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**Text File S1**

Reconstructing the erosional and tectonic record of the transition from Laramide contraction to Rio Grande rift extension, southern Indio Mountains, western Texas, U.S.A.

This document contains the following:

1. Description of all map units that are shown on Plates 1 and 2 and are described in the text and figures.
2. 40Ar/39Ar methods
3. Fault measurements and locations

Additional Tables included in the supplementary info include:

1. 40Ar/39Ar data tables
2. Thermochronology modeling parameters
3. **DESCRIPTION OF MAP UNITS**

**Qg** Unconsolidated gravel

**Qt** Terrace deposits. Moderately cemented, poorly sorted angular to sub-angular conglomeratic deposits. Clasts are derived almost entirely from the underlying units.

**Nt** Neogene terraces. Older terraces at higher elevations from modern drainages. These deposits are several meters thick and are located along the lower flanks of Flat Top.

**Tg** Gravels deposited in rift basin. Moderately- to well-cemented, poorly sorted, angular to subangular conglomerate. Clasts range in size from 1-2mm to 50 cm and are set within a sandy matrix. All clasts are from the underlying volcanic and Cretaceous sedimentary rocks.

**Tbva** Bell Valley andesite – Porphyritic andesite lava that contains plagioclase, hypersthene, augite, biotite, and hornblende (Hoffer et al., 1980). Unit has a thickness of 155-186 m. Davison (2014) report an eruption age 36.57 ± 0.80 Ma.

**Trt** Rhyolite tuff – Microporphyritic tuff that contains predominantly K-feldspar and quartz crystal fragments. Flattened pumice lapilli 3-5mm in size are abundant throughout the unit and partially to fully devitrified with axiolitic and spherulitic textures.

**Tb3** Basalt flow 3 – Basalt flow interbedded with unit Tra. Basalt is highly weathered, with abundant vesicles and amygdules filled with calcite. This unit, along with Tb2 and Tb1, are classified as a microgabbro containing olivine, clinopyroxene, and labradorite phenocrysts (Underwood, 1962).

**Tb2** Basalt flow 2 – Basalt flow interbedded with unit Tra. This flow lies stratigraphically beneath Tb3.

**Tgm** Garren Mountain tuff breccia – Dark brown lithic breccia that is clast supported and contains angular to sub-rounded volcanic lithic fragments ranging from 0.1-0.3 m in size. Angular lithic clasts suggest autobrecciation during deposition.

**Tra** Rhyolite ash – Whitish-gray ash fall deposit. Contains pumice lapilli that are largest in the center of the unit, where they are 10-15 mm in diameter. Farther up section, pumice lapilli decrease in size to 3-5 mm near the contact with the overlying unit. This unit has a reported U-Pb zircon age of 37.34 ± 0.48 Ma (Davidson, 2014).

**Tpd** Pond deposit – Consists predominantly of brownish-orange mudstone with interbeds of poorly to moderately consolidated beds of white and gray laminated ash and poorly consolidated conglomerate lenses. Conglomerate contains clasts 5-20 cm in size that are derived from the underlying Mesozoic section.

**Pylcgl** A distinctive reddish-brown conglomerate body containing rounded to sub-rounded clasts of conglomerate. These clasts are sourced entirely from the Lower Yucca Formation and are set within a reddish matrix.

**Tb1** Basalt flow 1 – This unit lies stratigraphically beneath Tb2 and Tb3 but has the same general characteristics. This unit has a sanidine 40Ar/39Ar age of 37.61 ± 0.07 Ma (this study).

**Tdwpt** Densely welded purple tuff – Small outcrop of distinctive purple tuff. Tuff is fine-grained and contains crystals of quartz in hand sample. Unit forms resistant ledges 0.5-1 m in height relative to the surrounding units.

**Tp** Pantera trachyte – Pale to grayish red, densely welded trachytic crystal tuff with microeutaxitic texture overlying a basal vitrophyre (Underwood, 1962; Teal, 1979; Hoffer et al., 1980). Phenocrysts consist of andesine (15-20%). K-feldspar (10%), augite (3-5%), and small amounts of quartz, biotite, and hornblende in a devitrified matrix (Teal and Hoffer, 1980). Unit has a reported thickness of 27-91 m (Teal and Hoffer, 1980).

**Pcgl** Paleogene conglomerate – Moderately-indurated, poorly- to moderately-sorted conglomerate that contains primarily clasts of sandstone, conglomerate and limestone derived from the underlying Cretaceous units. Clasts are moderately- to well-rounded, and range in size from 2-50 cm. These clasts are set within a sandy matrix that has the same composition as the clasts.

**MB3** Mega breccia 3 – Youngest mega breccia deposit. This deposit is interbedded with unit Thtu in the southern part of the northwestern paleovalley. The unit predominantly contains clasts of Lower Yucca Formation, but also includes angular sandstone clasts possibly sourced from the Upper Yucca Formation. There is also a marked increase in well-rounded limestone clasts that were most likely weathered out of the Lower Yucca Formation.

**Thtu** Hogeye upper tuff – Light green to yellowish white, poorly- to moderately-indurated ash. In outcrop, the crystals are predominantly feldspar and quartz and are secondary to arcuate bubble wall shards. Underwood (1962) described the unit as a vitric to crystal tuff with outcrops displaying both massive and finely laminated bedding. Unit has a reported zircon U-Pb age of 38.02 ± 0.99 Ma (Davidson, 2014).

**Thgt** Small patches of grey vitric tuff approximately 1.5 m thick. Contains minor amounts of feldspar, quartz, and sandstone lithic fragments. In thin section partially flattened bubble wall shards flow around crystal grains and minor lithic sandstone fragments. Pumice lapilli are present, but the unit consists mainly of ash-sized particles.

**MB2** Mega breccia 2 – Compositionally this unit closely resembles MB1 and contains chaotically-oriented conglomerate clasts of Lower Yucca Formation. However, these clasts are somewhat smaller than in MB1, and typically range from 0.1-1.5 m in size. This unit also contains clasts of chert clasts 0.1-1.5 m in size that are also likely sourced from the Lower Yucca Formation.

**Thtr** Hogeye trachyte – Densely-welded trachyte. Contains crystals of predominantly K-feldspar with minor quartz and magnetite. Phenocryst content is less than 5%, and most crystals are <1mm in length. Pumice lapilli are present in small quantities and are partially to fully devitrified. Ash and disaggregated bubble wall shards are partially to fully devitrified and comprise much of the interstitial material and are observed flowing around crystal grains. In most samples pumice and bubble wall shards are fully flattened, imparting a microeutaxitic texture. Overall, the unit is microporphyritic and crystal percentages range between 5-15% of the total constituents. Has a 40Ar/39Ar sanidine age of 38.17 ± 0.02 Ma (this study).

**Thtl** Hogeye lower tuff – White, highly calcareous tuff with fragments of quartz, volcanic lithics, ad limestone breccia (Underwood, 1962). Poorly sorted and poorly indurated lapilli ash fall with 2 cm pumice lapilli in the uppermost portion of the unit.

**MB1** Mega breccia 1 – Poorly sorted angular breccia. Clasts range in size from 0.5-5 m and the unit lacks any coherent bedding. Clasts are almost entirely conglomerate, derived from the underlying Lower Yucca Formation.

**Kb** Buda Formation – Conformably overlies the Eagle Mountains Sandstone Formation and is approximately 66 meters thick in the Indio Mountains (Underwood, 1962). Characteristics of the formation include off-white to light gray, micritic, nodular, thinly bedded limestone that weathers to a dull grayish yellow (Underwood, 1962). Turritella and Exogyra are two common fossils in the Buda formation (Underwood, 1962).

**Kem** Eagle Mountain Sandstone Formation – The Eagle Mountains Sandstone Formation is conformable with the top of the Espy Formation. The formation is approximately 24 meters thick in the Indio Mountains and consists of sandstone and sandy biosparite that exhibits a brown- to orange-colored weathering surface in outcrop (Underwood, 1962).

**Ke** Espy Formation – The Espy Formation conformably overlies the Benevides Formation (Underwood, 1962). The lower 15-20 meters of section consist of fossiliferous shale, marl, and nodular limestone (Underwood, 1962). Fossil assemblages include Kingena wacoensis, Pecten texasnus, and Gryphaea washitaensis (Underwood, 1962). Thick-bedded, resistant limestone beds are found higher in the section, and the upper 60-meters of the formation consists of a fossiliferous limestone containing rudistids and caprinids (Underwood, 1962). The formation ranges in color from medium dark gray to light brownish gray (Underwood, 1962).

**Kbe** Benevides Formation – The Benevides Formation unconformably overlies the Finlay Formation (Underwood, 1962). Underwood (1962) measured 37 meters of the Benevides in the Indio Mountains and described a lower non-resistant shale and siltstone member and an upper pale orange to pinkish gray sandstone member (Underwood, 1962). The upper sandstone member is further divided into upper and lower sections (Underwood, 1962). The lower sandstone section contains well-rounded, fine-grained quartz sandstone nodules approximately 12-cm in diameter (Underwood, 1962). The upper section of the sandstone member is a thick-bedded, fine- to medium-grained calcareous quartz sandstone with crossbedding (Underwood, 1962).

**Kf** Finlay Formation – The Finlay Formation disconformably overlies the Cox Formation in the Indio Mountains and the two formations are separated by a thin bed of calcic soil (Brunson, 1954; Underwood, 1962). A 121-meter section in the Indio Mountains was described as a thin- to thick-bedded micritic limestone that ranges in color from medium gray to light brownish gray and weathers to pale and grayish orange (Underwood, 1962). The base of the formation contains a 2.5-meter section of yellowish gray siltstone and a 2.5-meter section of fine-grained, grayish orange sandstone (Underwood, 1962). Fossil assemblages from the measured section include Toucasia texasa, Requienia, Monopleura, Eoradiolites, and Exogyra texana (Underwood, 1962).

**Kc** White to gray, orange, and brown sandstone consisting of fine- to medium-grained, well-sorted and well-rounded quartz and angular to sub-angular chert classified as a quartz arenite (Budhathoki, 2013). Common sedimentary structures in the sandstone sections include crossbedding, ripple laminations, and burrows (Underwood, 1962). The base consists of red, brown, and green shales (Underwood, 1962). A gray, nodular fossiliferous limestone section that separates the upper and lower sandstone sections contains Exogyra texana, Protocardia, Ostrea, and Nerinea (Gillerman, 1953).

**Kbm4** Bluff Mesa Formation 4 – Composed of dark blue grey beds of micrite that are 1 m thick. Contains the Early Cenomanian index fossil Orbitalina (Underwood, 1962).

**Kbm3** Bluff Mesa Formation 3 – Grayish brown shale. Forms valleys and is mostly covered with a thin layer of colluvium.

**Kbm2** Bluff Mesa Formation 2 – Contains an alternating sequence of quartz arenite, green to gray shale, and thin limestone beds. Beds in this unit are typically1-2 m thick.

**Kbm1** Bluff Mesa Formation 1 – Contains a lower bed of shale that is overlain by thick beds of fossiliferous oolitic boundstone. These beds are interbedded wit secondary sandstone and shale beds (Underwood, 1962).

**Kyu** Upper Yucca Formation – General characteristics include thick shales interbedded with thinly-bedded limestone beds, limestone conglomerate, and regularly repeating chert pebble conglomerates that are similar to those in the Lower Yucca Formation but display a finer-grained and more well-sorted sandstone matrix. Septarian concretions, nodules of micrite that contain shrinkage cracks filled with secondary calcite that formed in-situ, can be observed in many Upper Yucca shales (Campbell, 1968). Has a thickness of approximately 250 m.

**Kyl** Lower Yucca Formation – Consists predominantly of well-cemented cobble and pebble conglomerate. Clasts consist of chert, quartz sandstone and limestone that are set within a fine- to medium-grained sandstone matrix that varies from maroon to light grey in color (Underwood, 1962). Conglomerates are occasionally interbedded with red, well-indurated shale. Clasts are well-rounded and beds typically contain cross-beds on the order of 1 m.

**2. 40Ar/39Ar METHODS**

The analytical data are organized to comply with FAIR data reporting norms (see for instance Schaen et al., 2020). An Excel workbook is provided with data formatted within a variety of worksheets to facilitate ease of data viewing. Data are presented in isotope ratio format along with raw intensity format with the raw data sorted by run identifier and sample name. The workbook also has a worksheet with summary age information.

For the sanidine from the ash and the DS samples, separation included crushing, grinding, and sieving followed by treating with dilute HCl and HF and washing with water. K-feldspar was concentrated by standard magnetic and heavy liquid density separation. Handpicking DS grains was conducted while the sample was immersed in wintergreen oil while being viewed under a polarizing binocular microscope. Clear grains with no observable microtextures identified sandine from turbid and microstructually complex microcline and orthoclase. Sanidine from the ash sample was concentrated by heavy liquid floatation without further hand-picking. For the basalt sample, a groundmass concentrate was prepared by crushing and hand-picking fragments (~1 mm) under a binocular microscope that are visibly free of phenocrysts and that revealed no apparent alteration.

The samples were irradiated the USGS Denver, Colorado reactor (NM-316, 16 hours) along with Fish Canyon tuff sanidine (FC-2). FC-2 is assigned an age of 28.201 Ma (Kuiper et al., 2008) and all ages are calculated with a 40K decay constant of 5.463e-10 /a (Min et al., 2000) while isotope abundances are after Steiger and Jager (1977). All samples were irradiated in 1” diameter trays with sandine in trays with 24 holes drilled around the perimeter that contain 16 sample locations and 8 flux monitor locations. The groundmass was in a 16-hole tray with 8 sample and 8 flux monitor locations. Six flux monitor grains were analyzed from each flux monitor location and the J-value of the unknown locations is determined with a planar fit to the appropriate flux monitor locations.

After irradiation, monitors and unknowns were loaded into stainless steel trays, evacuated and baked at either 100 and 150°C 4 hours. For sanidine crystals and flux monitors a CO2 laser was used to fuse the crystals. These samples were analyzed using a Thermo-Fisher Scientific ARGUS VI multi-collector mass spectrometer equipped with five Faraday cups, and one electron multiplier (CDD) operated in ion-counting mode. The configuration has 40Ar, 39Ar, 38Ar, 37Ar and 36Ar on the H1, Axial, L1, L2, and CDD detectors, respectively. Resistors were 1013 Ohms for 40Ar and 39Ar, 1014 Ohms for 37Ar and 38Ar, whereas 36Ar was measured on the CDD that has a dead time of 14 ns. Extracted sanidine gas was cleaned with two NP 10 getters, one operated at 0.54 A and one at room temperature. Gas cleanup was during the 30 second fusion follow an additional 30 seconds after fusion. The groundmass sample was step-heated with a diode laser with a heating time of 60 seconds followed by 60 seconds of gas clean up with a SAES GP-50 getter operated at 1.6 A. Gas was also exposed to a cold finger operated at ~-140°C. Argon isotopes were measured using a Thermo-Fisher Scientific Helix MC-plus multi-collector mass spectrometer. Isotopes 40Ar, 39Ar, 38Ar and 37Ar were measured on Faraday collectors with 40Ar and 37Ar using a 1012 Ohm resistor, 39Ar using a 1013 Ohm resistor, and 38Ar using a 1014 Ohm resistor. 36Ar was measured on a CDD ion counter that has a dead time of 20 ns.

Calibration gases of air and a gas mixture enriched in radiogenic 40Ar along with 39Ar were analyzed interspersed with the unknowns to monitor instrument drift and determine detector intercalibration factors. All data collection was conducted with the in-house Pychron software and data reduction utilized MassSpec version 7.875. Isotopes for groundmass were collected for 360 seconds with baseline measurement of 60 seconds. Isotopes for sanidine were collected for 120 seconds with baseline measurement of 30 seconds. determination or provenance were analyzed for durations typically less than 60 seconds. Extraction line blank values that also include mass spectrometer backgrounds are provided in the intensity worksheet for all measurements. K-glass and CaF2 were included in the irradiations to determine interfering reaction correction factors that are also included in the argon data tables.

The mean age of the sanidine data from the ash sample as well as the plateau age for the groundmass is calculated based on a weighted mean with a weighting factor being the inverse variance (e.g., Taylor, 1982) and the error is the square root of the sum of 1/σ 2 values. The error is also multiplied by the square root of the MSWD for MSWD greater than 1 and errors are reported at 1σ. J-error and irradiation correction factor uncertainties are included for all weighted mean age errors. For the DS sample, a single analysis defines the maximum depositional age.

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**3. FAULT MEASUREMENTS AND LOCATIONS**

