Tucson Geologic History: Cenozoic (65.5 – 0 Ma (million years ago))

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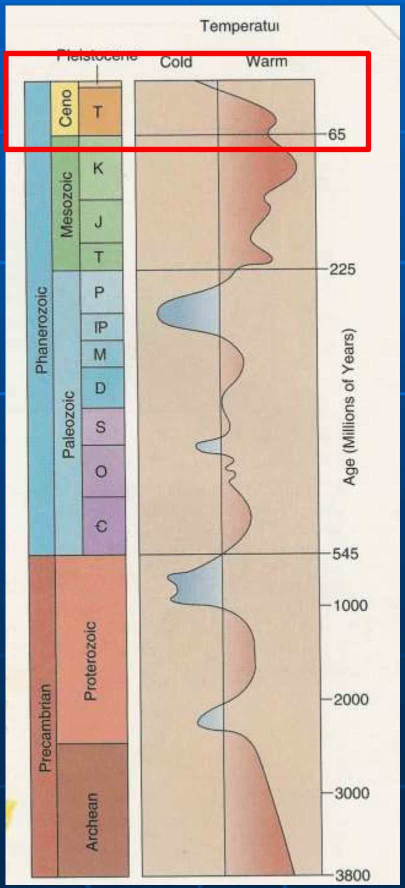
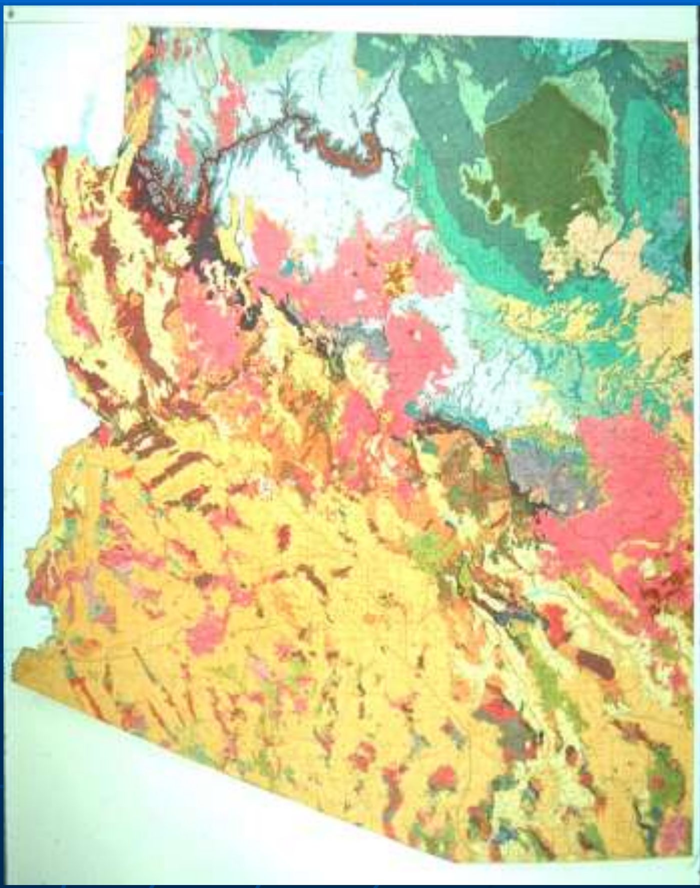




Temp. & Geologic Time Scale

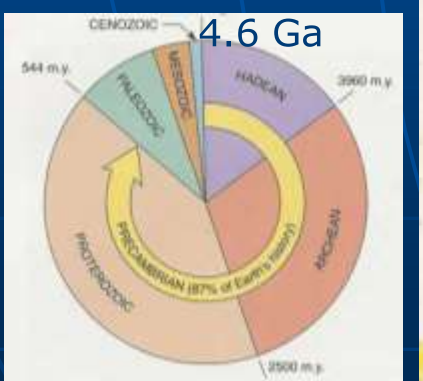
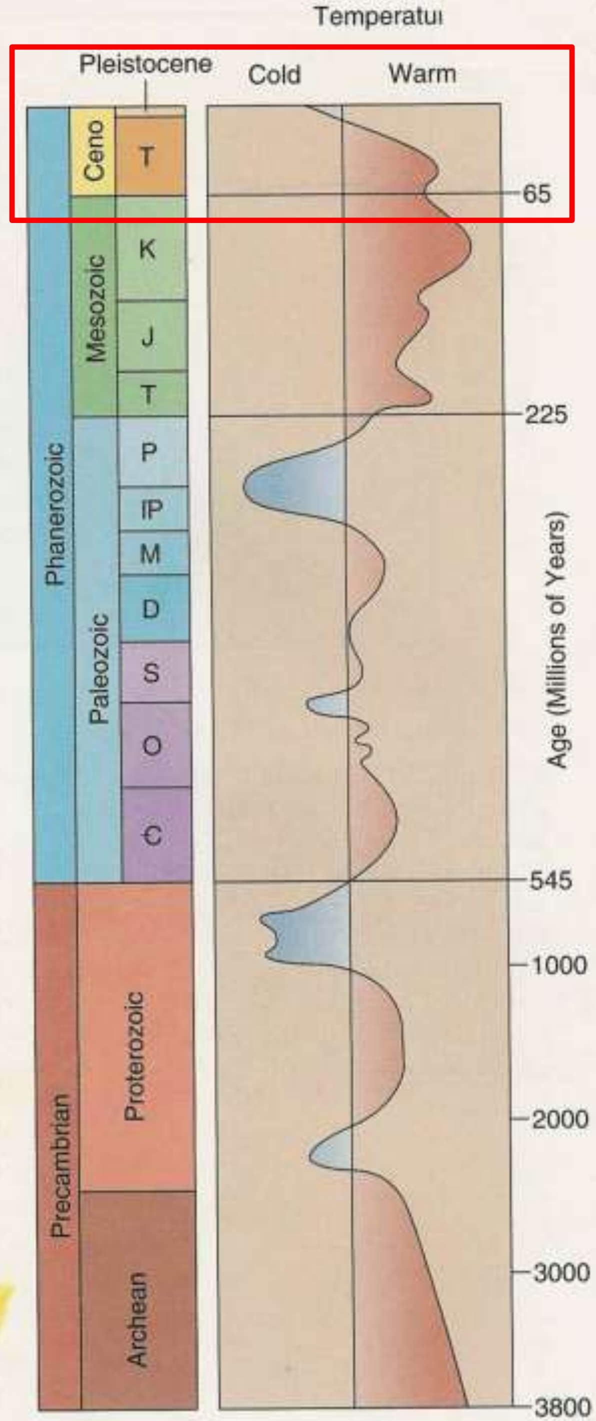
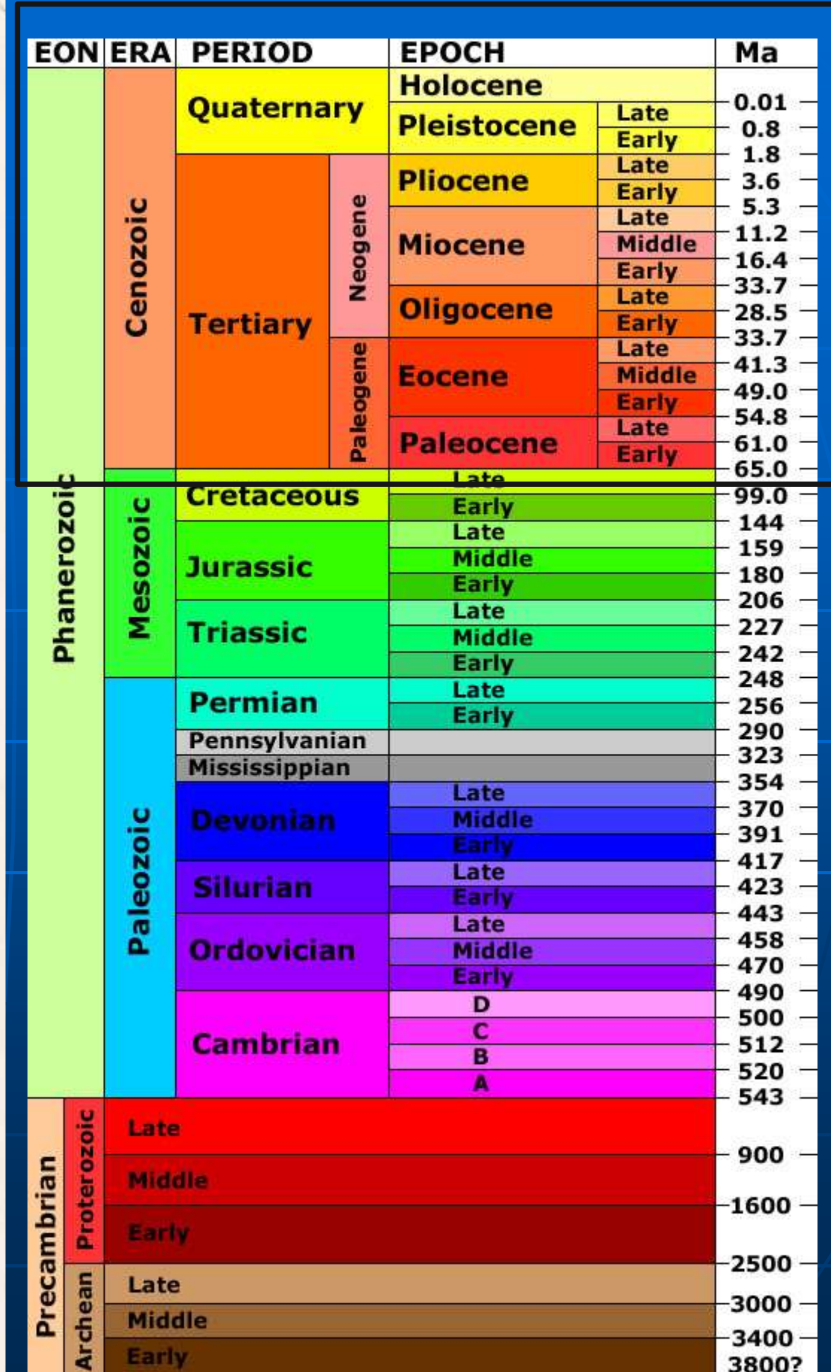


FIGURE 8-1 Proportions of geologic time encompassed by the Precambrian and its Hadean, Archean, and Proterozoic eons.





EON	ERA	PERIOD		EPOCH		Ma
Phanerozoic	Cenozoic	Quaternary		Holocene		0.01
				Pleistocene	Late	0.8
					Early	1.8
		Tertiary	Neogene	Pliocene	Late	3.6
					Early	5.3
				Miocene	Late	11.2
					Middle	16.4
					Early	33.7
				Oligocene	Late	28.5
			Paleogene		Early	33.7
				Eocene	Late	41.3
					Middle	49.0
					Early	54.8
				Paleocene	Late	61.0
					Early	65.0
	Mesozoic	Cretaceous		Late		99.0
				Early		144
		Jurassic		Late		159
				Middle		180
				Early		206
		Triassic		Late		227
				Middle		242
				Early		248
	Paleozoic	Permian		Late		256
				Early		290
		Pennsylvanian				323
		Mississippian				354
		Devonian		Late		370
				Middle		391
				Early		417
		Silurian		Late		423
				Early		443
		Ordovician		Late		458
				Middle		470
				Early		490
		Cambrian		D		500
				C		512
				B		520
				A		543
Precambrian	Proterozoic	Late				900
		Middle				1600
		Early				2500
	Archean	Late				3000
		Middle				3400
		Early				3800?

Tertiary – 65-0 Ma

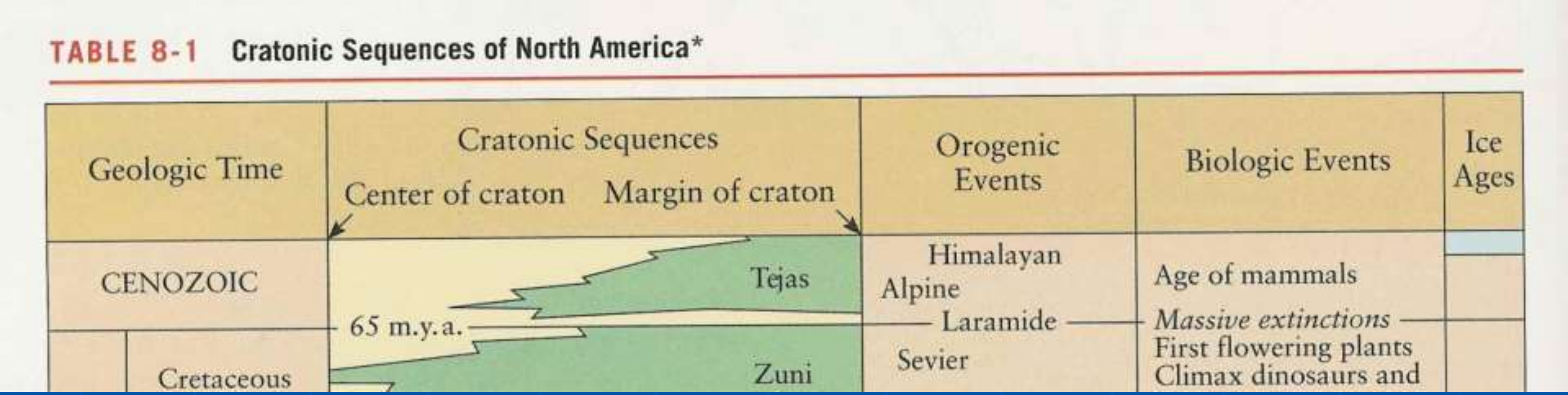
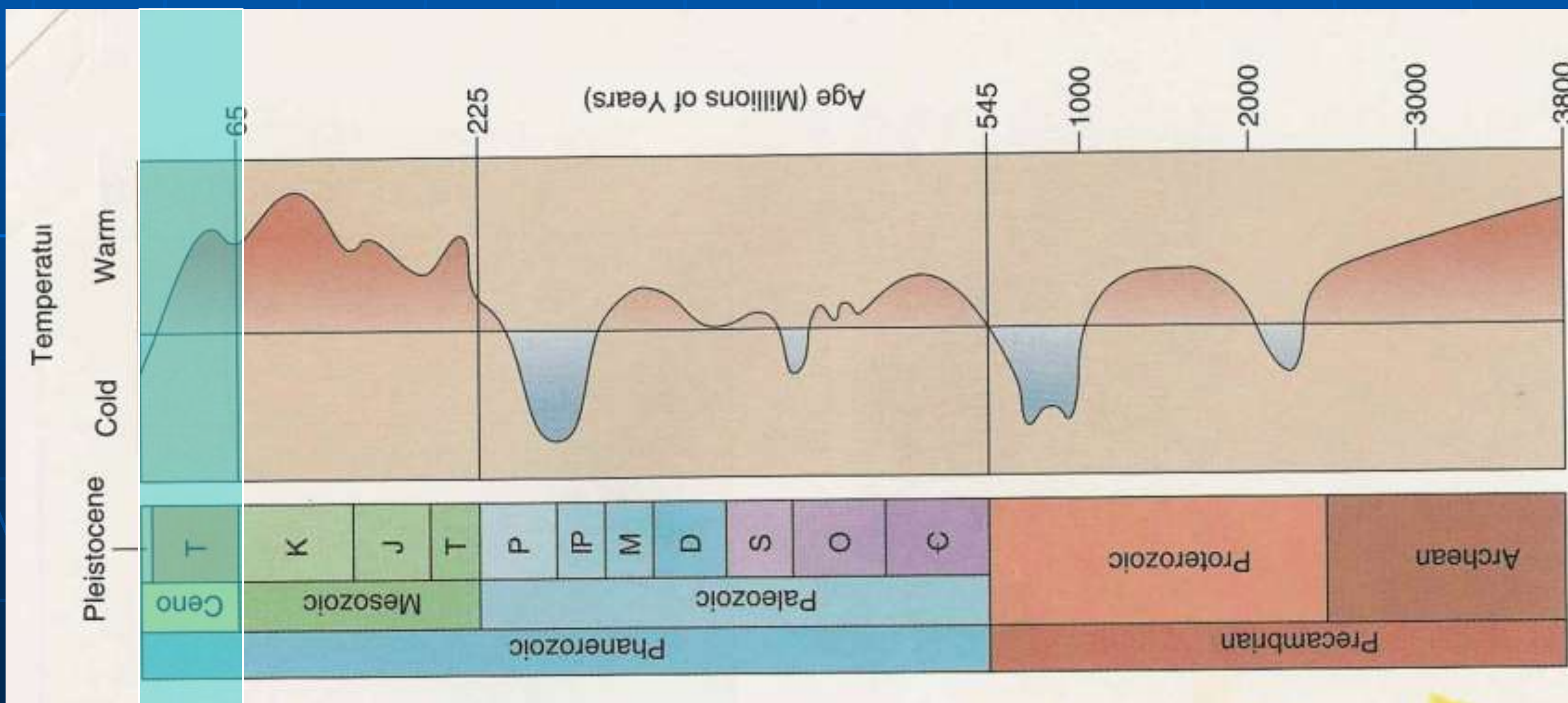


TABLE 8-1 Cratonic Sequences of North America*

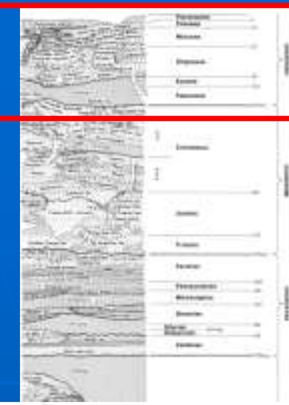
Geologic Time		Cratonic Sequences: Center of craton ↙ … Margin of craton ↘	Orogenic Events	Biologic Events	Ice Ages
CENOZOIC		Tejas	Himalayan Alpine	Age of mammals	
		65 m.y.a.	Laramide	*Massive extinctions*	
	Cretaceous	Zuni	Sevier	First flowering plants Climax dinosaurs and	

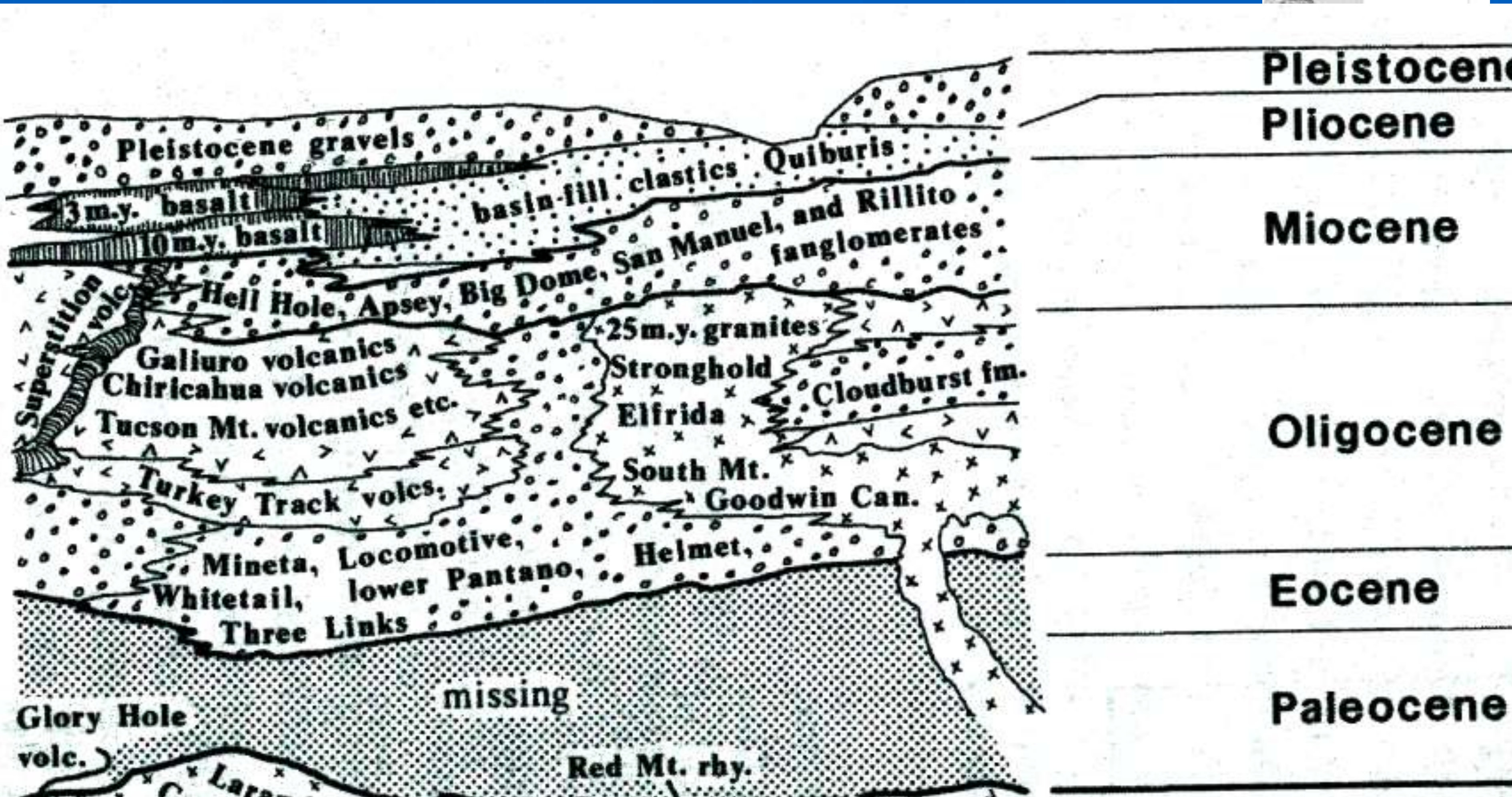


Orogenies (mountain building)

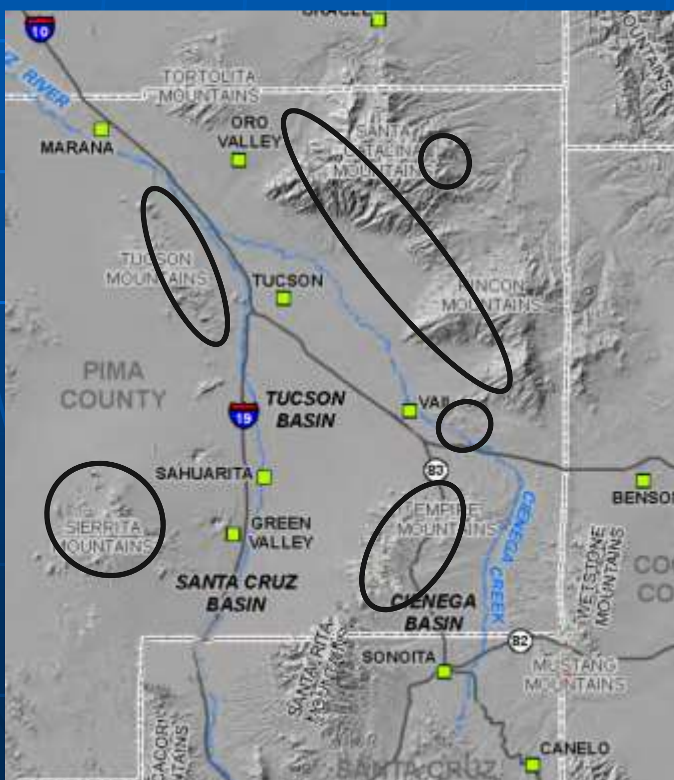
OROGENY	OROGENIC PHASE	ASSEMBLAGES	MAGMATISM	TECTONICS	MINERAL RESOURCES	EPOCH	TIME
SAN ANDREAS	Basin & Range	Basin & Range	basaltic volcanism	grabens	salt, cinders, sand gyp[illegible]	PLIOCENE	0-13

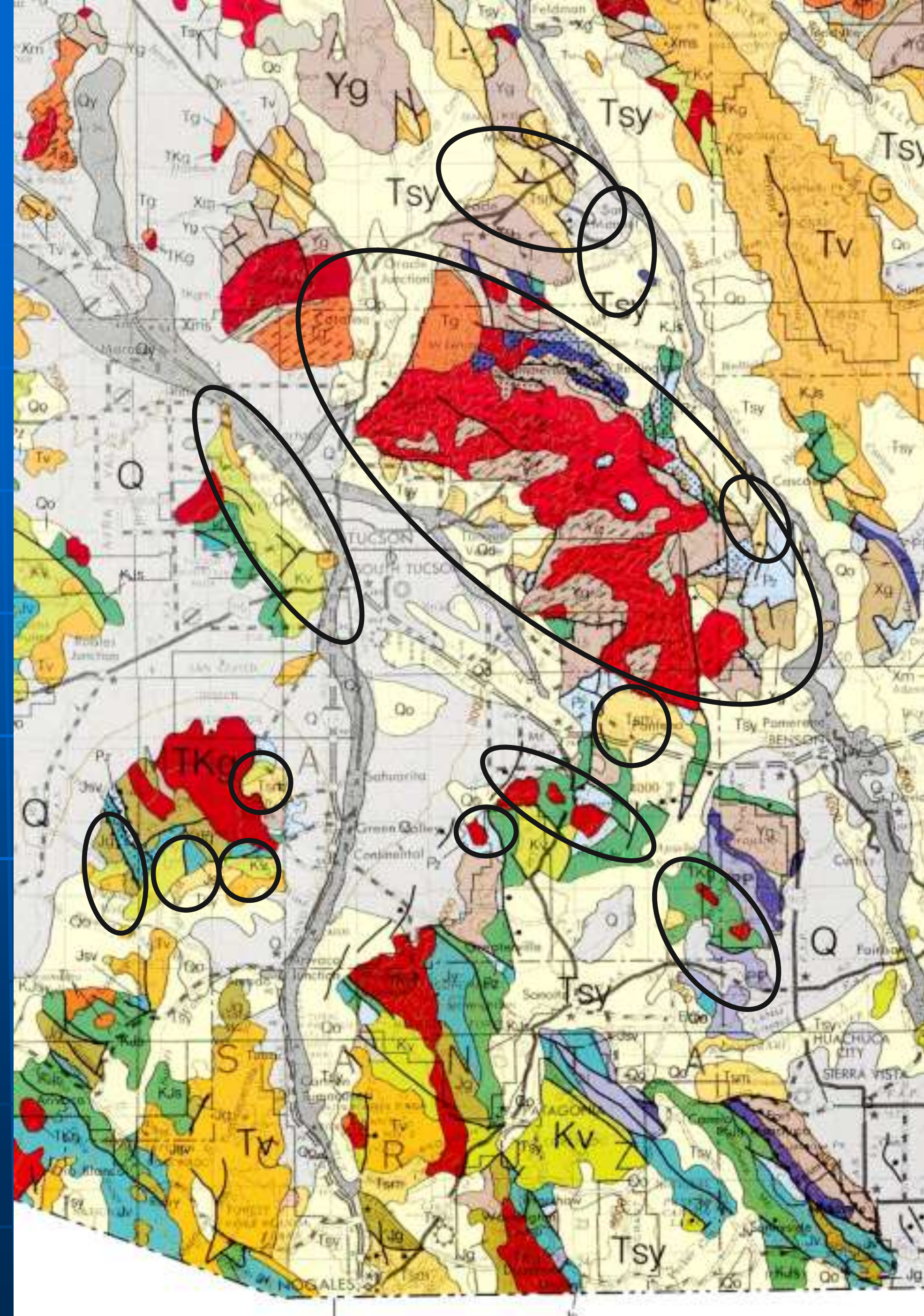
Cenozoic Formations near Tucson





Cenozoic outcrops around Tucson

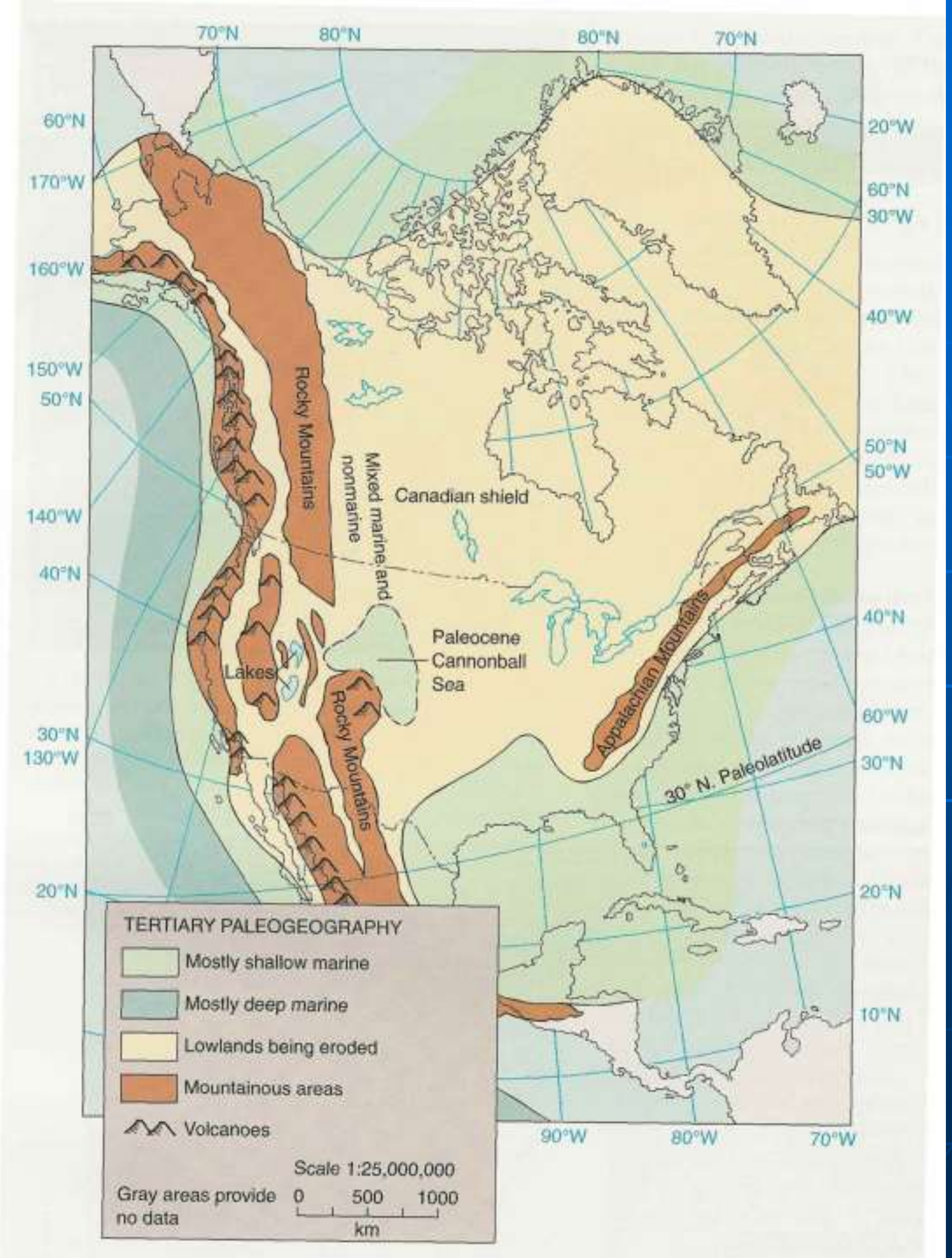




Early Cenozoic – porphyry Cu

OROGENY	OROGENIC PHASE	ASSEMBLAGES	MAGMATISM	TECTONICS	MINERAL RESOURCES	EPOCH	TIME
SAN ANDREAS	Basin & Range	Basin & Range	basaltic volcanism	grabens	salt, cinders, sand gyp	PLIOCENE	0-13

Early Tertiary paleogeography

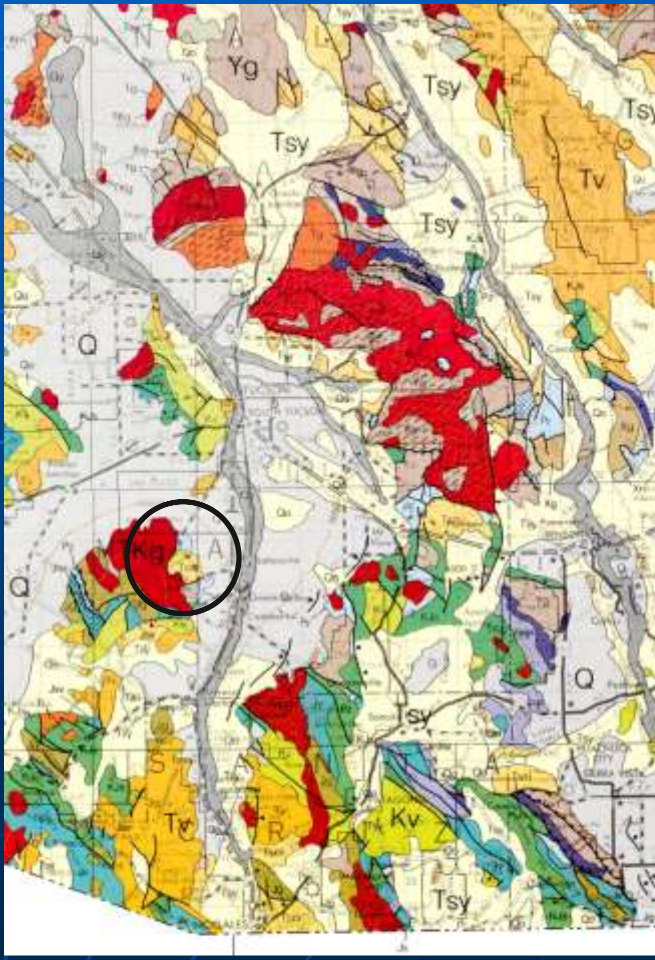


Tertiary (65-1.8 Ma)

Early Cenozoic - Middle Laramide (65-53 Ma) porphyry copper mines

Early Cenozoic - 65-54 Ma – porphyry copper deposits around Tucson

Early Cenozoic – porphyry Cu
Sierrita Mts. – Pima min. dist.



Porphyry copper deposits – Sierrita Mine

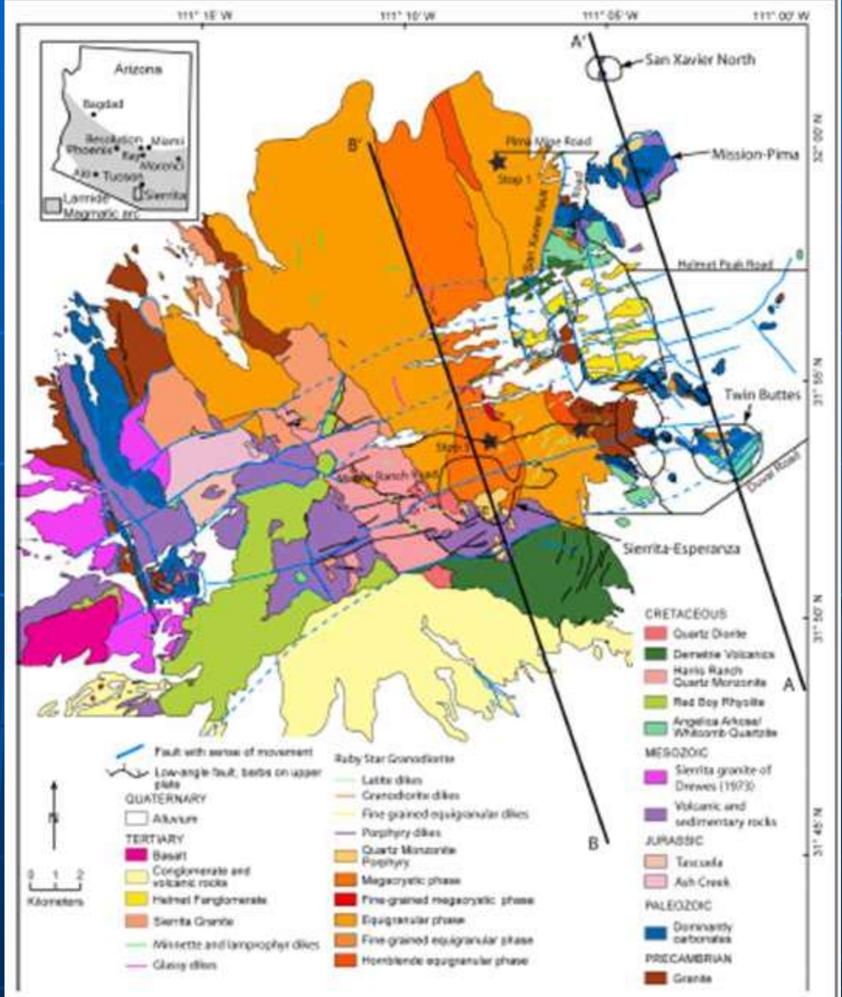


Figure 3. Geologic map of the Sierrita Mountains showing field trip stops, locations of mines, and locations of cross sections. Compiled and simplified from Cooper (1960), Drewes (1973), Ferguson et al. (2003), Johnson et al. (2003), Richard et al. (2003), and Spencer et al. (2003).

Minerals from Pima mining district

Mission mine

Ore Minerals from Mission mine

Chalcopyrite –
copper fools gold
Copper-iron-sulfide

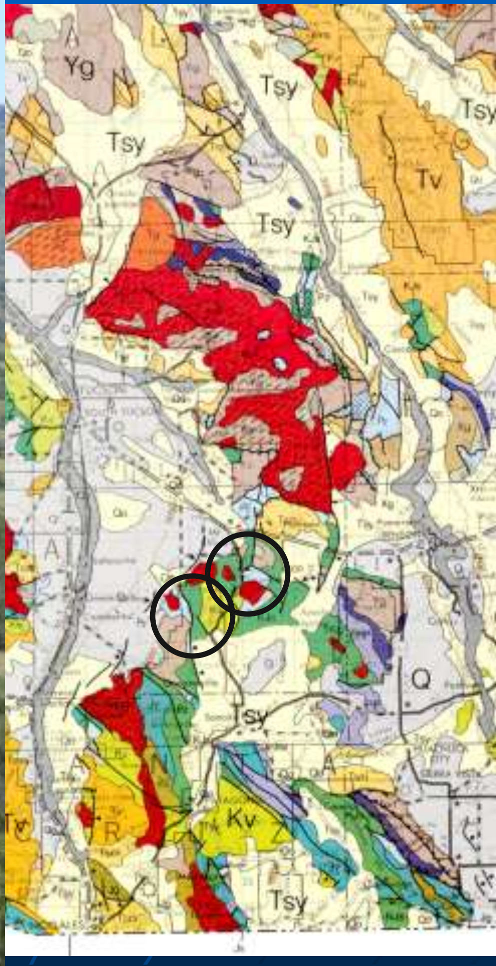
Bornite – peacock copper –
copper iron sulfide

Reclamation at Mission mine

Processing at Mission mine

Early Cenozoic – porphyry copper
Santa Rita Mts. – intrusive granitics

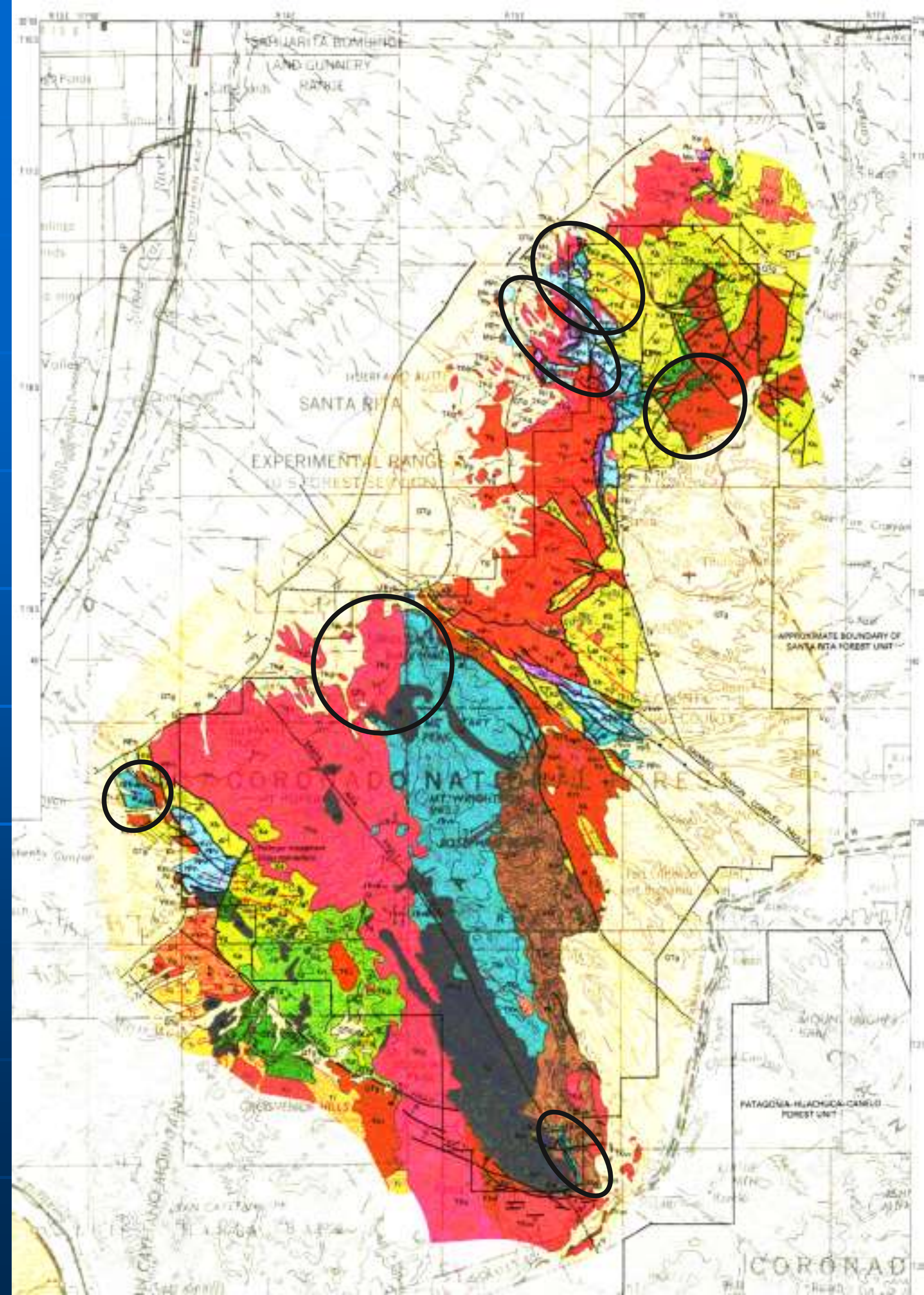
Rosemont/Helvetia



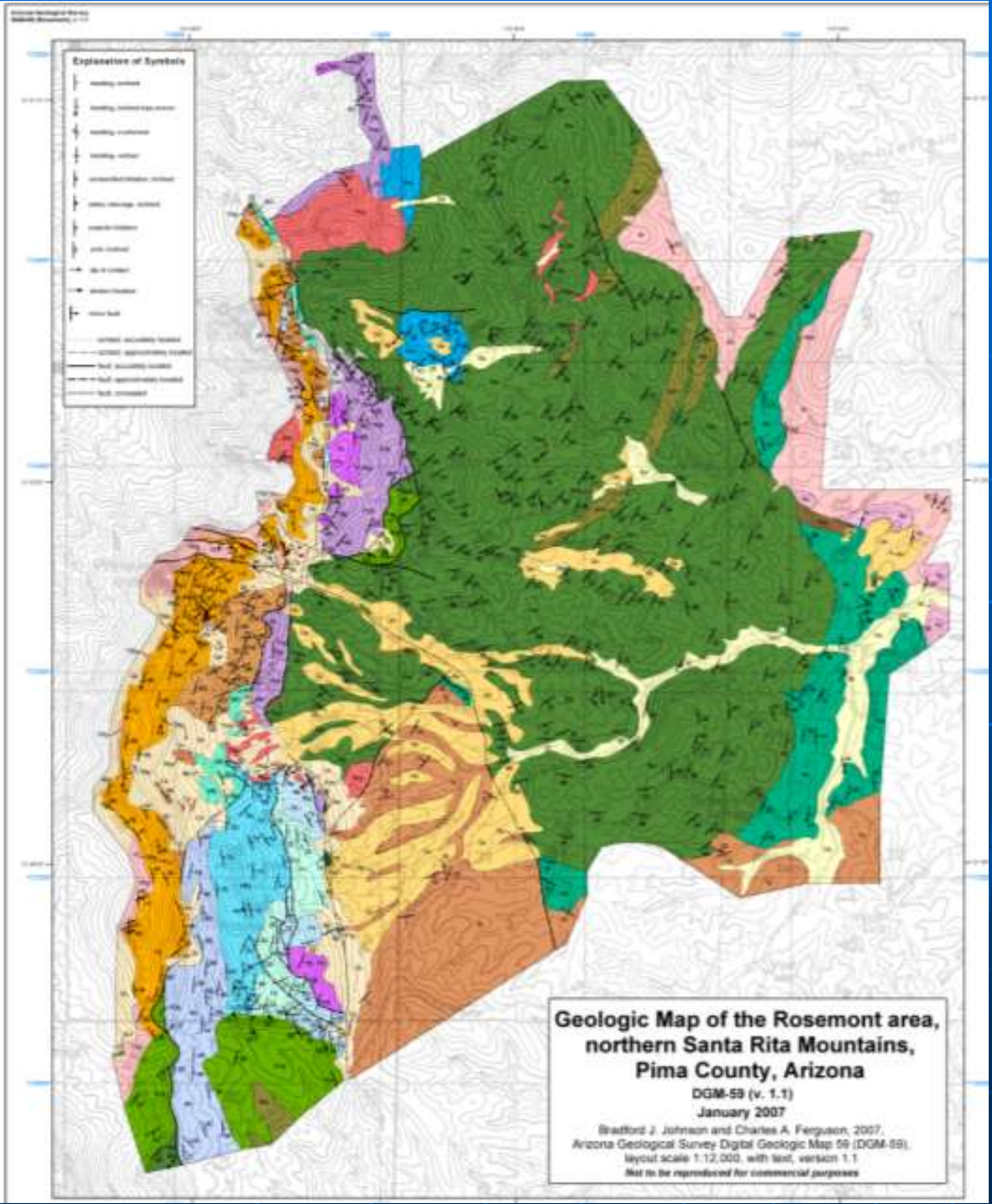
Early Cenozoic –

(54 Ma Ma)

Santa Rita Mts. – quartz monzonite porphyry

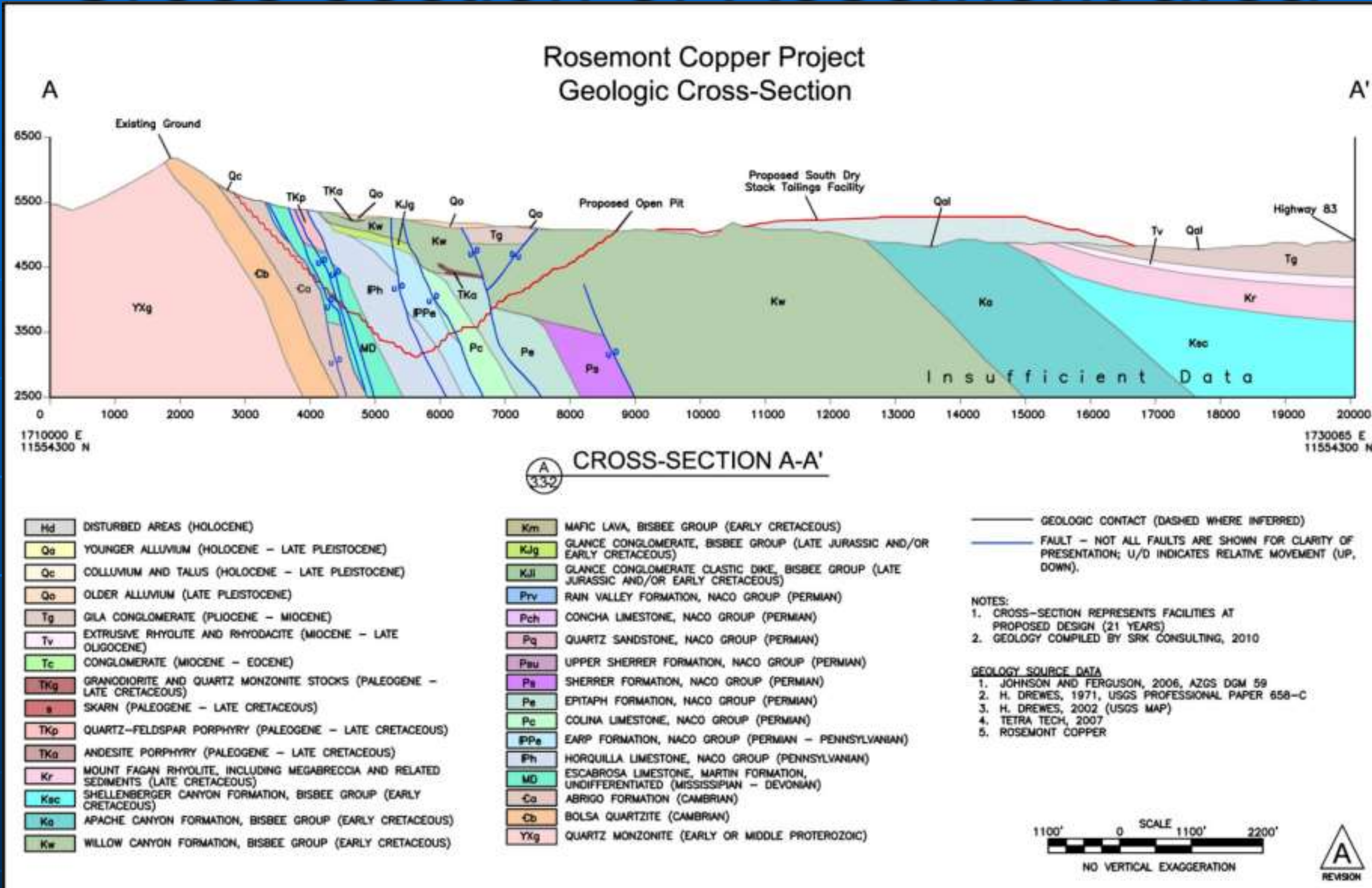


Geologic Map of Rosemont area

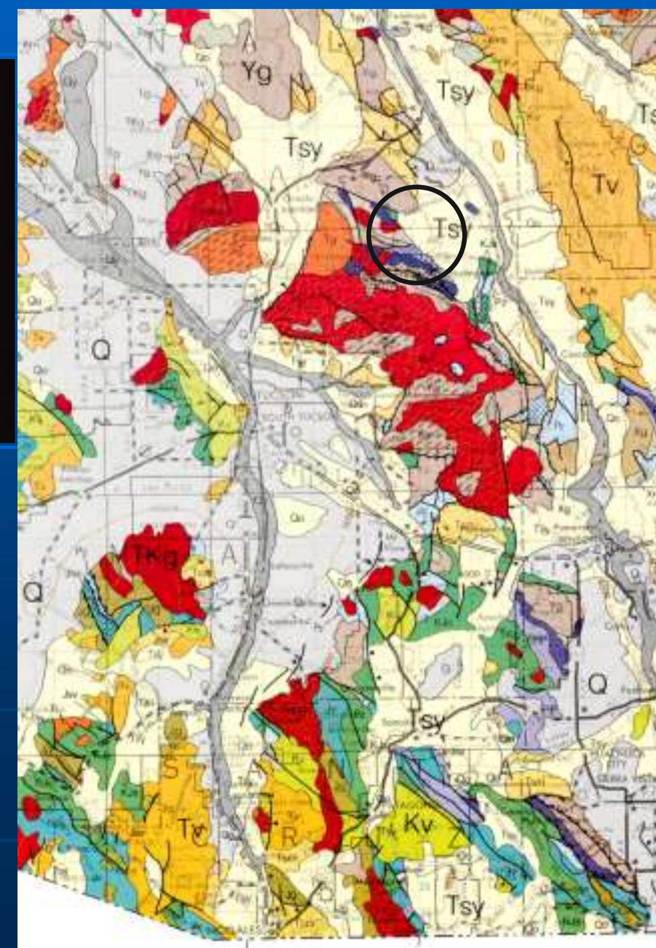


- Near vertical Paleozoic (blue) Limestones near crest
- Fault-bounded Paleozoics on west
- Mineralized Paleozoics buried under Cretaceous and Tertiary sedimentary rocks
- Cretaceous (green)bedding trends northeast

Cross section of Rosemont area



Early Cenozoic – porphyry Cu Catalina Mts. - San Manuel mine



1987

Santa Catalina Mts. - San Manuel mine - 1998

Santa Catalina Mts. - San Manuel mine

1999

2008

Santa Catalina Mts. - San Manuel mine

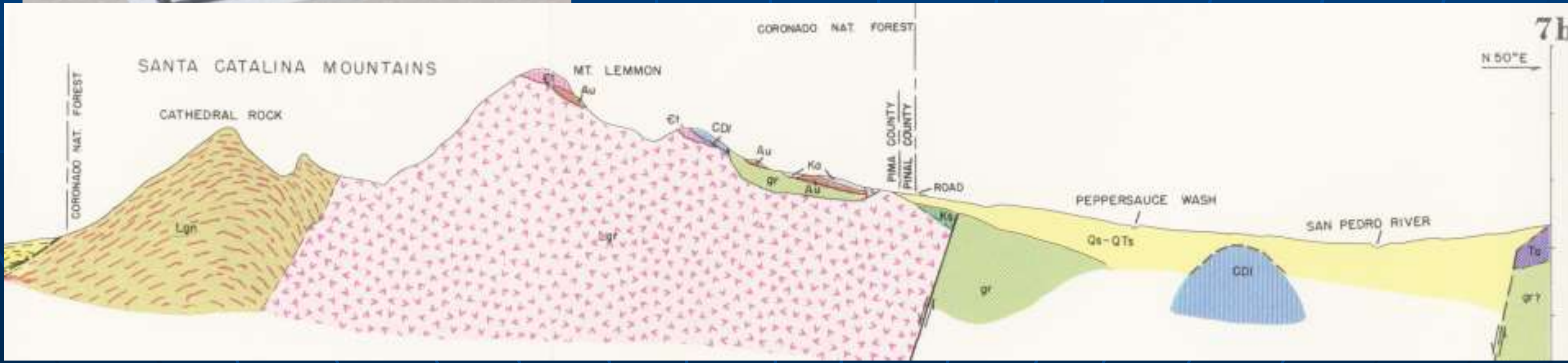
1999 Tailings impoundments

2008- tailings impoundments covered

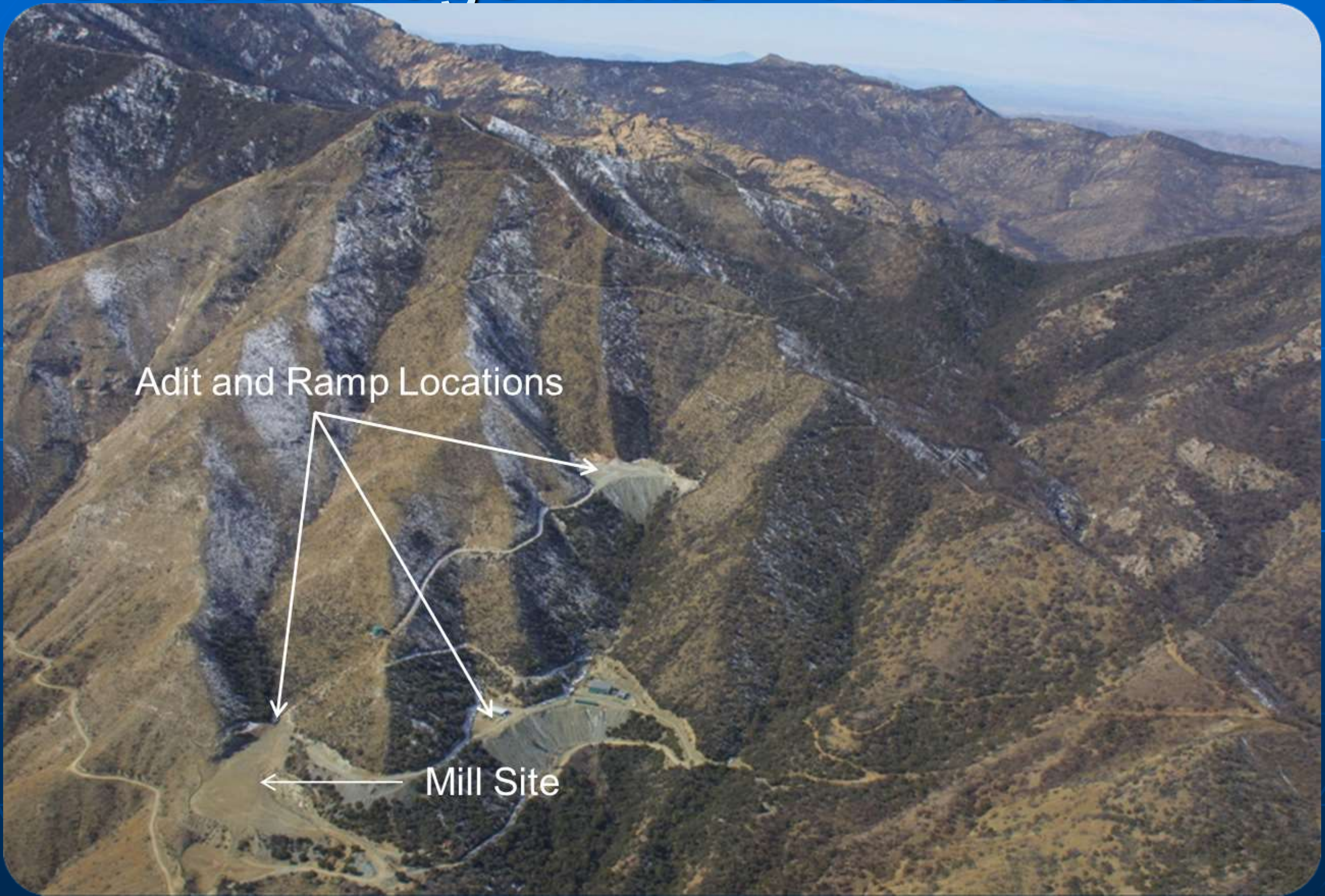
San Manuel minerals

Oracle Ridge mine – N. Catalinas

Leatherwood Quartz Diorite



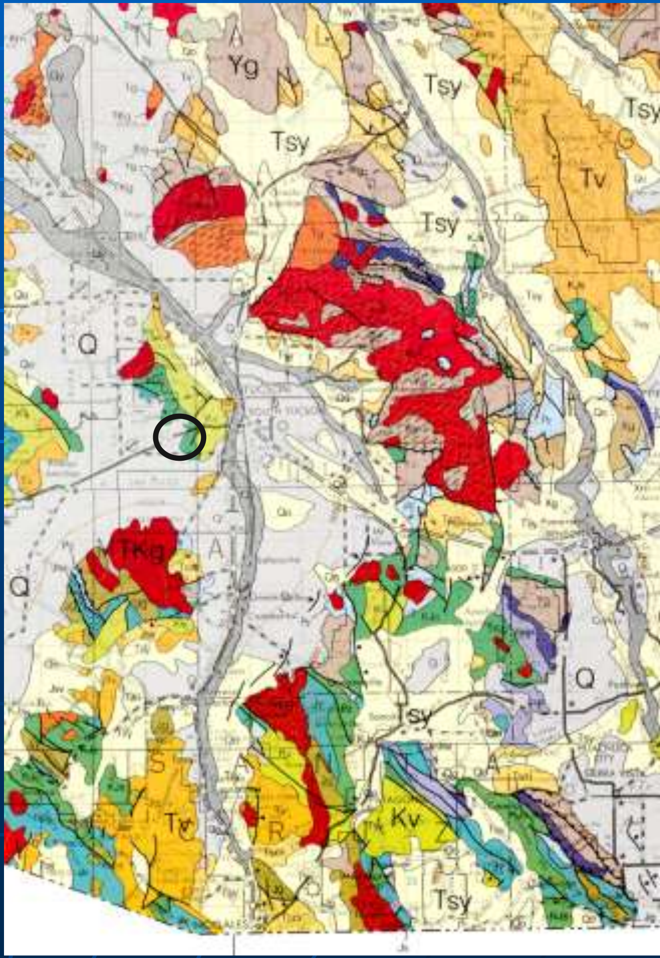
Oracle Ridge mine – N. Catalinas



Early Cenozoic – Laramide intrusions Tucson Mts.

Saginaw Hill

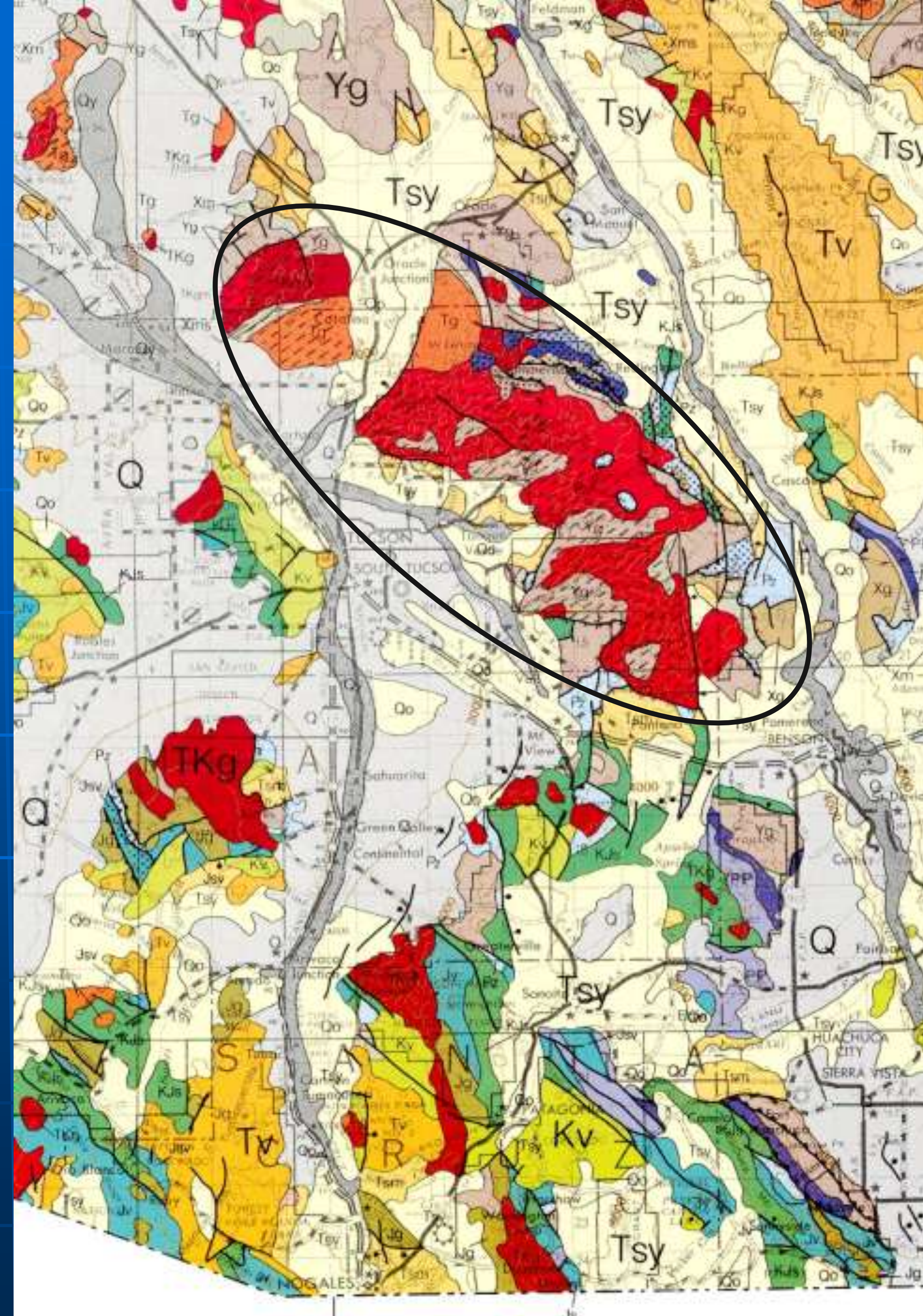
Sedimentary Hills



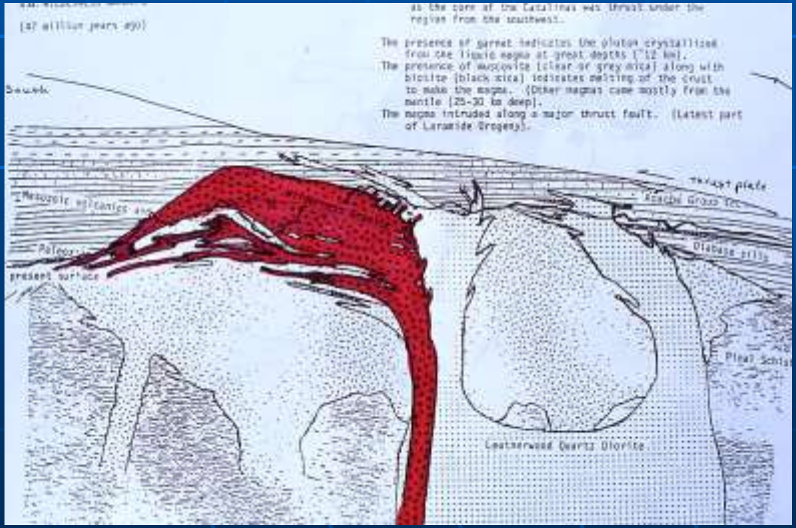
Latest Laramide Orogeny 53-43 Ma

OROGENY	OROGENIC PHASE	ASSEMBLAGES	MAGMATISM	TECTONICS	MINERAL RESOURCES	EPOCH	TIME
SAN ANDREAS	Basin & Range	Basin & Range	basaltic volcanism	grabens	salt, cinders, sand gyp[illegible]	PLIOCENE	0-13

Early Cenozoic Wilderness Granite suites



Wilderness Granite



Looking west from ~ Sabino

Bands of Wilderness granite in dark Oracle Granite

Looking east from west of Oro Valley

Santa Catalina Mts. - Wilderness Granite 43 Ma

Garnets in Wilderness Granite

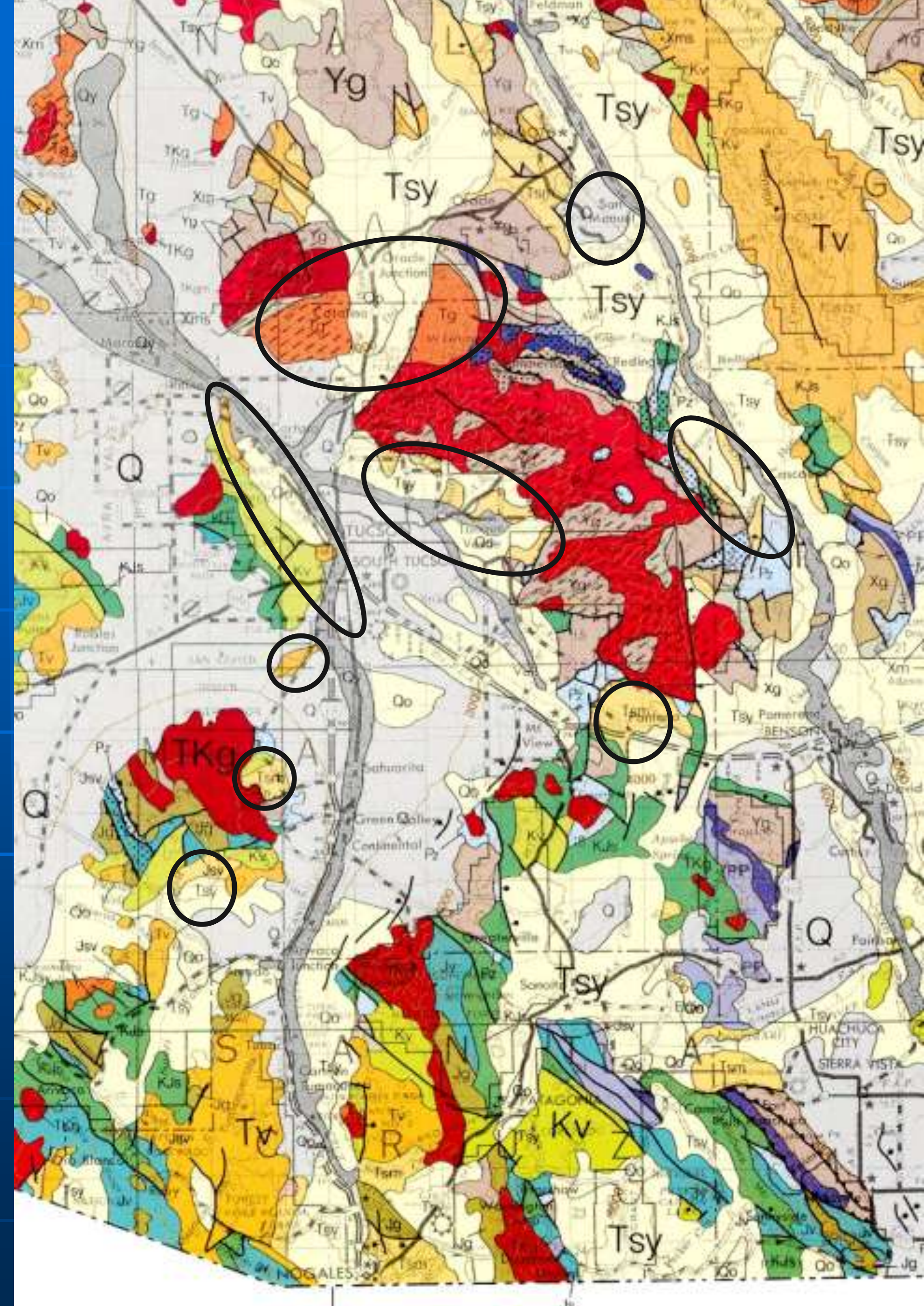
Santa Catalina Mts. - Wilderness Granite 43 Ma

Texas Canyon granite – ~45 Ma

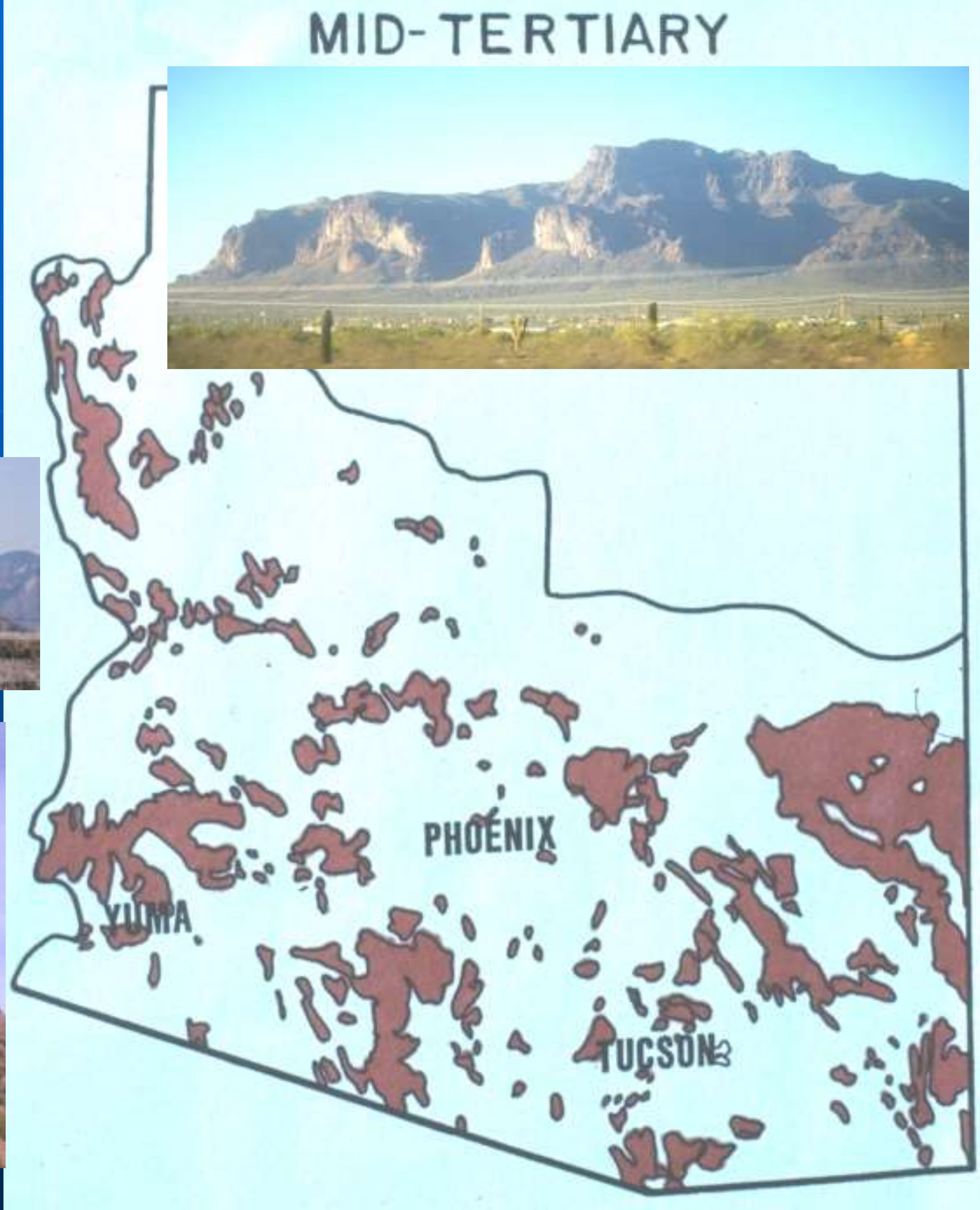
Mid-Cenozoic mountain building - volcanoes – like Cascades

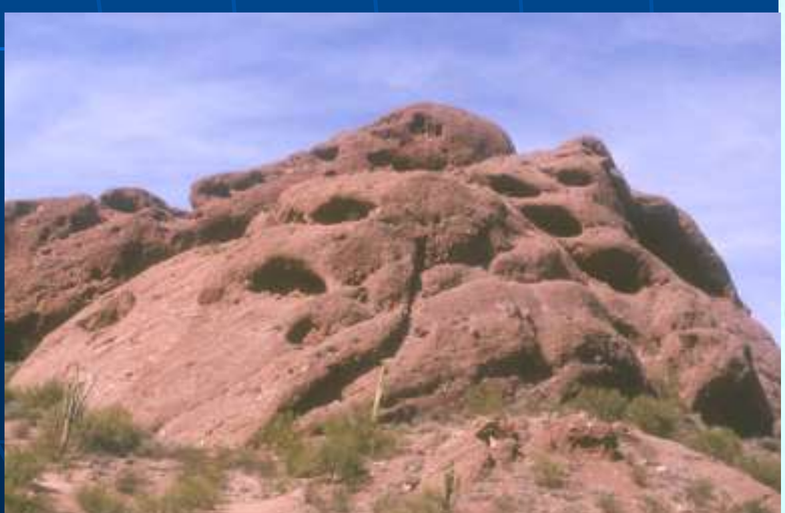
OROGENY	OROGENIC PHASE	ASSEMBLAGES	MAGMATISM	TECTONICS	MINERAL RESOURCES	EPOCH	TIME
SAN ANDREAS	Basin & Range	Basin & Range	basaltic volcanism	grabens	salt, cinders, sand gyp[illegible]	PLIOCENE	0-13

Mid-Cenozoic outcrops around Tucson

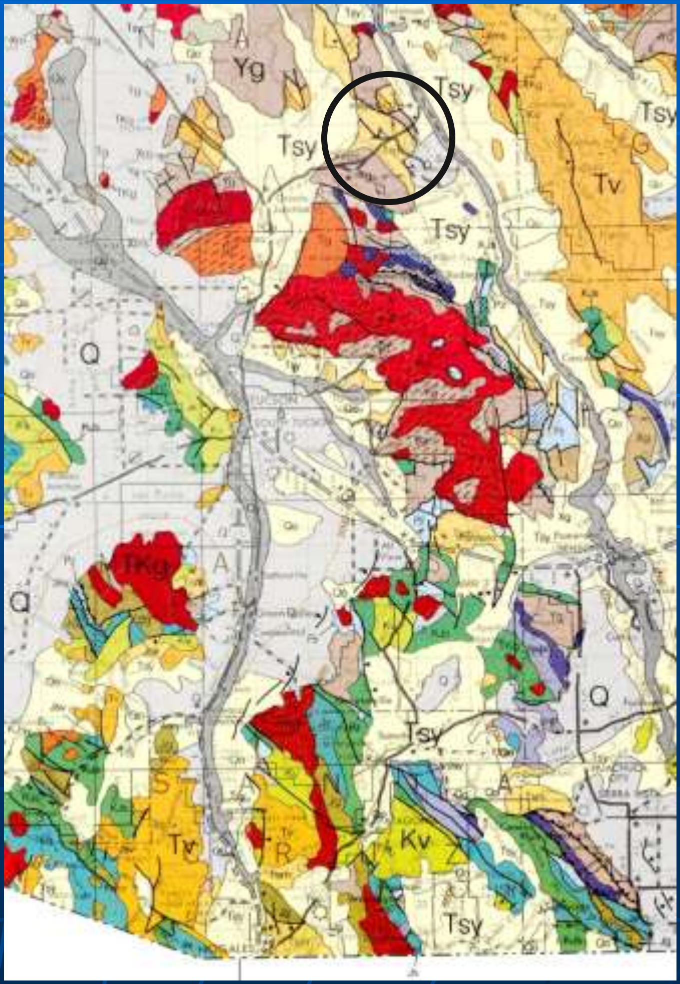


Mid-Cenozoic volcanics





Mid-Tertiary volcanics – rhyolite at Tiger, northern Catalinas



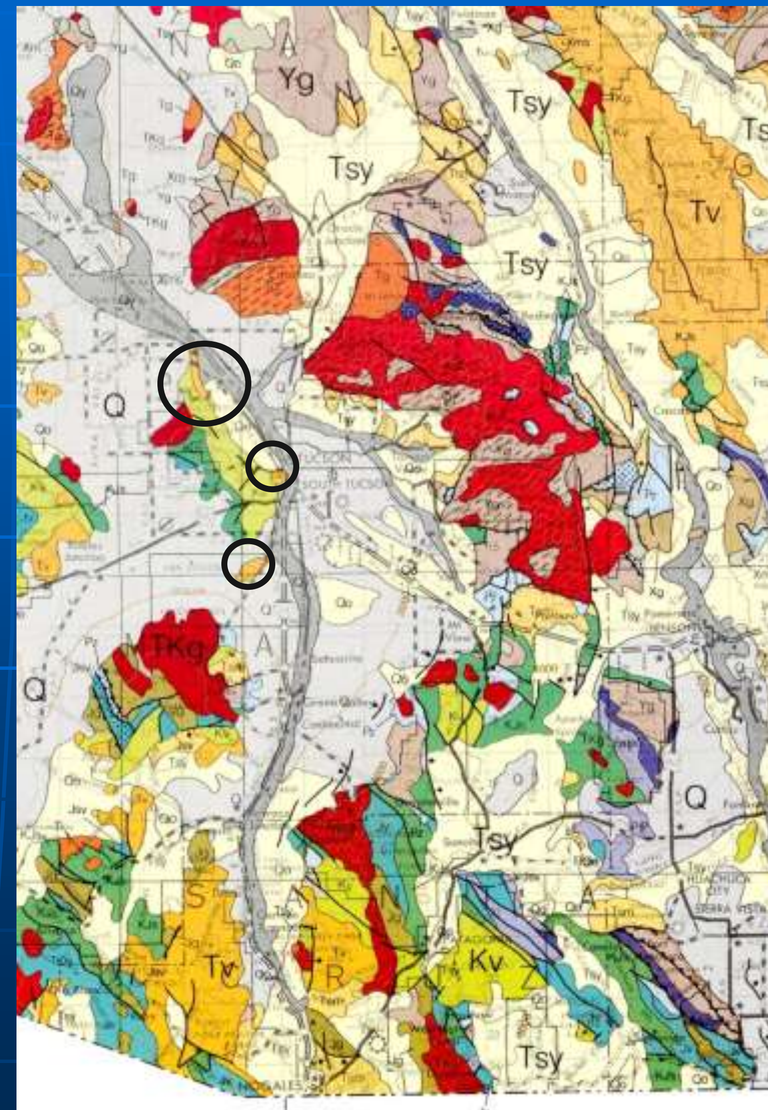
Mid-Tertiary – Santa Catalinas - Tiger – Mammoth-St. Anthony mine

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

Tucson Mts. mid-Tertiary volcanics

West of Contzen Pass, northern Tucson Mts.

Tumamoc Hill & A Mountain



Is A Mountain a volanic cone or is it an erosional remnant?

Sequence of Rocks, A Mountain

Map	Rock type	texture	Special features	name	formation	age
Ttb	Basalt	Fine-grained	Some vesicles	Tumamoc basalt	Lava flow	19.8
Ttt	Tuff	Pyroclastic	Pink tuff, Tan tuff, pumice fragments	Tumamoc tuff	Ash fall	25.8
Tal	Agglomerate	Pyroclastic	Basalt (< 1inch) fragments, tuff matrix	Agglomerate	Cinder fall	27
Tab	basalt	Fine-grained	Vesicular	basalt	Lava flow	28

Base of A Mountain – Mission Road

Andesite Porphyry at base of A Mountain

Caliche = natural concrete

Midway up = A Mountain basalt

Agglomerate

Tan tuff

Tan Tuff overlain by Pink Tuff

Pumice in Pink Tuff

Top basalt

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

Black Mountain, view to south from top of A Mountain

Age Dates, southern Tucson Mountains

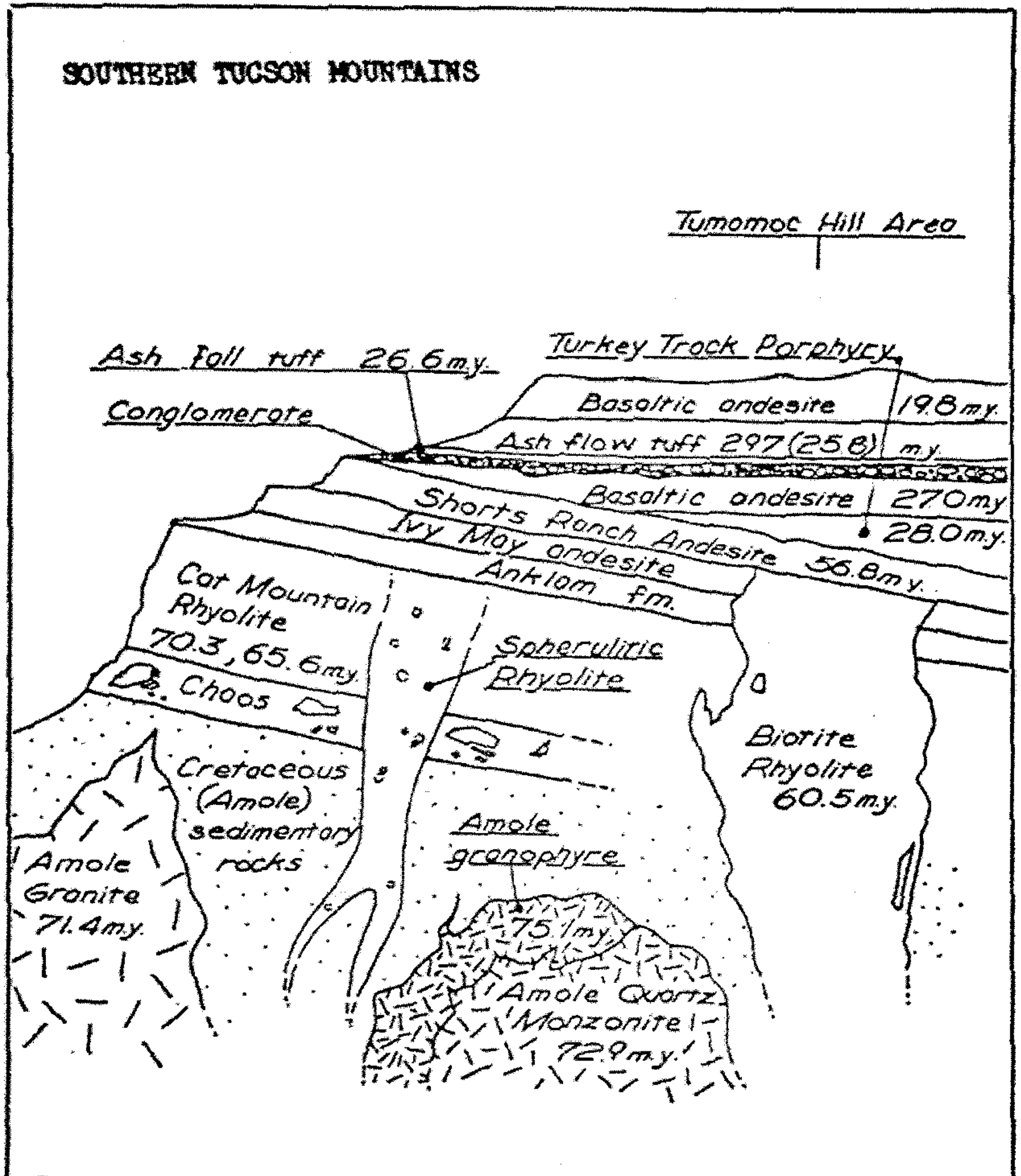
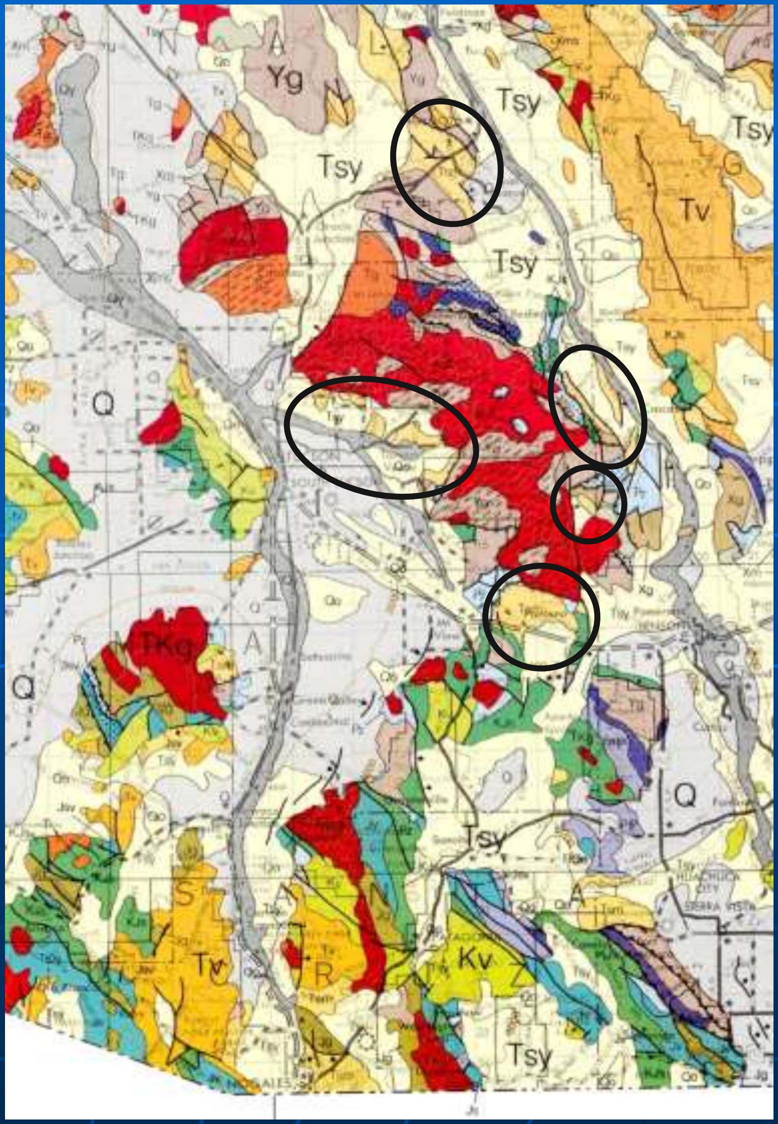


Figure 2. Idealized section through the southern Tucson Mountains, Arizona. Geology *after*: Tolman (1909); Brown (1939); J. E. Kinnison (1958, M.S. thesis, Univ. Arizona)

Rincon Mts – mid-Tertiary

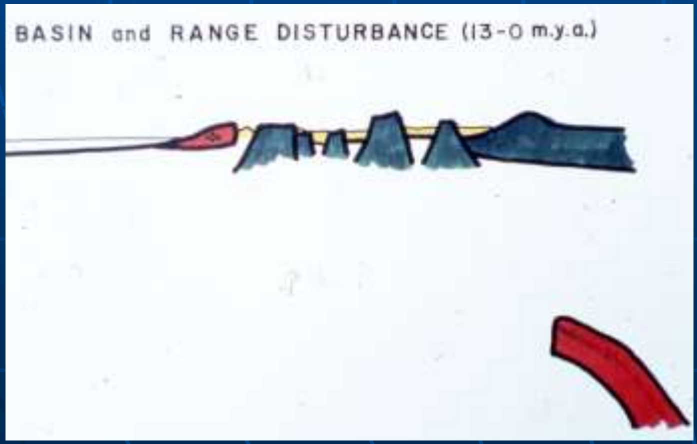
Turkey Track Andesite – 27 Ma

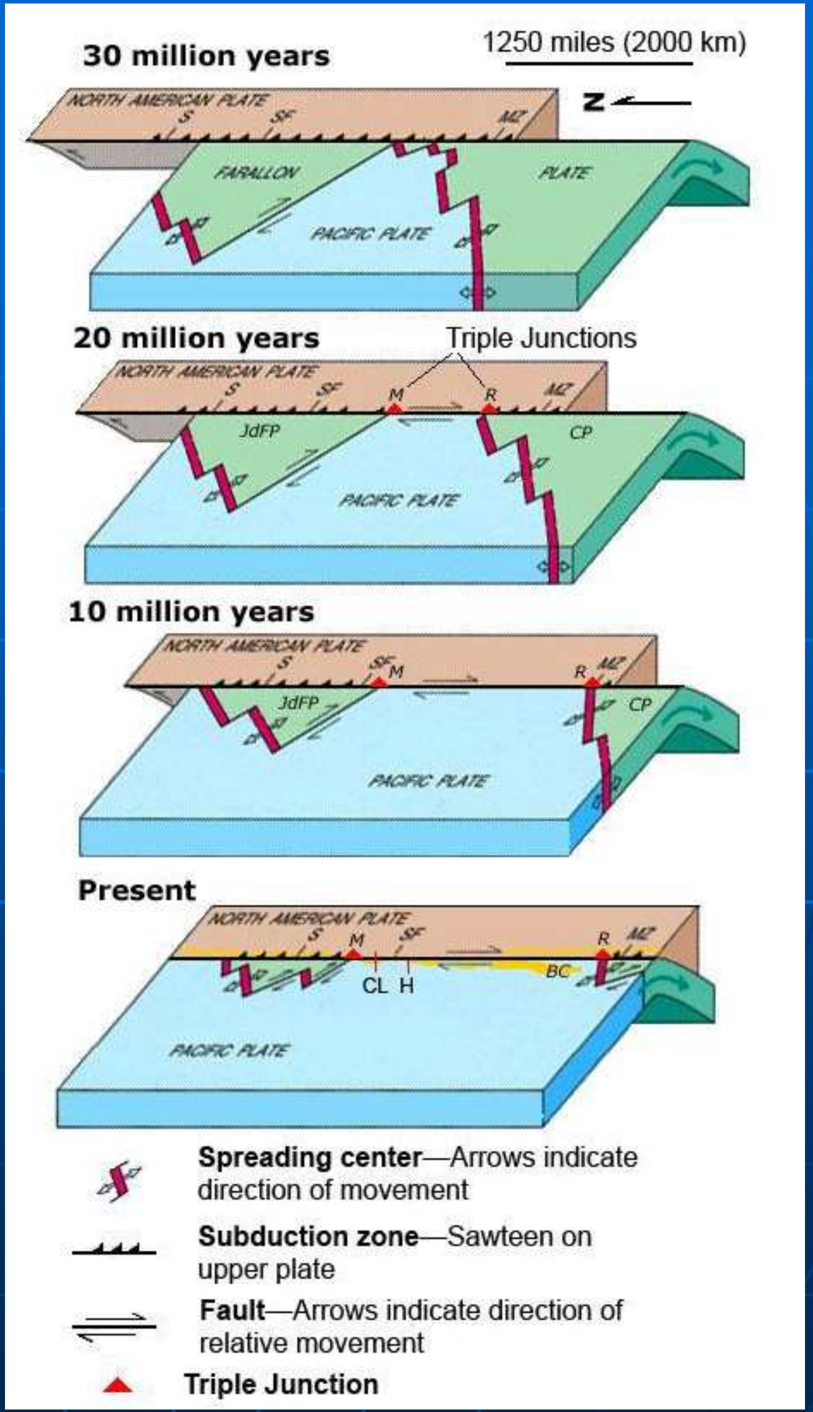


Late Cenozoic mountain building Basin & Range fault blocks

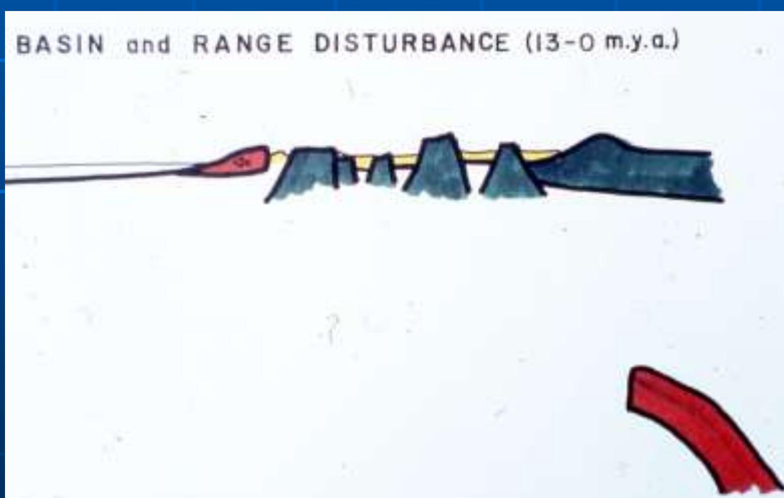
OROGENY	OROGENIC PHASE	ASSEMBLAGES	MAGMATISM	TECTONICS	MINERAL RESOURCES	EPOCH	TIME
SAN ANDREAS	Basin & Range	Basin & Range	basaltic volcanism	grabens	salt, cinders, sand gyp[illegible]	PLIOCENE	0-13

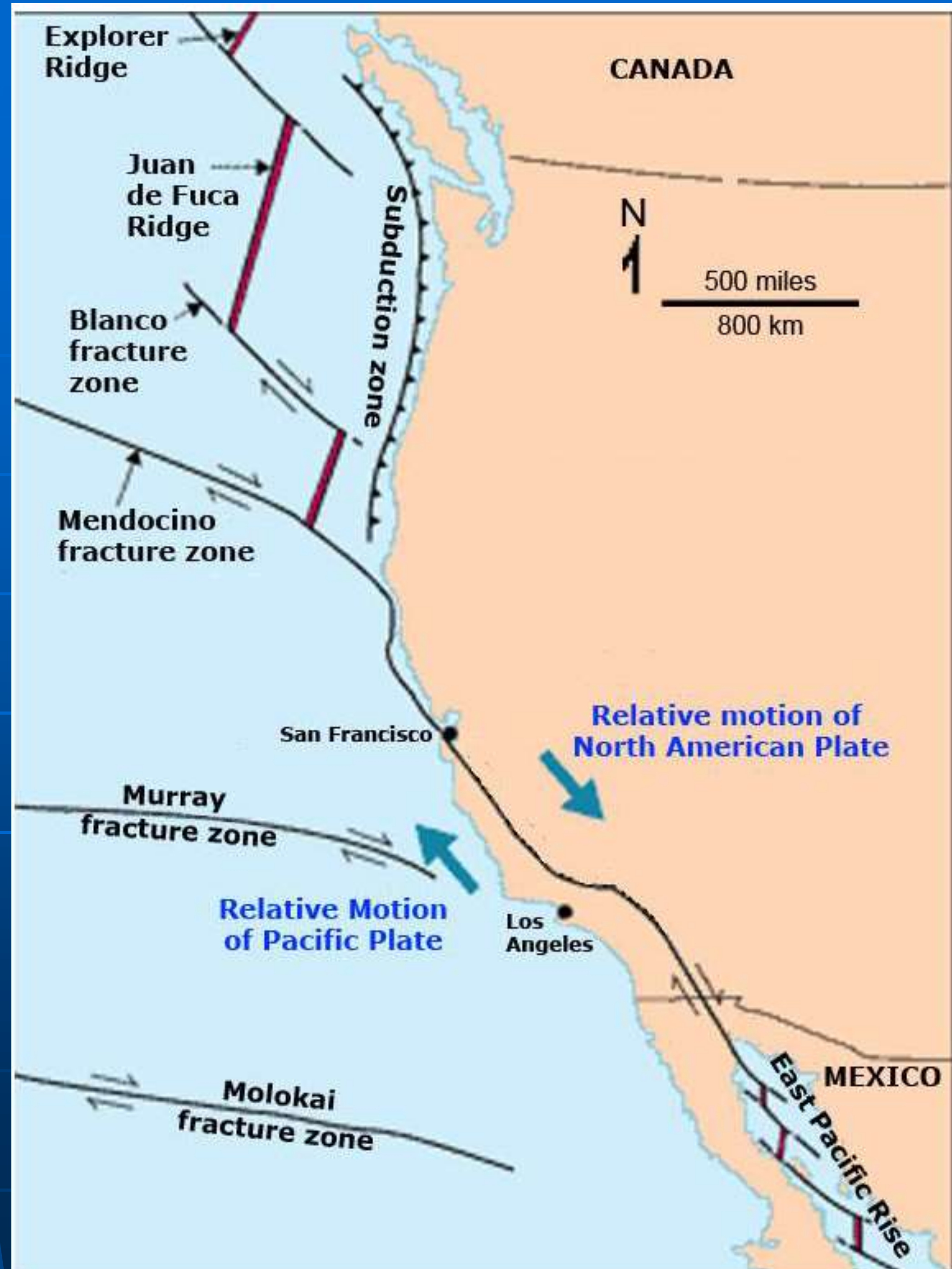
San Andreas fault cutting off subducting eastward moving plate



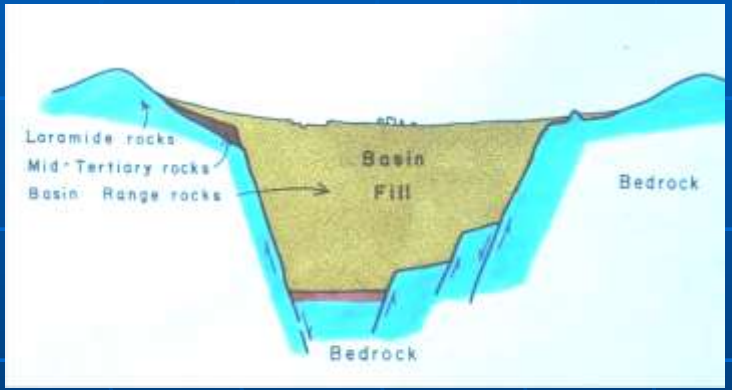


Current San Andreas fault





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



Late Tertiary sedimentary rocks

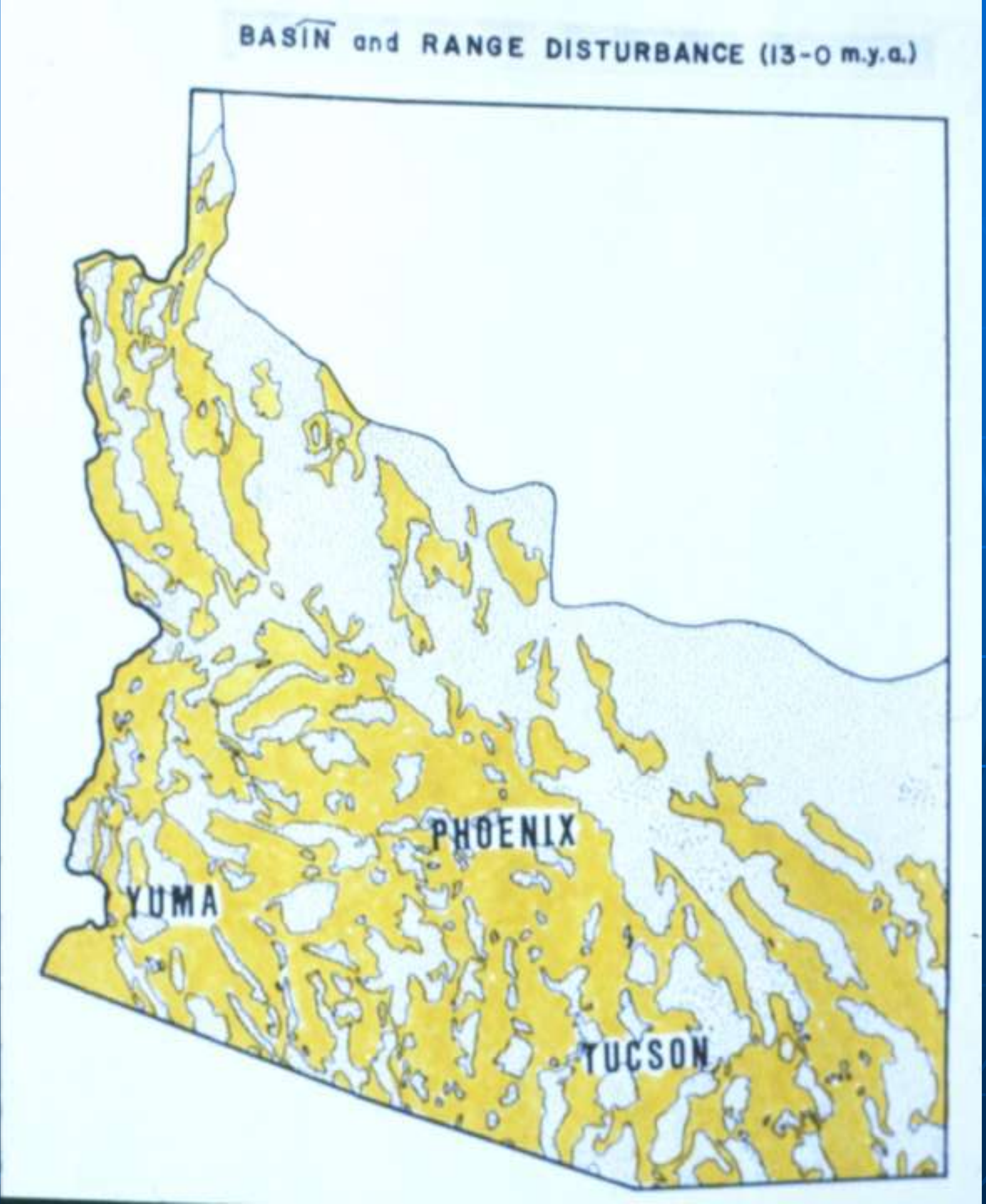
Rillito II - ~ 21 Ma

Pantano Fm. - ~25 Ma

Basin fill at Sonoita

Basin fill – sand, gravel, & clay

Basin and Range Disturbance – current basins



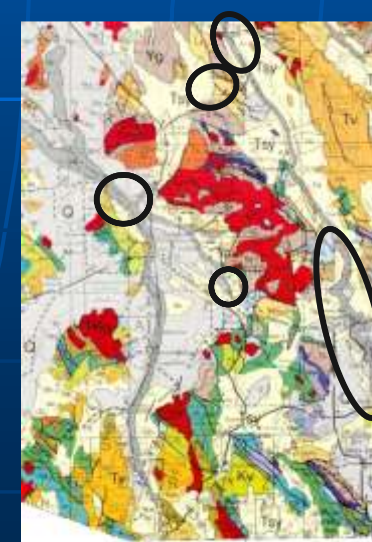
Industrial minerals in Late Cenozoic sediments

Sand & gravel

Kalamazoo Clay - 1987

Pantano Clay - 1987

Gypsum rose



Late Cenozoic volcanics

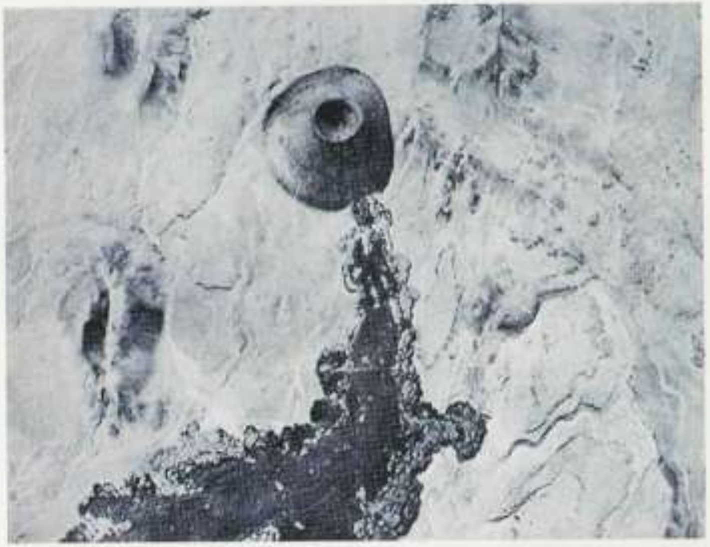
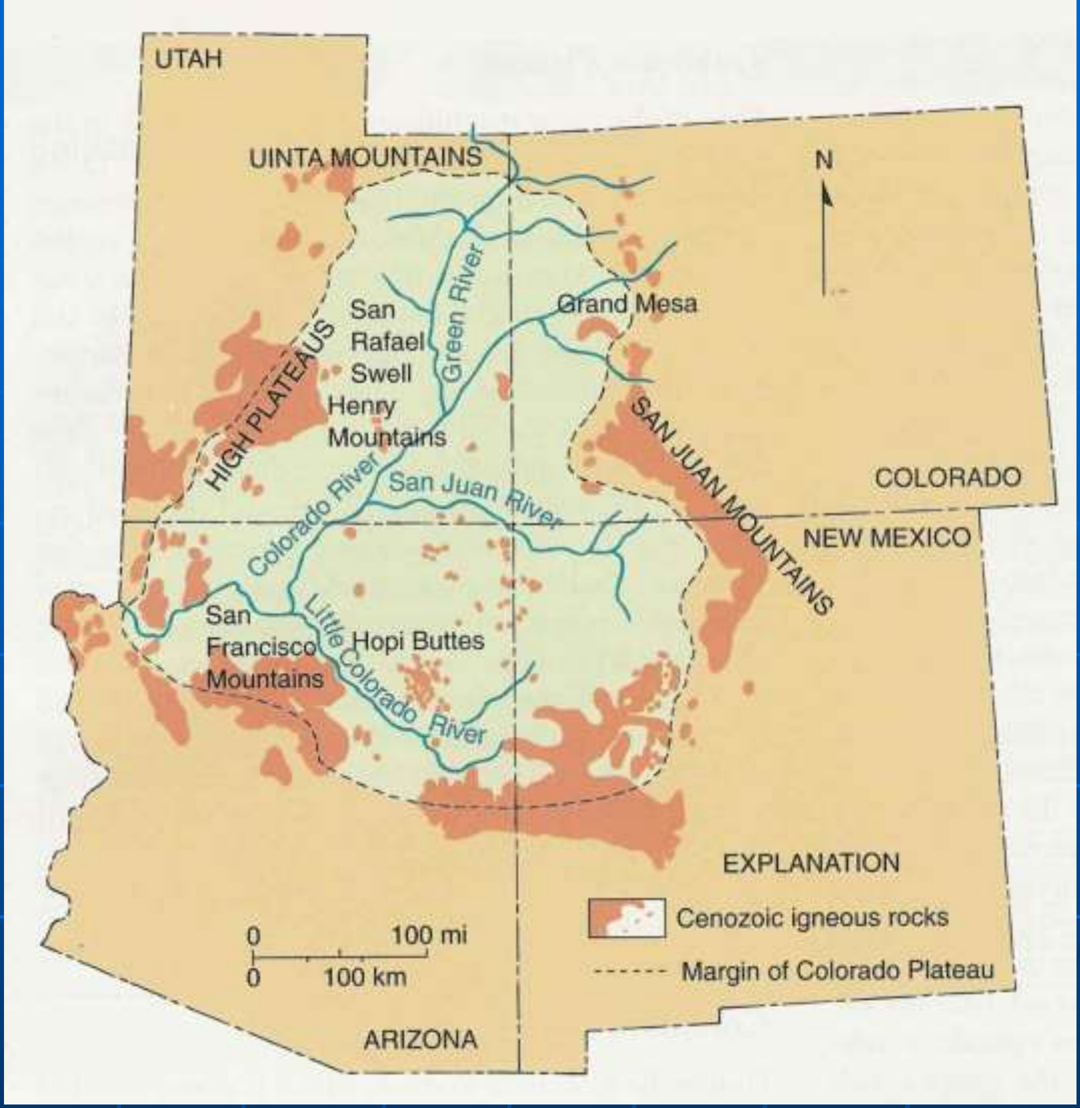


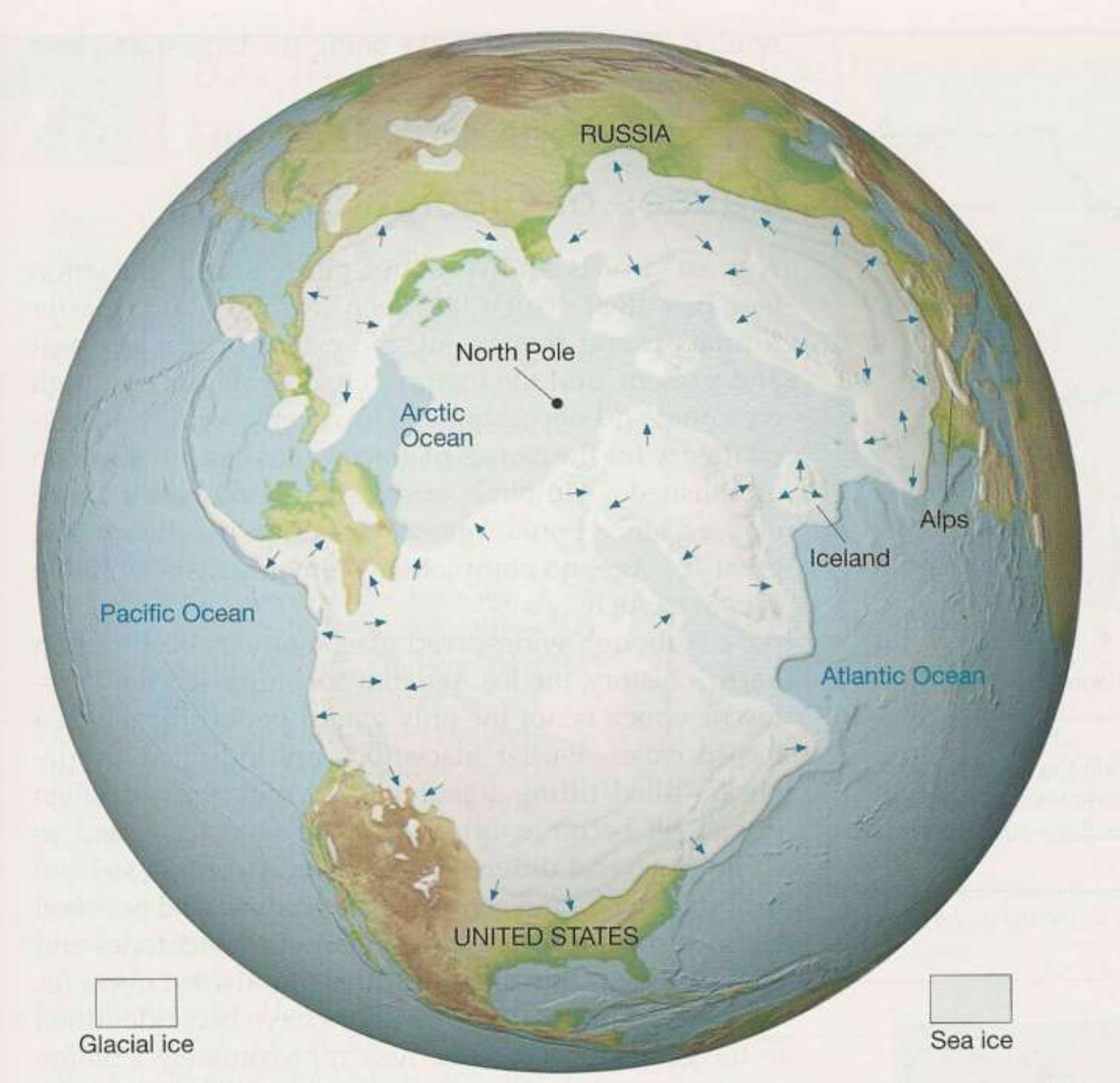
FIGURE 13-20 Vertical aerial photograph of a large cinder cone in the San Francisco volcanic field of northern Arizona. The solidified flow issuing from the cone is 7 kilometers long and more than 30 meters thick.



San Francisco Peaks volcanism 5-0 Ma

LaBrea tarpits, Los Angeles – Pleistocene 1 Ma

Pleistocene maximum glaciation – 18,000 years ago



Pleistocene glaciation

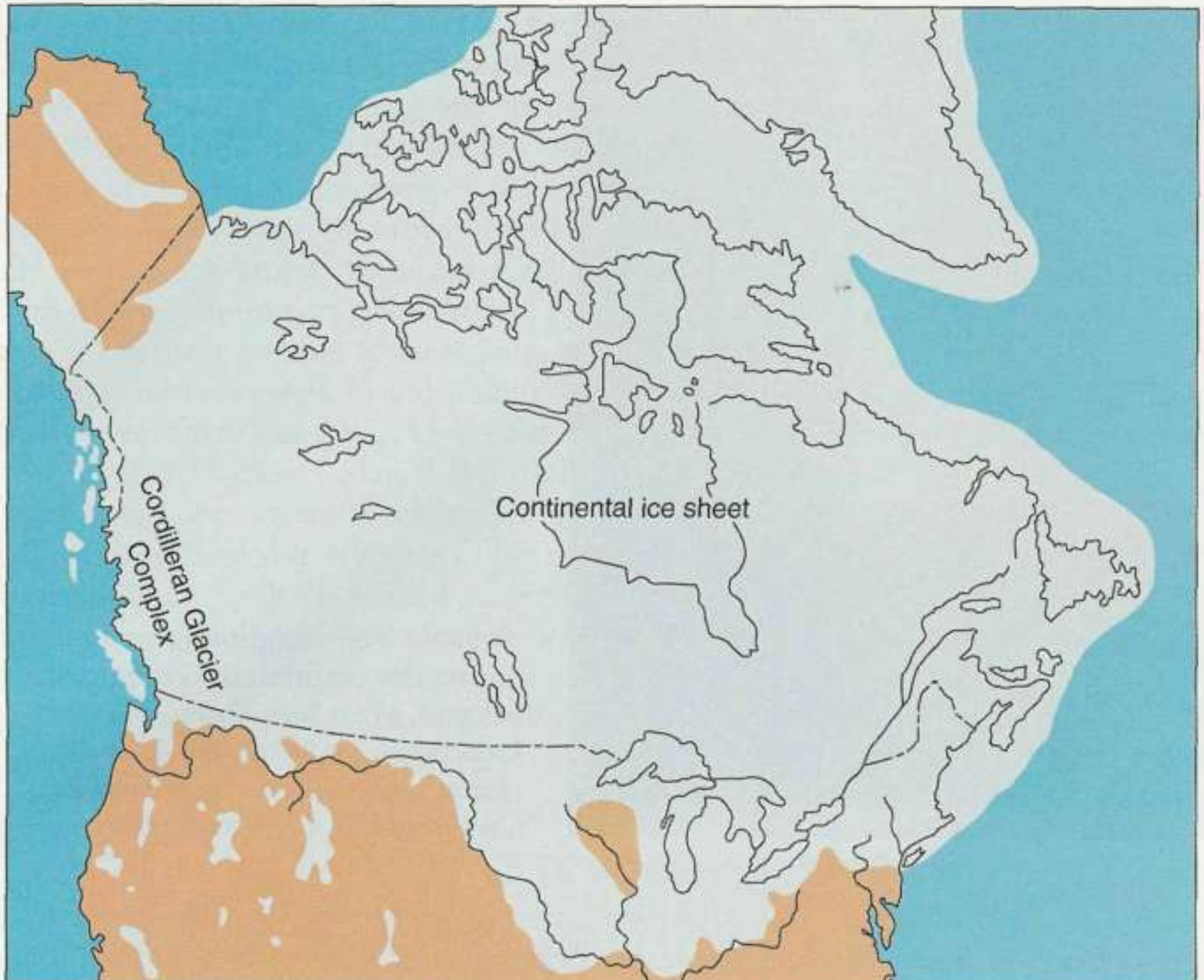


FIGURE 13-36 **Areal coverage of continental glaciers in North America during the latest glacial advance, about 18,000 years ago.** (*Courtesy of Thompson, G.R. and Turkl, J. 1997,* Modern Physical Geology, *Philadelphia: Saunders College Publishing.*)

Carbon dioxide, last 100,000,000 years

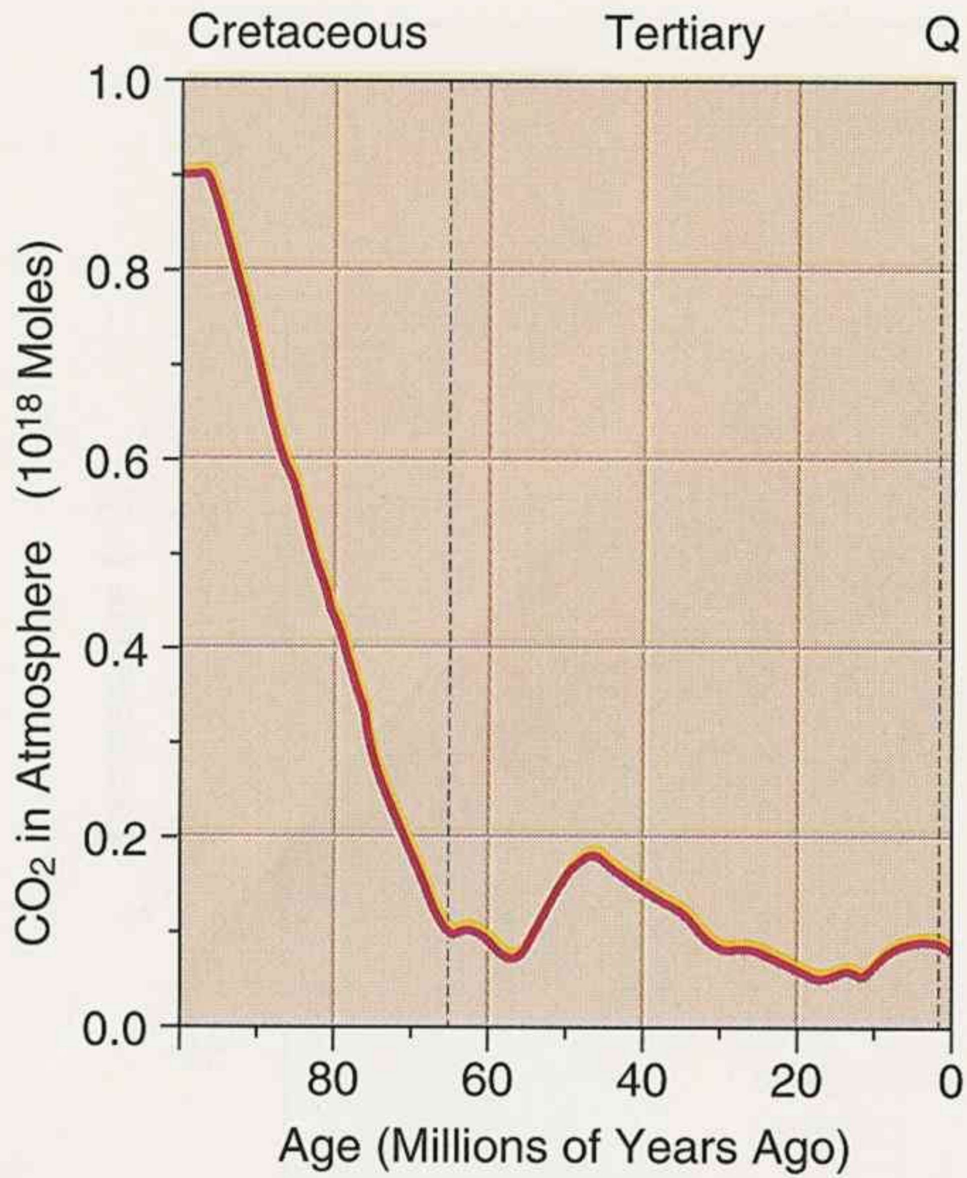


Figure 14.40 The abundance of carbon dioxide in Earth's atmosphere has declined dramatically during the last 100 million years. Loss of this important greenhouse gas may have allowed Earth to cool enough for glaciers to accumulate.

1,000,000 years of temperature change

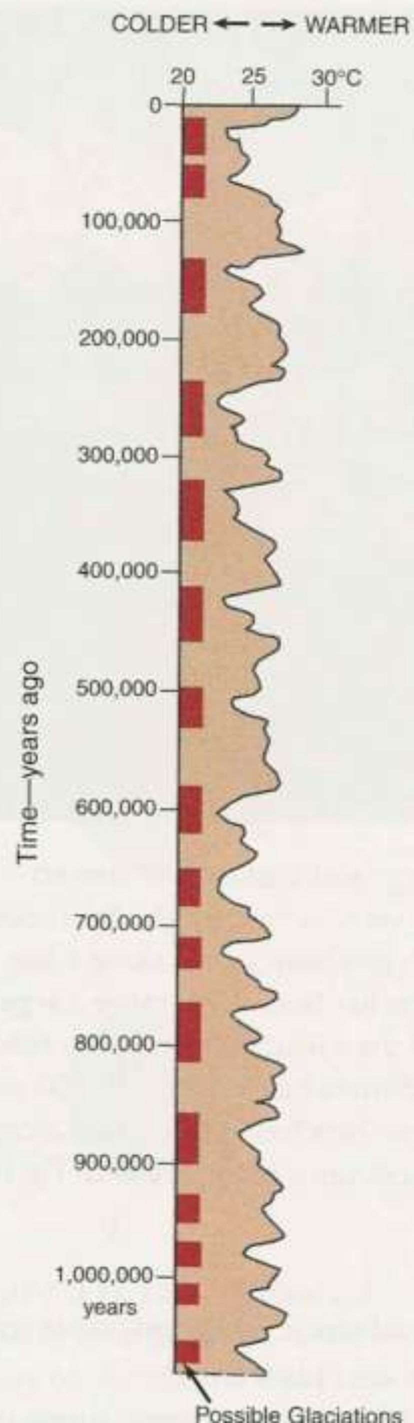


Figure 16.16 Late Pleistocene standard marine paleo-temperature curve *(left)* based upon oxygen-isotope analyses of calcium carbonate in microfossil shells from deep-sea cores of three oceans. Magnetic polarity measurements on the same cores *(right)* and limited isotopic dating of cores provide a time scale. Note that, for the last 600,000 years, cold intervals had a periodicity of about 100,000 years; from then back to about 1.4 million years, the period was about 40,000 years (J—Jaramillo brief normal polarity event). *(Adapted from Emiliani and Shackleton, 1974: Science, v. 183, pp. 511–514; and Shackleton and Opdyke, 1976:* Geological Society of America Memoir *145, pp. 449–464.)*

Glacial and Interglacial stages, last 2 million years

TABLE 13–2 Classic Nomenclature for Glacial and Interglacial Stages of the Pleistocene Epoch

NORTH AMERICA	ALPINE REGION	YEARS BEFORE PRESENT
		—10,000
WISCONSIN	Würm	
		—75,000
Sangamon	Riss-Würm	
		—125,000
ILLINOIAN	Riss	
		—265,000
Yarmouth	Mindel-Riss	
		—300,000
KANSAN	Mindel	
		—435,000
Aftonian	Günz-Mindel	
		—500,000
NEBRASKAN	Günz	
		—1,800,000
Pre-Nebraskan	Pre-Günz	

500,000 years - Pleistocene temperatures

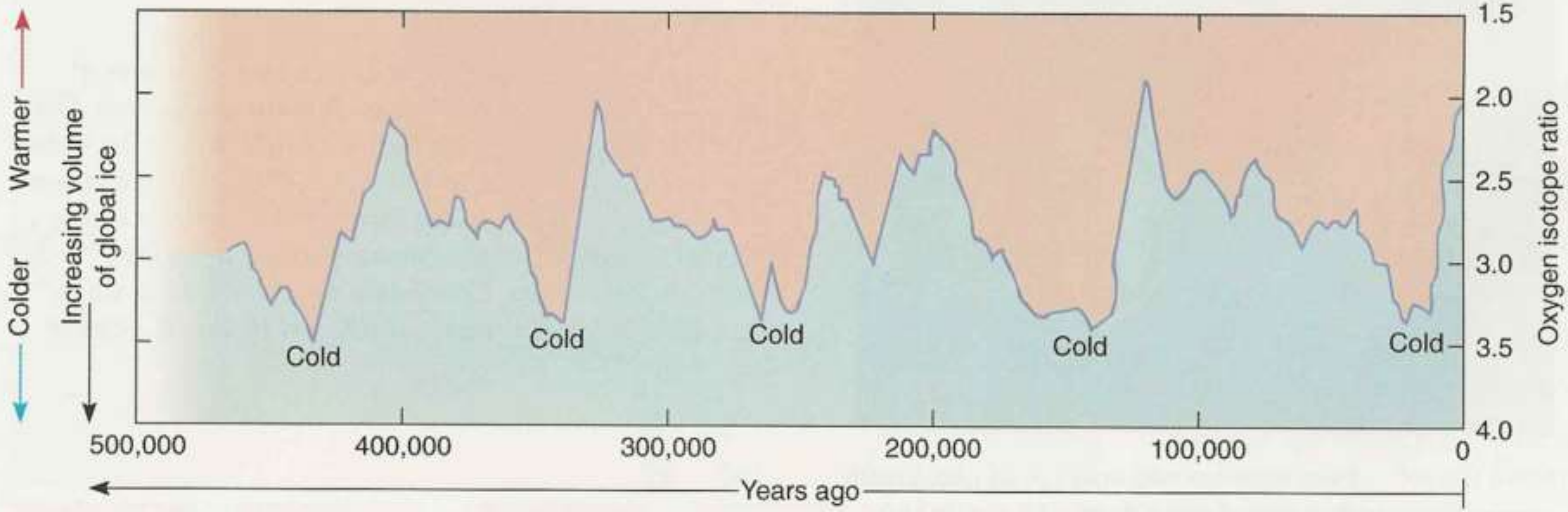
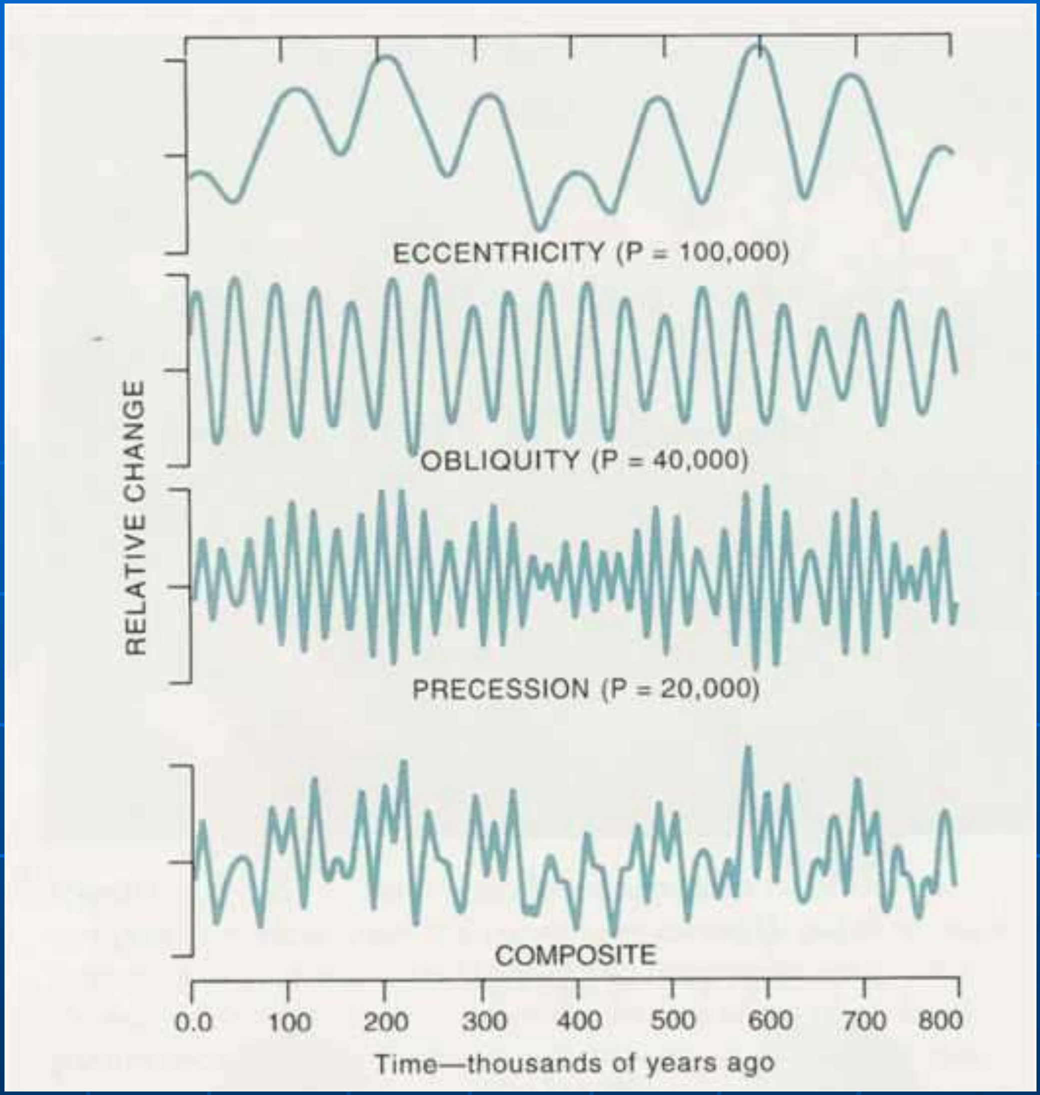
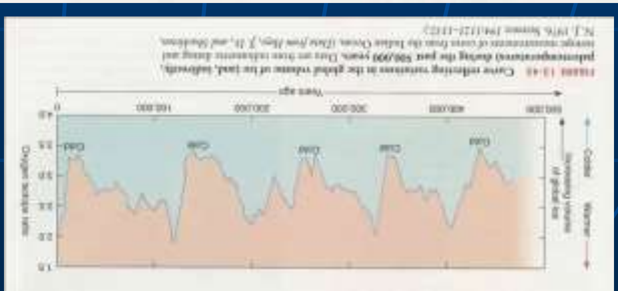


FIGURE 13-43 **Curve reflecting variations in the global volume of ice (and, indirectly, paleotemperatures) during the past 500,000 years.** Data are from radiometric dating and isotope measurements of cores from the Indian Ocean. (*Data from Hays, J. D., and Shackleton,* N. J. 1976. Science *194:1121–1132.*)

800,000 years – astronomical variations





Climate Change, last 160,000 years

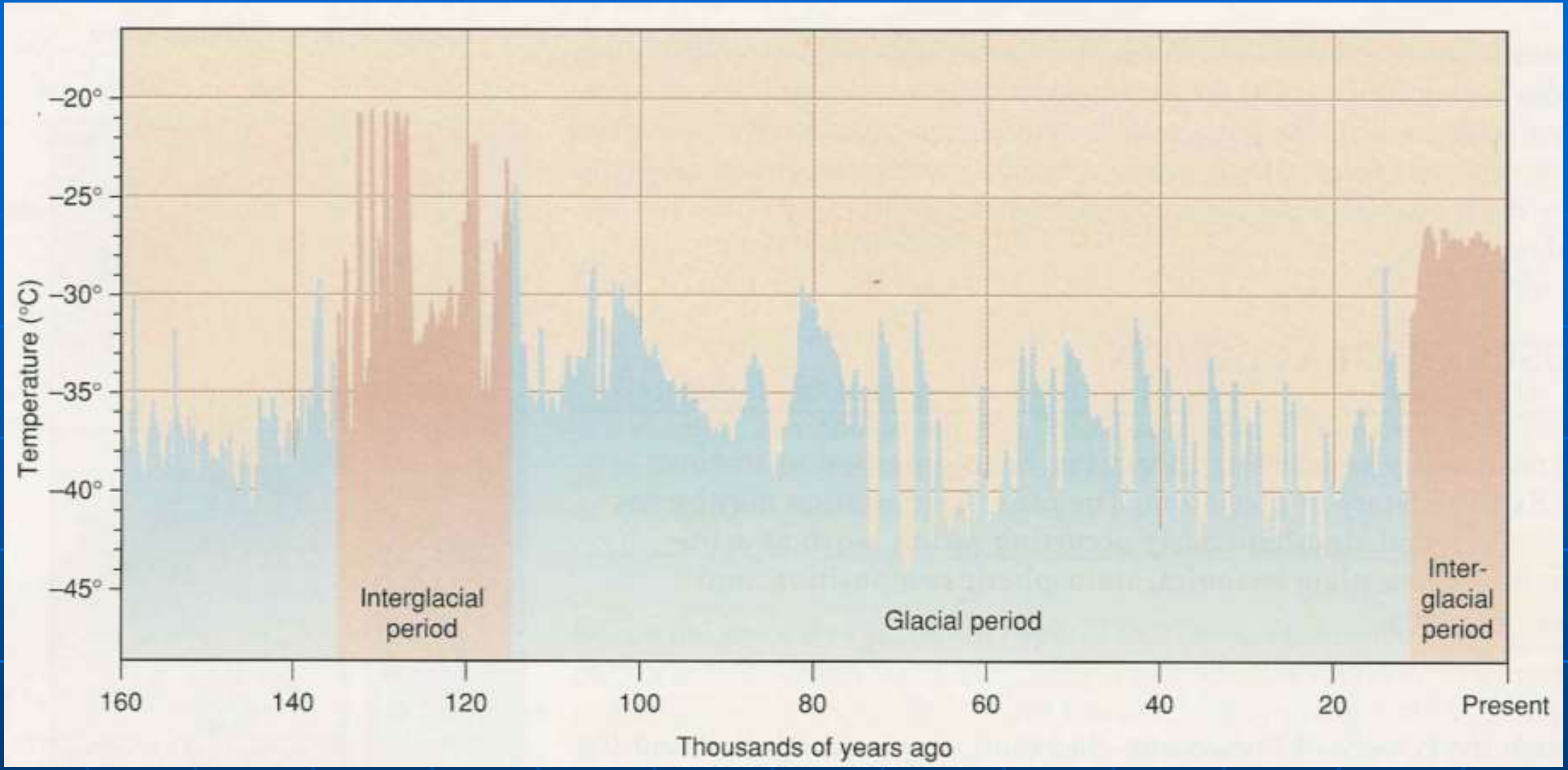
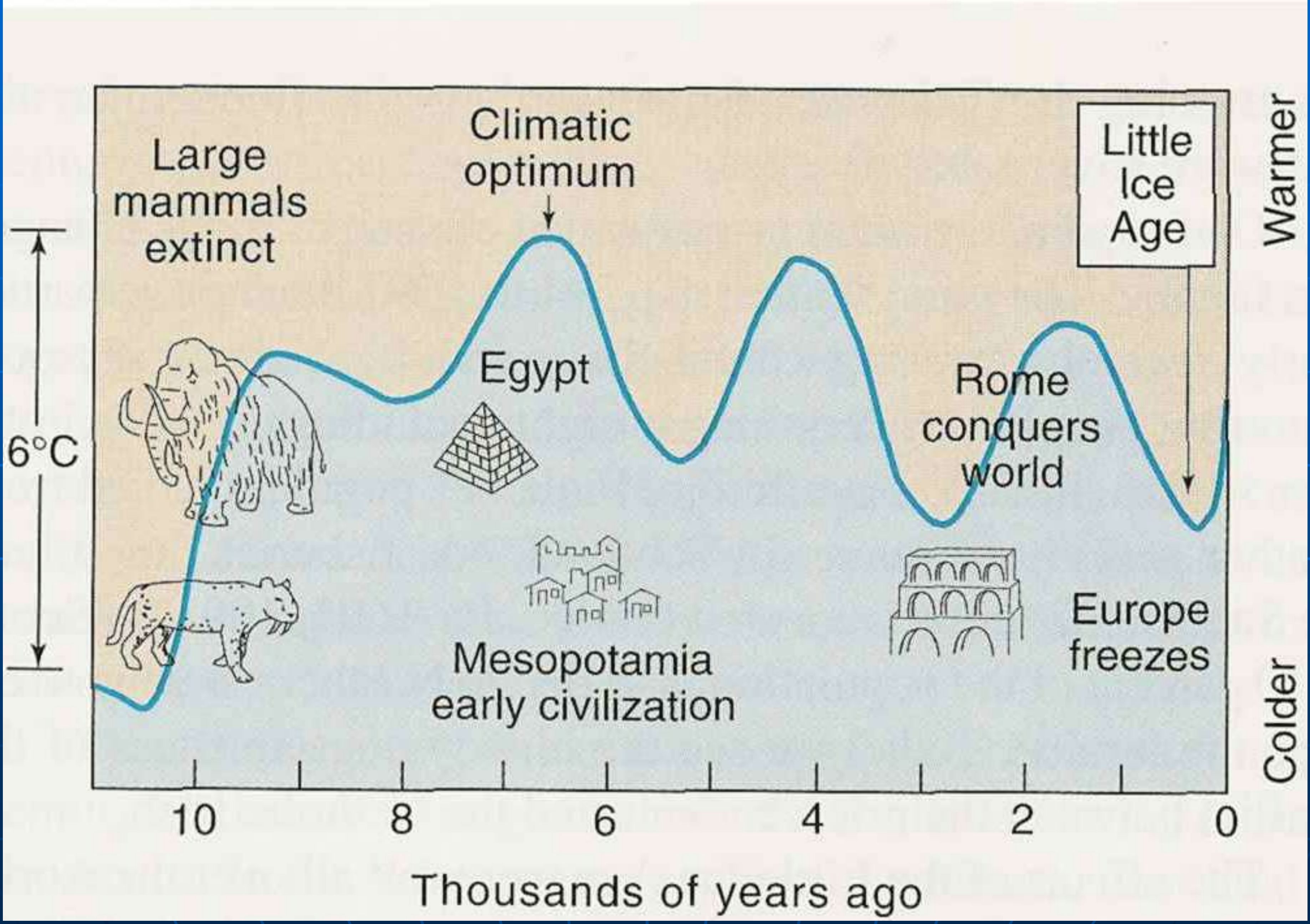


Figure 14.38 A record of climatic change during the last 160,000 years was assembled from studies of ice cores from Greenland's glacier. It shows that the normal pattern of change involves numerous rapid fluctuations in temperature—not only during glacial periods, but throughout interglacial periods as well. The stable warm temperature of the present interglacial period is distinctly abnormal.

Sea Level curve – last 20,000 years

Temperature, last 10,000 years



Temperature change, last 5,500 years

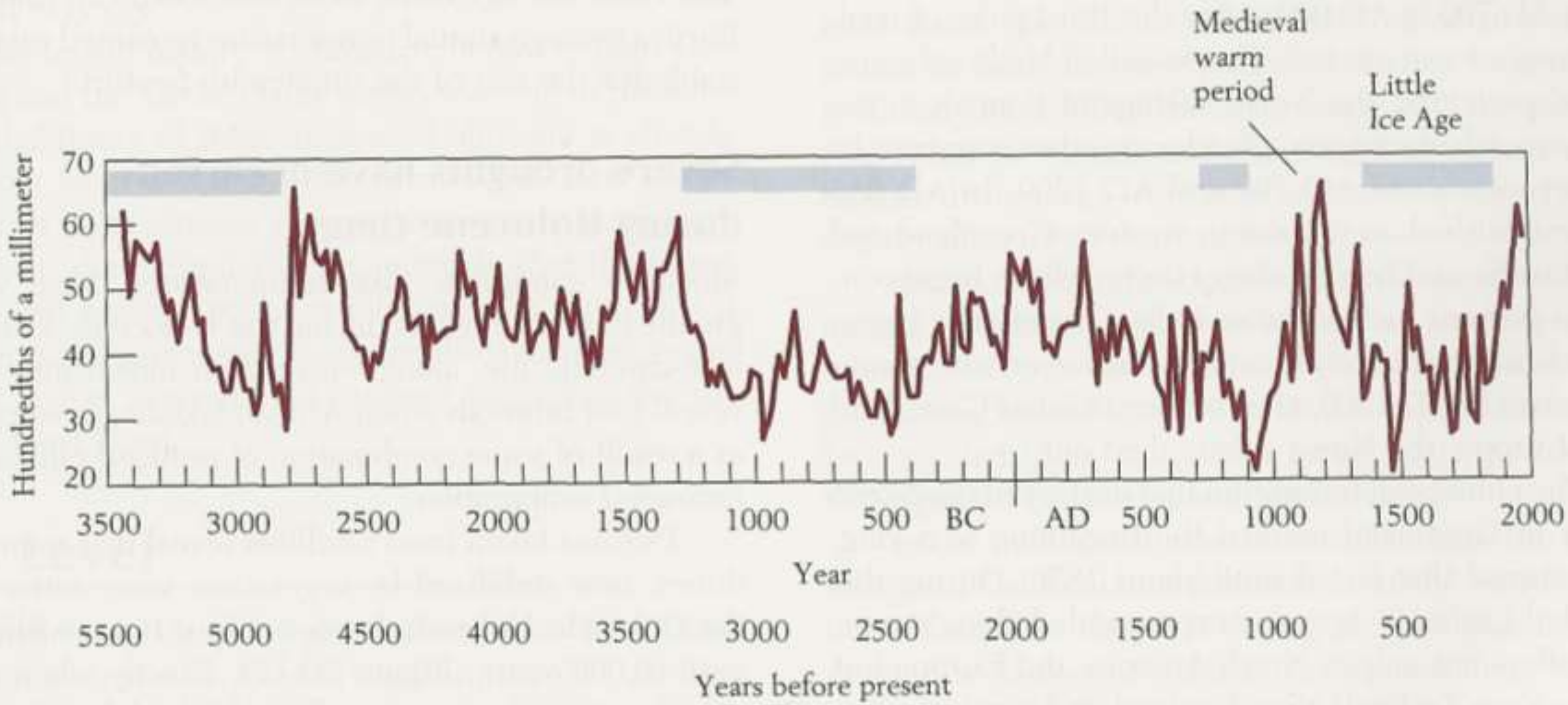


Figure 20-10 Cold intervals of the past 5500 years recorded by widths of annual growth rings in bristlecone pines near the upper tree line of the White Mountains of California. (Data from V. C. La Marche, in H. H. Lamb, *Climate History and the Modern World*, Routledge, London, 1995.)

Glaciation through Geologic time

- Depends on plate tectonics through geologic history
- Continental collisions = ice ages
- Big environmental changes through geologic time
- Warm periods vs. ice ages ~ every 250 million years