

attempt to determine the position, extent, and shape of the deep reflector. Given the station density, a tomographic study of near-surface velocities will also be conducted.

Regardless of the two interpretations listed above, correctly mapping the deep structures of this region will shed light on the evolution of rift zones and continental crust in back-arc basins. If the first interpretation is correct (15 kilometers of underplate), then 50 percent of the crust in continental back-arc systems can be created in time spans of a few million years. If instead the second interpretation is true, then the presence of a melt body at 30-kilometers depth would provide researchers with a rare image of magma pooling in the upper mantle subjacent to a line of active andesite volcanoes.

References

- Cook, K. L. (1962), The problem of the mantle-crust mix: lateral inhomogeneity in the uppermost part of the earth's mantle, *Advances in Geophysics*, 9, 296–371.
- Harrison, T. A., White, R. S. (2004), Crustal structure of the Taupo Volcanic Zone, New Zealand: Stretching and Igneous intrusion, *Geophys. Res. Lett.*, 31, L13615, doi:10.1029/2004GL019885.
- Stratford, W. R. and T. A. Stern (2004), Strong seismic reflections and melts in the mantle of a continental back-arc basin, *Geophys. Res. Lett.*, 31, L06622, doi:10.1029/2003GL019232.

—TIM STERN, ADRIAN BENSON, AND WANDA STRATFORD, Institute of Geophysics, Victoria University of Wellington, Wellington, New Zealand; STEPHEN BANNISTER, Institute of Geological and Nuclear Sciences, Lower Hutt, New Zealand.

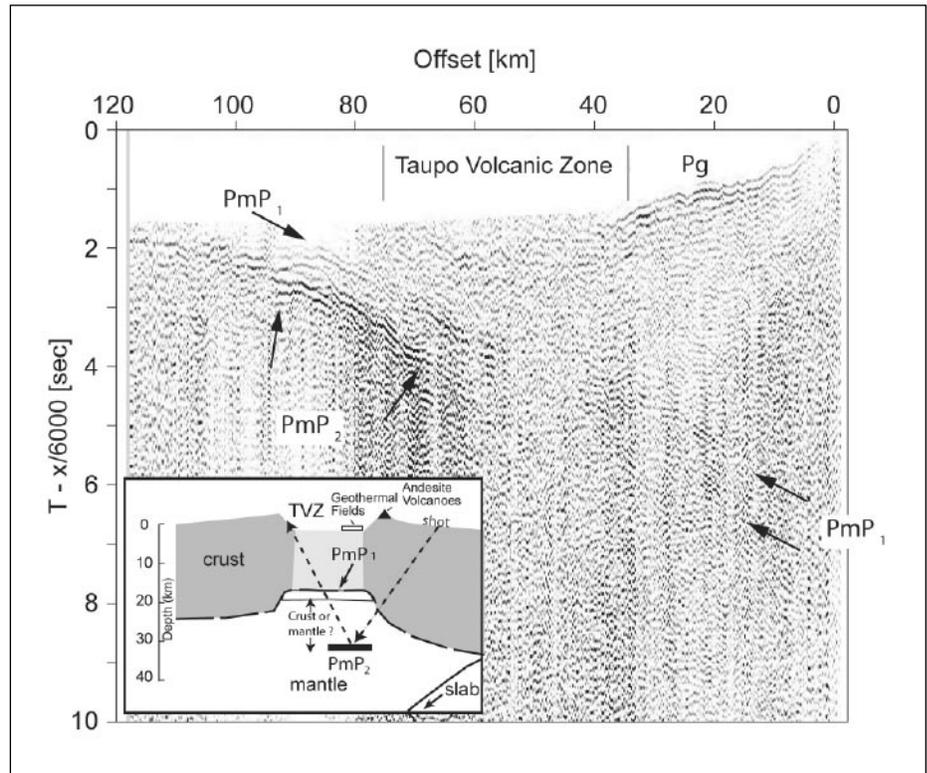


Fig. 2. Shot gather for shot 10 (locality shown in Figure 1). Reduced travel time is used with reduction velocity of six kilometers per second. The inset shows a conceptual model based on previous work and this study. The apparent extent of the PmP₂ reflector is unknown. PmP₁ refers to boundary at ~16 kilometers depth, separating six kilometers per second rocks from 6.8–7.2 kilometers per second rocks below.

MEETINGS

Implementing a U.S. National Phenology Network

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The passing of seasons, as gauged by annual events or phenophases in organisms' life cycles, is arguably one of the most pervasive environmental variations on Earth. Shifts in seasonal timing, or phenology, are observed in flowering and other stages of plant development, animal migration and reproduction, hibernation, and the seasonal activity of cold-blooded animals [e.g., Schwartz, 2003; Root et al., 2005]. As an important life history trait, phenology is an object of natural selection; depending on timescales, shifts in phenology can lead to evolutionary change. Thus, phenology is not only an indicator of pattern in environmental science, but also its variation has fitness consequences for individuals, and these can scale up to broader ecological dynamics.

Many phenological measures are easy to observe at relatively low cost, and they provide

integrative and powerful metrics of living systems. Phenological studies, spatially replicated at the continental scale, can reveal much about the ecology and status of species, communities, and ecosystems [Post, 2003].

For example, sustained, wall-to-wall phenological observations could be instrumental in revealing large-scale patterns of response by species to climate, including conspicuous advances and delays in phenophases across latitudes and elevations, and from coasts to interior. Such observations would be valuable in gauging climate variability and change, crucial in quantifying large-scale spatial synchrony/asynchrony in species' responses [Inouye et al., 2000], and important for the scientific management of land and biological resources.

Presently, the incomplete nature of existing phenological records and the lack of adequate baselines hinder characterization of historic phenological variations in most

locales and provide limited opportunities for extending variations observed across larger regions. Despite many applications, including its relevance for global change, sustained phenological monitoring at regional to continental scales is spotty worldwide and very sparse in the United States. Formal phenological networks have recently been established in Europe and Canada. Following their lead, a U.S. National Phenology Network (USA-NPN) is being organized.

Objectives and Details of the Workshop

A recent workshop, sponsored by the University of Arizona's Institute for the Study of Planet Earth, was convened to begin planning a national-scale, multi-tiered phenological network. With funding and cooperation from federal agencies (U.S. National Science Foundation, U.S. Geological Survey (USGS), U.S. National Park Service, U.S. Department of Agriculture (USDA) Forest Service, U.S. Environmental Protection Agency, U.S. National Oceanic and Atmospheric Administration (NOAA), and NASA), some 40 phenology, remote sensing, and climate experts discussed scientific, technical, and organizational aspects of the network.

Plenary talks included chronicles, by Mark Schwartz (University of Wisconsin, Milwaukee) and Joe Caprio (professor emeritus,

Montana State University), of prior efforts to establish U.S. phenological networks. These talks were followed by reports of established networks elsewhere in the world by Arnold van Vliet (Wageningen University, the Netherlands) for the European Phenological Network (<http://www.dow.wau.nl/msa/epn/>), Jill Attenborough (Woodland Trust, U.K.) for the U.K. Phenology Network (<http://www.phenology.org.uk/>), and Elizabeth Beaubien (University of Alberta, Edmonton) for Canada Plant-Watch (<http://www.naturewatch.ca/english/>).

Scientific issues discussed at the workshop included the selection and prioritization of species to observe, the development of protocols, and strategies to link phenological observations of plants and animals. Workshop participants also discussed methodology, focusing on the identification of technologies to enhance phenological observations, Web-based reporting for observers and for archival storage, and quality-control procedures. Organizational issues were also addressed, including station location and density, public participation and education opportunities, funding, administrative structure, and linkages with existing sites and networks.

Just as national weather and streamflow networks are critical for monitoring and interpreting weather, climate, and water-related issues, USA-NPN would help safeguard and procure ecological goods and services. With this potential in mind, conferees set goals for the network as (1) facilitating thorough understanding of phenological phenomena, including their causes and roles in the biosphere; (2) providing empirical data for ground-truthing, making the most of the large public investment in satellite platforms and remote sensing; (3) allowing the detection and prediction of environmental change for myriad applications, including but not limited to assessing impacts of land use and climate variability/change; and (4) engaging thousands of 'citizen scientists' to contribute to data collection.

The conference produced a framework for the USA-NPN, envisioning it as a five-tiered, expandable structure: (1) a backbone network of coordinated indicator and native species observations linked to existing climatic networks; (2) intensive observations, driven by specific research questions and made by technicians/scientists at established research sites; (3) observations taken by students as a part of regular science curriculums on college campuses; (4) observations reported by citizen scientists; and (5) remote sensing observations validated with surface observations that would allow wall-to-wall U.S. coverage. USA-NPN will also rely on natural history collections and historical data sets (e.g., lilac-honeysuckle observations in the United States that date back to 1957) to extend the significance of current observations.

Applications of the Network

Phenological data, experiments, and models focused around the network can serve

many uses and provide a framework for understanding the roles of climatic variability in the species interactions that shape community structure and dynamics, conferees noted. For instance, in his plenary talk on ecological applications, David Inouye (University of Maryland, College Park) noted that large-scale phenological studies can reveal whether responses to climatic variability by resident and/or sessile species, such as plants, outpace those of nonresident or migratory species, such as many birds and mammals [*Both and Visser, 2001*]. Understanding the causes underlying such patterns will serve to focus conservation and management policy related to climate change.

Conferees also noted that remote sensing-based phenology, coupled with USA-NPN ground-based observations, would provide mechanisms to progress from plant-specific to regional and continental-scale uses of phenology. Although there is a substantial and growing literature on remote sensing phenology [*Schwartz et al., 2002; Reed et al., 2003*], research validation is difficult. Ground-based phenology can help with validation, and, conversely, estimates from remote sensing can fill gaps between ground observations to produce a continuous surface of phenology estimates at the continental scale.

Some compelling applications of surface phenological data outlined by Brad Reed (USGS) include the integration of new spectral-physiological methods in characterizing the biophysics of phenology, such as hyperspectral measures of canopy chemistry, and determining exactly what species and phenophase are represented when phenology is characterized from remote sensing.

Linkages and Partnerships

The USA-NPN will require partnerships among multiple government agencies, universities, and nongovernmental organizations (NGOs). Key to the network's success will be a formal linkage with existing and developing ecological networks, including Long-Term Ecological Research, AmeriFlux, National Ecological Observatory Network, USDA Forest Service Inventory and Analysis, National Park Service Inventory and Monitoring, and state Agricultural Experiment Stations and the strategic co-location of phenological measurements with weather stations. Representatives from key agencies and networks who attended the workshop expressed support for these partnerships, and also for the overall USA-NPN concept.

A plenary talk by Ken Crawford (NOAA) and a follow-up breakout session focused on an important opportunity for USA-NPN: the ongoing modernization of the National Weather Service Cooperative Observer Network, sometimes called the Coop Network, and now known as NOAA's Environmental Real-Time Observation Network (NERON).

For over a century, the Coop Network has provided daily weather observations at thou-

sands of sites, relying on the dedicated volunteer efforts of cooperative observers. In the near future, real-time temperatures, precipitation, wind, insolation, humidity, and soil moisture will be monitored automatically at NERON sites, with cooperative observers responsible primarily for observing snow depths and water content. Automation will enhance the range and frequency of observations at these sites and will free volunteer observers to undertake other observations, including phenology.

USA-NPN will work with NERON to recruit observers and provide this new mission for the program. The large tier of citizen scientist observers will also be encouraged to make co-located climate observations.

NERON implementation began recently in several New England and southern states and will expand to the West next year. This expansion provides an excellent prospect for pilot studies to integrate phenological observations at key sites, rekindle interest in monitoring indicator plants (such as lilacs and honeysuckles) that are particularly sensitive to climate fluctuations, and help integrate statewide phenological networks. As illustrated in Mike Dettinger's (USGS) plenary talk on climate variability and climate change, the West has and will continue to experience disproportionate shifts in the onset and length of the growing season with warming trends, as registered in earlier lilac bloom dates, and in parallel with declining snowpacks, earlier snowmelt, and earlier snowmelt discharge [*Cayan et al., 2001; Mote et al., 2005*].

Based on conference discussions, varied levels of rigor and completeness of ancillary data are anticipated, depending on resources available at each site. For the most complete sites, USA-NPN organizers will work to facilitate, design, and arrange for phenological observatories to be established alongside intense climatic and environmental data collection efforts of existing environmental networks. These sites would allow the network to benefit directly from those programs, and in turn would benefit those efforts by providing a phenological base for interpreting climatic and other environmental observations.

The conference concluded with the formation of an implementation team of 23 scientists, whose expertise spans key disciplines and institutions, to prepare a report for review by the scientific community. As a trial run, USA-NPN will initiate the first set of phenological observations within existing environmental networks. When USA-NPN data systems are ready to assimilate observations from the public at large, the network plans to begin advertising and recruiting observers through appropriate NGOs, as well as through regional and national media.

The USA-NPN Implementation Planning Workshop was held on 23–25 August 2005 in Tucson, Ariz. Copies of plenary talks and breakout group notes are available at the prototype USA-NPN Web site: <http://www.npn.uwm.edu>

References

- Both, C., and M. E. Visser (2001), Adjustment to climate change is constrained by arrival date in a long-distance migrant bird, *Nature*, 411, 296–298.
- Cayan, D. R., S. A. Kammerdiener, M. D. Dettinger, J. M. Caprio, and D. H. Peterson (2001), Changes in the onset of spring in the western United States, *Bull. Am. Meteorol. Soc.*, 82, 399–415.
- Inouye, D. W., B. Barr, K. B. Armitage, and B. D. Inouye (2000), Climate change is affecting altitudinal migrants and hibernating species, *Proc. Natl. Acad. Sci. U.S.A.*, 97, 1630–1633.
- Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier (2005), Declining mountain snowpack in western North America, *Bull. Am. Meteorol. Soc.*, 86, 39–49.
- Post, E. (2003), Large-scale climate synchronizes the timing of flowering by multiple species, *Ecology*, 84, 277–281.
- Reed, B. C., M. White, and J. F. Brown (2003), Remote sensing phenology, in *Phenology: An Integrative Environmental Science*, edited by M. D. Schwartz, chap. 5.1, pp. 365–381, Springer, New York.
- Root, T. L., D. M. Mynowski, M. D. Mastrandrea, and S. H. Schneider (2005), Human modified temperatures induce species changes: Joint attribution, *Proc. Natl. Acad. Sci. U.S.A.*, 102, 7465–7469.
- Schwartz, M. D. (Ed.) (2003), *Phenology: An Integrative Environmental Science*, 592 pp., Springer, New York.
- Schwartz, M. D., B. C. Reed, and M. A. White (2002), Assessing satellite-derived start-of-season measures in the conterminous USA, *Int. J. Climatol.*, 22, 1793–1805.
- JULIO L. BETANCOURT, U.S. Geological Survey and University of Arizona, Tucson; E-mail: jlbetanc@usgs.gov; MARK D. SCHWARTZ, Department of Geography, University of Wisconsin-Milwaukee, E-mail: mds@uwm.edu; DAVID D. BRESHEARS, School of Natural Resources, University of Arizona, Tucson; E-mail: daveb@ag.arizona.edu; DANIEL R. CAYAN, Scripps Institution of Oceanography, La Jolla, Calif.; E-mail: dcayan@ucsd.edu; MICHAEL D. DETTINGER, U.S. Geological Survey, Scripps Institution of Oceanography, and University of California, San Diego; E-mail: mddettin@usgs.gov; DAVID W. INOUE, University of Maryland, College Park; E-mail: inouye@mail.umd.edu; ERIC POST, Eberly College of Science, Pennsylvania State University, University Park; E-mail: esp10@psu.edu; and BRADLEY C. REED, U.S. Geological Survey Flagstaff Science Center, Ariz.; E-mail: reed@usgs.gov

GEOPHYSICISTS

Alfred H. Woodcock (1905–2005)

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Alfred H. Woodcock, oceanographer and cloud physicist, died peacefully in his sleep on 26 February 2005 in Oakland, Calif., at age 99.

Born on 7 September 1905 in Atlanta, Ga., Woodcock's early years hardly foreshadowed his emergence as a successful scientist. After dropping out of high school before graduation, he went from one job to another, 25 in all. Some he left out of boredom, and others, well, he had no choice.

He once explained, "I was fired from the front desk at the Clarendon Hotel because I did not remember the guests' names and from the Western Union Telegraph Company file-clerk job because, while daydreaming, I once had filed an unsent telegram with those already transmitted. That was a no-no of the first magnitude."

Woodcock's final job, that of a scientist, was totally unplanned, a beautiful example of serendipity. In the spring of 1931 he was aboard a small yacht that sailed into Woods Hole, Mass., where a crew was being hired to go to Copenhagen, Denmark, to bring back the research vessel *Atlantis*, a new ship for the Woods Hole Oceanographic Institution (WHOI). Interested in signing on as a member of the crew, Woodcock approached Columbus Iselin, who was to be the captain of the *Atlantis* and years later would become the director of WHOI. Woodcock was hired on the spot.

Iselin said, "I liked him at once, and signed him on as ordinary seaman at \$45 a month, feeling that he would be a steady influence among what looked like a rather turbulent crew.... From the outset it was obvious that Woodcock was much more than a young sailor.... He has been



scientifically... productive.... In fact he is a remarkable person."

Over the next 10 years, Woodcock made many voyages on the *Atlantis*, far more than anyone else at WHOI. He let nature teach him the subtleties of how it worked, looking carefully at what he saw in the sea and in the air. He learned how to frame hypotheses and how to test them with simple experiments.

Woodcock's first three papers were on birds at sea. He believed that much could be learned from these birds about air motions over the sea. All he had to do was watch them.

His third paper on the birds contained his now-classic observations on the soaring of herring gulls. With nothing more than a thermometer and an anemometer to measure the temperature and the wind, he deduced from the gulls' soaring behavior two types of organized convection in the subcloud layer at sea: vertical convection at low wind speeds and horizontal roll vortices at higher wind speeds.

Woodcock was the first to observe Langmuir circulations at sea. He had long noticed that the Portuguese Man-of-War, a common jellyfish, floated at about 45

degrees to the left of the wind and that the *Sargassum* weeds and other floating debris lined up parallel to the wind. From this behavior he deduced that in the upper few meters of the sea there were pairs of counter-rotating cells with horizontal axes parallel to the wind.

At the end of World War II, Woodcock co-led, with Harvard University physical chemist Jeffries Wyman, an expedition to study temperatures below, outside of, and in the clouds in the trade wind areas of the North Atlantic. The conventional wisdom of the day proclaimed that the temperature lapse rate in a cloud was wet adiabatic (the dry lapse rate with the addition of latent heat), but Wyman and Woodcock found the lapse rate in the clouds to be between the wet lapse rate and the lapse rate in the clear air outside the cloud. This was the first demonstration of cloud mixing with the environment.

During his years at sea, Woodcock noticed that the air almost always contained sea-salt particles, and he wondered if these hygroscopic (moisture-absorbing) particles acted as nuclei for the formation of raindrops. Over four years starting in 1949, he published a series of seven pioneering papers on the measurement of atmospheric sea-salt particles. Field experiments were carried out in Hawaii where Woodcock and this author made simultaneous measurements of raindrop size distributions and the sea-salt particle spectrum. The results strongly suggested that the salt particles played a role in the formation of the raindrops.

Inspired primarily by Woodcock, the first large-scale, international attack on the physics and chemistry of warm rain, Project Shower, took place in Hilo, Hawaii, in the autumn of 1954. Participants from outside the United States included Christian Junge from Germany, Erik Eriksson from Sweden, and Sean Twomey, Jack Warner, and Patrick Squires from Australia. The huge mass of data collected during the project and some of the results were published in a special issue of *Tellus* in 1957.

Woodcock moved to Hawaii in 1963 to work at the University of Hawaii and to continue his studies on the role of salt par-