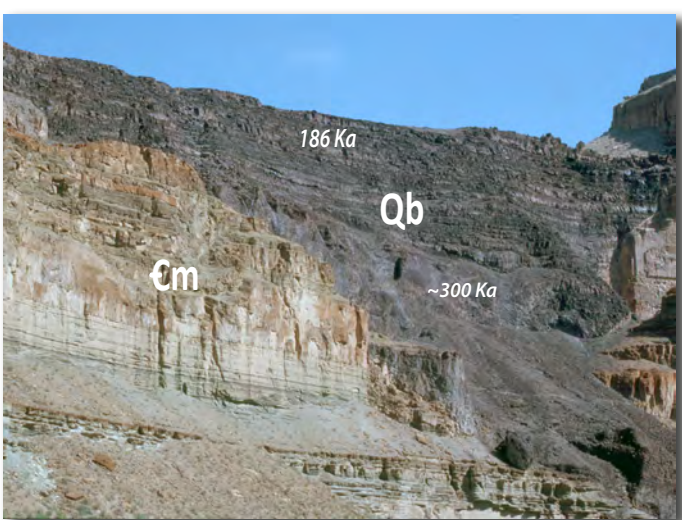


# GRAND CANYON STRATIGRAPHY

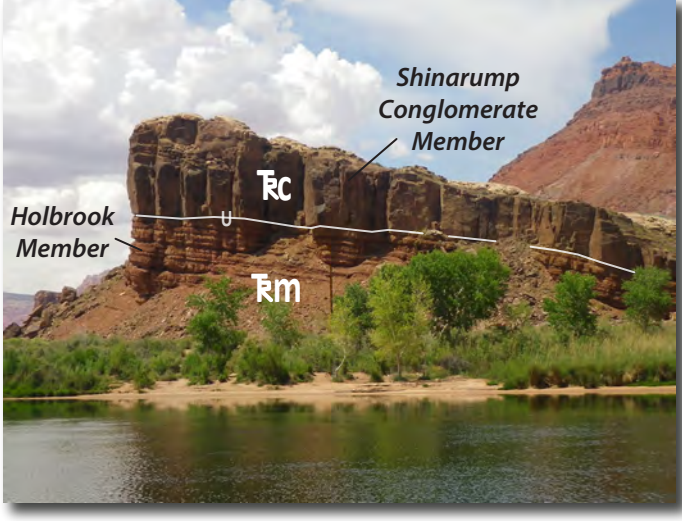
by Bob Leighty

## FIELD GEOLOGY

All images taken by B. Leighty



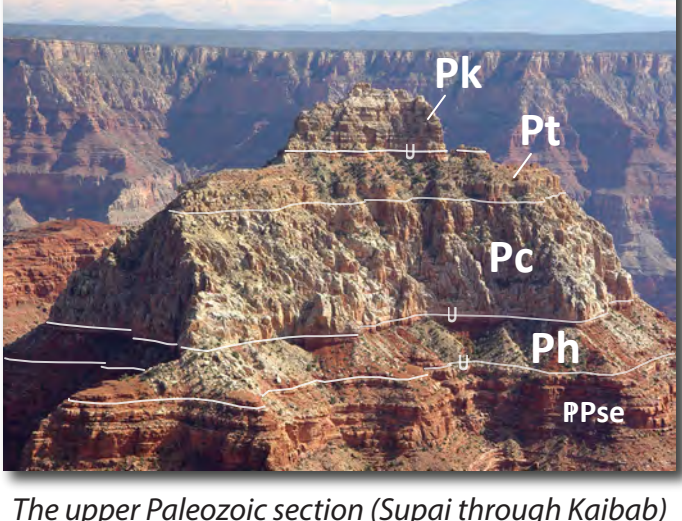
A basalt-filled Whitmore Wash paleochannel at the southern end of the Uinkaret volcanic field



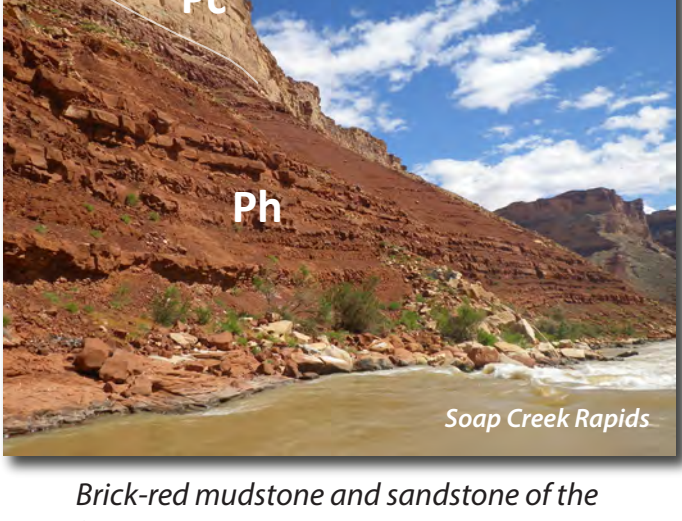
The Moenkopi and Chinle Formations are exposed at river level only in the Lees Ferry area



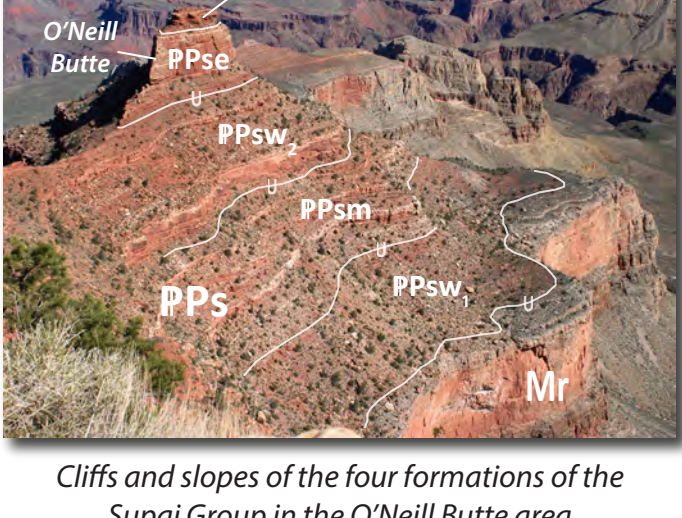
The cliff-forming Fossil Mountain member of the Kaibab Formation along the South Rim near Yaki Point



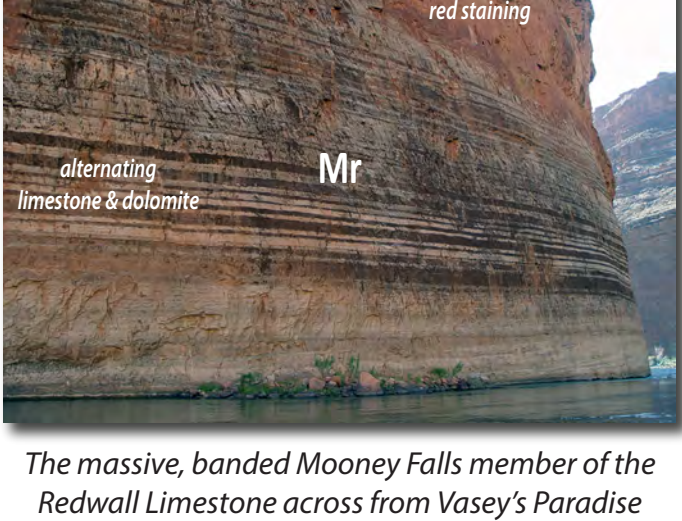
The upper Paleozoic section (Supai through Kaibab) at Vishnu Temple as seen from Cape Royal



Brick-red mudstone and sandstone of the slope-forming Hermit Formation at Soap Creek Rapids



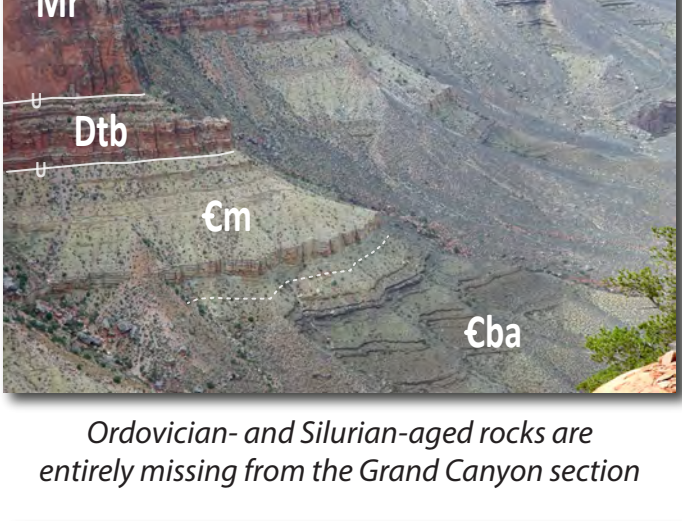
Cliffs and slopes of the four formations of the Supai Group in the O'Neill Butte area



The massive, banded Mooney Falls member of the Redwall Limestone across from Vasey's Paradise



Cliffs of Cambrian and Mississippian rocks along the Colorado River as seen from the Nankoweap Granaries



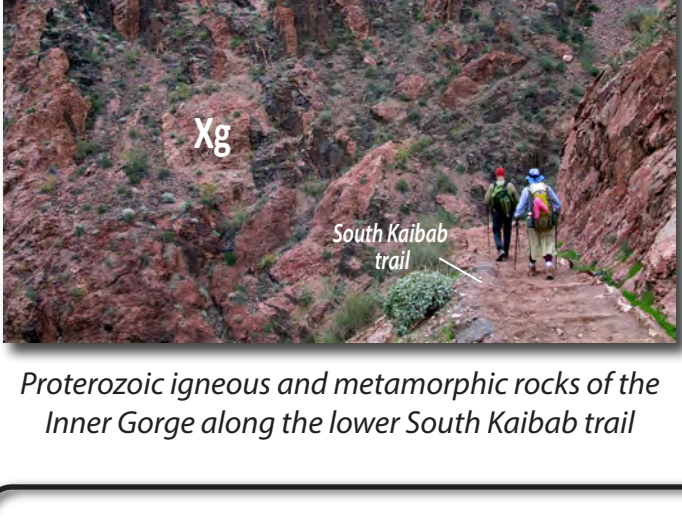
Ordovician- and Silurian-aged rocks are entirely missing from the Grand Canyon section



Tapeats Sandstone overlies Rama Schist and forms 'The Great Unconformity' in the Stephen Aisle area



A Cardenas diabase dike intrudes red beds of the Hakatai Shale at Hance Rapids

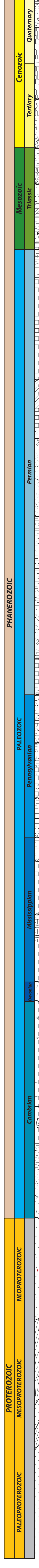


Proterozoic igneous and metamorphic rocks of the Inner Gorge along the lower South Kaibab trail

## GEOLOGIC TIME

Unit thicknesses not drawn to scale  
Lateral thickness changes are not depicted

west ————— east



## LITHOLOGIES

Unit thicknesses not drawn to scale  
Lateral thickness changes are not depicted

west ————— east

## ROCK UNITS

## EXPLANATION

### FILL PATTERNS

Sedimentary Rocks	
Sedimentary breccia	Conglomerate
Sandstone	Sandstone (cross bedded)
Mudstone	Mudstone & Sandstone
Gypsum	Travertine
Limestone	Limestone (sandy)
Limestone (muddy)	Limestone (cherty)
Dolomite	Dolomite (sandy)
Dolomite (muddy)	Dolomite (cherty)

Igneous & Metamorphic Rocks	
Mafic Volcanics	Felsic Tuff
Granitic Intrusives, Pegmatite	Diabase, Granodiorite, Diorite, Gabbro
Schist	Gneiss

### SYMBOLS

U	unconformity	---	contact	*742	isotopic date (in Ma)
---	notable location	---	Ribbon Falls	---	major waterfall
---	Cap Royal	---	Pumpkin Spring	---	major spring
---	fault movement	---	Neoproterozoic	---	Laramide

Sedimentary Structures & Fossils			
mud cracks	current ripples	cross bedding	convoluted bedding
molluscs	nautiloids	brachiopods	crinoids
sponges	coral	bryozoans	conodonts
trilobites	trilobite tracks	vertebrate tracks	burrows
stromatolites	algal domes	plants	

Tectonic Structures	
tight to isoclinal folds	boudinage

### IMPORTANT TERMS

fluvial = stream-related    eolian = wind-related  
lacustrine = lake-related    estuarine = tidal channel-related  
sabkha = coastal salt flat    subtidal = below the low tide water line  
alluvium = stream deposits    colluvium = slope deposits  
detrital = composed of rock fragments    arenite = sandstone  
sill = layer-parallel intrusion    dike = cross-cutting intrusion  
protolith = original rock type    foliation = tectonic layering  
orogeny = mountain-building event    isoclinal = parallel fold limbs

### Surficial Deposits, undivided (Qsu)

► **Pleistocene to Recent**  
fluvial sediment, spring-related travertine and tufa, eolian sand deposits, colluvium, talus, and landslides // stream channels, springs, slopes, rockfalls, landslides

### Basaltic Volcanics (QTb)

► **Miocene to Holocene (>9 Ma to 0.001 Ma)**  
basaltic lava flows, cinder cones, and tuff cones of the Uinkaret volcanic field (3.7 Ma to 0.001 Ma), San Francisco volcanic field (8.9 Ma to 0.001 Ma), Hopi Buttes volcanic field (8.7 Ma to 4.2 Ma), Mount Floyd volcanic field (6.8 Ma to 6.4 Ma), Shivwits Plateau basalts (9.1 Ma to 1.4 Ma), and Grand Wash basalts (>4.4 Ma) // mostly Hawaiian- to Strombolian-style eruptions

### Tertiary Sedimentary & Volcanic Rocks (Tsv)

► **Eocene to Late Miocene (~50 Ma to 5.9 Ma)**  
fluvial and lacustrine deposits, and rhyolitic ashflow and basaltic lava flows predating the modern Grand Canyon (Long Point lakebeds, Music Mountain and West Water Formations, Buck & Doe Conglomerate, Blue Mountain and Rose Well-Frazier Well gravels, Peach Springs Tuff (18.5 Ma) and basalts (19.94 Ma to 14.63 Ma), Shivwits and Separation Canyon gravels, Muddy Creek Formation, Bidahochi Formation (16 Ma to 5.9 Ma) // alluvial fans, braided streams, lakes

### Chinle Formation (Tc)

► **Late Triassic / Norian (~227 Ma to 209 Ma)**  
conglomerate, sandstone, mudstone, and volcanic ash, locally containing vertebrate fossils and abundant petrified wood fragments (Araucarioxylon arizonicum) // arid coastal plain, northwest-flowing braided streams and meandering streams, flood plains, lakes  
> correlates with: Dolores Formation (CO)

### Moenkopi Formation (Tm)

► **Middle Triassic / Anisian (~245 Ma to 240 Ma)**  
mudstone, sandstone, evaporite, and carbonate rocks // arid coastal plain, sabkha, tidal flat, shallow marine shelf (W)

### Kaibab Formation (Pk)

► **Late Early Permian to Middle Permian / Roadian (272 Ma to 269 Ma)**  
fossiliferous limestone, dolomite, sandstone, and chert // open to restricted shallow marine shelf, lagoon, sabkha  
> correlates with: Concho Limestone (southeastern AZ), Rain Valley Formation (southeastern AZ), Plympton Formation (UT), Garden Valley Formation (NV), Road Canyon Formation (TX)

### Toroweap Formation (Pt)

► **Early Permian / Kungurian (284 Ma to 272 Ma)**  
sandstone, evaporite, limestone, and dolomite // open to restricted shallow marine shelf, tidal flat, sabkha, eolian dunes  
> correlates with: Scherer Formation (southeastern AZ), Gloria Sandstone (northwestern NM), San Andres Limestone (NM), White Rim Sandstone member of the Cutler Formation (southeastern UT)

### Coconino Sandstone (Pc)

► **Early Permian / Kungurian (284 Ma to 272 Ma)**  
cross bedded quartz arenite (sandstone) // arid coastal sand dunes  
> correlates with: Schneibly Hill Formation (central AZ), De Chelly Sandstone (northeastern AZ), Gloria Sandstone (northwestern NM), Yeto Formation (northwestern NM), White Rim Sandstone member of the Cutler Formation (southeastern UT)

### Hermit Formation (Ph)

► **Early Permian / Late Sakmarian & Artinskian (292 Ma to 284 Ma)**  
mudstone and sandstone (redbeds) // arid coastal flood plains  
> correlates with: Organ Rock Formation (northeastern AZ, UT), Queantowep Formation (northwestern AZ), Earp Formation (southeastern AZ), Abo Formation (NM)

### Esplanade Sandstone (PPse)

► **Early Permian / Asselian & Sakmarian (299 Ma to 290 Ma)**  
cross bedded quartz arenite (sandstone) and minor mudstone // arid coastal sand dunes  
> correlates with: Cedar Mesa Sandstone (northeastern AZ, UT), Halgaito Formation (northeastern AZ, UT), Queantowep Formation (northwestern AZ)

### Pakoon Limestone (PPsp)

► **Early Permian / Asselian to Sakmarian (299 Ma to 295 Ma)**  
fossiliferous limestone and dolomite // shallow marine shelf  
> correlates with: Halgaito Formation (northeastern AZ), Queantowep Formation (northwestern AZ), Bird Spring Formation (NV)

### Wescogame Formation (PPsw<sub>2</sub>)

► **Late Pennsylvanian / Kasimovian to Gzhelian (307 Ma to 300 Ma)**  
sandstone, mudstone, limestone, minor conglomerate // arid coastal sand dunes and flood plains  
> correlates with: Hermosa Group (northeastern AZ), Earp Formation (southeastern AZ), Calville Limestone (NV)

### Manakacha Formation (PPsm)

► **Middle Pennsylvanian / early Moscovian (315 Ma to 311 Ma)**  
sandstone, mudstone, and minor limestone // arid coastal sand dunes and flood plains  
> correlates with: Hermosa Group (northeastern AZ), Calville Limestone (NV)

### Whathomigi Formation (PPsw<sub>1</sub>)

► **Early Pennsylvanian to Middle Pennsylvanian / Bashkirian and early Moscovian (323 Ma to 315 Ma)**  
mudstone and cherty limestone // coastal plain and shallow marine shelf  
> correlates with: Black Price Limestone (southeastern AZ), Moles Formation (southeastern AZ), Calville Limestone (NV)

### Surprise Canyon Formation (Msc)

► **Late Mississippian (~326 Ma to 325 Ma)**  
purple-red mudstone, limestone, and conglomerate // estuaries, karst  
> correlates with: Log Springs Formation (northwest NM), Chainman Formation (western UT), Ely Formation (southern NV), Indian Springs Formation (southern NV)

### Redwall Limestone (Mr)

► **Early to Middle Mississippian (~353 Ma to 335 Ma)**  
fossiliferous limestone, dolomite, and chert // shallow marine shelf  
> correlates with: Escabosa Limestone (southeastern AZ), Leadville Limestone (southwestern CO), Monte Cristo Group (southeastern NV)

### Temple Butte Formation (Dtb)

► **Middle to Late Devonian (~385 Ma to 375 Ma)**  
dolomite and sandy dolomite // estuaries (E) to shallow marine shelf (W)  
> correlates with: Jerome Member of the Martin Formation (central AZ), China Valley Formation (central AZ), Ebert Formation (northeastern AZ), Muddy Peak Limestone (southern NV)

### Frenchman Mountain Dolostone (Cfm) \* Formerly identified as Undifferentiated Dolomites

► **Early Late Cambrian (498 to 497 Ma)**  
dolomite // shallow marine shelf  
> correlates with: Bonanza King Formation (NV)

### Muav Limestone (Cm)

► **Middle to Early Late Cambrian (502 to 499 Ma)**  
limestone, dolostone, mudstone, and conglomerate // shallow marine shelf  
> correlates with: Carara Formation (NV), Bonanza King Formation (NV)

### Bright Angel Shale (Cba)

► **Middle Cambrian (507 to 502 Ma)**  
mudstone, sandstone, and dolomite // shallow marine shelf  
> correlates with: Carara Formation (NV), Bonanza King Formation (NV)

### Tapeats Sandstone (Ct)

► **Middle Cambrian (508 to 507 Ma)**  
cross bedded feldspathic arenite (arkose), fine-grained sandstone, and mudstone // nearshore marine shelf  
> correlates with: Boka Quartzite (southeastern AZ), Abrigo Formation (southeastern AZ), Zabriskie Quartzite (NV)

### Sixtymile Formation (Cs)

► **Late Early to Middle Cambrian (527 to 509 Ma)**  
sedimentary breccia, conglomerate, and sandstone // landslides, flood plains, and river channels  
> Formerly considered Neoproterozoic, now assigned as a Cambrian age (detrital zircons; Karlstrom et al., 2018; Karlstrom et al., 2020)

### Kwagunt Formation (Zck)

► **Late Proterozoic (750 Ma to 742 Ma)**  
mudstone, sandstone, and dolomite // shallow marine shelf and coastal plain  
> correlates with: Beck Springs Dolomite (CA), Red Pine Shale (UT)

### Nankoweap Formation (Zn)

► **Late Proterozoic (~800 Ma to 770 Ma)**  
hematitic sandstone and quartz arenite // lakes or shallow marine shelf  
> correlates with: Beck Springs Dolomite (CA), Red Pine Shale (UT)

### Cardenas Basalt (Yuc)

► **Middle Proterozoic (1104 Ma)**  
basalt and basaltic andesite lava flows, sandstone // extension-related volcanism

### Diabase Intrusions (Yd)

► **Late Proterozoic (770 Ma to 750 Ma)**  
mudstone, sandstone, dolostone, and limestone // shallow marine shelf and coastal plain  
> correlates with: Beck Springs Dolomite (CA), Red Pine Shale (UT)

### Dox Formation (Yud)

► **Middle Proterozoic (1140 Ma to 1104 Ma)**  
sandstone and quartz arenite // flood plains, river channels, tidal flats, and near-shore marine shelf  
> correlates with: Troy Quartzite (central AZ), Hazel Formation (western TX)

### Shinumo Quartzite (Yus)

► **Middle Proterozoic (<1167 Ma to ~1140 Ma)**  
cross bedded quartz arenite // near-shore marine shelf, tidal flats  
> correlates with: Troy Quartzite (central AZ)

### Hakatai Shale (Yuh)

► **Middle Proterozoic (<1187 Ma to ~1167 Ma)**  
mudstone and quartz arenite // tidal flats, shallow marine shelf  
> correlates with: Mescal Limestone (central AZ)

### Bass Limestone (Yub)

► **Middle Proterozoic (1254 Ma to ~1187 Ma)**  
limestone, marble, conglomerate // shallow marine shelf  
> correlates with: Mescal Limestone (central AZ), Crystal Spring Formation (CA)

### Post-Orogenic Granitic Rocks (Yg)

► **Mesoproterozoic (1400 Ma to 1300 Ma)**  
coarse-grained granitic rocks and pegmatite lacking foliation // various plutons

### Plutonic Rocks (Xg)

► **Paleoproterozoic (1840 Ma to 1662 Ma)**  
granite, granodiorite, diorite, gabbro, and pegmatite // various plutons  
Xg<sub>1</sub> - (1840 Ma) Tonalite and quartz diorite form the basement for younger metamorphic rocks  
Xg<sub>2</sub> - (1740-1714 Ma) Granodiorite, diorite, and gabbro intruded before 1.7 Ga deformation  
Xg<sub>3</sub> - (1713-1662 Ma) Granite and pegmatite intruded during peak metamorphism (1.70-1.68 Ga)

### Granite Gorge Metamorphic Suite (Xm)

► **Paleoproterozoic (1750 Ma to 1740 Ma)**  
deformed schist, amphibolite, gneiss, and migmatite (Brahma Schist, Rama Schist, Vishnu Schist) // medium- to high-grade metamorphism of volcanic and sedimentary protoliths  
► Phantom Ranch  
► Colorado River

## CANYON ETYMOLOGY

- Brahma // the god of creation (Hindu)
- Bright Angel // named by J.W. Powell from a Methodist hymn
- Cardenas // explored the Colorado River area in 1540 AD
- Chuar // short for "Chuar-oo-um-peak", a young Kaibab chief
- Coconino // "little water" (Havasupai)
- Hakatai // a transliteration of "Colorado River" (Hualapai)
- Hermit // named after the "hermit", Louis D. Boucher
- Muav // a topographic "divide" or "saddle" (Paiute)
- Mazatzal // "place of the deer" (Aztec)
- Moenkopi // "place of the running water" (Hopi)
- Navajo // "plateau" or "mountain" (Southern Paiute)
- Ramona // a perfect human and 7th avatar of Vishnu (Hindu)
- Redwall // named by G.K. Gilbert for its massive, reddish cliffs
- Shinumo // "peace" (Hopi)
- Supai // short for "blue-water people" (Havasupai)
- Tapeats // named by J.W. Powell after the Paiute "Ta Pits"
- Toroweap // "arroyo" or "dry wash" (Paiute)
- Uinkaret // "where the pines grow" (Paiute)
- Unkar // "red stone" (Paiute)
- Vishnu // the god of preservation and protection (Hindu)
- Yavapai // "people of the sun" (Yavapai)
- Zoroaster // an ancient Persian religious leader ~600 BC

## TECTONIC HISTORY

- **Basin & Range Disturbance**  
► **Miocene (~20 Ma to 10 Ma)**  
Post-subduction crustal extension formed high-angle normal faults // Bright Angel fault, Toroweap fault, Hurricane Fault, Grand Wash fault
- **Laramide Orogeny**  
► **Late Cretaceous to Paleogene (~80 Ma to 40 Ma)**  
Subduction-related compression formed high-angle reverse faults, thrust faults, folds, and monoclines // Butte fault, Bright Angel fault, Toroweap fault, Hurricane fault, East Kaibab monocline, Grandview monocline, Echo Cliffs monocline
- **Rodinia rifting**  
► **Neoproterozoic (<742 Ma)**  
Crustal extension formed normal faults and half-graben // Butte fault, Palisades fault, Tipoff fault, Wheeler fault
- **Mazatzal Orogeny**  
► **Paleoproterozoic (~1675 Ma to 1650 Ma)**  
Subduction-related compression formed high-angle reverse faults, thrust faults, and folds
- **Yavapai Orogeny**  
► **Paleoproterozoic (~1710 Ma to 1700 Ma)**  
Subduction-related compression and regional metamorphism produced foliation, isoclinal folds, boudinage, etc. // numerous shear zones (Vishnu, Bright Angel, Crystal, Bass, Gneiss Canyon, Separation)

## HYDROLOGIC FEATURES

- **Breccia Pipes & Collapse Structures**  
Form by dissolution of carbonate rocks by groundwater; commonly mineralized // Orphan, South Kaibab, 23-mile
- **Caves & Alcoves**  
Solution features commonly form in the Redwall and Muav // Stanton's Cave, Triple Alcoves, Cave of Domes, Rampart Cave
- **Springs & Waterfalls**  
Ubiquitous, but often emanate from the Redwall and Muav // Vasey's Paradise, Roaring Springs, Dripping Spring, Thunder River, Dutton Spring, Whispering Spring, Pumpkin Spring, Cheyava Falls, Ribbon Falls, Deer Creek Falls, Havasu Falls, Travertine Falls
- **Streams**  
Major stream drainages and tributaries // Colorado River, Paria River, Little Colorado River, Nankoweap Creek, Clear Creek, Bright Angel Creek, Crystal Creek, Tapeats Creek, Kanab Creek, Havasu Creek, Diamond Creek
- **Rapids**  
Typically form where side drainages deposit debris in the Colorado River // Badger, "The Roaring 20's", Unkar, Hance, Sockolages, Grapevine, Nankoweap, Hermic, Crystal, "The Gems", Bedrock, Duebendorf, Lava Falls, 205-mile, 232-mile

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