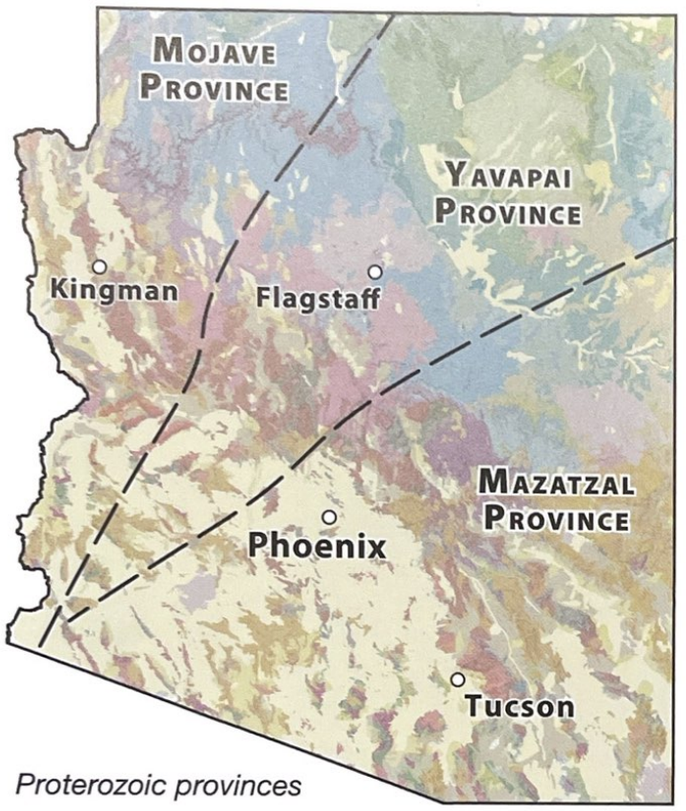
Early Proterozoic History

The initial chapter in Arizona's history occurred in the middle part of the Precambrian, the Early Proterozoic, which spans from 2.5 to 1.6 billion years ago. A few rocks in Arizona are older than 1.8 billion years, but the oldest rocks in most of Arizona are 1.8 to 1.6 billion years old, so the last part of the Early Proterozoic.

Early Proterozoic rocks in the state (▾) are subdivided into three provinces, based on their age of formation and whether they incorporated older materials, as evidenced by specific chemical and isotopic analyses. The oldest rocks in each province are metavolcanic and metasedimentary units that record formation of ancient seafloor before this part of North America had continental crust. Succeeding rocks increasingly show a more continental character, such as quartzites that contain grains eroded from preexisting granites.



Proterozoic provinces

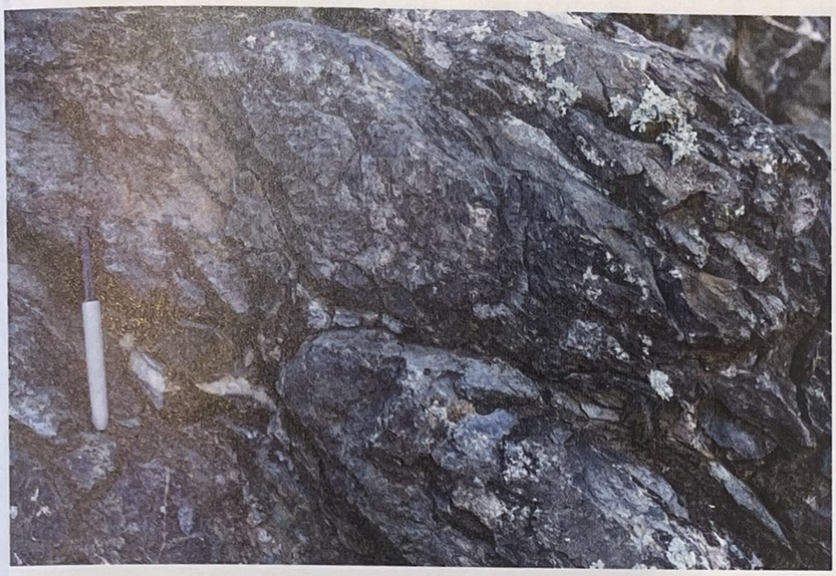
Metamorphic rocks in the Mojave Province are mostly 1.78 to 1.72 billion years old but bear a geochemical signature of having incorporated ancient material, such as sediment from older sources. The Yavapai Province has the same age of rocks, but these rocks lack isotopic evidence of older components. The Mojave and Yavapai Provinces are interpreted as being constructed from volcanic centers built on oceanic crust.

The Mazatzal Province contains younger units, some less than 1.7 billion years old. These units represent sedimentary and volcanic materials that accumulated along the edge of newly constructed Yavapai crust. In southeastern Arizona, they likely include materials that accumulated within a subduction-related oceanic trench along the southeastern margin of the incipient continent.

The oldest rocks in Arizona are metamorphic rocks, most of which display a steeply dipping foliation (▾). The metamorphic rocks were intruded by several generations of plutonic rocks, many dated at older than 1.65 billion years. The older of these plutons and their metamorphic hosts were then subjected to episodes of tectonic activity, or orogenies. The Mojave and Yavapai Provinces experienced the Yavapai orogeny, which ended at 1.7 billion years ago. Rocks in the Mazatzal Province were affected by the younger Mazatzal orogeny and Picuris orogeny, two orogenies that are difficult to distinguish and may overlap in age.

Metamorphic rocks from Mohave Point in the Grand Canyon

The metamorphic rocks preserve some original aspects, such as pillows, which are lumpy features formed when lava is erupted underwater. Most pillows are in basalt or andesite, with the rounded tops (◂) indicating which way was originally up in the rocks. Bedding is also preserved in some metasedimentary rocks that were metamorphosed at low- to moderate-metamorphic grades, such as in slates and quartzites. Generally, features are more obscure in schist and gneiss that represent metamorphism at higher temperatures.



Pillow basalts north of Kirkland, Iron Springs Road

Proterozoic rocks in Arizona are characterized by foliation, which can be expressed as a low-grade cleavage (▾), high-grade gneissic banding, or something in between. Such foliation tends to trend northeast to north and dip steeply. Most foliation is due to compression and shortening perpendicular to the foliation, but some is produced by shearing rather than shortening. Foliation was commonly accompanied by tight folding of rock layers and formed during the several orogenies that affected the region.

Steep cleavage in metamorphic rocks, Phoenix Mountains

Granitic rocks are an important component of Proterozoic exposures in Arizona, including several ages and types, ranging in age from 1.75 to 1.4 billions of years. Some granites have large, tabular feldspar in a matrix of smaller crystals, as in the example here (◂), but in other granites, all the minerals are about the same size. Most granites of this age have enough dark minerals to be light or medium gray up close, but others are very light colored. Some granitic bodies are foliated or sheared, but many of the youngest granites are not.

Proterozoic granite east of Crown King, Bradshaw Mountains

Middle Proterozoic History

Several important events occurred in the Middle Proterozoic from 1.6 to 1 billion years ago. The Picuris orogeny is a Middle Proterozoic event, so some deformation and metamorphism recorded in Early Proterozoic rocks is Middle Proterozoic. Also, voluminous amounts of granitic magma were injected into the crust between 1.5 and 1.4 billion years ago, producing widespread 1.4-billion-year-old granites. These granites are prevalent in all three Proterozoic provinces but are especially common in the Mazatzal Province. Some deformation accompanied or postdated these granites, but the 1.4 granites are mostly undeformed by Proterozoic events except for relatively minor shear zones.

Between 1.2 and 1 billion years ago, sedimentary units were deposited in two main basins, the Apache Group in south-central Arizona and the Grand Canyon Supergroup exposed in the Grand Canyon (▾). Both these sequences were mostly sandstone, siltstone, shale, and limestone with conglomerate, but burial and the addition of natural cements between grains converted some sandstones and siltstones to quartzite. Both sequences have interbedded basalt flows, and the Apache Group contains some felsic tuffs.

Middle Proterozoic basins

After deposition, the units were tilted, either by rotation of normal-fault-bounded blocks in the Grand Canyon or by inflation of the sequence by thick diabase sills, with the units draping over the ends of the intruded area. The lowest formations in each group rest unconformably on Early Proterozoic rocks, including those that were deformed into steep dips by the earlier orogenies. This contact is a major unconformity that represents 500 million years of geologic time that is not recorded along the contact.

The Grand Canyon Supergroup, one of the best-known sequences of latest Precambrian rocks, mostly consists of a lower Unkar Group, represented by the reddish and dark-gray rocks near river level, and the overlying Chuar Group, which forms the middle, light-colored, slopes in this view (◂). Both groups include sandstone, mudrocks, and some limestones, but the Unkar also has basaltic lava flows, the dark rocks in the lower part of this photograph. The supergroup was tilted and eroded before deposition of the Tapeats Sandstone (the main ledge above the Chuar), resulting in an angular unconformity.

Grand Canyon Supergroup from Desert View in the Grand Canyon

An important formation in the Apache Group is the Dripping Spring Quartzite, an orangish-brown to maroon unit (▾). This complex unit contains various clastic rocks, most of which were originally sandstone, as well as altered volcanic ash and the prominent quartz- and quartzite-pebble Barnes Conglomerate at the base (not shown). The Dripping Spring and the rest of the Apache Group are widely exposed in central Arizona, as in the Sierra Ancha (a mountain range south of Payson) and in mountain ranges north of Tucson and east of Phoenix.

Dripping Spring Quartzite, Roosevelt Dam, AZ 88

An upper unit in the Apache Group is the Mescal Limestone, a finely layered, light-gray to cream-colored limestone (▾). A similar unit, the Bass Limestone, forms the base of the Grand Canyon Supergroup. Both limestones are regarded as marine deposits but lack most types of fossils because they were deposited before larger life forms evolved. They do contain stromatolites, which are mound-shaped features with intricate layers interpreted to have been constructed sequentially by microscopic cyanobacteria.

Mescal Limestone, Salt River Canyon, US 60 milepost 292

A unit that is widely associated with the Apache Group and Grand Canyon Supergroup is a dark intrusive rock called diabase. Diabase has a similar composition to basalt but, because it solidified below the surface, it displays visible crystals, including tabular crystals of plagioclase feldspar in a matrix of dark crystals. Diabase is mostly expressed as sills representing magma injected as sheets between layers in adjacent lighter-colored units (◂). It is dated at 1 billion years and commonly displays columnar joints and spheroidal weathering.

Diabase sill intruded below quartzite, Roosevelt Dam, AZ 88