carbon cycle to the shorter periods and the causes of the change.

This month, a new team of 17 drillers and scientists will set out for Dome C, via Christchurch (New Zealand) and Terra Nova Bay. They will drill as close to the bedrock as they feel is safe with the current drill head and the warmer temperatures, and will process the ice already drilled and the new material from this season. Meanwhile, the analyses from the existing ice will be continued in Europe, and we should see the first record of greenhouse gases, climate and atmospheric chemistry from stages 11 and 12 emerging in the next 18 months.

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PLUME Investigates South Pacific Superswell

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The French Ministère de la Recherche is funding a multidisciplinary project, the Polynesian Lithosphere and Upper Mantle Experiment (PLUME), to image the upper mantle structures beneath French Polynesia. This region of the southwestern Pacific, which is far from any plate boundary, comprises oceanic lithosphere with ages varying between 30 and 100 Ma, as well as two major fracture zones. The area is characterized by a "swarm" of volcanic island chains—the Society Islands, the Austral Islands, and the Marquesas—that may represent "hot spot" tracks [*Duncan and McDougall*, 1976]. The individual hot spots are superimposed on the large South Pacific Superswell [*McNutt*, 1998]. The region is also characterized by a large-scale, low-velocity anomaly in the lower-most mantle [*Su et al.*, 1994] and anomalous converted phases from the 660-km discontinuity [*Vinnik et al.*, 1997].

These observations have been interpreted as evidence of a lower-mantle "super-plume" that is at least partially blocked in the transition zone, and crowned by several small-scale "upper mantle" plumes that give rise to the hot spot tracks observed on the surface. Such an image is in rather good agreement with large-scale mantle plumes observed in recent analogic [*Davaille*, 1999] and numerical [*Brunet and Yuen*, 2000] models of mantle convection.

Thus, French Polynesia is a unique area to study active mantle plumes. The experiment will combine seismological, bathymetric, and gravimetric observations; petrophysical and geochemical investigations of mantle xenoliths brought to the surface by the hot spot volcanism; and multi-scale numerical models. Researchers will study the interaction between plume and lithosphere, probe the interaction between mantle plumes and the large-scale mantle flow, image the geometry of plumes in the upper mantle and their eventual connection with the South Pacific super-plume, and quantify the mass transfers through the transition zone.

The PLUME seismic network is composed of 10 broadband stations deployed in French Polynesia for a period of 2 years. The first were deployed in October 2001 (Figure 1). The region under study covers an area equivalent to the one being studied in Europe, with a relatively short spacing of a few hundreds of kilometers between the temporary stations. The deployment of the PLUME network has been designed to supplement the permanent Incorporated Research Institutions for Seismology (IRIS), Geoscope, and Commissariat à l'Energie Atomique (CEA) stations available in the region, providing more homogeneous instrument coverage of the entire area.

The design of the experiment should primarily benefit surface-wave tomographic studies. Except in its southern-most part, the Pacific plate is surrounded by subduction zones that provide an excellent azimuthal distribution of deep events with well-excited overtones (Figure 2). In Australia, regional waveform analysis applied in a similar context has produced a surface wave tomographic model with a lateral resolution of a few hundred kilometers for both the lateral variations in shear wave velocities and the azimuthal anisotropy [*Debayle and Kennett*, 2000]. We expect a similar lateral resolution in the whole upper mantle beneath this region from the large number of higher modes provided by the subduction zone earthquakes and the dense ray crossing beneath the PLUME network. This study should significantly improve upon previous regional and global tomographic imaging in the southern Pacific. Researchers also hope to characterize the large-scale mantle flow from surface wave anisotropy to locate possible plumes in the upper mantle, and to address the question of their lateral extent and their possible connection with a deeper, larger-scale structure in the transition zone or lower mantle.

Upper mantle flow beneath each seismic station will be probed using body waves and particularly, the splitting of teleseismic shear waves. Seismic anisotropy in the upper mantle results from intrinsic elastic anisotropy of rock-forming minerals—particularly olivine in the upper mantle—and from their preferred orientations, which developed in response to tectonic flow. Measurement of teleseismic shear wave splitting induced by seismic anisotropy can be used to probe frozen or active mantle deformation with a lateral resolution of a few tens of kilometers, and to characterize its relationship with absolute or relative plate motion. From anisotropy inferred from body and surface wave, we should be able to detect the presence of several anisotropic layers in the upper mantle that could give insight into lithosphere-asthenosphere interactions and plate motion changes.

Figure 3 is an example of an event recorded at some of the recently deployed PLUME stations. The event occurred on 31 March 2002 in Taiwan and generated SKS and SKKS phases clearly visible on the radial components, but with no energy on the transverse components. This coherent "null" splitting measurement obtained throughout French Polynesia suggests a homogeneous structure beneath the whole area, either isotropic, or with a fast anisotropic direction within the upper mantle oriented close from the event back azimuth. Interestingly, this direction is close to the absolute plate motion vector. This could explain why an anisotropy induced by the plate drag could not be seen by a Taiwan event. Other splitting measurements with different back azimuths are needed to determine the presence and orientation of the possible upper mantle anisotropy.

Estimation of the topography on the 410- and 660-km discontinuities using receiver function analyses of converted waves should provide first-order information about vertical fluxes of material across the transition zone [*Niu et al.*, 2002]. We will determine whether the hot spots are local structures fed by upper-mantle instabilities, or whether they are fed by lower-mantle material.

Finally, the PLUME seismic network will provide a unique tool for monitoring both local seismicity and T-waves; the degree of local seismicity related to the hypothetic volcanic activity induced by the presumed Marquesas and MacDonald (Australs) hot spots is unknown at this time. T-wave propagation and transmission will be analyzed at various sites in French Polynesia, including unexplored sites on volcanic islands and atolls. Monitoring of T-waves generated in the South Pacific by volcanic and seismic activities should be improved, especially for the Pacific-Antarctic Ridge, from which events cannot be detected by permanent seismic networks.

Intraplate volcanism related to hot spot activity may open windows into the upper mantle. Geochemical analyses of mantle xenoliths brought up at the surface by volcanic explosions will be used to constrain lithosphere structure and composition, plume-lithosphere interaction, and thermo-mechanical erosion or "asthenospherization" of the lithospheric mantle [*Lenoir et al.*, 2001]. Although the mantle xenoliths lost their initial orientations at depth during extraction processes, one can calculate their petrophysical properties to constrain, for instance, tomographic models or shear-wave splitting measurements. The three-dimensional seismic velocities (Vp, Vs) and Vs anisotropy [*Mainprice et al.*, 2000] and also the thermal conductivities of these mantle rocks will be calculated by combining the single crystal elastic or thermal properties and the crystal orientations (mainly olivine and pyroxenes), measured by electron backscattered diffraction techniques at the scanning electron microscope.

By comparing geophysical and geochemical observations with model predictions, we will be able to describe the flow pattern as well as the thermal structure of the mantle above the South Pacific super-plume. Numerical models at scales varying from global circulation to crystal plasticity will provide physical constraints on the temperature field and anisotropy associated with different mantle flow patterns, as well as constraints on the interactions among deformation, thermal exchanges, and gravimetry responses. Global circulation patterns deduced from global tomographic models will allow mantle dynamics to be correlated to large-scale gravity and bathymetric signatures [*Doin and Fleitout*, 2000] and the investigation of mass transfers between the lower and upper mantle. Upper-mantle convection models will be used to investigate plume-lithosphere interactions, as well as the effect of lithospheric structure on upper-mantle flow. By coupling polycrystal plasticity models [*Tommasi et al.*, 2000] to these much larger-scale geodynamic models, we may predict the development of olivine lattice preferred

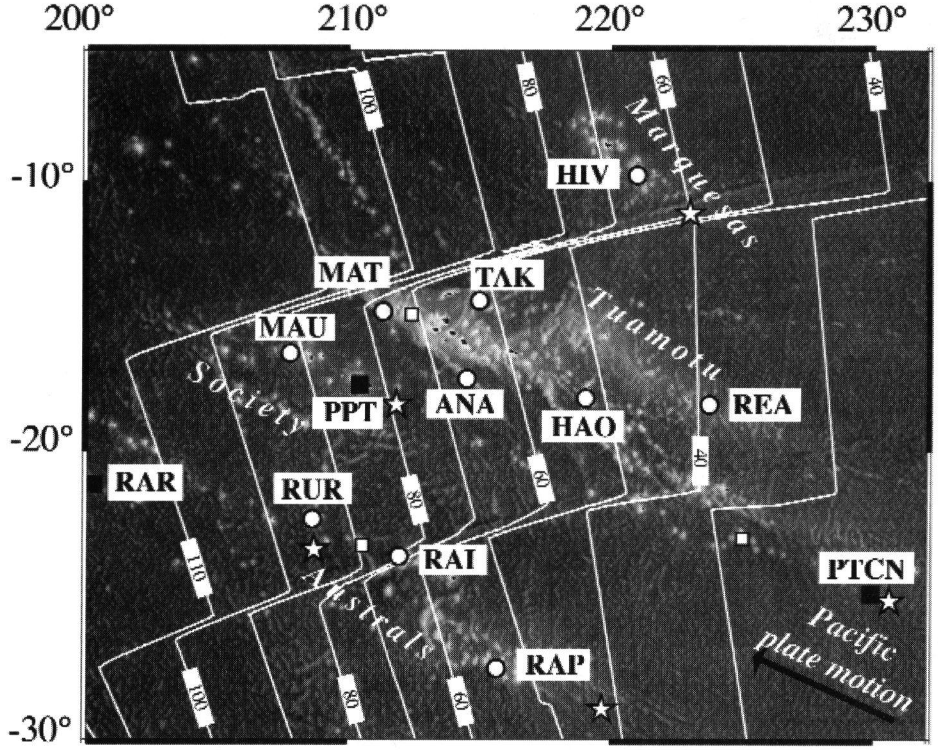

Fig. 1. Plate ages and locations of the permanent and temporary seismic stations are superimposed on the bathymetry of French Polynesia. RAR, PTCN, and PPT are permanent seismological stations (IRIS and Geoscope). White squares are long-period stations of Laboratoire de Géophysique/Commissariat à l'Energie Atomique (LDG/CEA) that are running or for which data already exist. White circles are three-component, broadband stations deployed for the PLUME passive seismic experiment during the period 2001–2003. White stars represent the expected locations of hot spots.

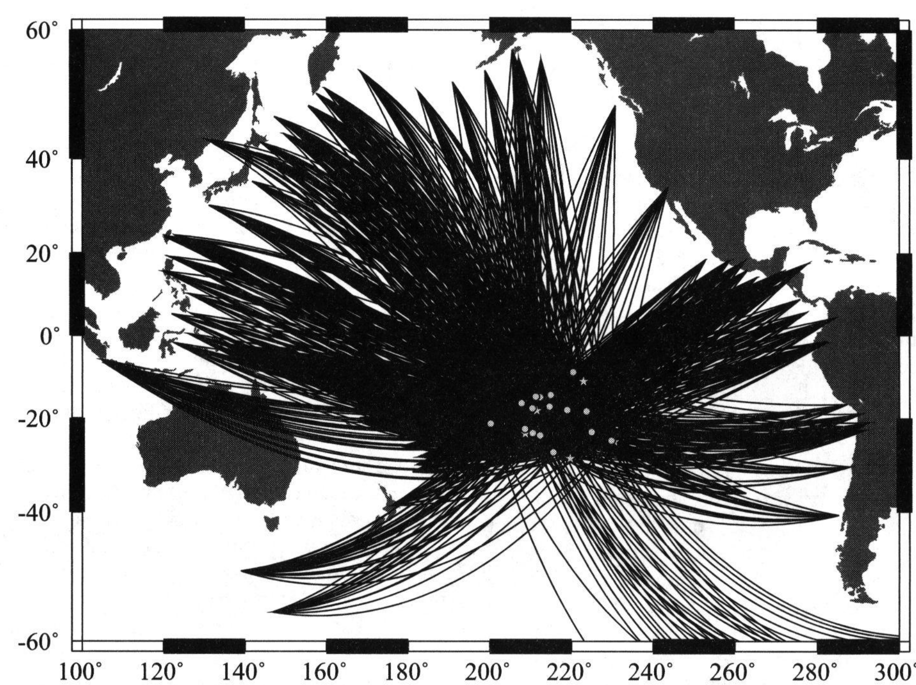

Fig. 2. Seismicity that could potentially be recorded at the French Polynesia stations is shown. This figure presents 1 year of seismicity (1999) of magnitude (Mb) greater than 6.0 and at distances less than 105° with the corresponding ray paths. Circles represent seismic stations and stars are presumed hot spot locations. This map shows that the expected back azimuthal coverage should be rather good, except from the south; and that the numerous ray crossings in Polynesia should significantly improve the resolution of the tomographic models.

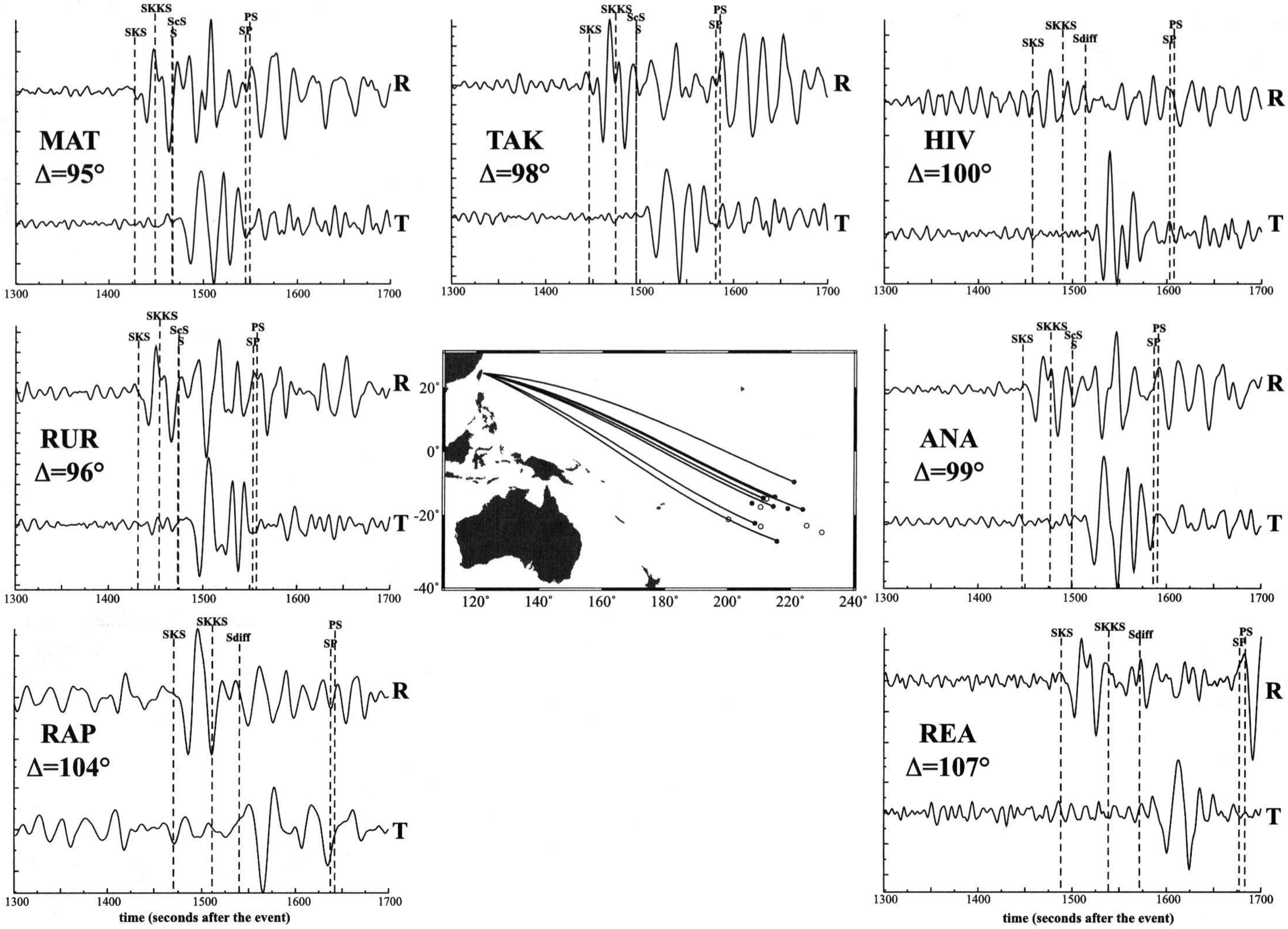

Fig. 3. Horizontal radial (R) and transverse (T) seismograms related to the Taiwan event (31 March 2002 at 06:52:50.4, lat = 24.279°N, long = 122.180°E, depth = 32 km, Mb = 6.2, MS = 7.4) are shown. Data are band-pass filtered for periods between 10 and 50 s. Due to the large epicentral distances—in the range 95 to 107°, depending on the station location—SKS and SKKS phases are well separated from the S and ScS phases. At all stations, SKS energy is restricted to the radial component, which suggests either an absence of anisotropy beneath this area or an anisotropy with a fast split shear wave trending around N100°E, consistent with an upper mantle flow related to the absolute plate motion.

orientations, and hence, the seismic, thermal, and mechanical anisotropy that may exist in the Pacific upper mantle.

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