

Parrish, J.T., et al., 2019, Earliest Jurassic U-Pb ages from carbonate deposits in the Navajo Sandstone, southeastern Utah, USA: *Geology*, v. 47, <https://doi.org/10.1130/G46338.1>

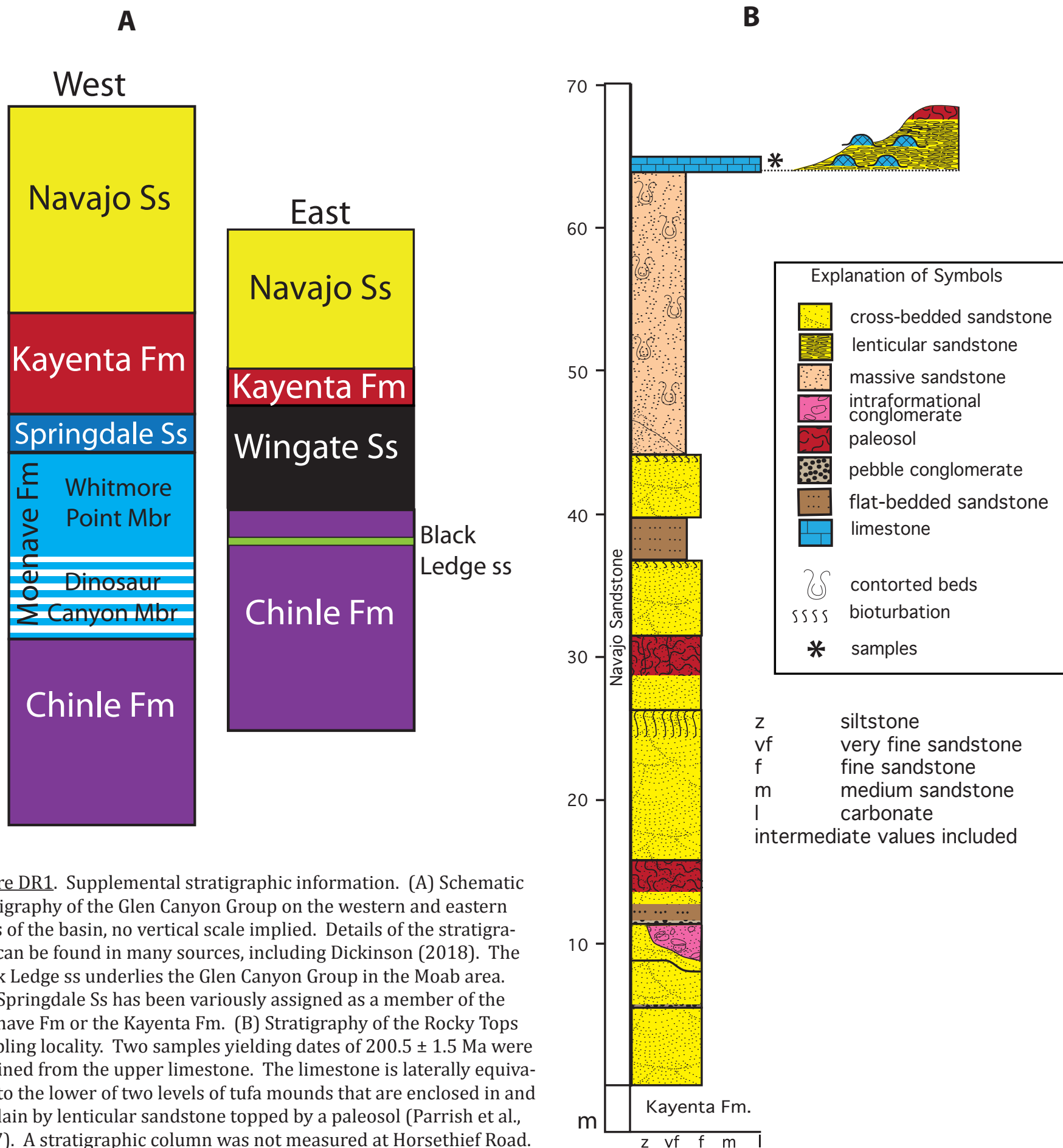
### **U-Pb Chemistry Methods Details**

Samples were microsampled with a Dremel tool, spiked with a mixed  $^{236}\text{U}$ - $^{205}\text{Pb}$  spike, and dissolved in nitric acid. Samples were capped and left on a hotplate for more than 12 hours before drying for column chemistry.

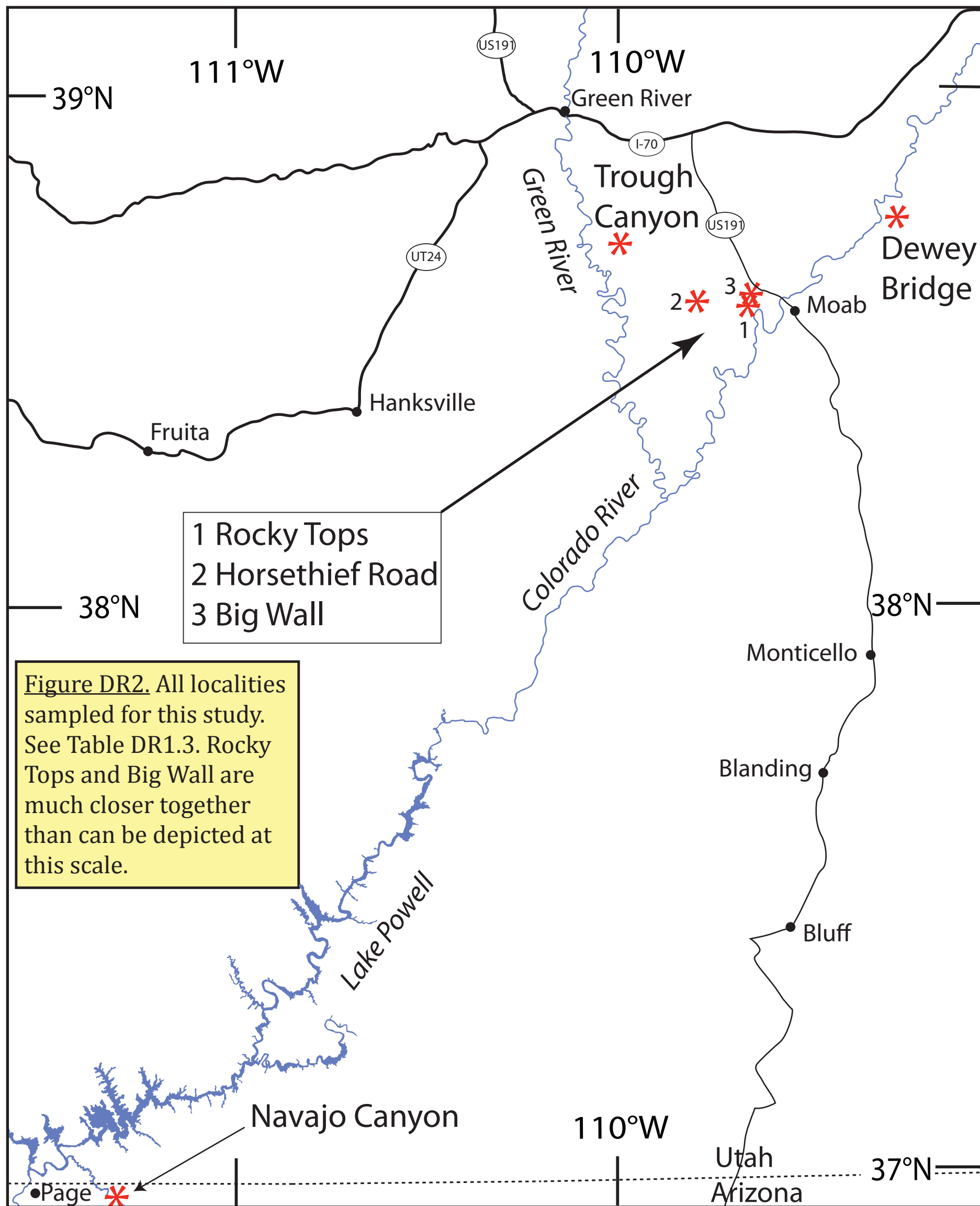
Fifty microliter columns made from Teflon shrink tubing with a cellulose frit were filled with Dowex AGX-1-8 200-400 mesh anion resin. Columns were cleaned with several reservoirs of deionized water, which elutes both U and Pb before equilibration with 0.7N HBr. Samples were redissolved in 0.7N HBr, typically about 100 microliters to make sure the aliquot is completely dissolved and loaded on the columns. The wash involves 250 microliters of 0.7N HBr, added twice ( $\sim 10\times$  column volume) to produce a clean Pb separate, which is eluted with 500 microliter of DI  $\text{H}_2\text{O}$ . The small loss of Pb in the wash step is more than compensated by the cleaner Pb cut. The load and wash steps were collected together for U. This was dried and then put through the same columns after equilibration with 7N  $\text{HNO}_3$ , to purify the U. The aliquots were dissolved with 100 microliters of 7N  $\text{HNO}_3$  and loaded on the equilibrated columns. The wash step used 250 microliters (150 + 100 microliters in two steps) of 7N  $\text{HNO}_3$  to wash everything but U out of the columns. The U was then eluted with 500 microliters of DI  $\text{H}_2\text{O}$ .

## **Sample descriptions**

The Rocky Tops (RT) samples are from a lacustrine carbonate unit (Parrish et al., 2017). Sample 0805123 has a thrombotic texture and 0805132 is finely laminated. Although the Navajo Ss is as much as 740 m thick in this region (Hintze and Kowallis, 2009), it is thinner near RT. A complete section measured by Parrish et al. (2017; their Big Wall locality) less than 2 km to the north is 135 m thick. The Horsethief Road (HR) sample has a thrombotic texture (Dorney et al., 2017) and is from near the middle of a tufa mound. The upper contact of the Navajo Ss does not crop out at either Horsethief Road or Rocky Tops.



**Figure DR1.** Supplemental stratigraphic information. (A) Schematic stratigraphy of the Glen Canyon Group on the western and eastern sides of the basin, no vertical scale implied. Details of the stratigraphy can be found in many sources, including Dickinson (2018). The Black Ledge ss underlies the Glen Canyon Group in the Moab area. The Springdale Ss has been variously assigned as a member of the Moenave Fm or the Kayenta Fm. (B) Stratigraphy of the Rocky Tops sampling locality. Two samples yielding dates of  $200.5 \pm 1.5$  Ma were obtained from the upper limestone. The limestone is laterally equivalent to the lower of two levels of tufa mounds that are enclosed in and overlain by lenticular sandstone topped by a paleosol (Parrish et al., 2017). A stratigraphic column was not measured at Horsethief Road.



### **Tables DR1.**

Table DR1.1. Summary of detrital zircon ages from the Glen Canyon Group and subjacent strata from Dickinson and Gehrels (2009a, b).

<u>Formation</u>	<u>Area collected</u>	<u>Ages (Ma)</u> (2009b)	<u>Ages (Ma)*</u> (2009a)
Navajo Ss	North Wash	328	331±8, 309±14
Kayenta Fm	Dolores	244	197±2, 197±2
Kayenta Fm	North Wash	239	208±5, 208±7
Kayenta Fm	CP10 (near Moenkopi, AZ)	229	195±3, 195±3
Wingate Ss	Hanksville	371	298±8, 299±8
Springdale Ss	CP37 (NE of Kanab, UT)	189	201±6, 199±3
“Black Ledge Ss”	Moab	197	201±4, 199±3

\*Single-grain (YSG) and calculated single-grain (YDZ) dates, respectively; see Dickinson and Gehrels (2009a) for more information.

Table DR1.2. Details for data in Figures 1 and 2.

<u>Locale</u>	<u>Stratigraphic unit</u>	<u>Type of data</u>	<u>Dates/Ages</u>	<u>Reference</u>
Moab area, Utah	Navajo Ss	U-Pb dates on limestone	200.5±1.5, 197±7.7 Ma	This study
Moab area, Utah	Kayenta Fm	Paleomagnetic	Late Triassic	Steiner and Helsley (1974)
Gold Spring, Arizona	Kayenta Fm	Detrital zircon	183.7±2.7 Ma	Marsh (2014)
Kanab area, Utah	Kayenta Fm	Paleomagnetic	190-187 Ma	Steiner and Tanner (2014)
Dolores, Colorado	Kayenta Fm	Detrital zircons	197±2 Ma	Dickinson and Gehrels (2009a)
Moenkopi, Arizona	Kayenta Fm	Detrital zircons	195±3 Ma	Dickinson and Gehrels (2009a)
Tuba City area, Arizona	Kayenta Fm	Paleomagnetic	Pliensbachian	Bazard and Butler (1991)
Kithchen Corral Canyon, Utah	Springdale Ss	Detrital zircons	201±6, 199±3	Dickinson and Gehrels (2009a)
Kanab area, Utah	Springdale Ss	Paleomagnetic	Late Hettangian-early Sinemurian	Steiner (2014a)
Kanab area, Utah	Whitmore Point Mbr, Moenave Fm	Paleomagnetic	Hettangian	Steiner (2014b)
Potter Canyon, Utah	Whitmore Point Mbr, Moenave Fm	Detrital zircons	201.33±0.07/0.12 Ma	Suarez et al. (2017)
Black Canyon, Utah	Dinosaur Canyon Mbr, Moenave Fm	Detrital zircons	201.28 ±0.11/0.15 Ma	Suarez et al. (2017)
Echo Cliffs, Utah	Dinosaur Canyon Mbr, Moenave Fm	Paleomagnetic	Rhaetian-earliest Hettangian	Molina-Garza et al. (2003)
Tuba City area, Arizona	Moenave Fm	Paleomagnetic	Hettangian-Sinemurian	Bazard and Butler (1991)
Moab area, Utah	“Black Ledge Ss”	Detrital zircons	201±4, 199±3	Dickinson and Gehrels (2009a)
Comb Ridge, Utah	Wingate Ss	Paleomagnetic	Rhaetian (approx. 2 m.y.)	Molina-Garza et al. (2003)
San Rafael Swell, Utah	Chinle Fm	Detrital zircons	203-204 Ma	Umbarger (2018)

Table DR1.3. Sample descriptions. Highlighted samples are the ones that yielded the dates reported here. See also Dorney et al. (2017) for more information on samples 0805004-0805032. Detailed petrography not available for samples 0805123-0805200 and 1505011.

<u>Locality</u>	<u>Sample #</u>	<u>Description</u>
Trough Canyon	0805004	Peloidal packstone
Trough Canyon	0805009	Peloidal wackestone
Trough Canyon	0805019*	Chert replacing peloidal pack- or wackestone
Horsethief Road	0805030*	Thrombolitic carbonate mudstone (< 1%; isolated dolomite rhombs)
Horsethief Road	0805031*	Thrombolitic mudstone (5% dolomite; recrystallized)
Horsethief Road	0805032*	Thrombolitic carbonate mudstone (5% dolomite; recrystallized)
Rocky Tops	0805123	Thrombolitic carbonate mudstone
Rocky Tops	0805132	Laminated carbonate mudstone
Rocky Tops	0805143	Carbonate mudstone
Dewey Bridge	0805162*	Carbonate mudstone
Dewey Bridge	0805187*	Carbonate mudstone
Dewey Bridge	0805195	Sandy carbonate mudstone
Dewey Bridge	0805200	Carbonate mudstone
Navajo Canyon	0808002	Dolomite
Navajo Canyon	0808004*	Laminated fenestral mudstone (99% dolomite)
Navajo Canyon	0808008	Thrombolitic carbonate mudstone (85% dolomite)
Big Wall	1505011	Laminated carbonate mudstone

\*Samples from tufa mounds. See Parrish et al. (2017)

Reference: Dorney, L. J., Parrish, J. T., Hasiotis, S. T., and Chan, M. A., 2017, Petrography and environmental interpretation of tufa and lake carbonate in the Jurassic Navajo Sandstone of southeastern Utah: Journal of Sedimentary Research, v. 87, p. 967-985.

**Table DR1.4.** List of samples processed for U-Pb dates. Laser ablation results only. Highlighted samples were analyzed by isotope dilution to yield more precise dates, reported in the article. Locality names from Parrish et al. (2017); see Figure DR2.

Sample No.	Locality	$^{238}\text{U}/^{206}\text{Pb}$	$^{207}\text{Pb}/^{206}\text{Pb}$	U (ppm)	Pb (ppm)	Outcome
0805004	Trough Canyon	1.5-6.1	0.67-0.82	4.6-13.8	9.6-26	$184 \pm 59$ Ma
0805009	Trough Canyon	0.2-5.2	0.71-0.92	0.7-4.1	5.7-75	$174 \pm 53$ Ma
0805019	Trough Canyon	9.1-27.3	0.26-0.64	0.5-2.4	0.1-1.0	$145 \pm 15$ Ma
0805030	Horsethief Road	<2	0.74-0.92	0.2-2.6	2.3-8.7	No age solution
0805031	Horsethief Road	0.3-19.0	0.32-0.85	0.1-40	1.1-54	$220 \pm 18$ Ma
0805032	Horsethief Road	0.4-26.3	0.4-0.9	0.02-13.8	0.4-1.4	$190 \pm 20$ Ma
0805123	Rocky Tops	0.2-13.7	0.5-0.86	0.6-9.6	2.2-33	$251 \pm 21$ Ma
0805132	Rocky Tops	0.5-10	0.6-0.89	0.3-29.4	1.3-9.1	$216 \pm 23$
0805143	Rocky Tops	0.6-10.1	0.54-0.82	0.1-17.5	1.1-30.6	$190 \pm 22$ Ma
0805162	Dewey Bridge	0-0.8	0.78-0.98	0.1-21.4	1.2-173	No age solution
0805187	Dewey Bridge	0.4-4.4	0.66-0.88	0.2-1.9	2.5-31.3	No age solution
0805195	Dewey Bridge	0-3.3	0.69-0.91	0.1-45.1	1.5-40.3	No age solution
0805200	Dewey Bridge	0.06-4.8	0.69-0.85	0.2-14.4	7.9-89	No age solution
0808002	Navajo Canyon	0.9-3.9	0.72-0.82	1.1-2.9	2.5-7.1	$270 \pm 120$
0808004	Navajo Canyon	2.7-5.7	0.68-0.76	3.6-7.0	8-33.6	$211 \pm 59$
0808008	Navajo Canyon	0-1.2	0.78-0.98	0.1-3.8	3.4-44.7	No age solution
1505011	Big Wall	0.05-3.4	0.76-0.9	0.19-3.6	2.5-98	$248 \pm 57$