RV SONNE
SO294 – CLOCKS

Northern Cascadia: Extent of locked zone, prism deformation, slip-to-toe, and the edge of subduction

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Vancouver (Canada) – Port Hueneme (USA)

5th Weekly Report
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After successful completion of the work in the Winona Basin on the Explorer Plate, we once again embarked upon the central continental slope of the Juan de Fuca Plate off Vancouver Island towards the end of our expedition. Here, a classic accretionary wedge has formed as a result of the subduction of the oceanic plate. This accretionary wedge consists of sediments which do not subduct together with the oceanic plate, but are compressed and pressed against the North American continent, such as if moved by a bulldozer. As part of our CLOCKS project, we are particularly interested in the deformation front, i.e. the westernmost part of the accretionary wedge, which is segmented in a very characteristic way. In contrast to other subduction zones where the deformation front does not change its shape much over hundreds of kilometers, here at the northern part of the Cascadia subduction zone, the front is broken into smaller segments. These individual segments are no longer than about 10 km and are distributed in a zig-zag geometric pattern (Figure 1). Understanding this and putting it in the context of the large subduction earthquakes is the goal of our work for the next 10 days.

Hereby, we will use reflection seismics with a small GI airgun (~355 in^3 or 7 L) and the multichannel channel streamer. We will also use refraction seismics with 12 ocean bottom seismometers (OBS) with the G-gun array (2860 in^3 or 45 L), and the heat flow probe.

At the beginning of the week, we briefly had to fight some adverse weather conditions and adapted our work to the strong wind and wave conditions. We first filled gaps in the seabed multibeam coverage with EM122 data, and expedited the deployment of the 12 OBS, which worked well even in force 8 winds.

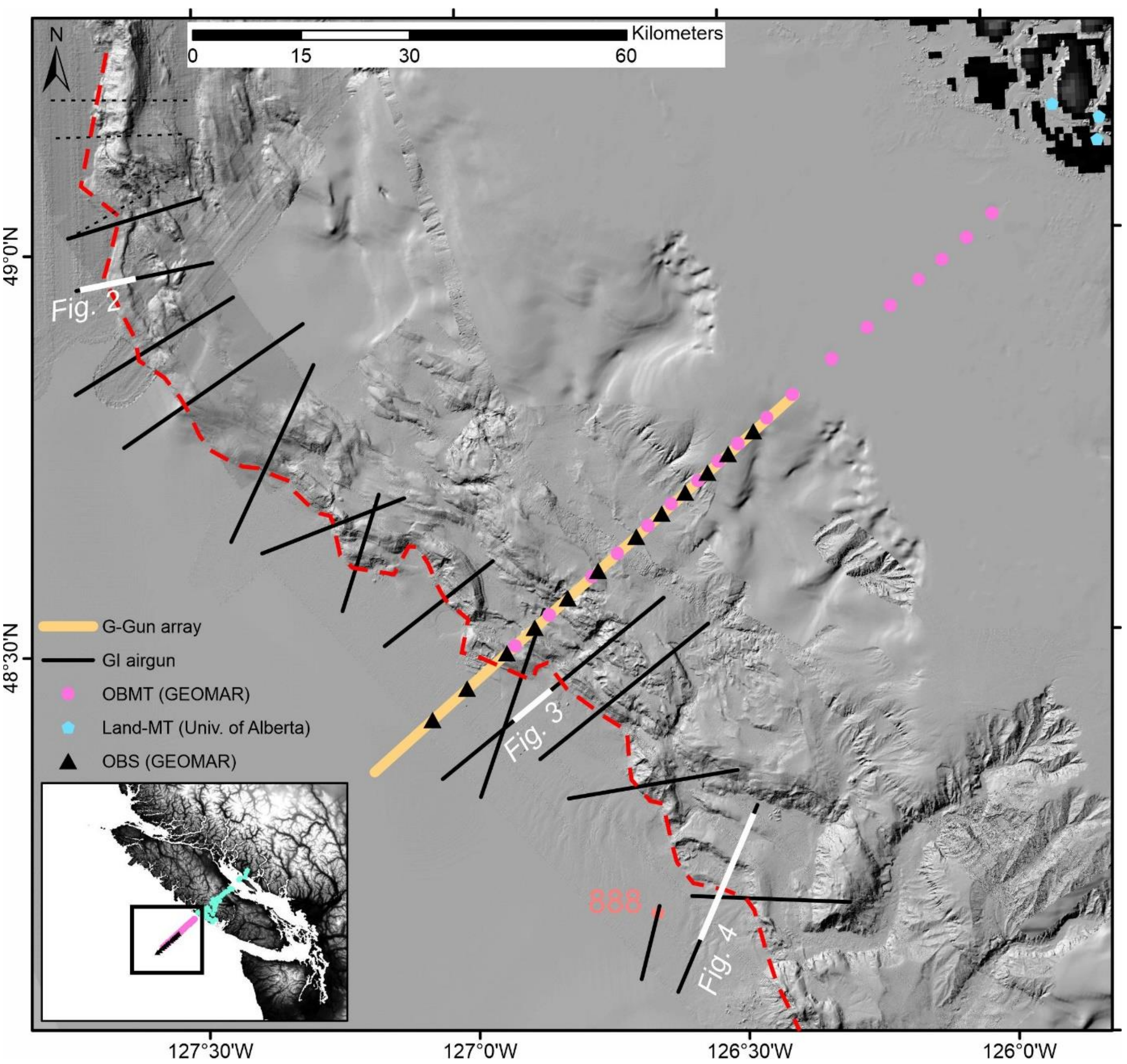
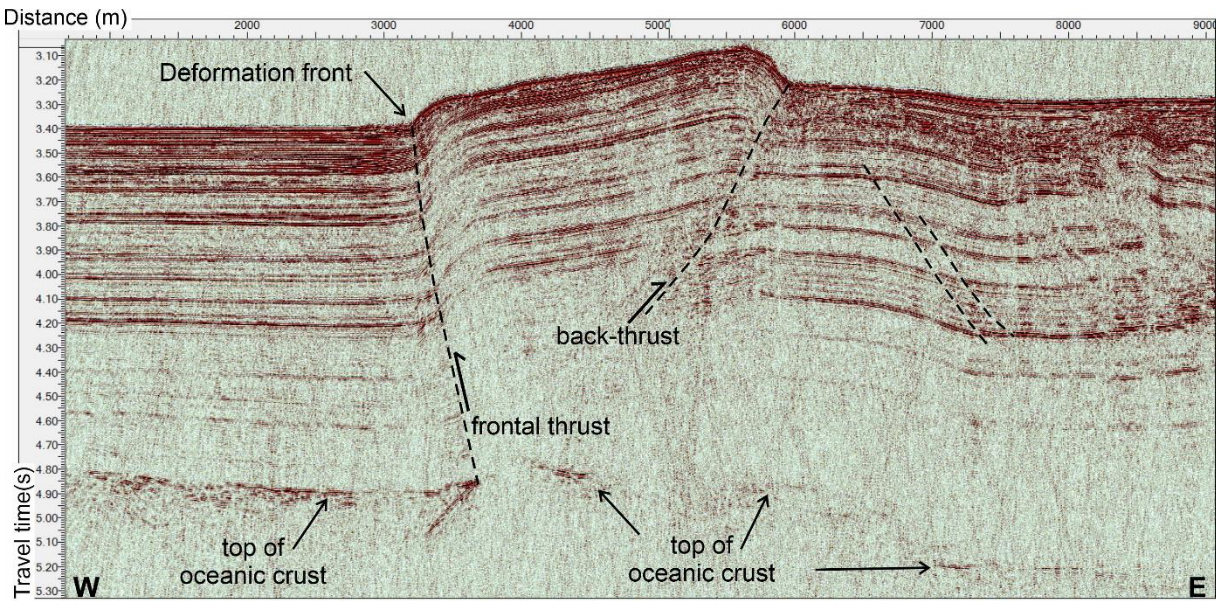


Figure 1: Seafloor image showing the segmented deformations front (red dashed line) at the northern continental Cascadia margin. The individual segments were imaged by our high-resolution seismic system (black lines) and the echosounder (PARASOUND). The northernmost lines (dashed black lines) were not acquired due to limited access to the region. One long seismic refraction profile consisting of 12 OBS follows the transect of the Ocean Bottom Magnetotelluric (MT) stations (marine and land). At the southern portion of our data acquisition, we ran one seismic line across Ocean Drilling Program borehole 888 for correlation of seismic to borehole data.

After the weather calmed down, we planned to start deploying the GI airgun, multi-channel streamer, and PAM system on Wednesday morning (October 12). However, we were prevented from accessing the northernmost part of our survey area (which is located in a military training area) by Canadian Navy activity, so we had to change our plans for mapping the deformation front at short notice. The two most northerly lines had to be dropped. Nevertheless, after almost 3 days of work until Friday afternoon (October 14), we completed a total of 14 profiles over the different segments of the deformation front. We also recorded a profile that overlaps well site 888 from Ocean Drilling Program (ODP) Leg 146. This gives us the opportunity to link our seismic data with the borehole information, and in particular providing the age estimates of prominent horizons.

Following this, we recovered the GI-airgun and deployed the G-gun array. With this array we recorded another refraction profile across the 12 OBS for just under 24 hours. This profile is used for the structural analyses of the subduction zone and dipping plate, and will be analyzed jointly with the MT data.

A first analysis of the multichannel seismic data acquired with the GI airgun shows a systematic change of faulting along the deformation front between the individual segments. Figure 2 shows line P6002 at the northern edge of the study area. Here, a landward dipping frontal thrust is seen, extending from the seafloor to the upper oceanic crust. A very different fault structure can be identified on line P6009 (Figure 3). Here, a seaward dipping thrust leads to an uplift of the first deformation-ridge without a fault breaching the seafloor at the actual deformation front. Instead, many crisscrossing faults are seen within a 6 km long section west of the ridge. At the southern edge of the working area, faults of a completely different style are visible (Figure 4). Three staggered, seaward-dipping thrusts are visible here. The frontal thrust is covered with sediment though. The nearby borehole Site 888 will provide us with information about which sediment packages of which age are involved.



<u>Figure 2:</u> Example of a seismic section at the northern part of the working area with strongly pronounced frontal thrust, recorded with the GI airgun and our multichannel streamer (for location see Fig. 1, processing: Elisa Klein).

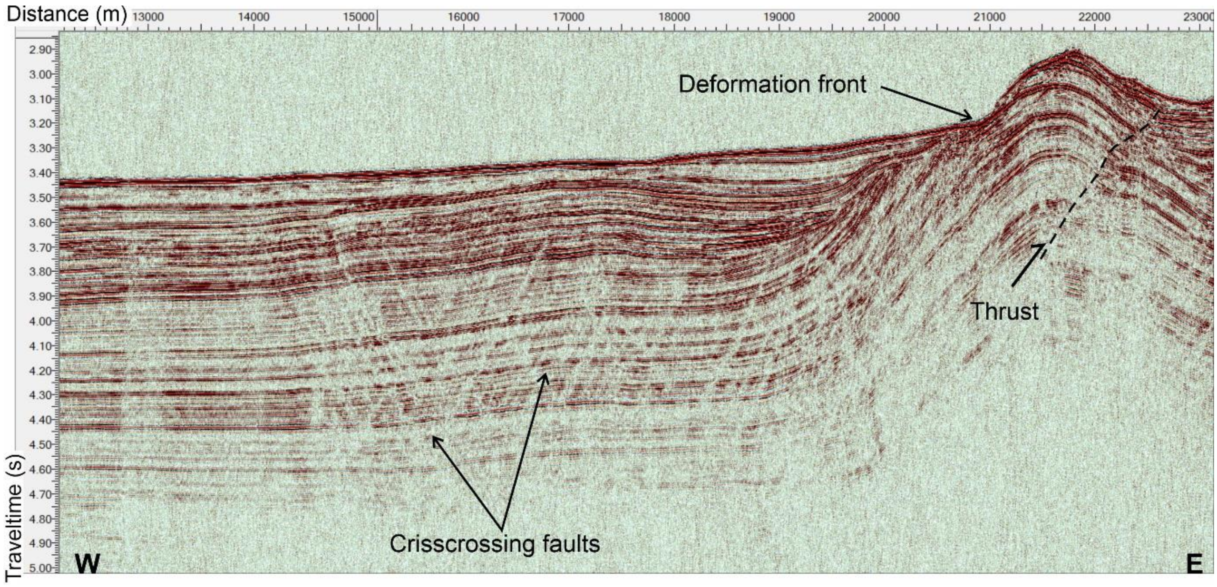


Figure 3: Example of a seismic section with clearly pronounced, crisscrossing proto-faults, west of the deformation front. A seaward dipping thrust is visible at the eastern end of the seismic section. (Location see Fig. 1, Processing: Elisa Klein).

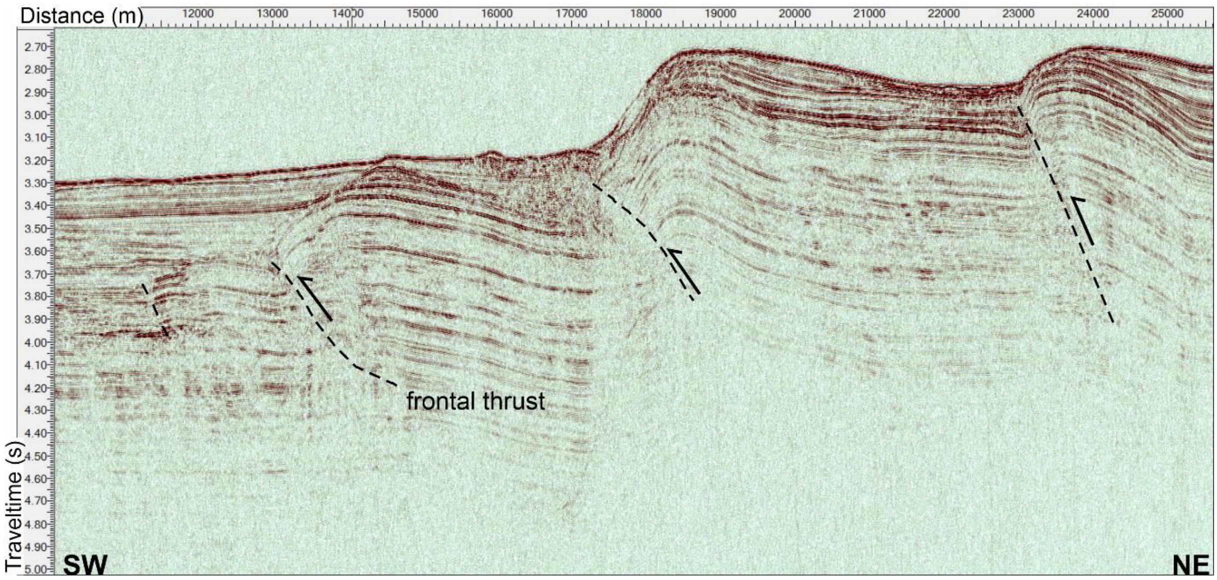


Figure 4. Example of a seismic section recorded with the GI airgun and our multi-channel streamer at the southern end of our working area with three landward dipping thrusts (location see Fig. 1, processing: Elisa Klein). The frontal thrust is sediment covered.

After detailed processing, the new bathymetric data recorded earlier this week also had a big surprise in store for us: a previously unknown strike-slip fault extends for at least 30 km in a north-south direction in the approx. 20 km wide basin east of the first three deformation ridges (Figure 5). The new bathymetric data show that the fault contains small basins (Figure 6a), similar to the structures we saw a few weeks ago along the Nootka Transform Fault. These small basins are up to 10 m deep and our echo sounder data (PARASOUND) also show a vertical offset of about 3 m at the fault trace (Figure 6b). The role of this strike slip fault in the overall deformation of the accretionary wedge is completely unknown so far and will certainly keep us busy for a while.

As we still have slight data gaps in the bathymetry in the area of the fault, we will try to better map this fault and fill the gaps in the next week, and also collect more sediment echo sounder data. So, it remains exciting!

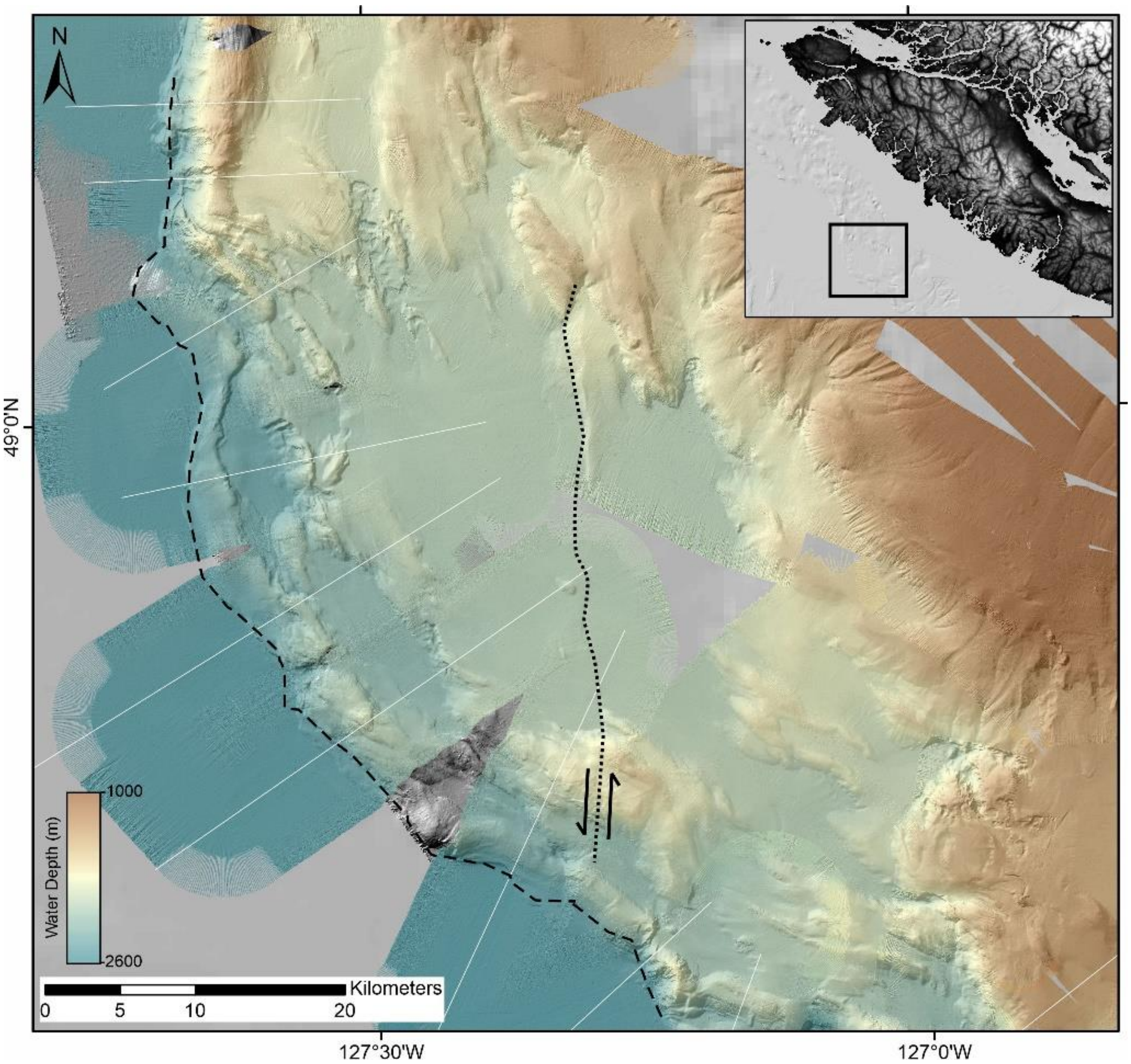
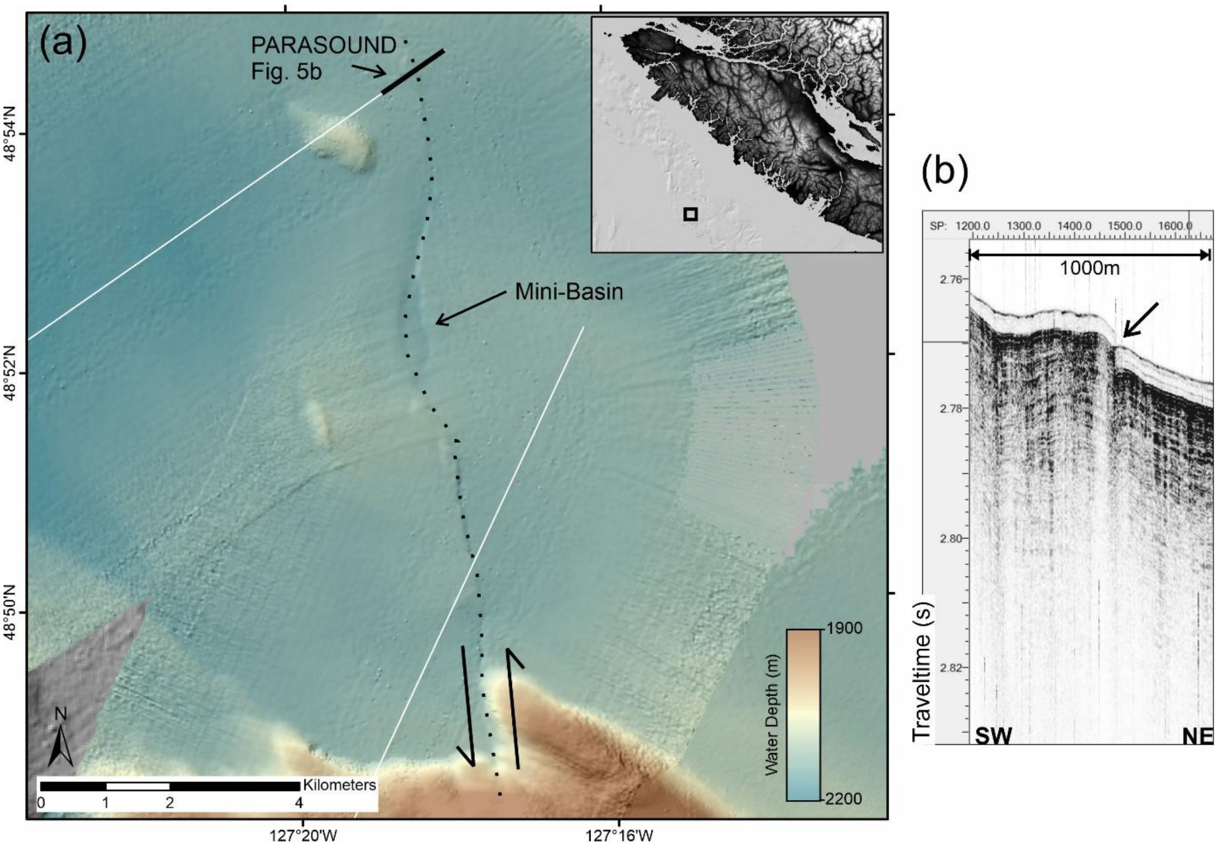


Figure 5: Extent of the strike-slip fault east of the deformation front (Map: Karen Douglas, Ingo Klaucke, Michael Riedel).

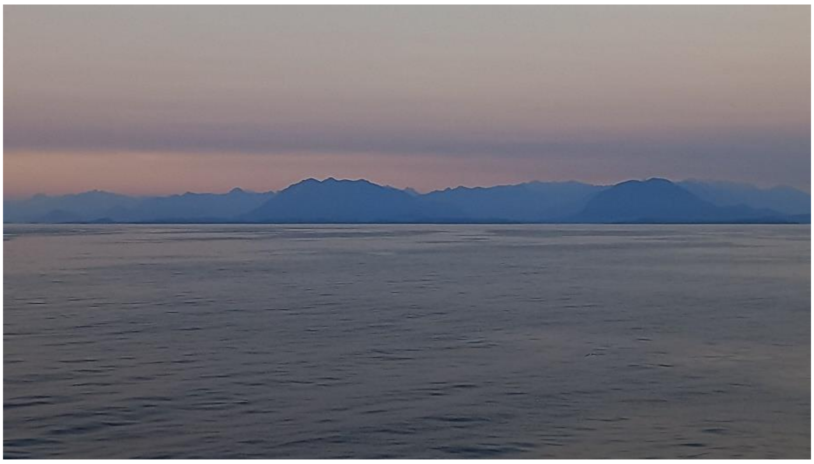


<u>Figure 6:</u> (a) Detailed image of the seabed morphology along the strike-slip fault with a pronounced mini-basin (ca. 10 m deep). (b) Section of the sediment echo sounder (PARASOUND) profile showing a vertical offset in the sediments of about 3 m at the fault trace (black arrow). (Map and echo sounder image: Karen Douglas, Ingo Klaucke, Michael Riedel).

But first, we have to be patient and recover our 30 remaining instruments from the seabed. The procedure for recovering the OBMT and OBS devices began on Saturday evening (October 15) after a successful end to the seismic work, and will keep us busy until early next week. During a brief moment to pause and celebrate the end of the seismic data acquisition on the evening of October 15, we were able to enjoy a magnificent sunset in almost completely calm seas (Figure 7a). Looking east gave us a beautiful view of Vancouver Island near Tofino, BC (Figure 7b).

<u>Figure 7a:</u> After the seismic survey was completed, we were treated to a picturesque sunset on the evening of October 15. (Photo: Michael Riedel).

<u>Figure 7b:</u> Looking east at the same time offered a view of beautiful Vancouver Island near Tofino, BC (Photo: Michael Riedel).



All on board are well and send greetings home.

Michael Riedel (on behalf of all participants of Expedition CLOCKS)

(GEOMAR Helmholtz Center for Ocean Research Kiel)