Volcanic events of the past 20 Ma in the western Grand Canyon region: Significance to Grand Canyon erosion

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INTRODUCTION

The record of volcanic events in the western Grand Canyon and southwestern Colorado Plateau extends back about 19 Ma as basalt lavas flowed northeastward onto the Hualapai Plateau and down several valley drainages. The Hualapai Plateau and Mogollon Rim were well developed before volcanism started. Volcanism generally migrated through time northeastward onto the southwestern Colorado Plateau about 30 miles. The volcanic events provide windows to how the ancient landscapes of this region may have looked prior to and during the establishment of an integrated Colorado River system. The chronological scenario present here is limited and subject to change as new dating techniques improve and new investigations are initiated. Future studies of the volcanic rocks of this region are highly recommended.

Prior to 19 million years ago, canyons as deep as Grand Canyon had eroded into the southwestern uplifted margins of the Hualapai Plateau from higher terrain southwest of the Plateau. These drainages became shallower in depth and wider northeastward onto the Shivwits and Coconino Plateaus. The present western Grand Canyon is the only area where a northerly drainage may have extended several miles onto the plateaus from the Peach Springs and Hualapai Plateau areas as suggested by Young (1987). From about the Granite Park area north, the drainage system was probably no longer confined to a canyon valley, but spread out as alluvial valleys or fans across soft Triassic rocks. The Mogollon Rim, an erosional escarpment, was within one or two miles of its present position when the first volcanic rocks were deposited **19.94±.4 Ma (A)** and **18.5±.2 Ma (B)** at Peach Springs and in other canyons of the Hualapai Plateau. A **19.03±.44 Ma (C)** basalt flow perched on an isolated hill (Separation Hill) near the head of south Separation Canyon, Hualapai Plateau, overlies Tertiary gravels. The gravels and basalt flow were derived from the Grand Wash Cliffs area about 25 miles southwest of Separation Hill. The 19 million year old volcanic rocks basically “pooled up” in the Peach springs and Hualapai Plateau areas as northeasterly drainages became filled with alluvial gravels. The widespread alluvial deposits occupied a strike valley that paralleled the Mogollon Rim escarpment from about the Surprise Canyon area southeastward into Aubrey Valley as well as drainages onto the Coconino and Shivwits Plateaus. Drainage reversal from north to south may have begun on the Shivwits and Coconino Plateaus about 18 or 17 Ma.

HUALAPAI DRAINAGE SYSTEM

Northeasterly drainage of the Hualapai Plateau is also supported by the **17.4±.9 Ma (D)** Iron Mountain basalt that flowed towards Grapevine Canyon on the southwestern edge of the Hualapai Plateau. About **15.25±.24 Ma (E)**, Grapevine Canyon volcano accumulated basalt and pyroclastic deposits on the east rim of and within Grapevine Canyon. Some of the basalt flowed at least 6 miles across the Hualapai Plateau in a northerly direction and into a developing Hualapai Plateau drainage system that was already eroding headward into the plateau from the Grand Wash Cliffs near the mouth of today’s Grand Canyon. Headward erosion of the Hualapai system proceeded along the Mogollon Rim strike-valley towards Diamond Creek. The Hualapai drainage began to capture all drainages of the Hualapai Plateau, western Aubrey Valley, and the Coconino Plateau. Drainage reversal by headward erosion advanced rapidly towards the Kaibab Plateau. During headward erosion, Blue Mountain volcano, east of Diamond Creek, erupted about **14.63±1.1 Ma (F)** and accumulated basal flows on Tertiary gravels that still blanketed that area, which was relatively flat terrain with the Mogollon Rim to the north and east. Surface drainage at Blue Mountain was relatively flat and non-directional because the Blue Mountain basalt appears to have flowed in a radial fashion but accumulated in a mound were it erupted. In the meantime, headward erosion of the Hualapai Plateau drainage had extended into the highlands of the

Kaibab Plateau and developed the ancestral Kanab and Cataract Creek tributaries and other tributaries from the Kaibab Plateau where large canyons are present today.

A two-foot thick layer of air-fall tuff was deposited in shallow fresh water siltstone and limestone beds of Hualapai Lake at the mouth of Grand Canyon about **12.67±.3 Ma (G)**. This tuff is near the base of the 1,000-foot thick Hualapai Limestone. The Hualapai and Grapevine drainages were supplying sediment to Hualapai Lake, but most of the fresh water limestone and siltstone came down the Hualapai Plateau drainage from as far away as the Kaibab Plateau. Lenses of conglomerate that came from the Grand Wash Cliffs were deposited along the margins of Hualapai Lake. About 15 miles southeast of Hualapai Lake, Colorado River Mile 264, Hualapai Plateau, basalt dikes intruded all Paleozoic rocks about **9.19±.13 Ma (H)**. These dikes are connected to basalt flows on Snap Point (**9.07±.8 Ma [I])**, about 9 miles north of Colorado River Mile 264. The Hualapai Plateau drainage at that time could have been a smaller canyon at Mile 264 and basalt flows from these dikes may have flowed into the smaller canyon and were subsequently eroded away. The Snap Point basalt on the Mogollon Rim did cascade down the west-facing slope of the rim into Snap Canyon and onto alluvial fans of the Grand Wash Trough at Nevershine Mesa (about 6 miles north of the modern Colorado River channel).

The volcano that erupted at Price Point on the Shivwits Plateau about **8.20±.1 Ma (J)** 5 miles west of Colorado River Mile 207 and Granite Park, is one of the oldest volcanoes on the Shivwits Plateau. The Price Point volcanic neck is exposed in the Hermit Formation about ¼ mile southeast of Price Point. The canyon rims of the Hualapai Plateau drainage system near Granite Park at that time was probably only about 3 to 4 miles wide and eroded down into the Hermit Formation. Other basalts erupted on the Shivwits Plateau about **7.64±.3 Ma (K)** near the head of today's Green Spring Canyon, **7.06±.49 Ma (L)** at Mount Dellenbaugh, **6.78±.15 Ma (M)** three miles northwest of Mount Dellenbaugh, and **6.2±.3 Ma (N)** elsewhere near Mount Dellenbaugh (location unknown). All these flows overlie the Kaibab and Moenkopi Formations.

COLORADO RIVER ESTABLISHED?

The Parashant dike swarm extends from the north rim of Parashant Canyon to Colorado River Mile 197, and southeastward into 196-Mile Canyon. The dike swarm is about **6.34±.16 Ma (O)** and intrudes all Paleozoic rocks in this 10-mile wide part of Grand Canyon. If the dikes require the presence of bedrock across this interval at elevations similar to their present locations, the canyon may not have been as deeply eroded then as it is today. The Hualapai drainage system or early Colorado River could have occupied a canyon about half the present size and depth of today's Grand Canyon.

The last air-fall tuff ash bed in Hualapai Lake was deposited within the upper part of the Hualapai Limestone about **5.97±.07 Ma (P)**. Hualapai Lake had accumulated 1,000 feet of fresh water limestone and siltstone sediments for nearly 5 to 6 million years. Shortly after the air-fall tuff, about **5.76±.26 Ma (Q)**, several dikes intruded all the Paleozoic rocks in the canyon about ½ mile west of Colorado River Mile 202. If it is assumed that the 202-Mile dikes intruded bedrock (otherwise they would have erupted as lavas near or at the lowest elevation of the developing canyon floor), a much smaller canyon may have been present, eroded down to down to about the Esplanade Sandstone level.

Between about 6.3 and 5.4 million years ago, the Hualapai drainage captured the Colorado River somewhere near the crest or east of the Kaibab/Coconino Plateau anticline of eastern Grand Canyon. The added discharge from this perennial stream would greatly increased the erosive power of the drainage system, and explain the large flood deposits that occasionally overwhelmed the Hualapai Lake deposits with Colorado River gravels.

Rapid down cutting of the Colorado River subsequently initiated vigorous headward erosion of all tributary drainages into the plateaus and Grand Wash Trough areas. Basalt flows of **5.45±1.11** and **4.70±.07 Ma (R)** flowed south down drainages north of the Colorado River in the Grand Wash Trough area. One of the basalts flowed down the Colorado River to Sandy Point at **3.80±.11** or **3.79±.46 Ma (S)**. The **4.75±.26 Ma (T)** basalt flows at Poverty Mountain on the Shivwits Plateau flowed a short distance down Hidden Canyon drainage towards the Grand Wash Trough. Hidden Canyon drainage was later captured by headward erosion of Parashant Wash (tributary of Grand Canyon) just south of Poverty Mountain when rapid down cutting of the Colorado initiated vigorous headward erosion of Parashant Wash.

In Grand Canyon several dikes intruded the Esplanade Sandstone and Hermit Formation at **4.56±.12 Ma (U)** about one mile west of Colorado River Mile 188 near the mouth of Whitmore Canyon. One of the dikes produced a basalt flow that cascaded down a steep talus slope on the Hermit Formation and stopped a few hundred feet short of the Esplanade Sandstone indicating that the Esplanade Sandstone may have been exposed to Grand Canyon erosion in this area. At about this same time, other basalt flows became active on the Shivwits and Uinkaret Plateaus just north of Whitmore Canyon, **4.3±.6 Ma (V)** at Diamond Butte, **3.47±.63 Ma (W)** at Mount Trumbull, and **3.67±.07 Ma (X)** east of Bundyville. All these flows overly the Chinle Formation or upper part of the Moenkopi Formation. These basalts are at similar elevations and stratigraphic positions before any faulting of this region began. Thus the Paleozoic and Mesozoic strata were at about the same elevation throughout the region. The Hurricane, Toroweap, and all others faults in this region began to become active about 2.5 to 3 million years ago, based on the basalt/fault relationships between Grand Canyon and Utah. Therefore, by 4.5 Ma, the Colorado River could have eroded a canyon down to or into the Esplanade Sandstone in the Whitmore Canyon area, to the Hermit and Esplanade level several miles upstream (east) of Whitmore Canyon, and into or below the Esplanade Sandstone downstream (west), because there were no fault offsets. The Hurricane, Toroweap, and all other faults in western Grand Canyon became active about 3 to 2.5 million years ago and most are active today.

Several volcanic eruptions occurred in the past one million years on the Uinkaret Plateau and in Grand Canyon. The eruptions began about **1.0±.4 Ma (Y)** at Little Tanks north of the town of Mt. Trumbull (Bundyville) and at Antelope Knoll about **850,000 (Z)** years ago. Volcanic activity was sporadic for a short time with a very active period about **300,000** and **100,000** years ago, when basalt flows formed temporary lava dams in the Grand Canyon. The most recent eruption occurred about 3 miles south of Mt. Trumbull Mountain about **1,000 (AA)** years ago.

The basalt dikes at Colorado River Mile 159 **(BB)** provide important constraints on the erosional rate of the Colorado River. The 159-Mile dikes are associated with three volcanic vents that erupted onto the Esplanade Sandstone surface within Grand Canyon because they are aligned on the same joint/fracture system. A pyroclastic neck is exposed in the Manakacha Formation just above the 159-Mile dikes on the south side of the river. This pyroclastic vent indicates that the Colorado River had eroded as deep as the Manakacha or Watahomigi Formation, but not into the Redwall Limestone because the dikes are exposed in the Redwall on both sides of the 2,000-foot deep canyon. An accurate age of the 159-Mile dikes has not been obtained because of alteration or contamination of the basalt. The K-Ar ages of basalt flows on Esplanade Sandstone are, **0.78±.15 Ma (CC)** at Yumtheska vent west, **0.76±.08 Ma (DD)** in Tuckup Canyon, and **0.41±.07 Ma (EE)** at The Cork. The probable age for the 159-Mile Dikes and associated vents on the Esplanade is about **760,000** years. This implies that the Colorado River had eroded its canyon to a depth of at least 2,000 ft p in the past 760,000 years at the 159-Mile dikes area. Coincidently, total offset of the Hurricane (1,300 ft) and Toroweap (700 ft) faults 20 miles downstream is about 2,000 ft, down-to-the-west. It is possible that gradual displacement along both faults formed erosional nick points that would account for the 2,000 feet of erosion up stream of the faults. Downstream of the faults, the canyon gets wider where down cutting and sediment accumulation were nearly in equilibrium. Canyon erosion below the faults concentrated on widening the river corridor rather then deepening it. The occasional lava dams downstream of the Toroweap and Hurricane Faults would also contribute to the canyon widening process. (See geochronology tables at end of abstracts for references to dates.)

Young, Richard A., 1987, Landscape development during the Tertiary, *In* Graf, W.L., ed., Geomorphic systems of North America: Geological Society of America, Centennial Special Volume, 2, p. 265-276.


Long Pt.
Seligman
H. Fault
Peach Sp.
Virgin Mts