USArray Initiative

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Consider what our understanding of North American tectonics would be like if our best image of the continent's topography was as blurred as that in Figure 1. First-order features like the Cordillera are barely resolved, and the characteristic topography within provinces like the Basin and Range and Great Valley are obscured beyond recognition. Yet it is precisely such a fuzzy view of the lithosphere and deeper mantle that we currently bring to the four-dimensional problem of understanding the structure, evolution, and dynamics of the North American continent.

At a workshop in Albuquerque, New Mexico, in March 1999, jointly sponsored by the National Science Foundation and IRIS (Incorporated Research Institutions for Seismology), seismologists and geologists discussed an ambitious plan to explore, map, and develop an integrated understanding of North American geology. Proposed is the development of a facility, USArray, that amounts to a "Hubble telescope for the earth sciences" (Levander et al., 1999).

OVERVIEW OF USARRAY

The USArray initiative will integrate a dramatic improvement in the resolution of seismic images of the continental lithosphere and deeper mantle with a diversity of geological data to address significant unresolved issues of continental structure, evolution, and dynamics. The USArray facility will consist of three major seismic components: (1) a transportable array of broad-band seismometers that will systematically cover the United States one region at a time; (2) about 2,400 seismometers of various types designed to augment the transportable array so that a range of specific targets can be addressed; and (3) several dozen permanent high-quality seismic stations administered largely by the U.S. Geological Survey within the context of the national seismic network. The goal of this layered design is to achieve imaging capabilities that flexibly span the continuous range of scales from global, through lithospheric and crustal, to local. The infrastructure provided by USArray presents a platform for a multidisciplinary field laboratory integrating geologic, geochemical, and geophysical data.

The core of USArray is a transportable telemetered array of 400 broad-band seismometers designed to provide real-time data from a regular grid with dense and uniform station spacing of ~50 km and an aperture of ~1,000 km. The array will record local, regional, and teleseismic earthquakes, providing resolution of crustal and upper-mantle structure on the order of tens of kilometers and increased resolution of structures in the lower mantle and core-mantle boundary. About 50 magnetotelluric field systems will be embedded within the array to provide constraints on temperature and fluid content within the lithosphere. The transportable array will roll across the country, being deployed for 1–2 years at each site. Multiple deployments will cover the entire continental United States over a period of 8–10 years, providing unprecedented coverage for 3-D seismic imaging. When completed, this will amount to systematic imaging from approximately 2,000

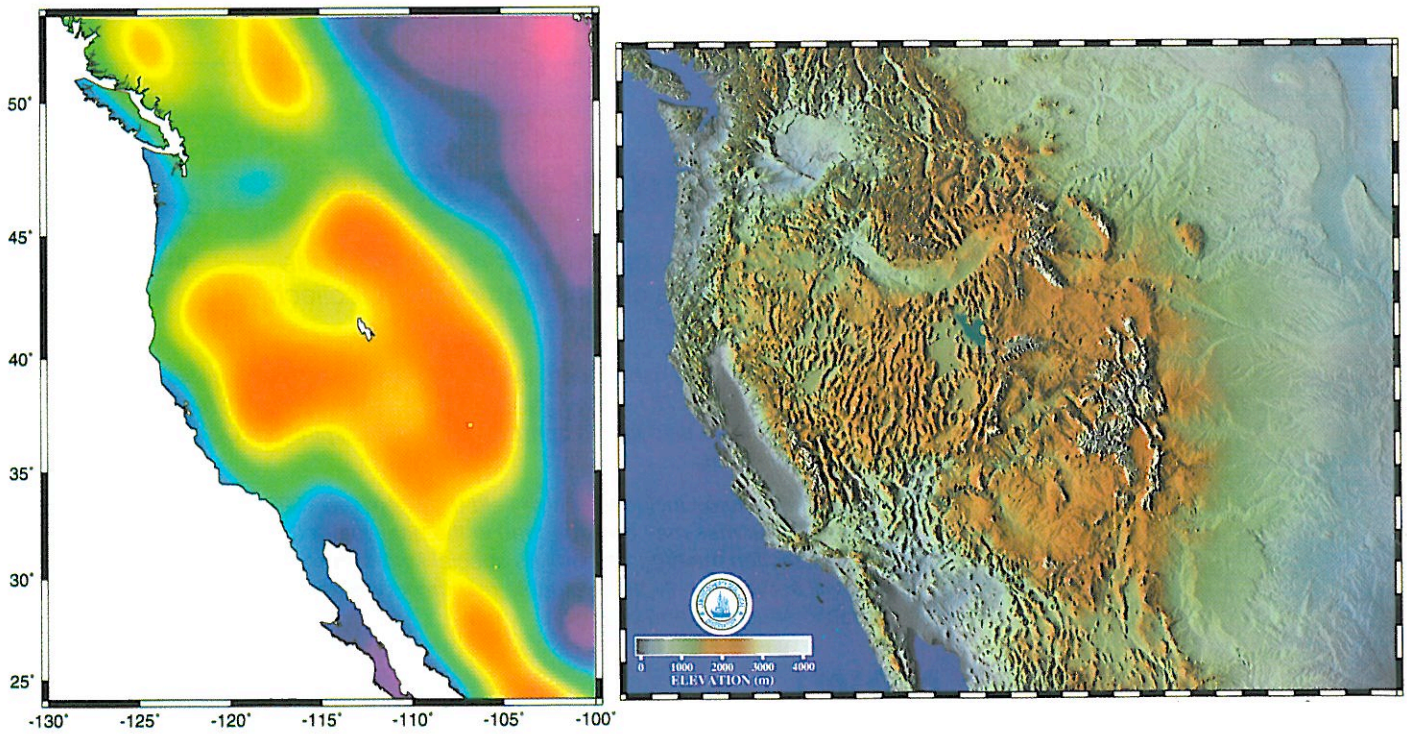

Figure 1. Topography of the western United States at different degrees of resolution. Left: Filtered at 500 km, a resolution similar to that of current global tomographic models. Right: At resolution of 1 km (Simpson and Anders, 1992). USArray will provide resolution of crustal and upper-mantle structure on the order of tens of kilometers.

seismograph stations (Fig. 2). The initial focus of USArray is coverage within the United States; extensions of the array into neighboring countries and onto the continental margins, in collaboration with scientists from Canada, Mexico, and the ocean science community, are natural additions to the initiative (Fig. 2).

The second component of USArray, an additional pool of about 2,400 instruments (broad-band, short-period, and high-frequency) that use flexible source-receiver geometries, will allow for high-density, shorter-term observations of key targets within the footprint of the larger transportable array. This component of USArray offers opportunities for a variety of focused investigations requiring high-resolution images within the context provided by the larger array. Linked with coordinated geological, geochemical, and/or geodetic studies, this part of USArray can address a wide range of problems in continental geodynamics and tectonics. Examples include imaging and study of the continental arc system in the Cascades from slab to edifice; examination of the deep roots of the North American craton and the paleotectonics by which the craton was formed; imaging old and modern orogens and rifts to determine secular variation in continental tectonics; and identifying the role of the mantle lithosphere during orogenesis and rifting.

The third component of USArray, an augmentation of the permanent seismic network in the United States, will provide fixed reference points for calibration of the transportable array, covering the continent with a uniform spacing of 300–350 km. The permanent network also adds an important fourth dimension—time—to the USArray facility, by providing a platform for continuous long-term observations. This component of USArray, to be undertaken in coordination with the USGS, complements the initiative under way at the Survey to install an Advanced National Seismic System. Some or all of the stations of the permanent component of USArray will be equipped as expanded geophysical observatories, with GPS receivers to provide direct real-time data on crustal deformation. Other investigations (for example, heat flow, coring, downhole logging) could take advantage of these platforms also.

Scientific studies that will be greatly enhanced by USArray include: processes of continent formation and breakup; relationship between crustal tectonic provinces and upper mantle structure; rheological stratification of the lithosphere with depth and its variation from orogenic belts to the cratonic interior of the continent; nature of the Moho, and mass transfer between the crust and mantle; lithospheric deformation and earthquake hazard assessment; variations in depth and sharpness of the 410 and 660 km seismic discontinuities and their relations to surface tectonics; heterogeneity, anisotropy, and flow in the mantle; role of fluids (magmas, partial melts, hydrothermal) in the crust; imaging of deep mantle and core structures using beam-forming methods; history of North American subduction and the locations of ancient slabs in the mantle; amd crustal recycling during subduction and orogenesis.

USArray has been designed to provide a structured yet flexible foundation for integrated studies of the continental lithosphere and deep Earth structure over a wide range of scales. The outcome will be an integrated, whole-continent view of North America and improved understanding of the processes that have shaped and continue to shape the continent. As USArray moves across the country, it will be accompanied by a comprehensive educational and outreach program highlighting both overarching and regional earth science issues (hazards, structures, resources) and links between earth science and society. Specific initiatives will include coordination with local news media, museum displays, teacher workshops, and distribution of educational materials, including activities linked to USArray data and results made available over the Internet. Programs will be designed and targeted to engage communities in USArray before, during, and after passage of the array through specific regions of the country.

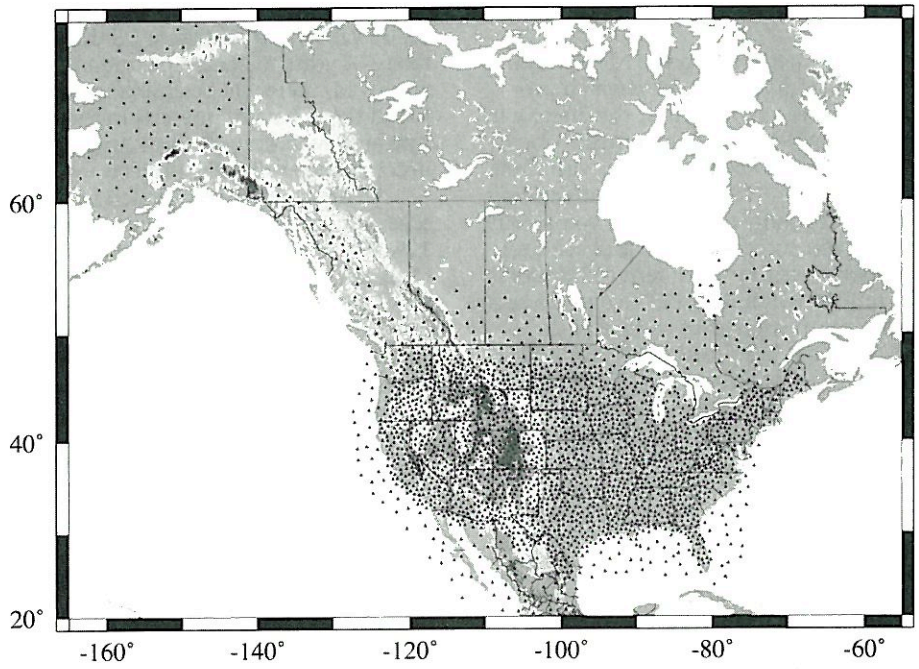

Figure 2. Coverage provided by the transportable component of USArray after installation of 2,000 stations in the continental United States and Alaska. Augmented by stations in Canada, Mexico, and the continental margin.

STATUS AND ORGANIZATION OF USARRAY

An initiative of the scope of USArray requires partnerships between the academic earth science community and such organizations as the National Science Foundation, the U.S. Geological Survey, regional seismic networks, state geological surveys, IRIS, UNAVCO (University NAVSTAR Consortium), and EMSOC (Electro-Magnetic Studies of the Continent). International partnerships and collaborations with industry will also be important as the project matures.

At NSF, program officers of the Division of Earth Sciences (EAR) have united several intertwining streams of research into a single integrated effort known as "EarthScope—A Look into Our Continent." EarthScope includes USArray and initiatives for a Plate Boundary Observatory (Silver, 1998), the San Andreas Fault Observatory at Depth (SAFOD); and Interferometric Synthetic Aperture Radar.

An appropriate source of support for the facilities component of USArray is the MRE (Major Research Equipment) account, an NSF-wide program created in FY1995 to provide funding for the construction and acquisition of major research facilities that are beyond the funding resources of any one directorate. MRE projects advanced by a directorate are reviewed in an NSF-wide competition and require approval by the National Science Board. The MRE account is funded as

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a separate item within the NSF budget, distinct from support for research programs; research budgets at the directorate or division level are augmented to facilitate research to be carried out with these new facilities. Other scientific disciplines (e.g., astronomy and physics) commonly champion successful MRE proposals for support in the range of tens to hundreds of millions of dollars, but to date no such proposal in support of earth science research has been forwarded or funded. The EAR Division and GEO Directorate at NSF and members of the steering committees of the initiatives involved have worked together to develop an EarthScope proposal for the MRE competition. The first phase of the EarthScope initiative, which includes USArray and SAFOD, has advanced and received approval within NSF to move forward for consideration by the National Science Board.

NEXT STEPS

The challenge of developing the technical facility is only one component of USArray. There is broad interest in exploring ways to leverage the resources associated with the USArray facility to catalyze establishment of a fully multidisciplinary field laboratory and to determine the diverse data sets and measurements that should become part of an integrated North American geoscience information system. The USArray initiative has the potential to unite North American geologists and geophysicists into a broad coalition of earth scientists devoted to a decade or more of multidisciplinary studies of the continent. Like the highly successful Lithoprobe program in Canada (Clowes, 1998), USArray stands to expand the culture of shared and coordinated resources within the earth sciences as a whole. A further goal of USArray is to develop an earth science information system including geophysical, geochemical, and geological data that can be easily accessed by the earth science community, educators, and government agencies. All data from USArray will be archived and available in near–real time to the community at large.

The USArray steering committee will continue to seek community input and involvement. The committee is coordinating workshop reports from the meeting in Albuquerque and a second one, in Houston, as well as a science and implementation plan that will be submitted to NSF as the geoscience community's input to USArray's role in the EarthScope MRE initiative. Forums at the autumn meetings of GSA and AGU provide further discussion of the opportunities of USArray to facilitate research in continental structure, evolution, and dynamics across the geoscience communities. Because the MRE competition will extend over the next 12–15 months and because USArray will take 3–4 years to begin operation if approved, there will be ample opportunity for all those having interests in the structure and evolution of North America to become engaged in the project.

USArray and our approach to solving scientific problems will evolve over the 10–15 year period of its operation. Novel ideas and new research targets will require new theory, analysis techniques, and research tools. USArray needs enthusiastic, broad-based support from the earth science community. Scientists in other disciplines regularly organize themselves to their advantage; USArray is a golden opportunity for earth scientists to do the same.

REFERENCES CITED

Clowes, Ron M., Cook, Fred A., and Ludden, John N., 1998, Lithoprobe leads to new perspectives on continental evolution: GSA Today, v. 8, p. 1–7.

Levander, Alan, Humphreys, Eugene D., Ekström, Göran, Meltzer, Anne S., and Shearer, Peter M., 1999, Proposed project would give unprecedented look under North America: Eos (Transactions, American Geophysical Union), v. 80, p. 245, 250–251.

Silver, P., et al., 1998, A plate boundary observatory: IRIS Newsletter, v. 16, no. 2, p. 3, 7–9.

Simpson, D., and Anders, M., 1992, Tectonics and topography of the western United States—An application of digital mapping: GSA Today, v. 2, p. 117–121.

Note: More information about USArray can be obtained from: www.iris.edu; www.iris.edu/newsletter/EE.Fall98.web/usarray.html; and IRIS Newsletter, v. 16 (1998), no. 2, p. 2–6.

Send comments and suggestions about the initiative to any of the members of the USArray steering committee listed as authors of this article. ■