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Supplementary Information

Geological Observations on History and Future of Large Earthquakes along the Himalayan Frontal Fault Relative to the April 25, 2015 M7.8 Gorkha Earthquake near Kathmandu, Nepal

Tables of unit descriptions and original radiocarbon laboratory analyses, discussion and log of Trench B, photo logs of all Bagmati and Tribeni trenches, and additional fault rupture scenarios.

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Supplementary Information S1 and Figures S1, S2 and S3

Trench B. The trench is located across the scarp bounding the lower, geomorphically younger T1 surface (**Figure 2b**). The character of the scarp is illustrated by the photo in **Figure S1**. A sketch of the trench exposure in is shown in **Figure S2** and a photo log of the same in **Figure S3**. The stratigraphy exposed in the trench is dominated by several rounded cobble-small boulder beds (units 2, 3, and 4) that are inclined to the west. The lowest of this sequence of beds (unit 4) is separated from flat-lying units 5 and 6 by a concentration of aligned and east-dipping clasts (colored red in **Figure S2**) that represent a zone of shear which is labeled unit 7. The occurrence of thrust displacement along the interpreted zone of shear is supported by the warping and overturning of aligned clasts in unit 4 to form what appears to be a drag fold as it approaches the shear zone (green clasts in **Figure S2**). The shear zone truncates and sits on flat-lying unit 5, a horizontally laminated fine sand that is the only fine grained unit in the exposure. Whether or not the shear zone extends into unit 3 is ambiguous. The presence in unit 3 of clasts similarly inclined and on projection with the underlying unit 7 shear zone allows speculation that shearing has occurred in unit 3. Such speculation is countered by the presence of numerous zones of similarly inclined clasts throughout the unit. There is no indication of shear in the massive rounded cobble small boulder gravel of unit 2. Material suitable for radiocarbon dating was not observed in the coarse deposits.

*Figure S1. Photo viewed northward shows character of scarp and spoils of Trench B at the Naryani site (**Figure** 6).*

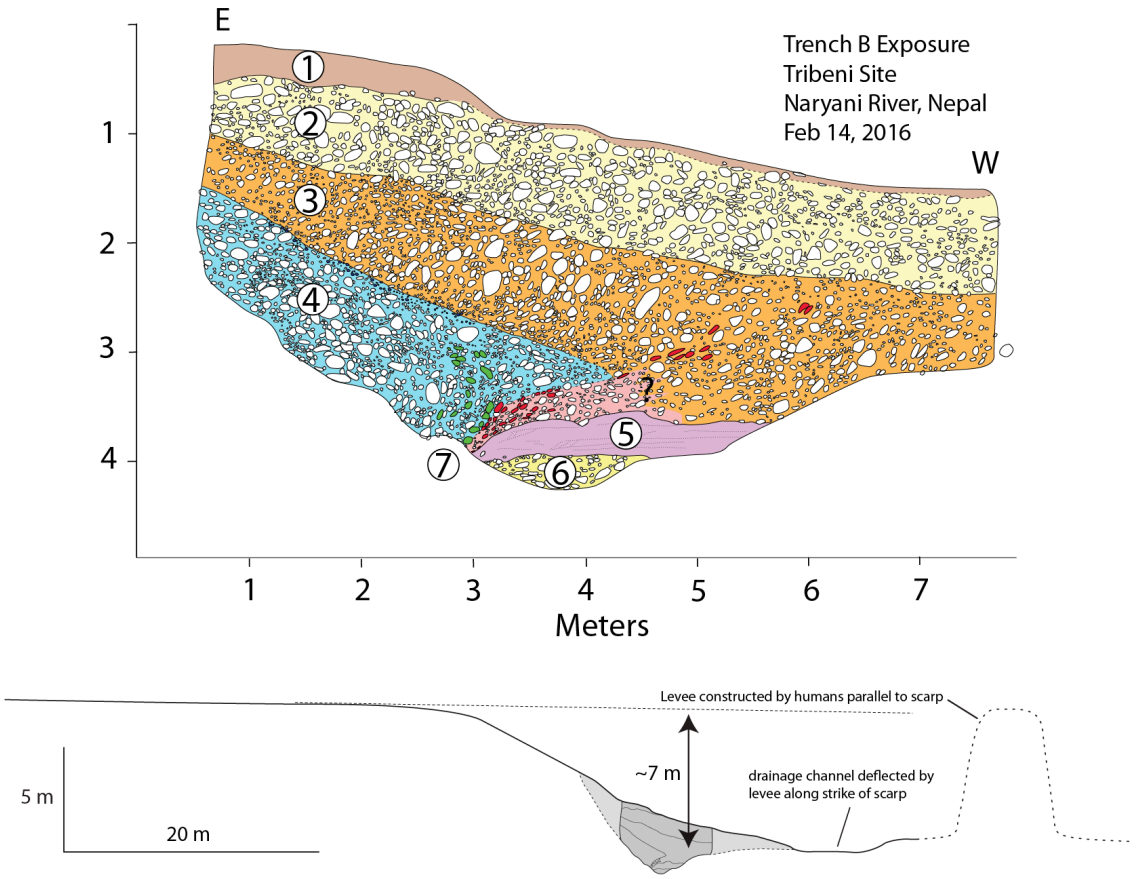


*Figure S2a. (upper) Log of Trench B at Tribeni (Narayani) site. Numbers in circles are unit numbers. Each unit is described in **Table S1**. Red clasts between units 5 and 7 are highlighted because of alinement of long axis along zone of shear. A similar alinement in unit 3 may reflect propagation of shear into unit 3, but the coarse nature of the unit and similar alinement of clasts elsewhere in unit 3 makes such an interpretation equivocal. The green clasts in unit 4 are similarly alined along there long axis, in this case suggesting the bulldozing and folding of the coarse gravel at the toe of a thrust. (lower) Profile of scarp and location of trench (grayed) with respect to scarp profile. The height and width of levee are approximate. Elevation of ground is same on each side of levee.*

Figure S2b. Shallow pit on footwall surface of Trench B scarp (T1 surface of Fig. 2a) shows thin layer (~20cm) overlying rounded cobble small boulder river gravel like that observed in Trench B (Figure S3). Pit located about 50m perpendicular to fault at 27.451349°N, 83.918102°W.

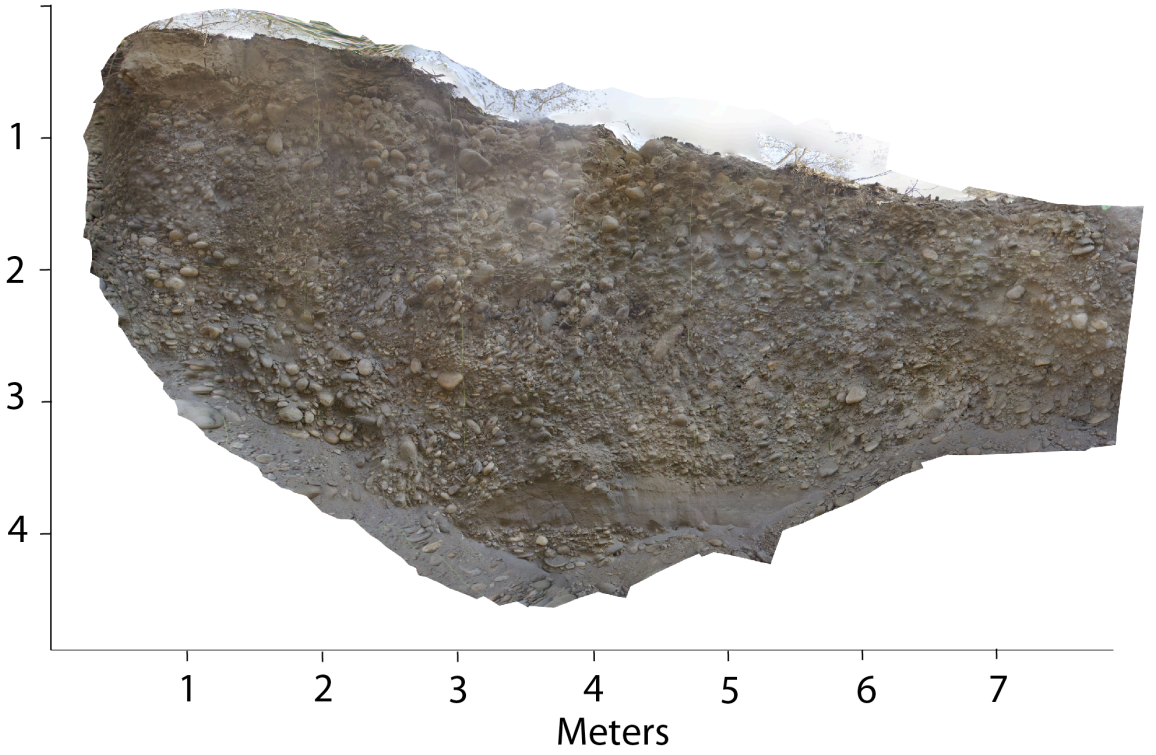


Figure S3. Photo Log of Trench B at Naryani site.

Supplementary Table S1: Unit Descriptions to Accompany Trench Logs

Bagmati

Unit	Description
1	Generally massive and poorly sorted subrounded boulder gravel. Discontinuous coarse sand lenses which are clast supported and concentrations of large boulders show sub horizontal fabric at NE end of exposure that bends downward to southwest: Fluvial Gravel.
2	Generally massive beds of brown silty very fine sand and light-gray fine and medium sand. Beds are generally massive. Contacts between beds clear and undulatory where dipping. Worm casts observed along basal contact of light-gray sands: Flood couplets. Clean gray sands are higher energy deposits of flood events resulting from flooding of nearby Bagmati river and overlying finer deposits are final slackwater stages of same respective flood events. Horizontally bedded at northeast end of trench and inclined southwestward toward southwestward end of exposure.
3	Clay rich very fine and fine sand. Distinguished from finer grained beds of unit 2 by significant component of clay and distinct pock-marked appearance upon scraping unit in outcrop: Likely the ground surface at time of faulting.
4	The basal portion of unit is a clean and massive beige-light brown medium coarse sand which locally exhibits erosion along basal contact with unit 3, less so near base. The basal sand grades upward across irregular diffuse contact to coarser sand and further upward to very poorly sorted rounded pebble and small cobble gravel. Internal coarse sand and pebble lens is horizontal. Channel and debris flow channel deposit.
5	Light brown very fine silty sand, generally massive in appearance and reddish brown in color. Unit is capped by regular darker clay enriched horizon. Upper contact visually clear though irregular: Growth stratigraphy from local flooding or Bagmati river.
6	Very fine silt and clay bearing sand distinguished by a distinctly darker tone than underlying unit 5. Growth stratigraphy from local flooding or Bagmati river.
7	Gray poorly sorted surrounded and rounded pebble gravel. Erosive basal contact. Channel deposit likely sourced from adjacent small drainage.
8	Light brown silty sand. Generally massive but for small lens of fine gray sand at meter 13 that is inclined parallel to sloping basal contact: Colluvium.
9	Basal portion of unit is fine and medium cross-laminated sand that is overlain by matrix supported poorly sorted rounded pebble gravel. Upper portion of unit is massive, possibly disturbed by humans.

Tribeni Trench

Unit	Description
1	Rounded pebbles and cobbles: Fluvial gravel.

2	Interbedded layers of (a-green) well sorted, loose, fine gray sand that locally displays laminations and (b-pink) light brown silty sand: Aggradation of flood and overbank deposits of nearby Naryani river. Coarser facies represent higher energy stage of flood events and finer facies the later stage low energy or slackwater deposits. Unit observed on both foot and hanging wall but correlation of individual beds across fault zone is not implied.
3	Silty very fine sand. Similar to underlying 2b beds though distinguished from by browner color (greater silt concentration?) and greater thickness: Low energy flood deposit from nearby Naryani river.
4	Fault bounded and rotated packages of sediment with texture and color similar to units 2 and 3.
5	Inclined layer of massive indurate light brown very fine sand: Basal portion of a shear zone.
6	Light brown very fine silty sand with occasional rounded pebble. Generally massive except near base of unit on footwall where discontinuous lens of rounded pebbles indicate horizontal fabric. Roots and organic matter abundant near surface: Cut and fill deposits accumulating from adjacent local drainage?

Naryani Trench B

Unit	Description
1	Brown silty sand
2	Massive matrix supported rounded cobble and small boulder gravel.
3	Generally clast supported rounded cobble and small boulder gravel distinguished from unit 2 by eastward dipping fabric resulting from inclination (imbrication) of elongate class. Unit may be faulted but interpretation limited by coarse nature of deposit and eastward inclination of class throughout the unit.
4	Genarally last supported rounded cobble small boulder gravel displaying fabric alined with westward dip of bed except at western limit where inclination of class locally steepen and overturn in form of a fold, likely due to shearing related to slip occurring on underlying shear zone.
5	Light brown fine horizontally laminated fine sand.
6	Rounded cobble and small boulder gravel displaying horizontal fabric.
7	Zone of elongate class inclined eastward and interpreted to be zone of shear. Continuation of zone into unit 3 uncertain.

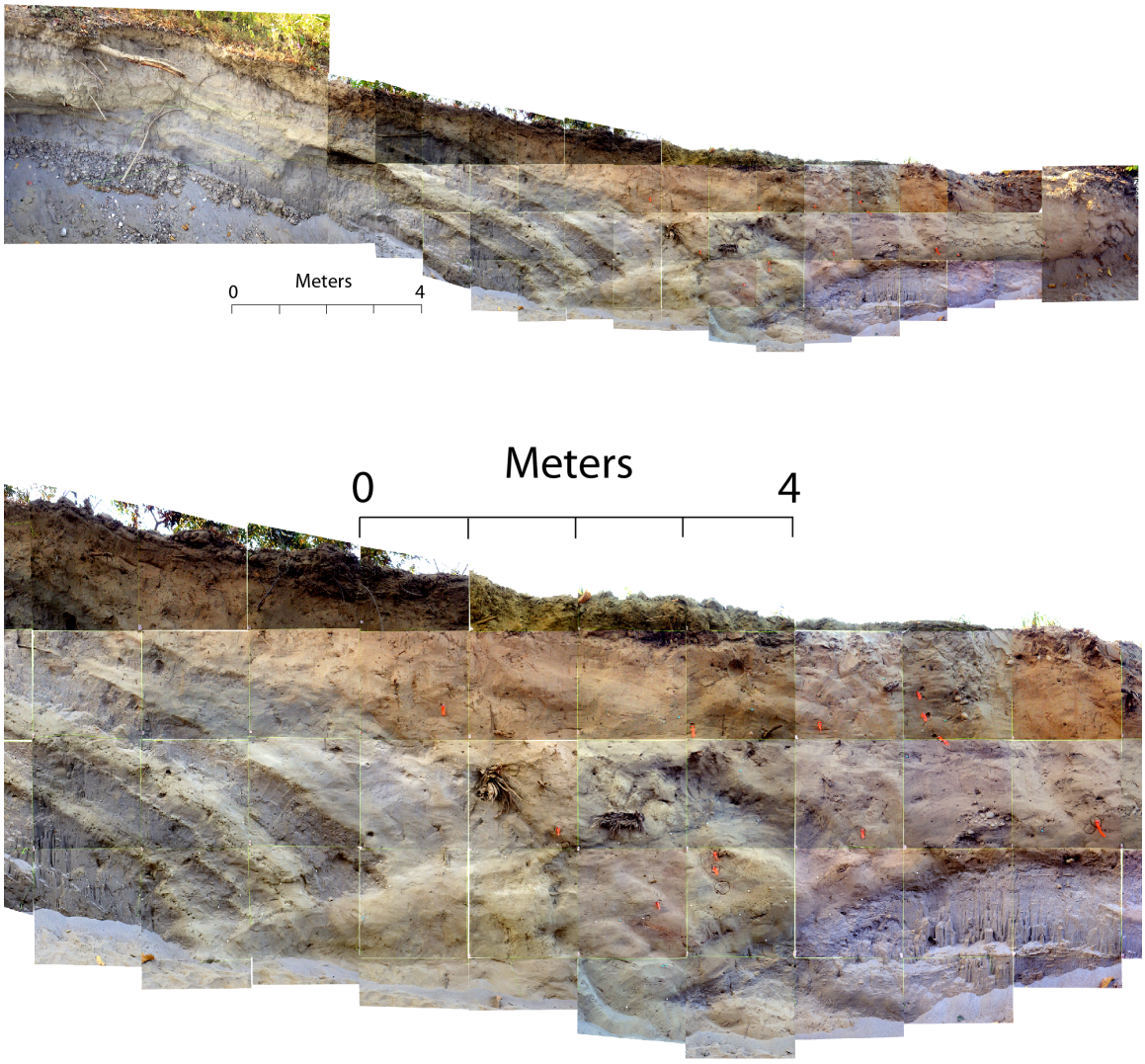


Figure S4. Tribeni trench photo logs. Upper of entire trench and lower enlarged about fault zone.

Supplementary Table S2. Radiocarbon Data Summary*

AA[Ψ]	lab #[Ψ]	sample ID	MASS	$\delta^{13}C$ (±0.1%)	Fraction Modern Carbon	14C age BP
AA107463	X29982	T1-1	1.58	-27.4	0.9043 ± 0.0022	808
AA107464	X29983	T1-2	2.11	-25.6	0.9097 ± 0.0022	761
AA107465	X29984	T1-3	1.89	-25.5	0.9042 ± 0.0022	809
AA107466	X29985	T1-5	1.36	-25.5	0.9026 ± 0.0022	823
AA107467	X29986	T1-6	1.74	-24.6	0.9201 ± 0.0023	669
AA107468	X29987	T1-8	1.86	-24.2	0.9413 ± 0.0023	486
AA107469	X29988	T1-11	1.77	-26.3	0.9486 ± 0.0023	423
AA107470	X29989	T1-13	1.34	-27.8	0.9592 ± 0.0024	334
AA107471	X29990	T1-14	1.44	-23.9	0.9546 ± 0.0024	373
AA107472	X29991	T1-15	2.08	-25.6	0.9020 ± 0.0022	828
AA107473	X29992	B-2	0.91	-26.7	0.0064 ± 0.0010	40,500
AA107474	X29993L	B-3	0.45	-27.3	0.9368 ± 0.0028	524
AA107475	X29994	B-4	1.53	-28.1	0.9304 ± 0.0023	579
AA107477	X29996	B-6	0.65	-28.3	0.8837 ± 0.0022	993
AA107478	X29997	B-7	1.71	-27.4	0.8659 ± 0.0022	1,156
AA107625	X30138	B-8	1.23	-27.3	0.8776±.0026	1,049
AA107626	X30139	B-11	1.88	-26.6	0.9246±.0028	630
AA107480	X29999	B-13	1.5	-26.6	0.7941 ± 0.0032	1,852
AA107481	X30000	B-14	1.9	-26.2	0.9250 ± 0.0029	626
AA107482	X30001LT	B-15	0.45	-29.3	0.9243 ± 0.0033	632
AA107484	X30003	B-18	1.54	-26.5	0.9252 ± 0.0048	624
AA107485	X30004	B-19	1.45	-27.5	0.7293 ± 0.0035	2,536

*Pretreatment and AMS analysis conducted at University of Arizona AMS laboratory. All detrital ch

[Ψ]University of Arizona AMS AA and Lab numbers.

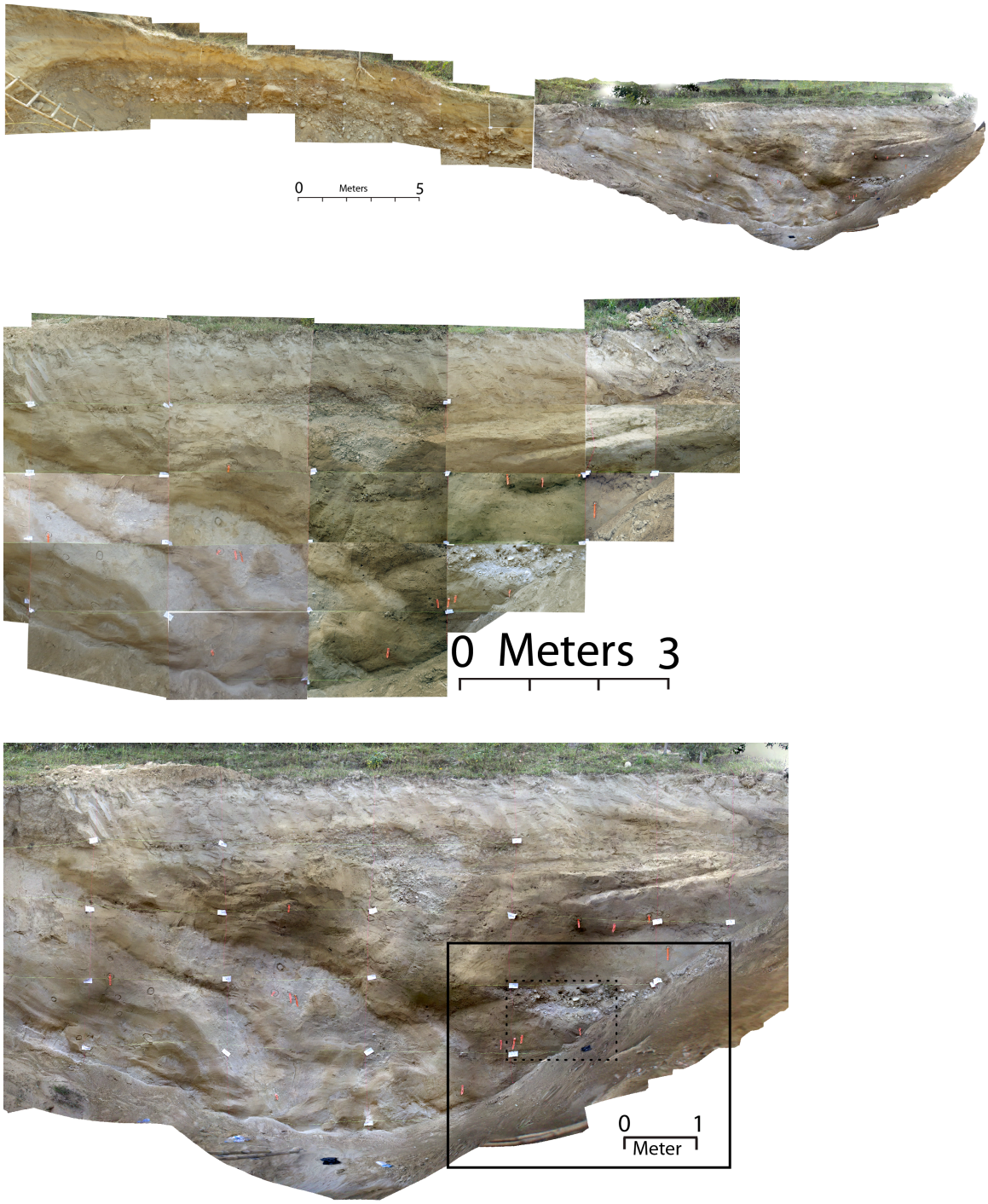
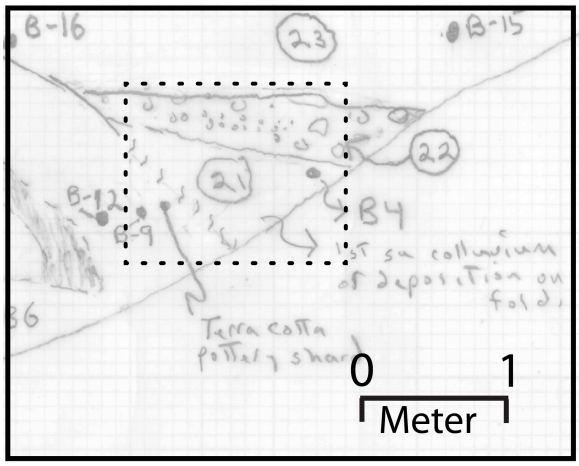


Figure S5. Bagmati trench photo logs. Uppermost is of entire trench while those below are enlarged about the fault zone. Middle is conventional photomosaic and lower constructed with PhotoScan software. Solid box outlines portion of original field log in **Figure S6a** and dashed box outlines large portion of photo log shown in **Figure S6b**.

a.



b.

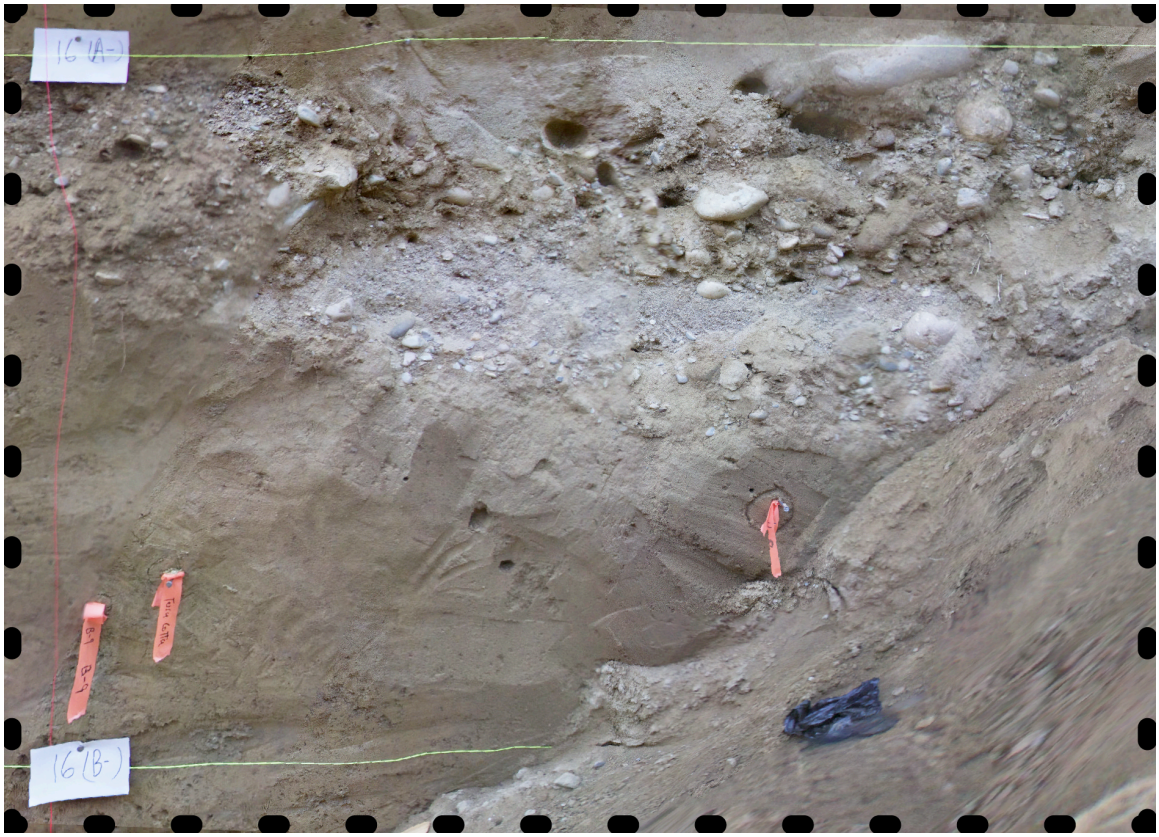


Figure S6. Enlarged section of (a) field log and (b) photo log at toe of unit 3 and unit 4 contact in log shown in Figure 4b of main manuscript. Extent of photo log in (b) shown approximately by dashed box in (a). The sand of unit 21 (commensurate to basal portion of unit 4 of Figure 4b is massive and the laminations apparent in the photo are not real but result author scraping the outcrop. Radiocarbon samples in the field log that do not appear in the trench logs of the manuscript and Supplementary Table S2 did not survive pretreatment. All radiocarbon samples that were collected from the trenches were submitted for analysis.

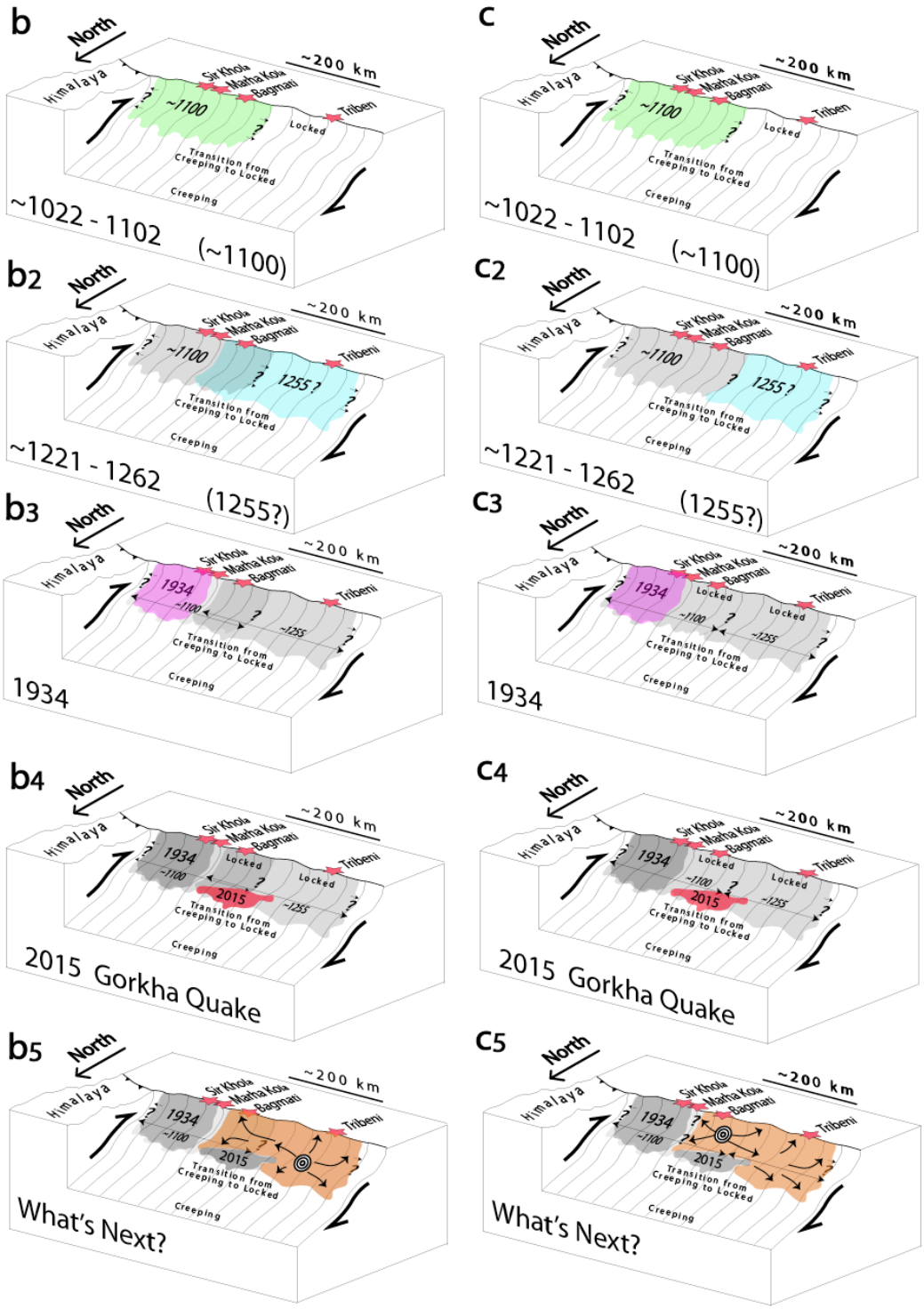


Figure S7. Two additional rupture scenarios to compliment Figure 6 of main manuscript. (b) Assumes ~1100 AD and ~1255AD earthquakes both produced rupture at Bagmati. (c) Assumes Bagmati only ruptured in ~1100 AD.