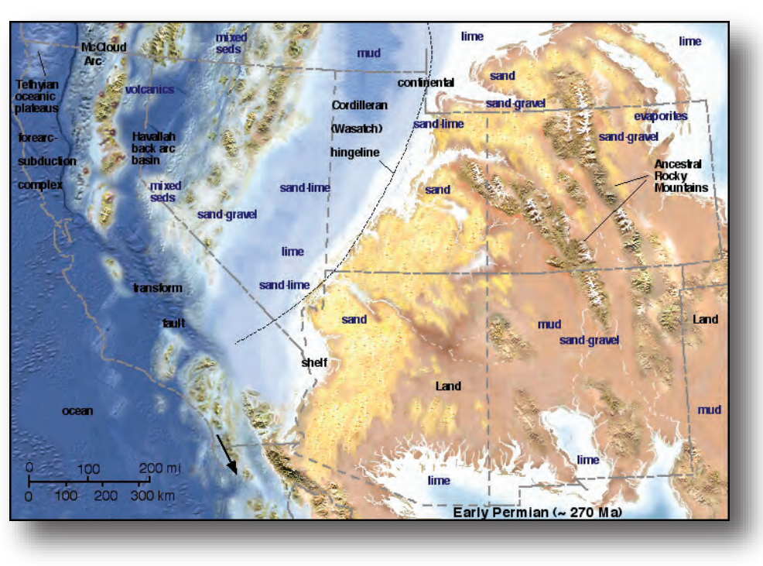
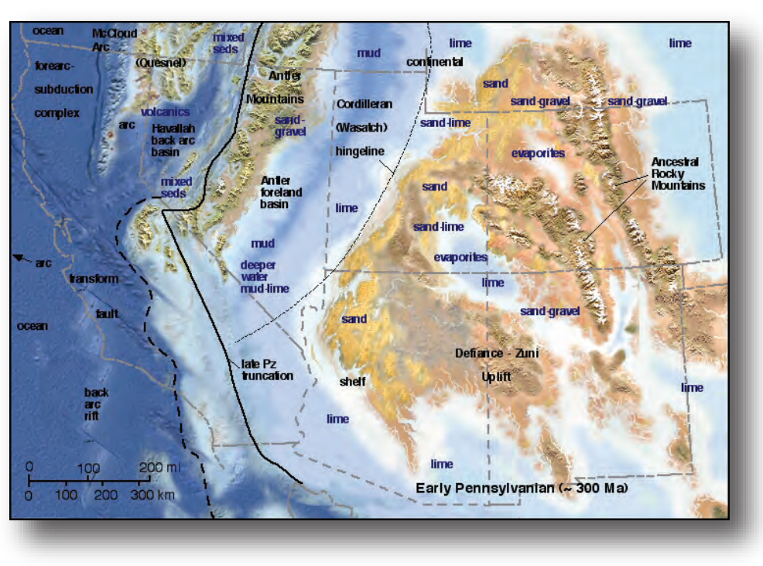
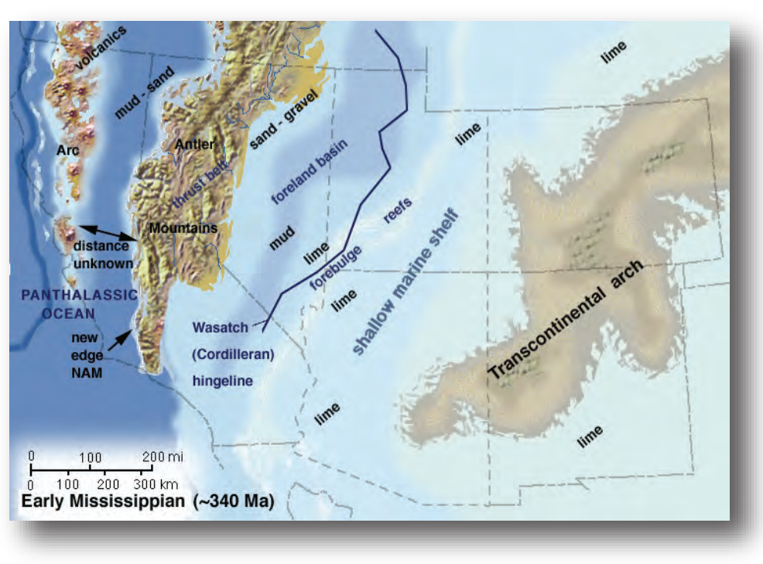
GRAND CANYON STRATIGRAPHY

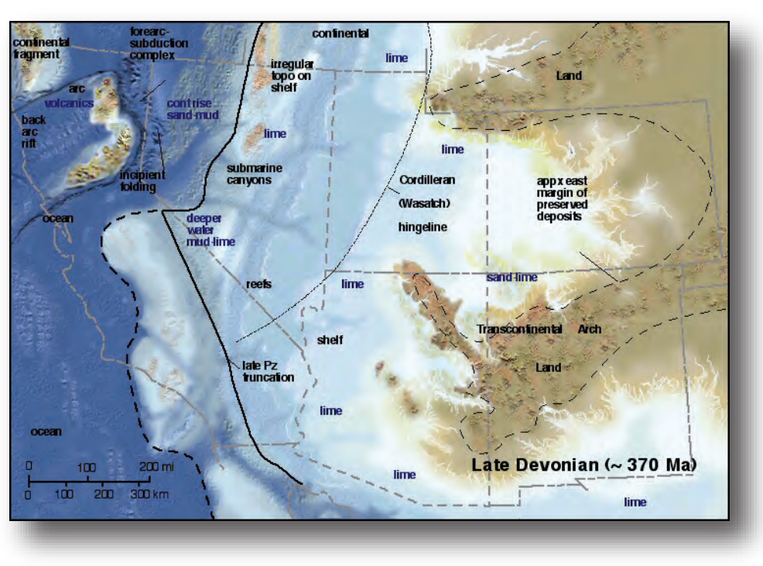
by Bob Leighty

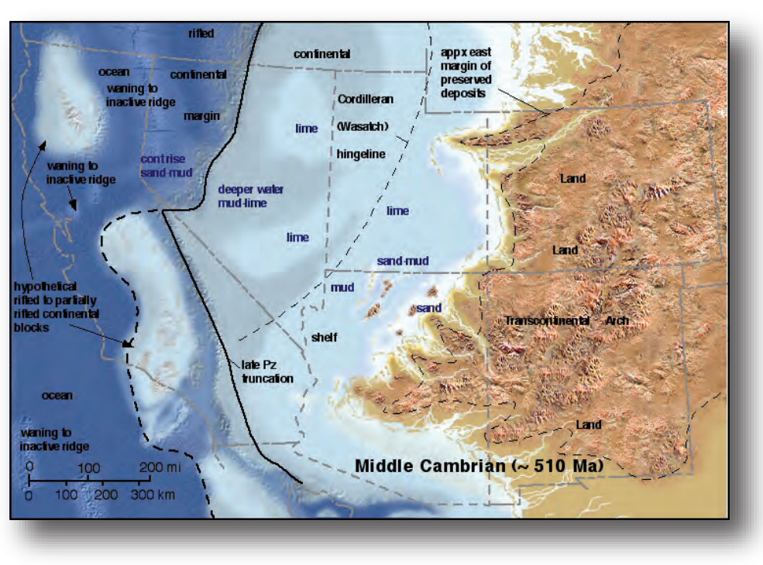
PALEOGEOGRAPHY[1] · GEOLOGIC TIME[2] · LITHOLOGIES[3] · ROCK UNITS[4] · EXPLANATION











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 (8.5 Ma to 4.1 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 6 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)) // alluvial fans, braided streams, lakes

Chinle Formation (₮c)

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

Moenkopi Formation (₮m)

▶ 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: Concha 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: Scherrer Formation (southeastern AZ), Glorieta 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: Schnebly Hill Formation (central AZ), De Chelly Sandstone (northeastern AZ), Glorieta Sandstone (northwestern NM), Yeso 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), Queantoweap 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), Queantoweap Formation (northwestern AZ)

Pakoon Limestone (PPsp)

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

Wescogame Formation (PPsw$_2$)

▶ 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), Callville 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), Callville Limestone (NV)

Whatahomigi Formation (PPsw$_1$)

▶ 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 Prince Limestone (southeastern AZ), Molas Formation (southeastern UT), Callville 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, dolostone, and chert // shallow marine shelf
> correlates with: Escabrosa 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)
dolostone and sandy dolostone // estuaries (E) to shallow marine shelf (W)
> correlates with: Jerome Member of the Martin Formation (central AZ), Chino Valley Formation (central AZ), Elbert Formation (northeastern AZ), Muddy Peak Limestone (southern NV)

Unclassified Dolomites (€ud)

▶ Late Early to Middle Cambrian (~521 Ma to 501 Ma)
dolomite // shallow marine shelf
> correlates with: Bonanza King Formation (NV)

Muav Limestone (€m)

▶ Middle Cambrian to Late Middle Cambrian (~521 to 500 Ma)
limestone, dolostone, mudstone, and conglomerate // shallow marine shelf
> correlates with: Carrara Formation (NV), Bonanza King Formation (NV)

Bright Angel Shale (€ba)

▶ Late Early Cambrian to Middle Cambrian (~521 to 500 Ma)
mudstone, sandstone, and dolomite // shallow marine shelf
> correlates with: Carrara Formation (NV), Bonanza King Formation (NV)

Tapeats Sandstone (€t)

▶ Late Early Cambrian to Early Middle Cambrian (~521 to 500 Ma)
cross bedded feldspathic arenite (arkose), fine-grained sandstone, and mudstone // nearshore marine shelf
> correlates with: Bolsa Quartzite (southeastern AZ), Abrigo Formation (southeastern AZ), Zabriskie Quartzite (NV)

SUPAI GROUP

TONTO GROUP

Sixtymile Formation (Zs)

▶ Late Proterozoic (<742 Ma)
sedimentary breccia, conglomerate, and sandstone // landslides, flood plains, and river channels

Kwagunt Formation (Zck)

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

Galeros Formation (Zcg)

▶ 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)

Nankoweap Formation (Zn)

▶ Late Proterozoic (<800 Ma to 770 Ma)
hematitic sandstone and quartz arenite // lakes or shallow marine shelf

Cardenas Basalt (Yuc)

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

Diabase Intrusions (Yd)

▶ Middle Proterozoic (>1104 Ma)
mafic sills and dikes (Comanche Point- to Cardenas-aged) // extension-related plutonism
> correlates with: Apache Group diabase (central AZ), Pahrump Group diabase (CA)

Dox Formation (Yud)

▶ Middle Proterozoic (1140 Ma to 1104 Ma)
siltstone and sandstone // 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)

CHUAR GROUP
770 Ma to 742 Ma

UNKAR GROUP
1254 Ma to 1104 Ma

GRAND CANYON SUPERGROUP
1254 Ma to 742 Ma

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$_1$ - (1840 Ma) Tonalite and quartz diorite form the basement for younger metamorphic rocks
Xg$_2$ - (1740-1714 Ma) Granodiorite, diorite, and gabbro intruded before 1.7 Ga deformation
Xg$_3$ - (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

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 (dashed where gradational)
*742 isotopic date (in Ma)
◀ Cape Royal notable location
Ribbon Falls major waterfall
Pumpkin Spring major spring

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

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
- ▶ Kaibab // "plateau" or "mountain" (Southern Paiute)
- ▶ Mazatzal // "place of the deer" (Aztec)
- ▶ Moenkopi // "place of the running water" (Hopi)
- ▶ Muav // a topographic "divide" or "saddle" (Paiute)
- ▶ Rama // 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 and Collapse Structures

▶ Formed by dissolution of carbonate rocks by groundwater; commonly mineralized // Orphan, South Kaibab, 23-mile

Caves

▶ Solution caverns commonly formed in the Redwall and Muav // Redwall Cavern, Stantons Cave, 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, Sockdolager, Grapevine, Horn Creek, Granite, Hermit, Crystal, "the Gems", Bedrock, Duebendorf, Lava Falls, 205-mile, 232-mile

NOTES & REFERENCES

1 - Paleogeographic maps by Ron Blakey (unpub. data).
2 - Geologic time scale based on the International Chronostratigraphic Chart v2016/04. Not drawn to scale.
3 - Major lithologic changes are shown west-east.
4 - This is a composite stratigraphic column for the Grand Canyon area. Unit thicknesses are not drawn to scale and lateral thickness changes are generally not depicted.

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