Geology Wall

1. Laying the Foundations Santa Catalina Mountains Region "Older" Precambrian (~1700 million years ago)

We know nothing about the first half of earth's history in this part of North America!

Nearly 2000 million years ago the most ancient rocks that we can now find in SE Arizona began to accumulate as sediments and lava flows deposited on the floor of a sea of uncharted dimensions.

By 1700 million years ago these sediments and lavas were intensely deformed and metamorphosed, forming the roots of a great mountain range oriented WSW to ENE across much of what is now the American Southwest. These various metamorphic rocks are now collectively known as Pinal Schist.

Today, Pinal Schist forms most of the Pinal Mountains, south of Globe, and can also be found in small areas in the northern Santa Catalina Mountains.

Several representative types that are found in the formation called Pinal Schist appear to your right, in the left end of the exhibit wall.

2. Finishing the Basement Santa Catalina Mountains Region "Older" Precambrian (~1650-1450 million years ago)

Several times during the next quarter billion years numerous plutons of granite magma solidified beneath great caldera-forming volcanoes. These plutons were emplaced within the previously metamorphosed rocks of the already ancient mountain routes.

The 1450 million years old Oracle Granite is an example of one of these Precambrian plutons.

Oracle Granite forms the northern foothills of the Santa Catalina Mountains, including the area surrounding the town of Oracle, for which this rock mass was named.

In the exhibit wall Oracle Granite is shown intruded into folded Pinal Schist below and to the right of this panel.

About 1400 million years ago the geologic dynamics of this region became still, and a long siege of erosion began.

This resulted in a progressive wearing down and ultimate leveling of the ancient mountains, until the entire region was finally reduced to a rather monotonous lowland, drained by sluggish streams, and nearly at sea level. Landscapes eroded to featureless lowlands of this kind are known as peneplains.

This great ancient peneplain was devoid of any forms of plant or animal life more complicated than microbes.

Pinal Schist together with Oracle Granite and other ancient granites of the region collectively constitute a crystalline basement for Southern Arizona—the foundations upon which all younger rocks of the region will be laid.

The top of the exhibit wall to the right of this panel portrays the ancient erosion surface or peneplain that developed on this crystalline basement of Pinal Schist and Oracle Granite.

3. Deposits in Ancient Seas Santa Catalina Mountains Region "Younger" Precambrian (~1400-800 million years ago)

Shallow seas eventually returned to this region, and gravel, sand, and mud once again began to accumulate. Late in the history of these seas limestone was deposited, much of it formed by colonies of algae called stromatolites. Basaltic lava flows were also extruded at a few places.

The piles of sediments and occasional lava flows that accumulated in these ancient seas were eventually compacted and cemented into a sequence of rock formations known today as the Apache Group.

The profound contact between Apache Group and underlying crystalline basement is called a nonconformity.

In the exhibit wall that contact can be seen near the top of this panel, where the lowest part of the Apache Group (Scanlan Conglomerate) lies nonconformably on Oracle Granite.

A different variety of Scanlan Conglomerate lies nonconformably on basement to the right of a fault zone about one quarter of the distance between this panel and the next. The entire Apache Group is present there. Stromatolites form most of the tan Mescal Limestone at the top of the Apache Group section.

Today, rocks of the Apache Group are especially exposed far to the north of Tucson in Gila County.

Apache Group rocks are also preserved in the northern parts Santa Catalina Mountains: they form most of the higher ridge crests in the northern Santa Catalinas, east of the upper Canada del Oro and north of Marble Peak. Apache Group rocks also form most of the hilltops you look down onto from the "San Pedro Overlook", on the Mount Lemmon Highway.

About 1275 million years ago, the relative geologic quiescence that prevailed during the encroachment of the Apache Seas was interrupted by vertical movement of great blocks of crust. Fractures along which such movements take place are called faults.

In many places, faults formed conduits for the passage heavy, iron-rich magmas from deep within the earth’s mantle. This molten material cooled to form dark basaltic rocks with a distinctive texture of interlocking elongate crystals of a white mineral called plagioclase. These rocks are called diabase.

Where diabase froze into solid rock within fault zones, or in other cracks and fissures which cut discordantly across granite for sedimentary layers, the resulting plutons are called dikes. More commonly, this diabase magma wedged between horizontal strata and flowed laterally for great distances to form tabular bodies oriented parallel to the sedimentary layering. These concordant layers of igneous rock are known as sills.

In the northern Santa Catalina Mountains diabase is frequently found as dikes that cut across Oracle Granite and other rocks older than Apache Group. Farther north, sills of diabase form readily noticeable dark layers in the walls of Salt River Canyon.

Diabase forms branching dikes in the exhibit wall on either side of this panel and also fills most of the fault zone to your right. Diabase also forms several sills between layers of the Apache Group to the right of this fault zone.

Apache Group
Youngest
Mescal Limestone
-characterized by fossil algae colonies (stromatolites), and occasional masses of black chert.
-ancient basalt flows cover Mescal Limestone in some places
Dripping Spring Quartzite
-notable for its content of pink potash feldspar grains intermixed with clear quartz sand.
Barnes Conglomerate
-distinguished by its content of egg-shaped beach cobbles of pale covered quartzites.
Pioneer Formation
-originally shale, now argillite, notable for its curious “splotchy” white on purple appearance.
Scanlan Conglomerate
-contains angular fragments of whatever resistant rocks were present on the surface of the land as it was once again covered by the sea aafter an absence more than a quarter billion years..
Oldest

4. A Great Transgression Santa Catalina Mountains Region Early Paleozoic Era (~550-390 million years ago)

When the Precambrian time drew to a close (a little more than one half billion years ago), another long interval of erosion again resulted in a general leveling of the landscape. This long erosional interval was not as thorough as the previous episode; so when the seas eventually returned during the Cambrian period, scattered elongate ridges, formed of resistant layers of slightly tilted Apache Group rocks, persisted as low islands in some areas of the region.

This great early Paleozoic transgression of the seas was the premier event of the Phanerozic Eon all along the western part of ancient North America. By the end of the Cambrian period even the off shore islands had been worn down and inundated and the coast of the shrunken continent now lay hundreds of miles to the northeast of Arizona.

As Cambrian seas transgressed across the low-lying continent from south and west, the shores of the mainland migrated inland and its beaches accumulated a variety of coarse sandy sediments. As the seas deepened, beach sands were progressively covered by offshore muds and limey deposits secreted by marine organisms.

The mud flats and limey organic deposits laid down during Cambrian time are now shales and limestones of the Abrigo Formation, while sands of those ancient beach deposits are now preserved as Bolsa Quartzite.

Bolsa Quartzite and Abrigo Formation are present in the exhibit wall as the lowest horizontal layers below the right side of this panel, and in the lowest exposed portions of the tilted stratigraphic sections between the faults to the right of this panel.

Scolithus tubes can be seen in the wall within uppermost Bolsa at the right end of its horizontal layers, and in the lowest portion of the section in the left of the two tilted blocks.

Cambrian Strata
-Ordovician (and perhaps Silurian) sediments might have once overlain youngest Cambrian Strata, but virtually nothing is known of these periods; the upper parts of this section were completely eroded away from this region during a withdrawal of the seas that lasted through the beginning of Devonian times.
Abrigo Formation
-Consists of thin layers of limestone and shale that are not very resistant to weathering and erosion, and thus are seldom well exposed.
-Distinctive flat pebble-or “edgewise” conglomerates are characteristic of the Abrigo Formation. These strata were formed from ripped up layers of nearby mudflats, attesting to great ocean storms, even in those ancient times.
-Some rocks of Cambrian age preserve evidence of ancient sea creatures. Fragments of rare trilobites have been found.
Trilobite: (*Tricrepicephalus sp.)*
Bolsa Quartzite
-Originally laid down as beach deposits, some of its lowermost layers contain a variety of different minerals and are preserved as sandstone. Most of this formation, however, is composed of pure quartz sand that was eventually saturated with hard silica cement, causing the Bolsa to now be typically preserved as quartzite.
-A layer of Cambrian beach sands eventually covered nearly all of western North America. Such strata commonly include numerous filled burrows of presumably

wormlike organisms known as *Scolithus.* These most usually occur in upper layers of Bolsa quartzite.
-Bolsa quartzite is a very hard, durable formation that commonly forms cliffs and ridge tops. Maroon and white layering is usually apparent but at many places it weathers to a brown coloration.
-The inclined orientations of Apache Group Strata caused an angular unconformity to form where they were covered with Cambrian strata

5. Seas Teeming With Life   Santa Catalina Mountains Region
Mid To Late Paleozoic Era (~390-230 Million Years Ago)

There is no record of Ordovician or Silurian times in the Santa Catalina Mountains, but during the remainder of the Paleozoic Era, Southern Arizona was subjected to repeated additional inundations and withdrawals of the sea. Various distinctive strata were left as evidence of different visits by the sea during successive Paleozoic periods.

Limestone deposits represent the Permian, Pennsylvanian, and Mississippian periods, and occur throughout SE Arizona. Devonian deposits are sandy or shaly at some places, but are most usually a magnesium-rich kind of limestone called “Dolomite”.

Fossils of ocean dwelling organisms that lived in this region during these geologic periods may be found in different limestone formations of the northern Santa Catalina Mountains.

Brachiopods

Dictyoclostus

Spirifer

Derbyia

Mid to late Paleozoic rock formations formed during successive geologic periods are present in the exhibit wall in their original positions along the right side of the previous panel. Parts of this Paleozoic “section” are also present as tilted strata in two disturbed fault blocks-one extending above and below this panel and another to its left.

Bivalved Brachiopods, the bases of solitary “horn” corals and stems of anchored starfish called crinoids are the most common fossils in these rocks. Examples of all these fossil marine organisms are present in various mid to late Paleozoic limestone layers of the exhibit wall.

Horn Corals

Lephophyllidium

Neozaphrentis

Some of these fossil remains have been converted to silica, which is much more resistant to erosion than their original calcium carbonate. Such silicified fossils are commonly etched into bold relief and stand out from their previously enclosing matrix.

Many limestones of Southern Arizona contain segregations and/or nodules of chert, a flinty siliceous material identical to quartz, precipitated in these rocks by ground water.

Paleozoic strata of Southern Arizona represent many different episodes of inundation by the sea, occasionally interrupted by times of emergence and erosion. But no great crustal disturbance is evident in the rocks formed during this very long span of time; continued crustal stability was the hallmark of our region for more that a quarter of a billion years!

Faulting, tilting, and metamorphism now seen in many of these strata took place long after they were formed, through events described in the next several panels.

In the exhibit wall, only a small amount of Colina Limestone is present-it is the almost black tilted layer seen over the left side of this panel. Younger Paleozoic strata in the exhibit wall have been metamorphosed into quartzite and marble above and below the right side of this panel.

“Jelly bean” conglomerate from the Earp Formation forms the top of the exhibit wall to the right of the fault that emerges from the top of Panel # 4. “Jelly bean” conglomerate is also present in the tilted fault blocks. Can you find it?

The grey limestone layer below the “jelly bean” conglomerate is more typical of the Earp Formation. This particular layer is rich in “forams”; they look like petrified “wheat grains”.

Grey layers of Horquilla Limestone with brachiopods and other fossil fragments now converted to salmon-colored silica, and maroon mudstone with brachiopod molds are present extending to the right from the upper part of Panel # 4. Crinoid stems are especially obvious in limestone Horquilla layers in the tilted blocks, such as can be seen immediately to the left of the center of this panel.

Thick layers of dark grey Escabrosa Limestone appear in the exhibit wall extending to the right from the lower half of Panel # 4, where they contain a veritable hash of crinoid stems and other fossil fragments. Silicified horn corals are evident in a tilted Escabrosa layer below this panel. They look like tiny ice cream cones.

In the northern Santa Catalina Mountains and elsewhere in the region, Devonian time is represented by the Martin Formation. Dolomite of the Martin Formation locally weathers to curious tan surfaces known as “elephant hide” texture.

In the exhibit wall, Martin Formation is the layer extending to the right from the right base of Panel # 4. The curious dark, resistant material at the top of the Martin layer is a discontinuous layer of chert.

Naco Group
-Young Paleozoic strata present in this region today include the very dark grey to black Colina Limestone of Permian Age and are underlying light grey Earp Formation of Permian and Pennsylvanian ages. Earp Formation contains resistant layers of limestone, as well as non resistant layers of mudstone.
-A distinctive stratum within the Earp Formation comprises many angular to partly rounded fragments of red chert, weathered out of older rocks of the Paleozoic section. The Pennsylvania- Permian time boundary lies very near this layer of gravel which is informally known as the "jelly bean conglomerate".
-Grey limestone layers of the Earp Formation contain abundant small fossils of fusilnids- tiny football shaped shells of single celled plankton related to modern day amoebae. Such microfossils represent a family designated Foramimferae, and geologists commonly call them "forams".
Fusilinids
Triticites
Pennsylvanian age, contains abundant silicified remains of crinoids and brachiopods. Grey limestones of Horquilla Formation are frequently interbedded with maroon mudstones.
Crinoids
Dimerocrinites
Escabrosa Limestone
-Typically a cliff-forming formation, usually several hundred feet thick. Its dark grey limestone is often packed with crinoid remains, and silicified horn corals are also common.
-Escabrosa Limestone is of Mississippian age. It is generally equivalent to the Red Wall Limestone of Central and Northern Arizona which forms "the great red wall" in the middle depths of the Grand Canyon.
Martin Formation
-Initial deposit of the region when the seas returned during the Devonian Period to cover most of Arizona after the Ordovichian-Silurian hiatus. It lies on Cambrian strata with "disconformity".

6. Times of Crustal Unrest Santa Catalina Mountain Region Late Mesozoic and Early Cenozoic Eras (~About 150-40 million years ago)

The Mesozoic Era was the time of the dinosaurs, but no evidence of them has yet been found in the Santa Catalina Mountains. Perhaps this is because the geologic record of our region became very complex during the middle and late Mesozoic Era.

We do know that by this time most of this region had once again emerged from the seas. Near Peppersauce Cave, in the northern Santa Catalinas, sedimentary rocks of cretaceous age are present. These strata are known as Glance Conglomerate and the American Flag Formation.

Glance Conglomerate contains angular fragments of late Paleozoic limestones. American Flag Formation contains rounded cobbles of early Paleozoic quartzite and boulders of Precambrian granite. We can thus infer that these sediments were probably deposited in alluvial fans, not far from their high-standing rugged source terrain. Some strata of American Flag Formation were deposited in an arm of the sea.

Faulting and mountain building must have occurred not long before, and very close by – perhaps to the north along the Mogul Fault. To the south, the Geesaman Fault was also probably active during this time period.

The American Flag Formation and Glance Conglomerate are present in the low area at the top of the exhibit wall on either side of the fault to the immediate left of Panel # 5.

Additional faults are represented to the left and to the lower right of Panel # 5.

The Leatherwood Quartz Diorite is the dark rock that forms the bulk of the exhibit wall below and to either side of this panel.

Marble, quartzite, and calc-silicate rocks may be seen immediately above and below Panel # 5. The white rock at the top of the wall directly above the right corner of Panel #5 is marble.

San Manuel Rice Peak andesite porphyry is the greenish rock displayed in the exhibit wall below the next panel.

Wilderness granite forms the crest of the exhibit wall above and to the right of this panel.

Near where Mount Lemmon and Marble Peak are today, a large mass of dark igneous rock known as Leatherwood Quartz Diorite was emplaced during the mid Mesozoic at a great depth under the earth's crust. A large volcano probably formed on the earth's surface at this site, but the only evidence for it today is the great diolite pluton which formed beneath it. Leatherwood Quartz Diorite can be recognized by its distinctive content of tiny, glassy, lime green epidote crystals and equally small crystals of khaki-colored apatite.

Sill-like masses of Leatherwood Quartz Diorite included layered rocks south and west of the main volcano pluton in what is now the Santa Catalina "forerange".

Intense heat from Leatherwood intrusions metamorphosed much of the overlying sandstone, shale and limestone. Some of the metamorphic rocks quartzite cal-silicate, and shales can be found near the Mount Lemmon Ski Area. Metamorphosed late Paleozoic limestone forms the white marble that caps Marble Peak.

Further north in the Santa Catalinas a mass of andesite porphyry was emplaced at about this same time. This andesite porphyry brought with it a valuable content of copper and other metals. This is seen near Mammoth and San Manuel. San Manuel andesite porphyry is usually grey where exposed in the mine, but surface exposures of related rocks in the northern Santa Catalinas are usually thoroughly altered to have a greenish color. In that area this form is known as Rice Peak andesite porphyry.

At some later time deep within the earth's crust to the south of the main intrusion of Leatherwood Quartz Diorite a large mass of garnet-bearing granite formed. This white granite is known as Wilderness Granite and is found today mainly in "The Wilderness of Rocks" south of Mount Lemmon.

Most good exposures of Wilderness Granite are accessible by trails, but a variety of this rock along the highway at the General Hitchcock Picnic Area. Wilderness Granite is noteworthy for its wine-red garnets, but is also unusual in that it contains crystals of both black mica (biotite) and white mica (muscovite).

7. Extremes of Heat and Pressure The Santa Catalina Mountains Region Middle Cenozoic Era (~About 50-25 Million Years Ago)

By about 45 million years ago, much heat and extreme pressure had affected huge volumes of rock south of the present crest of the Santa Catalina Mountains. Nearly all of the southern part of the range was converted into greatly deformed rocks called gneiss (pronounced nice). Catalina gneiss is the highly metamorphosed rock that forms the many layers exposed along the lower portions of the Mount Lemmon Highway, and most of the Rincon Mountains as well.

Catalina gneiss presents many enigmas to geologists. Its layered varieties are very evident throughout the "forerange" along the southern edge of the Santa Catalinas, and along the lower portions of the Mount Lemmon Highway. It is these layered "forerange gneisses" that are clearly visible from most locations in Tucson. More homogenous varieties of Catalina gneiss near "Windy Point" are very similar to Wilderness granite except for their intense deformation.

Many layers of Catalina gneiss contain small wine-red garnet crystals. After these erode out of the gneiss (and also from Wilderness granite), they are deposited in the canyon bottoms where local children later find them, pick them out of the streams, and call them "sand rubies".

Yet another thermal pulse during these times of great crustal change resulted in the emplacement of large "cupolas" or "teeth" of pegmatite and alaskite just south of Mount Lemmon, and near Pusch Ridge. Some geologists call these rocks Lemmon Rock Leucogranite. Rock-climbers scramble over these "teeth" at Rappel Rock, and hikers rest on them at the Lemmon Rock Fire Lookout.

Lemmon Rock Leucogranite is found as light-colored veins in larger masses at various locations in the exhibit wall between Panel # 5 and this panel. The highest point on the wall, just left of Panel# 6, is made of the pegmatite phase of Lemmon Rock Leucogranite.

The final major magmatic event in the Santa Catalina Mountains was the emplacement of a great pluton of granite at what is now the western margin of the range. This pluton is called Catalina Granite. It is of similar mineralogy and nearly identical in appearance to Precambrian Oracle Granite, but Catalina Granite is only 28 million years old.

Careful observation and comparison shows Catalina Granite to contain many small honey-brown, wedge-shaped crystals of sphene. Catalina Granite also contains proportionally more hornblende and less biotite than Oracle Granite.

Occasional "clots" of dark material included within Catalina Granite represent fragments of older "country rock" that were caught up in Catalina Granite magma when it was molten. Such clots are called inclusions, or xenoliths.

Various kinds of Catalina Gneiss are present in the upper portions of the exhibit wall, at panel level from left of the preceding panel to nearly the end of the wall at your right.

Lemmon Rock Leucogranite also forms in numerable light-colored dikes and veins which cut Leatherwood Quartz Diorite and also forms many sills in Catalina Gneiss. Strange lines made of myriads of very tiny garnet crystals, sometimes bordering very large crystals of white feldspar and grey quartz, are a distinctive feature of these rocks.

Several veins of Leucogranite can be seen to cut through Leatherwood Quartz Diorite below Panel # 6.

Catalina Granite forms the lower part of the exhibit wall immediately below and right of this panel. Several large xenoliths are evident.

8. Uplift and Erosion Santa Catalina Mountains Region Late Cenozoic Era (~The last 25 million years)

After Catalina Granite was emplaced, much crustal unrest and renewed fault activity affected this region. The entire southwest was uplifted more than a mile, while many individual blocks, such as where Tucson would someday be built, were down-dropped nearly twice as much. (Today the depth of bedrock in the deepest parts of the Tucson Basin is more than 10,000 feet below sea level, while the crest of the Santa Catalinas-at Mount Lemmon-is 9,167 feet above seal level).

Numerous earthquakes affected the area as adjacent mountain and valley locks moved into new positions along their bounding faults. The abrupt western and southern boundaries of the Santa Catalina Mountains are manifestations of two such faults - the western front of the Santa Catalinas is defined by the Pirate Fault, while their southern boundary is formed by the Catalina Frontal Fault.

Many fault zones contain angular debris broken off the adjacent walls. Such aggregates of broken fragments are called fault breccias. Fault breccias developed during these times in Catalina Gneiss and Catalina Granite typically have a resistant matrix formed of blood-red silica.

Red silicified fault breccia containing angular fragments of gneiss can be seen in the fault zone which vertically transects the left side of this panel.

While movements of various blocks in the developing Basin and Range province continued, materials eroding off the upper portions of Santa Catalina Mountains merged with debris from other nearby ranges to fill the developing valleys with many thousands of feet of coarse gravel, sand and silt.

The Tucson Basin was filled in three major episodes.

The oldest set of these valley-filling fanglomerates is exposed today at many places high in the Catalina "Foothills." These strata have a distinctive pinkish-maroon color, and are known as Pantano Formation.

In road cuts along Skyline Drive, just east of North Campbell Avenue, Fort Lowell Formation lies on Pantano Formation with pronounced angular unconformity. Thus the Santa Catalinas must have been uplifted sufficiently high to expose their gneissic interior sometime AFTER the consolidation of Pantano Formation but PRIOR to the time of deposition of Fort Lowell Formation.

Fossil mammal remains and radiometrically dated volcanic components indicate Pantano Formation was deposited during the late Oligocene and early Miocene Epochs of the Tertiary Period. Many rock fragments in Pantano gravels are volcanic materials from unknown locations.

At Colossal Cave and within the road loop of the east unit of Saguaro National Monument, Pantano Formation contains chaotic landslide debris, great masses of limestone and other formations shed from atop the not yet emergent gneissic core of the Rincon and Santa Catalina Mountains during Mid-Tertiary time.

Maroon gravels of Pantano Formation are represented as the lower part of the exhibit wall, here at its right end.

More normal conglomerates of Pantano Formation are seen in road cuts along Skyline Drive just east of north Campbell Avenue easily recognized by their pinkish-maroon color. Pantano Formation is severely faulted, and its sedimentary layers are nearly always tilted at moderately steep angles.

A younger set of valley-filling gravels has grey matrix, and is known as the Tinaja beds. Tinaja beds are only slightly faulted, usually only gently tilted, and contain abundant cobbles of Catalina Gneiss bound in a grey to tan sandy matrix. Tinaja strata are well exposed in road cuts along Sunrise Drive east of North Swan Road.

In the exhibit wall, the Tinaja beds are represented by a small wedge-shaped set of grey layers at the lower right edge of this panel.

The youngest gravels upon which most of urban Tucson is now built, consists almost exclusively of grey cobbles of Catalina Gneiss contained in an orangish sand and silt matrix, and are known as Fort Lowell Formation.

Fort Lowell Formation is well-exposed along the north side of River Road, as well as in most road cuts near Tohono Chul Park. The ground materials which support nearby building foundations and also form the soils at Tohono Chul Park are Fort Lowell Formation.

Fort Lowell Formation is represented at the top of the exhibit wall immediately over the right side and adjacent to the upper half of the right side of this panel.

Cobble contents and other relationships of Pantano, Tinaja, and Fort Lowell Formations comprise the record of how and when the Santa Catalina Mountains became established in their present configuration during the last 25 million years.

Pantano Formation contains very few fragments of nearby Catalina Gneiss; apparently the Santa Catalinas were not yet high enough to expose their gneissic core to erosional processes when Pantano Gravels were being deposited.

The final acts in the development of today's Santa Catalina Mountains are their ongoing weathering and erosion of all of the various promontories, canyons, and other geographic features, we encounter in the Santa Catalina Mountains today are the expressions of many millennia of weathering and erosion as they progressively expose, disintegrate and eventually destroy all of the rocks and other evidence of many different geologic processes which previously transpired during nearly two billion years of earlier geologic time.