The Long Valley Caldera – White Mountains Region: a Study of Coupled Tectonism and Magmatism

David P. Hill

U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025, E-mail: hill@usgs.gov

William Ellsworth

U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025, E-mail: ellswrth@usgs.gov

Susan Owen

Earth Science Department, University of Southern California, Los Angeles, CA 90089, E-mail: owen@terra.usc.edu

Long Valley caldera lies in a left-stepping offset along the eastern escarpment of the Sierra Nevada at the northern end of the Owens Valley and the western margin of the Basin and Range province. The Long Valley caldera-Inyo-Mono Craters (LVCIMC) volcanic system has produced multiple volcanic eruptions in the last 1 Ma including the caldera-forming eruption 760,000 ybp and the recent Inyo-Mono Craters eruptions 500-660 ybp and 250 ybp. This volcanic system is within the White Mountains "seismic gap" [*Wallace*, 1981] between the northern end of the M~7.6 1872 Owens Valley earthquake and the sequence of M>7 earthquakes in the central Nevada seismic belt. The transtensional tectonic environment Long Valley Caldera-White Mountains region is thus an area of closely coupled tectonism and magmatism characterized by crustal extension, basaltic underplating, and crustal intrusion.

Over the past two decades, Long Valley caldera has shown persistent unrest with recurring earthquake swarms, tumescence of the resurgent dome by over 80 cm, the onset of diffuse magmatic carbon dioxide emissions around the flanks of Mammoth Mountain on the southwest margin of the caldera, and other indicators of the invasion of magma to shallow depths beneath the caldera. Seismic activity within the White Mountains seismic gap during this period has included some seven M≥5 earthquakes east of Mono Lake, the M=6.0 Round Valley earthquake of 1984 and the M=6.4 Chalfant Valley earthquake of 1986. In response to onset of caldera unrest, the USGS established a suite of geophysical, geochemical, and hydrological monitoring networks within and adjacent to the caldera to track the unrest and to provide reliable, up-to-date information to local authorities on the nature of the hazard posed by this volcanic unrest. This monitoring effort has been consolidated under the Long Valley Observatory (LVO).

Although the Long Valley Caldera—White Mountains region is one of the most intensely studied areas in the world, the lithospheric-asthenospheric structure beneath this section of Sierra Nevada and its eastward transition to the extensional Basin and Range Province remains poorly known. Is the central Sierra Nevada underlain by a 55-km-thick crustal root as suggested by Pakiser and Brune [1980] or does it lack a significant root as appears to be the case for the southern Sierra Nevada [*Wernicke et al.*, 1996]? If the former, what is the nature of the structural transition from beneath the high Sierra to the Basin and Range, and where does the Long Valley Caldera-White Mountains lie with respect to this transition? The answers carry important implications for the evolution of the Sierra Nevada and volcanism in the eastern Sierra Nevada and northern Owens Valley. Seismic velocity structures in the upper 15 to 20 km of the crust beneath the LVCIMC volcanic system are reasonable well resolved by active seismic experiments and tomographic studies [see, for example *Dawson et al.*, 1990; *Hill et al.*, 1984; *Kissling*, 1988; *Steck and Prothero*, 1994]. As yet, however, these studies provide only blurred, and in some cases contradictory, images of the location, configuration, and size of crustal magma bodies underlying the volcanic system. The Long Valley Caldera – White Mountains region thus an obvious scientific target for the deployment of temporary seismic arrays using the USArray instrument pool as a basis for significantly advancing our understanding of the interaction between tectonic and magmatic processes in the transtensional tectonic regime of the eastern Sierra Nevada-western Great Basin.

A closely related issue, and one critical to understanding the dynamics of the region, is that of both transient and long-term deformations rates. The Long Valley Caldera – White Mountains region was recommended as one of the "volcano" clusters in the PBO array during the 2nd PBO Workshop of 29 October –1 November 2000. The successful deployment of some 27 continuous GPS sites and 15 borehole strainmeter sites spanning the region under this proposal (Figure 1) will certainly provide invaluable quantitative constraints on both transient and secular deformation patterns in the area. To complete the picture, however, requires relating current, geodetic deformation rates to longer-term geologic rates based on paleoseismological studies. An important issue in this regard involves the partitioning of extension deformation across the region by slip on range front normal faults and magmatic intrusion along dikes as pointed out by Bursik and Sieh [1989]. Studies of Quaternary faulting on the Hilton Creek range-front fault south of Long Valley caldera provide some constraints on this issue [see for example, *Berry*, 1997; *Clark and Gillespie*, 1981]. Tighter constraints for the broader region, however, will require more extensive and systematic trenching studies on the complete set of major range- faults in the region. The most obvious targets include the Hilton Creek/Round Valley/Wheeler Crest fault system, the White Mountains Fault, the Hartley Springs Fault, and the Lee Vining Fault.

Figure Caption

Figure 1. Existing and proposed locations (solid and open symbols, respectively) for borehole strainmeters and continuous GPS sites on a shaded relief map of the Long Valley caldera - White Mountains area.

References

Berry, M.E., Geomorphic analysis of late Quaternary faulting on Hilton Creek, Round Valley, and Coyote Warp faults, east-central Nevada, California, USA, *Geomorphology*, *20* (1-2), 177-195, 1997.

Bursik, M.I., and K.E. Sieh, Range front faulting and volcanism in the Mono Basin, eastern California, *Journal of Geophysical Research*, *94* (B11), 15,587-15,609, 1989.

Clark, M.M., and A.R. Gillespie, Record of late Quaternary faulting along the Hilton Creek Fault in the Sierra Nevada, California [abs], *Seismological Society of America, Earthquake Notes*, *52* (1), 46, 1981.

Dawson, P.B., J.R. Evans, and H.M. Iyer, Teleseismic tomography of the compressional wave velocity structure beneath the Long Valley region, California, *Journal of Geophysical Research*, *95* (7), 11,021-11,050, 1990.

Hill, D.P., E. Kissling, J.H. Luetgert, and U. Kradolfer, Constraints on the upper crustal structure of the Long Valley Mono Craters volcanic complex, eastern California, from seismic refraction measurements, in *Proceedings of Workshop XIX; Active tectonic and magmatic processes beneath Long Valley Caldera, eastern California*, edited by D.P. Hill, R.A. Bailey, A.S. Ryall, and M.L. Jacobson, pp. 151-187, U.S. Geological Survey Open-File Report 84-939, 1984.

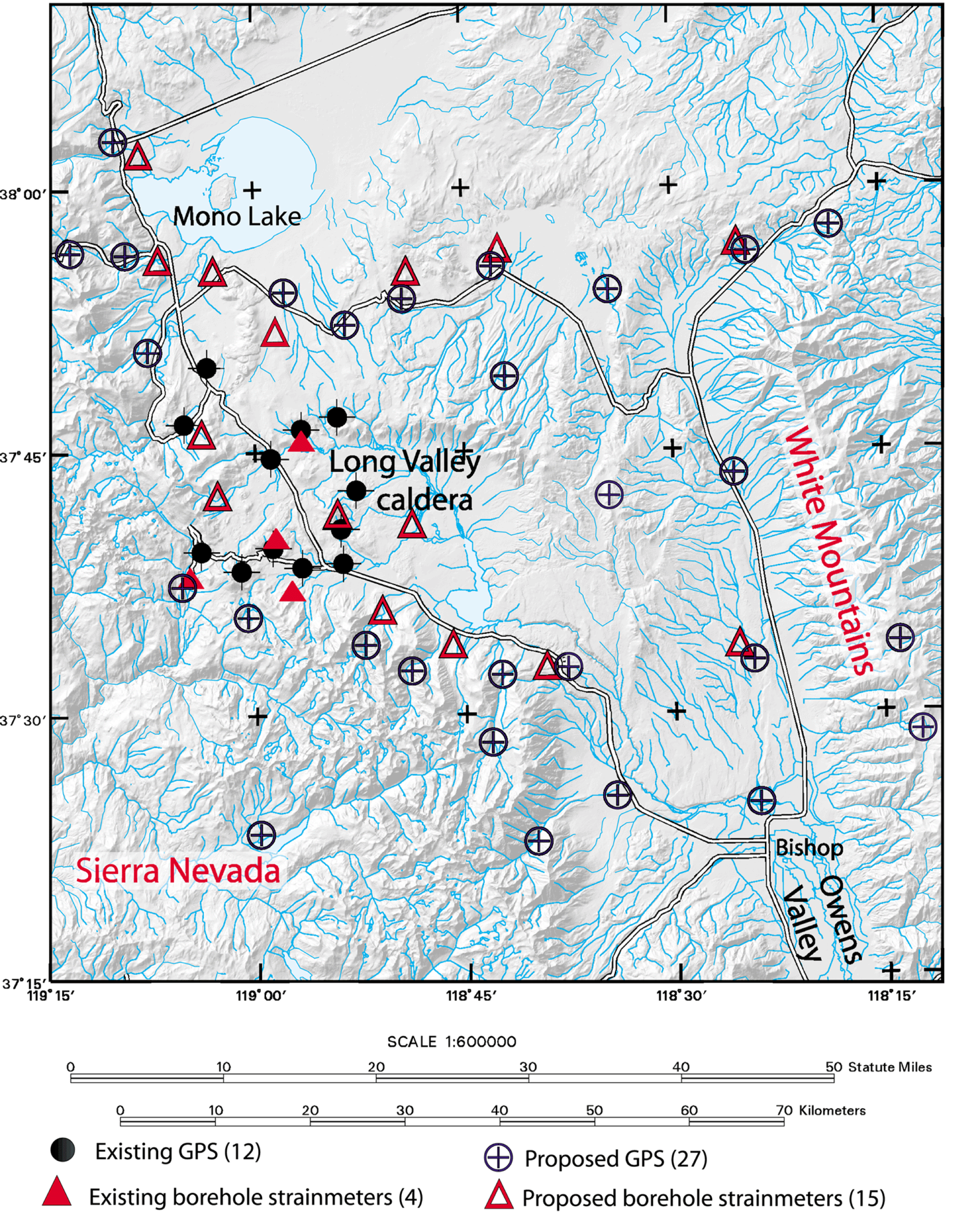
Kissling, E., Geotomography with local earthquake data, *Reviews of Geophysics*, *26* (4), 659-698, 1988.

Pakiser, L.C., and J.N. Brune, Seismic models of the root of the Sierra Nevada, *Science*, *210*, 1088-1094, 1980.

Steck, L.K., and W.A. Prothero, Jr., Crustal structure beneath Long Valley Caldera from modeling of teleseismic P wave polarizations and P-S converted waves, *Journal of Geophysical Research*, *99* (B4), 6881-6898, 1994.

Wallace, R.E., Active faults, paleoseismology, and earthquake hazards in the western United States, in *Earthquake Prediction* **--** *An International Review*, edited by P.G. Richards, and D.W. Simpson, American Geophysical Union, Washington, D.C., 1981.

Wernicke, B.P., R.W. Clayton, M.N. Ducea, C. Jones, H., S.K. Park, S.D. Ruppert, J.B. Saleeby, J.K. Snow, L.J. Squires, M.M. Fliedner, G.R. Jiracek, G.R. Keller, S.L. Klemperer, J.H. Luetgert, P.E. Malin, C.C. Miller, W. Mooney, D., H.W. Oliver, and R.A. Phinney, Origin of high mountains in the continents; the southern Sierra Nevada, *Science*, *271* (5246), 190-193, 1996.



Mono Lake
Long Valley
caldera
White Mountains
Sierra Nevada
Bishop
Owens
Valley
38° 00′
37° 45′
37° 30′
37° 15′
119° 15′
119° 00′
118° 45′
118° 30′
118° 15′
SCALE 1:600000
0
10
20
30
40
50 Statute Miles
0
10
20
30
40
50
60
70 Kilometers
Existing GPS (12)
Proposed GPS (27)
Existing borehole strainmeters (4)
Proposed borehole strainmeters (15)