SISIE: South Island, New Zealand, Subduction Initiation Experiment

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The South Island Subduction Initiation Experiment (SISIE) was successfully completed in February and March 2018 using the *R/V Langseth* (as MGL1803). Seismic reflection and refraction data were acquired across the Puysegur Trench and Ridge and the Solander Basin (Fig. 1A). For the multichannel seismic (MCS) imaging, the Langseth used a 12.6 km long streamer for much of the 1,300 km of lines acquired. A group of 28 ocean-bottom seismometers (OBSs) from the University of Texas Institute of Geophysics (UTIG) were used at 43 sites on two refraction lines. One combined refraction/MCS line targeted the more juvenile part of the Puysegur Ridge (SISIE 1) while the other targeted the more evolved part (SISIE-2). Two lines of onshore seismic receivers and several broadband seismometers on islands were deployed by New Zealand collaborators. Since the experiment, there have been important results from analysis of the seismic reflection and refraction data and modeling subsurface density structure. With SISIE, our understanding of the antecedent tectonics and evolving dynamics associated with subduction initiation have improved enormously.

With the new seismic images, much of the crust immediately to the east of the Puysegur Trench was found to be rifted continental crust (Fig. 1D) and not oceanic crust as previously interpreted along the entirety of the MRC. This is an important new observation, because the density difference across an ocean-continental margin is substantially larger than that across an ocean-ocean margin. A plate tectonic reconstruction shows that the density difference across the plate boundary rapidly increased during strike-slip motion between 18 and 15 Ma, just before subduction initiation, supporting the role of compositional differences in the initiation of Puysegur subduction. During initiation, a large fault (Tauru Fault) within the northern Solander Basin, inverted from normal to reverse.

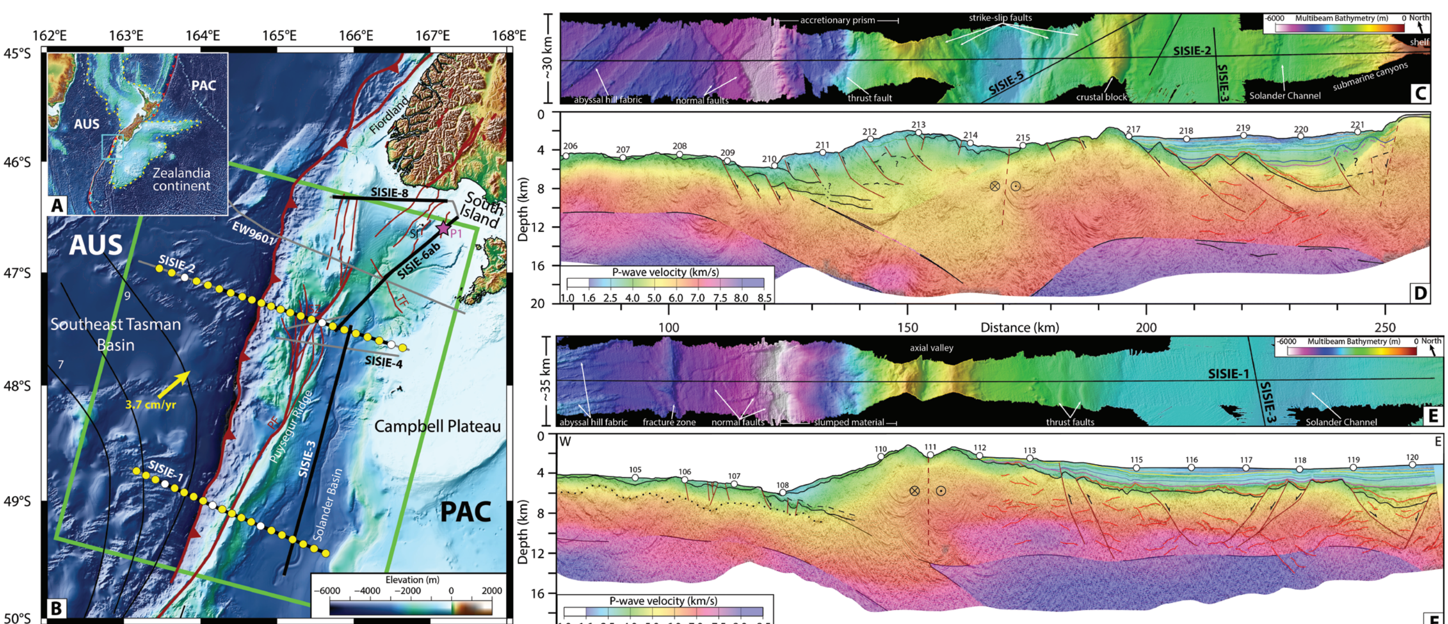

Figure 1. Regional A and detailed B elevation maps showing major tectonic features of the Puysegur margin and the SISIE survey. Gray and black lines are MCS lines. Yellow circles represent successful OBS deployments used in analysis. The box green delimits the region of the gravity inversion shown in Figure 2. SZ = Snares Zone; PB = Puysegur Bank; PF = Puysegur Fault; TF = Tauru Fault; PaF = Parara Fault; SF = Solander Fault; HF = Hauroko Fault; eBF = eastern Balleny Fault; SI = Solander Island. The combined MCS and seismic tomography results from the OBS are shown for lines SISIE-1 (F) and SISIE-2 (D) along with high resolution multibeam bathymetry (C and E). For D and F the compressional-wave (Vp) seismic velocity model overlain on the Pre-stack depth migrated MCS reflection images. Figure modified from Shuck et al. (2020).

Using sequence stratigraphy with the N-S MCS lines and an existing petroleum exploration well, we constrained the compressional event between 12 and 8 Ma. From our interpretation of the seismic images, we suspect that subduction may have initiated on the western-most, thickest fragment of the thinned Solander Basin crust, and through sequence stratigraphy we estimate that there was an evolution of stress from compression to tension from north to south. We also developed a seismic tomographic model of the crust and lithosphere with OBS-inferred velocities mapped to density (Fig. 1). These mapped images were then used as prior constraints in a 3D Bayesian gravity inversion, which showed that the crust below the Snares zone was thicker compared to the Puysegur Ridge to the south even though it was topographically depressed (Fig. 2). This likely reflects a strong change in the vertical force balance along strike. The structural model, constraints on the evolution of the state of stress, and inferences on the non-isostatic topography are being used for a high resolution, three-dimensional geodynamic model, which shows the change from forced to self-sustaining subduction. ■

References

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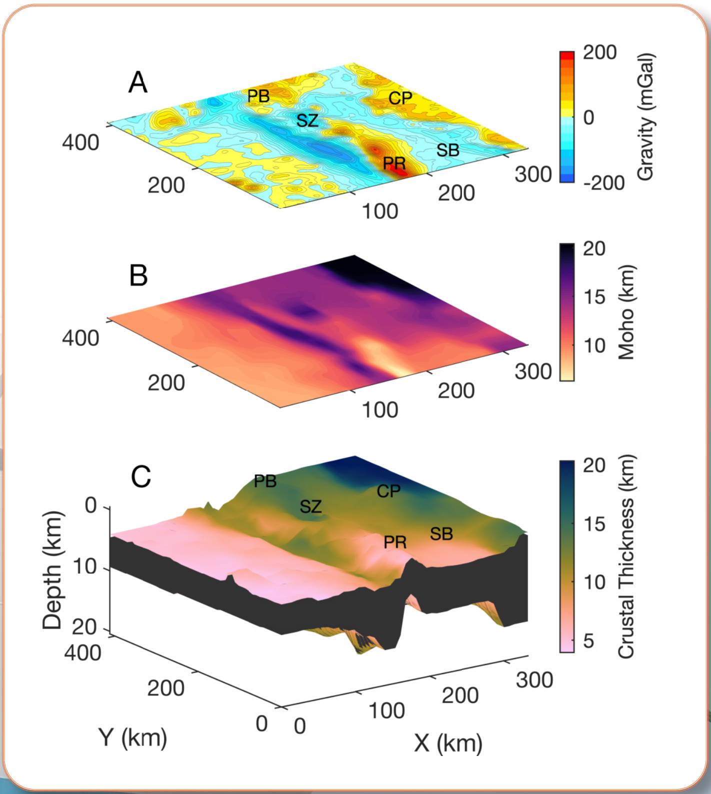

Figure 2. Perspective views looking north for the area shown by the green box in Figure 1. A. Free air gravity anomaly (from Sandwell et al., 2019) for the Puysegur study area used in the Bayesian gravity inversion of crustal thickness. PB, Puysegur Bank; SZ, Snares Zone; CP, Campbell Plateau; PR, Puysegur Ridge and SB, Solander Basin; B. Moho depth interpreted from the 3-D density model; C. Crustal thickness for the Puysegur study area calculated by subtracting the bathymetry from the Moho depth and overlain on the bathymetric surface. The crustal volume is filled to the base of the crust using the Moho surface in panel B. Figure modified from Hightower et al. (2020).

SISIE Science Party in front of the R/V Langseth