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)

2nd Weekly report
(19.09. – 25.09.2022)

After successfully deploying the long-term instruments in the southern part of the working area off Vancouver Island, we started a nearly 50 nautical mile transit out to the Juan de Fuca Plate, where we started the work on the *Cascadia-CO2* secondary user proposal by Dr. Jörg Bialas (GEOMAR) in collaboration with Ocean Networks Canada (Dr. Martin Scherwath). Although the *Cascadia-CO2* experiment requires only about 4 working days, it is logistically challenging with the deployment of over 20 ocean bottom seismometers, the airgun array, a streamer, and the PAM system for acoustic monitoring. We have decided to implement these 4 working days already at the beginning of cruise SO294, as an optimal weather window has just presented itself, and at the same time we have not yet been given the opportunity to work in the Northern Region off Brooks peninsula due to restrictions imposed by fishing industry.

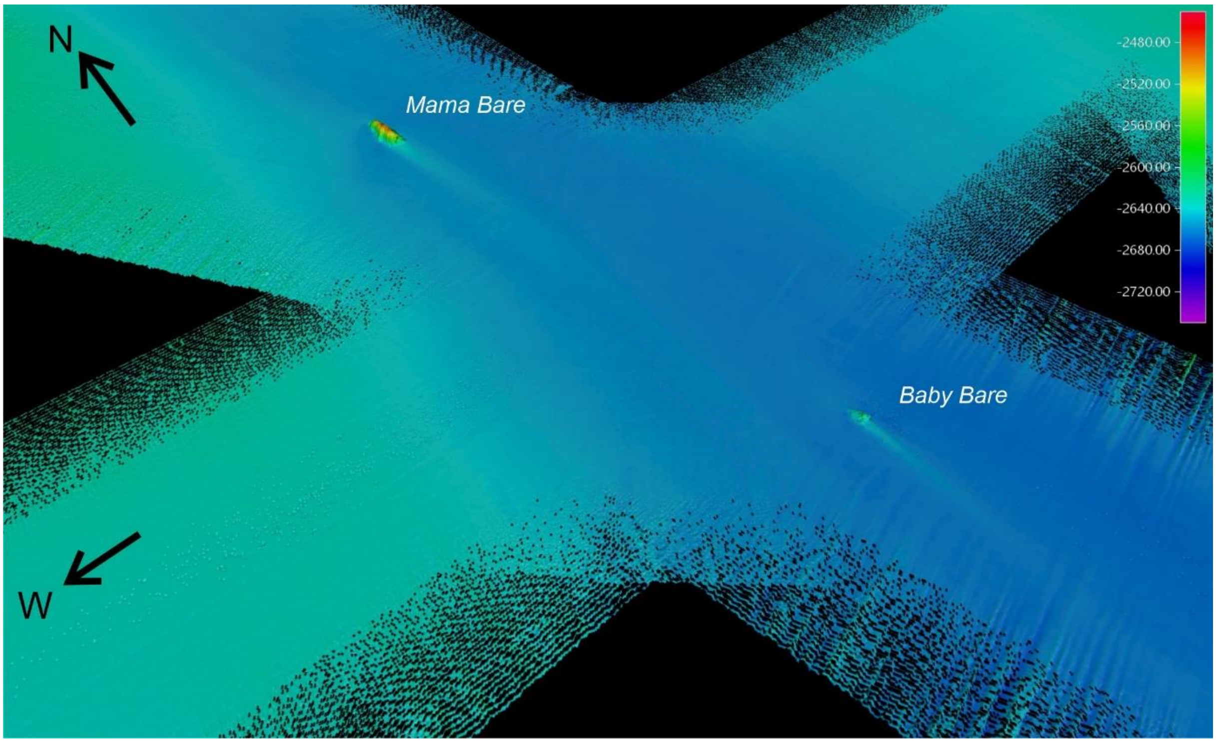

Figure 1: Perspective view of the seabed in the area of the Cascadia-CO2 experiment with the two seamounts Mama Bare and Baby Bare (naming of the seamounts see https://vents-data.interridge.org/; image credit: Karen Douglas, GSC)

The *Cascaida-CO2* experiment is one building block in a larger collaborative project with the long-term goal of storing CO_2 in the subsurface of the oceanic Juan de Fuca plate. Our work during SO294 will provide additional seismic data that can be used to describe the physical properties of the basaltic crust on the Juan de Fuca plate and its potential CO_2 storage capacity. During the transit to the first OBS deployment station, we mapped a smaller seamount (also known as "Mama Bare", Figure 1) and decided to shorten the OBS deployment somewhat, and not deploy equipment near the prominent flanks of the seamount.

The deployment of the 22 OBS took about 12 hours and we positioned the vessel in the early afternoon of Tuesday, September 20, to a spot and route that allowed the safe deployment of the seismic equipment. First, the airgun array went into the water and then the streamer, which records the reflection data. The streamer is about 300 m long and contains 184 channels spaced 1.65 m apart. Finally, the PAM equipment was launched and after less than 2.5 hours we were ready to start the seismic survey.

During the deployment of the equipment, the marine mammal observers continuously scanned the area around the vessel for any marine life present. After 15 minutes of additional checking on the PAM system and no acoustic detection of any marine mammal within the exclusion zone, we began to gradually ramp up the airgun array to maximum power. This process is to ensure that the marine mammals are not immediately exposed to the maximum volume of our sound waves. After 20 minutes we were ready to start the profile, which lasted through the night until 08:00 in the morning. The seismic reflection data (Figure 2) show a strongly varying depth of the oceanic crust, which is covered with sediments of an average thickness of 250 m.

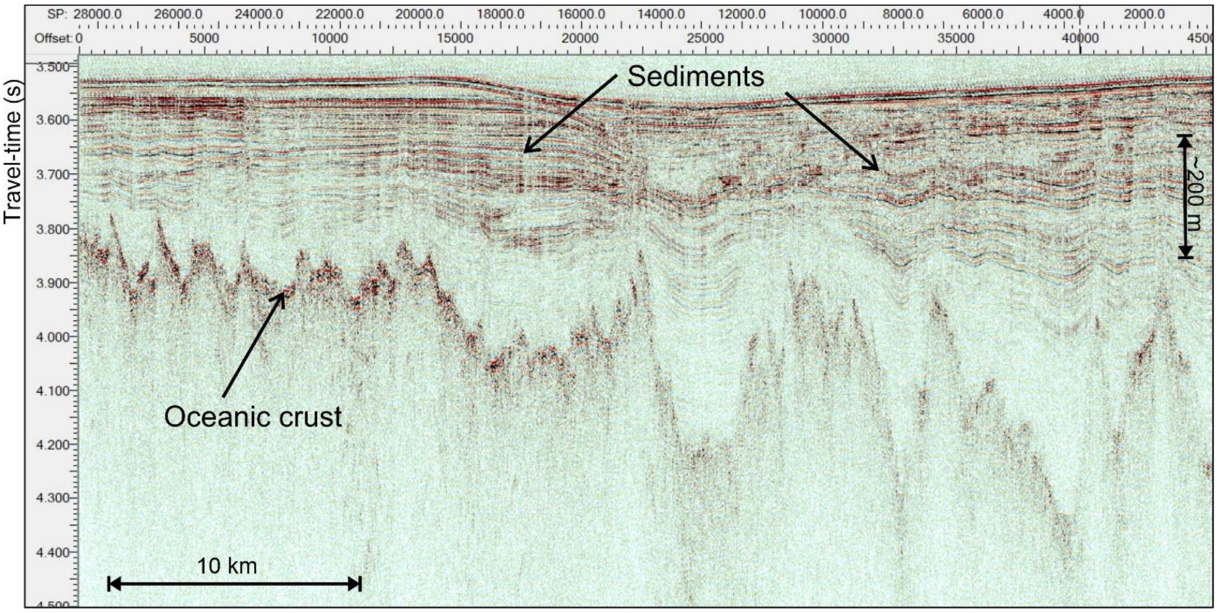

Figure 2: Seismic reflection profile P2 of the Cascadia-CO2 experiment with sediment layers above the reflection from the oceanic crust (image credit: Elisa Klein & Michael Riedel, GEOMAR).

The recovery of the equipment went smoothly as the weather continued to be very good with little wind and only light swell. Afterwards, we started to collect the OBSs from the seabed. Everyone was curious to see if all 22 instruments would surface again, as the water depth of 2640 m is not to be underestimated and it took an average of 45 minutes for an OBS to get from the seabed to the surface. Instrument by instrument we worked our way through the two profiles, and after about 26 hours all the OBS were back on deck, much to the delight and relief of all the participants.

Once all the equipment was on deck and the pressure tubes were secured with the recording equipment in the lab, we set off on a transit north to the Nootka fault, which is the tectonic boundary between the Juan de Fuca plate and the Explorer plate. The Nootka fault is a transform fault with a left-lateral sense of motion and has a mean displacement rate of 3 cm per year (averaged over several million years). The Nootka fault consists of several sub-segments with different orientations (Figure 3). At the eastern end of the fault are two mud volcanoes: "Maquinna", which resembles a donut, and "Haggis", which is flatter and pancake-shaped. Midway through SO294, we will also survey this fault with multichannel seismic and complete the mapping. At present, many new details can be seen in the new multibeam bathymetry and PARASOUND data that were not resolved in the older data.

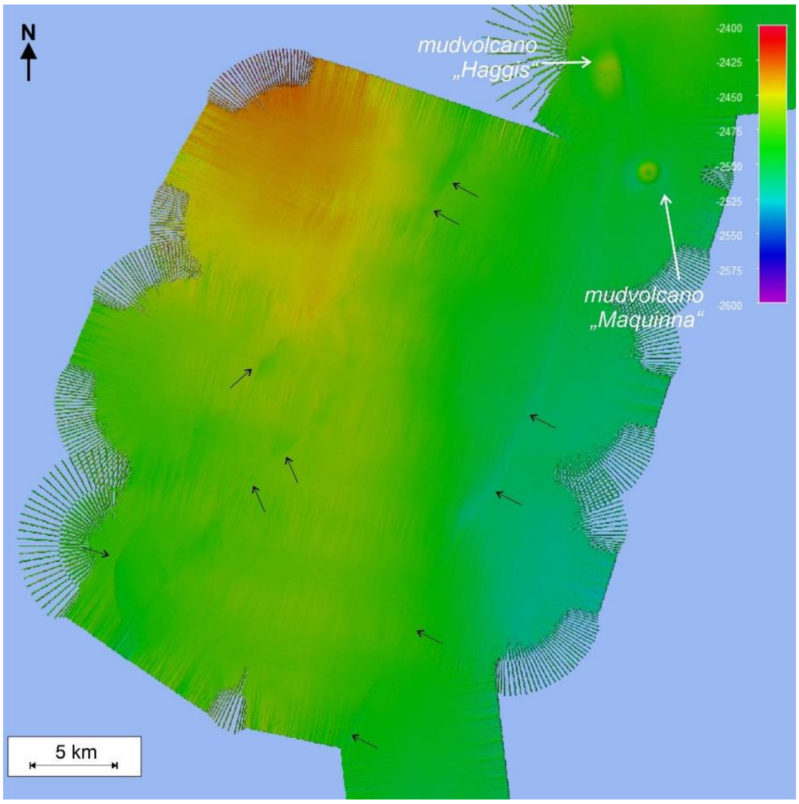

Figure 3: Nootka Fault zone and mud volcanoes (image: Karen Douglas, GSC).

On September 22nd, we started to deploy OBSs again for long-term earthquake monitoring. Alternating between daytime OBS deployment and nighttime mapping with the multibeam and PARASOUND systems, we obtained a first very detailed bathymetric map of the northern working area in the Winona Basin of the Explorer Plate after about 3 days. The bathymetric map shows several landslides (Figure 4) which are possibly caused by the large subduction earthquakes.

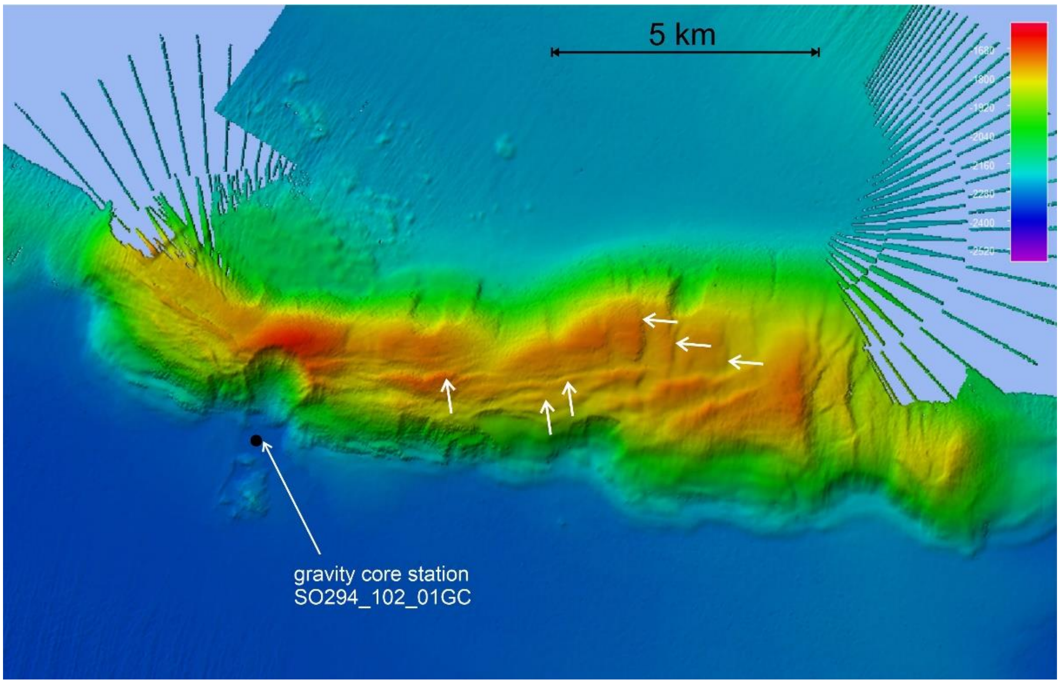

Figure 4: Bathymetric map of a ridge in the Winona Basin showing a prominent landslide (shell-shaped head scarp). A gravity core was taken at the base of the ridge in a small depression. Also note prominent lineations in two directions across the ridge indicated by white arrows (image: Karen Douglas, GSC).

After a short, but efficient detailed mapping of one of these slides, we deployed a gravity corer for the first time during SO294 on Saturday September 24 (Figure 5) to sample the top 5 metres of sediment. We hope to obtain evidence of deposits from which to determine the recurrence rate of the large earthquakes, a method that has been used very successfully several times for the Juan de Fuca Plate, but never before on the Explorer Plate. After successful retrieval of the corer back on deck, the core was cut into 1 m long segments on deck.

The segments were then sampled in the laboratory with so-called rhizones (Figure 6), which gives us clues about the chemical composition of the pore water. The analysis of the pore water will be carried out later in our laboratories at GEOMAR in Kiel, which is why our main focus is on collecting the pore water samples only. The cores are not processed further on board but kept in cold storage, and later analyzed in detail in the sediment laboratory at the Geological Survey of Canada in Sidney, BC. Delayed processing has no negative impact on the further analysis of sediment layers from mass-wasting events and their age dating, as well as measurements of physical properties of the sediments. Unfortunately, our capacity on board for a complete core description and analysis is limited.

(a) (b)

Figure 5: (a) Use of the gravity corer at Station SO294_102_01GC. (b) Picture on deck during core recovery; left: Lea Rohde, GEOMAR, right: Wanda Schmitz, Univ. Hamburg (Photo: Sarah-Marie Kröger, Univ. Kiel).

Figure 6: Photograph taken during sampling of the core segments with rhizones in the laboratory onboard SONNE (Photo: Sarah-Marie Kröger, Univ. Kiel)

On Sunday evening, the last four of the 26 OBSs were deployed for long-term earthquake monitoring. We will recover these devices in August 2023 with a Canadian Coast Guard vessel.

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)