Supplemental Material for Submarine Landslide Inventory for Coseismic Landslides Triggered by the 2016 Kaikōura Earthquake in the Upper Kaikōura Canyon

L. Gnesko[1], T. Stahl[1,2], J. Mountjoy[3], J. Carey[4], and J. Shulmeister[1]

[1.] School of Earth and Environment, University of Canterbury, Christchurch, New Zealand
[2.] Risk and Resilience, WSP New Zealand, Christchurch, New Zealand
[3.] Earth Sciences New Zealand, Wellington, New Zealand
[4.] School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK

1. Data and Methods

1.1 Bathymetric Data

Datasets and imagery used in this study are summarized in Table S1.

	Year	Survey name	Source	Area (km^2)	Resolution
Pre-Earthquake	2013	Ika1304_Kaikōura_Landslides	NIWA	9 km^2	0.5 - 2 m
	2015	Ika_DOC_Hikurangi	NIWA	8.8 km^2	0.5 - 2 m
		HikurangiMarineReserve	NIWA	7.8 km^2	0.5 m
Post-earthquake	2017	Tan1707_25m	NIWA	5910.6 km^2	25 m
		Ika1701_Kaikōura	NIWA	32.7 km^2	1 m
		Ika1701_Kaikōura	NIWA	84.7 km^2	0.5 - 2 m
	2018	iXBlue_Hydro	LINZ	187 km^2	2 m
	2017-2018	HS57_Kaikōura	LINZ	94.6 km^2	0.5 - 2 m
Pre- and post-earthquake overlapping DEM coverage	2015-2017	Polygon from the canyon head down to the mid-continental slope		3.5 km^2	0.5 - 2 m

Table S1: Summary of datasets used in this study, including the polygon area defining the overlapping extent of pre- and post- earthquake DEM coverage.

1.2 Mapping

The accompanying geopackage contains 23 morphology files organised into pre- and post-earthquake datasets, and two landslide inventory files: one feature class and one CSV. Tables S2-S5 document how features were identified, how landslides were classified, and how attributes are encoded, including the criteria, terms and attribute schemas used.

- **Table S2 - Landform feature definitions:** Defines each landform feature used in mapping, from uninterpreted morphology to interpreted landforms (p.3-9).
- **Table S3 – Morphology attribute schema:** Lists the per-feature morphological attributes and the domains used in the geopackage (p.10).
- **Table S4 – Landslide classification criteria:** Provides the classification terminology and decision criteria used to identify and classify slope movements from morphology and contextual information (p.11-13).
- **Table S5 – Landslide inventory schema:** Details the 37 attributes with names, description and domains used in the landslide inventory feature class (mirrored in the CSV). Parameter/metric naming conventions follow Clare et al. (2019) (p.14-15).

Bibliography

Belderson, R. H., Johnson, M. A., & Kenyon, N. H. (1982). Bedforms. In A. H. Stride (Ed.), Offshore tidal sands: Processes and deposits (pp.22–57). London: Chapman and Hall.

Canals, M., Lastras, G., Urgeles, R., Casamor, J., Mienert, J., Cattaneo, A., De Batist, M., Haflidason, H., Imbo, Y., and Laberg, J., 2004, Slope failure dynamics and impacts from seafloor and shallow sub-seafloor geophysical data: case studies from the COSTA project: Marine Geology, v. 213, no. 1-4, p. 9-72.

Clare, M., Chaytor, J., Dabson, O., Gamboa, D., Georgiopoulou, A., Eady, H., Hunt, J., Jackson, C., Katz, O., Krastel, S., León, R., Micallef, A., Moernaut, J., Moriconi, R., Moscardelli, L., Mueller, C., Normandeau, A., Patacci, M., Steventon, M., Urlaub, M., Völker, D., Wood, L., and Jobe, Z., 2019, A consistent global approach for the morphometric characterization of subaqueous landslides, Subaqueous Mass Movements and their Consequences: Assessing Geohazards, Environmental Implications and Economic Significance of Subaqueous Landslides, Volume 477, The Geological Society of London

Cruden DM, Varnes DJ (1996) Landslide types and processes. In: Turner AK, Schuster RL (eds) Landslides investigation and mitigation. Transportation research board, US National Research Council. Special Report 247, Washington, DC, Chapter 3, pp. 36–75

Holcombe, T. L., 1977, Ocean Bottom Features–Terminology and Nomenclature: GeoJournal, p. 25-47.

Hughes Clarke, J. E., 2018, Multibeam Echosounders, in Micallef, A., Krastel, S., and Savini, A., eds., Submarine Geomorphology: Cham, Springer International Publishing, p. 25-41.

Hungr, O., Leroueil, S., and Picarelli, L., 2014, The Varnes classification of landslide types, an update: Landslides, v. 11, no. 2, p. 167-194.

Kennett, J. P., 1982, Marine geology, Englewood Cliffs, N.J., Prentice-Hall.

Kenyon, N. H., 1970, Sand ribbons of European tidal seas: Marine Geology, v. 9, no. 1, p. 25-39.

Laughton, A. S., and Roberts, D., 1978, Morphology of the continental margin: Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, v. 290, no. 1366, p. 75-85.

Rib, H. T., and Liang, T., 1978, Recognition and identification: Transportation Research Board Special Report, no. 176.

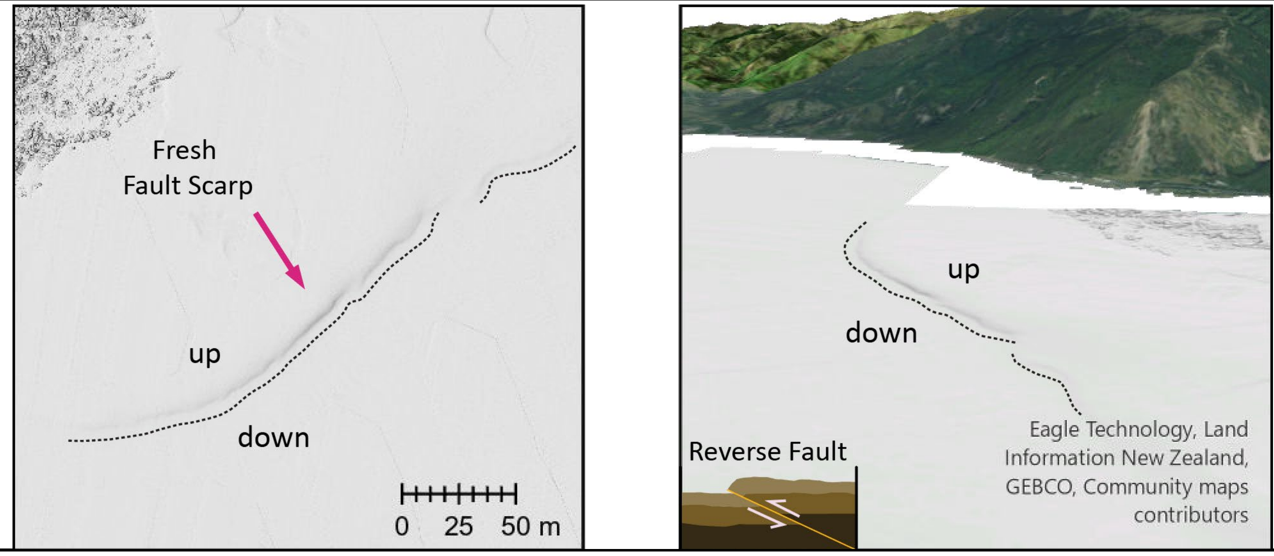
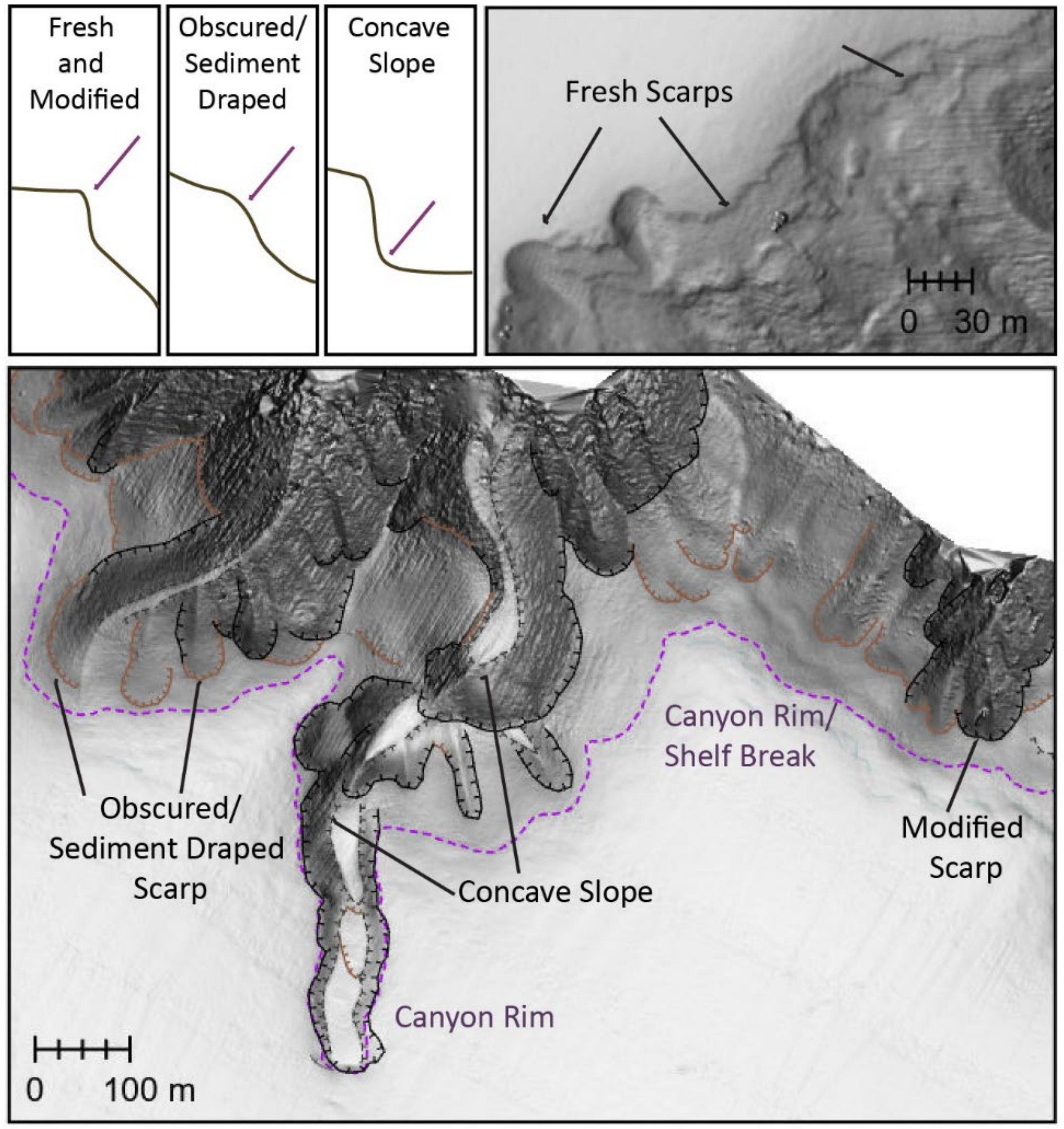
Sherman, D. J., 2022, 8.01 - Introduction to Coastal and Submarine Geomorphology, in Shroder, J. F., ed., Treatise on Geomorphology (Second Edition): Oxford, Academic Press, p. 1-3.

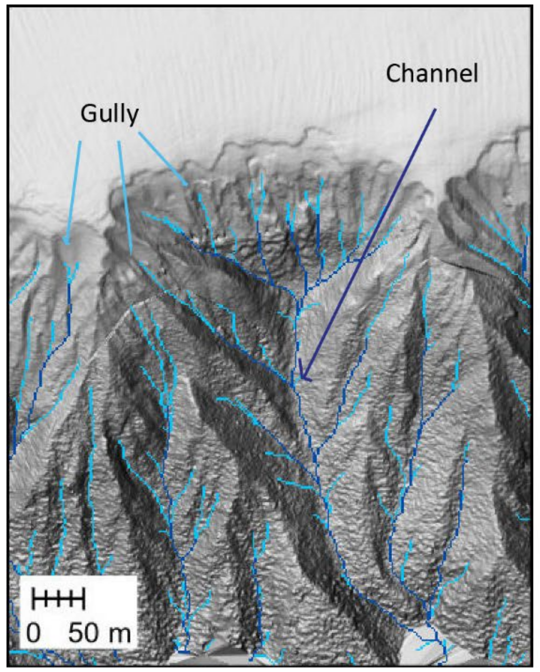
Stow, D. A., Hernández-Molina, F. J., Llave, E., Sayago-Gil, M., Díaz del Río, V., and Branson, A., 2009, Bedform-velocity matrix: the estimation of bottom current velocity from bedform observations: Geology, v. 37, no. 4, p. 327-330.

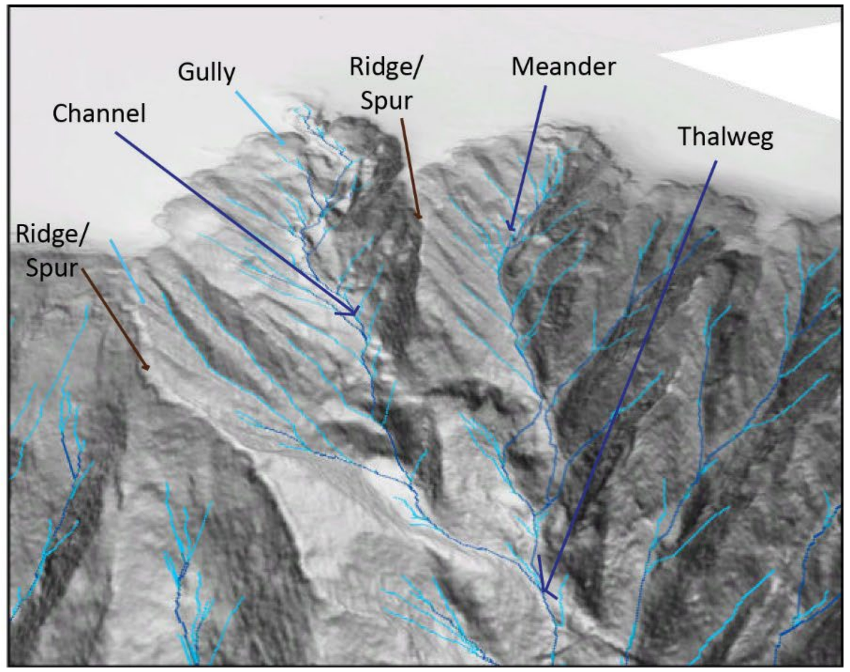
Thwaites, R. N., Brooks, A. P., Pietsch, T. J., and Spencer, J. R., 2022, What type of gully is that? The need for a classification of gullies: Earth Surface Processes and Landforms, v. 47, no. 1, p. 109-128.

Varnes, D., 1958, Landslide Types and Processes.

-, 1978, Slope Movement Types and Processes: Transportation Research Board.

Table S2: Landform feature definitions					
Morphological Feature	**Geomorphic Processes**	**Landform Feature**	**Description**	**Impacted Zone**	**Example**
Convex Break in Slope	Faulting	**Fresh Fault Scarp**	Surface expression of a fault plane.	Continental Shelf	
	Erosion and Mass Movement	**Fresh and Modified Scarp**	Steep outward facing slope separating areas of land at different elevations. Can be any height. Also referred to as an escarpment. Mapped as: Large Scarp (> 2m) and Small Scarp/Scarplets (< 2m)	Continental Shelf Canyon upper and middle course	
	Transport and Deposition	**Obscured/ Sediment Draped Scarp**	Clear break in slope with smooth appearance. Slope angle increases to ~20-25°. Interpreted as a pre-existing scarp that has been partially or entirely blanketed by sediment - often mapped along the shelf edge/canyon. Pre-existing scarps were likely formed by tectonic activity, erosion, or previous mass wasting events, which have since been overlain by sediment transported various sources.	Canyon upper course	
	Erosion, Transport, Deposition and Mass Movement	**Shelf Break/Canyon Rim**	<u>Shelf Break</u> Inflection point where continental shelf ends, and continental slope begins. Marked by an increase in slope angle to ~15°. Often coincides with the canyon rim. <u>Canyon Rim</u> Upper edge or boundary of a submarine canyon marking transition from relatively flat continental shelf to steep canyon walls. Can be a sharp well-defined feature or gradual (see Canyon Rim mapping methods). *Refer to canyon mapping methods	Shelf Break	
Concave Break in Slope	Erosion, Transport, Deposition and Mass movement	**Concave Slope**	Slope curves inward, creating a hollowed-out or bowl-like shape. Sharp decrease in slope angle downslope, resulting in a concave profile in cross-section.	Canyon upper, middle, and lower course	

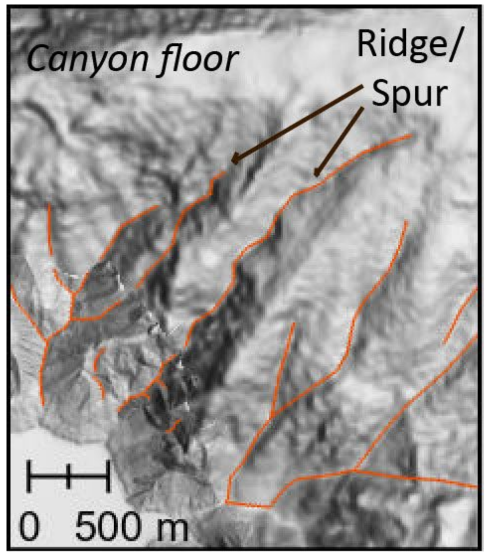
<table>
<tr><th colspan="6">Table S2: Landform feature definitions</th></tr>
<tr><th>Morphological Feature</th><th>Geomorphic Processes</th><th>Landform Feature</th><th>Description</th><th>Impacted Zone</th><th>Example</th></tr>
<tr><td rowspan="4">Subaqueous Drainage</td><td rowspan="4">Transport, Erosion and Mass Movement</td><td>Gully</td><td>Smaller, steep-sided channel formed by erosional and mass movement processes. Often found on canyon flanks and can serve as tributaries to larger channels. Classed as 1st and 2nd order streams using the Strahler Method.</td><td rowspan="4">Canyon upper, middle, and lower course</td><td rowspan="4">


</td></tr>
<tr><td>Channel</td><td>Long, narrow depression with steep walls, well-defined banks and beds that serves as a pathway for flow. Can extend for hundreds of kms and are typically formed by turbidity currents. Larger in scale than gullies. Classed as 3rd order streams and above using the Strahler Method.</td></tr>
<tr><td>Thalweg</td><td>Deepest part of channel, where current is typically strongest. It is the line of lowest elevation along the canyon floor and follows the path of maximum sediment transport. Scale is related to the channel or gully it occupies, as it is a linear feature within these landforms.</td></tr>
<tr><td>Meander</td><td>Sinuous bends or curves in the channel path that occupy a significant portion of the channel width. Bends are formed by variations in flow velocity and direction. Erosion occurs on the outer bends and deposition on the inner bends. Can influence the distribution and sorting of sediments within the canyon

*Note: Drainageways serve as pathways directing flow of water and sediment. The progression from smaller (gullies) to larger integrated drainage systems (channels), and channel specific features (thalwegs and meanders) helps understand the interconnected dynamics of the submarine canyon but are difficult to consistently distinguish. A description of each is provided but gully and channels are sometimes used interchangeably.</td></tr>
<tr><td>Crest</td><td>Erosion</td><td>Ridge/Spur</td><td>Linear, elongated elevated feature with a prominent crest. Features can extend along the canyon walls or across the canyon floor.

Mapped as:

Large ridges extending farther down the canyon slope, often reach the canyon floor. Large ridges were used to define the outer edges of subcatchments within the canyon system.

Small ridges are often shorter, discontinuous and smaller in height than large ridges. They do not extend from the upper canyon to the canyon floor.</td><td>Continental Slope
Canyon upper and middle course</td><td>

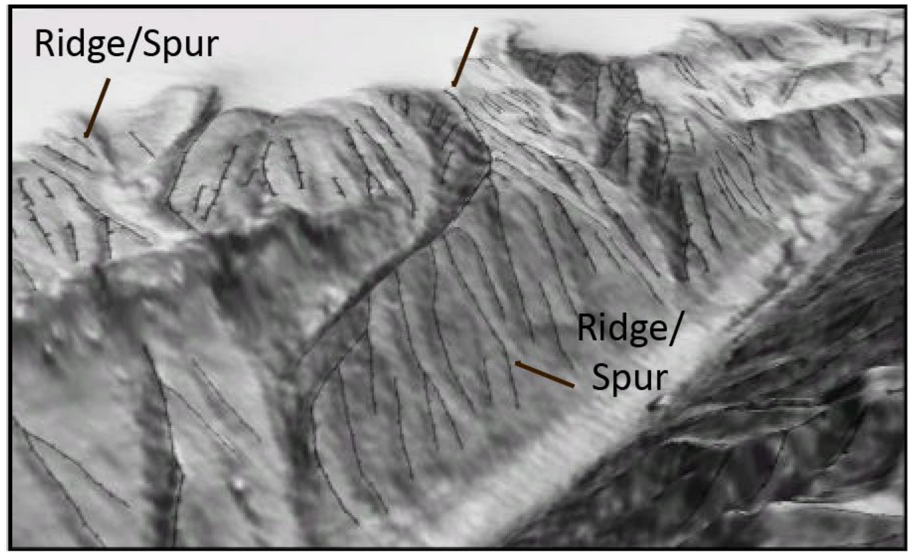

</td></tr>
</table>

Table S2: Landform feature definitions

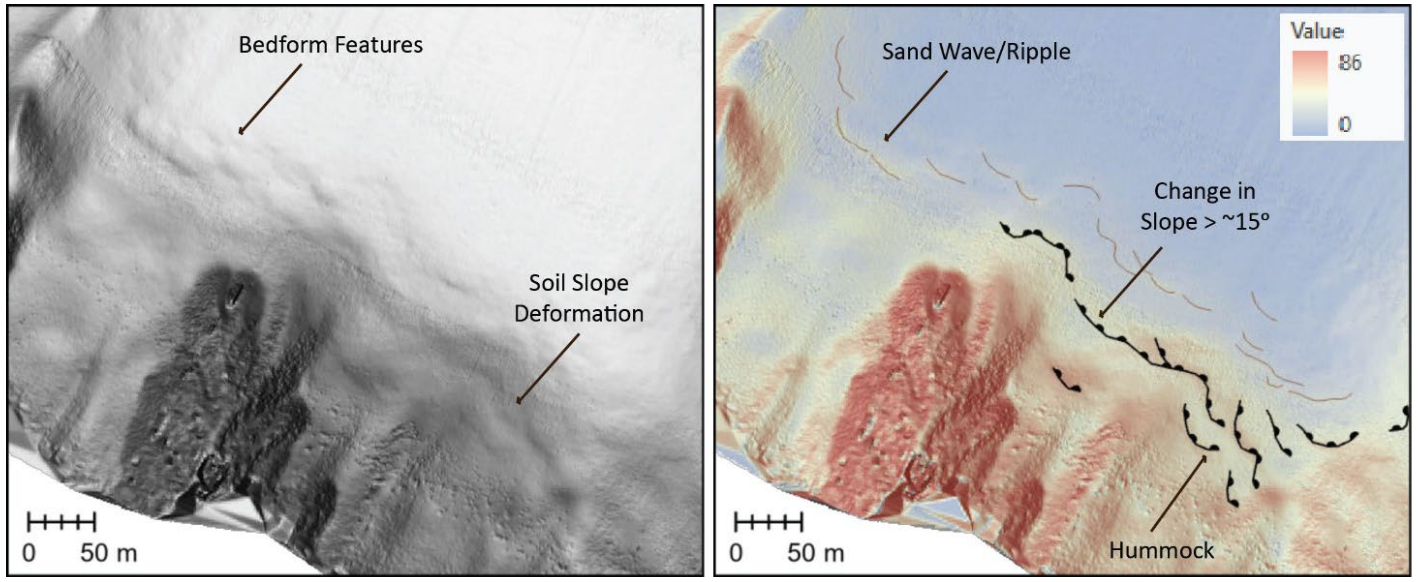
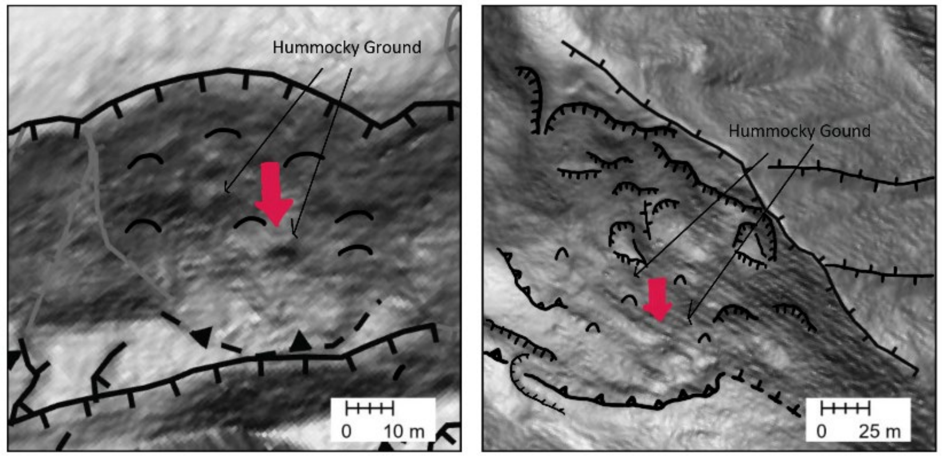
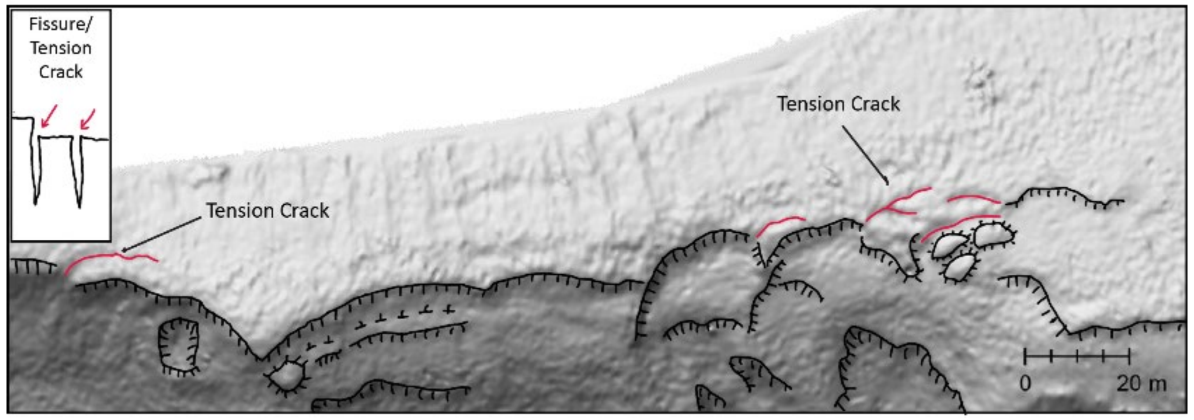
Morphological Feature	Geomorphic Processes	Landform Feature	Description	Impacted Zone	Example
	Transport and Deposition	**Sand Wave/Ripple**	<u>Ripples</u> Small-scale, symmetrical or asymmetrical bedforms, formed by the movement of water over sediment. They have a similar wavelength and amplitude to sand waves. Typically occur in groups in shallow marine environments. <u>Sand Waves</u> Large-scale, asymmetrical bedforms, formed by sediment deposition by currents. They have a crest and trough morphology (similar to dunes but smaller scale). Sediment accumulates on the lee side (down-current) due to reduced flow velocity. Sand waves are typically larger and longer than sand ripples, which was difficult to distinguish during analysis. *While there may be some erosional processes involved in shaping the initial morphologies, the overall formation and maintenance of these features are driven by depositional processes.	Continental Shelf	
Hummock	Mass Movement	**Soil Slope Deformation Feature**	Gradual slope deformation resulting in undulating, lumpy features. Hummocks generally occur on slopes exceeding ~15°. Shallower slopes tend to host depositional features i.e. sand waves and ripples. Once slopes exceed 15°, depositional features are more likely to transition to slow downslope movement. New hummocks formed post-EQ that do not align with typical landslide morphology or extensional features are classified as new soil slope deformation features.	Canyon upper course	
		Hummocky Ground	Hummocky ground resulting directly from rapid mass movement i.e. adjacent to features such as scarps (headscarp, evacuated scarps...), mounds, and extensional features.	Canyon upper and middle course	
Fissure	Mass Movement	**Tension Crack**	Extensional fractures that develop in the ground surface. Tensions cracks are particularly concentrated at the canyon rim and in headscarp areas.	Canyon upper course	

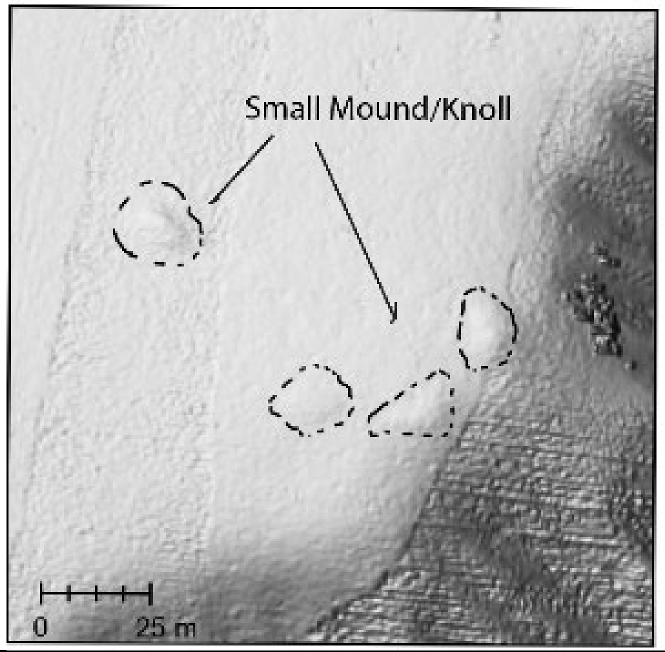
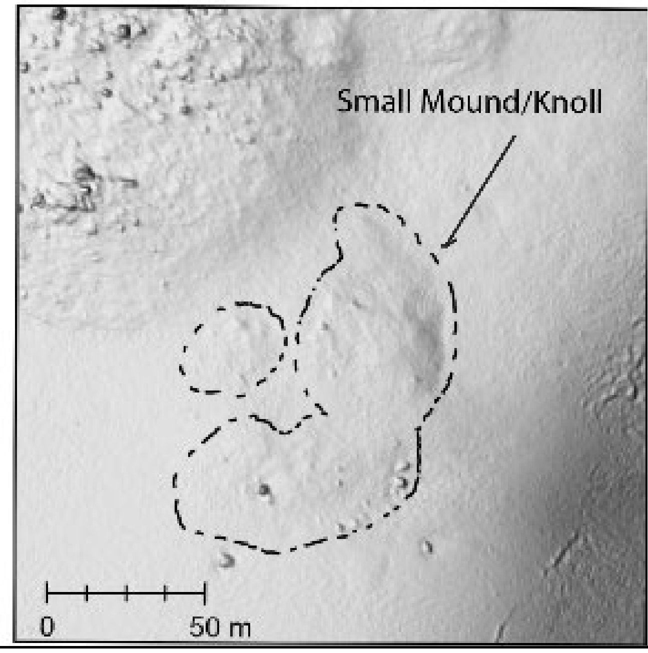
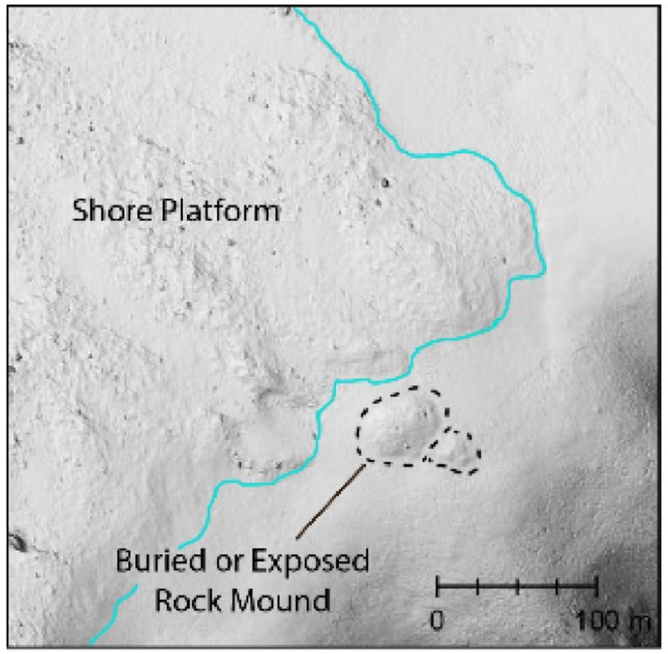
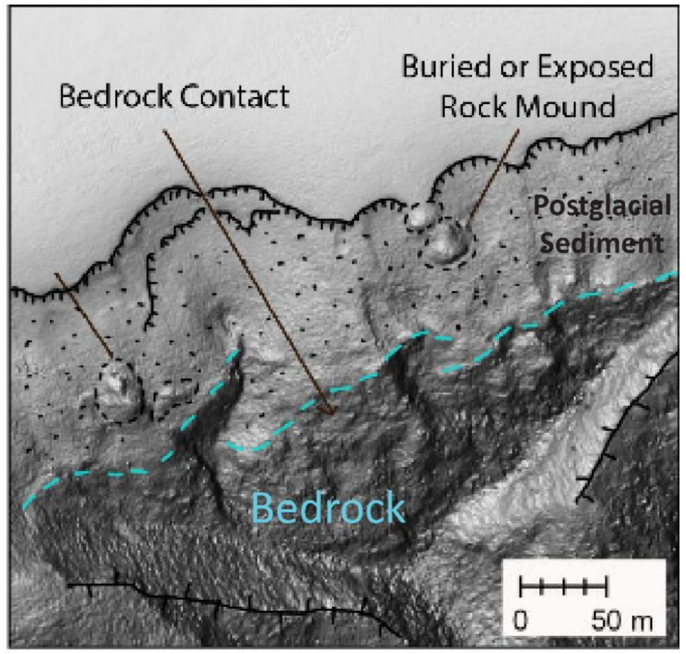
Table S2: Landform feature definitions					
Morphological Feature	**Geomorphic Processes**	**Landform Feature**	**Description**	**Impacted Zone**	**Example**
Mound	Erosion, Transport and Deposition	**Small Mound/Knoll**	Rounded or dome-shaped elevated feature on the seafloor. Ranging in size from a few meters to a hundred meters in diameter. Predominantly sedimentary features made up of post-glacial sediment.	Continental Shelf, Rock Outcrop	 
	Transport, Deposition and Mass Movement	**Buried or Exposed Rock Mound**	Resistant mounds ranging from 5-40 m in diameter were mapped protruding from post-glacial sediment in the canyon walls or adjacent to the submerged shore platform. Origins of the protruding mounds are unclear, but exposure is visible pre- and post-earthquake. They may be large, transported blocks within a post-glacial sediment matrix, or possibly weathered bedrock that was later infilled with post-glacial sediment. Mounds adjacent to shore platforms are likely resistant bedrock blanketed in sediment.	Canyon Upper course	 

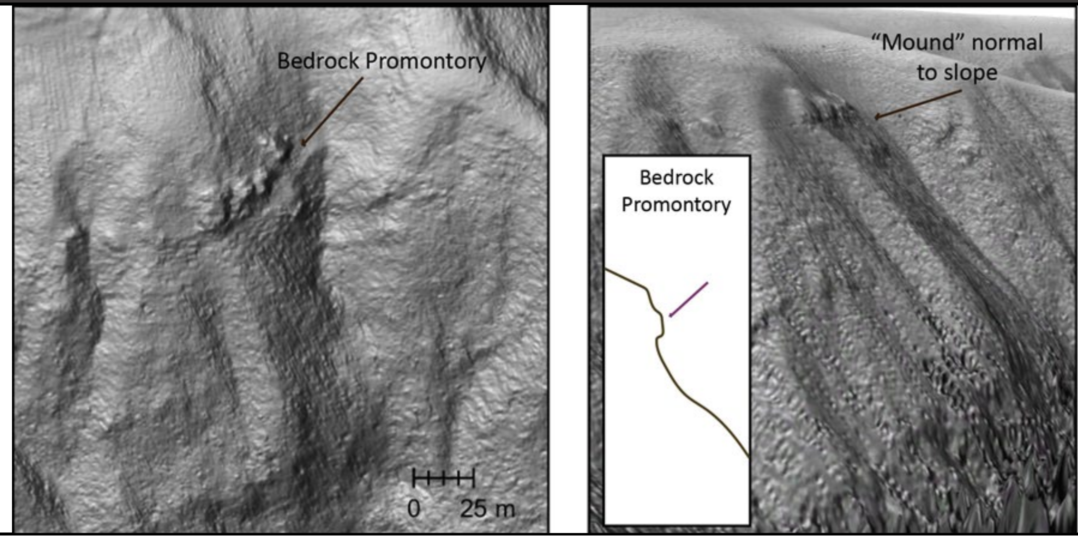
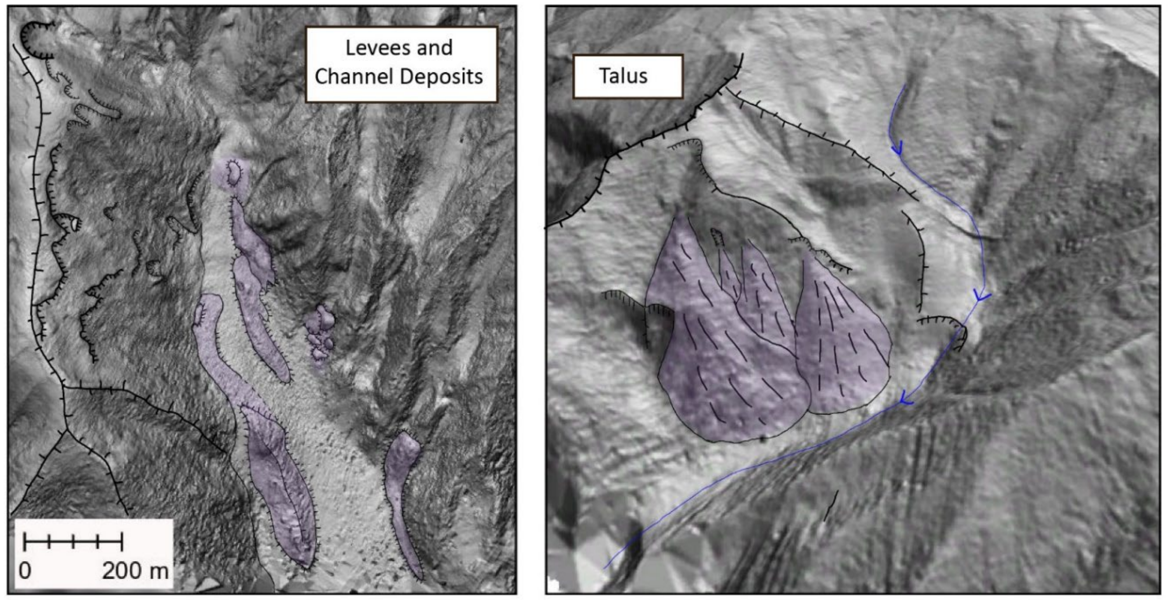
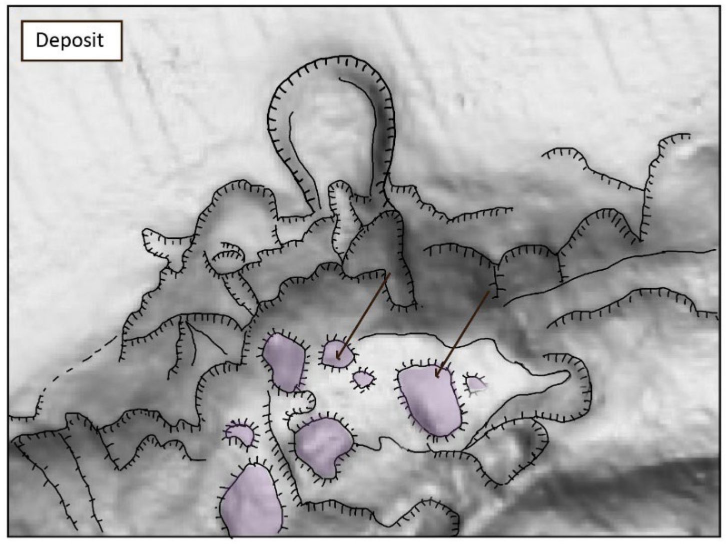
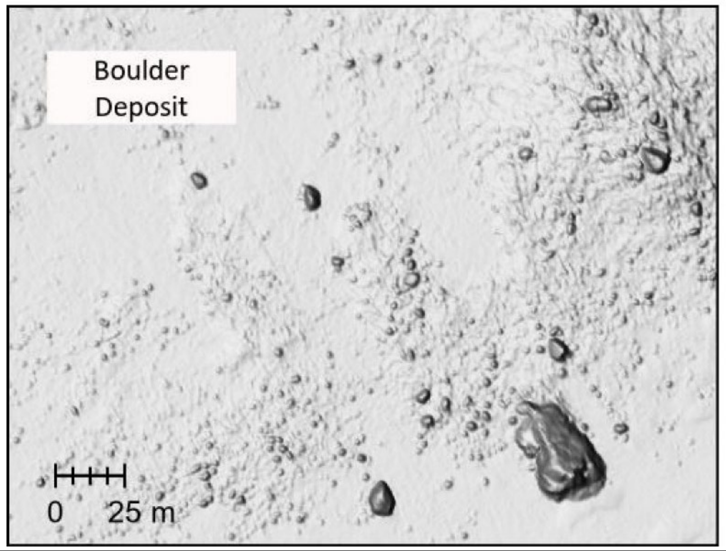
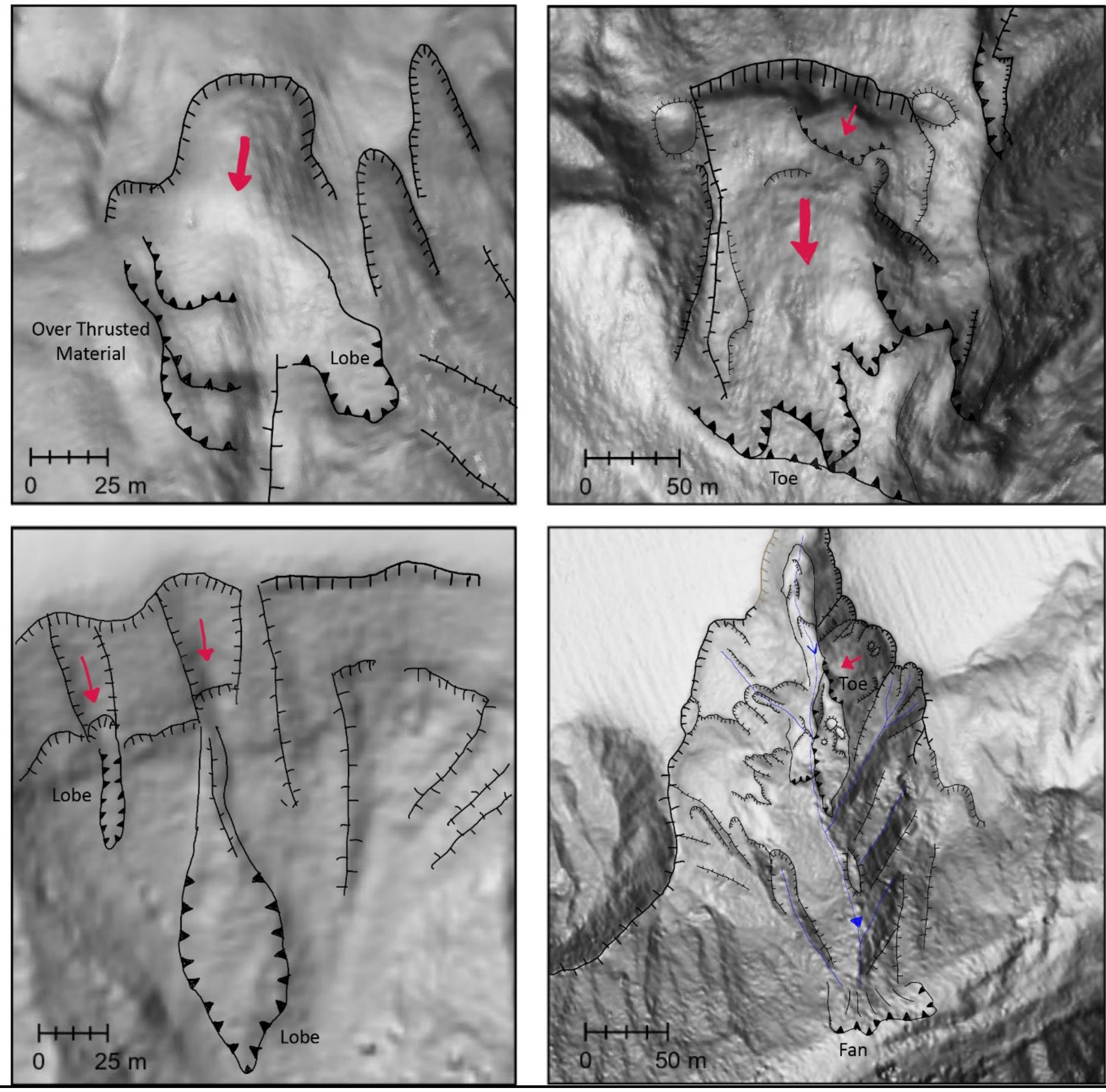
Table S2: Landform feature definitions					
Morphological Feature	**Geomorphic Processes**	**Landform Feature**	**Description**	**Impacted Zone**	**Example**
	Erosion	**Bedrock Promontory**	Prominent, protruding mass of bedrock that juts out from the continental slope into the canyon. Features extend outward normal to slope.	Continental Slope, Rock Outcrop, Bedrock	
	Mass Movement	**Levee**	Ridge or embankment of debris formed along the lateral margins of a flow channel. Levees preserved in the canyon resemble elongate mounds.	Canyon upper, middle, and lower course	
		Channel Deposit	Sediment mounds preserved within the gully or channels.		
		Talus	An accumulation of rock/soil debris at the base of a steep slope formed by rock fall and topples.		
		Deposit	General term used to describe colluvium, soil and debris accumulated at the base of the slope as a result of mass movement processes. Deposits are not always linked to a specific source. When available, landslide source and type are included within the landslide polygon attributes.		
	Unclear	**Mound**	Mounds of unknown origin.		

Table S2: Landform feature definitions					
Morphological Feature	**Geomorphic Processes**	**Landform Feature**	**Description**	**Impacted Zone**	**Example**
Blocks/Boulders	Transport and Deposition	**Boulder Deposit**	Individual blocks/boulders transported by waves and currents on the continental shelf. Accumulation of scattered blocks/boulders can also be referred to as boulder field.	Continental Shelf	
	Mass Movement	**Rock Fragments/ Boulders**	Individual blocks/boulders transported by mass movement processes downslope.	Canyon upper and middle course	
Bulge	Mass Movement	**Toe Bulge**	Downslope portion of the landslide where the material accumulates at the toe. Typically, a compressional zone that results in ground uplift or bulging associated with slides.	Canyon upper, middle, and lower course	
		Fan (Debris)	Fan-shaped deposit at the base of a slope. Material is sourced from a catchment upslope and flows out over a flatter area. The toe of the fan is often mapped as a bulge because of its' rounded, and/or protruding geometry indicating some internal deformation. Typically associated with flows		
		Lobe	Elongated deposit that spreads out similarly to a fan but is smaller in scale and has a broader, less defined peak. The landslide mass increases at the toe. Typically associated with flows.		
		Over thrusted Material	General term used to describe horizontal compression of rock or sediment layers resulting in material being thrusted over the existing ground surface. Not associated with a specific movement type unless specified.		

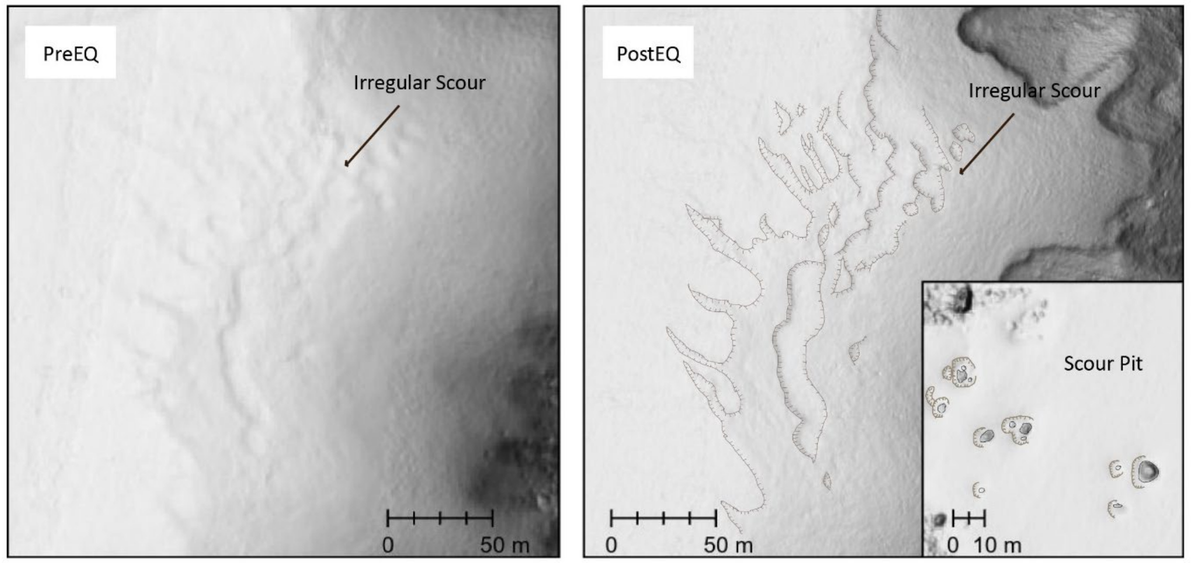
<table>
<tr><th colspan="6">Table S2: Landform feature definitions</th></tr>
<tr><th>Morphological Feature</th><th>Geomorphic Processes</th><th>Landform Feature</th><th>Description</th><th>Impacted Zone</th><th>Example</th></tr>
<tr><td rowspan="3">Depression</td><td>Mass Movement</td><td>Depression</td><td>Depression typically formed by collapse of underlying material. Some of the original surface morphology is often preserved despite downward movement. Size and shape are variable but generally have a sunken or hollowed-out appearance.</td><td>Canyon upper course</td><td rowspan="3">
</td></tr>
<tr><td rowspan="2">Erosion</td><td>Scour pit</td><td>Scour that creates a depression/pit around cobbles, boulders and blocks.</td><td>Continental Shelf</td></tr>
<tr><td>Irregular Scour</td><td>Irregular, jagged erosional features. Likely created by strong currents that can re-suspended and transport sediment along the edge of the continental shelf. Features are predominantly mapped near the shelf break and were unmodified by the earthquake.</td><td>Continental Shelf</td></tr>
</table>

Table S2: Defines each landform feature used in mapping, from uninterpreted morphology to interpreted landforms. Terminology adapted from Kenyon (1970), Holcombe (1977), Laughton and Roberts (1978), Belderson et al. (1982); Kennet (1982), Stow et al. (2009); Hughes Clarke (2018); Sherman (2022); Thwaites et al. (2022).

Table S3: Morphological Attributes Schema		
Metric/Parameter	**Description**	**Domain**
Morphological Feature	Uninterpreted morphologic element.	Blocks/Boulders Bulge Concave Break in Slope Convex Break in Slope Crest Depression Hummock Mound Subaqueous Drainage Fissure
Event	Survey period the feature was mapped from.	PreEQ PostEQ
Catchment	Geographic location within the Kaikōura Canyon System.	Kaikoura Canyon: North of Hundalee Kaikoura Canyon: South of Hundalee Haumuri Canyon
Geomorphic Process	Dominant process(es) inferred for the feature.	Erosion Transport Deposition Mass movement
Landform Feature	Interpreted landform used for mapping classification.	Boulder Deposit Rock Fragments/Boulders Toe Fan Lobe Overthrusted Material Concave Slope Fresh and Modified Scarp Obscured/Sediment Draped Scarp Ridge/Spur Sand Wave/Ripple Depression Scour Pit Irregular Scour Soil Slope Deformation Feature Hummocky Ground Small Mound/Knoll Buried or Exposed Rock Mound Bedrock Promontory Levee Channel Deposit Talus Deposit Mound Gully Channel Tension Crack
Size	Qualitative size class of the feature.	Small Large
Known Source	Whether the feature can be linked to a specific source area.	Yes No
Movement Type	High-level movement class associated with the feature.	Slide Flow Fall Complex Unclear
Stream Order	Strahler stream order for channelised features	1 2 3 4
Comment	Mapper notes and observations.	

Table S3: Lists the per-feature morphological attributes and the domains used in the geopackage.

Table S4: Landslide classification criteria				
Movement Type		**Material[1]**	**Morphology[2] and criteria used for Identification**	**Landslide Name**
Fall [3,4,5] Detachment of soil or rock from a steep slope/cliff by free fall (with possible bouncing or rolling) and may fragment on impact.		Soil	***Parts Surrounding the Slide*** **Crown:** Cracks behind scarp. **Main Scarp and Flanks:** Nearly vertical, fresh, and spalling on surface. ***Parts that have moved*** **Head:** Not well defined, fallen material forms heap/talus mound next to scarp **Body and Toe:** Irregular. **Foot:** If visible, shows controlling weakness, such as prominent joint or bedding surface, underlying weak material **Failure surface:** Steep, near vertical detachment surface. Source may be a large clast or coherent soil block detached from the sediment cap. Talus cones/mounds beneath steep slopes in post-glacial sediment were used to identify debris falls.[1]	**Debris Fall[1]**
		Rock	***Parts Surrounding the Slide*** **Crown:** Loose rock; cracks behind scarp; shape controlled by local joints. **Main Scarp:** Near vertical, irregular, bare, and fresh; exposes joints, faults, or bedding surfaces. **Flanks:** Bare edges of rock. ***Parts that have moved*** **Head:** Not well defined. Fallen rock forms a talus cone beneath the scarp. **Body:** Irregular jumbled rock sloping away from scarp. If the material is large and contrasting, may show radial fall direction. **Foot:** Buried, if visible, shows evidence of reason for failure. **Toe:** Irregular pile of debris or talus. Large rock mounds with hummocky sediment drape over high-relief blocks remain visible. **Failure surface:** Steep, near vertical rock face from which blocks detach. Often initiates as block detachment. Not guided by a basal slip surface. Rock fall volumes are typically smaller than debris avalanches.[1]	**Rock Fall[1,6]**
Movement Type	**Subtype**			
Slides[3,4,5,6] Downslope displacement of a coherent mass bounded by one or more distinct failure planes. Shear strain and displacement occur along visible or inferred surfaces. The moving mass may or may not be greatly deformed, and kinematic movement may be rotational or translational	**Rotational**[3,4] Downslope movement involving rotation of the displaced mass about a point (or axis) above its centre of gravity, along a curved, concave up failure surface. Deep-seated rotational motion is favoured under undrained conditions and is most common in saturated, low permeability soils.	Soil	***Parts Surrounding the Slide*** **Crown:** Numerous cracks curved and concave toward the slide. **Main Scarp:** Steep, bare, arcuate, concave toward slide; commonly high and vertical in upper part. Horseshoe/spoon shaped scarps. **Flanks:** Vertical near head and horizontal near foot; en-echelon scarps/fissures possible. Scarp height decreases downslope. ***Parts that have moved*** **Head:** Transverse cracks, minor scarps, grabens, fault blocks; back-tilted head. **Body:** Blocks broken into smaller masses with longitudinal cracks/pressure ridges; occasional overthrusts, rounded hummocky relief near the base of the scarp. Internal deformation present. **Foot/Toe:** Zone of uplift and pressure-ridges; toe may roll over and advance as a lobate form. The lower part may become churned and advance as a flow or debris slide **Failure surface:** Curved, concave-up rotational surface. Undrained failure in granular soils, triggered by liquefaction, can initiate circular sliding failures. These short-lived events may repeat as retrogressive slides, often evolving into flowslides.[1]	**Debris Slump[4,5]**
		Rock	***Parts Surrounding the Slide*** **Crown:** Cracks follow the rock fracture pattern. **Main Scarp:** Steep, bare, arcuate, concave toward slide; commonly high. **Flanks:** Vertical near head and horizontal near foot; en-echelon scarps/fissures possible. Scarp height decreases downslope. ***Parts that have moved*** **Head:** Transverse cracks, minor scarps, grabens; bedding attitude differs from surrounding area. **Body:** Partly broken slump blocks; limited plastic deformation; longitudinal cracks, pressure ridges, and occasional overthrusts. **Foot:** Transverse cracking and pressure ridges; has zone of uplift, few large individual blocks. **Toe:** Straight and close to foot; may have steep front. **Failure surface:** Curved, concave-up rotational surface. Arcuate scarps and curved failure surfaces with nearby bulges/hummocks were used to identify rotational slides. Rotational rock slides occur mainly in very weak or fractured rock masses[1]	**Rock Rotational Slide[1]**

Table S4: Landslide classification criteria

Movement Type		Material[1]	Morphology[2] and criteria used for Identification	Landslide Name
	Translational[4] Downslope or outward movement along a planar to gently undulating surface, typically with little internal rotation. Movement is controlled by structural or stratigraphic weaknesses, such as faults, joints, bedding planes, and contrasts in shear strength between beds, or by the contact between bedrock and overlying detritus.	Soil	***Parts Surrounding the Slide*** **Crown:** Near vertical cracks that follow the slope contour. Headscarp typically longer than in rotational slumps. **Main Scarp:** Near vertical in upper part; gently to steeply inclined lower part. **Flanks:** Straight lateral margins with low relief. Vertical cracks diverge downhill. ***Parts that have moved*** **Head:** Relatively undisturbed and non-rotated crown block. **Body:** One or a few translating soil blocks with limited internal deformation; arrested translating blocks mapped on the slope; block thickness and basal depth indicate movement within soil. **Foot:** No uplift zone. **Toe:** Ploughs or overrides ground surface. **Failure surface:** Planar to gently undulating surface. Typically, 0.5-2 m thick veneers on 20-60° slopes sliding over a smoother/stronger substrate; may accelerate and shed cohesion, transitioning to debris avalanche.	**Debris Slide[4]**
		Rock	***Parts Surrounding the Slide*** **Crown:** Loose rock; cracks between blocks. **Main Scarp:** Stepped according to joint or bedding plane spacing; irregular upper surface; gently to steeply inclined lower part; planar or composed of rock chutes. **Flanks:** Irregular. ***Parts that have moved*** **Head:** Many rock blocks; separation along a deep vertical tension crack. **Body:** Rough, blocky surface; some blocks retain original attitude. Surface may be stepped forward **Foot:** None **Toe:** Accumulation of rock fragments. **Failure surface:** Planar discontinuity that daylights the slope.	**Rock Planar Slide[4]**
	Wedge[1] Failure of a rock mass along the line of intersection between two planar discontinuities whose orientations allow downslope displacement.	Rock	***Parts Surrounding the Slide*** **Crown:** Tension cracks/open joints control discontinuity sets; headscarp typically planar and fresh where it coincides with the upper termination of one plane. **Main Scarp:** Surfaces are typically planar, smooth, and daylight the slope face. **Flanks:** Straight, joint controlled edges; line of intersection trends downslope and indicates the kinematic displacement direction. ***Parts that have moved*** **Head:** Detaching wedge bounded by two planes; little to no back tilting; separation often marked by a deep tension crack upslope. **Body:** Coherent block with limited internal deformation **Foot:** Local bulldozing and minor heave or shattering downslope **Toe:** Sharp, planar contact; short runout unless transformation occurs **Failure surface:** Line of intersection of two planar discontinuities forming a wedge. Two daylighting planes whose intersection line trends downslope; scarps are planar and joint-controlled rather than curved.[1]	**Rock Wedge Slide[1]**
	Unclear Cannot be confidently assigned due to insufficient or ambiguous morphological evidence	Soil	Slide is confined to post-glacial sediment, but failure subtype (rotational vs. translational) cannot be resolved.	**Soil Slide**
		Rock	Slide occurs in bedrock, but subtype (rotational/translational/wedge) is undetermined due to incomplete exposure or unclear kinematic markers.	**Rock Slide**
		Soil and Rock	Slide clearly includes soil and rock, but dominant material and subtype cannot be determined.	**Slide**
Flow[1,3,4] Rapid, surging flow of saturated disaggregated material with strong entrainment from the flow path. Displacement is dominantly fluid-like. High density flows can rapidly incise V-shaped channels. Sources commonly present an	**Established Channel[1]** Very rapid to extremely rapid surging flow of saturated debris confined within a pre-existing channel or drainage pathway	Soil	***Parts Surrounding the Slide*** **Crown**: Few cracks **Main Scarp**: Amphitheatre serrated or V-shaped cylindrical source feeding a confined channel; long and narrow. **Flanks**: Steep and irregular upper reach; levees and boulder trains accumulate in lower reaches; impact marks on obstacles. Channel deposits and levee remnants common; trim lines, overridden ridges, striations and scour marks present. ***Parts that have moved*** **Head**: May be absent. **Body:** Surges with coarse fronts in a finer matrix; clear flow lines, follows entrenched drainage and can make sharp turns. Typically, long compared to width. U-shaped eroded channels.	**Debris Flow[1,4]**

Table S4: Landslide classification criteria				
Movement Type		**Material[1]**	**Morphology[2] and criteria used for Identification**	**Landslide Name**
amphitheatre shaped or serrated evacuated area with distal deposits. The slip surface is cylindrical, short-lived or not preserved. Failures may initiate as slides on gentler slopes and transition to flows on steeper terrain.			**Foot**: Absent or buried in debris. **Toe:** Lateral spreading in lobes; may have a steep front (~ 1 m high) and coarse accumulation. Levee fragments or abandoned boulder fronts deposited, while finer fractions continue further downslope. **Failure surface:** Short lived or not preserved. Often initiated by slide/avalanche/rock fall inputs; entrainment along the channel controls final volume; spreads onto debris fans on exit from confinement[1]	
	Open Slope[1] Unconfined, very rapid flow of debris or fragmented rock down an open slope. Typically initiated by a debris slide or from catastrophic failure of a rock mass on a steep slope	Soil	***Parts Surrounding the Slide*** **Crown**: Few cracks **Main Scarp:** Serrated or V-shaped upper part; long and narrow. **Flanks:** Steep and irregular in upper parts; boulder trains and levees built up in lower parts; signs of impact loading on obstacles. ***Parts that have moved*** **Head:** May have none. **Body:** Large blocks within a finer matrix. Not bound to an established path but can enter established channels, destabilize channel infills, and become debris flows. The path widens downslope as undrained loading destabilises an increasing width of the slope segment. **Foot:** Absent or buried in debris. **Toe:** Spreads laterally in lobes, may have a steep front (~ 1 m high). **Failure surface:** Shallow, planar or irregular detachment surface before rapid disaggregation. Shallow unconfined flows on steep slopes; typically initiate as debris slides, with rapid undrained loading entraining additional material. Small initial landslides can mobilize and strip large volumes of debris, involving tens to thousands of cubic meters. Large debris avalanches may also result from the failure of thick accumulations of granular material, such as residual soil or loose fills. In such cases, distinguishing debris avalanches from flowslides can be challenging.[1]	**Debris Avalanche[1]**
		Rock	***Parts Surrounding the Slide*** **Crown:** Large, fresh, steep amphitheatre headscarp; brittle detachment. May have cracks behind scarp. **Main Scarp:** Almost vertical; irregular to planar, bare, and fresh; commonly exposes structural surfaces (joints, bedding, faults). **Flanks:** Bare rock margins; lateral limits sharply defined and often joint-controlled. ***Parts that have moved*** **Head:** Not well defined; immediate post-failure disintegration of the source mass. **Body:** Jumbled, angular rock fragments extending to the valley floor with hummocky and lobate morphology. Transverse ridges, inverse sorting/coarse fronts, and locally entrained substrate; mobility anomalously high relative to fall height. **Foot:** Typically indistinct; deposit grades downslope into lower relief lobes. **Toe:** Tongued, lobate fronts that can override low ridges or show run up against opposing valley walls **Failure surface:** Steep, brittle detachment surface in rock that rapidly fragments and flows out. Rapid fragmented rock derived from rockfalls/rock slides on steep slopes, long runout with hummocky lobes and transverse ridges. Deposits may record basal entrainment and dynamic fragmentation (rip ups, rafted blocks, inverse grading and high mounds).[1]	**Rock Avalanche[1]**
Complex[4,5] Combination of materials and/or types of movement		Soil and/or Rock	Used only in rare cases where multiple movement mechanisms are present with pervasive overprinting and intricate morphology, such that no single kinematic class is defensible. Indicators include high densities of small scarps in differing orientations, clear overprinting of successive/adjacent phases, resistant ridges cut by deep scour alongside levee deposits near steep valley walls, and distinct changes in geometry and surface texture downslope.	**Complex Slide[5]**
Unclear Cannot be confidently assigned due to insufficient or ambiguous morphological evidence		Soil	Failures occurring predominantly in soil where movement type cannot be determined.	**Undetermined Soil Failure**
		Rock	Failures occurring predominantly in rock where movement type cannot be determined.	**Undetermined Rock Failure**
		Unclear	Failures where neither material type nor movement type can be interpreted from available data.	**Undetermined**

Table S4: Provides the classification terminology and decision criteria used to identify and classify slope movements from morphology and contextual information. Adapted from 1. Hungr et al. (2014); 2. Rib and Liang (1978); 3. Varnes (1958); 4. Varnes (1978); 5. Cruden and Varnes (1996); 6. Canals et al. 2004.

Table S5: Landslide Polygon Attributes Schema		
Metric/Parameter	Description	Domain
ID	Unique identifier for individual landslide entries in the inventory.	
Landslide_Name	Published name for the landslide.	Debris Fall Rock Fall Debris Slide Rock Planar Slide Debris Slump Rock Rotational Slide Rock Wedge Slide Soil Slide Rock Slide Slide Debris Flow Debris Avalanche Rock Avalanche Undetermined Soil Failure Undetermined Rock Failure Undetermined Complex Slide
Movement_Type	High-level movement type classification.	Fall Slide Flow Unclear Complex
Movement_Subtype	Specifies subtypes for slides (e.g., rotational, translational, wedge slides) and flows (e.g., flows occurring in established channels versus avalanches on open slopes)	Translational Rotational Wedge Unclear Established Channel Open Slope
Material_Type	Predominant engineering material involved in failure. Interpreted from depth, relation to bedrock contacts, and post-glacial sediment thickness.	Soil Rock Soil and Rock
Aliases	Aggregated names used for analysis at a reduced interpretation level. Aliases collapse detailed names for soil slides and rock slides.	Debris Fall Rock Fall Debris Slide Rock Slide Debris Flow Debris Avalanche Rock Avalanche Undetermined Soil Failure Undetermined Rock Failure Complex Slide
Landslide_Zone	Process zone represented by the polygon.	Source Landslide
Object_type	Indicates whether the polygon in its current Landslide_Zone is a stand-alone feature or the main or subsidiary part of a multi-polygon landslide. Parent_ID links the main and subsidiary polygons belonging to the same landslide.	Single Main Subsidiary
Parent_ID	Group identifier for linked landslide complexes, where a main and subsidiary sequence exists. Example: Main Source and/or Main Landslide with associated Subsidiary features share the same label (e.g., LS1, LS2). Single landslides and sources do not have a Parent_ID.	
Catchment	Geographic location in which the landslide polygon was mapped.	Kaikoura Canyon: North of Hundalee Kaikoura Canyon: South of Hundalee Haumuri Canyon
Longitude_WGS84	Centroid X-coordinate in WGS 1984	
Latitude_WGS84	Centroid Y-coordinate in WGS 1984	
Easting_NZTM	Centroid X-coordinate in New Zealand Transverse Mercator	
Northing_NZTM	Centroid Y-coordinate in New Zealand Transverse Mercator	
Water_Depth_PreEQ_Min (m)	Minimum pre-earthquake depth below sea level (upper elevation on seafloor; negative values).	

Table S5: Landslide Polygon Attributes Schema		
Metric/Parameter	**Description**	**Domain**
Water_Depth_PreEQ_Max (m)	Maximum pre-earthquake depth below sea level (lowest elevation on seafloor; negative values).	
Water_Depth_PreEQMedian (m)	Median pre-earthquake depth below sea level (negative values).	
Total_Length (m)	Mappable length from headscarp to downslope limit along the axial course. For source polygons: headscarp to downslope limit of source area. For landslide polygons: headscarp to downslope limit of landslide.	
Shape_Length (m)	Polygon perimeter length, including side scarps.	
Width (m)	Maximum scar width.	
Headscarp_height (m)	Vertical difference between top and bottom of headscarp.	
Scar_Surface_Nature	Description of basal surface using geometry, texture, orientation, and morphologic indicators. May use single or combined terms (e.g., planar smooth, planar rough).	**Geometry** ***Concave:*** Curved surface open upward. ***Planar:*** Flat to straight failure surface with minimal curvature. ***Irregular:*** Uneven, locally variable geometry; non-uniform rupture surfaces. ***Stepped:*** Surface composed of discrete risers/treads, offset segments resembling steps. ***Angular:*** Surface with abrupt breaks in slope or facets. ***Multiple Failure Surfaces:*** A composite rupture surface made of several segments of different geometry/controls. ***Cylindrical:*** Surface approximates a cylinder. Uniform curvature in one direction. ***Circular:*** Arc-of-circle approximation to rotational scars in homogeneous soils. ***Undulating:*** Gently wavy surface with alternating shallow convex/concave segments. ***Scalloped:*** Scar surface with repeated concave embayments (cusps) suggesting staged/retrogressive or adjacent failure activity and coalescent scarps. **Texture** ***Rough:*** Irregular, coarse micro-relief such as protrusions, depressions, wrinkles or ridges; “rugose” is an appropriate synonym. ***Smooth:*** Minimal relief. **Orientation** ***Steep dipping:*** High angle relative to horizontal. Can be near-vertical. **Other morphologic indicators** ***Grooved:*** Linear grooves/striations due to sliding and flows. ***Overridden ridges:*** Pre-existing ridges planed, scoured or flattened by passing mass movements. ***Gully/Channel Scour***: U- to V- shaped erosional forms cut by high-density surges or flows. ***Hummocky:*** Irregular mounds and depressions. Usually, a deposit signature but sometimes overprints failure surfaces.
FailureDepth_Median (m)	Median failure depth value for the polygon, calculated from the deformation-corrected difference of DEMs.	
Landslide_Area (m^2)	3D surface area of the polygon.	
Landslide_Volume_Corr (m^3)	Volume derived from DEM corrected for tectonic deformation (Gnesko et al., 2025).	
Landslide_Volume_Uncorrected	Volume derived from uncorrected DEM (Gnesko et al., 2025).	
Slope_PreEQMin (°)	Minimum slope gradient from 2 m pre-earthquake DEM.	
Slope_PreEQMax (°)	Maximum slope gradient from 2 m pre-earthquake DEM.	
Slope_PreEQMean (°)	Median slope gradient from 2 m pre-earthquake DEM.	
Slope_PostEQMin (°)	Minimum slope gradient from 2 m post-earthquake DEM.	
Slope_PostEQMax (°)	Maximum slope gradient from 2 m post-earthquake DEM.	
Slope_PostEQMean (°)	Median slope gradient from 2 m post-earthquake DEM.	
Aspect_PreEQMeanDeg (°)	Mean aspect from 2 m pre-earthquake DEM.	
Aspect_PostEQMeanDeg (°)	Mean aspect from 2 m post-earthquake DEM.	
Distance_to_Fault (m)	Distance between landslide centroid and Hundalee fault.	
Comment	Mapper notes and observations.	
Polygon_OverlapCutoff	Indicates polygons truncated due to imagery extent differences (pre-event imagery ends mid-slope; post-event imagery extends to canyon floor). Marked “yes” where applicable.	Yes No

Table S5: Details the 37 attributes with names, description and domains used in the landslide inventory feature class. Parameter/metric naming conventions follow Clare et al. (2019).