Tables and figures to accompany

Landslides, earthquakes, and sedimentation rate in passive and active margins

By ten Brink, U.S., Andrews, B.D., and Miller, N.C.

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Fig. DR2a,b,c - Similar figures to Figures 2a,b,c, but excluding scars and margin areas with gradients < 3°.

2016187_Polygon Data.zip

MarginBounds.kmz shows the polygons of all the margin areas shown in Fig. DR1 as black lines surrounded by white lines.

ScarBounds.kmz shows the polygons of all the landslide scars marked in black in Fig. DR1.
## Table DR1

### Table DR1 – Bathymetry data sources

<table>
<thead>
<tr>
<th>Margin name</th>
<th>Multibeam bathymetry surveys</th>
<th>Resolution (m)*</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascadia N. (Washington)</td>
<td>TN265, AVON09MV, MGL1212</td>
<td>50</td>
<td>NOAA-National Centers for Environmental Information</td>
</tr>
<tr>
<td>Cascadia N. (Oregon)</td>
<td>Compilation of various surveys</td>
<td>100</td>
<td>NOAA- National Centers for Environmental Information* (<a href="http://efh-catalog.coas.oregonstate.edu/bathy/">http://efh-catalog.coas.oregonstate.edu/bathy/</a>)</td>
</tr>
<tr>
<td>Cascadia S. (Oregon)</td>
<td>Compilation of various surveys</td>
<td>100</td>
<td>NOAA- National Centers for Environmental Information* (<a href="http://efh-catalog.coas.oregonstate.edu/bathy/">http://efh-catalog.coas.oregonstate.edu/bathy/</a>)</td>
</tr>
<tr>
<td>Guatemala-El Salvador</td>
<td>SO173_L2</td>
<td>100</td>
<td>Federal Maritime and Hydrographic Agency of Germany</td>
</tr>
<tr>
<td>Israel</td>
<td>Sade et al., 2007</td>
<td>50</td>
<td>Gadol, 2015**</td>
</tr>
<tr>
<td>Makran</td>
<td>SO123</td>
<td>100</td>
<td>Federal Maritime and Hydrographic Agency of Germany</td>
</tr>
<tr>
<td>Queen Charlotte Fault</td>
<td>CCGS Vector (Barrie et al., 2013 _)</td>
<td>10</td>
<td>Canadian Hydrographic Service and Canadian Geological Survey**</td>
</tr>
<tr>
<td>Nicaragua-Costa Rica</td>
<td>SO163 L1 &amp;L2, SO144, SO144 L3</td>
<td>100</td>
<td>Federal Maritime and Hydrographic Agency of Germany</td>
</tr>
<tr>
<td>Nicaragua-Costa Rica</td>
<td>EW0005, EW0104</td>
<td>100</td>
<td>NOAA- National Centers for Environmental Information</td>
</tr>
<tr>
<td>N. Sumatra Trench</td>
<td>HMS Scott (Henstock et al., 2006)</td>
<td>50</td>
<td>National Oceanographic Centre, Southampton, U.K.</td>
</tr>
</tbody>
</table>

Comments:
*The vertical accuracy of the data is ≤ 0.2% of the water depth for a 12 kHz sonar (de Moustier, 2001), the lowest frequency sonar used in this study. It is difficult, however, to quantify the true vertical resolution of the data. A scarp is evident as an abrupt change in slope between pixels. Scarp identification therefore depends on the gradient of the surrounding pixels, the grid size, and the lateral continuity of the scarp.

**All bathymetry data, with the exception of data sources marked by *, were reprocessed using Caris Hips 9.0 from raw line files and the vessel configuration files, cleaned and gridded, following the procedure outlined in Andrews et al., 2013. We used already gridded data sets from Israel (50 m), Queen Charlotte fault (5 m), and Oregon (100 m) because of lack of access to the raw data.

References cited:
Table DR2- Morphological parameters, earthquake recurrence, and sedimentation rate for the regions bounded by polygons in Fig. DR1

<table>
<thead>
<tr>
<th>Margin name</th>
<th>Range of water depths (m)*</th>
<th>Margin area (km²)</th>
<th>Total failure area (km²)</th>
<th>Mean slide volume (km³)</th>
<th>Mean slide thickness (m)**</th>
<th>Mean margin gradient (°)</th>
<th>% margin &gt; 3°</th>
<th>% scar area &gt; 3°</th>
<th>Scar fraction</th>
<th>Scar fraction &gt;3° ***</th>
<th>Mean slide gradient (°)****</th>
<th>Earthquake recurrence (yr)</th>
<th>Sedimentation rate (cm/ kyr)</th>
<th>Inter-seismic sediment thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascadia N</td>
<td>668 - 2322</td>
<td>24171</td>
<td>579</td>
<td>31.56</td>
<td>63</td>
<td>5.4±5.9</td>
<td>54.8</td>
<td>85.2</td>
<td>0.02</td>
<td>0.04</td>
<td>6.9</td>
<td>500±75</td>
<td>9.8±1.3</td>
<td>4.9±1.4</td>
</tr>
<tr>
<td>Cascadia S</td>
<td>104 - 3111</td>
<td>12407</td>
<td>1638</td>
<td>109.91</td>
<td>78</td>
<td>5.7±5.3</td>
<td>61.3</td>
<td>87.9</td>
<td>0.13</td>
<td>0.19</td>
<td>8.8</td>
<td>500±75</td>
<td>9.8±1.3</td>
<td>4.9±1.4</td>
</tr>
<tr>
<td>Guatemala E</td>
<td>174 - 6645</td>
<td>31076</td>
<td>560</td>
<td>42.06</td>
<td>78</td>
<td>6.9±4.2</td>
<td>86.0</td>
<td>90.6</td>
<td>0.02</td>
<td>0.02</td>
<td>6.6</td>
<td>60±15</td>
<td>8.5±4.5</td>
<td>0.5±0.4</td>
</tr>
<tr>
<td>El Salvador</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Israel^</td>
<td>83 - 1130</td>
<td>2256</td>
<td>615</td>
<td>8.92</td>
<td>14</td>
<td>2.6±2.1</td>
<td>31.2</td>
<td>45.1</td>
<td>0.30</td>
<td>0.39</td>
<td>2604±1302</td>
<td>66.0±42.0</td>
<td>171.9±196.0</td>
<td></td>
</tr>
<tr>
<td>Makran</td>
<td>1226-3369</td>
<td>8675</td>
<td>424</td>
<td>20.05</td>
<td>54</td>
<td>6.0±6.3</td>
<td>52.5</td>
<td>85.9</td>
<td>0.05</td>
<td>0.08</td>
<td>7.2</td>
<td>175±74</td>
<td>70.5±23.3</td>
<td>12.3±9.3</td>
</tr>
<tr>
<td>Muertos</td>
<td>297 - 5579</td>
<td>37191</td>
<td>2065</td>
<td>118.15</td>
<td>63</td>
<td>6.1±5.2</td>
<td>69.0</td>
<td>79.0</td>
<td>0.06</td>
<td>0.06</td>
<td>5.6</td>
<td>1855±1232</td>
<td>4.3±2.1</td>
<td>8.0±9.2</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>306 - 5797</td>
<td>14133</td>
<td>546</td>
<td>55.11</td>
<td>108</td>
<td>6.4±3.9</td>
<td>85.0</td>
<td>95.4</td>
<td>0.04</td>
<td>0.04</td>
<td>8.2</td>
<td>75±19</td>
<td>35.0±21.0</td>
<td>2.6±2.2</td>
</tr>
<tr>
<td>Queen Charlotte F</td>
<td>7 - 1944</td>
<td>2861</td>
<td>25</td>
<td>0.53</td>
<td>24</td>
<td>8.2±9.2</td>
<td>80.0</td>
<td>97.2</td>
<td>0.01</td>
<td>0.01</td>
<td>12.8</td>
<td>100±30</td>
<td>1.0±0.5</td>
<td>0.1±0.1</td>
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<tr>
<td>N. Sumatra</td>
<td>393 - 4969</td>
<td>19067</td>
<td>1142</td>
<td>61.27</td>
<td>63</td>
<td>12.3±9.1</td>
<td>82.5</td>
<td>96.1</td>
<td>0.06</td>
<td>0.07</td>
<td>14.3</td>
<td>150±50</td>
<td>155.0±25.0</td>
<td>23.3±11.5</td>
</tr>
<tr>
<td>U.S. Atlantic</td>
<td>463 - 1962</td>
<td>4538</td>
<td>2407</td>
<td>55.91^</td>
<td>56^^</td>
<td>2.8±1.5</td>
<td>50.7</td>
<td>54.6</td>
<td>0.53</td>
<td>0.57</td>
<td>15000±5000</td>
<td>13.6±6^aaa</td>
<td>72.5±7.5^aaa</td>
<td>203.25±157</td>
</tr>
</tbody>
</table>

Comments:
- Average values and uncertainties in columns 12 and 13 are calculated from the range of values listed in Table DR3.
- Landslide scars in the Israeli margin were mapped and measured by Gadol (2015).
- Range of water depths includes the slope from the shelf-edge break to the trench axis (in convergent margins) and the rise in non-convergent margins. Bathymetry is unavailable from the uppermost slope of the Makran margin and the wide terrace at the base of the Queen Charlotte Fault margin.
- Mean slide thickness is the total slide volume divided by the total slide area.
- Calculated by dividing that part of the margin area covered by scars with a gradient >3° by the part of the margin area with a gradient >3°.
- Mean slide gradient is the sea floor gradient prior to failure, weighted to slide area. Sea floor gradient prior to failure is calculated by fitting a smooth surface that connects the tops of the slide scarp (see ten Brink et al., 2006; Chaytor et al., 2009 for more details).
- Approximate estimate because of the difficulty of associating scars with individual scars.
- Based on total area and volume for the entire U.S. Atlantic margin from Chaytor et al. (2009).
- Sedimentation rate for the Holocene.
- Sedimentation rate for the Pleistocene.

References cited:


### Table DR3

**DATA SOURCES FOR SEDIMENTATION RATE AND EARTHQUAKE RECURRENCE INTERVAL**

<table>
<thead>
<tr>
<th>Margin Name</th>
<th>Sedimentation Rate</th>
<th>Earthquake Recurrence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascadia</td>
<td>8.5-11 cm/kyr$^1$</td>
<td>500-600 yr$^{12}$</td>
</tr>
<tr>
<td>Guatemala – El Salvador</td>
<td>DSDP leg 84: hole 570; 13 cm/kyr$^2$ (Pleistocene); hole 567 (within a canyon) – 4 cm/kyr$^2$ (Pleistocene)</td>
<td>M7 – 41-50 yr$^{13}$, M7.5 – 40 yr$^{13}$; Northern Nicaragua and El Salvador west of 87°W$^{12}$: 63-91 yr; Guatemala 66-91$^{12}$</td>
</tr>
<tr>
<td>Israel</td>
<td>Northern part: 24.7 cm/kyr (last 14.8 kyr)$^3$; 29.4 cm/kyr (last 8.8 kyr)$^3$. Southern part: 24.1 (last 11.6 kyr)$^4$; 108 cm/kyr (last 3.7 kyr)$^5$</td>
<td>Recurrence is based on the following b-values: Log (N/yr) = 0.97*M+3.67 (Dead Sea Basin) and Log(N/yr) = 0.85M+2.36 (Northern Jordan Valley)$^{14}$. M7 every 1318 yr and 3890 yr, respectively.</td>
</tr>
<tr>
<td>Muertos Trough</td>
<td>Core 8: 2.2 cm/ky (last 11,810 yr)$^6$; Core 9: 6.4 cm/ky (last 10,610 yr)$^6$; Core 9: 5.11 cm/ky (last 30,500 yr)$^6$</td>
<td>Maximum displacement for reverse faults log (max. displ.) = -1.84+.29M$^{15}$ yields 1.55 m for M7 and 2.16 for M7.5. Assuming 50% coupling, the average displacement per earthquake is expected to be 3.1 m - 4.32 m. Estimated convergence rate across Muertos Trough is 1-3 mm/yr$^{16}$. Hence estimate recurrence interval is: 1855±1232.</td>
</tr>
<tr>
<td>Makran</td>
<td>Cores NIOP470 and NIOP471$^7$ are located within the multibeam bathymetry grid. An age of 8 kyr was identified and marked in these cores$^7$ by correlation with other dated cores outside the multibeam bathymetry grid. Measured graphically, the marked age is at 68% and 80% of the core length (550 cm and 940 cm respectively), yielding average sedimentation rates of 47 cm/kyr and 94 cm/kyr, respectively.</td>
<td>100-250 yr$^7$; 175 yr or longer$^{21}$</td>
</tr>
<tr>
<td>Nicaragua – northern Costa Rica</td>
<td>30-40 cm/kyr$^8$ (Holocene and latest Pleistocene) but with large variations. In detail: Hole M54 - 2 35 cm/kyr (between 15-25 kyr BP), and 13.3 cm/kyr (more recent); Hole M54-3 – 2.2 cm/kyr;</td>
<td>M7 – 53-68 yr$^{13}$; M7.5 – 51-99 yr$^{13}$; Northern Nicaragua – El Salvador west of 87°W: 63-91 yr$^{12}$</td>
</tr>
<tr>
<td>Location</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>SO173-18 - M66-178</td>
<td>~0 to 40,000 ¹⁴C yr BP in 3 cores within the fault valley⁹ (Vaughn Barrie, written. Comm., 8/24/2015)</td>
<td></td>
</tr>
<tr>
<td>N. Sumatra</td>
<td>Holocene: 180 cm/kyr¹, also 130-170 cm/kyr⁴</td>
<td></td>
</tr>
<tr>
<td>U.S. Atlantic margin</td>
<td>Holocene sedimentation rates¹⁰: Core 463-2PC 10.8 cm/kyr; Core 463-15PC - 7.6 cm/kyr; Core 463-16PC - 17 cm/kyr; Core 463-18PC - 9.3 cm/kyr; Core 463-19PC - 19.73 cm/kyr; Core 463-21PC - 11.23 cm/kyr</td>
<td></td>
</tr>
<tr>
<td>New England</td>
<td>Pleistocene sedimentation rate: Site 1073 (in open slope 60 km south of mapped polygon) &gt;65 cm/ky up to ~80 cm/ky¹¹;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landslides are dated at 10,000-20,000²⁰. If they were generated by earthquakes, then the last earthquake occurred 15,000±5000 yr ago.</td>
<td></td>
</tr>
</tbody>
</table>


Figure DR1a
Figure DR1b
Figure DR1c

Distance along margin (km)

Depth (m)

- Makran
- Cascadia N
- Cascadia S
- Muertos
- QCF
- Israel
- U.S.-SNE
- Sumatra
- Guatemala
- Nicaragua

0 20 40 60 80
Erosive
- N. Sumatra
- Guate-El Salvador
- Nicaragua
- Southern Cascadia
- Makran
- Queen Charlotte
- Israel

Accretionary
- Northern Cascadia
- U.S. Atlantic (Pleist.)
- U.S. Atlantic (Holocene)

Transform
- Passive
- Muertos

**Fig. DR2**

**Graph A**
- Scar fraction vs. Sedimentation rate (cm/k.y.)
- Parameters:
  - \( a = 7.096 \times 10^{-3} \pm 2.288 \times 10^{-5} \)
  - \( b = 0.9112 \pm 3.403 \times 10^{-2} \)
  - RMS(e) = 0.2460

- \( b = 0.5079 \)
- \( b = 0.3774 \)
- \( b = 1.152 \)

**Graph B**
- Scar fraction vs. Earthquake recurrence interval (yr)
- Parameters:
  - \( a = 4.526 \times 10^{-3} \pm 4.049 \times 10^{-5} \)
  - \( b = 0.4295 \pm 9.393 \times 10^{-2} \)
  - RMS(e) = 0.1328

- \( b = 0.7203 \)
- \( b = 0.1728 \)
- \( b = 0.3139 \)

**Graph C**
- Scar fraction vs. Sediment thickness per earthquake cycle (cm)
- Parameters:
  - \( a = 2.298 \times 10^{-2} \pm 6.736 \times 10^{-7} \)
  - \( b = 0.3382 \pm 2.758 \times 10^{-4} \)
  - RMS(e) = 0.1401

- \( b = 0.3879 \)
- \( b = 0.3139 \)
- \( b = 0.4069 \)
- \( b = 0.3774 \)