Passive margin earthquakes as indicators of intraplate deformation

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Seismicity of the North American Passive Margin

Repeatedly studied, yet intriguing questions remain.

Selected references:
Gutenberg & Richter, 1954
Hashizume, 1973
Stein et al., 1979; 1989
Basham & Adams, 1983
Adams & Basham, 1989
Schulte & Mooney, 2005
Mazzotti & Adams, 2005

1929 Grand Banks, $M_w=7.2$

1933 Baffin Bay, $M_w=7.4$
Formation of a Passive Margin

- Continental and oceanic crust part of same plate
- Local stresses can reactivate old rift faults
- Most sedimentation stresses relax quickly
- Deglaciation may be significant, particularly for North America
Global Passive Margin Seismicity
1344-2003

Data from Schulte & Mooney, 2005

Data from Schulte & Mooney, 2005
Can passive margin earthquakes generate large landslides and/or tsunamis?

Can large landslides occur without a seismic trigger?

Important for evaluating seismic & tsunami hazards

Part I

1929 Grand Banks, $M_w=7.2$

1933 Baffin Bay, $M_w=7.4$

Events from Schulte & Mooney (2005), ANSS, and Earthquakes Canada

1920-2009
How is passive margin seismicity linked to glacial isostatic adjustment (GIA)?

Sella et al., 2007

http://earthguide.ucsd.edu/
Grand Banks, 1929

- November 18, 1929; $M_w=7.2$
- Enormous ($\sim 100 \text{ km}^3$) submarine landslide cut trans-Atlantic telegraph cables
- Tsunami responsible for 27 deaths

*Earthquakes Canada; Hasegawa & Kanamori (1987)*
Grand Banks, 1929

<table>
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<th>Slope instability</th>
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Problem: limited data

Alternative approach: examine aftershocks
Aftershock Duration

• Rate-and-state friction theory predicts aftershock duration inversely proportional to fault loading rate

• Expect long aftershocks in Grand Banks area, if a tectonic earthquake

• Expect few aftershocks, if a landslide

Stein & Liu, 2009
Grand Banks
Seismicity 1929-1950

Mechanism and fault planes from Bent (1995); event data from Earthquakes Canada
Mechanism and fault planes from Bent (1995); event data from Earthquakes Canada

Grand Banks
Seismicity 1929-1959
Grand Banks
Seismicity 1929-1979

Mechanism and fault planes from Bent (1995); event data from Earthquakes Canada
Grand Banks
Seismicity 1929-2009

Mechanism and fault planes from Bent (1995); event data from Earthquakes Canada
Grand Banks Aftershocks

Seismicity looks like a decaying aftershock sequence

Compare to 1933 Baffin Bay earthquake
Baffin Bay
Seismicity 1933-1943

1933 $M_w=7.4$

Mechanism and fault plane from Bent (2002); event data from Earthquakes Canada
Baffin Bay
Seismicity 1933-1953

Mechanism and fault plane from Bent (2002); event data from Earthquakes Canada
Baffin Bay
Seismicity 1933-1963

Mechanism and fault plane from Bent (2002); event data from Earthquakes Canada
Baffin Bay
Seismicity 1933-1973

Mechanism and fault plane from Bent (2002); event data from Earthquakes Canada
Baffin Bay
Seismicity 1933-2009

Mechanism and fault plane from Bent (2002); event data from Earthquakes Canada
Aftershocks of both earthquakes continue for decades

• Can’t place an upper bound on aftershock duration until “background” level of seismicity can be resolved
• Difficult to resolve due to short observational window
Is GIA a major control on seismicity?

1920-2009

Events from Schulte & Mooney (2005), ANSS, and Earthquakes Canada

Vertical Velocities (GPS)

IGb00
1 5 mm/yr
+ve
-ve
Comparison of GPS vertical velocities and total moment release (1920-2009)

Moment release is notably higher along deglaciated portion of the margin.

1929 Grand Banks, $M_w=7.2$

1933 Baffin Bay, $M_w=7.4$

Relatively uniform catalog (EqCan + ANSS + Schulte & Mooney)

Shorter time span
Comparison of GPS vertical velocities and total moment release (1568-2003)

Moment release is higher in deglaciated region despite completeness issues.

1929 Grand Banks, $M_w=7.2$

1933 Baffin Bay, $M_w=7.4$

Longer time span, but less uniform catalog (Schulte & Mooney only)
Conclusions

• Both the 1929 Grand Banks and 1933 Baffin Bay events were followed by similar long aftershock sequences.

• Thus, the 1929 Grand Banks landslide was most likely triggered by a large tectonic earthquake.

• Correlation of moment release with GPS velocities suggests that GIA is a major influence on seismicity of the North American passive margin.
Future Work

• Compare North American passive margin to other deglaciated and nonglaciated passive margins

• Expand comparison of GIA and moment release to include continental earthquakes

• Draw more detailed comparisons with GPS data