RV SONNE
SO294 – CLOCKS

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

13. September – 27. October 2022
Vancouver (Canada) – San Diego (USA)

3rd Weekly Report
(26.09. - 02.10.2022)

The third week at sea began with our first intensive sediment sampling program. After the first successful use of the gravity core the day before (Sunday, 25 September), we now wanted to investigate a submarine slope failure in more detail.

One of the goals of expedition SO294-CLOCKS is to find out whether large subduction earthquakes also occur on the Explorer Plate and, if so, how often. We know from previous studies that during these large earthquakes, sediments on the continental slope start to slide. These events can be distinguished as characteristic deposits from normal background sediment, for example by increased grain sizes. For the Juan de Fuca plate, a total of 12 such deposits have been previously identified at a prominent slope failure by piston coring, with the oldest of these layers being about 10,800 years old (Hamilton et al., 2015). Thus, a recurrence rate for the major subduction earthquakes of the Juan de Fuca Plate of 460 +/- 140 years has been determined, which is in line with older studies on the Cascadia subduction zone along the coast off Oregon and Washington (Atwater & Griggs, 2012). Therefore, we want to use the same approach to investigate landslides in the Winona Basin, an area which has not yet been investigated in this way. After a thorough bathymetric survey, we have identified up to 20 landslides. Only four of the slides seem to be more recent, as the angular landslide masses are still visible in the bathymetry as a rough seafloor (Figure 1). We chose a slide with distinct blocks for sampling and imaged it acoustically with a sediment sub bottom profiler, the PARASOUND system onboard (Figure 2). The sediment layers are partly seen down to a depth of 70 m below the seafloor. They show an upper veneer of sediment which is acoustically not very reflective and probably belongs to the Holocene (< 14,000 years). Therefore, our gravity coring with 5-metre penetration will only sample this youngest layer, which can be then compared with previous studies further to the South. Deeper landslide masses, which are clearly visible in the profile, will not be accessible with our gravity coring. Dating of the three cores taken will be done later after further measurements have been taken in the laboratory of the Geological Survey of Canada in Sidney, BC.

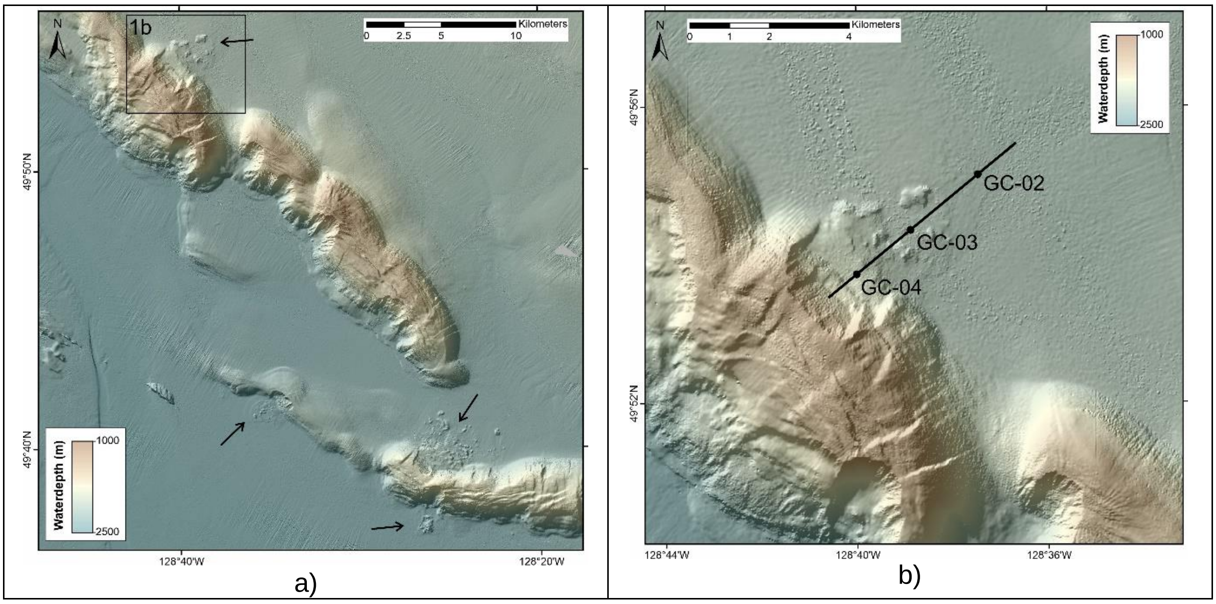

Figure 1: a) Bathymetry showing landslides in the Winona Basin, four of which are suitable targets for sediment sampling as recent deposits are still visible on the seabed (black arrows). b) Detailed map of a landslide with position of gravity cores and location of the sub bottom profiler data (Fig. 2).

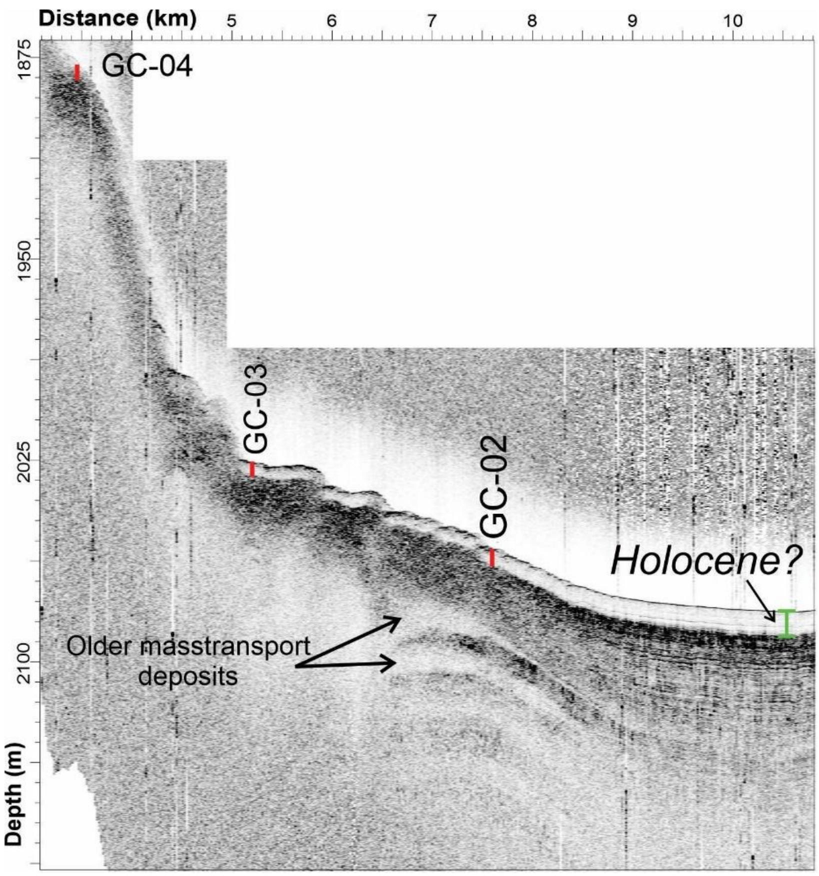

Figure 2: Sediment sub bottom profiler data across a landslide (Fig. 1b) and positions of gravity cores (GC-02, -03, -04). At least two older, deeper landslide masses can be identified, which are overlain by layered sediments. Our sampling with a maximum of 5 meter penetration is likely to have penetrated only Holocene sediments. Age determinations will be made later to test this hypothesis and interpretation.

References:

Atwater, B. F., and Griggs, G. B. 2012. Deep Sea Turbidites as Guides to Holocene Earthquake History at the Cascadia Subduction Zone – Alternative Views for a Seismic-Hazard Workshop, United States Geological Survey Open File Report 2012-1043: 58 p.

Hamilton, T.S., Enkin, R.J., Riedel, M., Rogers, G.C., Pohlman, J.W., Benway, H.M., 2015. Slipstream: an early Holocene slump and turbidite record from the frontal ridge of the Cascadia accretionary wedge off western Canada and paleo seismic implications, Canadian Journal of Earth Sciences, 52, 405-430.

On Tuesday, September 27th, we started deploying 20 ocean bottom seismometers (OBS) along 2 profiles across the Winona Basin. Having surveyed the area with our multibeam systems, some initially planned stations had to be moved a bit to avoid overly steep slopes along canyons. Although we quickly finished deploying the OBS instruments, we were not able to start seismic work immediately because of strong winds. With wind force 6 and gusts up to force 8, it was too dangerous to deploy the air guns. Thus, we extended our bathymetric mapping until the wind and the swell had died down. By 4pm on Wednesday, September 28th, things had calmed down sufficiently for us to deploy the airgun array, streamer, and Passive Acoustic Monitoring (PAM) system - just in time to be compliant with marine mammal protection rules demanding a pre-airgun visual survey of 1 hour, as sunlight was already diminishing. This time we did a slower ramp-up of the airgun array up to the maximum volume (45 L) lasting just over 1 hour. We did this as we first had to move far enough away from a protection zone to the west of our working area so that the sound emitted by the guns would be below the threshold of 160 dB in the protection zone.

After 1.5 days, we had successfully completed the refraction profiles for the OBS. We even had time to run a cross profile, which provides additional information about the depth of the oceanic crust. Although the refraction profiles are mainly analyzed with the OBS, we also recorded the reflections with our approximately 300 m long streamer (Figure 3).

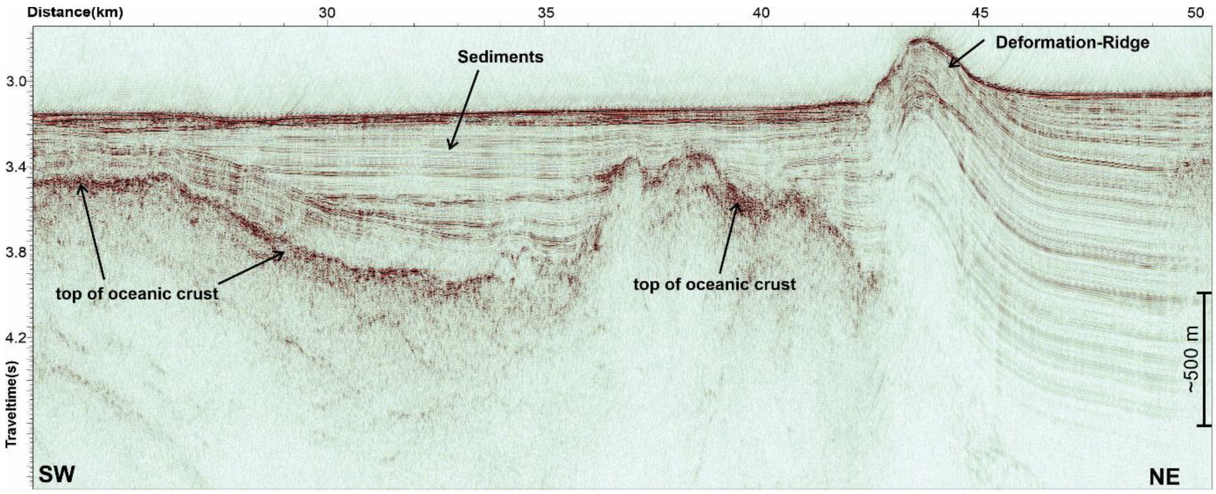

Figure 3: Seismic reflection image along the southeast profile P2000 with clearly visible reflection from the upper oceanic crust, thick sedimentary overburden, and a deformation ridge in the Winona Basin.

We aim to better understand the deformation of the Winona Basin and the change from subduction of the Juan de Fuca and Explorer plates to the Queen Charlotte Transform fault further north. To do this, we are recording higher resolution seismic reflection data with a single GI airgun (7L volume) and our streamer in addition to the refraction profiles. For this purpose, we briefly interrupted the seismic work on the afternoon of September 30th and retrieved the airgun array and deployed a single GI airgun. This was followed by minor maintenance work on the streamer and the PAM system, but after less than 2 hours, all equipment was fully operational again, and we continued with data acquisition. The seismic data we recorded with the streamer show the deformations, faults and folds in the sediment in great detail that occur due to the complex tectonic stresses in the Winona Basin (Figure 4).

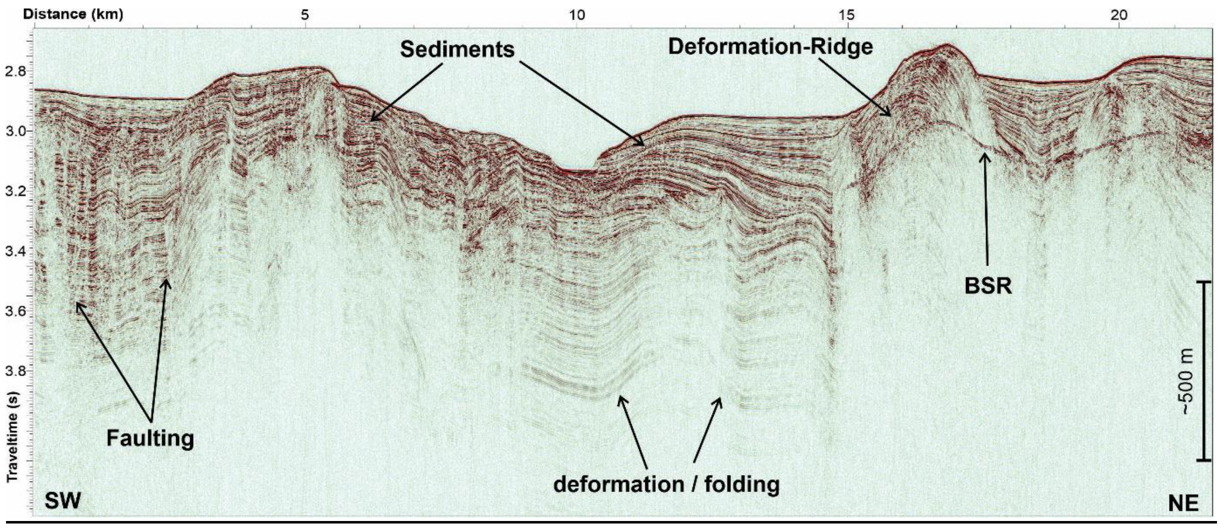

Figure 4: Reflection seismic image of profile P4000 recorded with a GI airgun (volume 7 L) and the streamer. Although this smaller signal source only allows the sound to penetrate to about 800 m below the seabed, it increases the vertical resolution compared to the larger airgun array. Along this line, we identified various fault systems and folds and also a so-called "BSR" (Bottom Simulating Reflector), which marks the lower limit of the gas hydrate stability zone.

The eight marine mammal observers on board work continuously around the clock, to listen for and keep a lookout for marine mammals and other endangered species while we are doing seismic surveying. In case a mammal or endangered species comes too close to the ship, all acoustic sources have to be shut down immediately. To improve the detection of mammals, especially whales, we also use the infrared camera, which often clearly detects the warm exhaled air of whales (Figure 5).

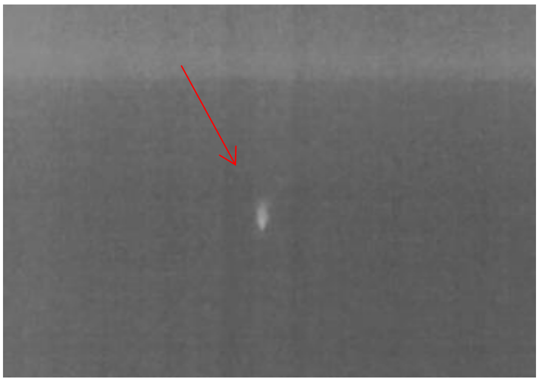

Figure 5: Infrared image of a blow from a fin whale (Photo: Toyon Research Corporation).

During the third week, numerous marine mammals and other wildlife were seen. These species included fin whales (Figure 6), the second largest whale only to the blue whale, northern right whale dolphins (Figure 7a), Pacific white-sided dolphins (Figure 7b), ocean sunfish (*Mola mola*, Figure 8), Steller sea lions (Figure 9), and several species of birds including the Laysan Albatross (Figure 10), and the raptor visitor, Peregrine falcon (Figure 11).

While fewer animals were seen this week compared to the previous week, the marine mammal and wildlife sightings did not disappoint. Last week, several dark porpoising animals with no dorsal fin were observed far off in the distance, and the observers were not sure what to make of these, simply referring to this sighting as the mystery of the “flying blob”.

Upon further research, photo review, and a closer sighting (top photo in Figure 7), the marine mammal observers confirmed that the distant “flying blobs” were northern right whale dolphins, which can be easily confused with sea lions or fur seals when seen at a distance because of their similar body shape, colour, and behaviour. Northern right whale dolphins are often seen with Pacific white sided dolphins, as was the case this week when this mixed group of dolphins approached the vessel. Another interesting observation in the offshore reaches of the survey area was a single Steller sea lion (Figure 9) that swam up to the vessel, displaying some acrobatic behaviour. Although this non-migratory species can be seen far from shore at times, it is typically found closer to shore.

(a) (b)

Figure 6: (a) Photograph of a fin whale (Balaenoptera physalus) with typical dorsal fin, taken at a greater distance from the ship (photo: April Houweling) and (b) fin whale with expelled breath (photo: Magena Warrior).

Figure 7: Two examples of dolphin species sighted. Top: Northern right whale dolphin (Lissodelphis borealis), Bottom: Pacific white-sided dolphin (Lagenorhynchus obliquidens) (Photos: Bruce Mactavish).

Figure 8: School of seven sun fish (Mola Mola), which are called Moonfish in German (Photo: Bruce Mactavish).

(a) (b)

Figure 9: Photos of Steller Sea Lion (Eumetopias jubatus) (photo: Magena Warrior).

Figure 10: Laysan Albatross (Phoebastria immutabilis) (Photo: Bruce Mactavish).

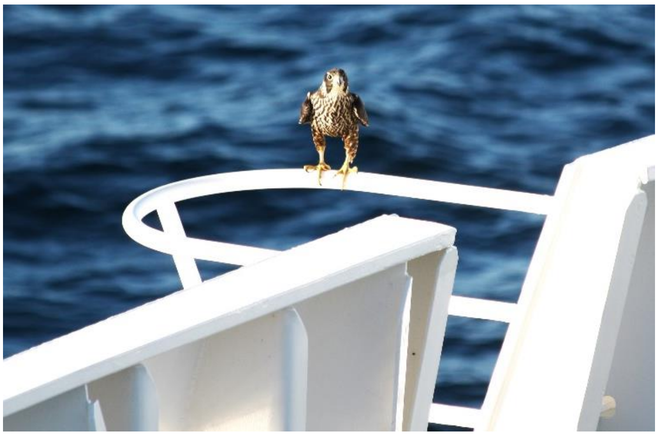

Figure 11: A falcon joined the RV FS SONNE (Photo: Magena Warrior)

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)