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SHEET 2 OF 2
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PALEOSEISMOLOGY OF THE NEPHI SEGMENT OF THE WASATCH FAULT ZONE, JUAB COUNTY, UTAH—PRELIMINARY RESULTS FROM TWO LARGE EXPLORATORY TRENCHES AT WILLOW CREEK

By

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RECURRENCE INTERVALS

From the preliminary dating results from Willow Creek, it appears that three surface-faulting events occurred between about 300 yr ago (estimated time of P1) and 2,320 yr ago (the average of several ages for faulted deposits). This period of less than about 2,000 yr spans two full recurrence intervals and perhaps part of a third (prior to P3). This means that the maximum average recurrence interval for events P1 and P2 is <1,000 yr. Previously, the average recurrence interval for the Nephi segment was reported to be about 2,500±2,100 yr (Lund, 2005).

DISPLACEMENTS

The offset in the WCN trench is larger (7–8 m, vs. 5–6 m for WCS), and the footwall deposits are older (WCN-R1: 6,238±57 cal yr) than in the WCS trench. However, in WCN, deposits on the hanging-wall block are younger than on the footwall, and have buried evidence for any faulting events between about 6,200 and 2,300 yr ago. Refinement of repeat times and slip rates awaits synthesis of radiocarbon dates and luminescence age estimates from both trenches.

SLIP RATES

Vertical slip rates are hard to determine at Willow Creek owing to the large amount of tilting associated with the fault's movement. However, if we assign most of the tilting (about 3–4 m) to P3, which has a small colluvial wedge compared to P1 and P2, then the remaining offset results mainly from the P1 and P2 events (4–5 m vertical offset in WCS; about twice the maximum thickness of Cw1 and Cw2). In this scenario, the average minimum slip rate in the 2.0 kyr (maximum) P1–P3 interval is 2.0–2.5 mm/yr. Thus, our data suggest a 2 to 3 times higher slip rate than previously considered for the Nephi segment

CONCLUSIONS

The Willow Creek trenches record three surface faulting events in the past 2,300 yr, with the most recent event (MRE or P1) having occurred about 300 yr ago. We suspect that the fault has a late Holocene slip rate of 2.0–2.5 mm/yr, which would be the highest documented rate for the WFZ. However, further estimates of repeat times and slip rates await refinement and synthesis of radiocarbon dates and luminescence age estimates from both trenches.

Table 1. Luminescence age estimates from the Willow Creek trenches.

USGS Sample No.	Timing and sampled unit	K (%)[a]	Th (ppm)[a]	U (ppm)[a]	Total dose rate (Gy/k.y.)[b] and moisture (%)[c]	Equivalent dose (Gy)	N^d	Preferred age (k.y.)
WCN-L01	Min. P3 Unit Cw3	0.66 ± 0.01	2.40 ± 0.07	1.48 ± 0.13	1.48 ± 0.13 26 (39)	9.03 ± 0.32	26 (39)	5.13 ± 0.28[e]
WCN-L02	Max. P1, Min. P2 Unit Cw2	0.81 ± 0.02	2.66 ± 0.08	1.52 ± 0.06	1.52 ± 0.06 27 (30)	2.02 ± 0.13	27 (30)	1.04 ± 0.07[e]
WCN-L03	Min. P3 Unit 2	0.90 ± 0.02	3.06 ± 0.08	1.60 ± 0.03	1.60 ± 0.03 20 (41)	2.61± 0.15	20 (41)	1.24 ± 0.08[e]
WCS-L01	Max. P3 Unit 3-3	0.91 ± 0.02	3.33 ± 0.09	1.79 ± 0.04	1.79 ± 0.04 11 (15)	3.48 ± 0.24	11 (15)	2.32 ± 0.17[f]
WCS-L02	Max. P3 Unit 3-3	0.90 ± 0.02	3.32 ± 0.07	1.63 ± 0.04	1.63 ± 0.04 31 (34)	3.75 ± 0.14	31 (34)	2.57 ± 0.12[e]
WCS-L03	Max. P3 Unit 4-7	1.15 ± 0.02	3.24 ± 0.08	1.67 ± 0.05	1.67 ± 0.05 24 (33)	8.35 ± 0.25	24 (33)	4.94 ± 0.21[f]
WCS-L04	Max. P3 Unit 4-2	0.95 ± 0.02	3.20 ± 0.08	1.76 ± 0.05	1.76 ± 0.05 22 (29)	3.64 ± 0.27	22 (29)	2.50 ± 0.19[f]
WCS-L05	Max. P2, Min. P3 Unit Cw3	0.71 ± 0.01	2.34 ± 0.09	1.29 ± 0.04	1.29 ± 0.04 30 (35)	4.34 ± 0.16	30 (35)	3.05 ± 0.15[f]

Notes: a Analyses obtained using in-situ Gamma Spectrometry with Exploranium probe, 2 counts for 1000 s each. K, potassium; Th, thorium; U, uranium.
b Cosmic doses (in Gy, grays-unit of measure for absorbed dose) and attenuation with depth calculated using the methods of Prescott and Stephans (1982) and Prescott and Hutton (1994). Cosmic doses are 0.18 Gy/k.y. for all samples except WCS-L03 (0.29 Gy/k.y.) and WCS-L05 (0.27 Gy/k.y.).
c Moisture content used in calculation of age (that is, 60 percent of total saturation). Figures in parentheses indicate saturation.
d Number (N) of replicated equivalent dose estimates used to calculate the mean. Figures in parentheses are total number of measurements made including failed runs with unusable data.
e Dose rate and age for fine-grained 90–180 µm quartz sand. Linear regression used on age, errors are 1 sigma.
f Dose rate and age for fine-grained 90–250 µm quartz sand. Linear regression used on age, errors are 1 sigma.

Table 2. Calibrated radiocarbon ages from the Willow Creek trenches.

USGS Sample No.	Laboratory No. [a]	Trench, Unit	Dated material and weight	^{14}C age in yr B.P.	Two-sigma age[b] and probability	Preferred age[c] in calendar yr
WCN-R1	123540*	North, unit 5-6	Charred monocot/herbaceous dicot stems; 0.005 g	5,420±35	6,134 yr @ 2% 6,238 yr @ 98%	6,238±57
WCN-R2	----------	North, unit 5-6	Charred unidentified organics; too small to date	----------		
WCN-R3	117550*	North, unit Cw2	Charred *Asteraceae* (sage-brush?); 0.003 g	1,275±35	1,227 yr @ 100% (unique solution)	1,227±54
WCN-R4	123541*	North, unit Cw2	Charred from unidenti-fied hardwood; 0.010 g	725±35	675 yr @ 5% 688 yr @ 95%	688±39
WCN-R5	12212*	North, unit Cw3	Charred monocot stems; 0.005 g	265±35	4 yr @ 15% 161 yr @ 10% 306 yr @ 46% 403 yr @ 42%	306±28 or 403±53
WCN-R6	----------	North, unit 3-1	Charred woody twigs; too small to date	--------		
WCN-R7	123542*	North, unit 2	Charred from sagebrush (*Artemisia*); 0.009 g	330±30	390 yr@ 100%	390±8
WCS-R1	117546*	South, unit 1-3	Charred woody twigs; 0.006 g	210±35	-2 yr @ 16% 180 yr @ 52% 283 yr @ 32%	180±43
WCS-R2	117547*	South, unit 3-3	Charred woody twigs; 0.011 g	230±35	-2 yr @ 11% 180 yr @ 42% 292 yr @ 43% 410 yr @ 4%	180±37 or 292±25
WCS-R3	544391	South, unit 3-3	Charred monocot/ herbaceous dicot stems; 0.011 g	310±45	388 yr @ 100 %	388±97
WCS-R4	117548*	South, unit 4-9	Charred from oak (*Quercus*); 0.064 g	2,965±35	3,129 yr @ 100%	3,129±125
WCS-R5	544401	South, unit 4-9	Charred from oak (*Quercus*; 0.027 g	3,000±35	3,174 yr @ 89 % 3,307 yr @ 11 %	3,174±98
WCS-R6	117549*	South, unit 2	Charred from maple (*Acer*); 0.007 g	500±60	342 yr @ 1% 513 yr @ 74% 615 yr @ 24%	513 ±59 (too young) 282±26
WCS-R7	122213	South, unit Cw2	Charred monocot stem; 0.043 g	205±35	15 yr @ 17% 180 yr @ 53% 282 yr @ 30%	

Notes: Radiocarbon ages calibrated using Calib. v. 5.0.1 (see http://radiocarbon.pa.qub.ac.uk/calib/).
a Symbol * denotes samples dated by Lawrence Livermore National Laboratory; symbol ǂ denotes samples dated by Woods Hole Oceanographic Laboratory.
b Age is midpoint of reported age range
c Preferred age is midpoint and standard deviation of most probable age solution(s).

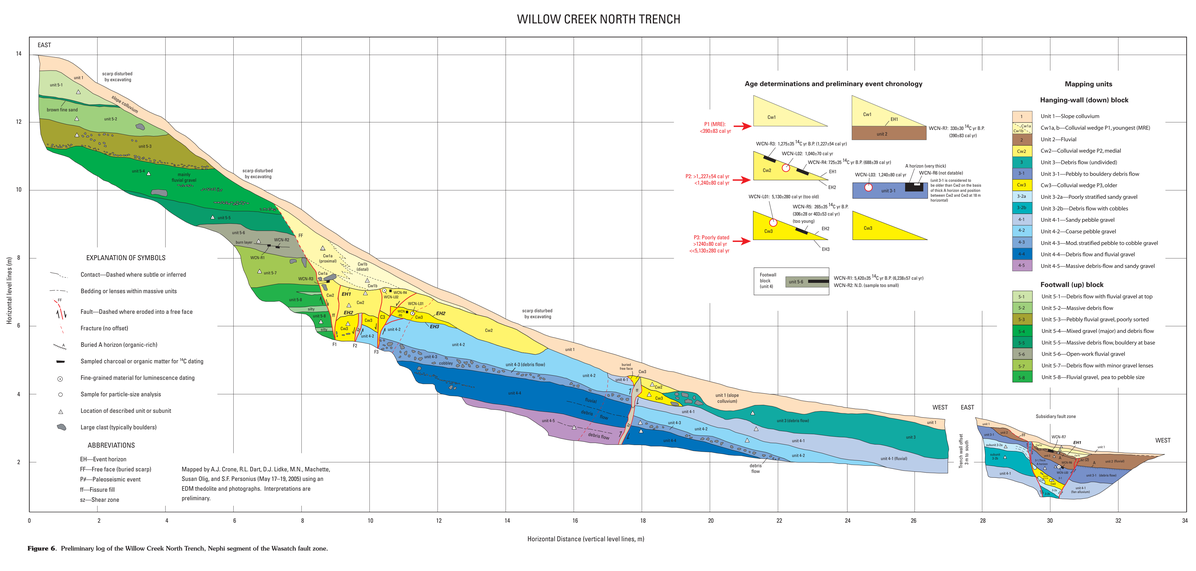

Figure 6. Preliminary log of the Willow Creek North Trench, Nephi segment of the Wasatch fault zone.

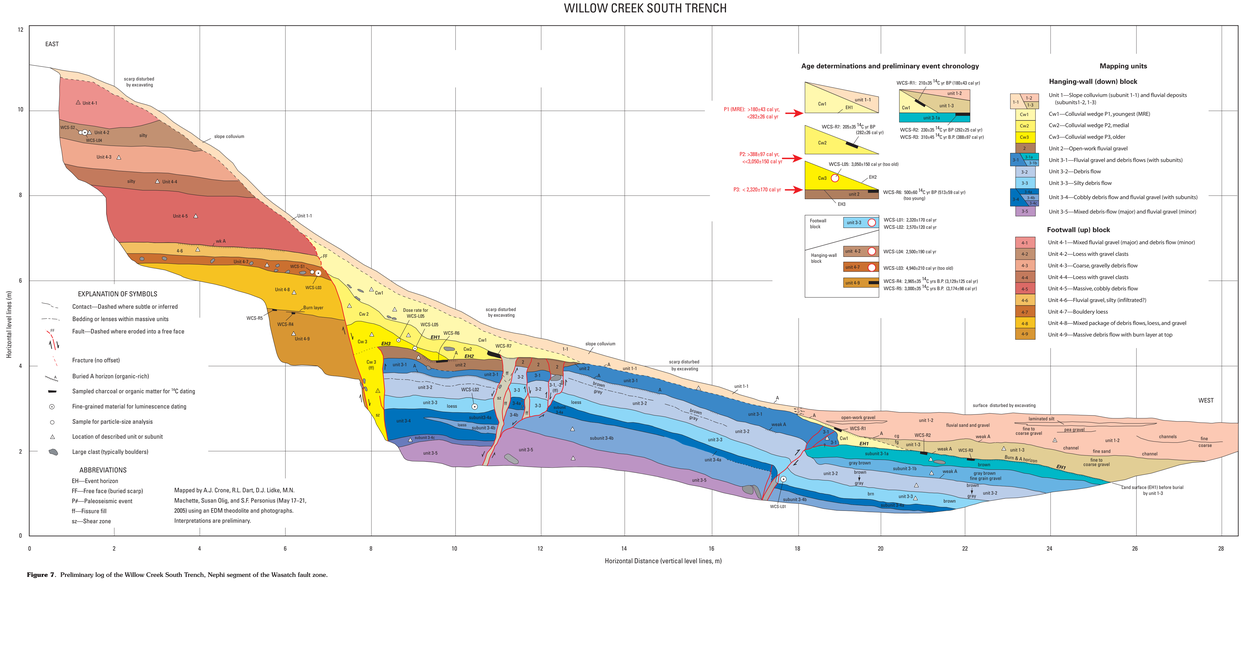

Figure 7. Preliminary log of the Willow Creek South Trench, Nephi segment of the Wasatch fault zone.

Table 3. Description of units in northern trench (WCN) at Willow Creek, Nephi segment of the Wasatch fault zone. Location of described samples shown on trench logs by triangular symbol.

Map Unit	Origin (and location for multiple descriptions)[a]	Grain size (%) >2 vs < 2mm	Clast sizes (cm)[b]	<2mm texture[c]	<2 mm color[d]	Bedding	Comments[e]
1	Slope colluvium	35/65	3/1.0.5	Si Sa	10YR 4/3m	Crude	Modern A horizon; slope-parallel clasts
Cw1a	Scarp coll. @ 8.3 m, prox.	45/55	35/9/2	Si f Sa	10YR 4/3m	Crude	Wash-slope facies; slope-parallel clasts
Cw1b	Scarp coll. @ 10 m, distal	80/20	20/10/4	Si Sa	10YR 5.5/3.5d	Crude	Debris-slope facies; open-work gravel at toe
Cw1a	Scarp coll. @ 30.4 m, prox.	70/30	3.5/1.5/1	Si Sa	10YR 6.5/4d	Crude	Stage I coats on clasts; wash-slope facies
Cw1b	Scarp coll. @ 30.3 m, distal	90/10	8/4/3	Si Sa	10YR 3.5/3m	Massive	Stage I coats on clasts; debris-slope facies
2	Fluvial (W end trench only)	75/25	7/3/1	Si f-m Sa	10YR 7/3d	Crude	Stage I coats on clasts; A horizon
Cw2	Scarp coll. @ 9.9 m, prox.	50/50	12/6/1	Si m-c Sa	10YR 3/2.5m	Massive	Moderately organic (from above)
Cw2	Scarp coll. @ 9.4 m, distal	60/40	16/6/1.5	Si Sa	10YR 4/4m	Massive	Non rotated stage I coats on clasts
Cw2	Scarp coll. @ 18.3 m	55/45	12/9/1	Si f Sa	10YR 4/3m	Massive	Younger colluvium from fault at 17–18 m
3	Debris flow @ 21.2 m)	75/25	26/10/2	Si Sa	10YR 5/4m	Massive	Undivided unit; see subunits 3-1, 3-2a, 3-2b
3-1	Debris flow (@30.2)	60/40	7/2/1	Si f Sa	10YR 5/4m	Massive	Undivided unit; A horizon 10YR 3/3m
Cw3	Scarp coll. @ 9.4 m	55/45	14/9/1	Si Sa	10YR 4/4m	Massive	Weak stage I coats on clasts
Cw3	Scarp coll. @ 18.3 m	70/30	20/6/2	Si f Sa	10YR 5/3m	Massive	Stage I coats on clasts
Cw3	Scarp coll. @ 30.1 m	80/20	5/2/0.5	Si f Sa	10YR 5/3.5m	Crude	Weak stage I coats on clasts
3-2a	Fluvial @ 28.4 m	75/25	4/2/0.5	Si f-m Sa	10YR 6.5/4d	Crude	Subdivided in western part of trench
3-2b	Debris flow@ 28.4 m	75/25	25/10/2	f Sa Si	10YR 6/4d	Massive	Subdivided in western part of trench
4-1	Fluvial	80/20	9/1.5/0.5	Si f-m Sa	10YR 5/3m	Crude	Minor debris flows; brown to gray colors
4-2	Fluvial	75/25	8/1.5/1	Si f Sa	10YR 5/4m	Crude	Coarse pebble-gravel
4-3	Debris flow	85/15	40/7/3	Si Sa	10YR 5/6m	Massive	Matrix-poor debris flow
4-4	Fluvial and debris flow	75/25	23/14/5	Si Sa	10YR 5/6m	Moderate	Fluvial gravel over debris flow (like unit 4-3)
4-5	Fluvial and debris flow	75/25	12/8/2	Si Sa	10YR 5/3m	Crude-mod.	Similar to unit 4-4
5-1	Debris flow and fluvial	80/20	18/5/2	Si Sa	10YR 6/4m	Massive	Upper 10-15 cm is fluvial pea-size gravel
5-2	Debris flow	50/50	12/6/1	Si m-c Sa	10YR 5/3m	Crude	Clasts float in matrix; thin, fine sand at top
5-3	Fluvial	75/25	15/8/3	Si Sa	10YR 4/3ms	Massive	5–15 cm thick open-work pebble gravel at base
5-4	Fluvial and debris flow	85/15	6/3/1	Si Sa	10YR 5/4m	Crude	Basal 10 cm is debris flow with 48 cm clast
5-5	Debris flow and fluvial	65/35	16/5/1	f Sa Si	10YR 5/4m	Moderate	Clasts float in matrix
5-6	Fluvial	70/30	15/6/1	f Sa Si	10YR 5/3m	Massive	Open-work gravel clogged with silt
5-7	Debris flow and fluvial	60/40	11/5/0.5	Si Sa	10YR 4/4m	Crude	Lenses of open-work gravel
5-8	Fluvial	70/30	4/1/0.4	Sa	10YR 4/3.5m	Well	Granule to pebble gravel with shale fragments

Notes:
a — Abbreviations: coll., colluvium; prox., proximal,
b — Clast sizes: Diameters for maximum/common/average clasts.
c —Textural terms abbreviations: Si, silt; Sa, sand; f, fine; m, medium; c, coarse; that is, Si f Sa is a silty fine-grained sand.
d — Soil ped or matrix colors determined using Munsell® Soil Color Charts (1994). m, moist; d, dry.
e — Stage I morphology: calcium carbonate coats base of clasts only.

Table 4. Description of units in southern trench (WCS) at Willow Creek, Nephi segment of the Wasatch fault zone. Location of described samples shown on trench logs by triangular symbol.

Map Unit	Origin (and location for multiple descriptions)[a]	Grain size (%) >2 vs < 2mm	Clast sizes (cm)[b]	<2mm texture[c]	<2 mm color[d]	Bedding	Comments[e]
1-1	Slope colluvium	65/35	20/6/1.5	Si f Sa	10YR 4/4m	Crude	A horizon on slope; clasts parallel slope
1-2	Fluvial	70/30	35/15/4	Si m-c Sa	10YR 3/3m	Moderate	Minor open-work gravel; stage I coats on clasts
1-3	Fluvial	65/35	25/10/3	Si m Sa	10YR 3/4m	Crude	Weak A horizon on unit; fill channel at base of slope
Cw1	Scarp colluvium@18.75 m)	80/20	15/8/6	Si f Sa	10YR 5/2d	Massive	Stage I coats on clasts; 5-cm A horizon, broad wedge
Cw1	Scarp colluvium, proximal	55/45	15/8/1.5	c Sa	10YR 5/3m	Crude	Broad, thin wedge; slope-parallel clasts
Cw1	Scarp colluvium, distal	90/10	18/12/2	Si f Sa	10YR 6/4d	Crude	Open-work gravel at toe
Cw2	Scarp colluvium, proximal	65/35	20/6/1	Si c Sa	10YR 5.5/4d	Massive	Classic wedge; slope-parallel clasts stage I coats
Cw2	Scarp colluvium, distal	80/20	20/10/2.5	Si Sa	10YR 6/4d	Crude	Classic wedge; open-work gravel at toe
Cw3	Scarp colluvium, main	60/40	15/6/1.5	Si Sa	10YR 6/3.5d	Crude	Small classic wedge
Cw3	Scarp colluvium in fissure	60/40	15/8/2.5	Si Sa	10YR 6/2d	Massive	Fissure-fill (early) colluvium; highly sheared
2	Fluvial	80/20	12/8/1.5	Si m-c Sa	10YR 3/3m	Moderate	Mainly open-work gravel in channels and lenses
3-1a	Debris flow	80/20	25/15/1.5	Si f-m Sa	10YR 4/4m	Massive	5–15 cm thick A horizon; low % <2mm for debris flow
3-1b	Fluvial	80/20	9/5/1.5	Si Sa	10YR 4/3m	Crude	Stage I coats on clasts; clasts bimodal (small, medium)
3-2	Debris flow	65/35	10/5/2	Sa Si	10YR 4/4m	Massive	Weak A horizon; unit grades down from brown to gray
3-3	Debris flow	50/50	12/9/0.5	Si f Sa	10YR 4/4m	Massive	Stage I coats on clasts which float in matrix
3-4a	Debris flow	65/35	15/7/1	Si c Sa	10YR 7/3d	Massive	Matrix-supported clasts; only subunit at main fault
3-4b	Debris flow and fluvial	60/40	25/10/1	Si f-m Sa	10YR 5.5/3d	Crude	Stage I coats on clasts; minor fluvial lenses
3-4c	Loess-rich debris flow	5/95	5/3/0.5	Si f Sa	10YR 6/3d	Massive	Only mapped in fault block between 8 m and 11 m horizontal
3-5	Fluvial and debris flow	95/5	5/3/0.5	Si f Sa	10YR 6/3d	Massive	Sampled mixed fluvial and debris flow at top
3-5	Fluvial and debris flow	50/50	35/10/1	Sa Si	10YR 6/4d	Crude	Sampled debris flow at base
4-1	Fluvial and debris flow	55/45	25/12/1.5	Si Sa	10YR 5/3m	Crude	15–20 cm of fluvial at top; stoneline at base of debris flow
4-2	Loess and colluvium	2/98	10/3.5/0.5	Sa Si	10YR 6.5/3d	Crude	Massive loess with lenses of debris flow (gravelly)
4-3	Debris flow	65/35	26/15/3	Si Sa	10YR 6.5/3d	Massive	Large clasts float in matrix; no fluvial
4-4	Loess and colluvium	85/15	15/5/0.5	f Sa Si	10YR 6.5/3d	Massive	Minor fluvial lenses of pebble gravel
4-5	Debris flow	80/50	22/8/3	m Sa Si	10YR 7/3d	Massive	Stage I coats on clasts; 1.5-m- thick coarse debris flow
4-6	Fluvial	60/40	12/5/1	Si m-c Sa	10YR 6/3d	Moderate	Stage I coats on clasts
4-7	Loess and colluvium	25/75	16/10/8	f Sa Si	10YR 6.5/3d	Crude	Mainly loess with large floating clasts
4-8	Debris flow, loess, fluvial	65/35	20/9/2	Si f-c Sa	10YR 6.5/3d	Varied	Mixed unit: 40 cm fluvial, 25 cm loess, 50 cm debris flow
4-9	Debris flow	55/45	20/9/5	Sa Si	10YR 6.5/3d	Crude	Contains minor fluvial lenses; burn layer at top

Notes:
a — Abbreviations: coll., colluvium; prox., proximal,
b — Clast sizes: Diameters for maximum/common/average clasts.
c —Textural terms abbreviations: Si, silt; Sa, sand; f, fine; m, medium; c, coarse; that is, Si f Sa is a silty fine-grained sand.
d — Soil ped or matrix colors determined using Munsell® Soil Color Charts (1994). m, moist; d, dry.
e — Stage I morphology: calcium carbonate coats base of clasts only.

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