Cratonic Earthquakes around the Crust-Mantle Transition, Western Canada

Brian Chen (1, 2), Simon Klemperer (1), Axel Wang (1)

(1) Stanford University (2) The Harker School; Emails: 23brianc@students.harker.org, sklemp@stanford.edu

Introduction/Methods

It is debated whether intraplate earthquakes occur below the Moho. Current knowledge of such earthquakes is from comparisons of independently determined earthquake depth and Moho depth. However, both measurements have significant uncertainties.

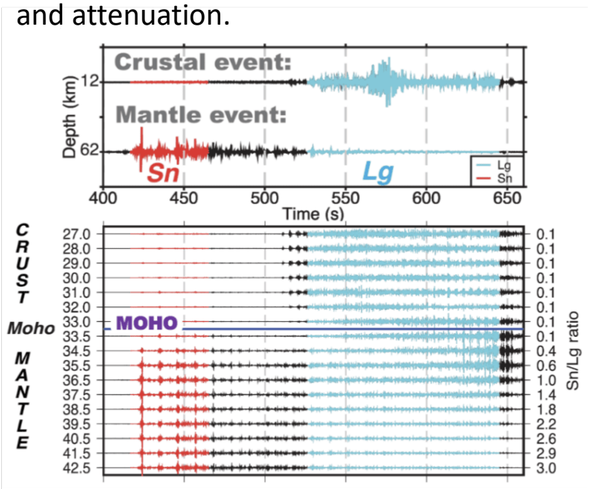
New Sn/Lg Method:

Sn waves: Seismic wave that travels principally below the Moho discontinuity; most strongly excited by earthquake sources below the Moho

Lg waves: Propagates principally by internal reflections within the crust; most strongly excited by earthquake sources above the Moho

(e.g. Barazangi et al. 1997)

Wang & Klemperer (2019, 2021) show that Sn/Lg is always stronger for mantle earthquakes than for crustal earthquakes, in both craton and active-tectonic wave speed models, and with variable focal mechanism and attenuation.

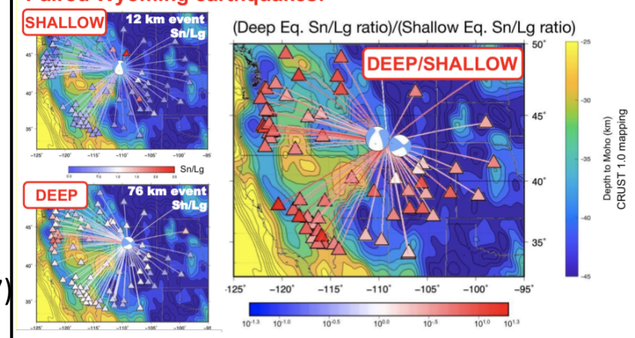


We calculated Sn and Lg amplitudes on the transverse component.

Wyoming Case Study

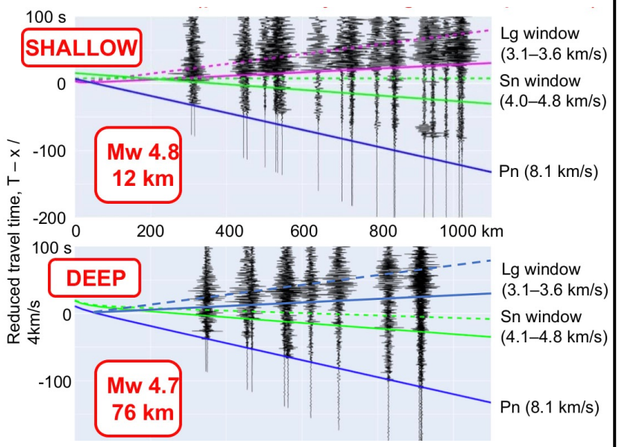
We measured Sn/Lg ratio for a well-known 4.8 m_b, 72 km-deep earthquake beneath the Moho in central Wyoming (Prieto et al. 2017), and compared to Sn/Lg for a shallow earthquake with same size and similar epicenter (O' Rourke et al. 2016).

Ray-paths over a crustal thickness map (Fig. 1)



Deep/Shallow "Ratio of ratios" > 1 at all common recording stations (i.e. Sn/Lg is aways larger for the sub-Moho event)

Record Sections (Fig. 2)

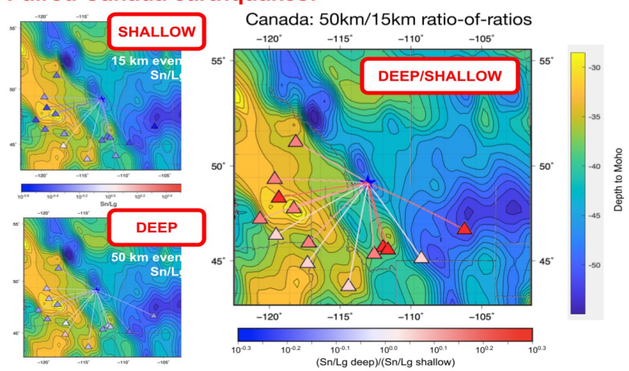


Sn energy is much more obvious for the deep earthquake than for the shallow earthquake. Lg is very high energy for the shallow earthquake.

Canada Study: New Mantle Eqs.

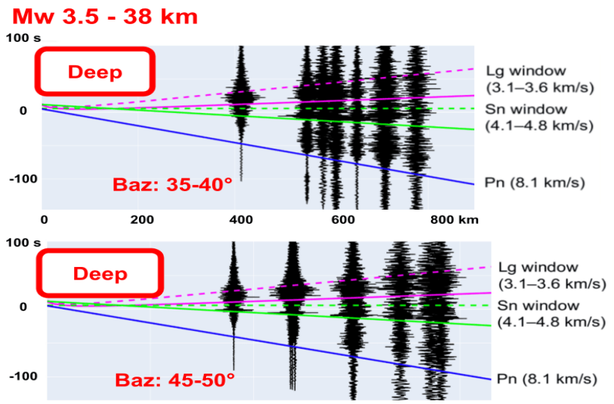
We study a 2005-2018 cluster of earthquakes m_b > 2.8 in the Canadian Rocky Mountain foreland close to the U.S. border. The cluster includes shallow earthquakes (5–25 km) and three with nominal hypocentral depths close to the Moho (30 km, 38 km, 50±10 km) in a region where Moho depth varies rapidly from ~42–49 km (Laske et al. 2017).

Ray-path Maps (Fig. 3): "50-km" event, 2.7 m_b



Ratio of ratios for 50-km/15-km is >1 at all common stations, suggesting the 50-km event is below the Moho.

Record Sections (Fig. 4): "38-km" event, 3.5 m_b



We see clear excitation of Sn energy for the 38-km earthquake.

Discussion

Discussion

The "50-km" event was recorded by 14 stations in common with a 15-km event with similar epicenter and magnitude (Fig. 3). The ratio-of-ratios map shows that for all common stations, the Sn/Lg amplitude ratio of the 50-km deep earthquake exceeds that of the 15-km crustal earthquake. This shows that the 50-km earthquake is exciting significant Sn energy, which suggests it is below the Moho.

We believe that the 50-km earthquake is a sub-Moho earthquake.

The 38-km event was well-recorded by a temporary array in Montana, but we have no shallow earthquake with similar epicenter recorded on the same stations, so instead we show record sections in two back-azimuthal sectors (Fig. 4). The selected record sections show that the 38-km deep earthquake has clear Sn Airy phases within the Sn window and relatively high Sn/Lg ratios strongly suggesting a sub-Moho earthquake. However, stations with Baz. 35-50° record energy traveling into a region of thinner crust, which may cause Lg waves to impinge on the Moho and convert into Sn waves.

The 38 km earthquake may well be a sub-Moho earthquake, but could be within a crust-mantle transition zone so close to the Moho as to experience Lg->Sn conversions which our Sn/Lg method has difficulty accounting for.

Conclusions

We suggest that the "50-km" and maybe the "38-km" earthquakes in Canada occurred in the upper mantle, because they preferentially excite Sn seismic waves.