Tuzlak, D., Pederson, J., Bufo, A., and Rittenour, T., 2021, Patterns of incision and deformation on the southern flank of the Yellowstone hotspot from terraces and topography: GSA Bulletin, <https://doi.org/10.1130/B35923.1>.

Supplemental Material

ITEM 1: Surficial map of Alpine Canyon

ITEM 2: Optically stimulated luminescence (OSL) supplemental data

TABLE S1. DOSE RATE INFORMATION

Figure S1. Equivalent-dose distributions (DE) for samples along the Hoback River plotted in stratigraphic position. Overdispersion (OD) is the scatter in the DE distributions beyond expected from instrumental error.

Figure S2. Equivalent-dose distributions (DE) for samples along the Snake River, plotted in stratigraphic position. Overdispersion (OD) is the scatter in the DE distributions beyond expected from instrumental error.

ITEM 3: Bedrock strength

Figure S3. Normalized percentage of limestone, siltstone/sandstone, and shale for each bedrock group. Estimated from stratigraphic columns recorded by Wanless (1955). Note that older rocks have higher percentages of limestone, while younger formations are mostly shale, sandstone, and siltstone.

ITEM 1: Surficial map of Alpine Canyon (next page)

ITEM 2: Optically stimulated luminescence (OSL) supplemental data

OSL Sample Processing

Optically stimulated luminescence (OSL) samples were analyzed at the Utah State University Luminescence Laboratory in Logan, Utah. Samples were opened under dim amber light (~590 nm) and sieved to selected size fractions between 90 μm and 250 μm (see Table DR1 for grain-size ranges for each sample). The quartz fraction was isolated by using 10% hydrochloric acid (HCl) and 5% sodium hypochlorite (bleach) to dissolve carbonates and organic material, sodium polytungstate (2.7 g/cm³) to remove heavy minerals. Feldspar and other non-quartz minerals were removed using three 30-minute etchings in concentrated hydrofluoric (47% HF) followed by hydrochloric (45% HCl) to prevent formation of fluorite precipitates (see Rittenour et al. 2005 for details). Purity of the samples was checked using infrared (IR) stimulation; all aliquots with an IR response signal to background ratio of > 2.0 were rejected and not used for age calculation.

Dose Rate Determination

Sample dose rates were determined from the concentrations of the K, Rb, Th, and U in the sediments surrounding the OSL target intervals. In cases where sediments contained heterogeneous mixture of different grainsizes that may have different sediment source and dose-rate contribution, we determined the proportion of each grain-size class and analyzed the sand, pebble and cobble/rock subsamples separately. Analyses of radio-elemental concentrations were conducted using ICP-MS and ICP-AES measurements and converted to dose rate using conversion factors (Guérin et al. 2011), corrected for attenuation due to grain-size (Brennan, 2003) and water attenuation (Aitken, 1989).

Total dose-rate values include cosmic contribution using sample depth, elevation, and longitude/latitude following Prescott and Hutton (1994). Dose-rate uncertainties were calculated in quadrature using the methods of Aitken and Alldred (1972) and Aitken (1976, 1985) and include uncertainty in the elemental concentrations related to ICP detection limits (following Rittenour et al., 2005), 10% moisture content variability, 3% uncertainty for dose-rate conversion (Murray and Olley, 2002) and 10% uncertainty in cosmic dose. Elemental concentrations, water content and contributions of different grain-size fractions to the dose rate are shown in Table DR1.

Optical Measurements

OSL samples were analyzed following the SAR technique of Murray and Wintle (2000) on small-aliquot (1-2 mm diameter, ~20-80 grains per disk) of fine quartz sand. Optical measurements were performed on Risø TL/OSL Model DA-20 readers, with stimulation by blue-green light emitting diodes (LED) (470 ± 30 nm) and the luminescence signal was detected through 7.5-mm UV filters (U-340) over 40 seconds at 125°C with LED diodes ($36\text{-}45$ mW/cm²). Preheat temperatures prior to the measurement of the natural and regenerative doses were 240°C for 10s and cutheat pretreatments prior to measurement of the repeated test dose steps (12-24Gy) were 160°C for 10s. Luminescence signals were calculated by subtracting the average of the last 5 seconds (background signal) from the sum of first 0.7 seconds of signal for the natural and regenerative dose steps. Test dose signals were subtracted from the background of the previous natural or regenerative dose measurement following Murray and Wintle (2000). Dose-response curves were fit to five regenerative dose points that included zero-dose and repeat-dose steps.

Equivalent Dose (D_E) and Error Calculation

We analyzed 17 to 42 aliquots of each sample to calculate the equivalent dose (D_E) of radiation the sample received following deposition, or burial dose, to calculate the OSL ages. D_E values were calculated using interpolation onto dose-response plots fit with saturating-exponential and saturating-exponential plus linear fits to the given regenerative-dose points. Data from aliquots were rejected and not used in age calculation if they had evidence of feldspar contamination, corrected signals from repeated doses >15% of unity, recuperation of the zero-dose point >10% of the natural signal, or D_E greater than the highest regenerative dose given. D_E distributions for each sample were largely symmetrical and had overdispersion (scatter beyond instrumental error) that range from 11% to 37% (Figure DR1 and Figure DR2). Sample from shallower depths had greater overdispersion, suggesting that bioturbation or pedogenic processes may have mixed the eolian sediment.

Representative D_E values for age determination for each sample were calculated using the central age model (CAM) of Galbraith and Roberts (2012). Errors on D_E are reported at 2-sigma standard error (σ) and uncertainty on ages are reported at 1 σ . Reported errors include uncertainty related to instrument calibration, and dose-rate and equivalent-dose calculations and were calculated in quadrature using the methods of Aitken and Alldred (1972).

TABLE DR1. DOSE RATE INFORMATION

Sample number*	In-situ H ₂ O (%) [†]	Grain size (µm)	K (%) [§]	Rb (ppm) [§]	Th (ppm) [§]	U (ppm) [§]	Proportion of grain size fraction [#]	Cosmic (Gy/ka)
USU-2106	-	90-150	1.96±0.05	103.0±4.1	12.6±1.1	3.9±0.3	100% sand	0.23±0.02
USU-2079	3.1	150-250	1.42±0.04	61.1±2.4	7.2±0.7	2.4±1.7	100% sand	0.19±0.02
USU-2020	22.6	90-150	1.34±0.03	52.7±2.1	6.4±0.6	1.8±0.1	100% sand	0.25±0.02
USU-2302	4.6	75-150	1.15±0.03	45.7±1.8	6.2±0.6	1.7±0.1	80% sand	0.10±0.01
			1.21±0.03	47.7±1.9	5.4±0.5	1.4±0.1	10% pebbles	
			3.96±0.10	106.0±4.2	37.2±3.4	3.1±0.2	10% granite	
			1.11±0.03	37.8±1.5	4.5±0.4	1.8±0.1	20% sand	
USU-2296	3.8	212-250	0.84±0.02	28.0±1.1	2.5±0.2	1.1±0.1	10% pebbles	0.27±0.03
			1.07±0.03	49.0±2.0	3.1±0.3	1.2±0.1	70% cobbles	
USU-2294	14.3	125-212	1.30±0.03	53.8±2.2	7.3±0.7	2.3±0.2	100% sand	0.27±0.03
USU-2295	6.5	150-250	1.29±0.03	46.7±1.9	6.5±0.6	2.3±0.2	100% sand	0.20±0.02
USU-1999	5.4	125-250	1.40±0.04	54.1±2.2	7.0±0.6	1.9±0.1	100% sand	0.04±0.00
USU-2293	4.6	150-250	1.07±0.03	39.4±1.6	4.7±0.4	2.1±0.2	55% sand	0.22±0.02
			0.57±0.01	17.5±0.7	2.5±0.2	1.5±0.1	45% pebbles	
USU-2080	8.0	90-150	1.41±0.04	58.2±2.3	7.7±0.7	2.0±0.1	100% sand	0.02±0.00
USU-2019	15.4	90-150	1.60±0.04	74.2±3.0	11.0±0.99	2.9±0.2	100% sand	0.06±0.01
USU-2303	4.9	150-250	1.16±0.03	46.4±1.9	4.9±0.4	1.9±0.1	75% sand	0.03±0.001
			1.66±0.04	70.8±2.8	6.7±0.6	1.7±0.1	25% pebbles	
USU-1996	6.5	90-150	1.32±0.03	57.6±2.3	10.6±1.0	2.8±0.2	100% sand	0.17±0.02
USU-1998	7.0	90-150	0.94±0.02	31.8±1.3	4.4±0.4	1.7±0.1	100% sand	0.04±0.00

* Organized by stratigraphic position along the Hoback River and Snake River.

† Assumed 10±3% for all samples as moisture content over burial history.

§ Radioelement concentrations determined by ALS Chemex using ICP-MS and ICP-AES techniques; dose rate is derived from concentrations by conversion factors from Guérin et al. (2011).

Proportion of sand, pebble, cobble and/or rock subsample used in beta and gamma dose rate calculation. For USU-2302, beta dose rate uses radioelement composition of sand only and gamma dose rate uses proportional radioelement composition from all fractions.

Figure DR1. Equivalent-dose distributions (D_E) for samples along the Hoback River plotted in stratigraphic position. Overdispersion (OD) is the scatter in the D_E distributions beyond expected from instrumental error.

Figure DR2. Equivalent-dose distributions (D_E) for samples along the Snake River, plotted in stratigraphic position. Overdispersion (OD) is the scatter in the D_E distributions beyond expected from instrumental error.

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References Cited

- Aitken, M.J., 1976, Thermoluminescent age evaluation and assessment of error limits: revised system: *Archaeometry*, v. 18, p. 233-238.
- Aitken, M.J., 1998, Introduction to optical dating: the dating of Quaternary sediments by the use of photon-stimulated luminescence: Clarendon Press.
- Aitken, M.J., Alldred, J.C., 1972, The assessment of error limits in thermoluminescence dating: *Archaeometry*, v. 14, p. 257-267.
- Brennan, B.J., 2003, Beta doses to spherical grains: *Radiation Measurements*, v. 37, p. 299-303.
- Guérin, G., Mercier, N., Adamiec, G., 2011, Dose-rate conversion factors: update: *Ancient TL* 29, p. 5-8.
- Murray, A.S. and Olley, J.M., 2002. Precision and accuracy in the optically stimulated luminescence dating of sedimentary quartz: a status review: *Geochronometria*, v. 21, p. 1-16.
- Murray, A. S., Wintle, A. G., 2000, Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol: *Radiation Measurements*, v. 32, p. 57-73.
- Prescott, J. R., Hutton, J.T., 1994, Cosmic ray contributions to dose rates for luminescence and ESR dating: *Radiation Measurements*, v. 23, p. 497-500.
- Rittenour, T.M., Goble, R.J., and Blum, M.D., 2005, Development of an OSL chronology for late Pleistocene channel belts in the lower Mississippi valley: *Quaternary Science Reviews*, v. 24, p. 2539-2554.
- Wanless, H.R., 1955, Paleozoic and Mesozoic Rocks of Gros Ventre, Teton, Hoback, and Snake River Ranges, Wyoming: Geological Society of America, v. 63.
- Wintle, A.G. Murray, A.S., 2006, A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regenerative protocols: *Radiation Measurements*, v. 41, p. 369-391.