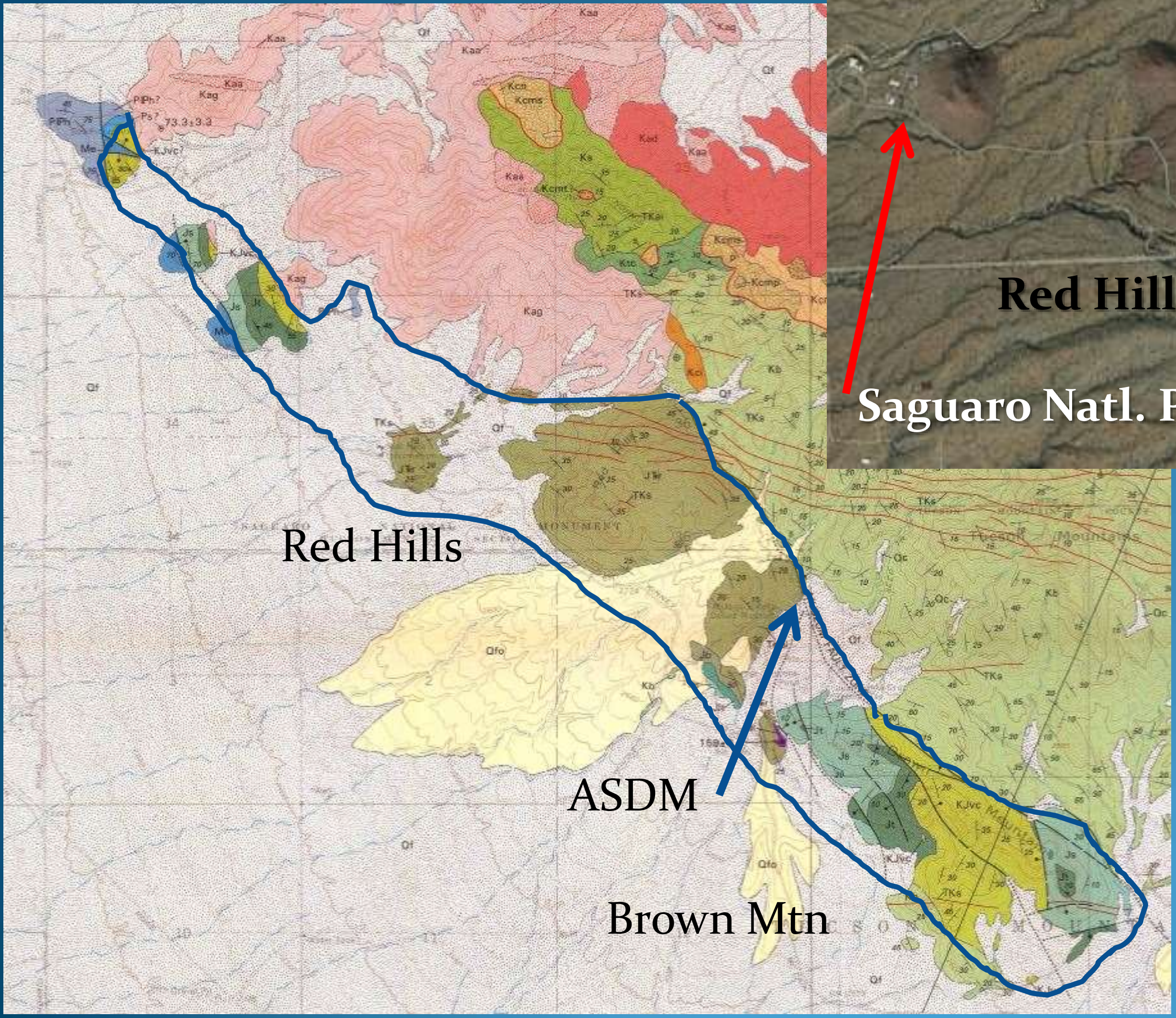
Red Hills

Brown Mtn.

Red Hills

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

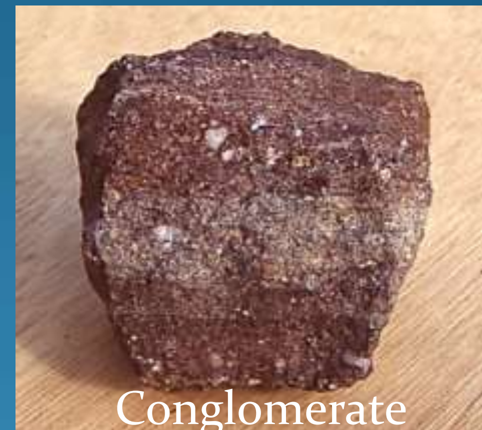
Triassic?-Jurassic (252-145 Ma) – W. Tucson Mts.



ASDM

***Coelophysis* in Chinle Fm. N AZ**

Early Mesozoic – Triassic? - Jurassic
Tucson Mts. – Recreation Red Beds



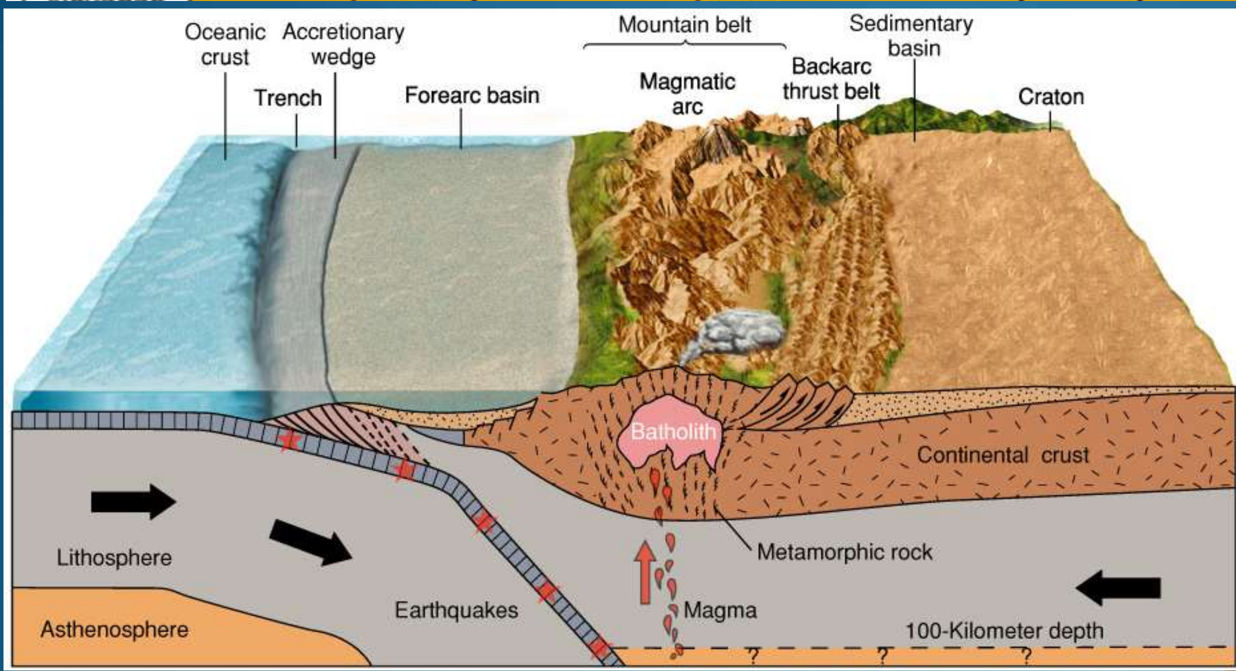
Sandstone

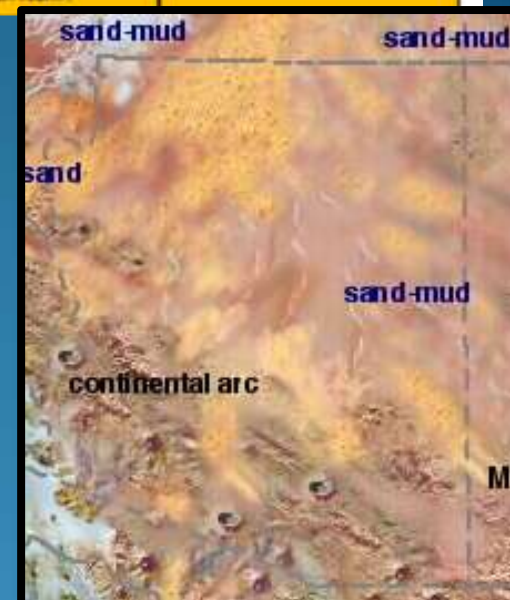
Siltstone

Sandstone

Middle Mesozoic – Jurassic (201-145 Ma)
Nevadan Orogeny (mountain building)

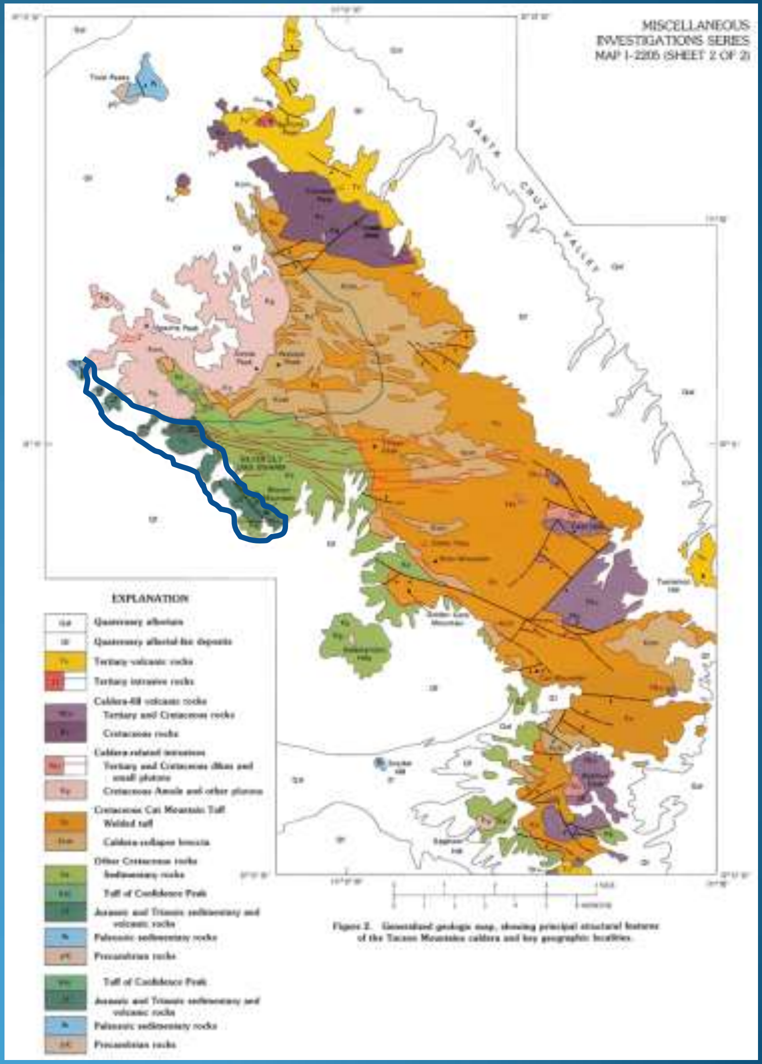
Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Nevadan	Late	160-145	Late Jurassic	volcanics	MCA	Andesite porphyry of Brown Mountain	159 Ma





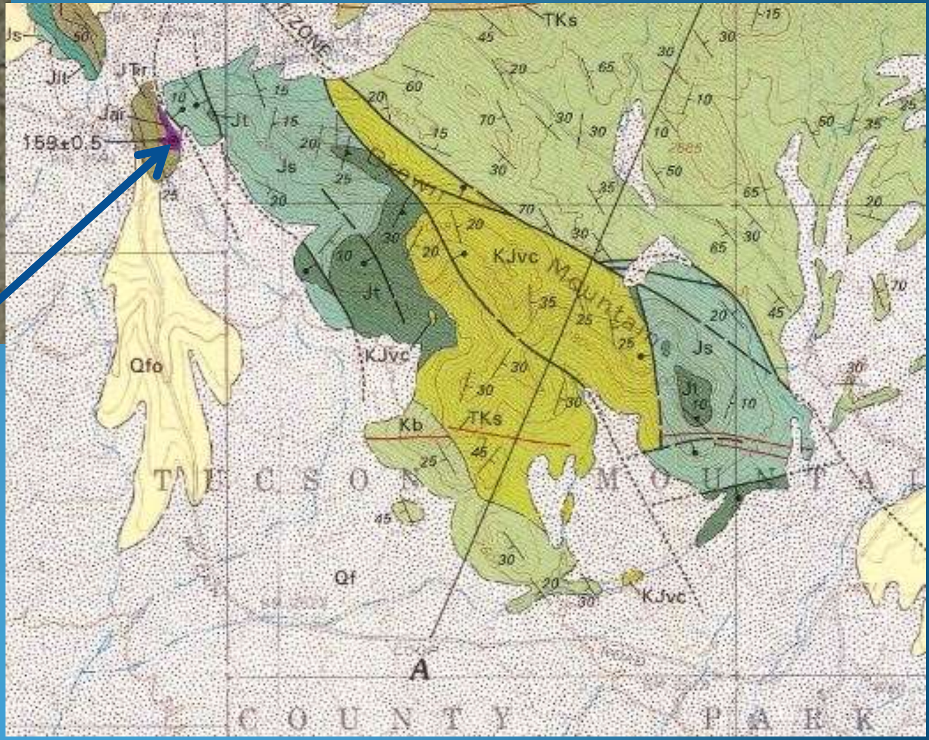
Jurassic outcrops (201-145 Ma) – W. Tucson Mts.

Basaltic lava flow, welded ash flow sheet with lithophysal cavities, reddish sandstone and siltstone, rhyolite ash flow tuffs, andesite porphyry dike



Jurassic Brown Mountain (201-145 Ma) – W. Tucson Mts.

Looking southeast from ASDM

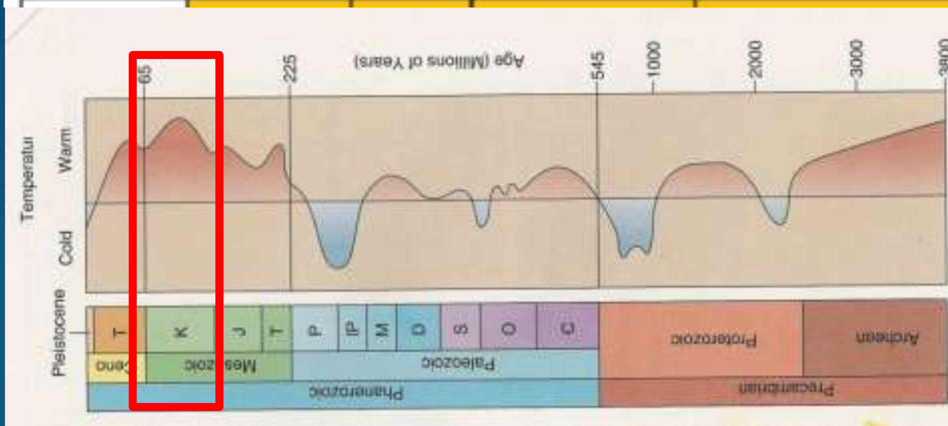


Brown Mountain

159 Ma andesite porphyry

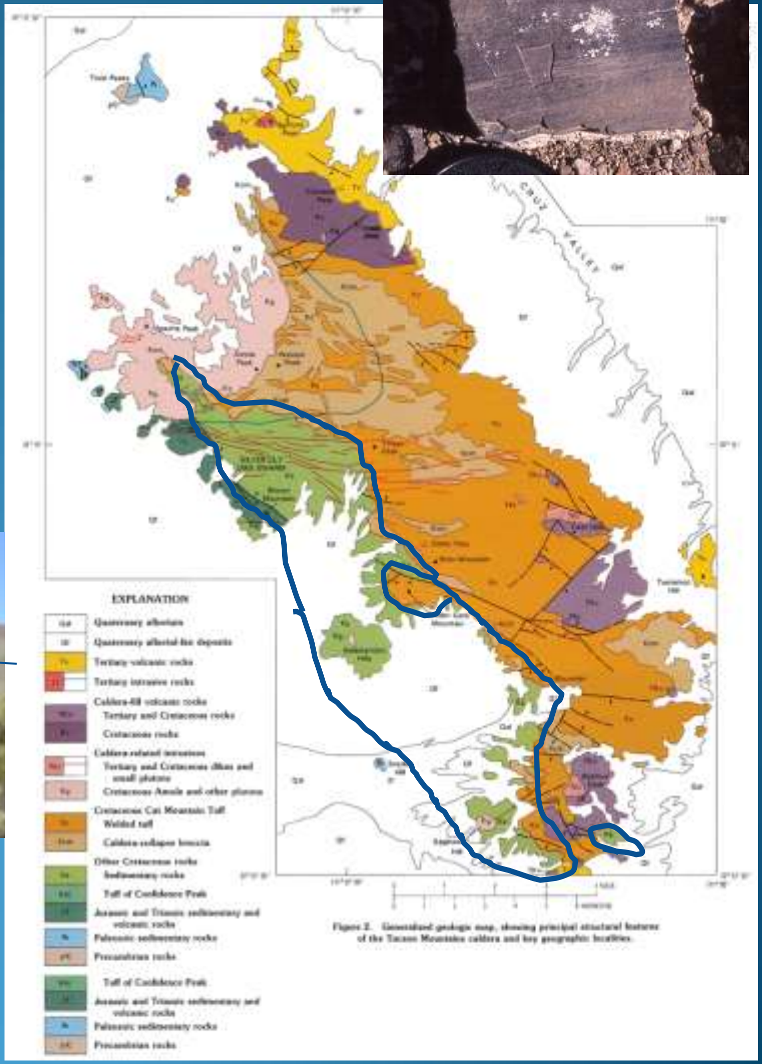
Late Mesozoic – mid-Cretaceous (145 – 66 Ma)
Sevier Orogeny in CA; sedimentation in AZ

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Sevier		145-89	mid-Cretaceous	None	-	Amole Arkose	100 Ma



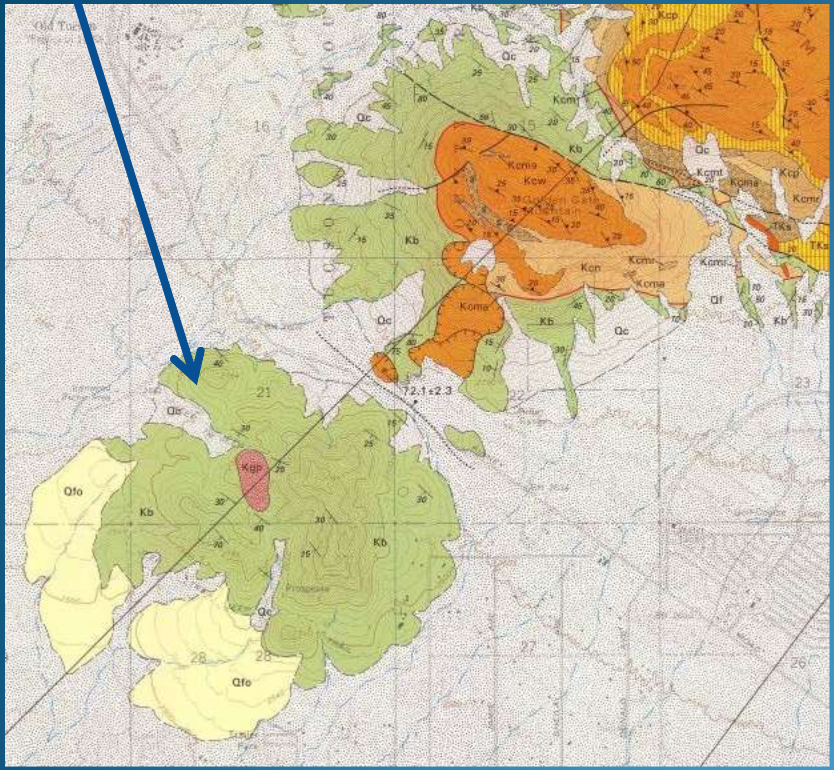
Amole Arkose (correlated with Bisbee Group)

Mid-Cretaceous – West Tucson Mts. – Amole Arkose



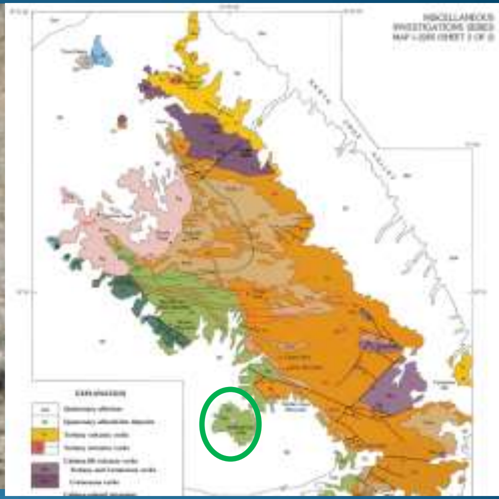
Gray to brown siltstone, arkosic sandstone, finely laminated limestone, sparse conglomerate – correlates with Bisbee Group

Mid-Cretaceous – Amole Arkose in Sedimentary Hills (W. Tucson Mts.)



Green = Amole Arkose ~ 100 Ma

Mid-Cretaceous – W. Tucson Mts. – Amole Arkose - Sedimentary Hills



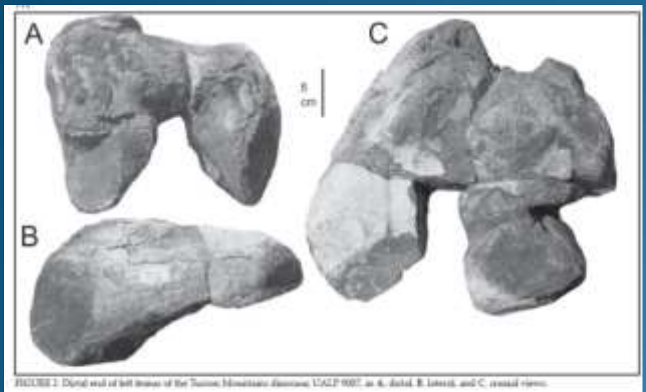
Sedimentary Hills, looking west from Kinney Road, dipping southwest

Mid-Cretaceous – W. Tucson Mts. – Sedimentary Hills & W. Ajo Rd.

Amole Arkose ~ 100 Ma

Fish fossil, ASDM (Kring, 2002)

Late Cretaceous – Ft. Crittenden correlative

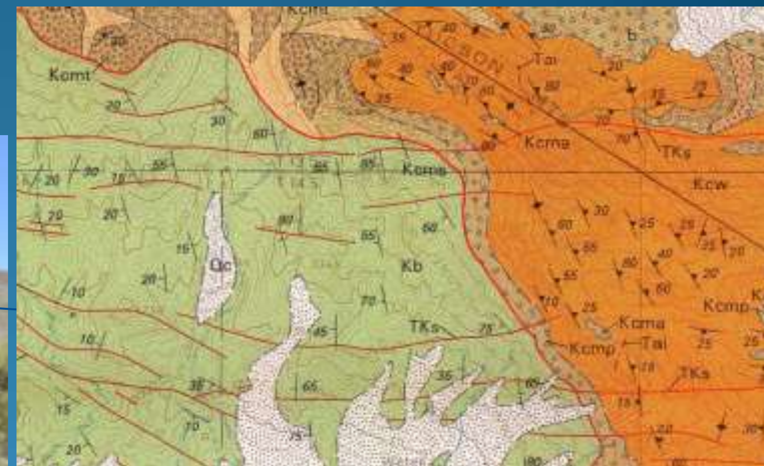


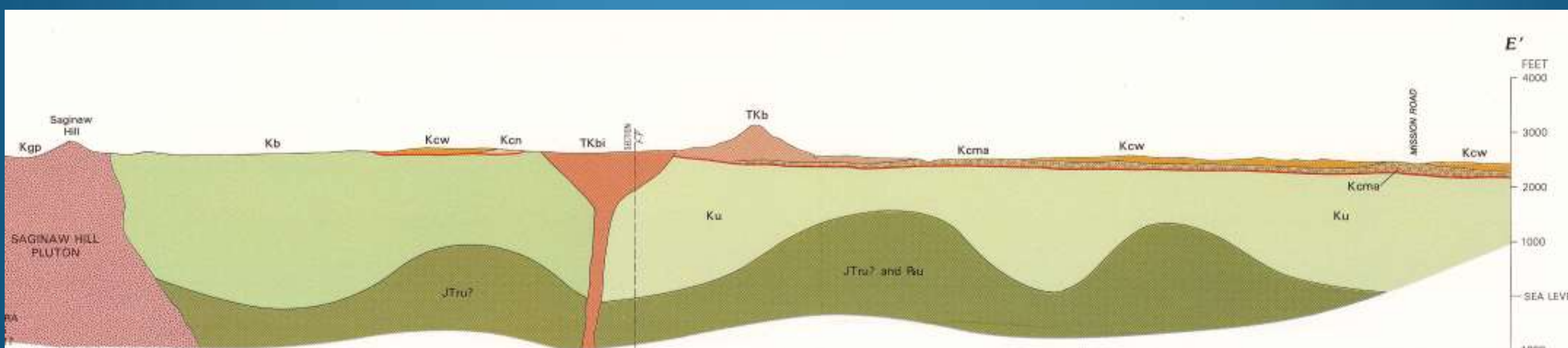
Incomplete left hind limb, ilium, femur, tibia, etc. hadrosaur (duck billed dinosaur) of Late Cretaceous age (Campanian [83 Ma] or Maastrichtian [66 Ma])

Gates Pass Road

~550 m NNW of Gates Pass in megabreccia clast in Tucson Mountain Chaos (now called basal Cat Mountain Tuff)

Folding after mid-Cretaceous Amole Arkose, before Late Cretaceous Cat Mountain Rhyolite





Folded mid-Cret. Amole Arkose truncated by erosion in a nearly flat plane pre-Cat Mtn. (Late Cretaceous)

Earliest Laramide Yuma Mine Volcanics

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
	Earliest	85-76	Late Cretaceous	Porphyritic andesite flows & dikes ?	MQA ?	Yuma King volcanics ?	

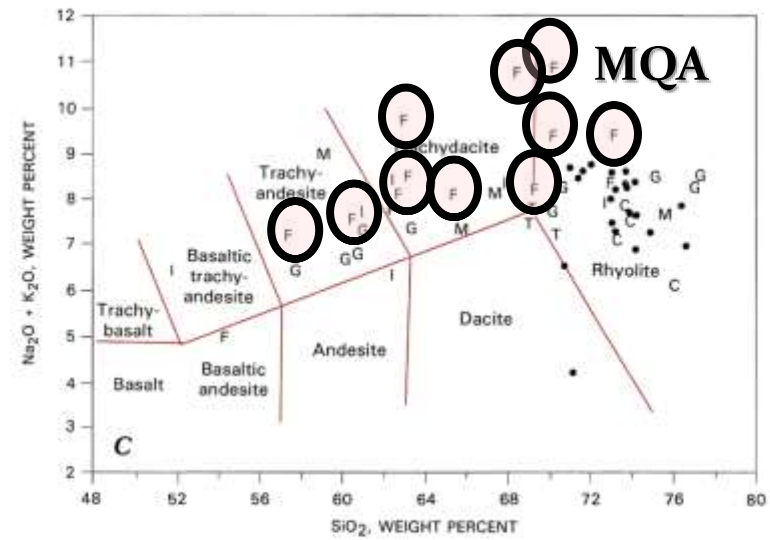
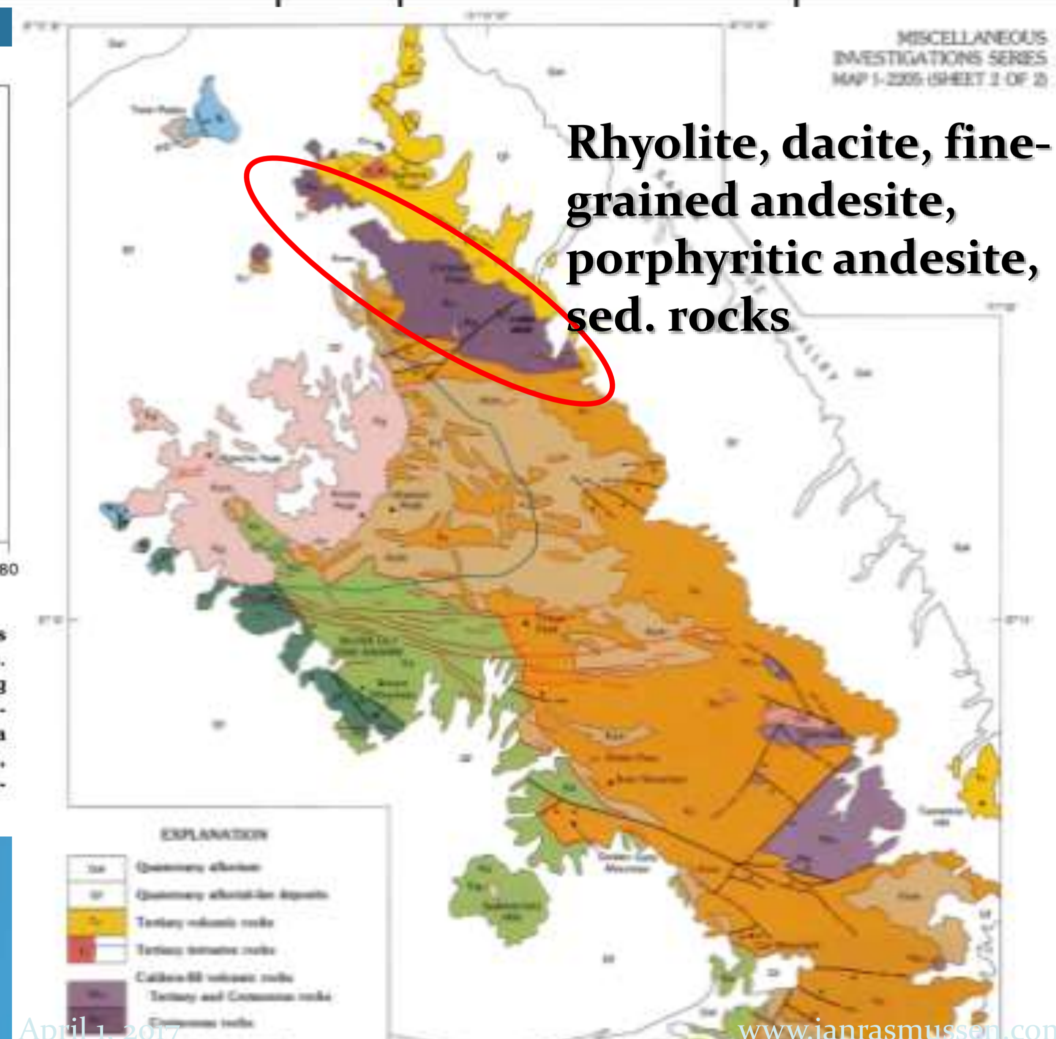
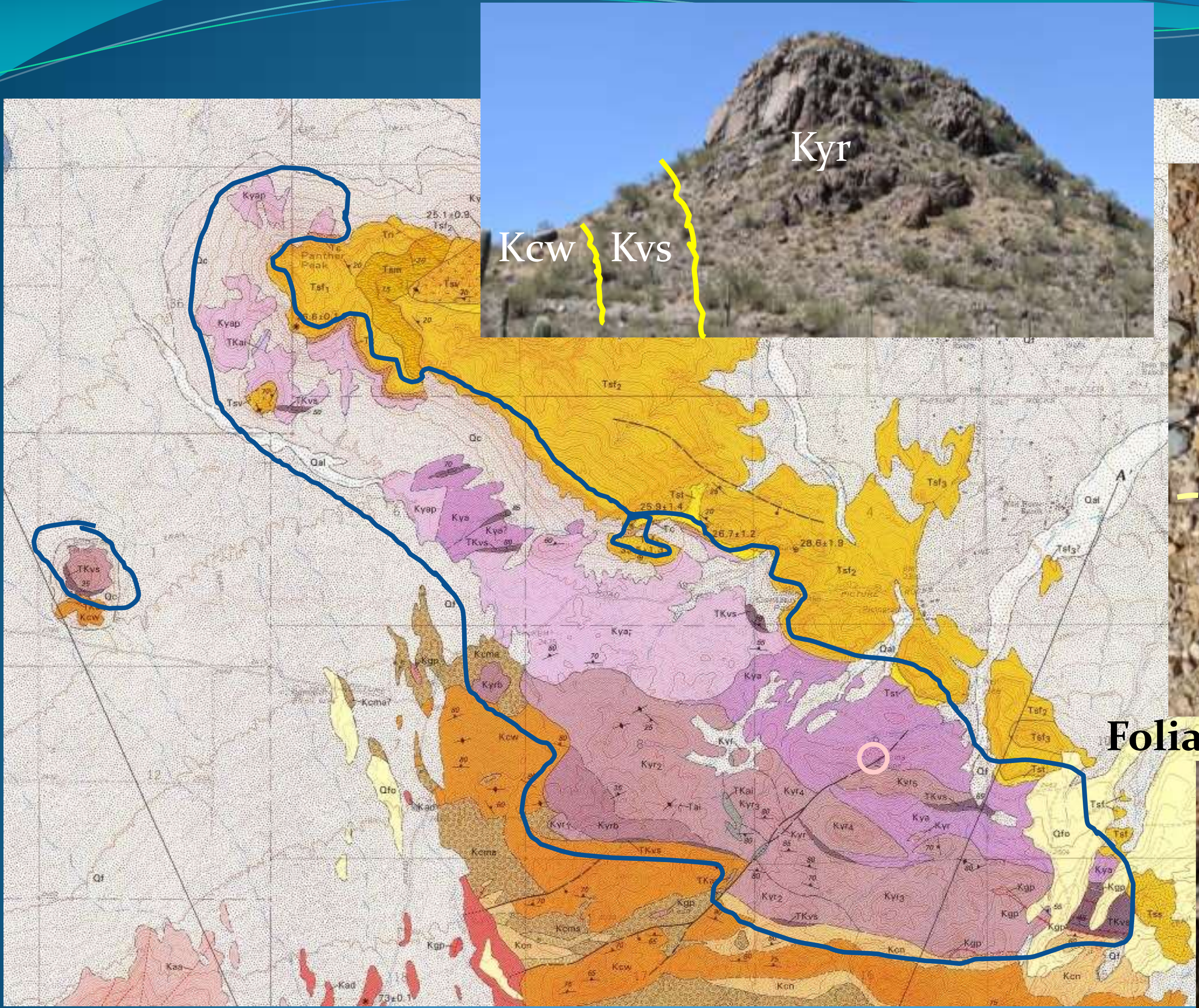


Figure 3. Chemical variation diagrams for Cretaceous igneous rocks associated with the Tucson Mountains caldera cycle. *A*, Silica vs. total iron. *B*, Silica vs. zirconium. *C*, Silica vs. total alkalis, showing IUGG compositional divisions (Le Bas and others, 1986). Plot symbols: •, Cat Mountain Tuff; C, tuff of Confidence Peak in megabreccia blocks; F, postcaldera lavas; T, postcaldera tuff (Beehive Peak); G, granite of Amole pluton; I, porphyritic dikes and other small intrusions; M, precaldera volcanics in megabreccia blocks.



MQA is consistent with mineralogy at Old Yuma mine.

Earliest Laramide - Yuma Mine Volcanics



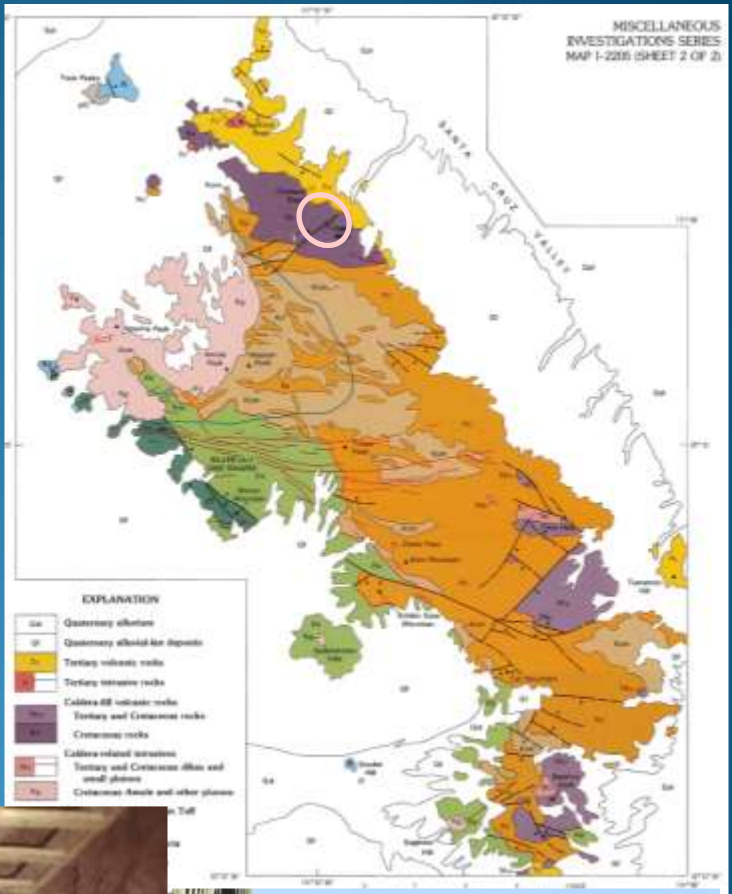
Baked zone in Yuma mine volcani-clastic sediments

Foliated Cat Mountain Tuff

'Oatmeal' porphyry ~75 Ma - plagioclase texture in Yuma Mine shoshonitic andesite

Late Cretaceous – Old Yuma Mine

Dick Bideaux

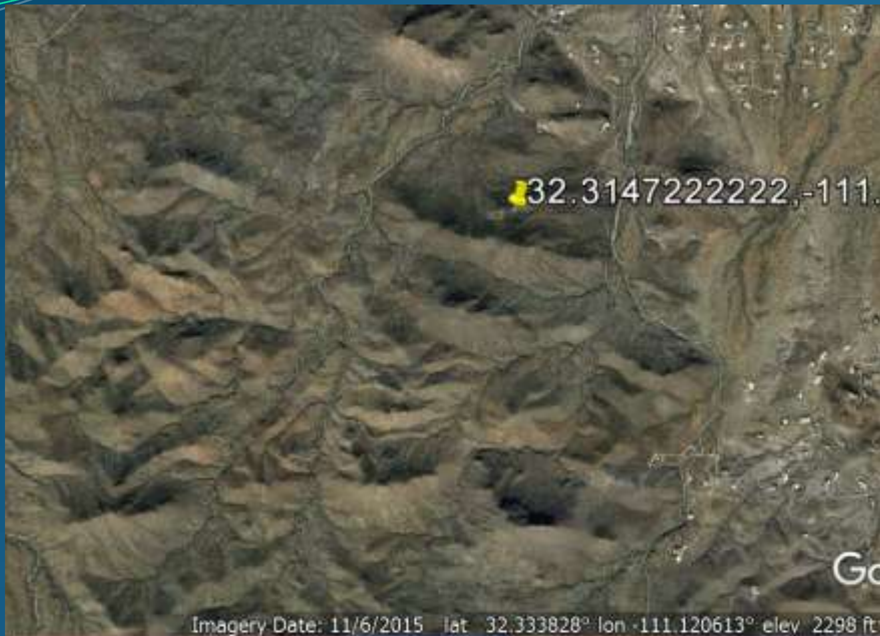


Mark Hay's

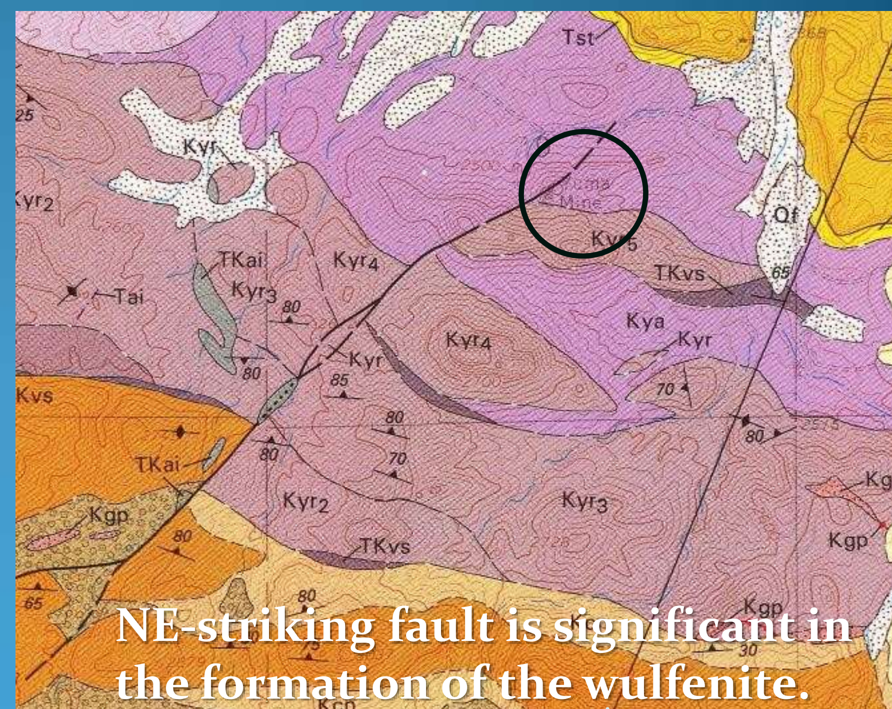
Frank Sousa's

Jan C. Rasmussen, Ph

Late Cretaceous – Old Yuma Mine



Photos by Dick Bideaux



NE-striking fault is significant in the formation of the wulfenite.

Late Cretaceous – Old Yuma Mine

- Anglesite
- Calcite
- Cerussite
- Chrysocolla
- Descloizite
- Fornacite
- Galena
- Hematite
- Malachite
- Minium
- Mottramite
- Plattnerite
- Quartz
- Tetrahedrite
- Vanadinite
- Willemite
- Wulfenite

Vanadinite, Pb5(VO4)3Cl, owner Les & Paula Presmyk, TGMS 2012 display

Cerussite, ($PbCO_3$) 1” bar, Rock Currier, H. Oboda collection, mindat.org

Vanadinite, owner Tony Potucek

Minium, ($Pb^{2+}{}_2Pb^{4+}O_4$) 6 mm FOV, photo by Michael C. Roarke, mindat.org

Wulfenite – Old Yuma Mine

Owner Jim & Gail Spann

Owner Frank Sousa

Owner John & Karen Cesar

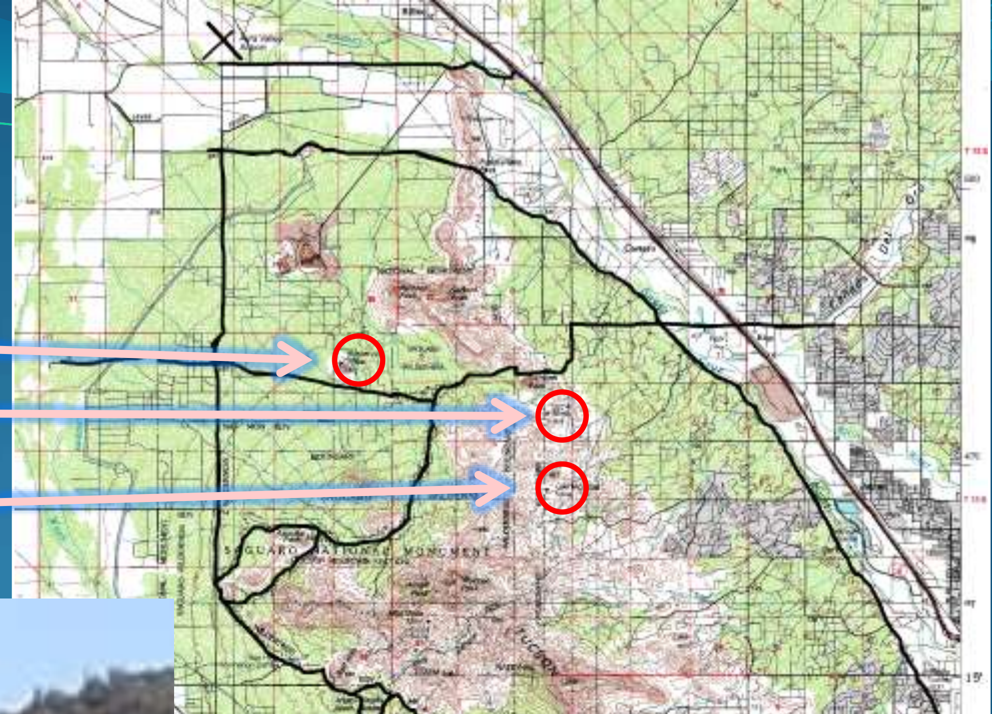
Owner Stan Keith

Owner Paul Harter

Owner Les & Paula Presmyk

MQA Mines in N. Tucson Mts.

- Busterville
- Old Yuma
- Gila Monster



Mine Production from Northern Tucson Mts. (MQA) (Keith, 1974)

No.	Mine	Production Period (years)	Ore (short tons)	Au (oz/T)	Ag (oz/T)	Cu (%)	Pb (%)	Zn (%)
1	Arizona Consolidated (Uncle Sam)	Early 1900s	1,100	trace	2.6	0.7	0	0
12	Old Yuma	1916-1947	5,700	0.1	1	1	4	0.6
18	Twin Hill prospect	1944	40		1		4	4

Minerals in Northern Tucson Mts.

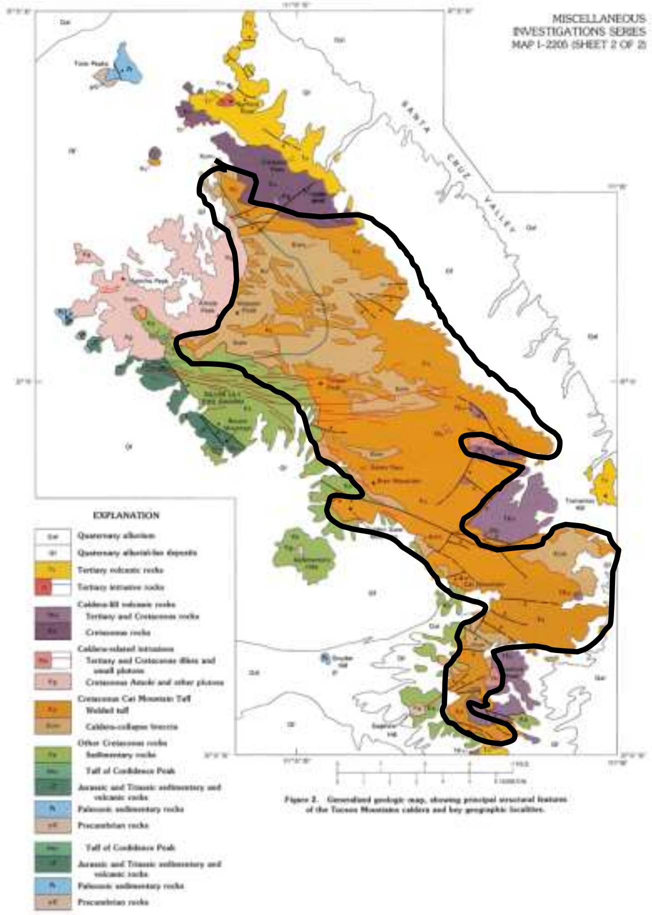
No.	Mine	Primary minerals	Secondary minerals	Other minerals
1	Arizona Consolidated (Uncle Sam)	Copper sulfides	Copper carbonates, copper oxides, copper silicates	Quartz
12	Old Yuma	Base metal sulfides	Wulfenite, vanadinite, etc.	Quartz, calcite
18	Twin Hill prospect		Lead-zinc carbonate	

Source: Keith, 1974, Index of Mining properties in Pima County, Arizona: Arizona Bureau of Mines Bulletin 189. Mindat.org

Early Laramide - 75-65 Ma – Cat Mountain Tuff

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
	Early	75-65	Late Cretaceous	Granite & granodiorite stocks; rhyolite ash flows, dikes	MAC	Cat Mountain Tuff rhyolite; Amole Granite-granodiorite; Silver Lily dikes	73.1 Ma welded tuff Kcw, 72.3 Ma Silver Lily dikes; 73 Ma Amole Granite

Cat Mountain Rhyolite 73 Ma



Late Cretaceous – Early Laramide orogeny – large volume of volcanics, calderas, intrusions (75-70 Ma)

Mt. Pinatubo, Philippines, 1991

Tucson Mts. – Golden Gate (S. of Gates Pass) - Cat Mountain Rhyolite – 73.1±0.2 (Lipman) Ma ignimbrite (rhyolite ash flows)

Early Laramide (75-65 Ma) – Exotic Blocks

4 possible origins

- Landslide blocks that slid into the caldera from its walls during eruption (Lipman)
- Out-of-place blocks shed from thrust faults (Kinnison)
- Wall rocks plucked from the magma chamber wall below and then entrained in the erupting ash flows (Bikerman & us)

House- and car-sized blocks of limestone in Tucson Mtn. Chaos under/intercalated with Cat Mountain Rhyolite – 74 Ma ignimbrite (rhyolite ash flows)

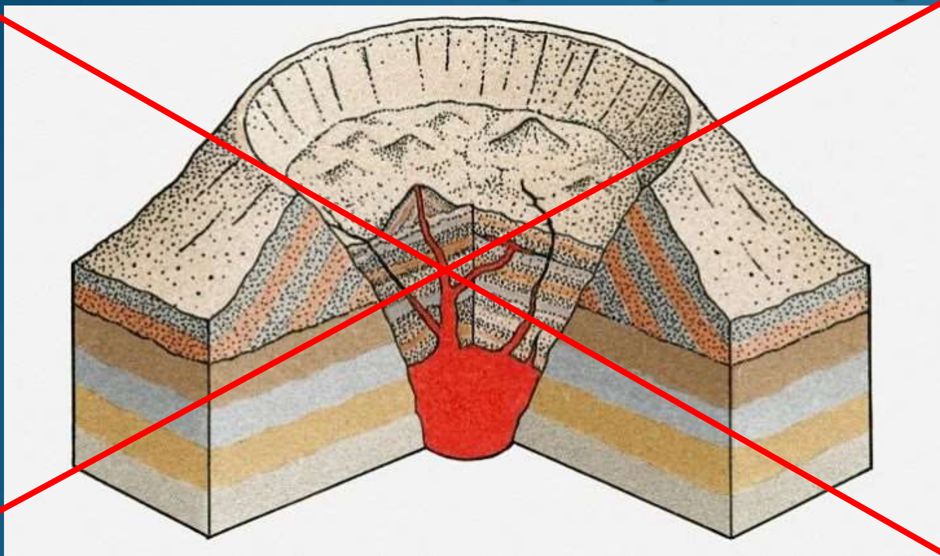
Exotic block of Amole Arkose/Ft. Crittenden equivalent in Gates Pass

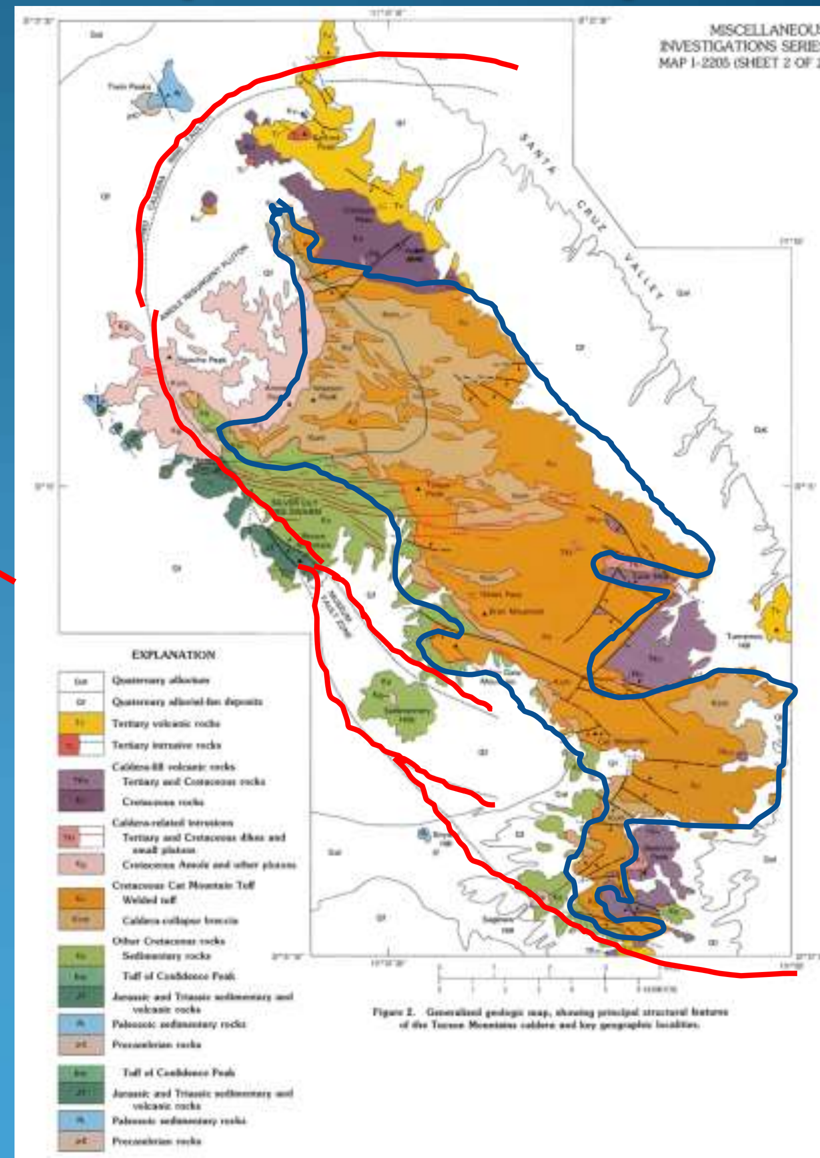
Lithic tuff matrix

Ft. Crittenden exotic block

Similar exotic block NNW of Gates Pass contains hadrosaur dinosaur limb bones.

Lipman's Cretaceous 'caldera' model – Cat Mountain (Rhyolite) Tuff (73-71 Ma)



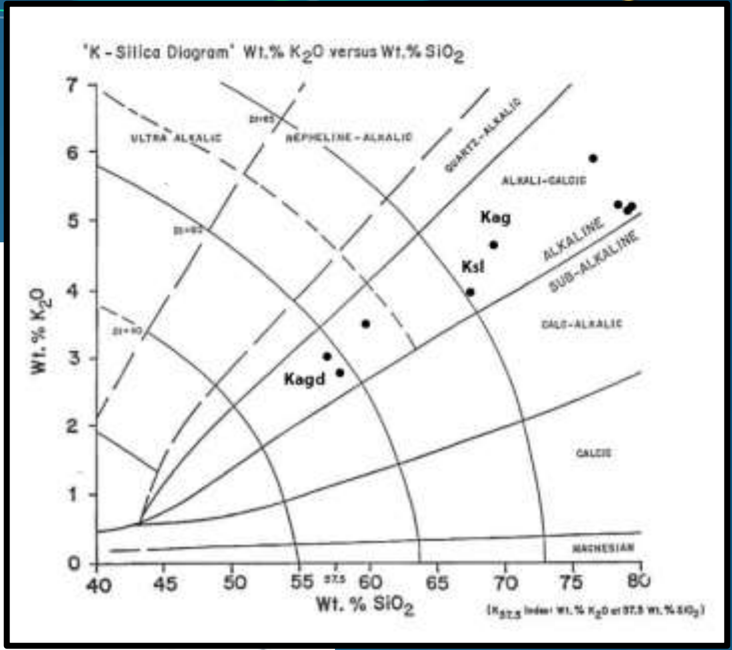


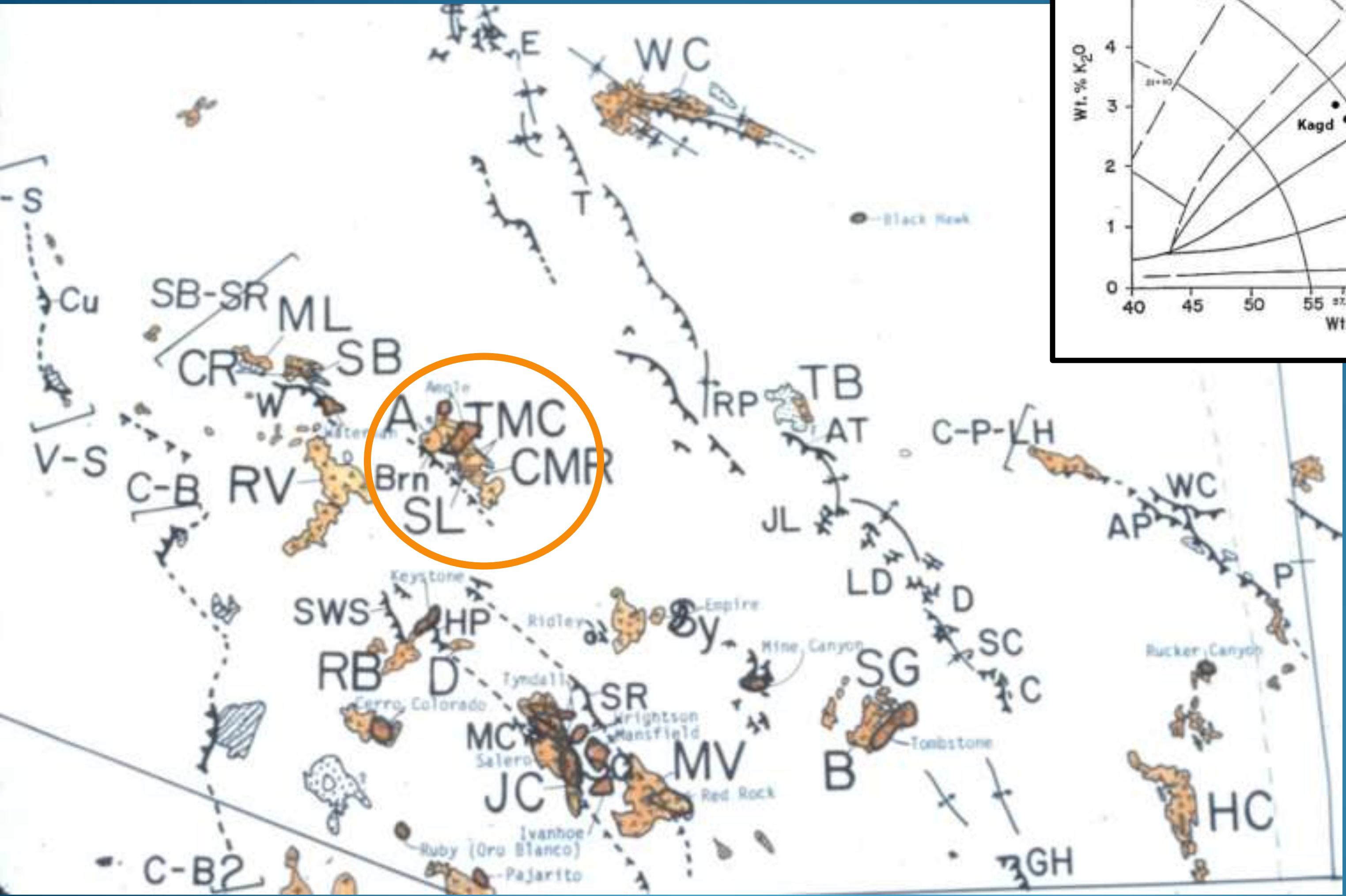
Caldera showing collapse of center after magma spewed out as ash flows

Lipman's estimated caldera wall – all dotted, except Museum fault (for us, it is a pre-eruptive, high-angle reverse fault)

Early Laramide - 75-65 Ma (Late Cretaceous)

Amole Granodiorite, Amole Granite, Silver Lily dikes, Cat Mountain Tuff (rhyolite), Tucson Mountain Chaos





Alkali-calcic

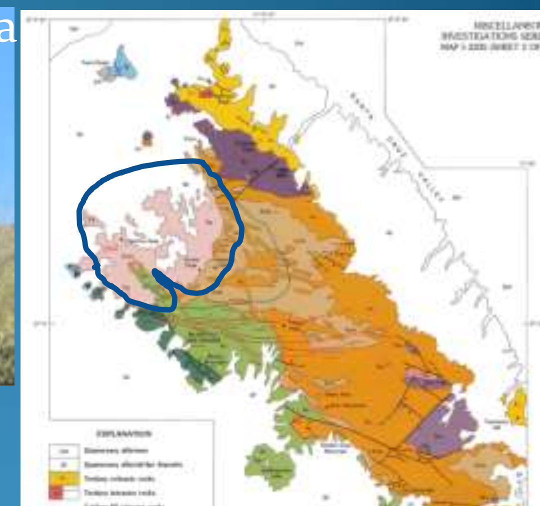
Silver, Tombstone

Cat Mountain Tuff (rhyolite) - Gates Pass (Late Cretaceous 73.1-67.3 Ma)

Rhyolitic ash-flow tuff, gray-brown to red-brown with dark lenses of flattened pumice

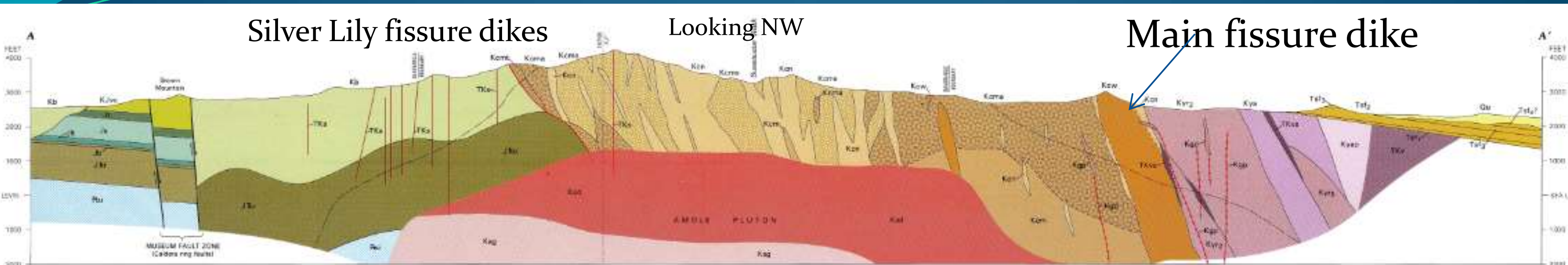
Late Cretaceous – Amole Granite 73.3 Ma

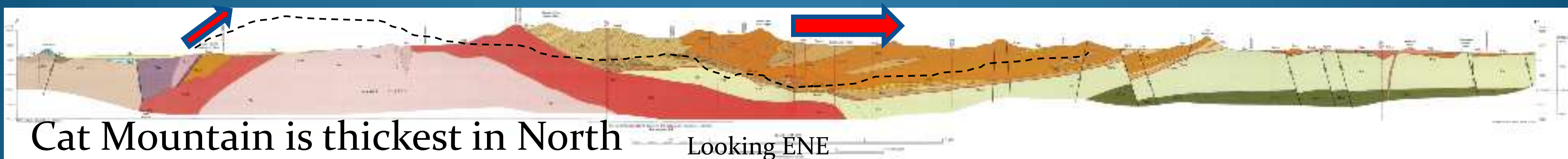
Amole Granite from Sus Picnic Area

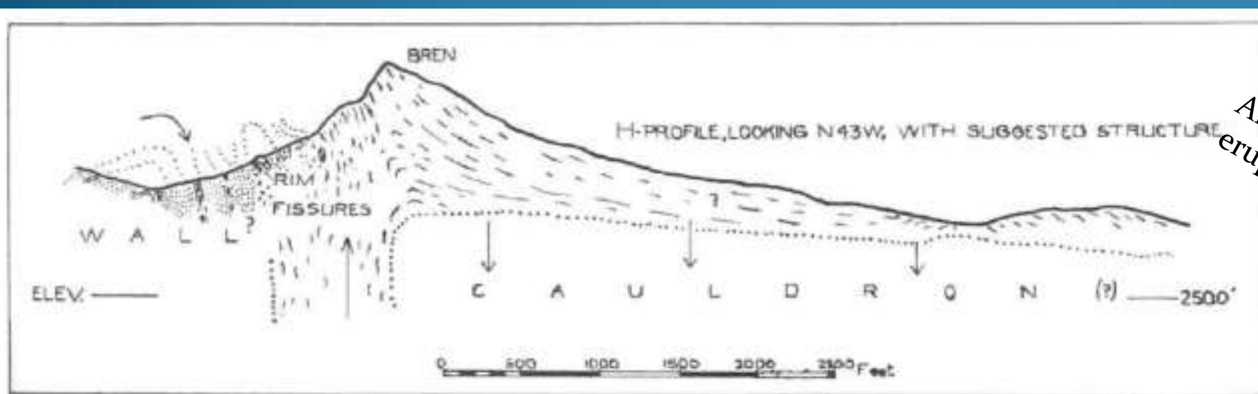


Amole monzo -diorite border phase

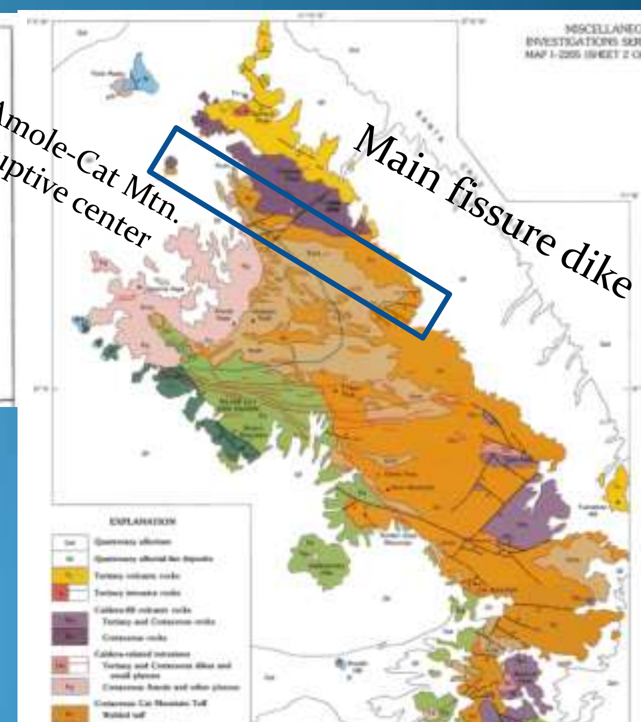
Fissure eruption model for Cat Mountain Rhyolite



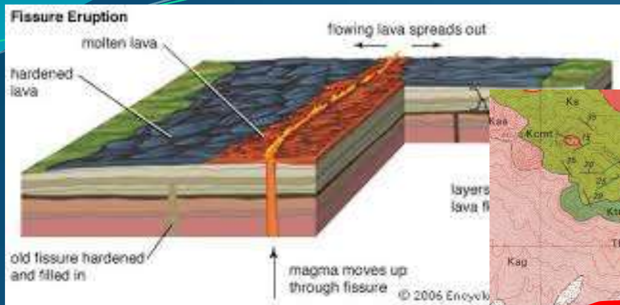


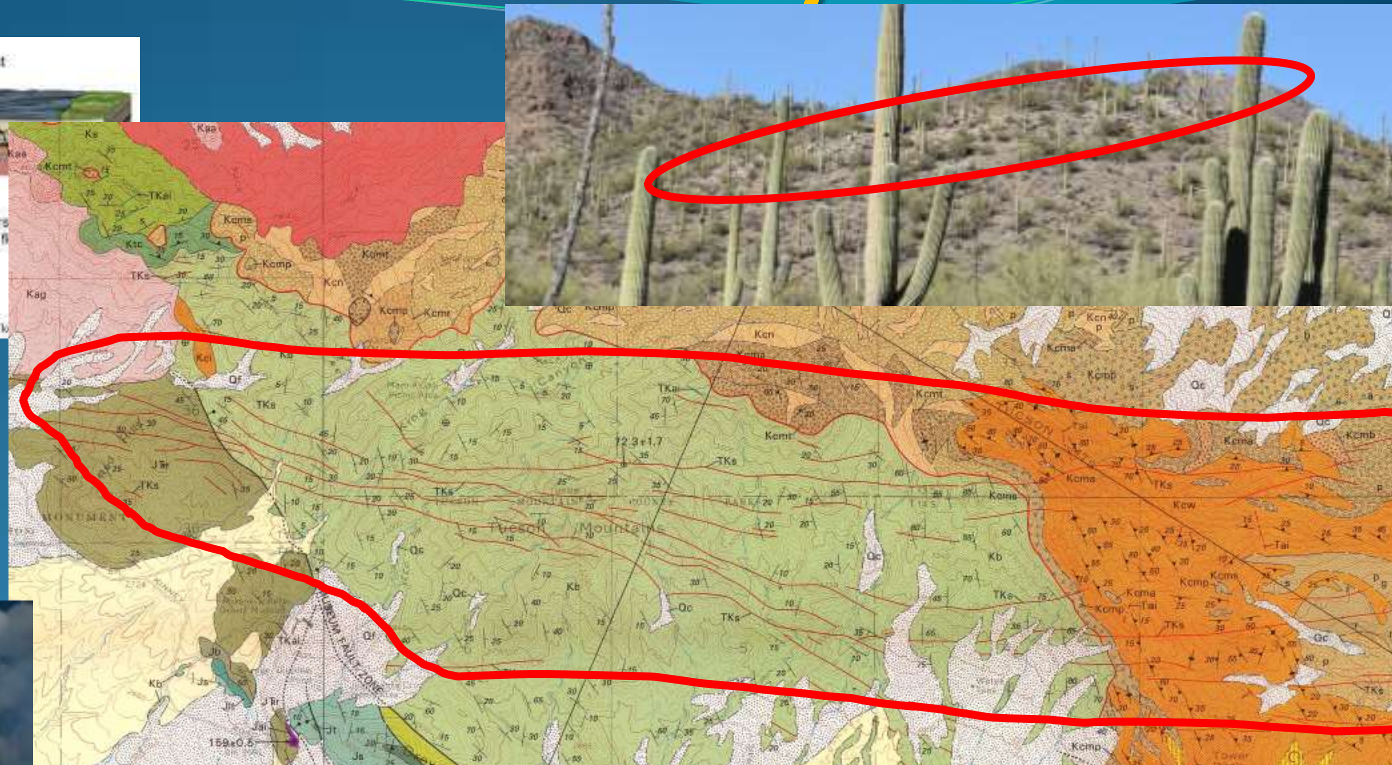


Fissure eruption feeder model at Bren Mountain (from Mayo, 1971)

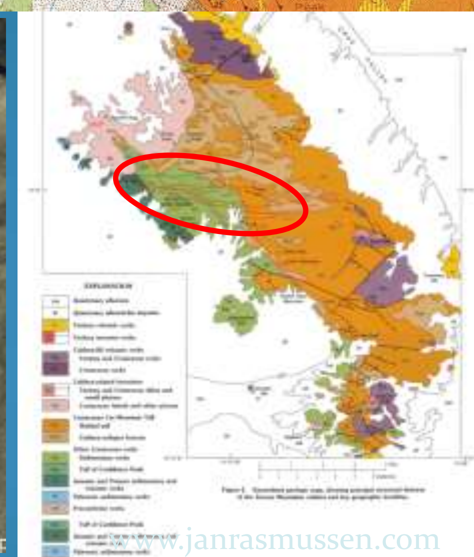


Late Cretaceous – Silver Lily dikes 72.3 Ma





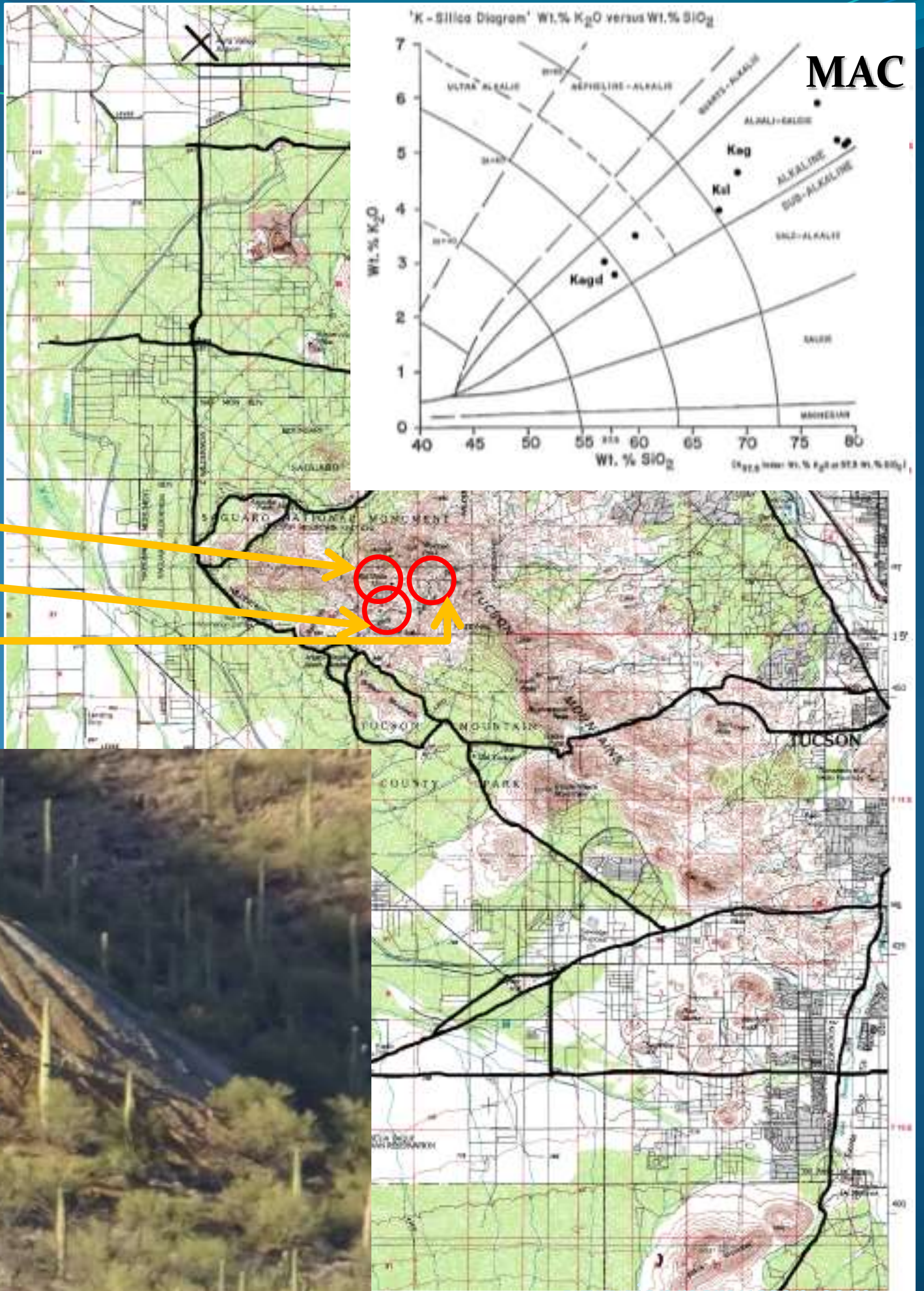
Fissure eruptions can also erupt rhyolitic volcanic rocks (Banda Aku)



The Silver Lily dikes could be fissure vents from which the Cat Mountain Tuff erupted.

MAC Mines – central Tucson Mts.

- Mile Wide (Columbia, Copper Bell, Copper King)
- Gould
- Isabel



Gould Mine dump

www.jamrasmussen.com

Mine Production & Minerals from Central Tucson Mts. (MAC)

No.	Mine	Production	Ore (T)	Au (oz/T)	Ag (oz/T)	Cu (%)	Pb (%)	Zn (%)
4	Columbia (Mile Wide)	1954	130	0	0.4	2	0	0
5	Copper Bell (Mile Wide)	1937, 1956	90	Trace	1.1	4.6	0	0
6	Copper King	1917-1918, 1943	1,400	Trace	0.5	6	0	0
7	Gould	1907-1912, 1940	1,500	0	0.1	2	0	0
8	Isabel	1919, 1962	170		2	1	3	

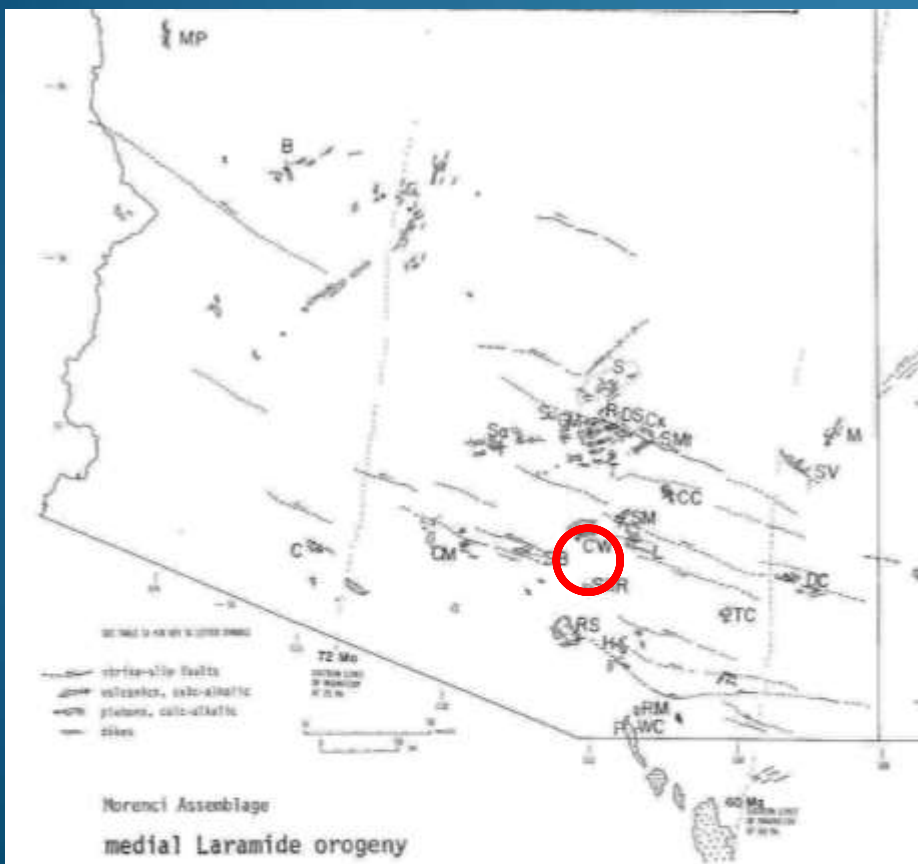
No.	Mine	Primary minerals	Secondary minerals	Other minerals
4	Columbia (Mile Wide)	Spotty copper sulfides	Copper carbonates	
5	Copper Bell (Mile Wide)	Spotty copper sulfides	Spotty copper carbonates	
6	Copper King	Chalcopyrite, pyrite	Copper carbonates	Amphibole, garnet, calcite
7	Gould	Copper sulfides, pyrite	Minor copper carbonates	Quartz, epidote, garnet
8	Isabel (Bonanza Park, Sweetwater)	Lead and copper sulfides	Partly oxidized lead and copper sulfides	

Source: Keith, 1974, Index of Mining properties in Pima County, Arizona: Arizona Bureau of Mines Bulletin 189.

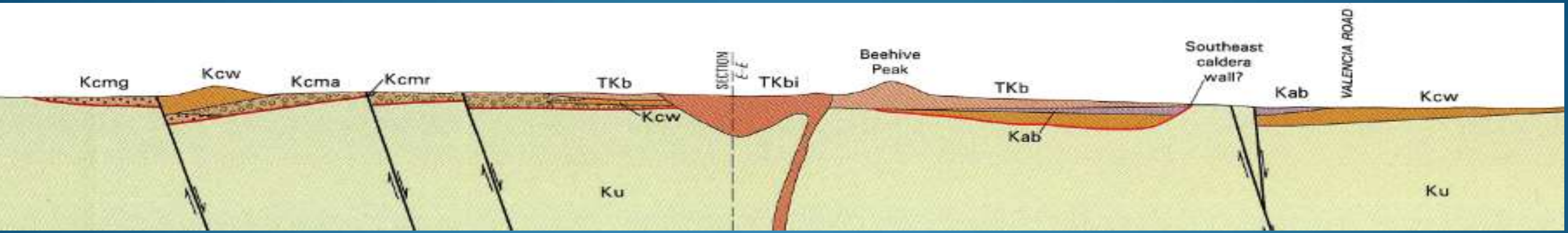
Middle Laramide – Early Tertiary (65-55 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Laramide	Middle	65-55	Cretaceous-Tertiary	Granodiorite - quartz monzonite porphyry stocks, NE to ENE-striking dike swarms	MCA	Tuff of Beehive Peak, porphyritic granodiorite of Sedimentary Hills & Saginaw Hill	58.3 Ma Twin Hills dacite

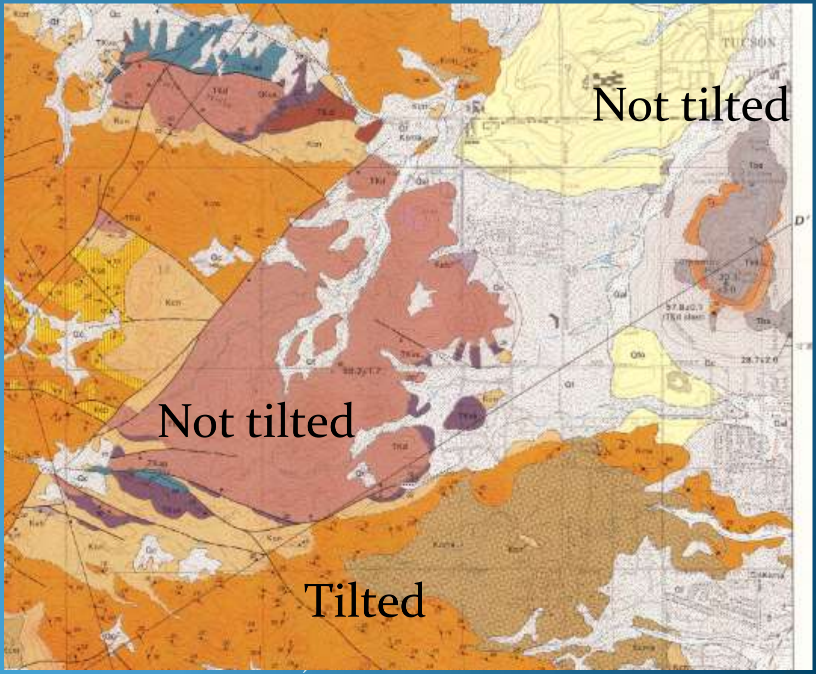
No current producing porphyry copper mines in Tucson Mtns.

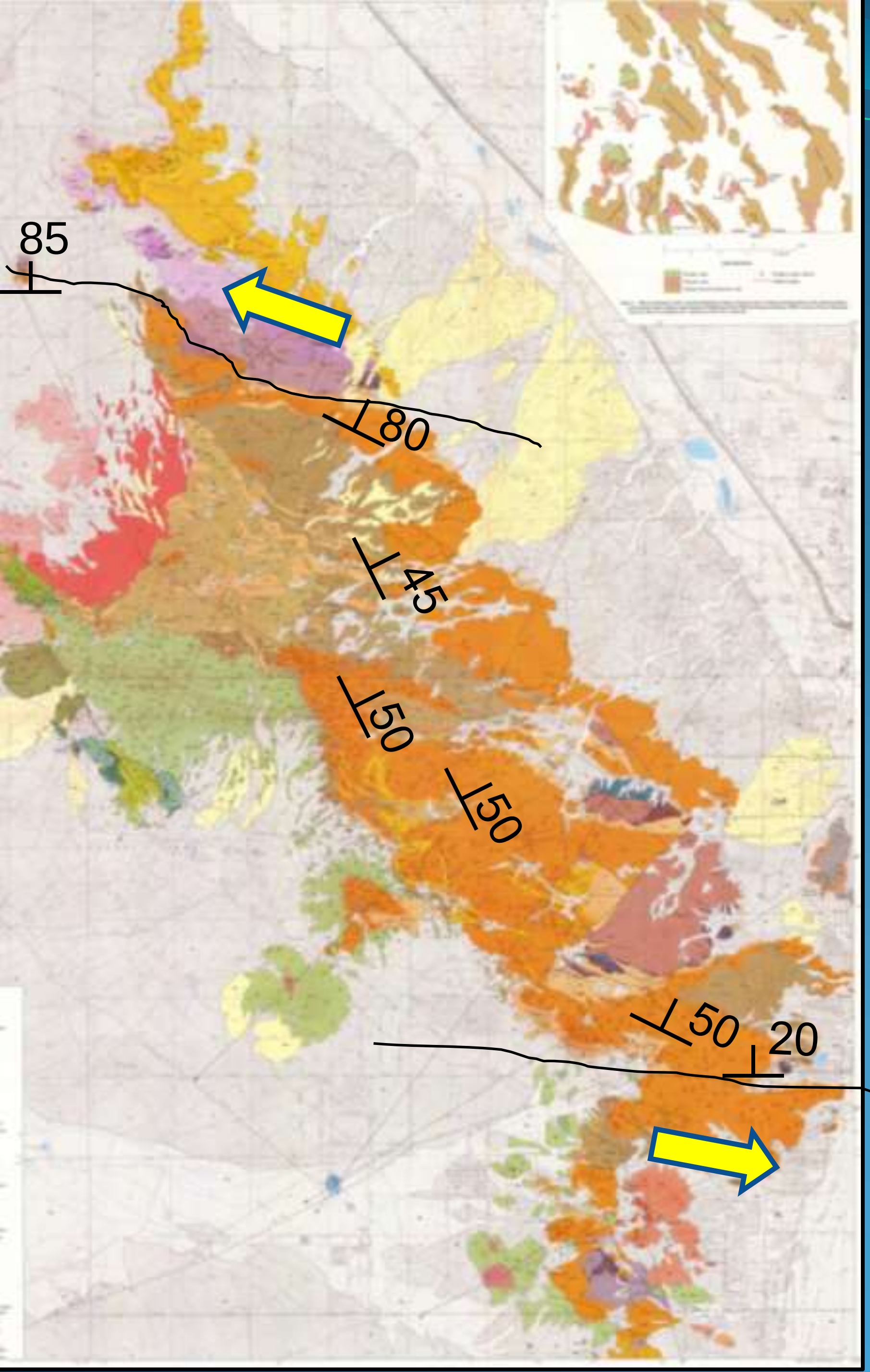


Early Tertiary - MCA (Beehive Rhyolite 61-58 Ma) cutting Late Cretaceous - MAC (Cat Mountain 73-70 Ma) – angular unconformity - structural event in between



Cat Mountain Rhyolite is steeply tilted, but overlying Dacite of Twin Hills is not tilted





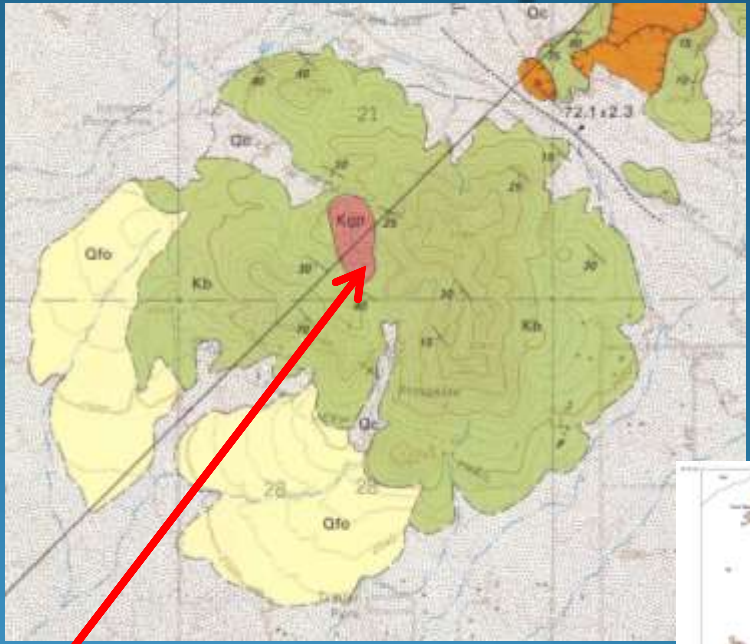
Syn-Morenci Assemblage, Left Wrench Tectonics in the Tucson Mountains (67-60 Ma)

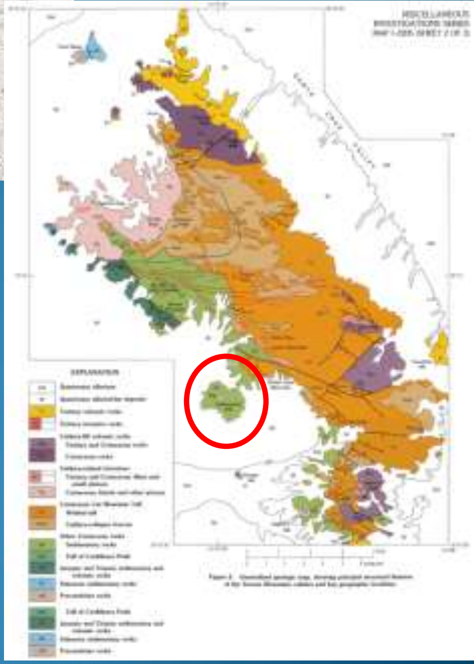
The strike and dip patterns of the Cat Mountain rhyolite describe a sinusoidal pattern that forms a broad, oroclinal, 'Z' –shaped, north- to east-dipping flexure that is consistent with left wrench deformation on WNW-striking, deep-seated, wrench fault elements of the Texas Zone .

The Cat Mountain Rhyolite eruptions utilized the northern wrench fault as a feeder structure for its eruption around 73-71 Ma.

The wrench deformation more-or-less ended by 58 Ma (the age of the flat-lying Twin Hill hornblende dacite).

Early Cenozoic – Laramide por. Cu intrusions – Sedimentary Hills - W. Tucson Mts.

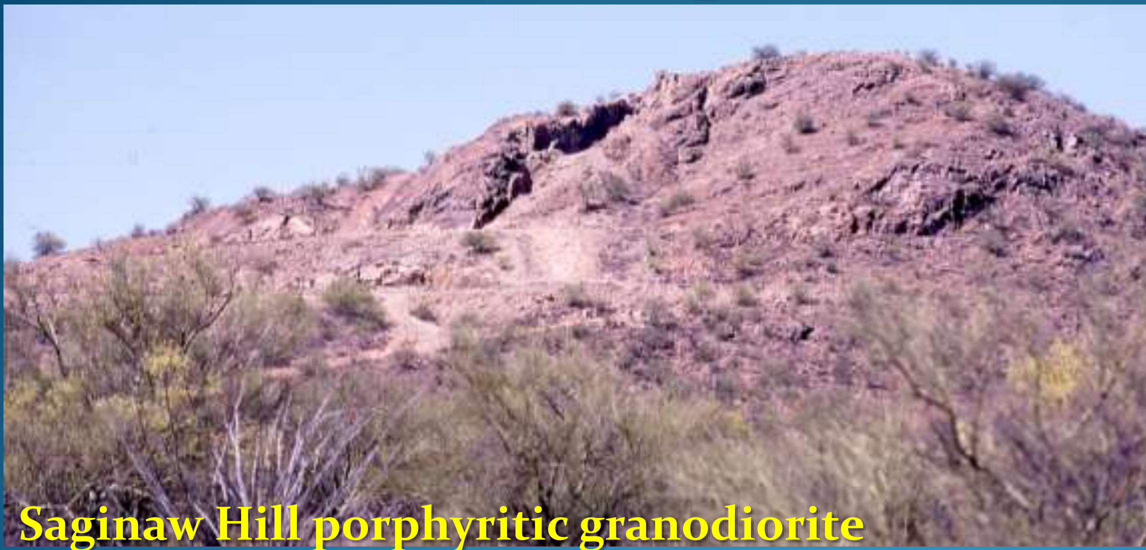




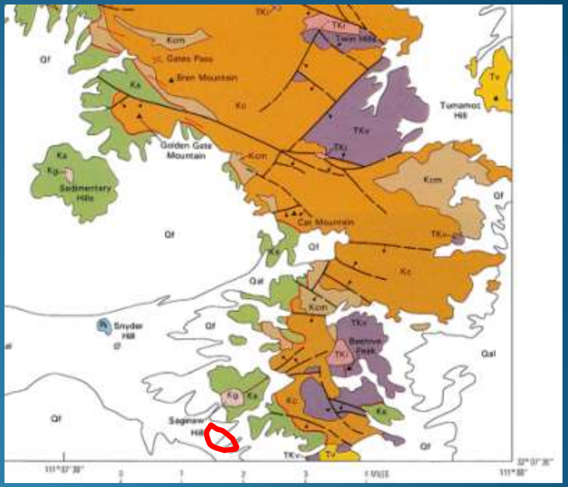
Porphyritic granodiorite

Sedimentary Hills – from Ironwood Picnic Area looking south

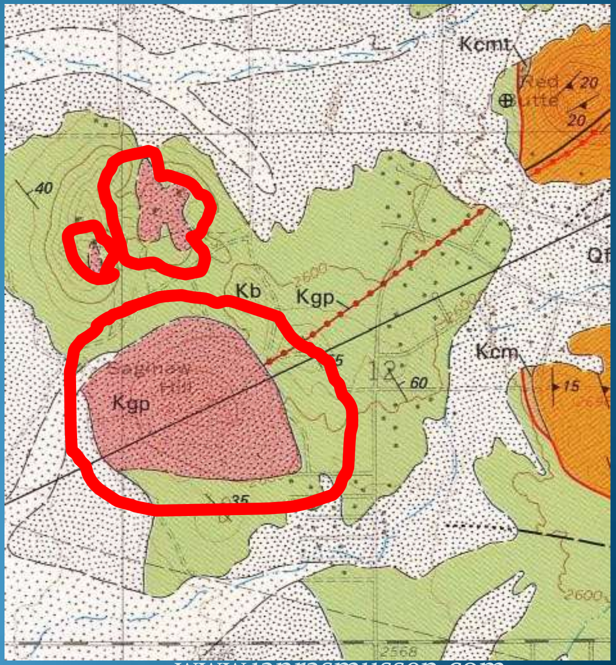
Early Cenozoic – Laramide por. Cu. intrusion Saginaw Hill - SW Tucson Mts.



Saginaw Hill porphyritic granodiorite



Phyllic alteration in fine-grained tan to light-gray porphyritic granodiorite



Early Tertiary – MCA – Saginaw Hill

Mineral List

- 'Clay'
- Cuprite
- Epidote
- 'Garnet'
- 'Limonite'
- Malachite
- Muscovite
  var. Sericite
- Pyrite
- Adamite
- Atacamite
- Beudantite
- Brochantite
- Carminite
- Chrysocolla
- Cornetite
- Libethenite
- Pseudomalachite

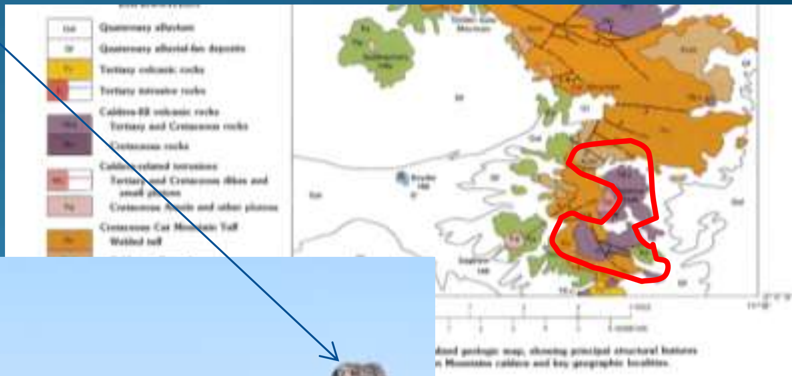
Cornetite, $Cu_3(PO_4)(OH)_3$ - ASDM 03698, photo by Rhonda Spencer, mindat.org

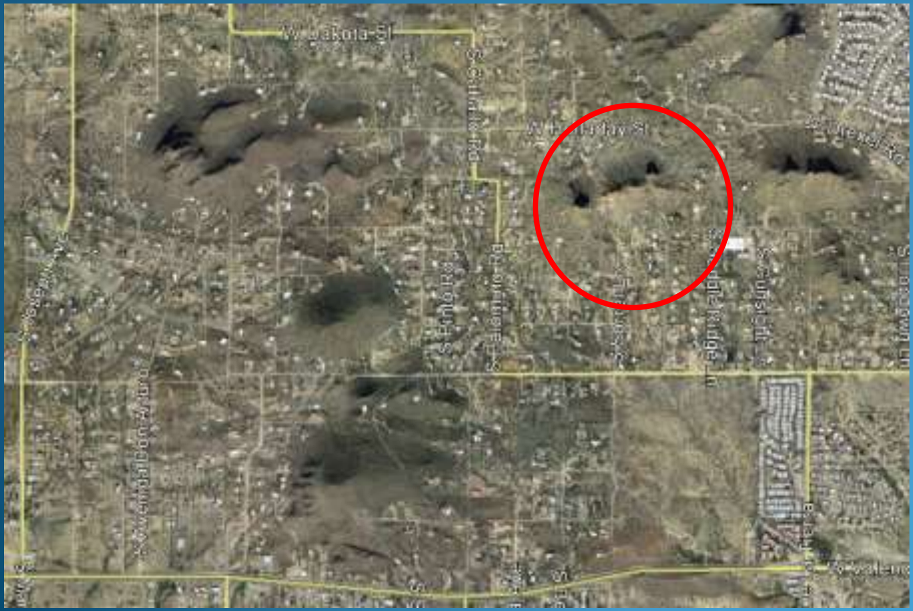
Pseudomalachite $Cu_5(PO_4)_2(OH)_4$
Photo & specimen by Bruce J. Murphy: mindat.org

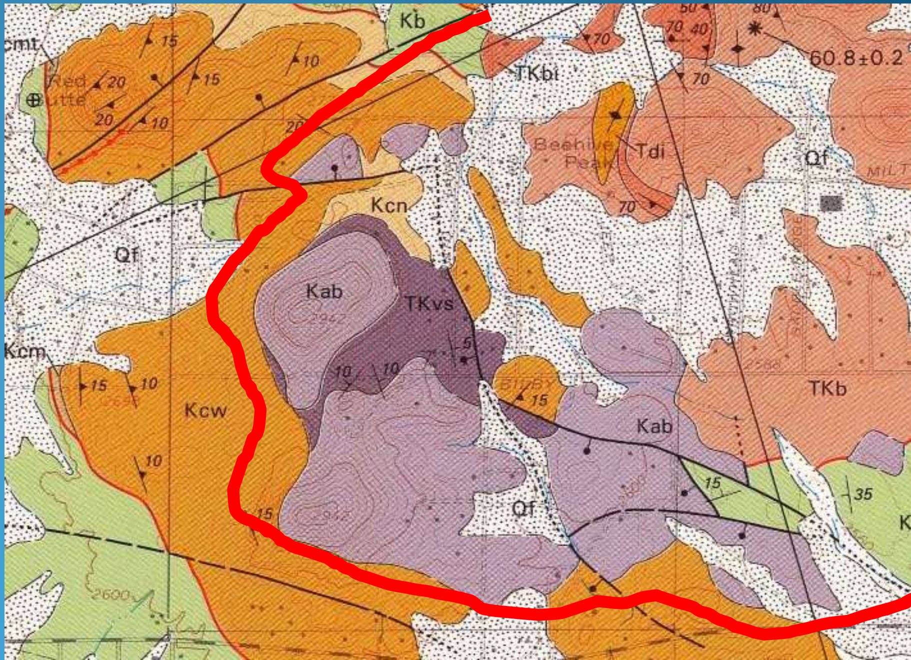
Early Cenozoic – Laramide por. Cu.

Tuff of Beehive Peak- SW Tucson Mts.

Beehive Peak – light gray to tan, massive dacite ash-flow tuff (formerly Beehive Rhyolite and Biotite Rhyolite) – 60.2 Ma



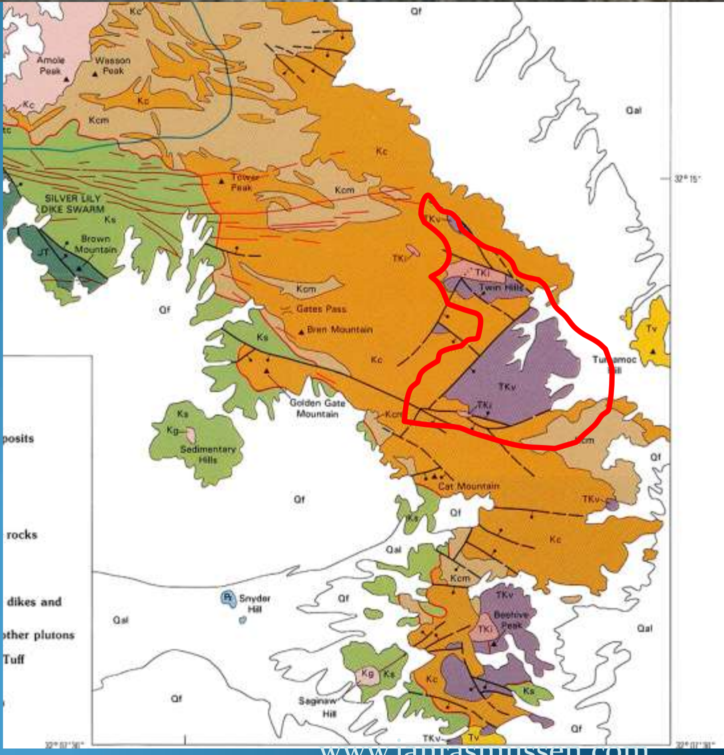




Early Cenozoic – Laramide MCA (por. Cu) intrusions - SE Tucson Mts.

Dacite of Twin Hills (Shorts Ranch Andesite) (W. 22nd St.) – Quien Sabe mine area - 58.3 Ma

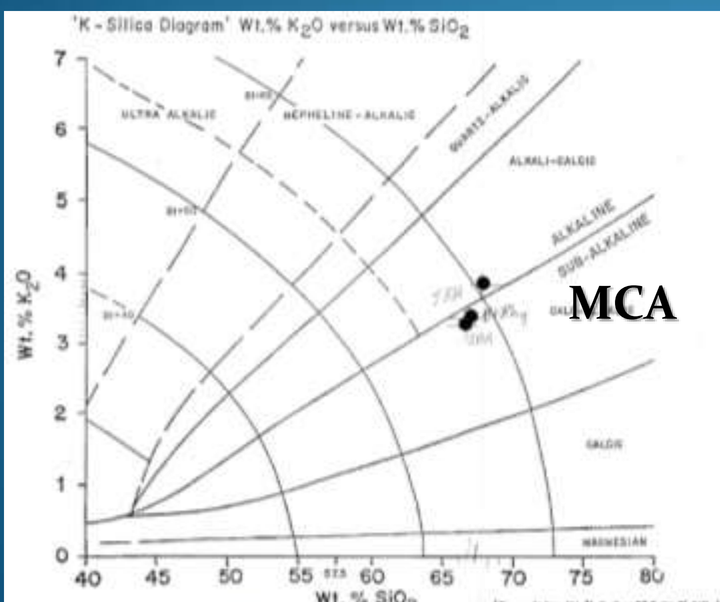
Massive, light-gray lava flows with phenocrysts of plagioclase, biotite, and hornblende

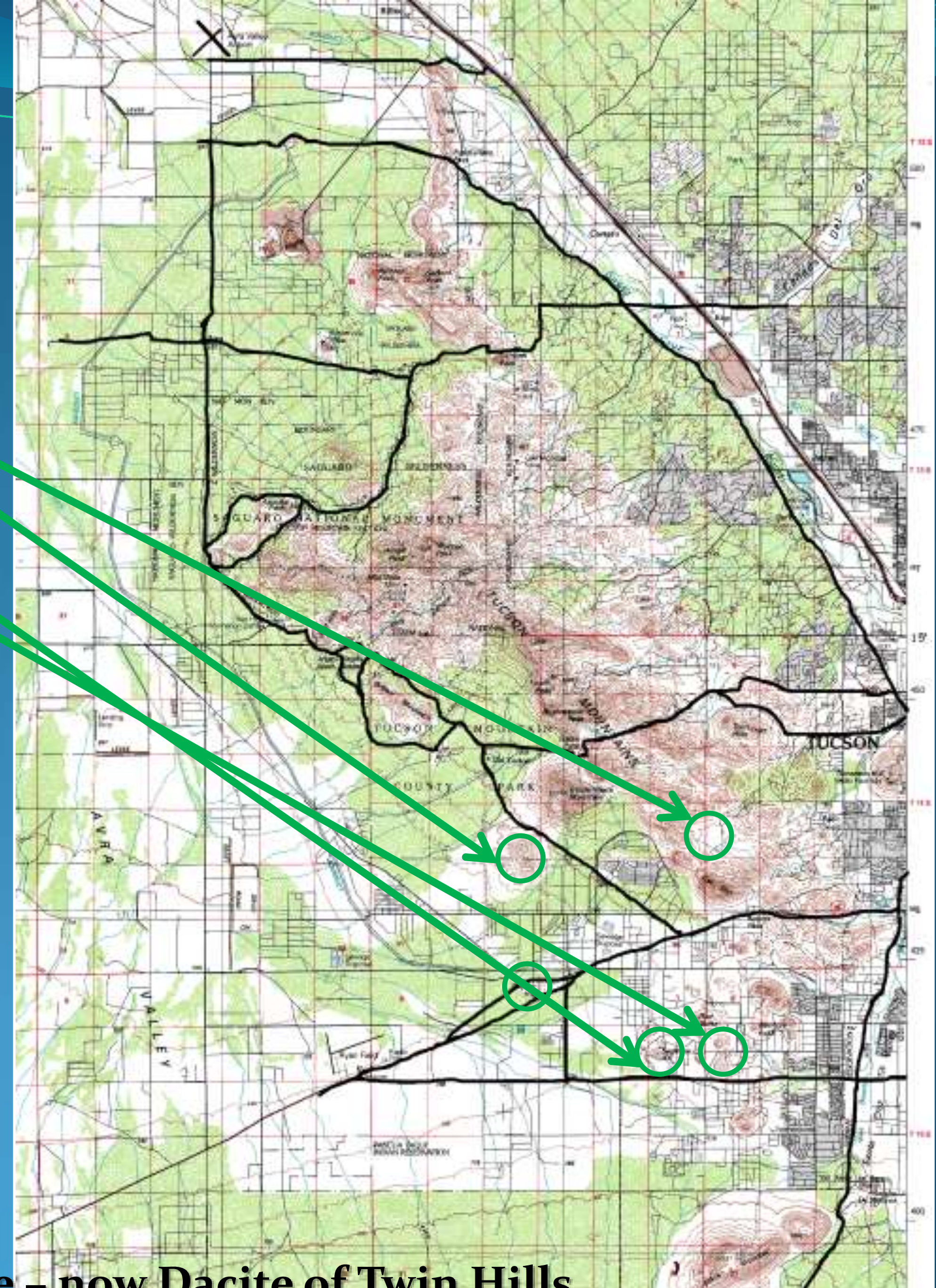


Only igneous rocks in Tucson Mts. that contain hornblende.

MCA Mines – S. Tucson Mts.

- Sedimentary Hills
- Quien Sabe, Battle Axe
- Saginaw Hill, Paloverde, Papago Queen, Ivy May
- Old Mission, Pellegrin





Shorts Ranch Andesite, Biotite Rhyolite – now Dacite of Twin Hills

Early Cenozoic – Laramide (MCA) S. Tucson Mts. mine production

No.	Mine	Production (years)	Ore tons	Au (oz/T)	Ag (oz/T)	Cu (%)	Pb (%)	Zn (%)
2	Battle Axe	1969-1970	14,000 smelter flux	0	traces	0.2	0	0
3	Bee Hive	1925, 1929	small	0	12	4.5	1.5	0
9	Ivy May	1890s, 1920-1950	500	0.1	1.3	4	0.2	0
10	Old Mission (Old Bat)	1920-1921; 1923,1937-1938	150	0.1	10	1	0.3	0
11	Old Pueblo (Quien Sabe)	1907-1909, 1936 1937-1970	67 17,895	0.04 0.046 g/T	1.2 6.1 g/T	5 0.8	0 0.0025	0 0
13	Palo Verde (Amole Group)	1918-1954	2,300	0.06	2.5	0.7	2.2	13
14	Papago Queen (Saginaw Hill, Gold Hill, Amole Group)	1917-1934; smelter flux 1956-1959	3,700	0	0.5	1	0	0
15	Pellegrin (Arizona, Old Padre, Starr)	1918-1938	71	0.2	6	2	3	0
16	Saginaw	Pre-1900	100	0	0	0	0	0
17	Snyder Hill prospect	1922	15	0.01	301	0	5	0

Source: Keith, 1c74, Index of Mining properties in Pima County, Arizona: Arizona Bureau of Mines Bulletin 189; Keith et al.,, 1985 data base

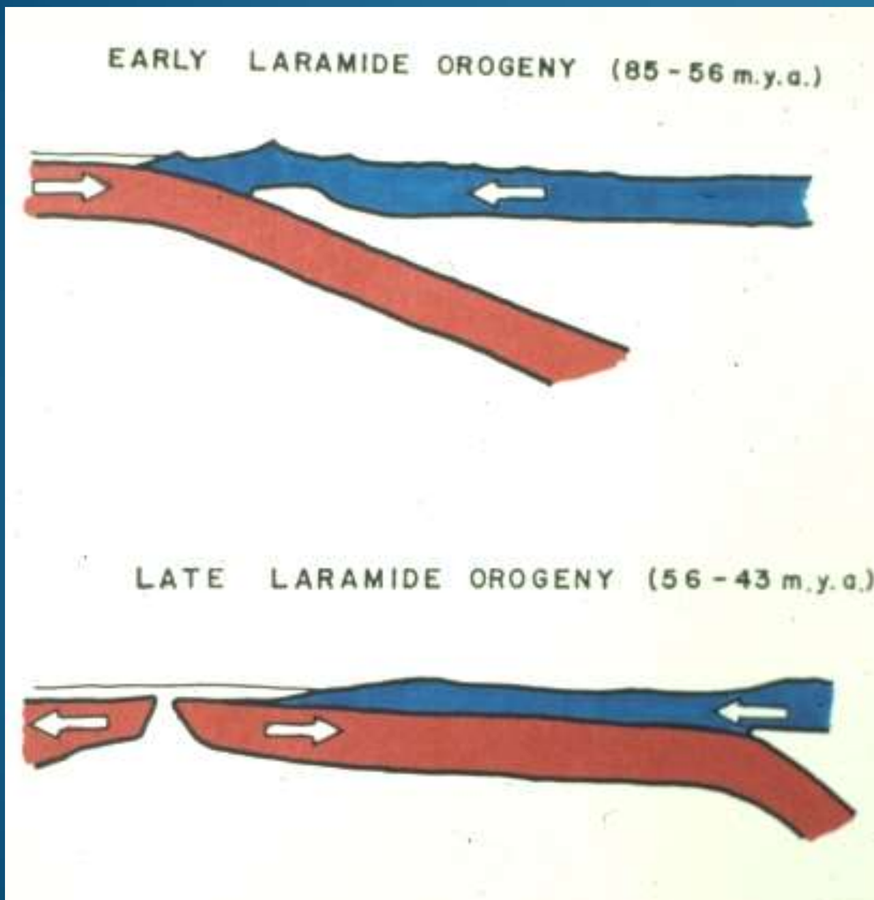
Minerals in Early Cenozoic – Laramide (MCA) S. Tucson Mts. mines

No.	Mine	Primary minerals	Secondary minerals	Other minerals
2	Battle Axe	Acanthite, chlorargyrite	Weak and spotty copper oxides and silicates; cerussite	Baryte, hematite, quartz, siderite
3	Bee Hive	Pyrite, chalcopyrite, galena	Spotty chrysocolla, malachite and partly oxidized galena	Quartz
9	Ivy May	Lead and copper sulfides; bornite, pyrite	Partly oxidized lead and copper sulfides; cuprite	
10	Old Mission (Old Bat)		Copper oxides, cerussite, argentite, cerargyrite,	Barite, hematite, jasper, massive manganiferous siderite
11	Old Pueblo (Quien Sabe)	Chalcocite	Copper silicates	Drusy quartz
13	Palo Verde (Amole Gp.)	Sphalerite, galena, chalcopyrite, pyrite	Slightly oxidized sphalerite, galena, chalcopyrite and pyrite	
14	Papago Queen (Saginaw Hill, Gold Hill, Amole Group)		Disseminated cuprite and malachite, minor molybdenum oxides	Quartz
15	Pellegrin (Arizona, Old Padre, Starr)		Spotty oxidized lead and copper mineralization	
16	Saginaw	Sparse, spotty base metal sulfides	Partly oxidized base metal sulfides	
17	Snyder Hill prospect	Argentiferous galena	Silver halides; chlorargyrite, cerussite, bindheimite, stetefeldtite	Baryte

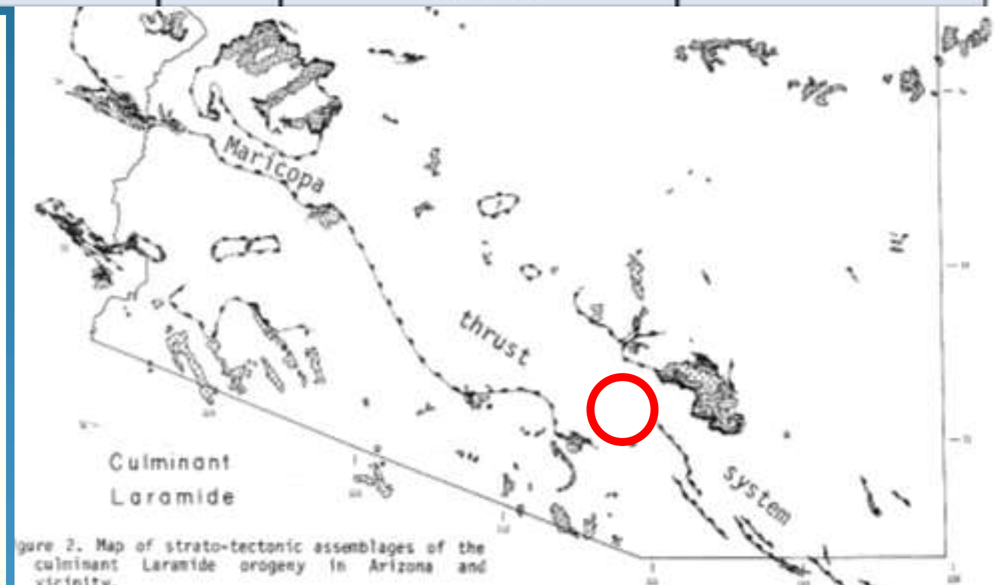
Source: Keith, 1974, Index of Mining properties in Pima County, Arizona: Arizona Bureau of Mines Bulletin 189; and www.MinDat.org.

Latest Laramide – Wilderness (55-40 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
	Late	55-40	Early Tertiary	Peraluminous 2-mica granites	PAC	None; Eocene erosion surface/unconformity below Safford Peak volcanics	43 Ma Wilderness Granite in Santa Catalina Mts.



Flat subduction



STRUCTURES

SW-directed,
low-angle thrusts
widespread,
shallowly dipping
mylonitic zones
general SW shear

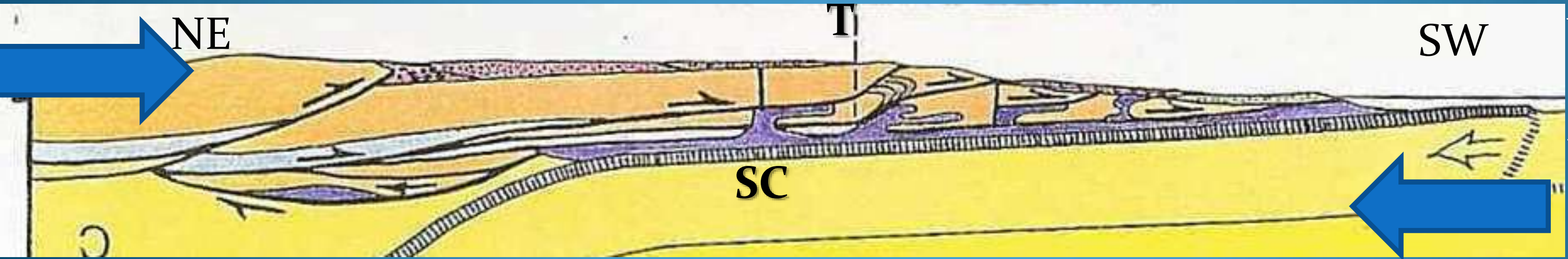
MAGMATISM

widespread, (2-mica)
garnet-muscovite,
granitoid stocks,
batholithic sills,
aplo-pegmatite dikes
peraluminous,
calc-alkalic & calcic

Latest Laramide - 53-43 Ma


W. Santa Catalina Mts. from El Conquistador

Garnet-bearing Wilderness Granite - top of Mt. Lemmon

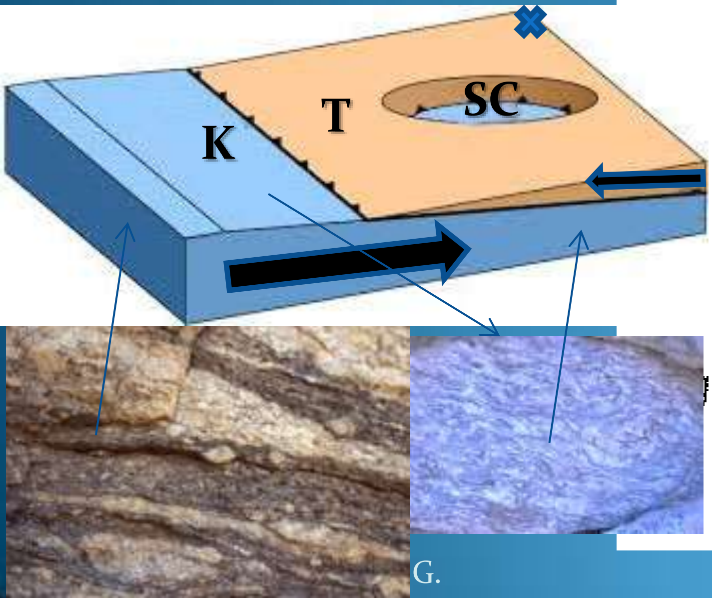


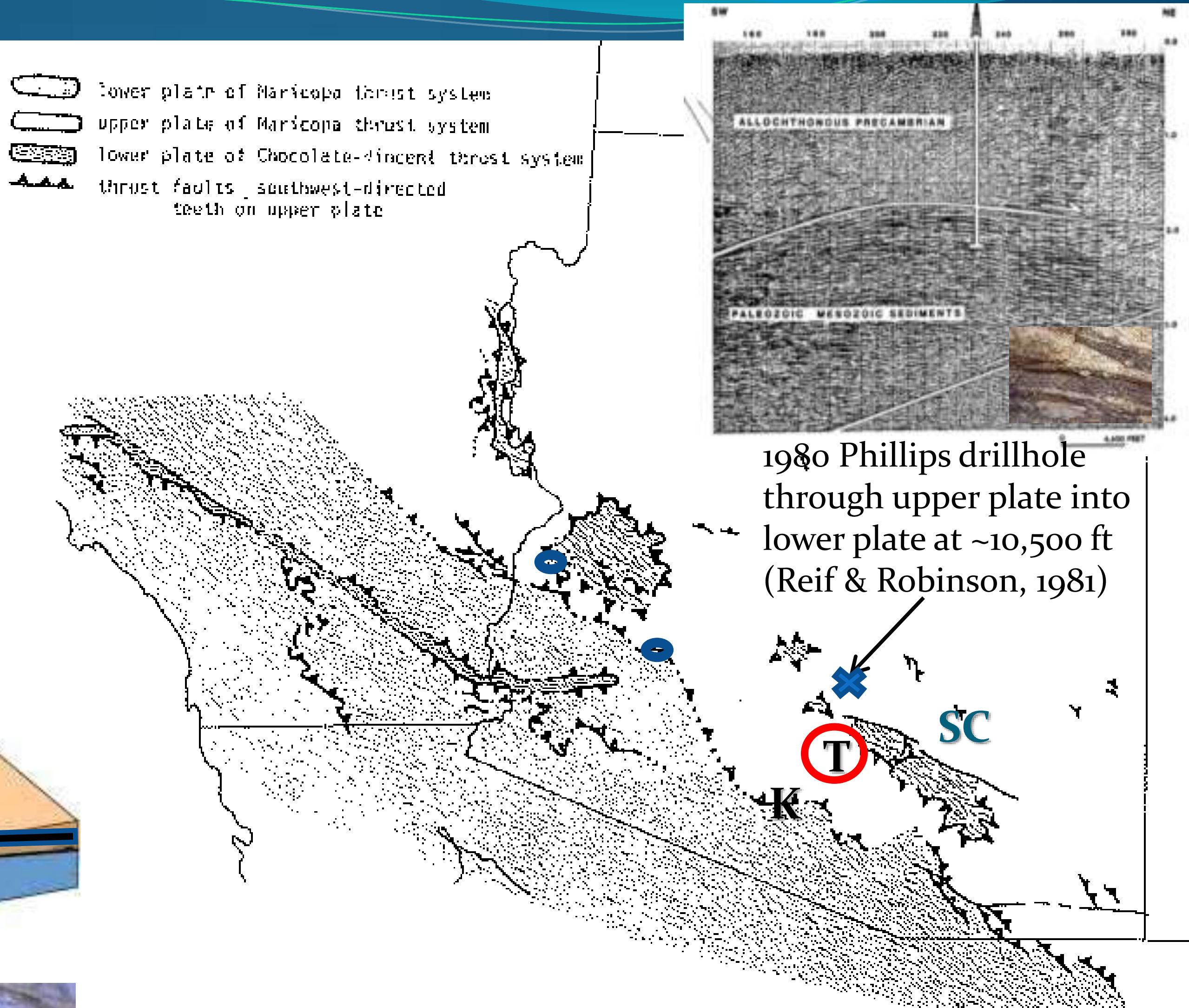
Underthrusting of subducting plate toward the NE = SW-directed in upper plate

Santa Catalina Mts. – window into lower plate

Looking SW from Catalinas looking over Tucson Mts. to Kitt Peak

Wilderness Granite 43 Ma arched up circa 28-24 Ma

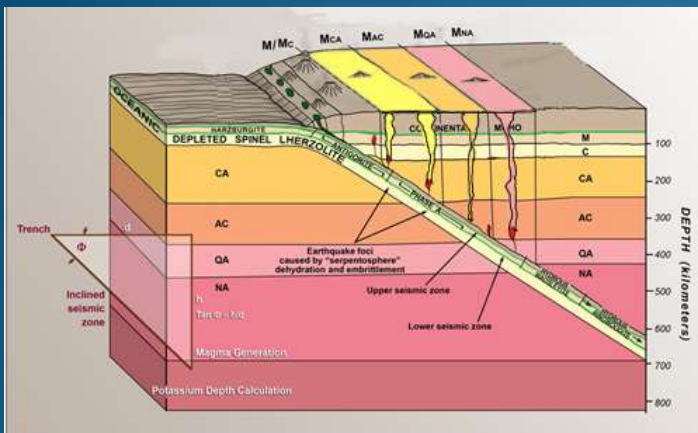


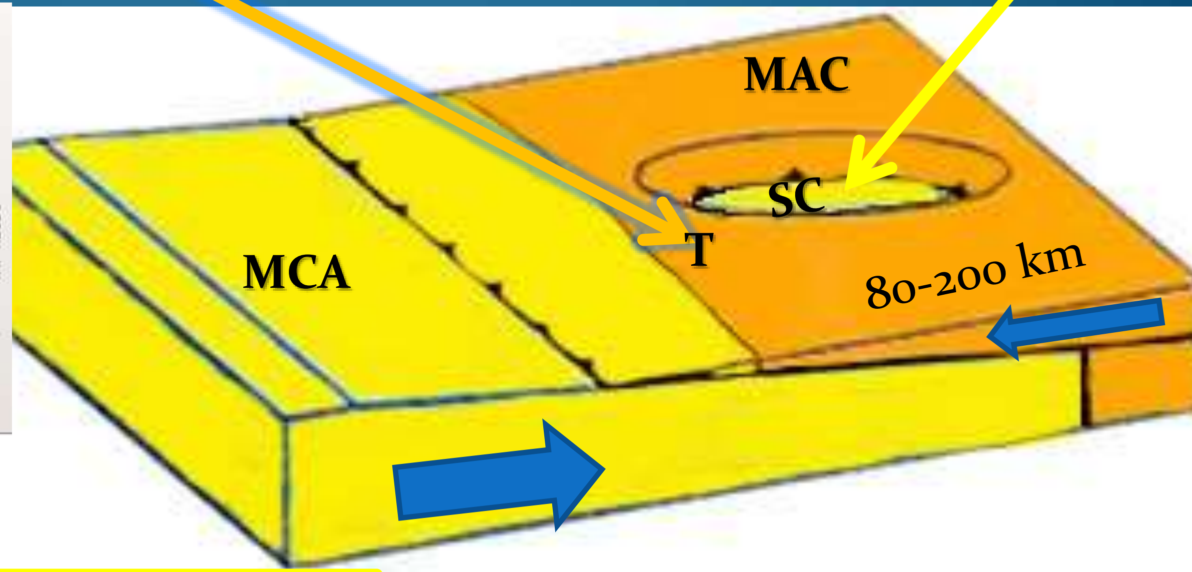


1980 Phillips drillhole through upper plate into lower plate at ~10,500 ft (Reif & Robinson, 1981)

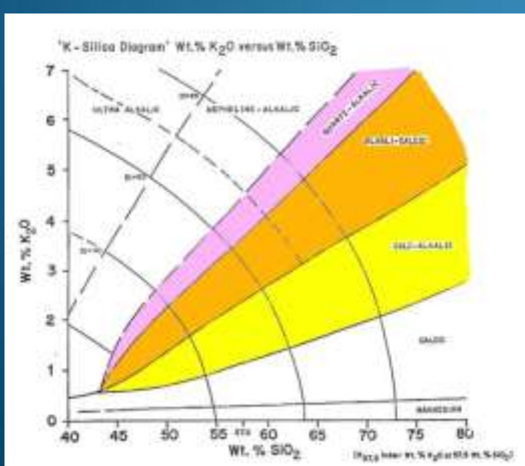
...ure 8. Map of lower plate of the Maricopa thrust system, showing the windows previously called 'metamorphic core complexes'. Keith & Wilt, 1986

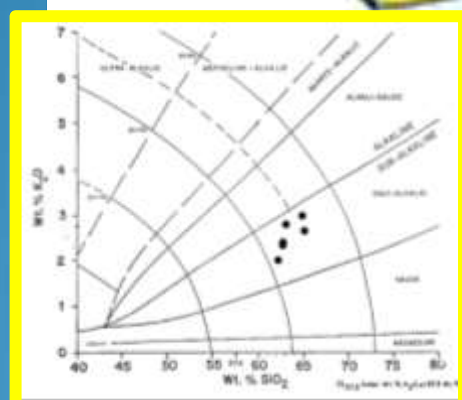
Tucson Mts. MAC (Amole Granite 73 Ma) in upper plate of Maricopa Thrust Fault; MCA (Leatherwood 72 Ma) in Santa Catalina Mts. in lower plate



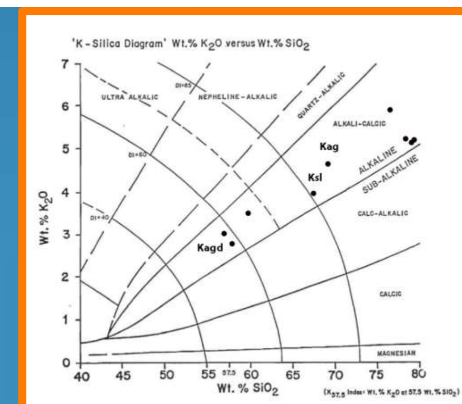


MAC=Alkali-calcic
MCA= Calc-alkalic





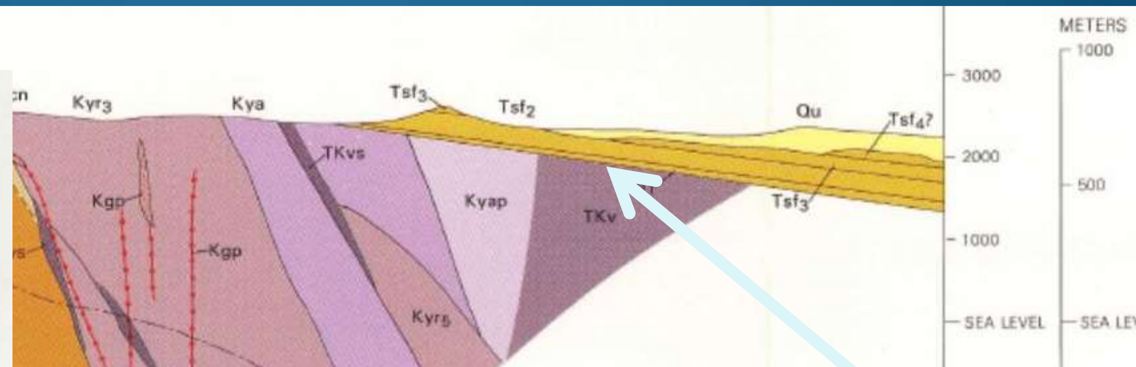
MCA Leatherwood Quartz Diorite Santa Catalina Mts.



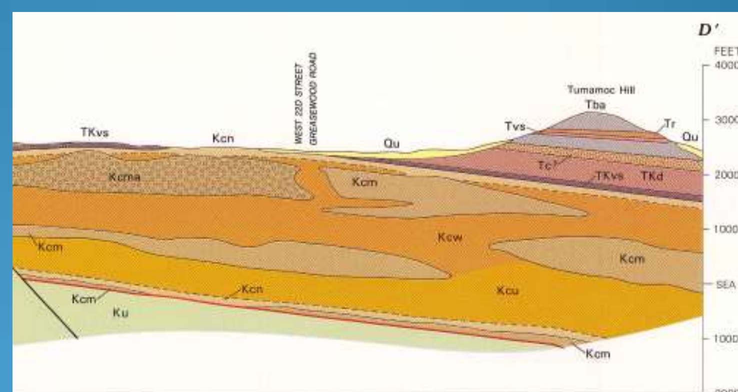
MAC Amole granite & granodiorite, Cat Mtn. Rhyolite, and Silver Lily dikes

N. Tucson Mts. Evidence of epeiric uplift & erosion = Eocene erosion surface above flat subduction zone

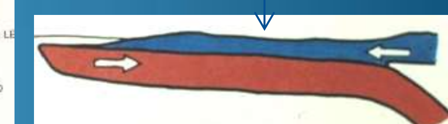
Figure 18-25 The subsummit surface formed by the flat-topped Rocky Mountains. This surface, seen here near Derby Peak, Colorado, formed near the end of the Eocene Epoch and has since been uplifted and dissected by erosion. (Michael Collier.)



Angular unconformity between Late Cretaceous Yuma Mine volcanics and mid-Tertiary volcanics of Safford Peak



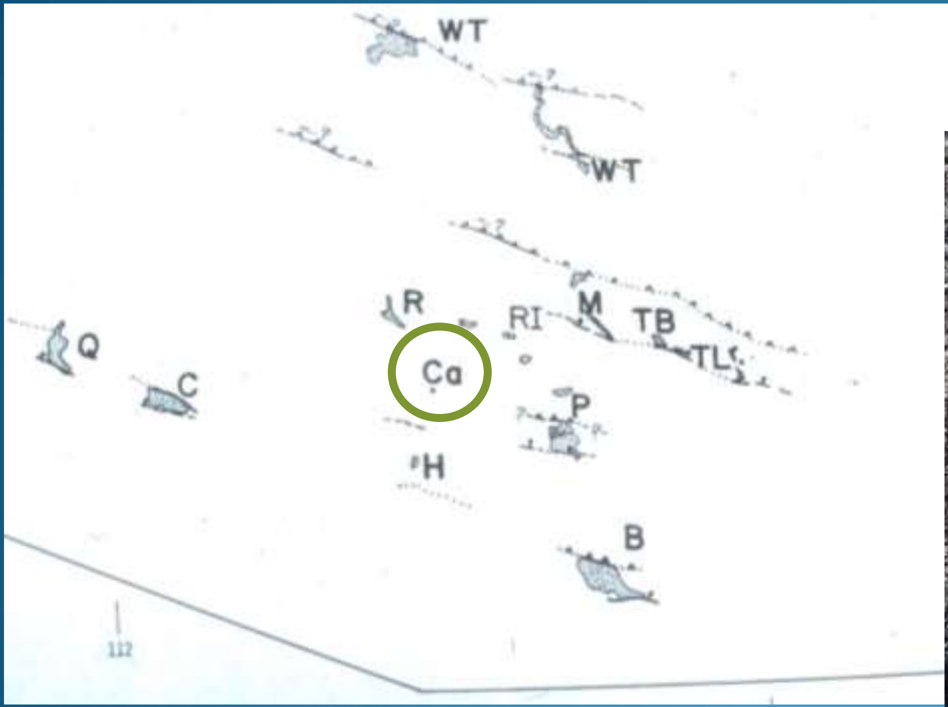
Eocene erosion surface



Unconformity under Tumamoc Hill mid-Tertiary overlying Twin Hills Dacite and Cat Mtn. (Late Cretaceous)

Early Galiuro - Cardinal Ave. U (38-28 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
	Earliest	39-28	Mid-Tertiary	Lake beds and possible erosion & secondary enrichment of Cu	?	Uranium sedimentary beds at Cardinal Avenue & Mission Rd.; Pantano Fm.	39.5 Ma basal Safford volcanic flow 1



Cardinal Avenue uranium (S of Valencia)

Tertiary Limestone, Cardinal Avenue

Continued erosion exposed mineral deposits to oxidation and supergene enrichment.

Middle Galiuro orogeny – Datil (28-18 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Galiuro	Middle	27-18	Mid-Tertiary	Alkali-calcic ignimbritic volcanics & plutons	MAC	Safford Dacite, Volcanics of Tumamoc Hill	25.1 Ma Safford Peak dacite, 25.9 Ma Safford Tuff, 20.3 Ma Tumamoc basalt top

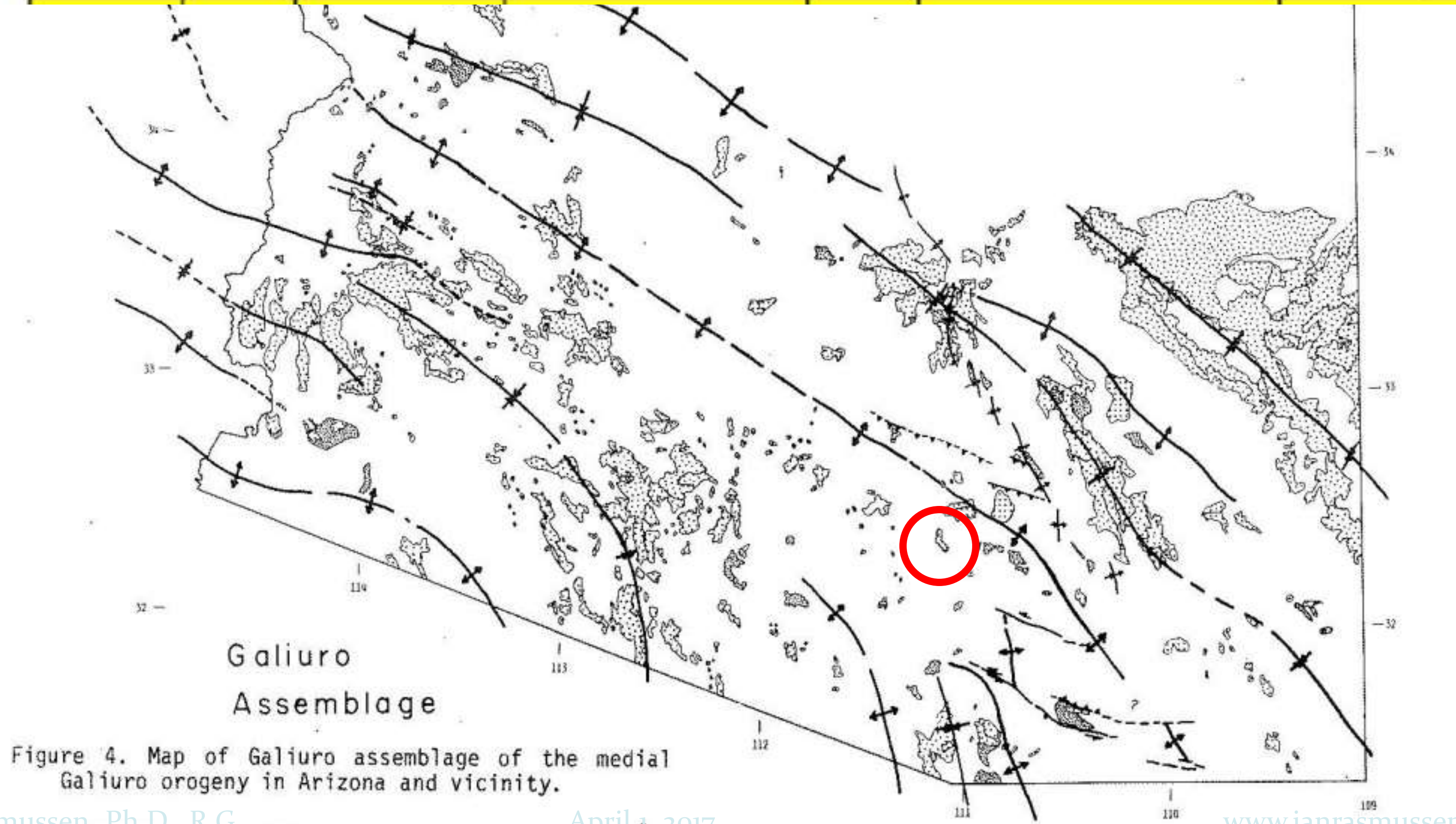


Figure 4. Map of Galiuro assemblage of the medial Galiuro orogeny in Arizona and vicinity.

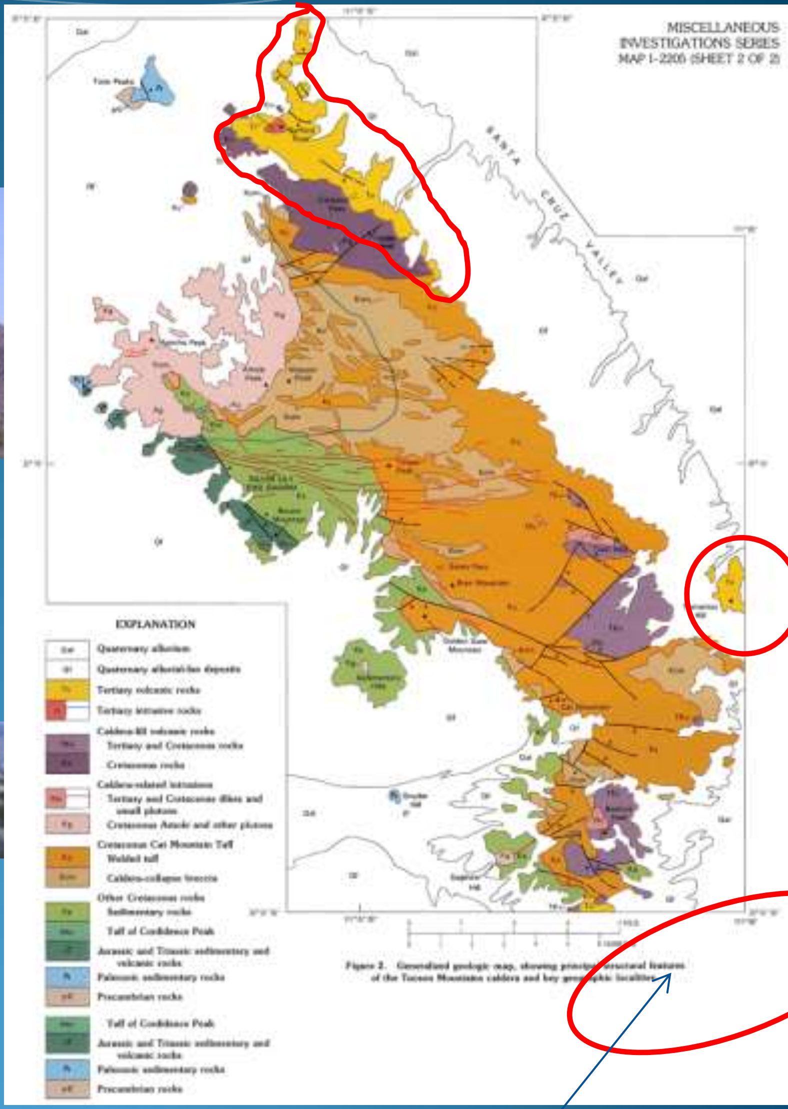
Mid-Tertiary MAC rocks - Tucson Mts.

Flat lying lava flows and ash fall tuffs

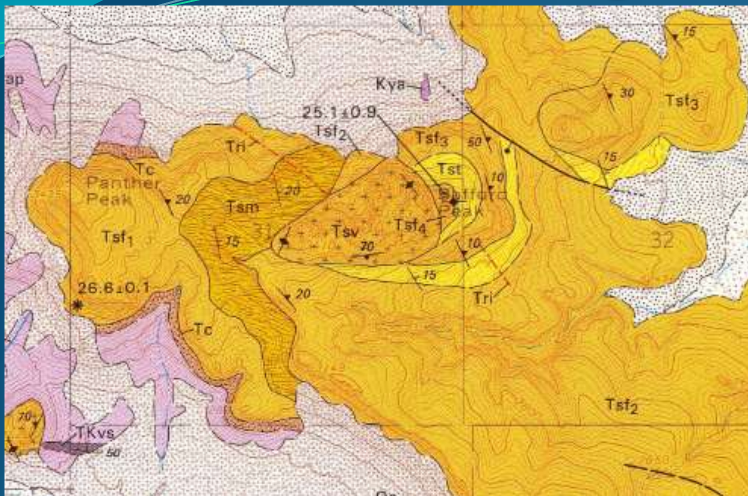
Safford Peak

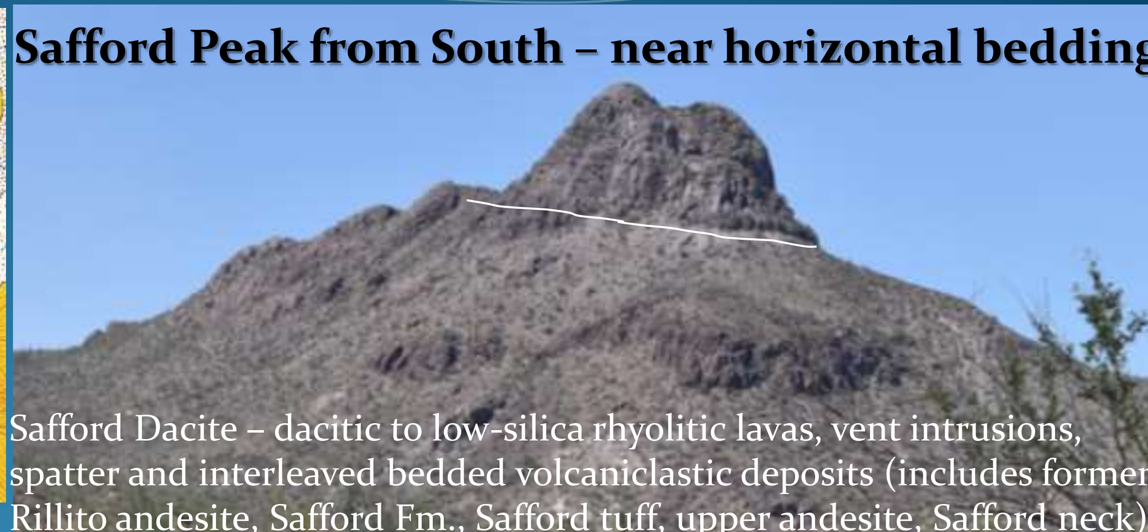
'A' Mountain,
Tumamoc Hill

Black Mountain,
Del Bac Hills



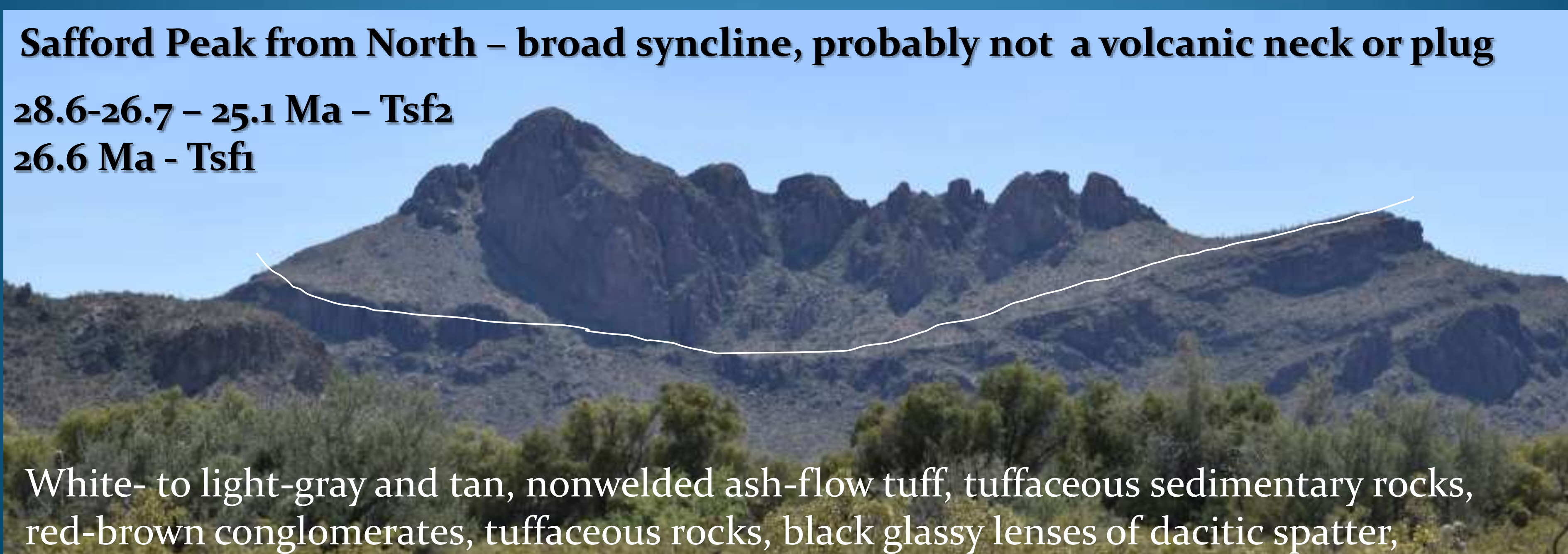
Mid-Tertiary volcanics – Safford Peak





Safford Peak from South – near horizontal bedding

Safford Dacite – dacitic to low-silica rhyolitic lavas, vent intrusions, spatter and interleaved bedded volcaniclastic deposits (includes former Rillito andesite, Safford Fm., Safford tuff, upper andesite, Safford neck)

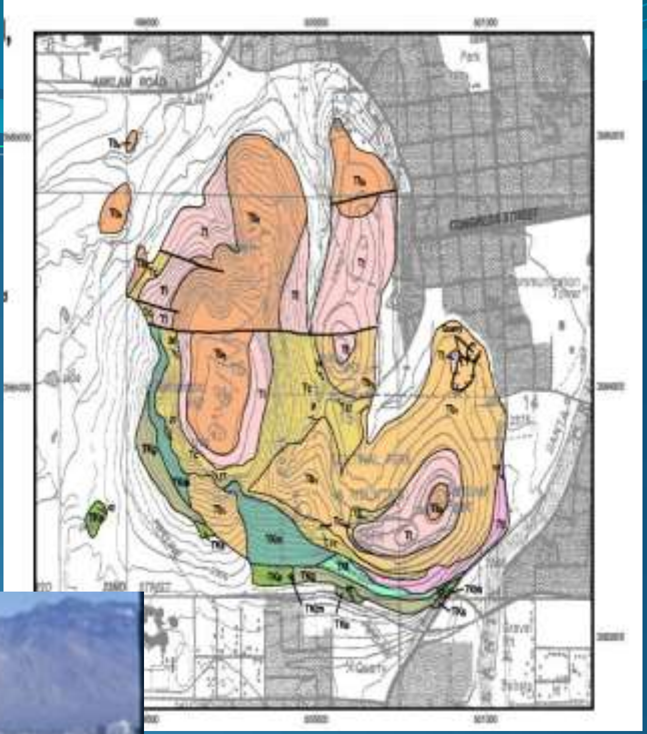


Safford Peak from North – broad syncline, probably not a volcanic neck or plug

28.6-26.7 – 25.1 Ma – Tsf2
26.6 Ma - Tsf1

White- to light-gray and tan, nonwelded ash-flow tuff, tuffaceous sedimentary rocks, red-brown conglomerates, tuffaceous rocks, black glassy lenses of dacitic spatter,

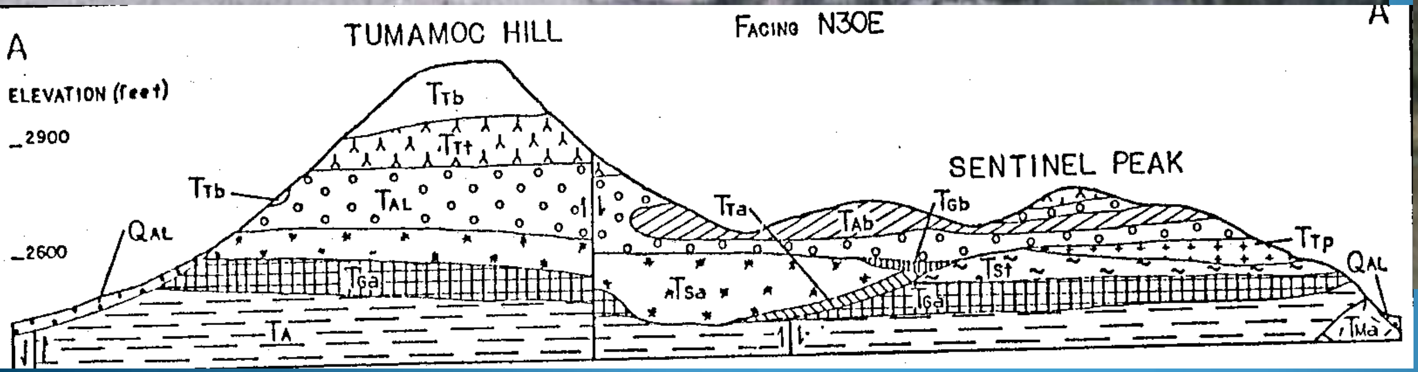
Tumamoc Hill and 'A' Mountain, viewed from the south (Ajo Rd)



Spencer and others, 2003

Student field trip question: Is 'A Mountain' a volcanic cone or is it an erosional remnant of lava flows and ash fall tuff?

Tumamoc Hill & Sentinel Peak ('A' Mountain)



Sequence of Rocks, ‘A’ Mountain

Map	Rock type	Special features	name	formation	Age (Ma)	
Ttb	Basalt	Some vesicles	Tumamoc basalt	Lava flow	23-24	
Ttt	Tuff	Pink tuff, Tan tuff, pumice fragments	Tumamoc tuff	Ash fall	26.4 27.4	
Tc	Agglo merate	Basalt (< 1inch) fragments, tuff matrix	Agglom-erate	Cinder fall, streams	26-28	
Tab	Basalt	Vesicular	basalt	Lava flow	27.6	
Ttt	Ande-site	Large plagioclase crystals	Turkey Track andesite		28.6	

Black Mountain (Del Bac Hills) 25.4-24.1 Ma

Black Mountain, view to south from Valencia Rd.

Turkey Track porphyry ~28 Ma

Late Galiuro – Whipple (18-13 Ma)

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
	Late	18-13	Late Tertiary	Quartz alkalic volcanics; detachment faulting	MQA	None in Tucson Mts.	

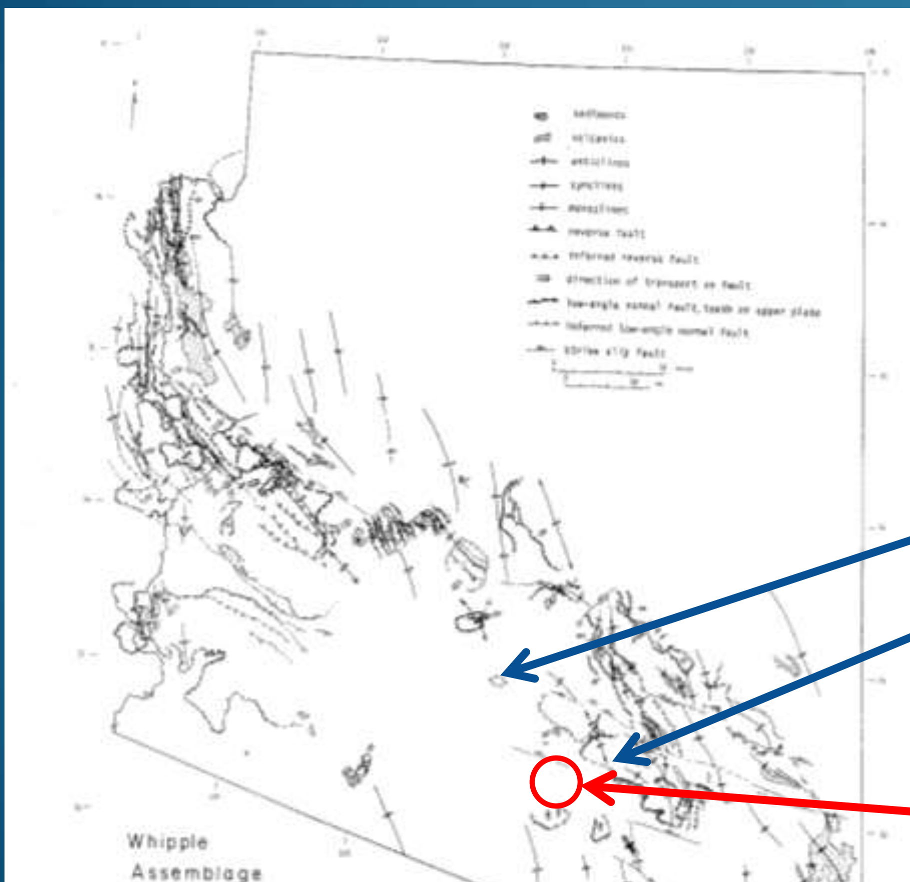
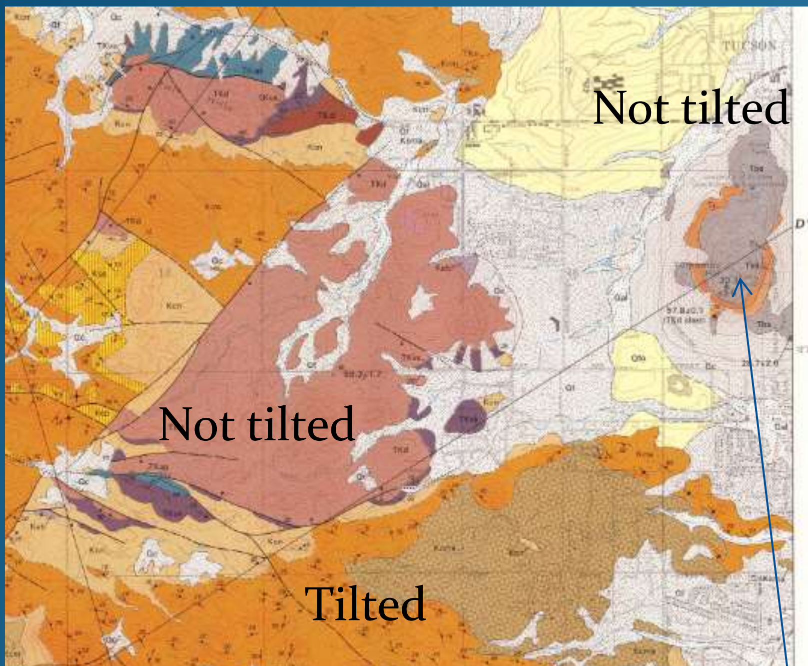


Figure 5. Map of Whipple assemblage of the culminant Galiuro orogeny in Arizona and vicinity.

- Model of detachment faulting at Picacho Peak and Catalina fault
- For us this is denudation faulting on the former Maricopa thrust system during uparching ~ 24-24 Ma
- No denudation faulting in Tucson Mts.

Late Galiuro – 18-13 Ma

Eastward tilting of Cretaceous volcanics was pre-58 Ma, before denudation faulting.



"Resurgent Amole pluton (≃72 Ma) in the northern Tucson Mountains was emplaced soon after eruption of the Cat Mountain Tuff but cooled and was magnetized after northeastward tilting (50°–85°) of the adjacent caldera-fill sequence" (Hagstrum & Lipmann, 1991)

Tucson Mountains did <u>NOT</u> slide off of the top of Santa Catalina Mountains

Late Galiuro – 18-13 Ma

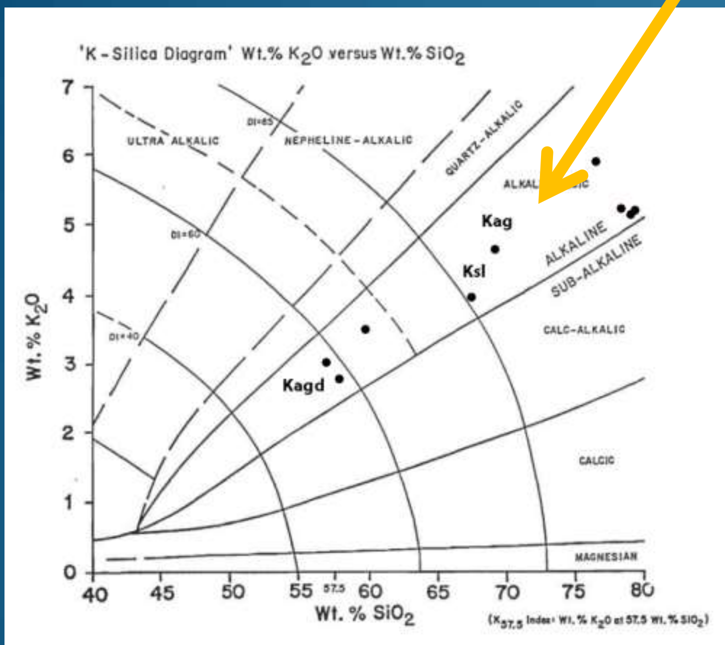
- **Nearly flat-lying volcanics on 'A' Mountain were earlier (28 Ma) than movement on the Catalina detachment fault (20.5-14.6 Ma) and are not tilted by detachment faulting in the Catalinas.**

- Outcrops of Cat Mountain Rhyolite, and Tertiary volcanics are not broken up into listric fault blocks as in upper plates of detachment faults in western AZ.

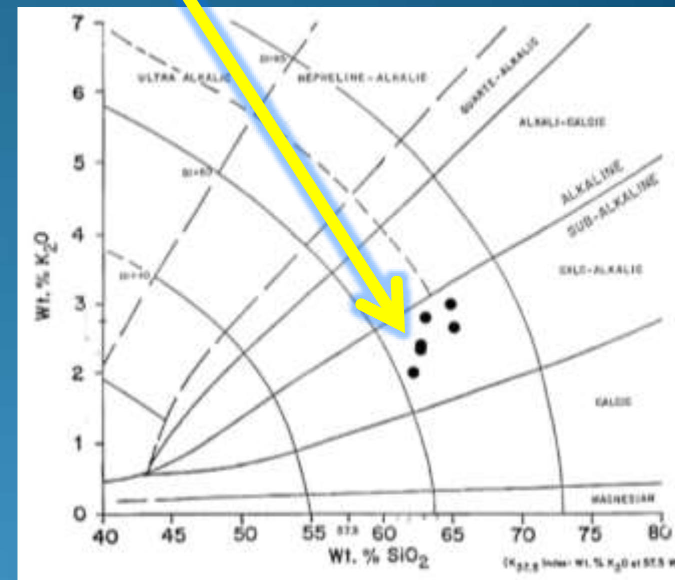
Tucson Mountains did NOT slide off of the top of Santa Catalina Mountains

Late Galiuro – 18-13 Ma

Chemistry of 72 Ma Leatherwood Quartz Diorite is calc-alkalic, while whole rock chemistry of 73 Ma Amole Granite is alkali-calcic. These are <u>not</u> the same rock mass, as their geochemical characteristics are very different.



MAC Amole granite & granodiorite, Cat Mountain Rhyolite, and Silver Lily dikes



MCA Leatherwood Quartz Diorite Santa Catalina Mountains

Tucson Mountains did <u>NOT</u> slide off of top of the Santa Catalina Mountains

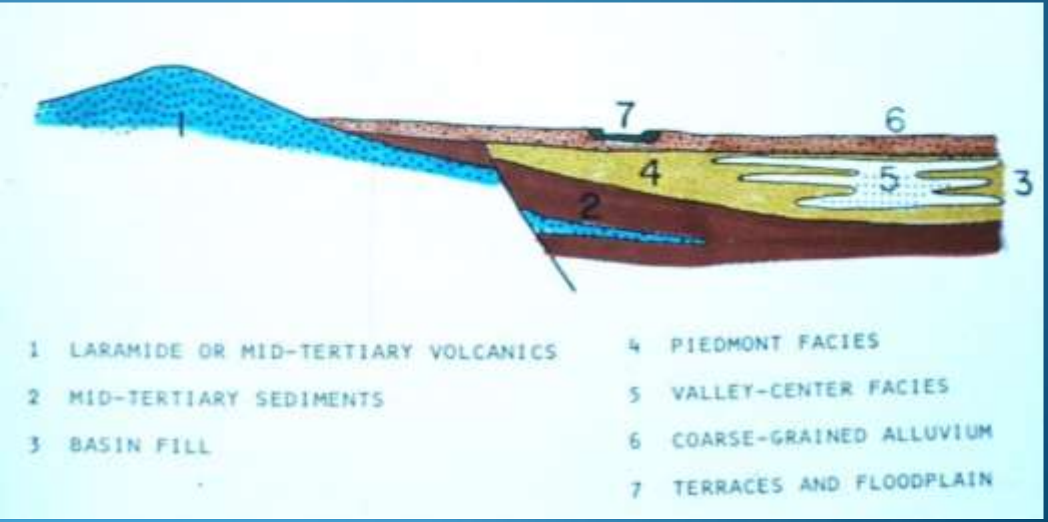
Late Tertiary - Basin & Range fault blocks

Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
Basin & Range	San Andreas	13-0	Latest Tertiary	anhydrous basaltic volcanism		Tertiary-Quaternary alluvium	

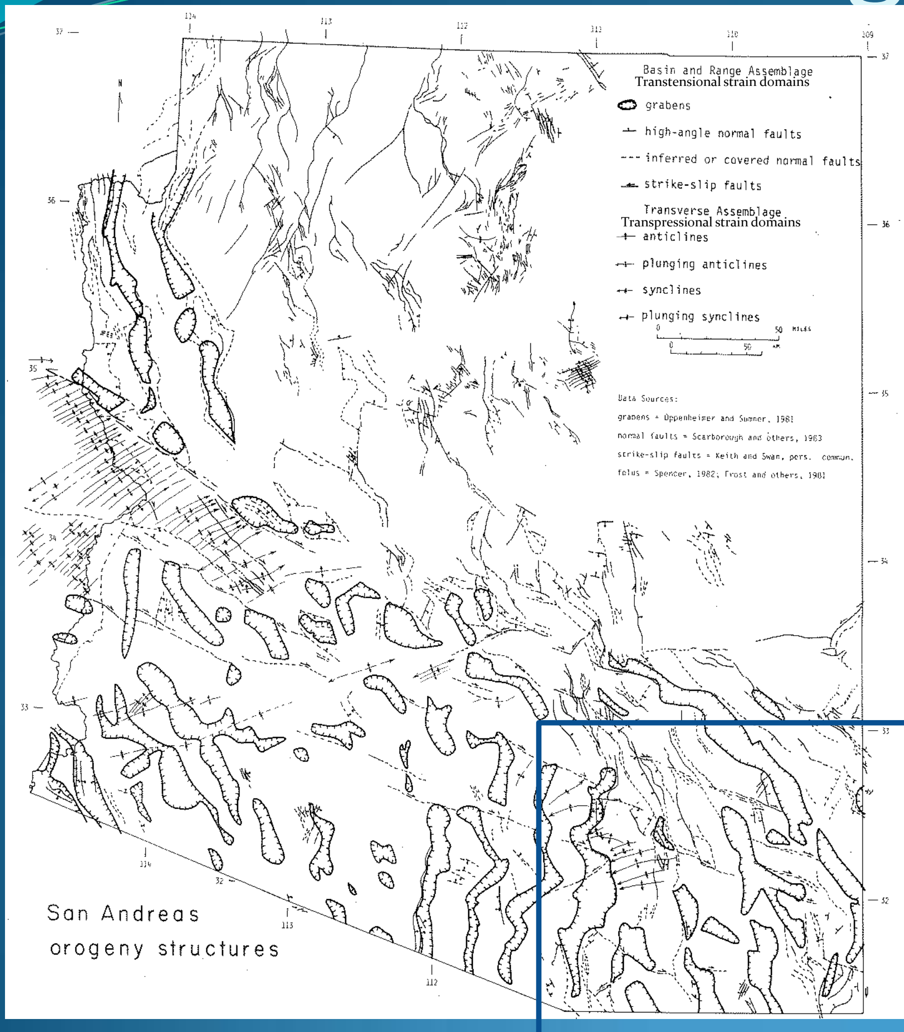
Yellow=basins

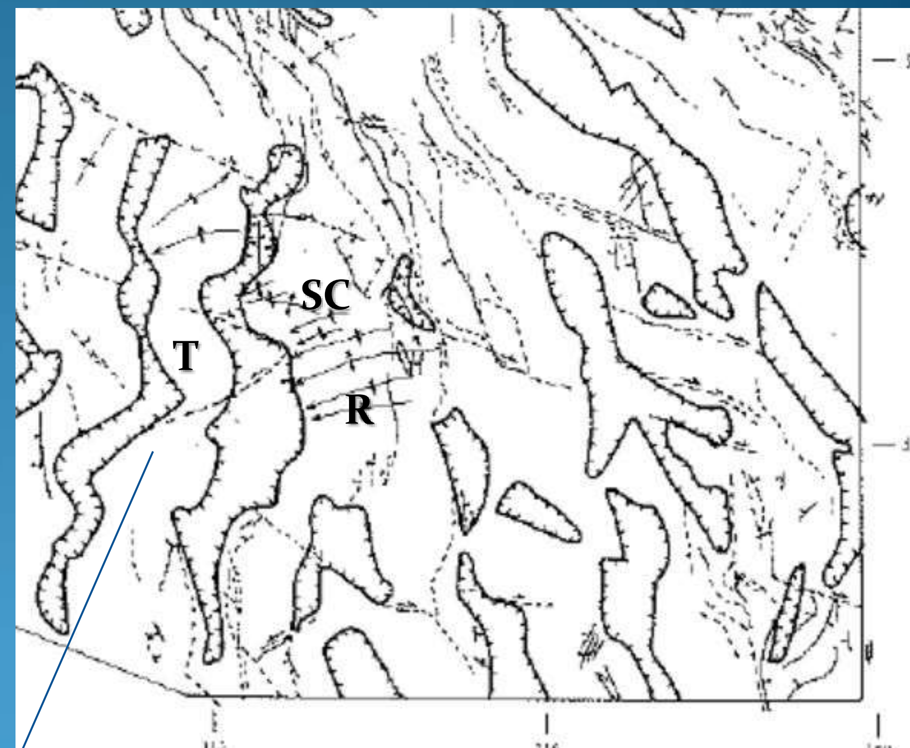
Basin and Range Valleys filled with sand, gravel, clay, gypsum, & salt

Sand & gravel

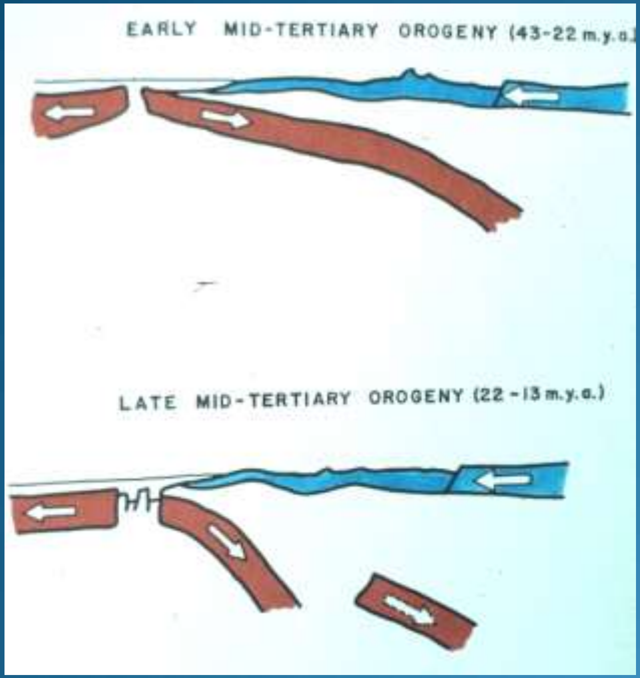


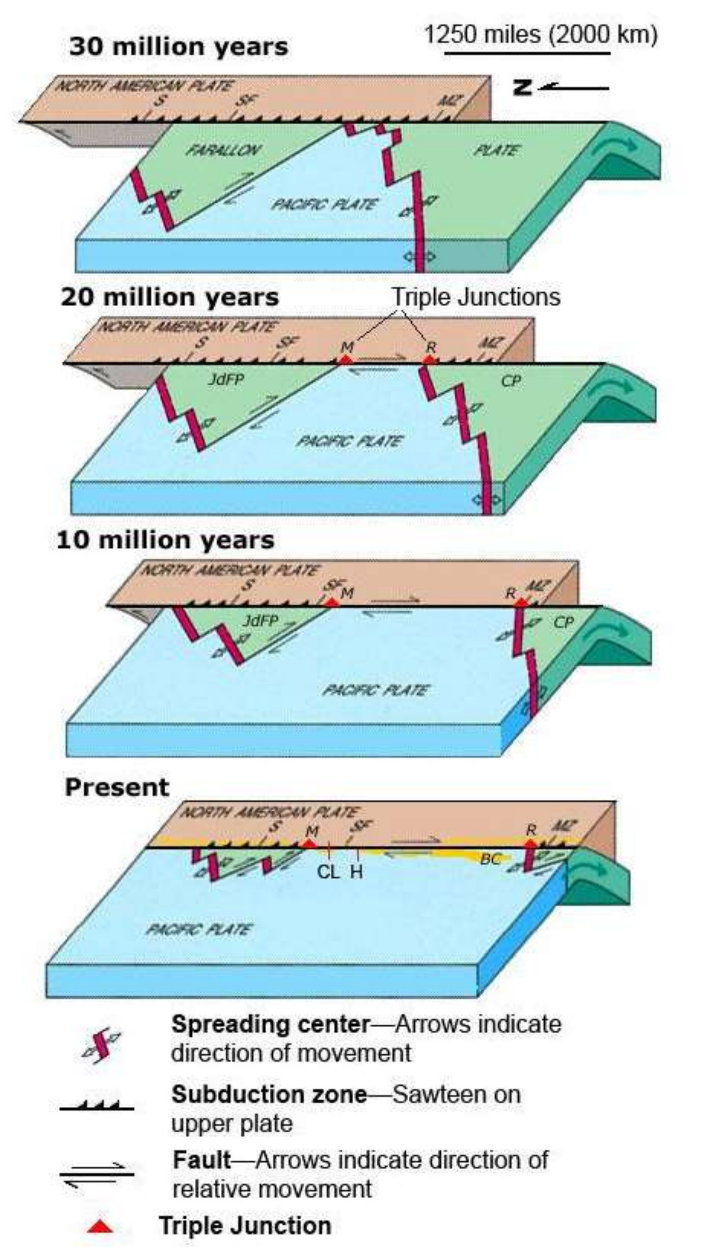
San Andreas Orogeny -13-5 Ma





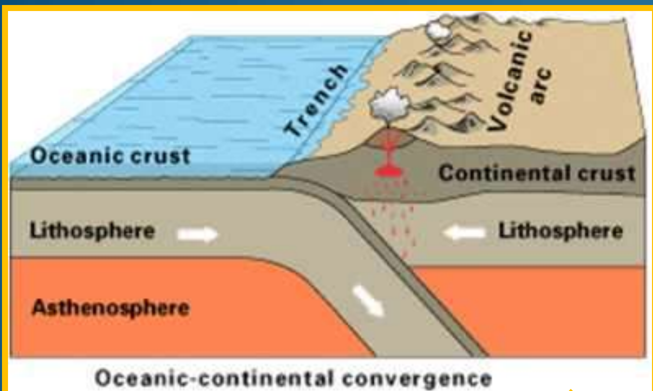
San Andreas-type transform fault cuts off eastward-subducting slab





Unsupported crust collapses into expanding area of no-slab window - transtensionally guided

Mountain Building Episodes in Tucson Mts.



Orogeny	Orogenic Phase	Age (Ma)	Age (period)	Arizona Magmatism	Alkalinity	Tucson Mts. formations	Age dates
San Andreas	Basin and Range	13-0	Latest Tertiary	Anhydrous basaltic volcanism		Tertiary-Quaternary alluvium; Recortado Tuff in Roskruge Mts.	12.9 Ma
Galiuro	Late	18-13	Late Tertiary	Quartz alkalic volcanics; detachment faulting	MQA	None in Tucson Mts.	
	Middle	28-18	Mid-Tertiary	Alkali-calcic ignimbritic volcanics & plutons	MAC	Safford Dacite & associated tuffs, Volcanics & tuffs of Tumamoc Hill	25.1 Ma Safford Peak dacite, 25.9 Ma Safford Tuff, 39.5 Ma basal Tsf1; 28.6-26.4 Ma Tumamoc basalts
	Earliest	39-28	Mid-Tertiary	Lake beds and possible erosion & secondary enrichment of Cu		Uranium sedimentary beds at Cardinal Avenue & Mission Rd.; Pantano Fm.	39.5 Ma basal Safford volcanic flow
Laramide	Late	55-40	Early Tertiary	Peraluminous 2-mica granites at great depths	PAC	None; Eocene erosion surface/unconformity below Safford Peak volcanics	43 Ma Wilderness Granite in Santa Catalina Mts.
	Middle	65-55	Cretaceous-Tertiary	Porphyritic granodiorite stocks, dacites, andesites, tuffs	MCA	Tuff of Beehive Peak, porphyritic granodiorite of Sedimentary Hills & Saginaw Hill, S. Tucson Mts.	58.3 Ma Twin Hills dacite
	Early	80-65	Late Cretaceous	Granite & granodiorite stocks; rhyolite ash flows, dikes	MAC	Cat Mountain Tuff rhyolite; Amole Granite-granodiorite; Silver Lily dikes	73.1 Ma welded tuff Kcw, 72.3 Ma Silver Lily dikes; 73 Ma Amole Granite
	Earliest	85-75	Late Cretaceous	High K shoshonite, latite, and rhyolite lavas	MQA	Yuma Mine volcanics in N. Tucson Mts.: Ft. Crittenden ss. equivalent	Large hadrosaur dinosaur bones in sandstone
Sevier		145-89	mid-Cretaceous	None	-	Amole Arkose (Albian-Cenomanian)	100 Ma
Nevadan	Late	160-145	Late Jurassic	Volcanics		Andesite porphyry of Brown Mountain	159 Ma
	Middle	205-160	Late & Middle Jurassic	Volcanic and plutonic rocks		Recreation Redbeds	190 Ma?
Alleghenian		290-260	Permian	None	-	Naco Group (Concha & Rain Valley at Snyder Hill; Scherrer at Sus P.A.	
Ancestral Rocky Mts./ Ouachita		315-307	Middle Penn.	None	-	Horquilla at Sus P.A. and Twin Peaks	
Acadian (E coast) Antler (NV)		410-380	Devonian	None	-	Martin, Escabrosa at Twin Peaks, Rillito Cement mine; Sus PA	
Taconic (E coast)		470-440	Ordovician	None	-	Cambrian Bolsa, Abrigo at Twin Peaks	
Picuris		1440 - 1335	Meso-proterozoic	K-feldspar megacrystic or porphyritic granites	PCA, PAC, some M	Porphyritic Oracle Granite – Twin Peaks South side	~1440 Ma
Mazatzal		1750 - 1600	Paleo-proterozoic		MC	Pinal Schist – Twin Peaks West side	~1650 Ma

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