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Separation Canyon Hill (upper right) capped by 30 feet of Miocene basalt.

Brief Cenozoic Geologic History of the Peach Springs Quadrangle and the Hualapai Plateau, Mohave County, Arizona (Hualapai Indian Reservation)

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BRIEF CENOZOIC GEOLOGIC HISTORY OF THE PEACH SPRINGS QUADRANGLE AND THE HUALAPAI PLATEAU, MOHAVE COUNTY, ARIZONA

(Hualapai Indian Reservation)

To accompany the Peach Springs Geologic Quadrangle Map,
Cross Section and Legend

By

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Based on fieldwork and research completed from June 1962 through January 2011

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Introduction

The Hualapai Plateau contains one of the longest (Paleocene to Pliocene), best preserved, and well exposed sections of Cenozoic geology in Arizona. The Cenozoic sediments and volcanic rocks are preserved in Laramide-age northeast-trending paleocanyons, which converge on the Hurricane fault zone. Adequately dating the full range of Cenozoic terrestrial sediments preserved in these paleocanyons is a frustratingly slow process, due to the relative scarcity of fossil remains and volcanic ash horizons. Milkweed, Hindu and Peach Springs Canyons (re-excavated paleocanyons) on the Hualapai Plateau preserve the best record of the Cenozoic history, in addition to descriptive logs from deep wells located close to the thalwegs of the paleochannels near Truxton and Peach Springs Arizona (Young, 1979, 1987, 1989; Young and Spamer, 2001, Elston and Young, 1991; Peach Springs Quadrangle, geologic map, 2011). Figures 1a and 1b are general location maps illustrating important geologic features.

Early Eocene, late Oligocene, and early to middle Miocene ages have been established from scarce fossils (Long Point, AZ) and locally occurring basalt flows and volcanic ash. The Peach Spring Tuff (revised terminology, Young, 1999) is a widespread key Miocene volcanic ash flow (18.5 Ma) that extends from Barstow, California, approximately 210 miles (345 km) eastward to the Mohave-Yavapai County line along Interstate Route I-40 in Arizona, and from near the latitude of Hoover Dam in the north southward to the vicinity of Parker Dam on the Colorado River (Figures 20, 21). Its source is reportedly the Silver Creek caldera at the western edge of the Black Mountains near Secret Pass Canyon (Pearthree et al., 2009). The Peach Spring Tuff, interbedded with the Tertiary sediments and basalts found in and near Milkweed, Hindu and Peach Springs Canyons on the Hualapai Plateau, provided the earliest means of determining the relative ages and continuity of stratigraphic units across the region from the western Grand Canyon southward to the Aquarius and Mohon Mountains near Trout Creek (Figures 11, 20, 21). The tuff also preserves useful information pertaining to the nature and relative age of the Basin and Range episode of structural deformation along the Plateau margin.

The oldest Cenozoic sediments in the region are the widespread remnants of the Arizona "Rim gravels", Paleogene relics of the arkosic fluvial sediments shed northward and eastward from former Laramide uplifts and ranges (Mogollon Highlands) that bordered the modern edge of the southwestern Colorado Plateau (Cooley and Davidson, 1963) (Figure 2). These sediments are more widespread than typically shown on existing geologic maps, and probably covered much of the Colorado Plateau in northern Arizona to depths of several hundred feet (Flowers, et al., 2008; Young, 1982, 2001a). It is sometimes difficult to distinguish the true Laramide-age sediments (deeply weathered arkosic sediments and associated lag gravels) from similar deposits that have been reworked from these in situ Laramide deposits during late Eocene through Pleistocene time. However, the inclusion of Miocene volcanic clasts in many younger, reworked units, and the highly weathered nature of the original Laramide sediments, usually clarify this important distinction. The Arizona "Rim gravels", renamed the Music Mountain Formation by Young (1966, 1999), contain occasional limestone and/or marl beds from 1 to 100+ feet (30m) thick. Thin limestone beds near Long Point, Arizona (Duff Brown Tank on the Howard Spring 1:24,000-scale topographic map) contain a variety of gastropod species that J. H. Hartman has determined to be of early Eocene age (Young and Hartman, 2011). The gastropods are located in thin limestone lenses within the upper portion of an erosionally truncated section of the arkosic Laramide sediments (Figure 9). Therefore it is assumed that the lower portion of the Laramide sediments (Music Mountain Formation) is likely to extend back into Paleocene time. The erosion of the buried paleocanyons in which these fluvial arkoses were deposited probably was initiated in late Cretaceous time.

Previous Mapping Projects

The first modern comprehensive geologic mapping project on the Hualapai Plateau (Hualapai Indian Reservation) is USGS Water-Supply Paper 1576-A (Twenter, 1962), which includes a simplified geologic map (1:125,000 scale) that combines the now-recognized 9 Cenozoic rock units into a single volcanic map unit and a single Tertiary gravel (labeled west and east of the Hurricane fault as Tf and Tg, respectively). Tf was designated the "fluvial beds of Hindu Canyon" as described in the Master's Thesis of R. S. Gray (1959) from the University of Arizona.

R.A. Young's initial geologic mapping project began in June 1962, funded by the Museum of Northern Arizona under the supervision of E.D. McKee (USGS, Denver), and was intended to document a proposed alternate outlet for the ancestral Colorado River on the Hualapai Plateau. Young was initially unaware of the work of Twenter (in press in 1962), and subsequently found that the limited areal study by Gray (1959) confused and inaccurately described some key Tertiary units and their correlations throughout the broader region. The history of the evolution of the stratigraphic nomenclature and the establishment of formal geologic names for the Tertiary rock units is described in detail by Young (1999).

The field mapping by Young began prior to the availability of 1:24,000-scale topographic maps for most of western Arizona, and relied primarily on 1936 aerial photographs obtained during a second field mapping season in 1963. The only topographic map available at that time (Williams AMS sheet; 1:250,000 scale) had a 200-foot contour interval. Only a portion of the Hindu Canyon 1:62,500 scale (15-minute) USGS topographic map (Bridge and Hindu Canyon areas) had been completed as a result of preliminary studies for the subsequently abandoned Bridge Canyon dam site on the Colorado River. A series of four geologic maps by R.A. Young were completed in 1966 (PhD dissertation) on a mylar base from the 1936 aerial photography, supplemented with aneroid barometer elevation control points for key sections. These maps contain the typical errors associated with photogrammetric distortion, especially in deep canyons. Crude planimetric control was achieved by reproducing the drainage pattern in detail. The bedrock geology for these maps relied primarily on the 1962 general map by Twenter. The Cenozoic geology was mapped in detail, and all of the nine rock units shown on the current Peach Springs Quadrangle geologic map and legend were defined (Young, 2011). Some of the original names proposed have been revised (Young, 1999). The greatest attention to detail for the 1962-1966 mapping project was focused on the deposits exposed in and near Milkweed, Hindu, and Peach Springs Canyons, with lesser attention accorded the similar deposits occurring east of the Hurricane fault near Blue Mountain and throughout the Truxton Valley. The Music Mountain Formation equivalents east of the Hurricane fault were first described in the reconnaissance studies of E.D. Koons (1948a, 1948b), work that also introduced some confusion into the true nature, stratigraphic position, and relative ages of the different Cenozoic gravel units as explained by Young (1999).

During the 1990s the USGS completed a cooperative mapping project with the Bureau of Indian Affairs and the Hualapai Tribe, subsequently published as USGS Miscellaneous Investigations Series Maps I-

2440, I-2643, I-2522, and I-2554 (Billingsley et al. 1999, 2000). This mapping project focused mainly on defining the bedrock units, the geologic structures, and the location of uranium-bearing breccia pipes. Cenozoic sedimentary deposits were only subdivided into units labeled QTg and Tg, based on the main objective of the mapping and the limitations associated with 1:48,000 scale maps. R.A. Young participated to a limited degree in the Cenozoic gravel mapping for the I-2554 map sheet (Billingsley et al, 1999), and completed the 30-page Appendix which accompanies the map and defines the nature and ages of all the Cenozoic rock units and the evolution of the nomenclature, including establishment of appropriate type sections (Young, 1999). The I-2554 Map Appendix also describes the reasons for changing the name, Peach Springs Tuff, to Peach Spring Tuff, based on the recommendations in the North American Stratigraphic Code (AAPG, 1983) and the conflict resulting from the preexisting name of the Peach Springs member of the Muav Limestone.

Description of Cenozoic Rock Units

The following pages include brief descriptions and photographs of all the Cenozoic rock units shown on the Peach Springs Canyon geologic quadrangle map (from oldest to youngest) and that also occur throughout much of the surrounding Hualapai Plateau, west of the Hurricane fault. See R.A. Young (1966, 1979, 1982, 1999, 2001a, 2001b) for more complete descriptions of environments of deposition and regional age relationships. Additional geologic maps of the Hindu Canyon and Milkweed Canyon NW topographic quadrangles are nearing completion and will further illustrate the most significant geologic relationships in the adjacent major Laramide paleocanyons on the Hualapai Plateau (Figures 1a, 28,29).

Music Mountain Formation (Tmm)

The poorly indurated, Paleogene, Music Mountain Formation is composed mainly of deeply and thoroughly weathered fluvial arkosic sediments with subordinate gravel lenses that contain a wide variety of Precambrian crystalline rock clasts (Young, 1000, 2001b). Quartzite pebbles and cobbles make up the predominant lithologies in the gravel beds (and related surficial lag deposits). Late Cretaceous silicic volcanic cobbles are rare, but are readily located due to their relatively greater hardness and distinctive porphyritic textures. The ages and locations of three of these clasts are marked by black dots with ages on the geologic quadrangle map. The inverted age relations (oldest near top) support the evidence that the gravels represent an unroofing sequence as the source rocks were sequentially stripped off adjacent uplifts (Young, 2001a,b). East of the Hurricane fault volcanic clasts of Cretaceous and Paleogene age make up as much as 50% of clasts near the tops of some sections, reflecting differences in source regions, random preservation of gravel sections, and a possible late Laramide flare up of orogenic volcanism (Young, 2001b). In outcrops that retain the original texture of the arkosic sediments the feldspar-rich igneous and metamorphic clasts are easily crushed in the hand and often only appear as ghost pebbles in outcrop. Only the quartzites and other highly silicic lithologies remain relatively intact, but also exhibit thick weathering rinds. The inclosing arkose beds consist of finer-grained, darker reddish overbank or slack water deposits alternating with courser-grained, lighter pinkish channel sediments (including finer-grained, imbedded, rip-up clasts; Figures 3,5). In the thicker preserved sections the Music Mountain Formation appears to have greater concentrations of course gravel lenses near the tops and bases of sections, but this may be due to the random preservation and exposure of limited and incomplete sections. Overall, the formation is an artifact of a deeply incised drainage system that flowed onto the modern plateau from Laramide highlands located to the west and south. An early Eocene age for the upper portion of the formation is established, based on gastropod fossils from near Long Point, Arizona (Young and Hartman, 2011). One of the unusual characteristics of the Music Mountain Formation is the conspicuous scarcity of local Paleozoic limestone clasts, even close to the steep limestone-bearing walls of the deeply incised paleocanyons. Paleozoic limestones form the exposed cover rocks over most of the Hualapai Plateau and dominate most canyon wall exposures.

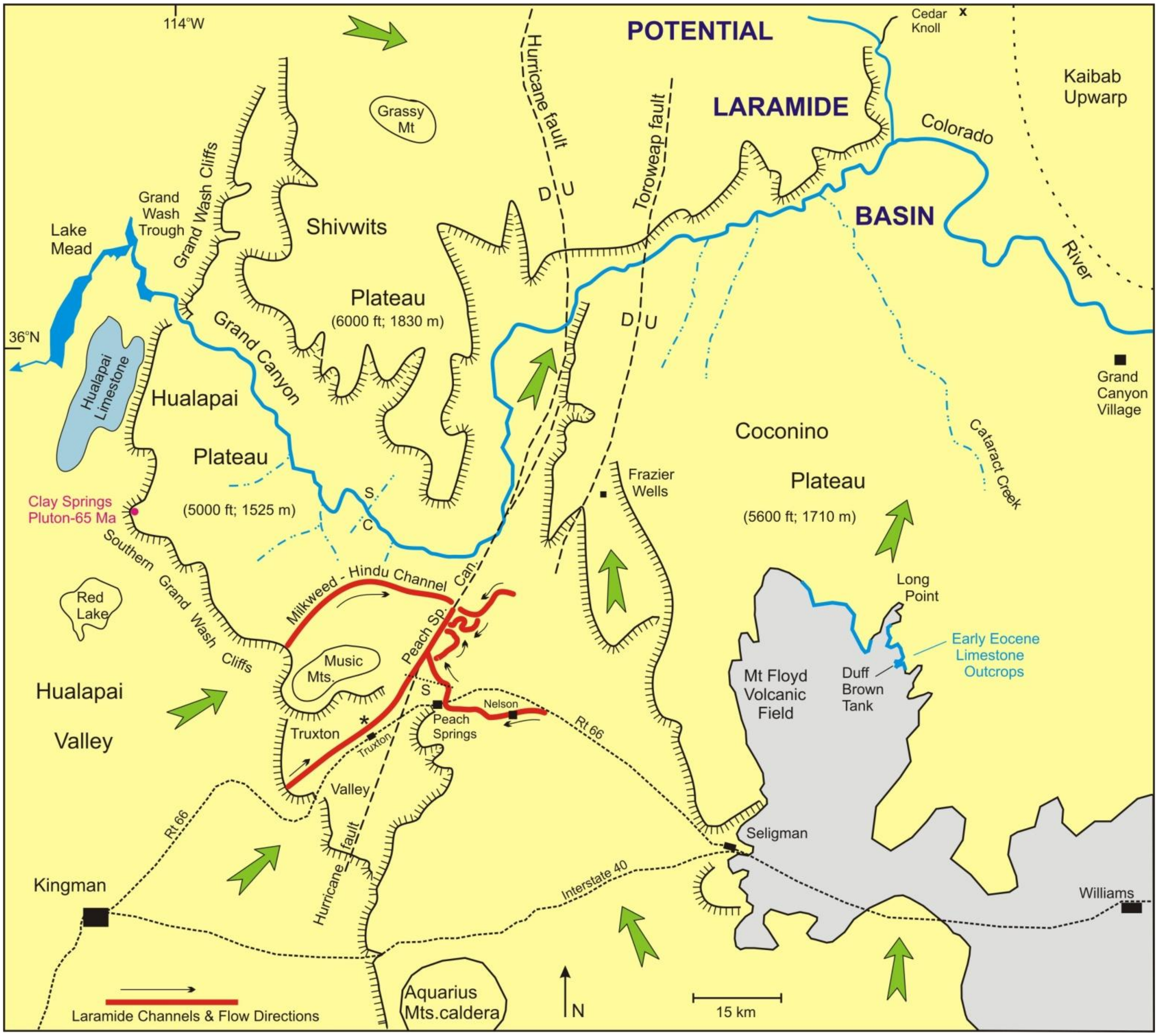

Figure 1a. Generalized map of important structural and physiographic features near western Grand Canyon discussed in text. Red lines show locations of Laramide paleochannels converging on Hurricane fault. Separation and south Separation Canyons are indicated by “S” and “C” north of Hindu channel. Green arrows show inferred directions of flow associated with regional deposition of Music Mountain Formation during Laramide time. Separation Canyon Hill (Figures 28,29) is at “C” north of Hindu channel. “S” with dotted line immediately north of Peach Springs is approximate location of geologic cross section on map. Potential Laramide basin is postulated area filled by Music Mountain Formation.

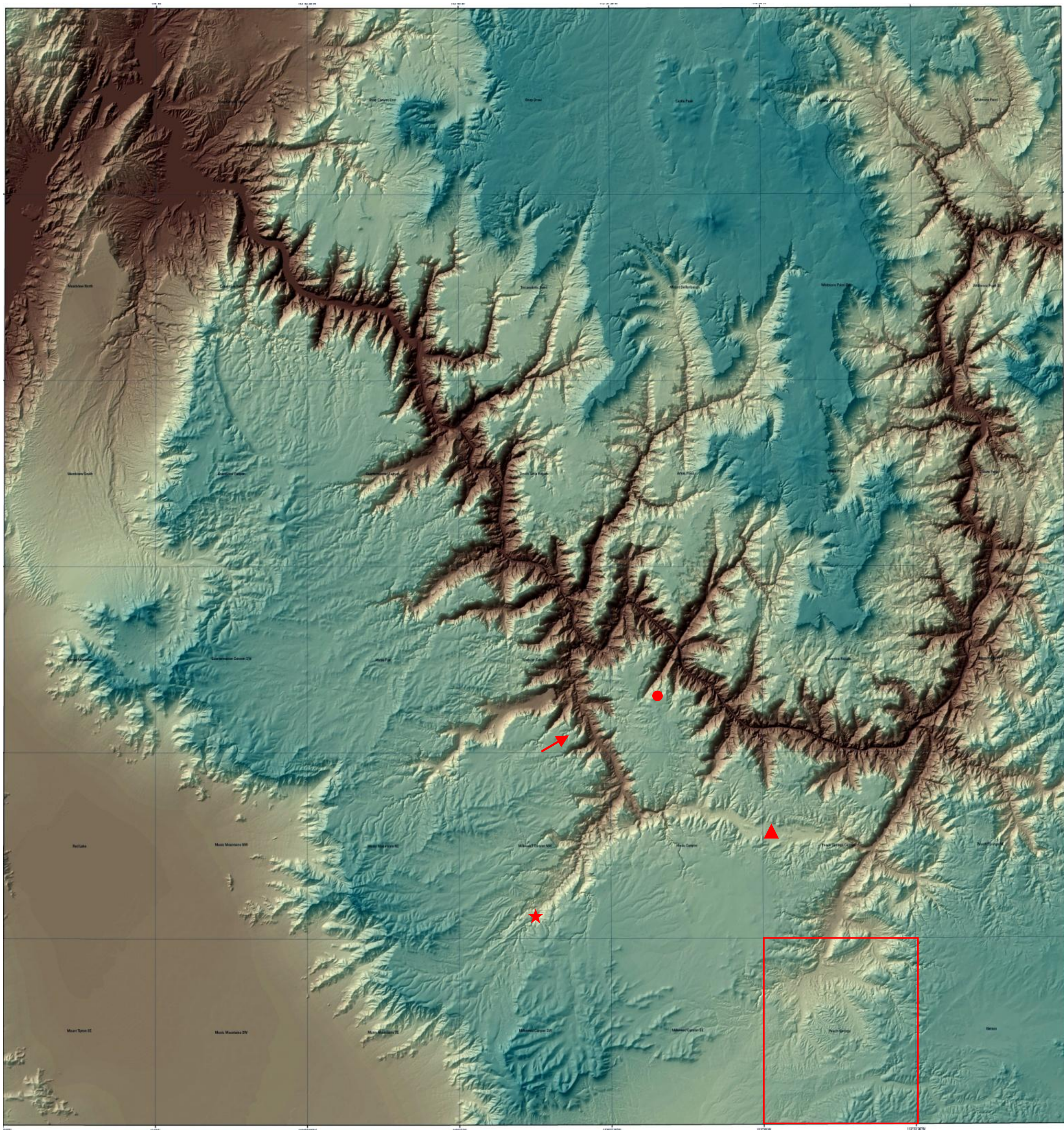

Figure 1b. Special edition map of Hualapai and Shivwits Plateaus of western Grand Canyon with 1:24,000-scale quadrangle map outlines compiled by US Geological Survey, Courtesy of J. Luke Blair and Thomas Hanks, USGS, Menlo Park, CA. Peach Springs Quadrangle is outlined in red. Red dot is “Separation Canyon Hill” butte (Figure 28); Red arrow is source of basalt shown on Figures 28 and 29. Large canyon between arrow and red dot is Spencer Canyon. Red star is location of Milkweed Canyon section shown in Figure 30. Triangle is in Hindu Canyon channel. Width of image: 80 km (49.6miles).

Figure 2. Music Mountain Formation (Tmm) capped by 1.2 m. of Milkweed member of Buck and Doe Conglomerate (Tbd) in lower Peach Springs Wash. (Location: NE1/4 Section 34, T26N, R11W).

Figure 3. Location as above. Fault left of person offsets Tmm but not Buck and Doe Conglomerate.

Figure 4. Tmm in lower Peach Springs Wash illustrating development of quartzite cobble lag deposits commonly covering Tmm surfaces in areas of low relief. (Location: NW1/4 Section 34, T26N, R11W)

Figure 5. Rip-up clasts (2 large red blocks) in Tmm fluvial channel deposit. Location same as Figure 2.

Figure 6. Typical exposure of gravel horizons in Tmm arkose. (Location: Section 26, T26N, R11W)

Figure 7. Exposure of Tmm in foreground capped by thin section of Milkweed member of Buck and Doe Conglomerate (Tbd) (thin light unit on top of ridge at center). View north toward narrowing of wash into Peach Springs Canyon at Hurricane fault. (Location: NE1/4 Section 34, T26N, R11W)

Figure 8. Petrified wood from trees indigenous to Music Mountain Formation environment as indicated by preservation of delicate bark details (showing lack of transport) and large dimensions of some preserved trunks. Some logs exceed 10 feet (3 m.) in length. (Location: Section 26, T26N, R11W)

Figure 9. Fossil locality near Long Point, Arizona, at Duff Brown Tank. Thin, light-colored limestone beds in Tmm-equivalent arkosic sediments are visible at center in cut along ranch road leading to dirt tank. Not located on Hualapai Reservation. (Early Eocene gastropods described in Young and Hartman, 2011)

This further supports the likely existence of a semitropical environment with a presumed thick soil cover, protective vegetation, and the domination of chemical over physical weathering, resulting in a relative inability of local tributaries to deliver carbonate clasts to the through-flowing trunk drainages, with the exception of local debris flows (Hindu Fanglomerate, Thf).

West Water Formation (Tw)

The top of the Music Mountain Formation exhibits a deeply weathered, darker red interval, which contains obvious soil horizon features, such as strongly developed ped structures, and is assumed to reflect tropical or paratropical conditions (Figures 10-13). Some Tertiary sections upstream from Laramide monoclines and faults include white limestone or marl beds, suggestive of ponding by structural drainage disruption as proposed by Young (1979). This can be demonstrated from well logs described by Darton in old Santa Fe Railroad borings at Peach Springs (see red number locations on map) and reinterpreted by Young (1979). The only known thin marl exposure on the Peach Springs Quadrangle near Red Spring (near line of geologic map cross section) was destroyed during improvements to the Diamond Creek Road during the 1970s, and no comparable, carbonate-rich horizon in Peach Springs Wash Tertiary sediments has been located, as yet. West of the Hurricane fault (Milkweed Canyon) the only fossil collected to date from presumably equivalent limestone beds is a single small specimen of the Genus Physa, a gastropod that is more abundant at the fossiliferous Long Point locality (Duff Brown Tank, Figure 9), but that is not by itself age diagnostic (Young and Hartman, 2011). The West Water Formation is a distinctive and mapable unit in the major basins (paleocanyons). However, aside from the limestone or marl beds, it could also simply be considered as the upper weathered portion of the Music Mountain Formation. The West Water horizon marks the only significant disconformity (period of nondeposition) in the Cenozoic section, and the weathering episode is assumed to be of Eocene age (late Laramide), possibly recording, in part, the warm wet conditions of the Early Eocene Climatic Optimum (EECO, ~53-50 Ma). See Figure 30 for excellent red Tw exposure in Milkweed Canyon section.

Hindu Fanglomerate (informal member of the Music Mountain Formation) (Thf)

Where the Music Mountain Formation occurs close to steep canyon walls or adjacent to cliffs and fault scarps it interfingers in some places with a massive limestone-dominated fanglomerate (Figures 14, 15). The fanglomerate contains large angular blocks of local bedrock in a reddish-orange, finer-grained, silty to sandy matrix. Limestone blocks several meters in length are present in some locations (Figure 14). This poorly stratified unit includes local, steeply dipping depositional packages and is inferred to be the result of debris flows and/or landslides generated by the steep relief under paratropical to tropical climatic conditions, especially near fault scarps and monoclines. The generally reddish to orange coloration of both the Hindu Fanglomerate and the Music Mountain Formation contrasts markedly with the buff to tan colors of most of the younger, post-Laramide rock units, which presumable formed under much drier climatic conditions. (See Figure 30 for view of dramatic color contrast between Laramide and younger Cenozoic rock units.)

Figure 10. Reddish outcrop of West Water Formation (Tw) with person for scale (right center). View looking to the southwest. See also location on Figure 22. (location: N ½ Section 5, T25N, R11W)

Figure 11. Aerial view of Tw looking south near top of Diamond Creek Road at Red Spring near map cross section. Reddish-colored Tw in lower half of view is located below slump block capped by Peach Spring Tuff at center. Basalt (19.94 Ma) caps mesa at top. (Location: N ½ Section 14, T25N, R11W)

Figure 12. West Water Formation (Tw) capped by Milkweed member of Buck and Doe Conglomerate (Tbd) in wash near east end of geologic map cross section. (Location: NE ¼ Section 14, T25N, R11W).

Figure 13. Tw with thick lacustrine limestone facies located in Milkweed Canyon (26 km to NW). Ponding in canyon possibly related to deformation along Meriwhitica monocline (near left horizon).

Figure 14. Hindu Fanglomerate (Thf) along Hurricane fault trace. Figure near left center indicates scale. Compare figure to size of large clasts of Paleozoic limestone. (Location: NE ¼ Section 28, T26N, R11W)

Figure 15. Hindu fanglomerate outcrop along west side of Hurricane fault in lower Peach Springs Wash. (Location: W ½ Section 32, T26N, R11W)

Buck and Doe Conglomerate (Milkweed member, Tbd)

The Milkweed member of the Buck and Doe Conglomerate (late Eocene?-middle Oligocene?) is the more widespread and generally thinner lower member of the formation. It is a fluvial conglomerate composed mainly of Cambrian to Mississippian limestone clasts from formations that crop out over most of the Hualapai Plateau. It reaches 150 feet (46 m) in thickness in Milkweed Canyon (Figure 30), but is generally much thinner in Peach Springs Canyon (Figure 7). The contact between the Buck and Doe Conglomerate and the underlying Laramide sediments (Hindu Fanglomerate or Tw soil zone) is usually sharp with a pronounced upwards color change from reddish to buff or tan (Figures 12, 16, 30). The conglomerate is strongly cemented and tends to break across clasts. Its lithification by carbonate cementation produces an overall hardness similar to the strongly indurated limestone clasts contained within it. The clast lithologies vary somewhat depending on proximity to local bedrock exposures. On the central Hualapai Plateau the unit contains rare but conspicuous Precambrian quartzite beach pebbles that have weathered out of beds within the Tapeats Sandstone near the headward reaches of Milkweed Canyon. In several places the upper few feet of the Milkweed member contain increasing numbers of exotic pebbles, including Precambrian rocks derived from near the southern Grand Wash Cliffs or from around the Truxton Valley. This suggests that following the cessation or structural disruption of the original northeast-flowing Laramide drainage, deposition from local bedrock divides on the plateau became the dominant source of fluvial sediment. However, over some undetermined period of time, some reestablishment of drainage from further upgradient supplied increasing numbers of exotic clasts either from immediately off the current plateau margin, and/or from limited reworking of the underlying arkosic unit. The Milkweed member of the Buck and Doe Conglomerate eventually formed a conspicuous, relatively level level surface near 5000 feet (1525 m) in elevation across much of the Hualapai Platau. It buried most of the former paleocanyons and spilled out over the adjacent divides (Figures 28, 29) to create a relatively featureless plain across the central Hualapai Plateau, although it was not as thick or extensive in Peach Springs Canyon.

Buck and Doe Conglomerate (Peach Springs member) (Tbp)

As one approaches Peach Springs Canyon from the northwest, the Buck and Doe Conglomerate gradually becomes divided into a lower limestone conglomerate and an upper arkosic conglomerate, which is similar to, but different in important aspects from the underlying Music Mountain Formation. In addition to being separated from the older Music Mountain arkose by the intervening Milkweed member, the Peach Springs member is conspicuously less weathered, and contains less weathered clasts whose sources are identifiable Precambrian rock outcrops located around the margins of the Truxton Valley. One of the most identifiable Precambrian rock clast types is traceable to a physiographic feature known locally as "Slate Mountain", which occupies the southern extension of the Hurricane fault structural trend on the Valentine, SE, quadrangle (Beard and Lucchitta, 1993). The most obvious rock type is an unusual Precambrian, micaceous, stretch-pebble conglomerate (containing deformed quartzite pebbles). In Peach Springs Canyon, the Peach Springs member of the Buck and Doe Conglomerate is much thicker than the Milkweed member, as illustrated on geologic cross-section A-A'. The Peach Springs member of the Buck and Doe Conglomerate represents the temporary, post-Laramide, re-establishment of northeast-flowing drainage into Peach Springs Canyon from the Truxton Valley. A volcanic ash layer near the top of the Peach Springs member of the Buck and Doe Conglomerate in Peach Springs Wash (Figs. 18-19) has a late Oligocene age of 23.97 $\pm$ 0.03 Ma (Young et al., 2011). The nearest volcanic source for an ash of this age is the Aquarius Mountains (Figure 1a), approximately 28 miles (45 km) south of Peach Springs (Young and McKee, 1978). The Oligocene ash location is also designated by an asterisk on the geologic map and cross-section A-A’. The vertical location of this late Oligocene ash in the section so far above the Music Mountain Formation, yet close to the overlying Miocene Peach Springs Tuff horizon, gives further credence to the substantial time interval inferred between the basal Paleogene arkose and the end of Buck and Doe time (late Oligocene or Miocene?). The Peach Springs member of the Buck and Doe Conglomerate filled in ancestral Peach Springs Canyon to form a relatively featureless surface, much like the Milkweed member did elsewhere, onto which Miocene volcanic flows were erupted (Figures 11, 22, 23). The deposition of both Buck and Doe Conglomerate members, followed by local volcanism, essentially filled in the older Laramide paleochannels to form a surface of relatively low relief stretching northward to the vicinity of the modern Grand Canyon (Figures 11, 28).

Hualapai Volcanic Rocks (Tb)

Miocene basalt flows that are both older and younger than the Peach Spring Tuff crop out across much of the Hualapai Plateau. The Peach Spring Tuff is 18.5 Ma old (Nielson et a., 1990). The basalt ages range from 14.63 Ma in the east (Blue Mountain) to 19.94 Ma near Peach Springs (Figure 11) (Wenrich et al. 1995). The source vents for the basalt flows are mainly fissures buried beneath flows or located west of the present plateau boundary fault (southern Grand Wash Cliffs). Visible basaltic dikes and intrusive bodies cut the basal Tertiary gravels in Milkweed Canyon at the southern Grand Wash Cliffs and near the location of Figure 30. An additional volcanic eruptive center is located in upper Milkweed Canyon, a short distance west of the Hualapai Reservation boundary fence. Blue Mountain is a small volcanic shield located west of the Hurricane fault, and is the youngest dated volcanic feature in the local region. Volcanic agglomerate facies occur near the local source vents of some of the basalt flows, such as in upper Milkweed Canyon. Dates and localities for volcanic rocks in the western Grand Canyon and Hualapai Plateau regions can be found in Wenrich at al. (1995) and in Young and Spamer, 2001, Appendix A).

In several Tertiary sections across the Hualapai Plateau the Buck and Doe Conglomerate members underlying the Miocene volcanic rocks contain increasing and varying amounts of fluvially reworked volcanic clasts immediately below the volcanic flows. This suggests that the earliest Miocene volcanism began west of the plateau and progressed eastward, with local drainages contributing increasing amounts of reworked volcanic debris through early Miocene time. This implies that there was a less imposing physiographic barrier along the modern plateau edge (southern Grand Wash Cliffs) at that time. A thick exposure of basalt flows at the head of Milkweed Canyon along the southern Grand Wash Cliffs clearly demonstrates that during early Miocene time the modern fault boundary was no impediment to lavas that flowed onto the plateau from vents located further west in the adjacent Basin and Range province. Some of the down-faulted source vents are buried beneath the late-Miocene and post-Miocene fill in the adjacent Hualapai Valley.

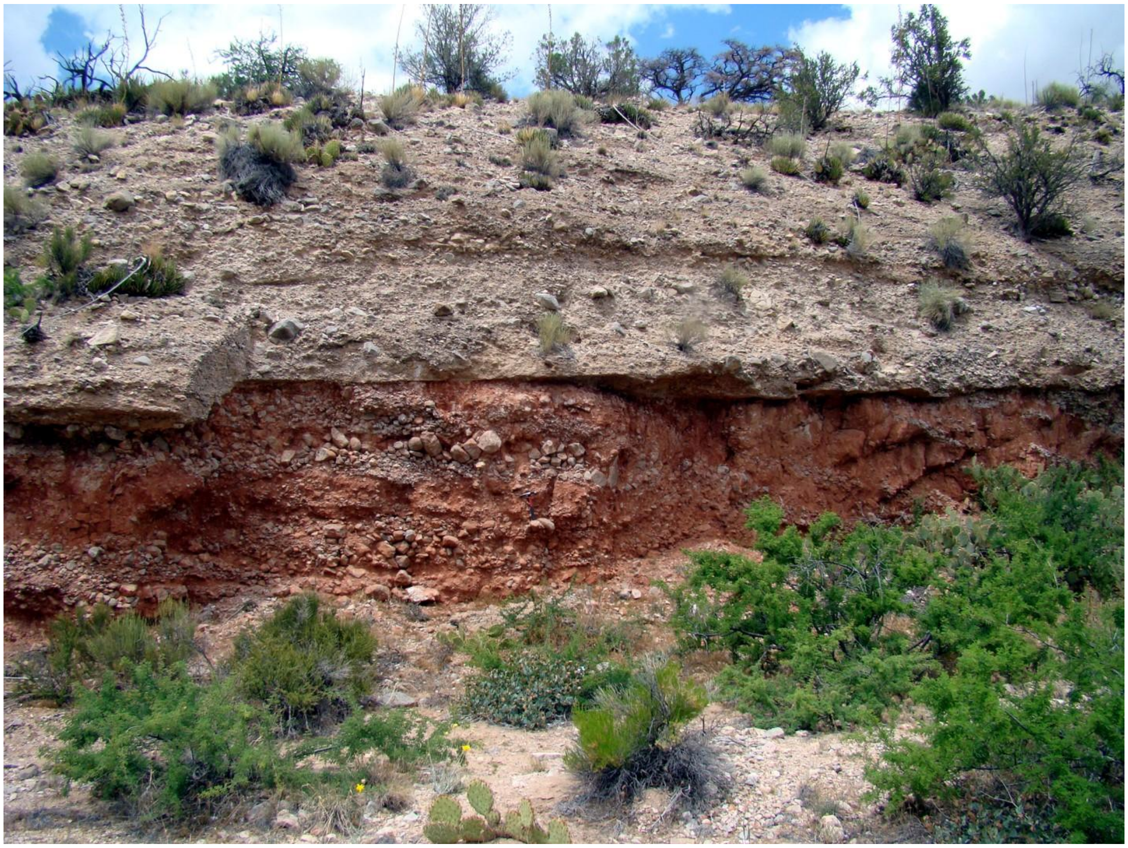

Figure 16. Milkweed member (Tbd) of Buck and Doe Conglomerate (top) in sharp contact with Hindu Fanglomerate (base) in small wash near map cross section. (Location: SE ¼ Section 14, T25N, R11W)

Figure 17. Small, low angle, reverse fault with associated folding (arched beds) in Milkweed member of Buck and Doe Conglomerate. Fault trends from upper left to right center. Possibly indicative of late Laramide(?) compressional deformation. (Location: SE ¼ Sect.34, T26N, R11W)

Figure 18. Oligocene volcanic ash bed (lower part of cliff) location near top of Peach Springs member (Tbp) of Buck and Doe Conglomerate. (Location: NW ¼ Section 13, T25N, R11W). (See Figure 19.)

Figure 19. Close-up view of ash in Tbp of Figure 18. Four-inch thick Oligocene ash bed is at right center.

Coyote Spring Formation (Tcs)

Following the relatively short interval of Miocene volcanism west of the Hurricane fault, drainage from local divides on the Plateau became dominant once again, producing a younger fluvial deposit very similar to the Milkweed member of the Buck and Doe Conglomerate, and also dominated by Paleozoic limestone clasts. The major difference in the two units is that the younger limestone-dominated conglomerate is generally less strongly cemented and often contains basalt clasts derived from the local basalt flows. However, where the Coyote Spring Formation and the Milkweed member of the Buck and Doe Conglomerate occur far from the local basalt flows (without the Peach Springs member), they may grade subtly into one another, and might conceivably represent a depositional continuum from late Eocene into early Pliocene time.

Presumably Colorado River incision began to affect areas progressively further back from the main western Grand Canyon throughout Pliocene time. For this reason the age of the Coyote Spring Formation could range from late Miocene to Pliocene time. In places outside the Peach Springs Quadrangle, such as the Truxton Valley, deposition may have continued, following Miocene volcanism, into early Pleistocene time (Twenter, 1962), prior to gradual headward erosion by drainages from the west and the east, as suggested by modern erosion patterns and local divide positions (Young, 2008).

Structural Geology and Significant Physiographic Relationships

There is evidence that the modern Hurricane fault marks a zone that has experienced a long history of alternating compressional and extensional events, similar to other large faults and monoclines in the Grand Canyon region. Currently the fault exhibits approximately 1500 feet of normal offset at the Colorado River, decreasing to approximately 200 feet as measured on Peach Spring Tuff outcrops near the line of the accompanying map cross section (Figures 22, 23, 25). Discussion of the structural history of the Grand Canyon faults and monoclines is contained in Huntoon (1981), as well as being illustrated on the four USGS 1:48,000-scale map sheet references (Billingsley et al., 1999). Young (1979, 1982) suggests compressional deformation of Laramide monoclines near Milkweed and Peach Springs Canyons was contemporaneous with deposition of the upper Music Mountain and West Water Formations, as indicated by the formation of lacustrine limestones and/or marls immediately upstream (upgradient) from the locations where monoclines intersect Laramide paleocanyons. The small compressional fault and folds in the Buck and Doe Conglomerate (Figure 17) provide further evidence that the oldest part of the Buck and Doe Conglomerate is possibly as old as middle Eocene (late Laramide).

Colorado River Erosion Interval

The tuff-capped twin buttes located in Section 9 (T25N, R11W) and depicted in Figures 22 and 23 illustrate the minimum thickness of Tertiary fill that has been removed from the Peach Springs Canyon region since late Miocene time. The position of the basalt-capped Buck and Doe Conglomerate outlier at the very edge of the western Grand Canyon (Figures 28, 29) also indicates that deposition, not incision, was dominant across the entire Hualapai Plateau until at least 19 Ma. The widespread occurrence and thickness of the younger Coyote Spring Formation in many of the same areas that contain Buck and Doe Conglomerate indicate that this period of regional aggradation continued for some indeterminate time, into the late Miocene. This is in agreement with all of the additional published data that indicate the Colorado River was not through-flowing in this region until approximately 5 million years ago.

Figure 20. Peach Spring Tuff (top) underlain by volcanic-rich fluvial sediments (center) with Miocene basalts at base of cliff along west side of Hurricane fault. (Location: S ½ Section 8, T25NR11W)

Figure 21. Closer view of fluvially reworked and agglomeratic sediments below Peach Spring Tuff at same location as Figure 20.

Figure 22. South-looking aerial view along Hurricane fault offset (200 feet) at “twin buttes” (center left). See buttes in Fig. 23. Red Tw at lower right is location of Figure 10. (Location: Section 8, T25N, R11W). Peach Spring Tuff (Tps) on downthrown side of fault caps shadowed cliff at center right (See Figure 20).

Figure 23. View to east across Hurricane fault offset to “twin buttes” (upthrown side) capped by Peach Spring Tuff (Tps). Slump blocks of Tuff in foreground. (Location N ½ of Sections 8 & 9, T25N, R11W).


Figure 24. Outcrop of Pliocene Coyote Spring Formation (Tcs) near east end of map cross section.


Figure 25. View to NNE from Peach Springs Wash into Peach Springs Canyon along trend of Hurricane fault. Slump blocks of Peach Spring Tuff in foreground. (Camera location: NE ¼ Section 8, T25N, R11W)

Figure 26. Disconformity associated with the Rampart Cave member of the Muav Limestone (middle of cliff). A weathered “bouldery zone” marks the horizon that is a source for springs (Lower Peach Springs) and has been a target for groundwater exploration wells. (Location: Center, Section 34, T26N, R11W)

Figure 27. Close up of same disconformity as in Figure 26, located on east side of road near Lower Peach Springs.

Figure 28. View to NE across Hualapai Plateau from US Route 66 when entering town of Peach Springs from the east. Peach Springs Canyon is prominent cliff in foreground; Shivwits Plateau is escarpment in distance at right. “Separation Canyon Hill” (small butte on left horizon) sits directly on the south rim of Grand Canyon and consists of Buck and Doe Conglomerate (Milkweed member) capped by basalt dated as 19 Ma (See also Figures 1a, 1b, 29). The position of the small butte (20 miles from camera position) demonstrates the antiquity of the Hualapai Plateau surface into which the western Grand Canyon is incised (Young, 1982, 1985). It also demonstrates the level to which the Hualapai Plateau was formerly covered by Buck and Doe Conglomerate. The “butte” is completely surrounded by Hindu, Spencer, and Grand Canyon (see locations on Figures 1a, 1b). The existing topographic relationships indicate that lavas capping the butte could not have reached their present location if incision of western Grand Canyon had already begun in early Miocene time. The eruptive source for the basalt is to the left on the opposite side of Spencer Canyon (red arrow, Figure 1b). The existence of even small tributaries to Grand Canyon, such as the adjacent south Separation Canyon, would have diverted the lava flow and prevented it from reaching its current position (Figure 29). Thus Grand Canyon <u>and</u> associated tributaries are demonstrably much younger than the Miocene basalt capping this butte.
The light-colored surficial deposit in the foreground of Figure 28 is Coyote Spring Formation.

Figure 29. “Separation Canyon Hill” (informal name) at the upper right, capped by 30 feet of dark Miocene basalt (19 Ma; Wenrich et al. 1995) over a similar thickness of lighter-colored Buck and Doe Conglomerate (Milkweed member), sits directly on the south rim of Grand Canyon adjacent to “south Separation Canyon” in left foreground (not formally named on published maps). Same butte as in Figure 28. The Shivwits Plateau is on the horizon and Grand Canyon is partially visible at left center. South Separation Canyon is a small, fault-controlled canyon in direct structural alignment with the better-known Separation Canyon (of J.W. Powell fame) located on the opposite side of the Colorado River. Note that even minor erosion to begin the formation of south Separation Canyon would have provided a lower, more logical route for the thin, fluid basalt flows to follow as they flowed to this location from their southerly source vent (Red arrow, Figure 1b). The logical inference is that neither Grand Canyon nor its modern tributaries could have existed, even in a less incised state, when streams carried Buck and Doe gravels to this location. The subsequent basalt flows, whose source is nearly 5 miles distant, would also have followed the lowest available elevation. Therefore, if any precursor to south Separation Canyon had existed at that time, the fluid basalt would have been diverted along such a lower route and would have flowed into any older canyon that might be postulated to have existed. Figure shows scale.

Comparable Stratigraphic Section: Milkweed Canyon, Central Hualapai Plateau

Peach Springs Canyon, Arizona, is one of the most accessible locations from which to view some important geologic relationships that constrain the age of the western Grand Canyon. Aside from the obvious pre-Colorado River history preserved in the Laramide-age canyons described above and illustrated on the accompanying geologic map, the view across the Hualapai Plateau from the highway descending into Peach Springs (Figure 28) illustrates important physiographic and geologic relationships that are best explained in the captions of Figures 28 and 29. The accompanying map and cross section were completed to better document the Cenozoic history preserved in one of the largest Laramide paleocanyons that dominate the paleogeography of the Hualapai Plateau. A similar section of Cenozoic deposits and stratigraphic history is more dramatically exposed in Milkweed Canyon (Figure 30). Maps for Hindu and Milkweed Canyons are currently in preparation (September, 2011).

Figure 30. In comparison with the Cenozoic sections described and pictured in Peach Springs Wash, this image from Milkweed Canyon includes all of the Cenozoic rocks described in the text above within a single section, except for the Peach Springs member of the Buck and Doe Conglomerate. The black letter "A" marks the contact between the Laramide and post-Laramide sequence, and is located at the base of the Buck and Doe Conglomerate (Milkweed member). The brownish-colored Peach Spring Tuff caps the main section and is underlain by basalts. The middle white unit is the lacustrine limestone within the red West Water Formation, with Music Mountain arkose partially exposed at the base of the image. The Coyote Spring Formation caps the basalts on the far right horizon. For scale, the Buck and Doe Conglomerate is 150 feet (63 m) thick. The complete section rests disconformably on Tapeats Sandstone located below and a short distance to the lower right of the view. See location on Figures 1a and 1b (star). Also see Young and Hartman, 2011, Figure 3.

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