# Seafloor, Sediments, Seismicity and Shallow Structures Offshore Southern Chile – Selected Preliminary Results from TIPTEQ Cruise SO181

**Scherwath M. (1), Grevemeyer I. (1), Flueh E.R. (1), Ranero C.R. (1), Kaul N. (2), Weinrebe W. (1), Contrares-Reyes E. (1), Tilmann F. (3), Gossler J. (4), and TIPTEQ Working Group**

(1) Leibniz-Institut fuer Meereswissenschaften, IFM-GEOMAR, Wischhofstr. 1-3, 24148 Kiel, Germany, E-Mail: mscherwath@ifm-geomar.de
(2) Fachbereich Geowissenschaften, Universität Bremen, Klagenfurter Str., 28359 Bremen, Germany
(3) Bullard Laboratories, University of Cambridge, Adingley Road, Cambridge CB3 0EZ, United Kingdom
(4) K.U.M. Umwelt und Meerestechnik Kiel GmbH, Wischhofstr. 1-3, 24148 Kiel, Germany

## 1. Introduction

Age-dependent structure and deformation of subduction zones is best studied in regimes of laterally heterogeneous oceanic plates near active spreading centre subduction. This is because here the subducting oceanic plate is youngest and hence hottest. Differences in the thermal structure are large between oceanic plate ages ranging from 0-20 Ma and almost absent in older plates (Kirby et al., 1996). A favourite locality for determining this age-dependence of structure and deformation is Southern Chile. Here, the oceanic Nazca plate, the oceanic Antarctic plate and the continental South American plate join at the Chile Triple Junction at 46.5°S. Within eight degrees to the north the age of the subducting Nazca plate changes from 0 to 25 Ma across several fracture zones (Tebbens et al., 1997). This segmentation enables data acquisition along corridors of distinct ages, i.e. thermal states, within a relatively small area. Furthermore, a simple plate motion environment exists with a constant convergence rate between the Nazca and the South American plate, constant spreading rates at the spreading centres, and a homogeneous plate motion vector parallel to the fracture zones and perpendicular to the trench, thus establishing a favourable natural laboratory for subduction zone process studies. In addition, Southern Chile is the site of the world's largest historic earthquake, the Mw 9.5 event of 1960.

The multi-disciplinary, multi-institutional project TIPTEQ (from The Incoming Plate to mega-Thrust EarthQuake processes) is investigating this age dependence in Southern Chile through various geophysical and geological techniques. Our contribution here focuses on first results from the RV SONNE cruise SO181 that took place from 6 December 2004 to 24 February 2005.

Slab-age dependent effects on the tectonics and volcanism of the overriding continental plate are anomalously high regional forearc subsidence due to tectonic erosion (e.g. Behrmann et al., 1994) producing up to several kilometres of along-forearc subsidence north of the subducting ridge. This is driven by the steepness of the subduction thrust which, when older, cooler and thus denser, subducts at a steeper angle in the north. Here, the incoming plate also forms an bulge-like outer rise, whereas close to the margin the outer rise is small or absent (Cande and Leslie, 1986). Similarly, in older regimes the ocean depth and top of the oceanic basement lie at greater depths than in hotter, younger regions, and the sediments are thicker when the plate is older.

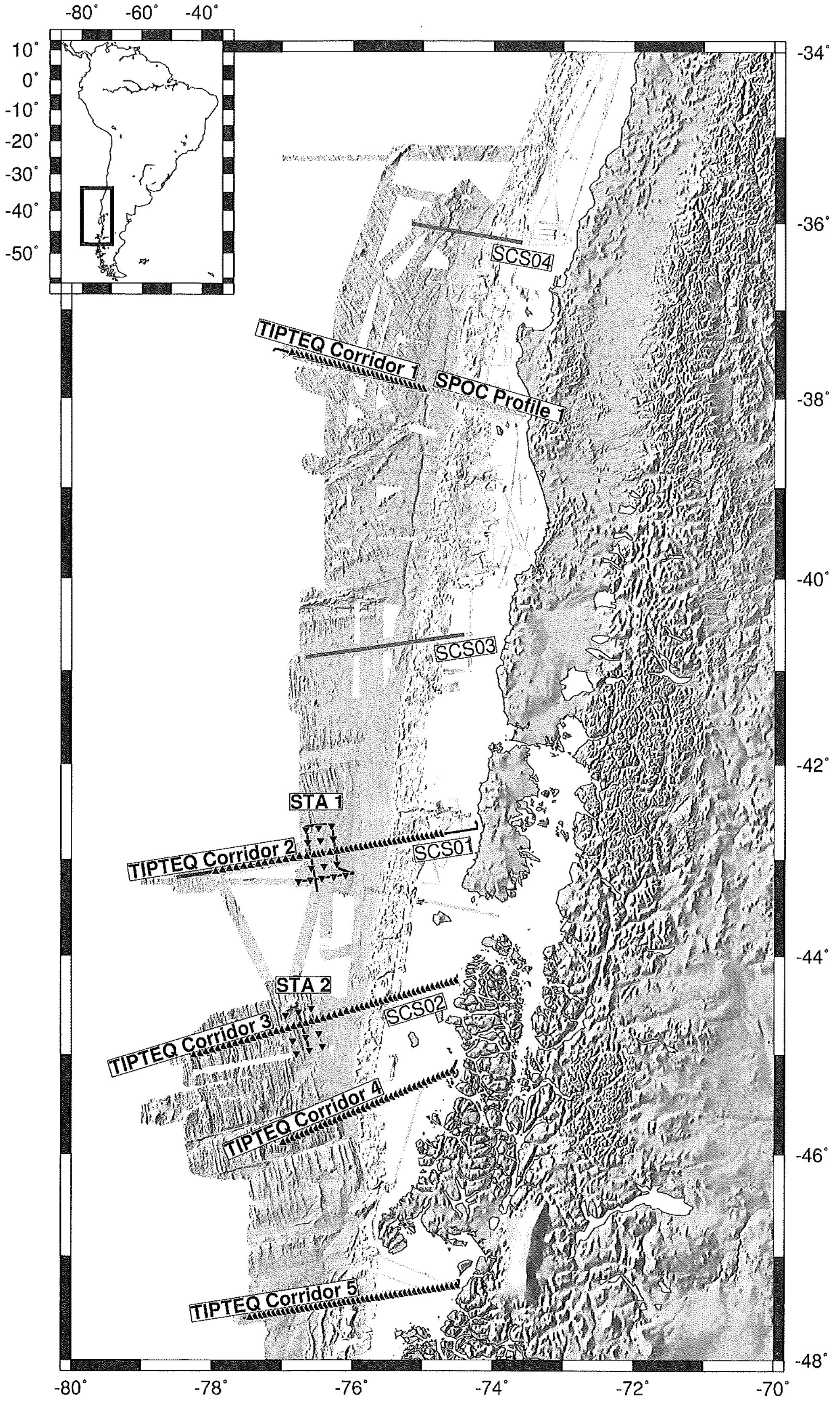

Figure 1: Basemap of TIPTEQ cruise SO181, indicating the major corridors of data acquisition, outer rise seismic networks (STA1, STA2), high resolution reflection seismic (SCS 01-04), and high resolution bathymetric coverage; land topography from TOPEX.

## 2. Objectives, Data and Techniques

TIPTEQ principally aims at studying the relationship of the seismogenic zone, subduction zone processes, tectonic subduction erosion, continental accretion and arc magmatism. For the quantification of cause and effect, the required techniques offshore comprised high resolution imaging of lithospheric structure, predominantly from seismic velocity, seismicity, bathymetry, sedimentation, and thermal and resistivity distribution. In addition, newly collected magnetic data allow accurate age determination. This will be complemented by onshore-offshore data acquisition comprising structural imaging from seismic and magnetotelluric methods, ground probing, seismological investigations, and finally land GPS studies examine the coseismic, possibly segmented land deformation.

To achieve these goals for the marine part, TIPTEQ acquired various complementary data sets along five major corridors. These data sets were seismic wide-angle and vertical incidence data, heat-flow measurements, multibeam bathymetry and magnetic data; the latter two data sets were also collected pervasively throughout the survey area. In addition, two short-term (six weeks) and two long-term (nine months) seismological networks were deployed to study microseismicity at the outer rise and regional seismicity across the shelf.

Extensive bathymetric swath mapping was employed not only to produce high resolution images of the seafloor itself, but also to identify and trace outcropping subsurface faults, as could be shown for pervasive normal faulting at outer rises (Masson, 1991; von Huene et al., 1999, 2000). Previous cruises into the study area also collected multibeam bathymetry data (e.g. CTJ, Bourgois et al., 2000; SPOC, Kopp et al., 2004) which are supplementing our new data. High resolution seismic streamer data, collected along all TIPTEQ corridors, show sedimentary and basement structures, important to identify possible causes for the bathymetric features (such as faults), but also to correlate heat flow, seismicity, and deep imaging data from seismic wide-angle data. These wide-angle data illuminate the lithosphere to highlight large scale structures such as depths and shapes of the oceanic layers, in particular the depth and dip of the subducting slab. Estimated P- and S-wave velocities show anomalous, deformed regions and yield Poisson ratios. The velocity structure is also important to locate earthquakes from the seismological networks. Accurate localisations exhibit in particular how deep the seismicity occurs and whether outer rise faulting penetrates into the mantle.

## 3. Preliminary Results

Initial data processing concentrated on basic data enhancement to obtain preliminary data quality assessments. Overall the data quality appears good to excellent. Many of the multibeam bathymetry data were cleaned from noise already during the cruise and are now merged with the existing data from previous cruises (Figure 1). The continental slope is now mapped completely, and large gaps on the oceanic plate between the extensive SPOC and CTJ cruises could be filled. The data clearly show spreading ridges where the sedimentary cover is thin, and normal faults from plate bending, the latter, though, largely in the north. It appears that the sedimentation overall is relatively high except around 41°S.

This result is confirmed by the high resolution seismic reflection data. Focusing on TIPTEQ Corridors 2 and 3, where the outer rise seismological short term arrays were installed, both seismic sections in Figure 2 show roughly 2-km thick sediments at the trench, despite the difference in ages. The oceanic crust of Corridor 2 at the trench is 14.5 Ma old, and 6.5 Ma at Corridor 3, i.e. the thermal difference between these lines is relatively large. A greater difference between the lines exists in the structure; there clearly exists a bulge at the outer rise of Corridor 2, whereas the seafloor deepens only gradually towards the trench on Corridor 3 (Figure 2, disregarding the small scale spreading ridges here).

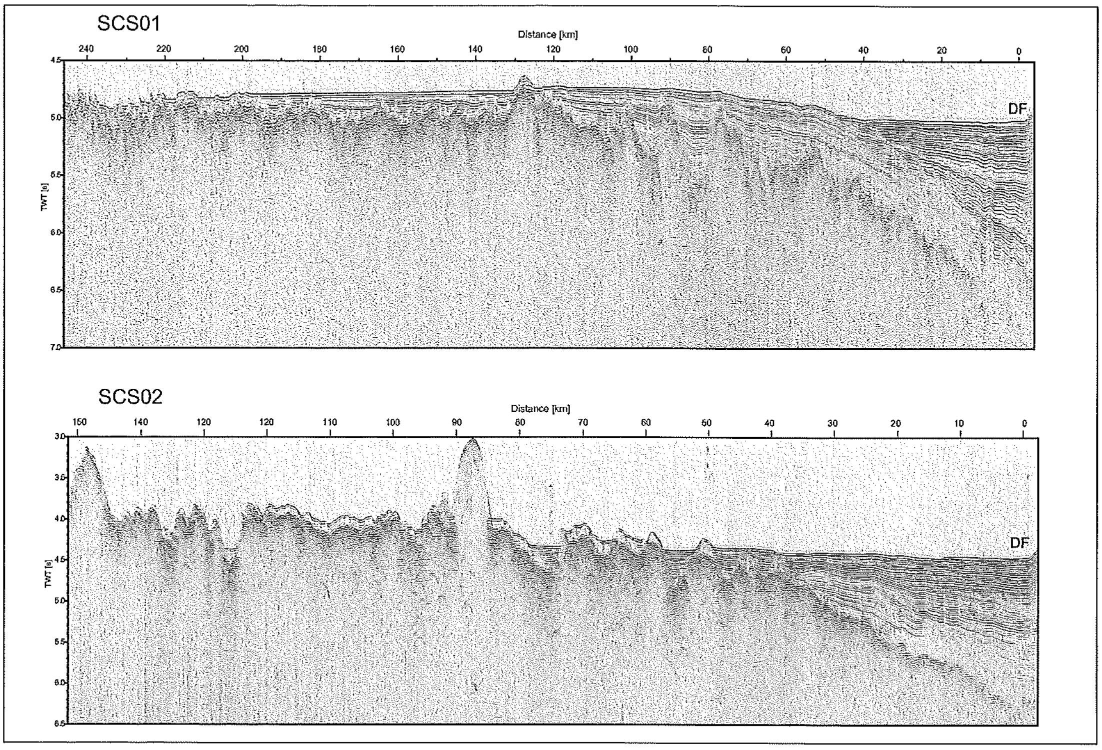

Figure 2: Vertical incidence seismic reflection lines from TIPTEQ Corridors 2 (line SCS01) and 3 (line SCS02). Distances are from Deformaion Front (DF).

The microseismicity is also different between the two corridors. During the six weeks deployment of the arrays, the northern array above the older crust registred almost 2000 earthquakes, which is roughly half the number of events registred in the southern network. Onboard analysis during cruise SO181 located 139 events in the northern network and 449 events in the southern network. Figure 3 shows the epicentres of these earthquakes. It appears that the northern network location was slightly outside the main microseismic activity. It is possible that more events would have been registred if the network would have been closer to the major zone of microseismicity. Alternatively, however, it may be that when the bulge has already formed as on Corridor 2, the microseismicity is naturally reduced, so the larger number of events in the younger, southern area are from the early stages of bulging. Further analysis is required to go beyond the hypotheses.

## 4. Conclusions

New data from Southern Chile yield clear evidence of age-dependent lithospheric structure and deformation. Here, we summarise initial results of the shallow structures and outer rise microseismicity focused on two TIPTEQ corridors. Where the oceanic crust at the trench is 6.5 Ma old, bathymetric and high-resolution seismic reflection data show a gently dipping ocean floor with no bulge at the outer rise, and microseismic activity is high in this region. At 14.5 Ma old oceanic crust an outer rise bulge exists and only half as many events as at the southern seismic network were registred here. However, many more data are available and await analsys, and excellent data quality promises excellent results to be expected from the TIPTEQ initiative.

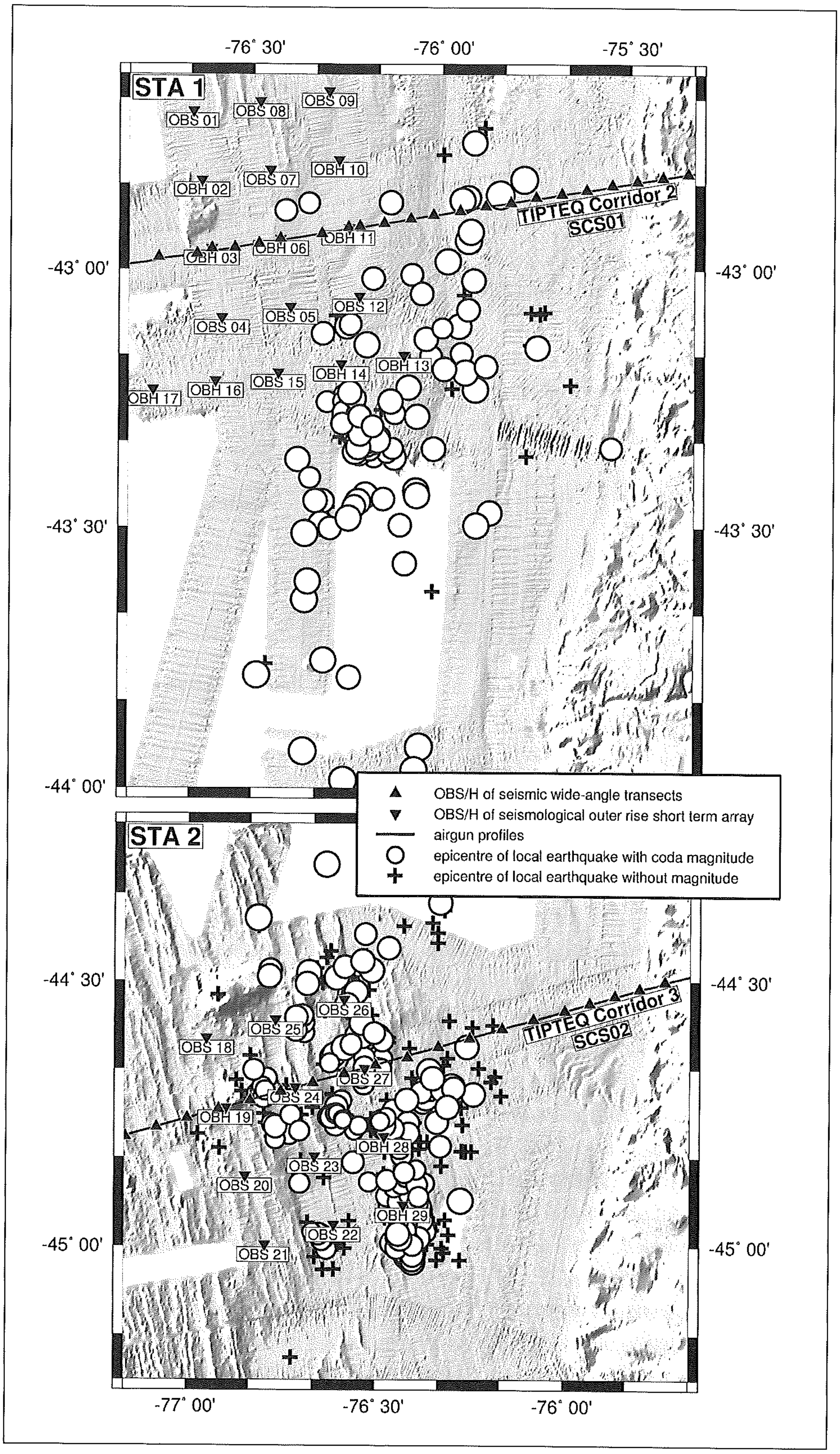

Figure 3: Microseismic activity recorded at TIPTEQ outer rise networks.

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