Title: LOBSTER - „**L**igurian **O**cean **B**ottom **S**eismology and **Te**ctonics **R**esearch"
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Goals:

The LOBSTER project comprises the offshore component of the AlpArray seismic network using ocean bottom seismometers (OBS) to record teleseismic and local events in order to define subsurface structures at the transition from the Western Alps to the Apennines and to improve our understanding of the 3D-geometry of the system and its kinematics. The LOBSTER network consists of 23 OBS that recorded continuously over a period of 8 months (June 2017 – February 2018). Additionally, two seismic refraction profiles were shot to provide the velocity distribution within the Ligurian Basin lithosphere (Fig. 1) with the aim to image the offshore ocean-continent boundary. Profile P01 extends from the Central Corsican margin across the Ligurian Basin to the Ligurian Provencal margins. A total of 35 stations were deployed along the 147 nm long E-W profile, which was extended on Corsica with 3 land stations recording the 2418 air gun signals. The NE-SW trending profile P02 covers the central Ligurian Basin with a length of 73.5 nm. A total of 15 stations recorded 1033 shots. The data quality of both refraction seismic profiles is good and instruments show clear PmP Moho reflections and Pn mantle phases. The technical goals for the seismic network are to apply time corrections to the instrumental clock, to determine the sensor orientation, and to integrate the data and their metadata in to the GEOFON data centre. The scientific goals are to provide seismic velocity information along the two profiles and to interpret the results in their geological context.

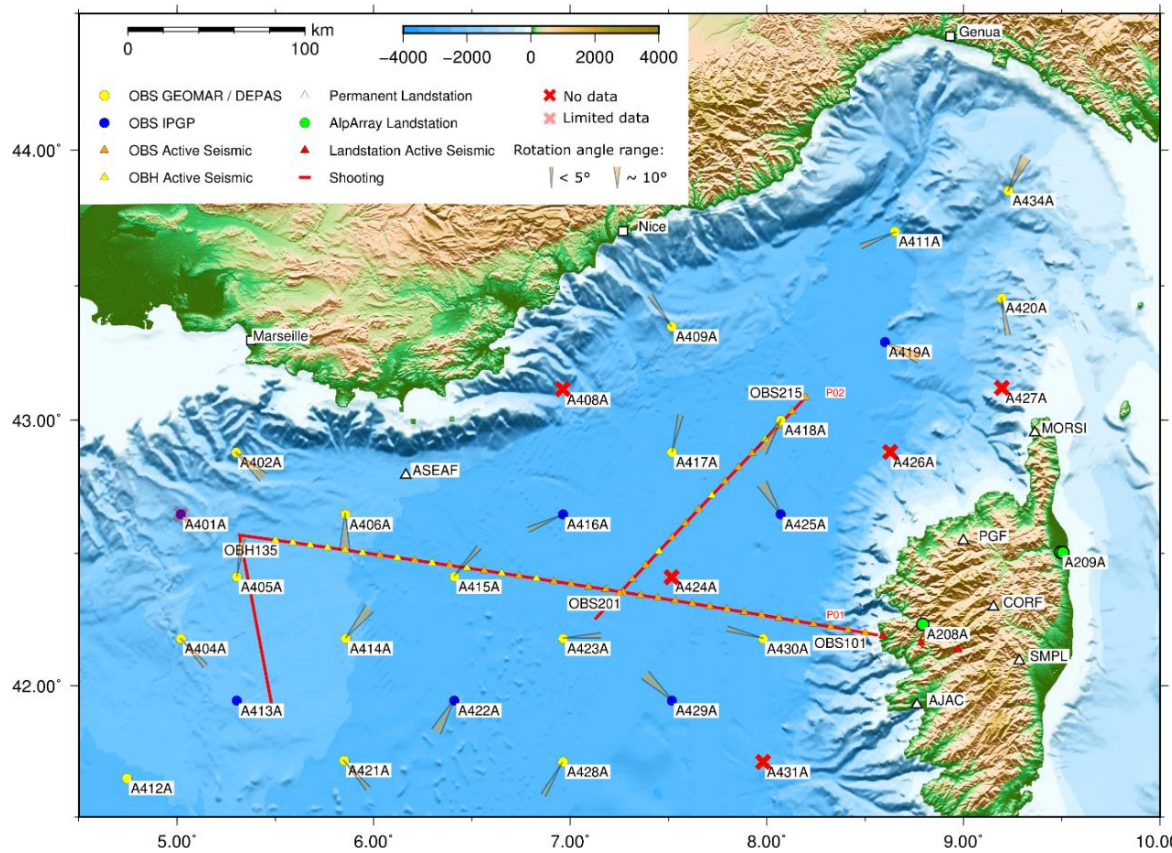

Figure 1 – Station and profile distribution in the Ligurian Sea. Two refraction/reflection profiles (P01 and P02) were acquired with 35 and 15 stations, respectively. In addition, shooting along profile P01 was extended to the southeast in order for the long-term AlpArray OBS to record the airgun shots. The yellow shades indicate the orientation of the first horizontal seismometer component (H1) used for rotation to geographical horizontal components.

New results and interpretations:

At the long-term network, the data quality of the seismometer components is good and the instruments recorded local as well as teleseismic events. The instruments are working autonomously at the seafloor. Therefore the clock is not permanently synchronised via GPS as would be the case for land stations. Clocks are synchronised before and after the deployment. Drift of up to 4.5 s was observed and the data were corrected for the time difference assuming a linear drift. The correct timing was verified by the active shots recorded at the end of the deployment. All recorded data were corrected for timing errors. Once the instruments are deployed from the vessel they sink through the water column down to the seafloor. During the free fall they drift in the water column and turn around

their own axis resulting in an unknown instrument location on the seafloor and unknown directions of the horizontal components, while the Z-component will be oriented vertical. The vertical alignment of the Z-component was assessed every 30 days by a tiltmeter. The trillium seismometer that was used is also equipped with a magnetic compass. Due to magnetic material on the flotation frame and the steel anchor of the instrument it is difficult to calculate the absolute directions of the horizontal components based on compass measurements. However, we could prove for all instruments that the horizontal components did not change their orientation during deployment time. The same is true for the vertical alignment of the Z-component. To provide absolute values of the direction of the horizontal seismometer components (H1 and H2) we used the active shots of the wide-angle profile P01, recorded at the end of the deployment period. Shots were recorded on all stations at the seafloor during this time, except OBS A412A. Seismic shot sections for P01 were generated. The data were high pass filtered to remove the refraction phases, leaving the direct arrivals and their multiples (Fig. 2a). The data were subsequently plotted in a hodogram and orientation angles were calculated based on the shot azimuth (Fig. 2b). For all 22 OBS the rotation angles could be calculated with an accuracy of 5 to 10 degrees (Fig. 1). In Figure 2b (left panel) two data examples of the rotated horizontal components are displayed in the shot sections of the active seismic profile P01.
The gained information on rotation angles of the horizontal components and the channel polarity where stored in the seismogram MSEED headers and metadata (station.xml file). Instrument responses were generated and included into the metadata as well. Day files of 16 OBS stations were uploaded to the data archive GEOPHON and are available for download. The raw data as stored on the recorder during the deployment were uploaded to the German archive PANGAEA.

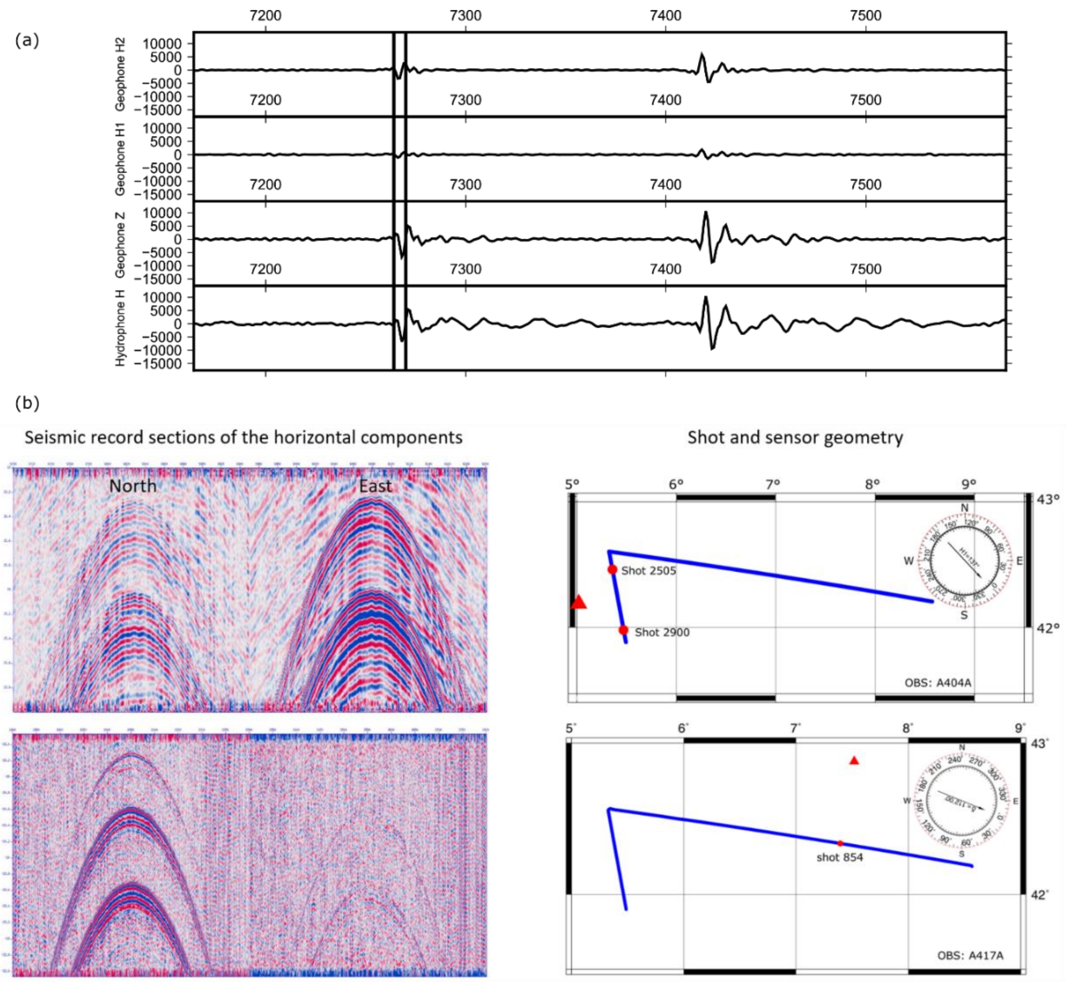

Figure 2 – (a) The three seismometer components and the hydrophone component for shot 2900 at OBS404 are displayed after a high pass filter of 10 Hz to minimise refracted phases and impose the direct arrival through the water. (b) Left panel shows a seismic shot section of the two horizontal components H1 (east) and H2 (north) after rotation. Right panel displays the geometry of single shots (red circle) and OBS (red triangle). The blue line represents all active source shots.

By means of seismic travel time tomography, a seismic velocity profile imaging the uppermost lithospheric structure has been developed along wide-angle refraction profile P02 that follows the basin axis (Fig. 3 from Dannowski et al., 2020). The velocities have been converted to densities and the gravity Free Air Anomaly response was calculated and compared to measured gravity field from satellite data. Syn- and post-rift sediments of 6-8 km thickness fill the

basin. The crust-mantle boundary in the centre of the Ligurian Basin is determined at 11 km to 13 km depth below the sea surface. The acoustic basement is difficult to map seismically. Sparse seismic phases indicate the transition to the crystalline crust at a depth of ~6.5 km below the seafloor (dotted red line in Fig. 3a). The crustal portion interpreted from the seismic velocities thickens toward the north. Seismic results and the converted densities are in good agreement with the measured gravity field.
We observe a gap of seismic velocities in the range between 6.7 km/s and 7.2 km/s (Fig. 3f), suggesting that no typical oceanic crust and no thick layer of gabbroic rocks is present along the profile. We interpreted the nature of the crust in the centre of the Ligurian Basin as a hyper-extended continental crust or serpentinised oceanic mantle. However, the observed reduced seismic P-wave velocities within the upper mantle suggest only a low degree of serpentinisation (up to 20%). Thus, mantle was not directly exposed to the seafloor during the opening of the basin due to syn-rift sedimentation or the occurrence of extremely thinned brittle continental crust.

Main results and conclusions:

- The recorded data were corrected for timing errors and it could be verified that the instruments did not move while deployed on the seafloor, i.e. major change in tilt or instrument orientation.
- Active shots where used to estimate the orientation of the horizontal seismometer components H1 and H2.
- The data of the majority of the OBS stations are uploaded to the German GEOFON seismic data archive (https://geofon.gfz-potsdam.de/waveform/archive/network.php?ncode=Z3&year=2017) and are available for download with the network code Z3.
- The seismic velocity distribution, gained from travel time tomography, supports hyper-extended crust or serpentinised mantle directly underneath a ~6 km thick sediment pile. The depth of the crust-mantle boundary is at 8-10 km below seafloor.
- Rifting in the Ligurian Basin failed before oceanic spreading was initiated and the extremely thinned continental crust thickens towards the NE.

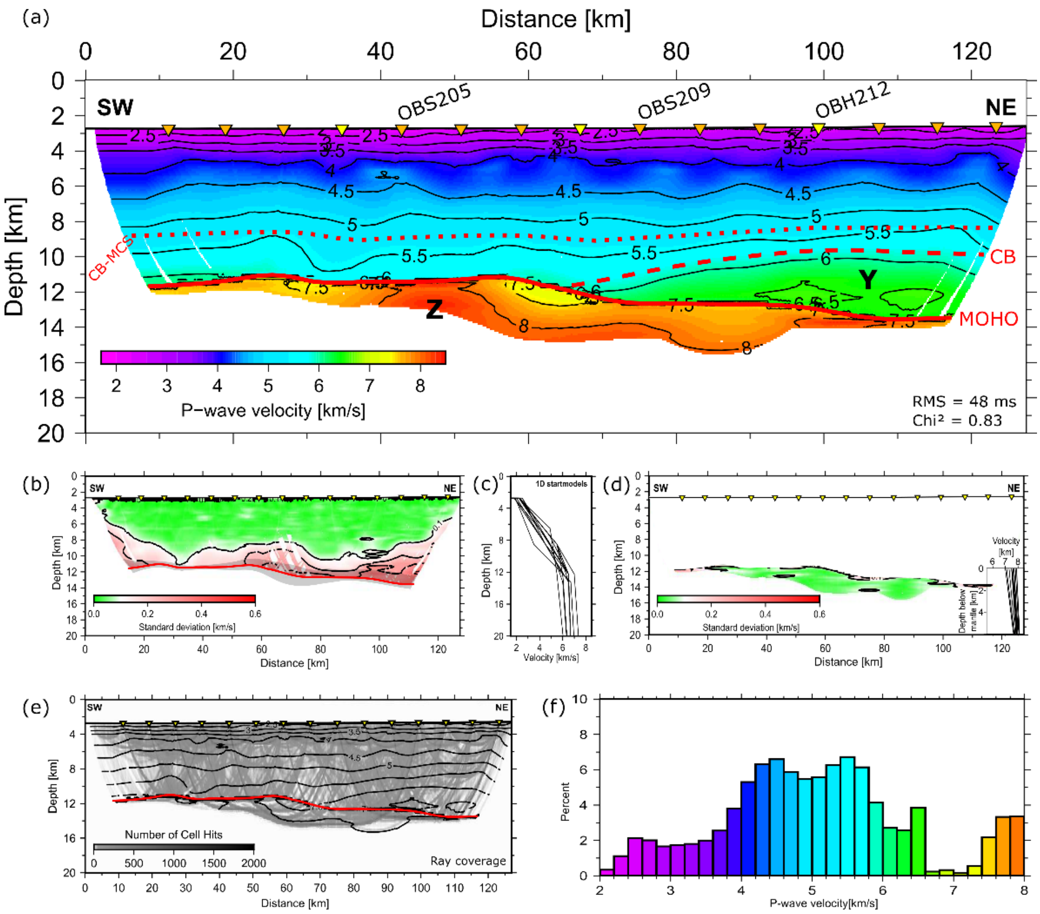

Figure 3 – (a) Final velocity model based on the averaged velocities from the plausible starting models. The red dashed line marks the crystalline basement (CB) as determined from the refraction seismic data. The red dotted line presents the CB inferred from MCS data (CB-MCS) crossing our profile (details given in the text). The solid red line marks the crust–mantle boundary (Moho). (b) Standard deviation for 17 inverted velocity models, covering the crustal part down to the Moho. (c) Starting models used in the inversion and to calculate the resulting average model in (a). (d) Standard deviation for 14 inverted velocity models (starting models in the inlay), covering the upper mantle up to the Moho. (e) Ray coverage for the final average velocity model. (f) Histogram with the velocity distribution of the final average velocity model.

Publication:

Dannowski, A., Kopp, H., Grevemeyer, I., Lange, D., Thowart, M., Bialas, J., and Wollatz-Vogt, M. (2020) Seismic evidence for failed rifting in the Ligurian Basin, Western Alpine domain. *Solid Earth*, **11** (3), pp. 873-887, doi: 10.5194/se-11-873-2020.

Dannowski, A.; Kopp, H.; Lange, D. (2020): Seismic refraction and wide-angle reflection data from profile MSM71-P02 of Maria S. Merian cruise MSM71 in the Ligurian Basin, with links to SGY data files. *PANGAEA*, https://doi.org/10.1594/PANGAEA.910561.

Kopp, H, Lange, D., Thorwart, M., Paul, A., Dannowski, A., Petersen, F., Aubert, C., Beeck, F., Beniest, A., Besancon, S., Brotzer, A., Caielli, G., Crawford, W., Deen, M., Lehmann, C., Marquardt, K., Neckel, M., Papanagnou, L., Schramm, B., Schröder, P., Steffen, K.-P., Wolf, F. N., and Xia, Y., eds. (2018) RV MARIA S. MERIAN Fahrtbericht / Cruise Report MSM71 LOBSTER: Ligurian Ocean Bottom Seismology and Tectonics Research, Las Palmas (Spain) – Heraklion (Greece) 07.02.-27.02.2018 . *GEOMAR Report, N. Ser. 041 . GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel*, Kiel, Germany, 47 pp. doi: 10.3289/GEOMAR_REP_NS_41_2018 .

Conference abstracts:

Kopp, H. , Dannowski, A. , Grevemeyer, I. , Lange, D. , Thorwart, M., Caielli, G., Franco, R., Petersen, F. , Wolf, F. N., and Schramm, B. (2020) Investigations of the Oligocene-Miocene opening of the Ligurian Basin using refraction seismic data. Open Access [Poster] In: EGU General Assembly 2020. , 04.05.-08.05.2020, Vienna, Austria. doi: 10.5194/egusphere-egu2020-6950.

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