

**Supplementary information**

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**Carbon and sediment fluxes inhibited in the submarine Congo Canyon by landslide-damming**

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In the format provided by the authors and unedited

1 **Extended Data Figures**

2 Extended Data Figure 1. Two other possible canyon-flank landslides identified in the 2019 bathymetry.

3 a) Possible landslide headscarp and deposit which are interpreted to have involved similar processes

4 to those envisaged for the canyon-flank landslide seen in Fig. 2. b) Canyon-flank landslide appears to

5 constrict the canyon floor leading to the development of a new thalweg channel due to enhanced

6 turbidity current erosional capacity. Processes envisaged here are similar to those described in Fig. 4a,

7 c.

8

9

10 **Supplementary material**

11 **SM1. Other possible canyon-flank landslides in the 2019 data**

12 Other features visible in the 2019 bathymetry data are also interpreted as potential canyon-flank  
13 landside deposits (SFig. 1). However, in neither case did the canyon-flank landslide occur between  
14 2005 and 2019. Therefore, we cannot say for certain that the interpreted morphology is a  
15 consequence of a canyon-flank landslide. A first possible headscarp and deposit, with similar  
16 morphologies to that seen in the upper part of the study area (Fig. 2b), are located at 1980 m water  
17 depth on the northern canyon-flank (SFig. 1a). If indeed a canyon-flank landslide, the headwall is 200  
18 m high and 290 m wide with a perimeter of 1.73 km. Here, the main canyon thalweg is situated  
19 between the landslide headscarp and the interpreted deposit. The shape of the infill is suggestive of  
20 a palaeo-meander which has been cut-off.

21 A second potential landslide complex with a different morphology is observed at 1300 m water depth  
22 on the northern canyon-flank, at the eastern end of the study area (SFig. 1b). Here, multiple  
23 headscarps are associated with a lobate deposit covering 0.65 km<sup>2</sup>. The deposit constricts the canyon  
24 thalweg, but does not block it. A channel, which has been incised into the canyon floor meanders  
25 around the landslide deposit with a knickpoint up-canyon of the deposit (SFig. 1b). The channel is 6  
26 km long with a maximum depth and width of 10 and 200 m, respectively. We interpret the processes  
27 associated with this canyon-flank landslide to be similar to those described in Fig. 4a, c.

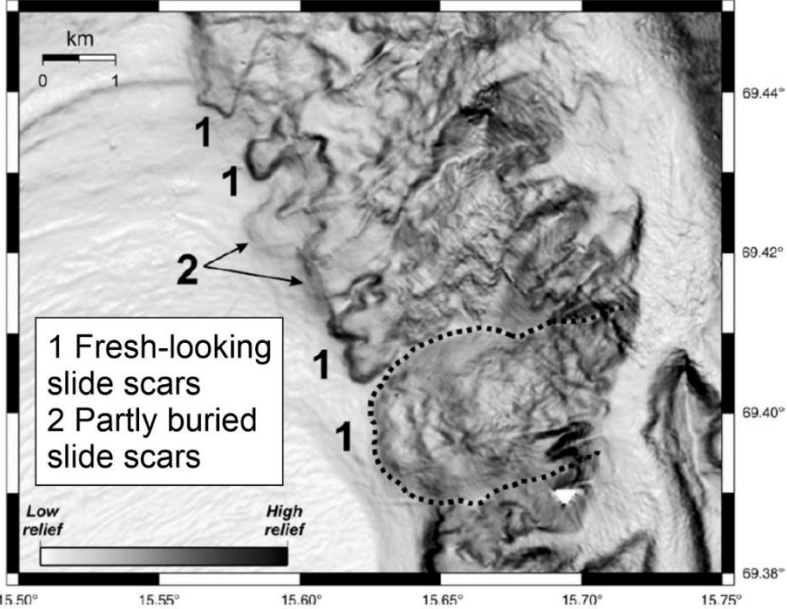
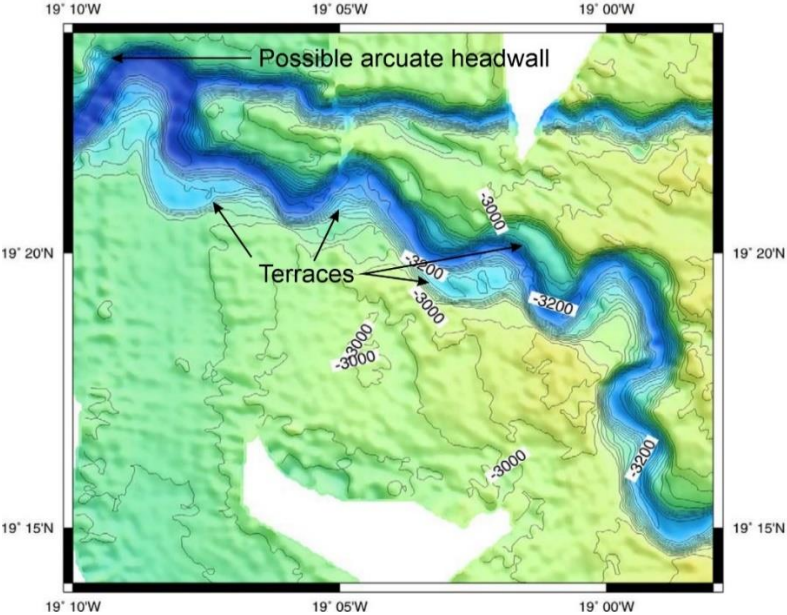
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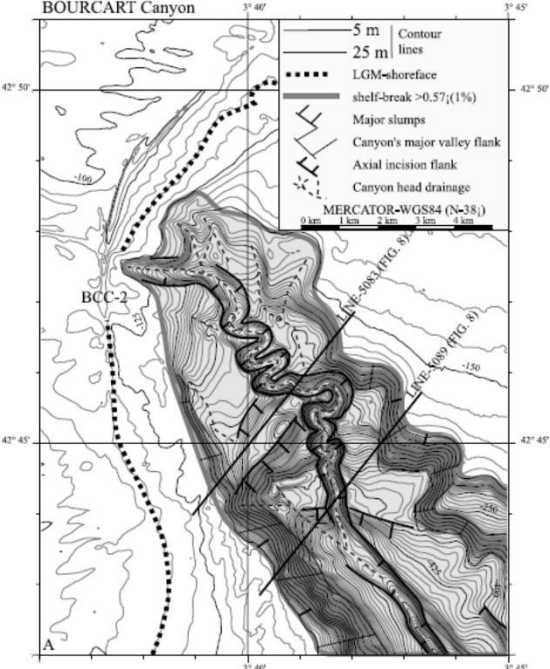
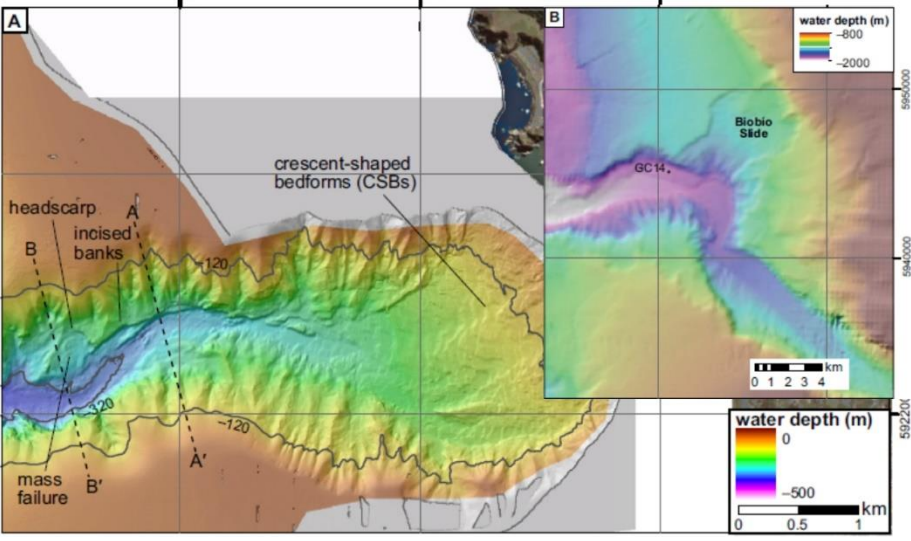
29 **Supplementary Tables**

30 Supplementary Table 1. Submarine canyons where high resolution multibeam bathymetry is available.  
31 Studies which include repeat multibeam bathymetry similar to this study are identified. Mass wasting  
32 features, terraces and canyon sidewalls similar to those observed in this study are described.  
33 Bathymetry examples of the described features are also shown. For example, terraces are identified  
34 which are likely to be areas of high sediment accumulation, and may be prone to collapse. Other  
35 examples where submarine canyons exhibit similar seafloor geomorphic features in 3-D seismic data,  
36 such as the Niger Channel, but where bathymetric data has not been published have been omitted.

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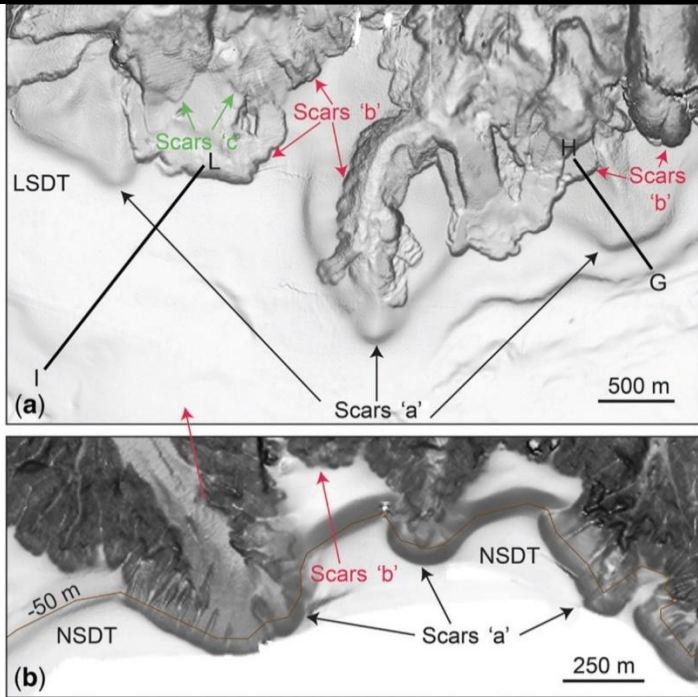
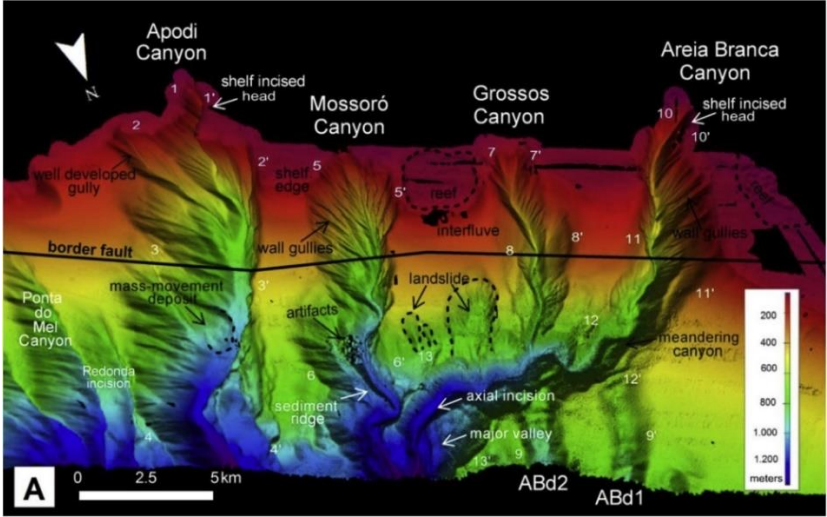
Canyon/ Margin	Date of Survey	Multibeam bathymetry resolution (m)	Reference	Description of mass wasting or terrace features	Swath bathymetry of submarine canyon showing similar landslide or terrace features as identified in the Congo Canyon
Dohrn	2000 - 2014	10	Aiello et al. 2020 <sup>51</sup>	Landslide scars located around the rim of the canyon. Additional slope failure deposits identifiable in seismic profile data	
Magnaghi	2000 - 2014	10	Aiello et al. 2020 <sup>51</sup>	Slope failure deposits identifiable in seismic profile data	

<p>Andøya</p>	<p>2004, 2005</p>	<p>5 (shallower than 1000 m)  25 (deeper than 1000 m)</p>	<p>Amundsen et al. 2015<sup>52</sup>  Laberg et al. 2007<sup>53</sup></p>	<p>Landslide headwalls visible in bathymetry.</p>	
<p>Cap Timiris</p>	<p>2003</p>	<p>Not reported</p>	<p>Antobreh and Krastel 2006<sup>54</sup></p>	<p>Slump deposits identifiable in canyon thalweg from steep canyon walls.  Similar arcuate terrace features to Congo Canyon</p>	

Bourcart	1995 – 2002	Not reported	Baztan et al. 2005 <sup>55</sup>	Slide headwalls visible in bathymetry and seismic cross sections	 <p>The figure is a bathymetric map of Bourcart Canyon. It features contour lines at 5 m and 25 m intervals. A dashed line indicates the LGM-shoreface, and a thick line shows a shelf-break with a slope of &gt;0.57 (1%). The map identifies major slumps, the canyon's major valley flank, axial incision flanks, and canyon head drainage. A specific location is marked as BCC-2. The map uses a Mercator-WGS84 projection (N=38) and includes a scale bar from 0 to 4 km. Geographic coordinates range from 3° 40' to 3° 45' longitude and 42° 45' to 42° 50' latitude.</p>
Biobío	2011	5	Bernhardt et al. 2015 <sup>56</sup>	<p>Arcuate headscarps present with hummocky material partially blocking the canyon.</p> <p>Additional detachment surfaces are visible in</p>	 <p>The figure shows a bathymetric map of Biobío Canyon. It highlights features such as headscarps, incised banks, mass failure, and crescent-shaped bedforms (CSBs). A specific location is marked as gc14. The map includes a scale bar from 0 to 4 km and a color-coded water depth scale from 0 to -2000 m. Geographic coordinates are provided along the axes, ranging from 660000 to 664000 longitude and 5922000 to 5960000 latitude.</p>

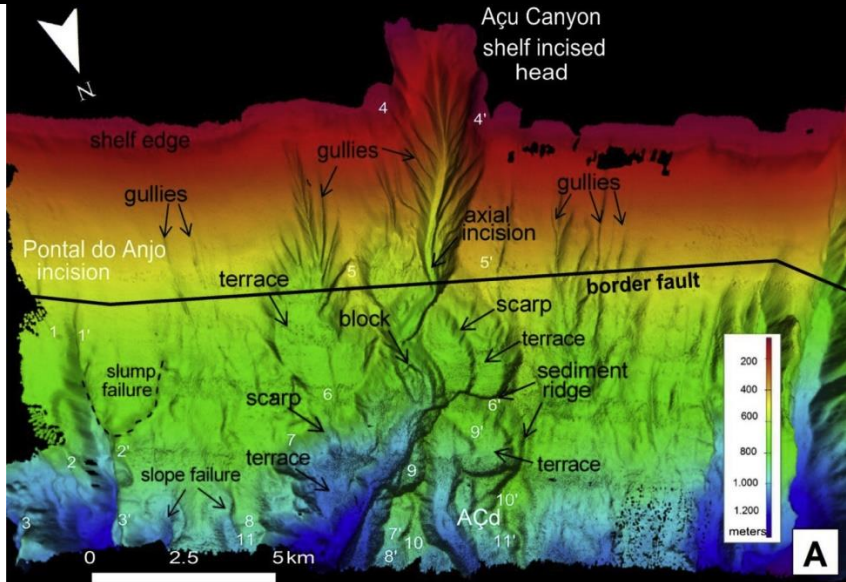
				seismic profiles																												
Cap Lopez	2004 – 2008 (repeat bathymetry)	10	Biscara et al. 2013 <sup>57</sup>	Canyon flank landslide identified. Estimated mass of $95,000 \text{ m}^3 \pm 15,000 \text{ m}^3$ . 60% of thalweg deposit reworked within one year.	<p>Map A (2006-2007) shows a landslide headscarp and a landslide deposit. Map B (2006-2008) shows the same area after reworking. The legend indicates sediment thickness (m) for erosion and deposition, and bathymetry (m).</p> <table border="1"> <thead> <tr> <th colspan="2">Sediment thickness (m)</th> <th>Bathymetry (m)</th> </tr> </thead> <tbody> <tr> <td>Erosion</td> <td>Deposition</td> <td></td> </tr> <tr> <td>&gt; 20</td> <td>1-2</td> <td>0</td> </tr> <tr> <td>15-20</td> <td>2-4</td> <td>100</td> </tr> <tr> <td>10-15</td> <td>4-6</td> <td></td> </tr> <tr> <td>5-10</td> <td>&gt; 6</td> <td></td> </tr> <tr> <td>4-5</td> <td></td> <td></td> </tr> <tr> <td>2-4</td> <td></td> <td></td> </tr> <tr> <td>1-2</td> <td></td> <td></td> </tr> </tbody> </table>	Sediment thickness (m)		Bathymetry (m)	Erosion	Deposition		> 20	1-2	0	15-20	2-4	100	10-15	4-6		5-10	> 6		4-5			2-4			1-2		
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Cape D'Orlando Basin	2011, 2012	1 (0 – 100 m water depth)  20 (100 – 1000 m water depth)	Casalbore et al. 2020 <sup>58</sup>	280 landslide scars recognised in bathymetry down to 550 m water depth.	
Areia Branca	2011	50	de Almedia et al. 2015 <sup>59</sup>	Arcuate headwalls with the presence of marginal terraces	
Grossos	2011	50	de Almedia et al. 2015 <sup>59</sup>		
Mossoro	2011	50	de Almedia et al. 2015 <sup>59</sup>	Landslide scars on canyon walls.	

Apodi	2011	50	de Almedia et al. 2015 <sup>59</sup>	Mass movement deposit in the canyon axis.	
Ponta do Mel	2011	50	de Almedia et al. 2015 <sup>59</sup>		
Porto do Manguê	2011	50	de Almedia et al. 2015 <sup>59</sup>	Triangular landslide scars in the canyon head	

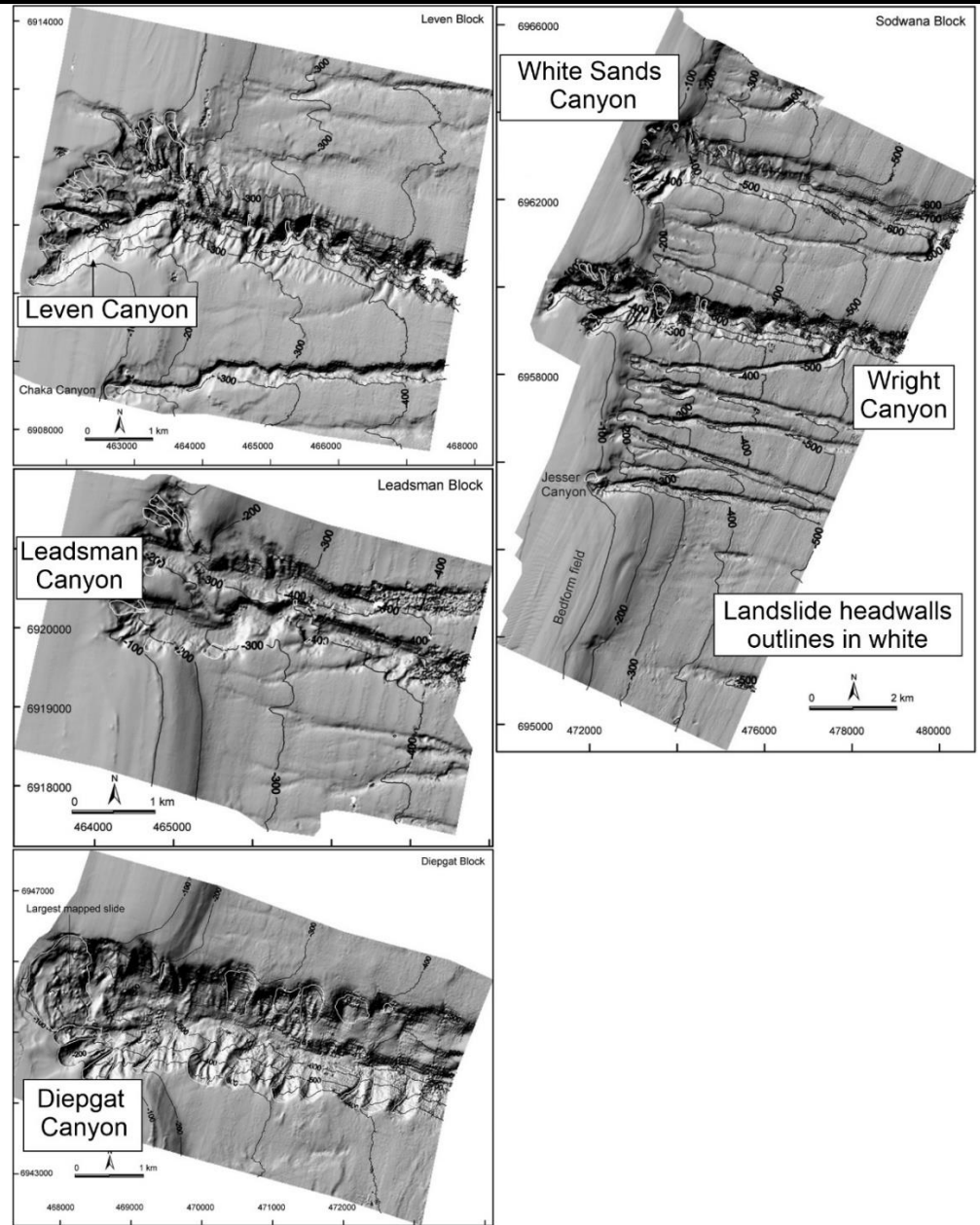
Macau	2011	50	de Almedia et al. 2015 <sup>59</sup>		<p>The figure is a topographic map of the Macau Canyon and Porto do Mangue Canyon region. It features a color-coded elevation scale on the right, ranging from 0 meters (red) to 1,200 meters (blue). The map shows a prominent 'border fault' running diagonally across the center. To the north of the fault is the 'Macau Canyon' area, characterized by 'feeding gullies' and a 'non excavated slope'. To the south is the 'Porto do Mangue Canyon' area, featuring 'well-developed gullies' and 'wall gullies'. A 'shelf edge' is marked near the top right. The map includes a north arrow in the top left, a scale bar (0, 2.5, 5 km) at the bottom left, and a small 'A' in the bottom left corner. Elevation markers '1', '2', and '3' are placed at various points on the map.</p>
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Acu	2011	50	de Almedia et al. 2015 <sup>59</sup>	Arcuate headwalls associated with terraces present.	
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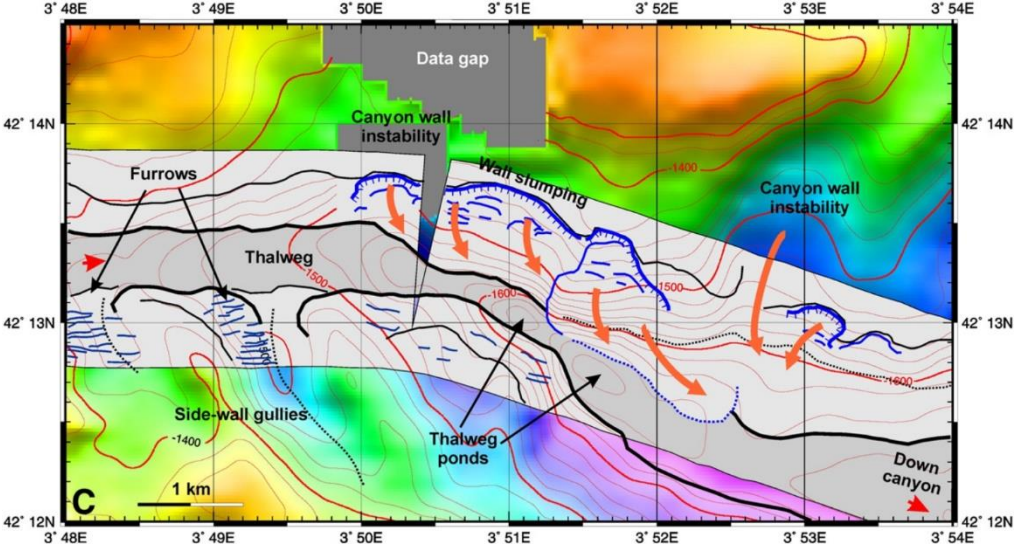
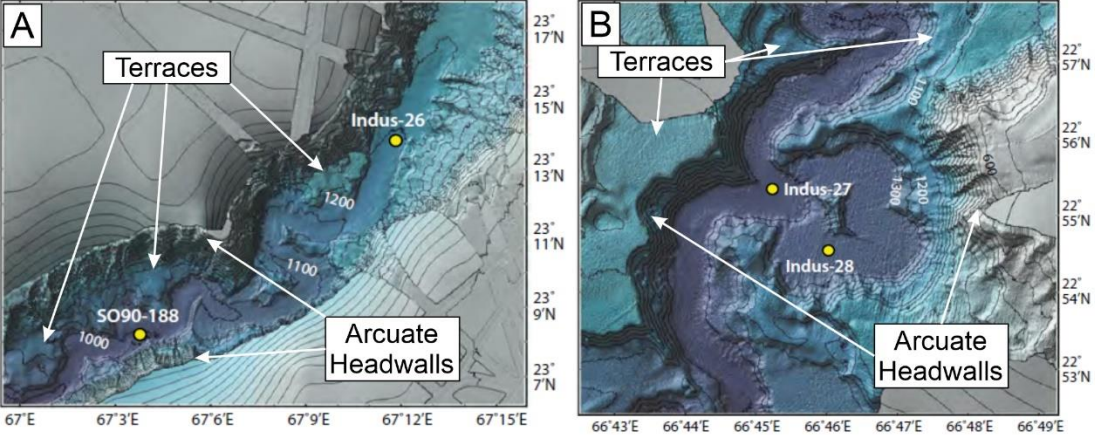
Hatteras Transverse	2005, 2008, 2012	100	Gardner et al. 2016 <sup>60</sup>	Landslide scarps and deposits occur across large sections of the canyon. Deposits as high as 25 m down canyon of the confluence of the Hatteras Transverse and Lower Hatteras Canyons have impeded present flow down-canyon.	
Leven		10	Green and Uken, 2008 <sup>61</sup>	Arcuate headwalls in canyon head and on mid-canyon walls.	



			Green, 2011 <sup>62</sup>	
Leadsman		10	Green and Uken, 2008 <sup>61</sup>  Green, 2011 <sup>62</sup>	Arcuate headwalls in canyon head and on mid-canyon walls.
Diepgat		10	Green and Uken, 2008 <sup>61</sup>  Green, 2011 <sup>62</sup>	Arcuate headwalls and terraces identifiable.
Wright		10	Green and Uken, 2008 <sup>61</sup>  Green, 2011 <sup>62</sup>	Arcuate headwalls in canyon head and on mid-canyon walls.
White Sands		10	Green and Uken, 2008 <sup>61</sup>	Landslide deposit visible in channel thalweg in



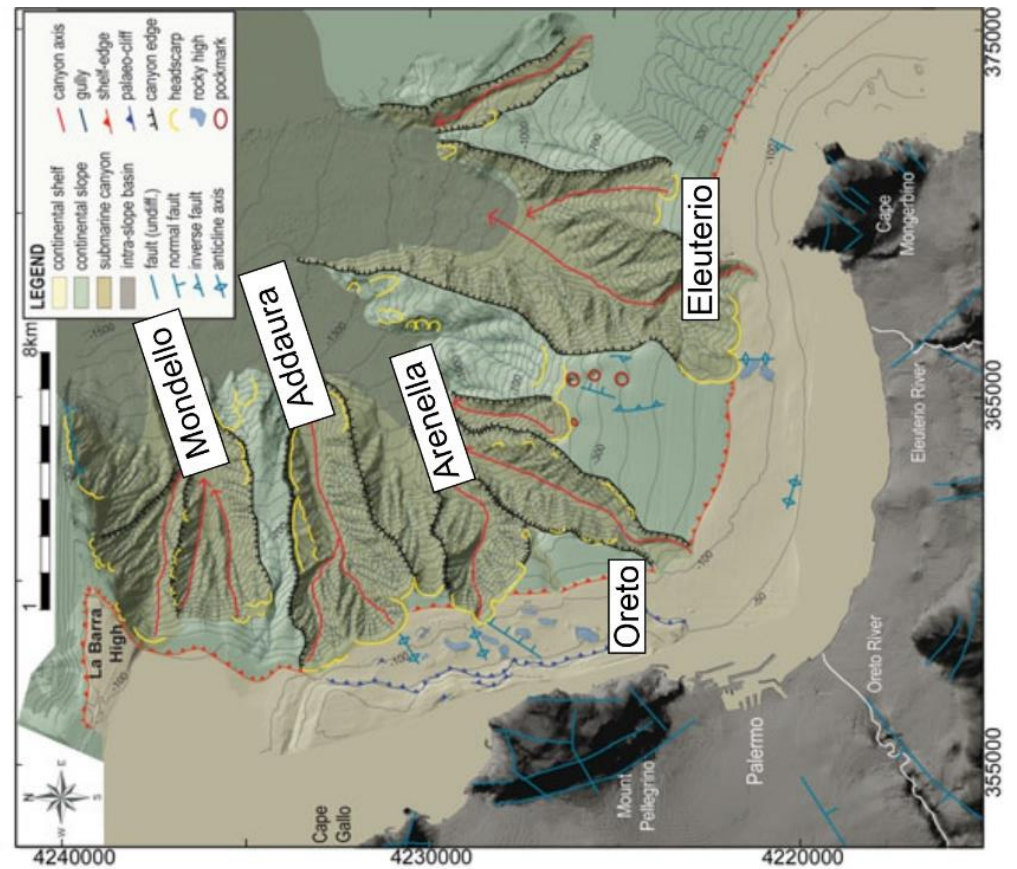
			Green, 2011 <sup>62</sup>	seismic reflection data.	
Mabibi		10	Green and Uken, 2008 <sup>61</sup>  Green, 2011 <sup>62</sup>	Arcuate headwalls in canyon and on mid-canyon walls. Slump deposit in the canyon thalweg.	
Sur	1998	25	Harris et al. 2014 <sup>63</sup>	Arcuate landslide scars and multiple terraces visible.	
Partington	1998	25	Harris et al. 2014 <sup>63</sup>	Arcuate landslide scars and multiple terraces visible.	

Avon	2012		Jimoh et al. 2018 <sup>64</sup>	Sidewall scarps and terraces visible.	
Cap de Creus	1995, 2002, 2004	4, 50, 200	Lastras et al. 2007 <sup>65</sup>	Side wall slumping leading to narrowing of the canyon thalweg.	 <p>This topographic map shows the Cap de Creus canyon with various geological features. The map includes a coordinate grid from 3° 48'E to 3° 54'E and 42° 12'N to 42° 14'N. Key features labeled include Furrows, Thalweg, Side-wall gullies, Thalweg ponds, Wall slumping, Canyon wall instability, and Down canyon. A 'Data gap' is indicated at the top. A 1 km scale bar is provided at the bottom left.</p>
Indus	2008		Clift et al. 2014 <sup>66</sup>  Li et al. 2018 <sup>67</sup>	Terraces and arcuate scars visible. Slump deposits visible in seismic data.	 <p>Two panels (A and B) of topographic maps of the Indus region. Panel A shows features like Terraces, Arcuate Headwalls, and specific locations SO90-188 and Indus-26. Panel B shows Terraces, Arcuate Headwalls, and locations Indus-27 and Indus-28. Both panels include coordinate grids.</p>



Gaoping			<p>Yeh et al. 2013<sup>68</sup></p> <p>Liu et al. 2016<sup>69</sup></p>	<p>Canyon-rim slumping and landslides visible in bathymetry. Slump deposits identified in seismic data.</p>	<p>The figure consists of two 3D bathymetric maps of the Gaoping Canyon area. The top map shows a wide view of the canyon with labels for 'turbidite deposit', 'boulder', 'minor channel', 'Kaoping Canyon', 'carbonate ridge', and 'channel cutting'. A north arrow is in the top right. The bottom map shows a more detailed view of the canyon rim with labels for 'landslide deposit', 'slumping cliff', 'channel cutting', and 'slope basin'. A north arrow is also present in the top right of this map.</p>
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Mondello	2001, 2004, 2009	15	Lo Iacono et al. 2011 <sup>70</sup>	Headscarps present at heads of gullies.
Addaura	2001, 2004, 2009	15	Lo Iacono et al. 2011 <sup>70</sup>	Headscarps present along northern wall.



Oreto	2001, 2004, 2009	15	Lo Iacono et al. 2011 <sup>70</sup>	Headscarps visible. Obstruction clearly visible in canyon thalweg.	
Eleuterio	2001, 2004, 2009	15	Lo Iacono et al. 2011 <sup>70</sup>	Headscarps visible. 20 m high obstruction clearly visible in canyon thalweg.	
Cook	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry.	
Nicholson	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry.	
Wairarapa	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry.	

Campbell	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry.	
Palliser	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry. Landslide blocks are visible on canyon floor.	
Opouawe	2002, 2005	10	Micallef et al. 2013 <sup>71</sup>	Landslide scars clearly visible in bathymetry.	
Embro Margin	1995, 1999	50	Micallef et al. 2014 <sup>72</sup>	Slide scars visible in bathymetry. Multiple terrace levels visible.	
Mona	1995, 2004	150	Mondziel et al. 2010 <sup>73</sup>	Landslide headscarps visible. Slump deposits	

visible in seismic data.

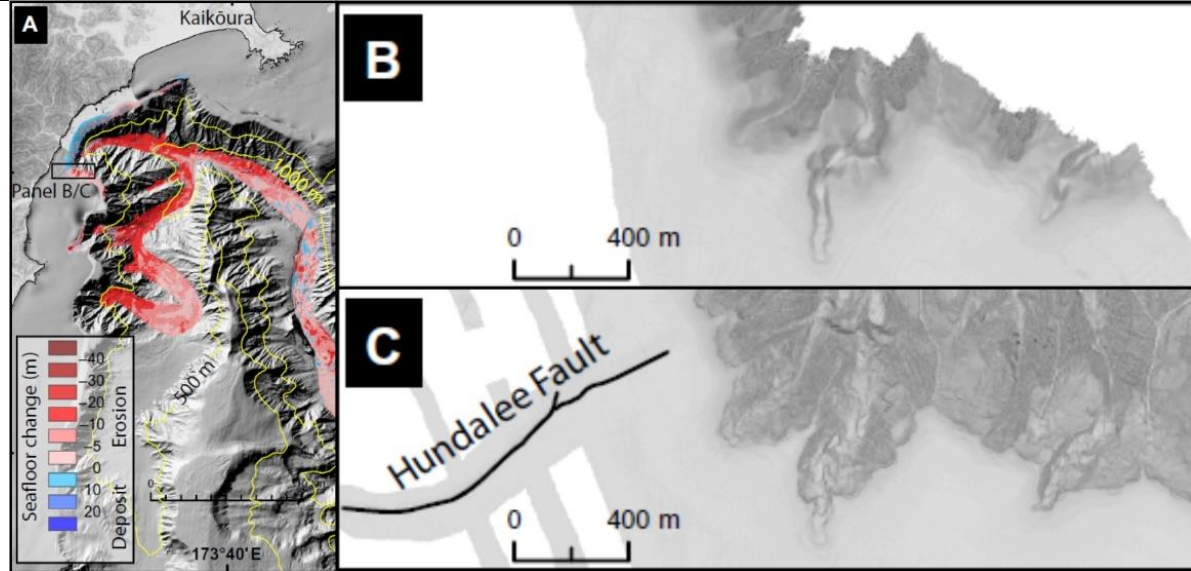
Kaikoura

2018  
(Repeat bathymetry)

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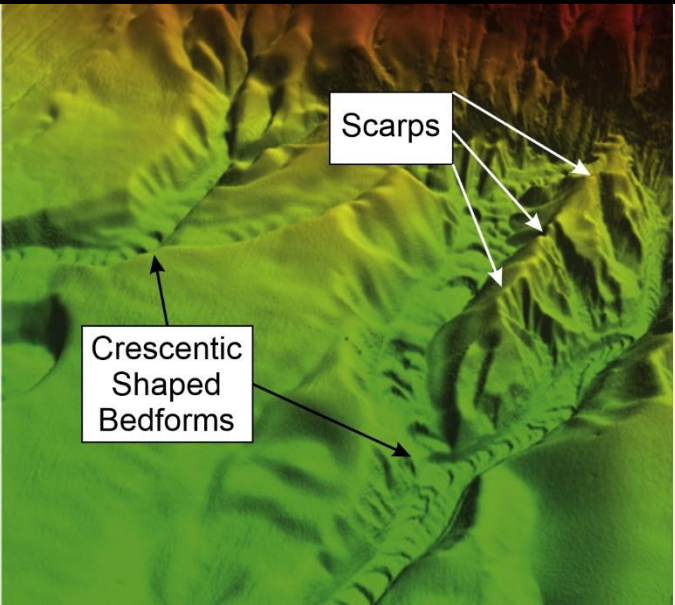
Mountjoy et al. 2018<sup>11</sup>

Canyon rim landslide evacuated through the canyon triggered by an earthquake.





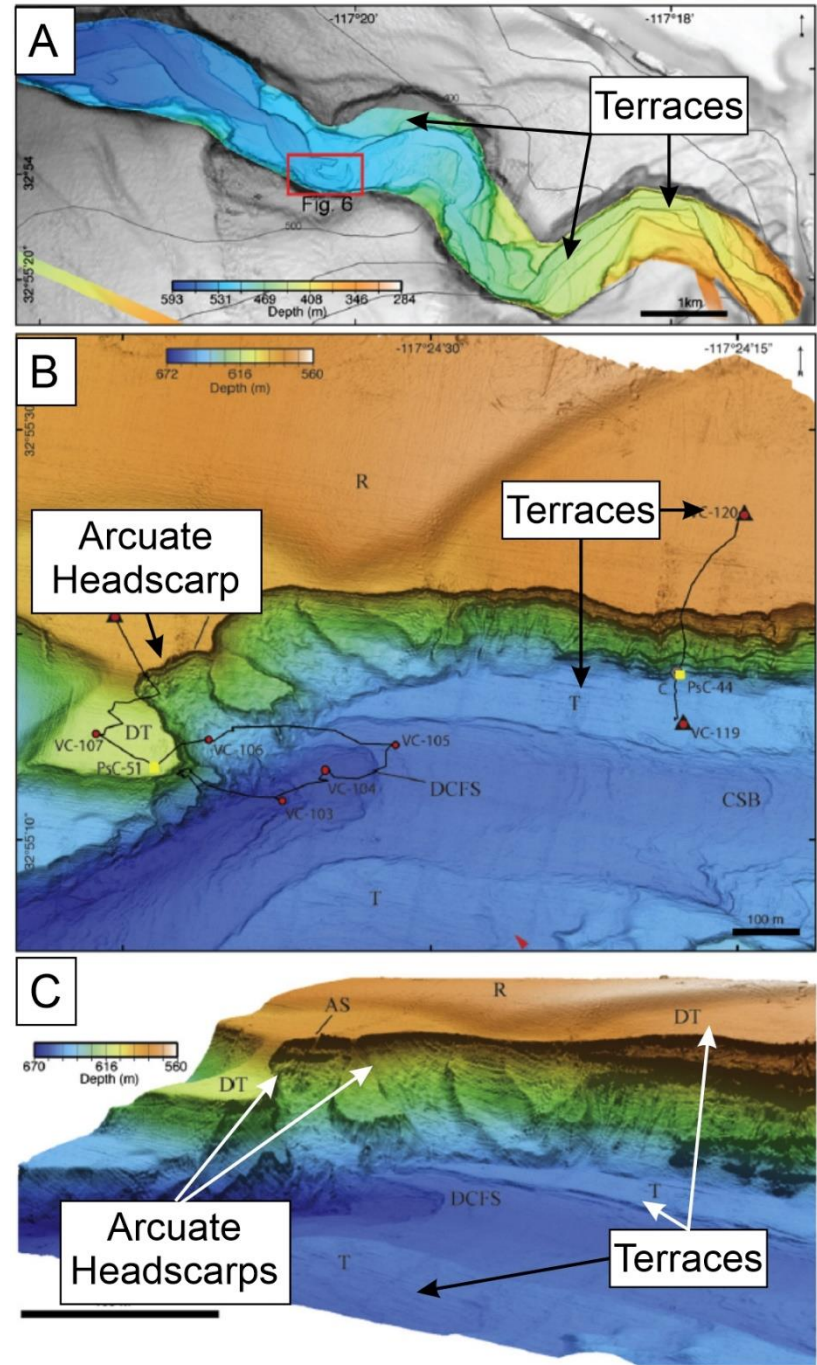
<p>Perth</p> <p>2014, 2015, 2017, 2018</p> <p>(Repeat bathymetry in some areas)</p>	<p>20</p>	<p>Nanson et al. 2022<sup>74</sup></p>	<p>Landslide scars visible. Repeat bathymetry shows failures of some canyon headwalls due to earthquakes. Small accumulations of slump deposits visible in thalweg.</p>	<p><b>Change in seafloor pre- and post 2018</b></p> <p>Difference: +78 m (blue), -61 m (red)</p> <p>Scale: 1 km</p> <p><b>Geomorphology map</b></p> <p>Labels: map limit, blind canyon, Escarpment, slump scar, fan levee, NP4, entrenched fan floor, fan terrace, cyclic step (or block), plunge pool (or block top), terrace dunes, slab, channel, gully network, sediment wave, Rottne Island, Swan River, Figure 12B, Figure 12A, Figure 13, Figure 14, 40 m grid (ship tracks), (inset: i), (inset: ii), map limit, NP3, NP2, NP1, map limit, 20 km, -5000 to 0</p> <table border="1"> <thead> <tr> <th>Morphology surfaces</th> <th>Geomorphology:</th> <th>Incisional</th> <th>Failure</th> <th>Aggradational</th> </tr> </thead> <tbody> <tr> <td>Plane</td> <td>channel</td> <td>palaeo-valley belt</td> <td>slab</td> <td>sediment wave</td> </tr> <tr> <td>Slope</td> <td>floor</td> <td>gully network</td> <td>slump scar</td> <td>cyclic step (or block)</td> </tr> <tr> <td>Escarpment</td> <td>plunge pool (or block top)</td> <td>entrenched floor</td> <td>block</td> <td>dunes</td> </tr> <tr> <td></td> <td>nick-point</td> <td>blind canyon</td> <td>creep</td> <td>levee</td> </tr> <tr> <td></td> <td></td> <td>terrace</td> <td></td> <td></td> </tr> </tbody> </table>	Morphology surfaces	Geomorphology:	Incisional	Failure	Aggradational	Plane	channel	palaeo-valley belt	slab	sediment wave	Slope	floor	gully network	slump scar	cyclic step (or block)	Escarpment	plunge pool (or block top)	entrenched floor	block	dunes		nick-point	blind canyon	creep	levee			terrace		
Morphology surfaces	Geomorphology:	Incisional	Failure	Aggradational																														
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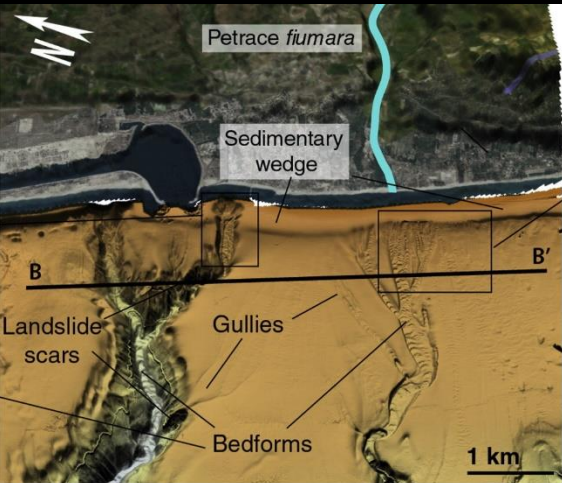
Pont-des-Monts	2007, 2012 (Repeat bathymetry)	3	Normandeau et al. 2014 <sup>75</sup>	Small scarps are visible.	
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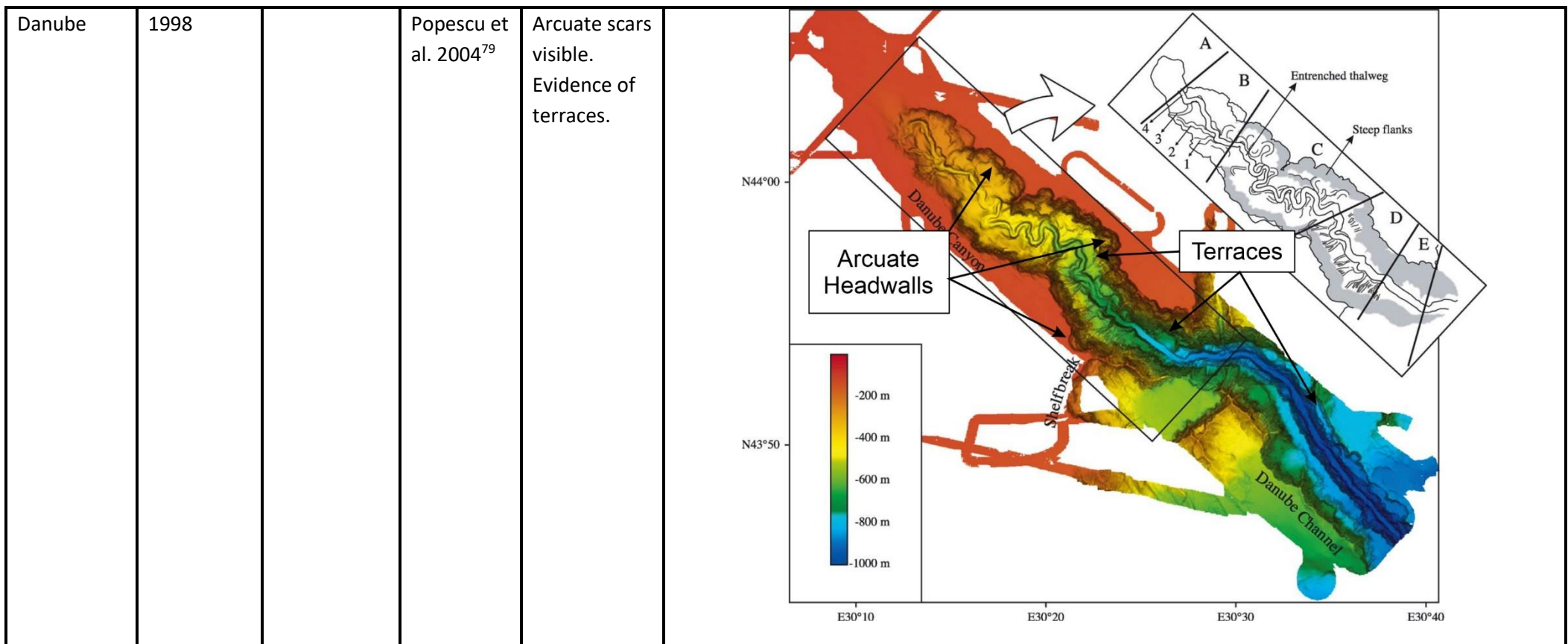
Goto	2008	25	Oiwane et al. 2011 <sup>76</sup>	Landslide headwalls observed in bathymetry.	
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La Jolla	2008	0.7	Paull et al. 2013 <sup>77</sup>	Arcuate shaped scarps and terraces clearly visible.
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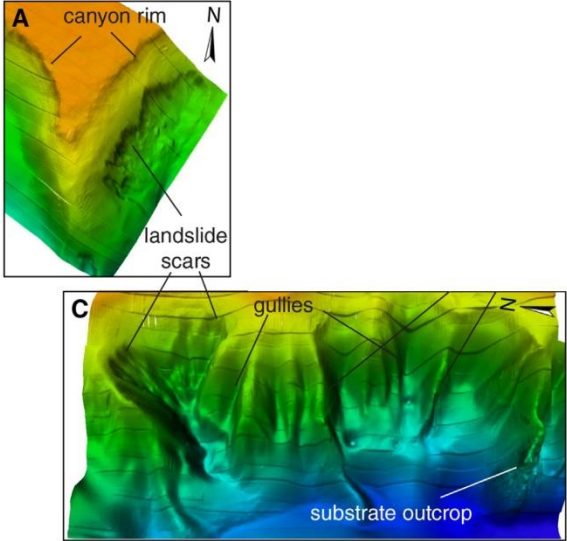
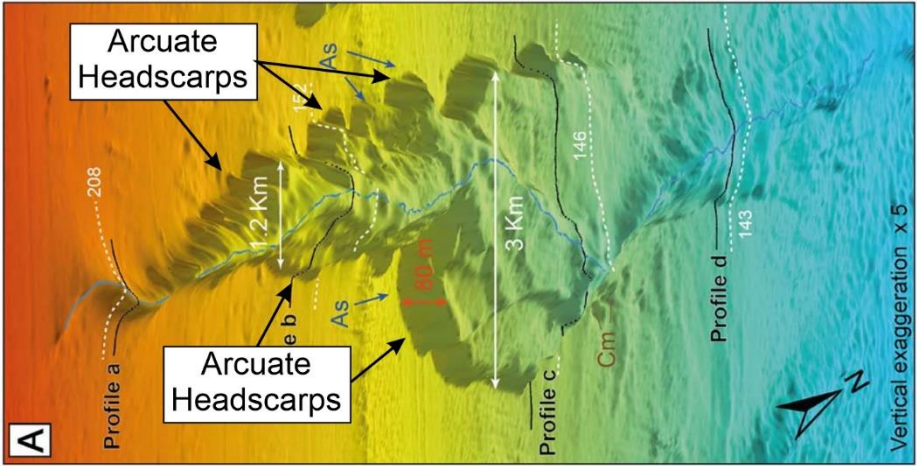


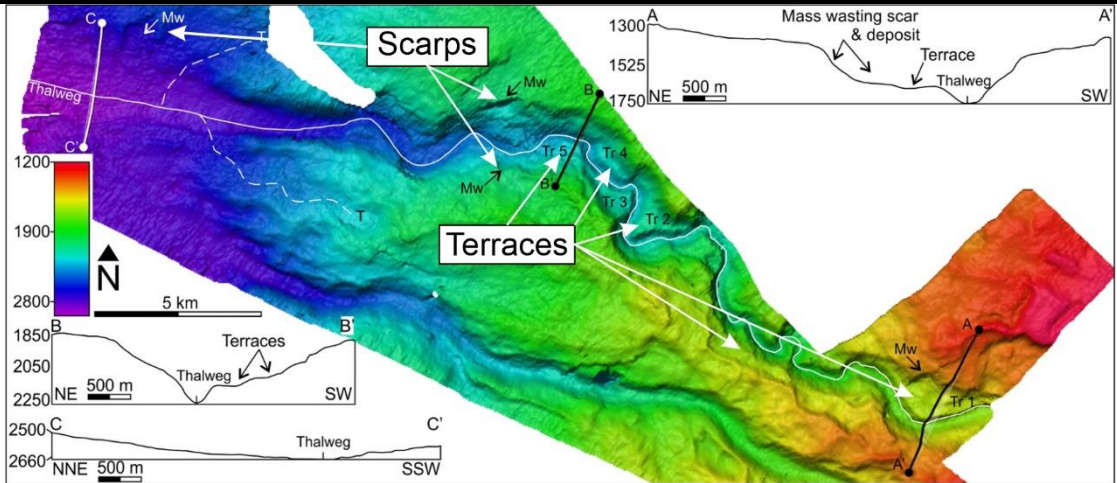
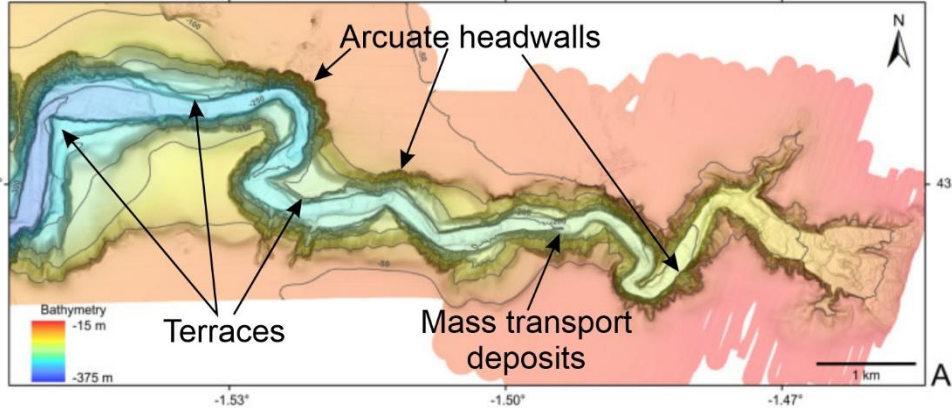
Gioia	2009, 2012	10	Pierdomenico et al. 2016 <sup>78</sup>	Landslide headwalls visible.	 <p data-bbox="1279 560 1839 598"><b>Gioia Canyon      Petrace Canyon</b></p>
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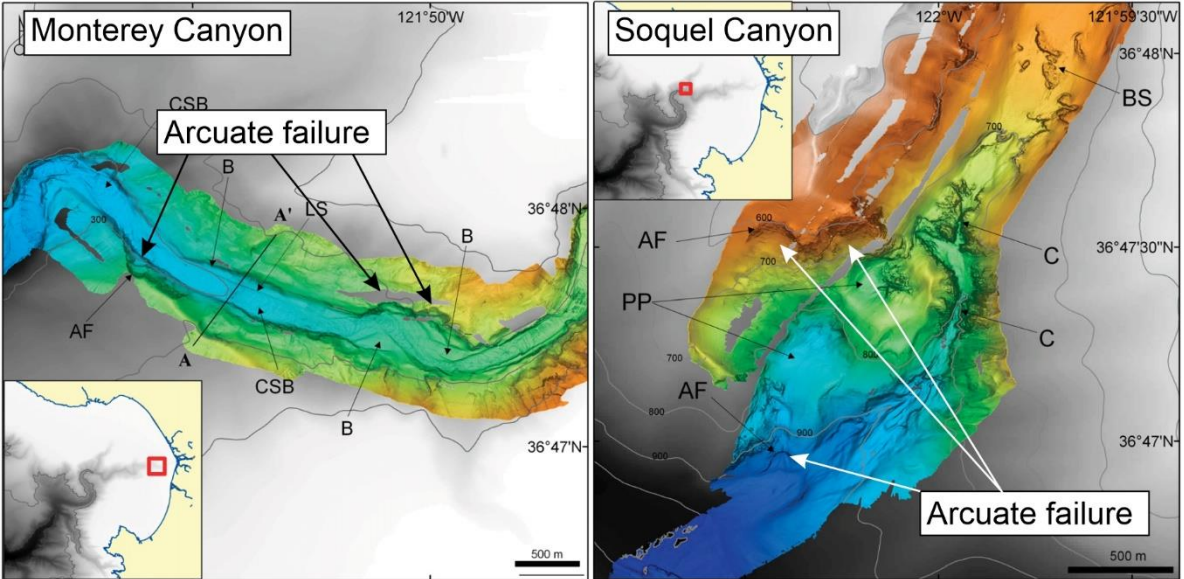


Ribbon Reef	2007	40	Puga Bernabeu et al. 2011 <sup>80</sup>	Landslide headwalls visible in bathymetry. Suggested that knickpoints in canyon long profiles may be the result of slide deposits.	
Patia/Mira	2005	60	Ratzov et al. 2012 <sup>81</sup>	Headscarps visible in bathymetry. Slump deposit has resulted in a canyon dam and infill visible in seismic data.	

Hudson	2007, 2008, 2009	3	Rona et al. 2015 <sup>82</sup>	Landslide scars visible on side walls.	 <p>Figure A: 3D topographic map showing a canyon rim and landslide scars. Figure C: 3D topographic map showing gullies and a substrate outcrop.</p>
São Vincente	2001 – 2009	250	Serra et al. 2020 <sup>83</sup>	Slide scars visible.	
Bahama Bank	2010	20	Tournadou r et al. 2017 <sup>84</sup>	Arcuate scarps visible.	 <p>Figure A: 3D topographic map showing arcuate headscarps. The map includes profiles a, b, c, and d, with distances of 1.2 Km and 3 Km, and elevations of 208, 146, and 143. A vertical exaggeration of x 5 is noted.</p>

Mozambique Channel	2014	40	Wiles et al. 2019 <sup>85</sup>	Mass wasting scars identified on sidewalls.	 <p>This figure is a bathymetric map of a section of the Mozambique Channel. The map uses a color scale to represent depth, with shallower areas in red and orange, and deeper areas in blue and purple. Key features are labeled: 'Scarps' (steep slopes) and 'Terraces' (flatter, stepped areas). Specific terraces are labeled Tr 1 through Tr 5. Mass wasting scars (Mw) are also indicated. Three cross-sections are shown: A-A' at the top right, B-B' in the middle, and C-C' at the bottom. Each cross-section shows a profile of the seafloor with labels for 'Mass wasting scar &amp; deposit', 'Terrace', and 'Thalweg' (the deepest part of the channel). A 5 km scale bar and a north arrow are included.</p>
Capbreton	1998, 2020 (Repeat bathymetry)	0.5 - 5	Guiastrennec-Faugas et al. 2020 <sup>6</sup>	Arcuate slide scars, slump scars and terraces	 <p>This figure is a bathymetric map of the Capbreton area. It shows a complex seafloor topography with various features. Key features are labeled: 'Arcuate headwalls' (curved slopes), 'Terraces' (stepped areas), and 'Mass transport deposits' (large, irregularly shaped areas). A bathymetry scale is provided, ranging from -15 m (red) to -375 m (blue). The map includes a north arrow and a 1 km scale bar. Geographic coordinates are marked along the top and right edges.</p>
Monterey	2008, 2009	1	Paull et al. 2011 <sup>86</sup>	Arcuate scars visible on canyon sidewalls	



Soquel	2008, 2009	1	Paull et al. 2011 <sup>86</sup>	Arcuate scars visible on canyon sidewalls	 <p>The figure consists of two bathymetric maps. The left map is titled 'Monterey Canyon' and shows a cross-section of the canyon with labels for 'CSB' (Canyon Side Bank), 'AF' (Arcuate Failure), 'A', 'A'', 'LS' (Lateral Scar), and 'B'. A box labeled 'Arcuate failure' has arrows pointing to several curved features on the canyon walls. The right map is titled 'Soquel Canyon' and shows a similar cross-section with labels for 'BS' (Basal Scar), 'AF', 'PP' (Pinnacled Point), and 'C'. A box labeled 'Arcuate failure' has arrows pointing to curved features on the canyon walls. Both maps include a 500 m scale bar and an inset map showing the canyon's location on a larger geographic scale.</p>
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41 STable. 2. Estimates of sediment and organic carbon masses displaced by submarine mass movement  
 42 events, flood events and annual discharges from selected large rivers. The table demonstrates the  
 43 efficiency of sediment and carbon capture and storage by the Congo Canyon landslide-dam.

		Displaced Mass (Mt)	Organic Carbon (Mt C)	Reference
<b>Marine Settings</b>				
Congo Canyon	Landslide	120±10	3.2 - 3.5 (min 3.1, max 3.8)	This study
Congo Canyon	Infill	170±40	4.6 - 5 (min 3.9, max 6.2)	This study
	Total	290±50	7.8 - 8.5 (min 7, max 10)	This study
Kaikōura Canyon/ Hikurangi Channel	2016 Kaikōura Earthquake/Landslide	850	7	Mountjoy et al. 2018
Continental shelf/ Japan Trench	2011 Tohoku-oki Earthquake/mass movement	360'	>1.73	Kioka et al. 2019
<b>Fluvial Events</b>				
Eel River	1995 flood	25	0.24	Leithold and Hope, 1999
North St. Vrain Creek	2013 flood	0.216	0.01	Rathburn et al. 2017
Kaoping River/Stored on floodplain	2009 Typhoon Morakot flood		0.72*	West et al. 2011
Kaoping River	2009 Typhoon Morakot flood		1.2 - 2.5*	West et al. 2011
Choshui River	2004 Typhoon Mindulle flood	61.4	0.5	Goldsmith et al. 2008
<b>Annual fluvial discharge</b>				
				Baudin et al. 2020 Coynel et al. 2005
Congo		43	2	Milliman and Farnsworth, 2011
				Bouchez et al. 2014
Amazon		900	11.5	Milliman and Farnsworth, 2011
				Wakeham et al. 2009 Rosenheim et al. 2013
Mississippi		210	9	Milliman and Farnsworth, 2011
				Li et al. 2015
Yangtze		478	4.4	Milliman and Farnsworth, 2011
				Galy et al. 2008 Galy and Eglinton, 2011
Ganges/Brahmaputra		1670	8	Milliman and Farnsworth, 2011
				Hilton et al. 2015
Mackenzie		100	2	Milliman and Farnsworth, 2011
				Galy et al. 2015
	<b>Global Total</b>	19,000 ± 500	200 +135/-75	Milliman and Farnsworth, 2011
Notes		*Coarse woody debris 'assumes density of 1,300 kg/m3		

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