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)

1st Weekly Report
(12.09. – 18.09.2022)

All 31 participants of expedition SO294 – CLOCKS arrived at the harbour and berth of the SONNE on Monday, September 12th in Vancouver. All scientists boarded the ship after successfully completing the (negative) COVID test and immediately began with the preparations for the cruise.

The aim of the SO294 - CLOCKS cruise is to investigate subduction earthquakes using the Cascadia continental margin off Vancouver Island as an example. Earthquakes at subduction zones with magnitudes M>8.5 are among the most hazardous earthquakes worldwide. The Cascadia subduction zone is one of the regions for which such an earthquake is expected in the near future. Despite decades of intensive research, many questions remain about the behaviour of the Cascadia seismogenic zone off Vancouver Island and important details about the tectonic structure along the deformation front have not yet been explored. The focus of SO294 is to determine the boundary of the seismogenic zone, especially the seaward limit. For this purpose, seismic data are used together with bathymetric data to map the deformation structure and fragmentation of the deformation front. Thermal data are combined with seismic methods to determine the temperature at the plate boundary and associated drainage processes. Magnetotelluric data along an approximately 230 km long amphibious profile will be acquired to determine the extent of this fault surface and fluid accumulations at the lower limit of the seismogenic zone. All of these data will help to determine whether the seismogenic zone has ruptured to the base of the accretionary wedge during previous earthquakes. This will not only make it possible to better isolate geohazards from such subduction earthquakes off Cascadia, but also improve estimates of the tsunami hazard. The work builds on an excellent collaboration with the Geological Survey of Canada, the University of Alberta, the Japan Agency of Marine-Earth Science & Technology (JAMSTEC), Kobe University, University of Tokyo, and Ocean Networks Canada (ONC).

The cruise officially began (02:00 PDT) on September 13th, when the SONNE departed Vancouver Harbour, providing a magnificent view of the Vancouver skyline at night (Figure 1).

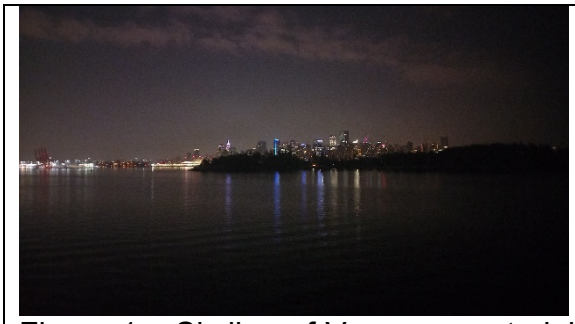

Figure 1a: Skyline of Vancouver at night (photo-credit: Michael Riedel, GEOMAR)

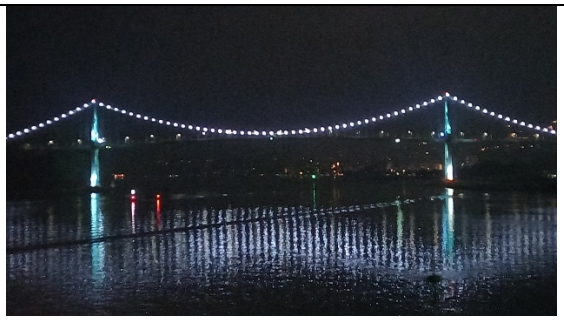

Figure 1b: Lions-Gate Bridge at night, (photo-credit: Michael Riedel, GEOMAR)

After passing the Victoria pilot station at about 09:00 PDT in the morning, our journey continued westwards through the Juan de Fuca Strait to the working area. With a beautiful view of the nearby coast, we carried out the ship's safety orientation so that everyone on board knows how to respond and which lifeboat is assigned to them in an emergency.

We immediately went to the first deployment site about 120 km west of Vancouver Island at a water depth of just under 2600 m. Here, all acoustic trigger devices for our various ocean bottom instruments were tested for functionality and pressure load. We also acquired a water sound speed profile. Following this, we began deploying four ocean bottom seismometers (OBS, Figure 2), three ocean bottom pressure sensors (OBP), and eight ocean bottom magnetotelluric (OBMT) stations. We paused the long-term deployments at 05:30 PDT on Thursday, September 15th, and in preparation for later instrument deployments, we mapped the seabed along the planned MT profile with the multibeam sounder instead.

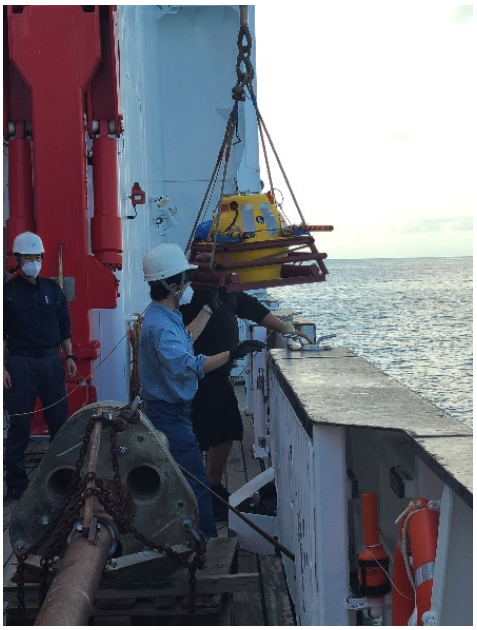

Figure 2: Deployment of an OBS from JAMSTEC (photo-credit: Sarah-Marie Kröger, GEOMAR).

We set off on the transit towards Vancouver, where we picked up spare parts and scientific equipment that could not be delivered during the first port call. During the transit we had the unique opportunity to enjoy the beauty of the coastal region off Vancouver Island with its abundance of whales and other marine mammals. Much to everyone's delight, but especially to our marine mammal observers on board, we cruised through an area where 25 orcas and 5 humpback whales were present (Figure 3).

Figure 3: Orcas off Vancouver Island (photo credit: Bruce Mactavish, LGL).

In addition, the infrared camera was used to test its use for early detection of whales (Figure 4).

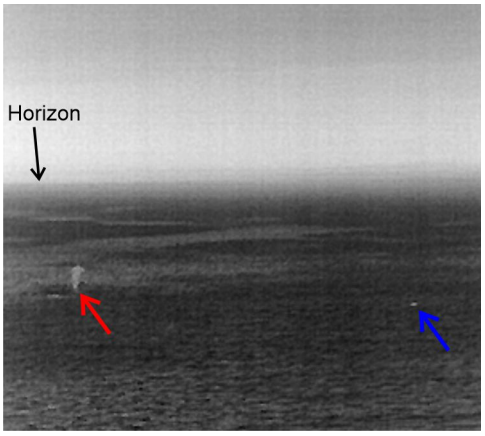

Figure 4: Infrared image of the exhaled breath (blow) of a whale (red arrow). A seabird (unknown species) is also clearly visible as a small IR anomaly (blue arrow), water masses with different temperature and roughness are well visible in different grey scales. (image credit: Toyon Research Corporation).

In the early afternoon of 16 September, we arrived at Vancouver harbour and all the necessary work was successfully completed by 21:00. The anchor was lifted and we headed back through the Georgia Strait towards the pilot station off Victoria. After dropping the pilot at 03:00 on Saturday morning (17 September) we headed back out the Juan de Fuca Strait towards the open ocean.

At the exit of the Juan de Fuca Strait, a field of natural gas seeps on the seabed was discovered in April this year. Colleagues from the Geological Survey of Canada (GSC) and Fisheries and Ocean Canada (DFO) asked us to map this area (also called Swiftsure Bank) with our multibeam sounders and to verify the gas seeps. For this purpose, we received a special research permit from the Canadian government to map this area during daylight hours while using the passive acoustic monitoring (PAM) system. We started deploying the PAM at about 13:00. Even before that, the observers thoroughly searched the area for whales and other marine mammals. Our mapping began at 13:40 and was successfully completed at 19:30 as darkness fell. The deployment of the PAM was a successful dress rehearsal for deployment for the seismic work still to come. More than 30 individual gas seeps were found in the mapped area of Swiftsure Bank (Figure 5), but still need to be verified in detail through further data processing. Following the mapping, we recorded a water sound speed profile to process the bathymetric and water column data. First results show a spectacular seabed topography with rugged seafloor morphology in sections of the survey (Figure 6).

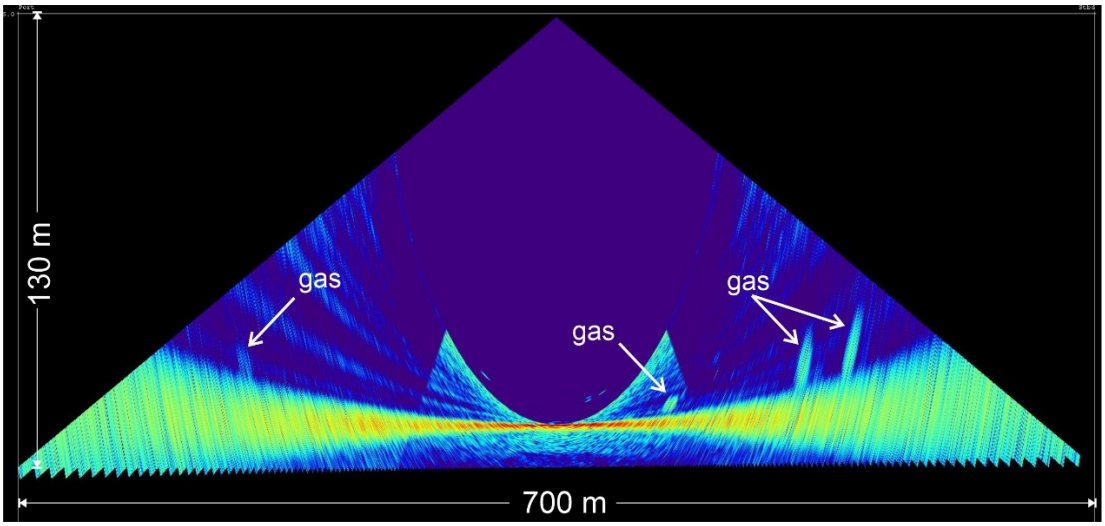

Figure 5: Acoustic recording of the water column at Swiftsure Bank (EM710) with four gas flares (image credit: Ingo Klaucke, GEOMAR, Jessie Kehew, Univ. of Ottawa).

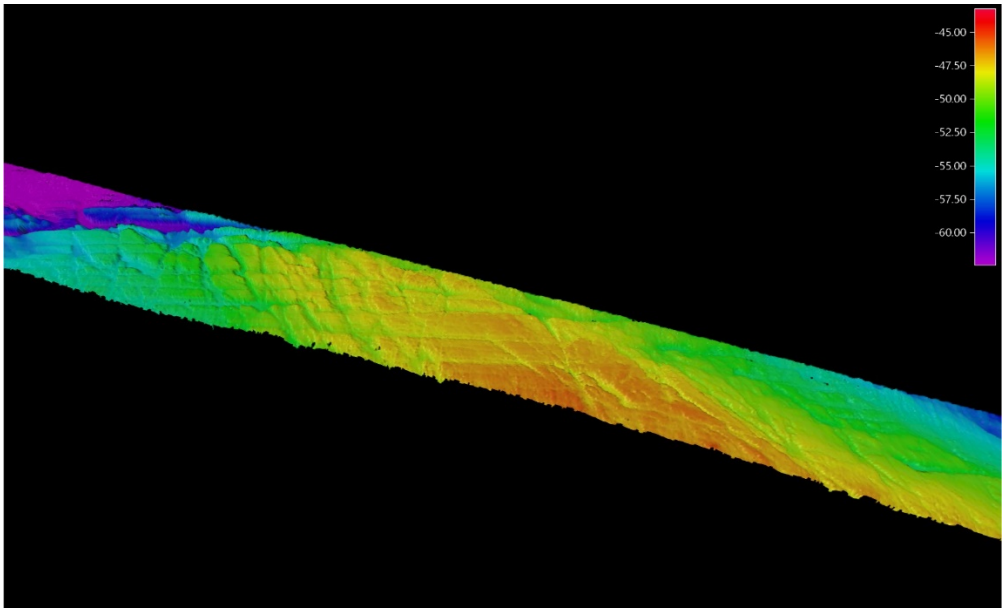

Figure 6: Portion of the rough seabed topography across Swiftsure Bank (image credit: Karen Douglas, GSC).

Shortly after midnight (Sunday, September 18th) we were approximately 6 nautical miles offshore Tofino, and began deploying the remaining 10 OBMT instruments. The OBMT profile is the seaward component of an overall transect that extends 230 km from the seaward edge of the deformation front, across Vancouver Island, Texada Island, to about 16 km east of Powell River on the BC mainland. The land-based part of the deployment was carried out by scientists from the University of Alberta in Edmonton by Prof. Dr. Martyn Unsworth's research group in August this year. All data will then be analyzed together after the completion of the CLOCKS cruise.

After installing the OBMT instruments, we deployed the remaining OBS and pressure sensors from our Japanese collaboration partners, and additionally deployed six broadband seismometers from GEOMAR in a star-shaped array. This special deployment, in combination with the nine JAMSTEC OBS, allows for the application of special evaluation methods for earthquake analysis. Thus, a large part of the tasks of CLOCKS

for earthquake monitoring and MT data recording have been successfully completed within the first week at sea.

To everyone's delight, we were able to relax the strict COVID restrictions on Sunday morning and the mask requirement was dropped for the time being, as 5 days have passed with all aboard showing daily negative COVID test results.

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)