drawn out over the entire transition and do not suggest geologically instantaneous, catastrophic causes. The lack of change in the bulk of the fauna also argues against indiscriminate, periodic extraterrestrial extinction events (*10*). The Chadronian-Orellan transition strongly suggests that there was a major ecological and climatic change, since similar changes in the reptilian fauna (*11*), the vegetation (*12*), and the soil horizons (*13*) have been reported at this time.

A major mid-Oligocene cooling event, as suggested by the benthic foraminiferal $\delta^{18}O$ record (*14–16*), and circulation event, as suggested by the planktonic foraminiferal $\delta^{13}C$ record (*14*), are known to have occurred. The largest regression in the Tertiary is reported (*15, 17*) from the mid-Oligocene and apparently was caused by a glacio-eustatic fall in sea level (*15*). Evidence from planktonic microfossils (*15*) suggests that this regression began at the top of planktonic foraminiferal zone P20 or the base of zone P21a. Cooler water forms of planktonic foraminifera (*18*) increasingly dominate in the mid-Oligocene. *Braarudosphaera*, a coccolithophorid that is associated with crises, is common in the mid-Oligocene (*19*).

The combined faunal and isotopic evidence together have been interpreted as indicating an increase in Antarctic ice volume and concomitant global cooling in the mid-Oligocene (*15, 20*). This might have been caused by increased development of the circum-Antarctic current and resulting refrigeration of the Antarctic continent due to circumpolar deepwater circulation between Tasmania and Antarctica (*20*). Better knowledge of the precise sequence and timing of these events worldwide will allow a more definite chain of cause and effect to be reconstructed.

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Soil Radon and Elemental Mercury Distribution and Relation to Magmatic Resurgence at Long Valley Caldera

Abstract. *The response of a large geothermal system to magmatic resurgence was analyzed by a survey of soil gas radon and elemental mercury at 600 sites in the silicic Long Valley Caldera, California. The broad geochemical anomaly over the caldera has superimposed on it a small zone of pronounced radon enrichment and mercury depletion coincident with the surface projection of a postulated dike of rising magma. Soil gas geochemistry studies can complement traditional geophysical and geodetical methods in the evaluation of potential volcanic eruption hazards.*

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Geochemical monitoring of volcanic gases from high-temperature fumaroles (*1*) and from soil gas (*2*) has demonstrated that changes in gas ratios or flux are sometimes related to eruptions or seismic activity at volcanoes. In the study reported here I sought to identify geochemical changes caused by magmatic resurgence (*3*) at Long Valley Caldera, California. This silicic caldera formed 700,000 years ago during the explosive eruption of the Bishop Tuff (500 km^3) (*4*). It has since been the site of smaller eruptions, including some as recent as 550 years ago (*5*). Increases in seismicity, uplift, and ground deformation beginning in 1978 led the U.S. Geological Survey to issue a warning of potential volcanic eruption hazard in 1982 (*6*).

In previous studies (*2, 6, 7*), investigators identified a widespread Hg^0 anomaly associated with the caldera geothermal system and a new Hg^0 anomaly in the Inyo craters zone after magmatic resurgence commenced. Radon (*9*), hydrogen (*2*), and helium (*2, 10*) have also been studied in Long Valley since 1978.

This study included approximately 600 measurements of Rn in soil gas and Hg^0 on soil particles from the caldera and the surrounding area. These two elements were studied because, although both are heavy, they have contrasting geochemical characteristics. Radon is inert and has been detected in geothermal steam (*11*) and on faults over active volcanoes (*12*). Because it is radioactive (half-life, 3.8 days), it can be detected at very small concentrations. Its movement is probably promoted by convection set up by high geothermal gradients. Mercury is reactive, important in geothermal systems (*13*), and accumulates on the clay-size fraction of soils. Anomalous concentrations thus indicate zones in which vertical convective heat flow is (or has been) present. Differences in Rn and Hg^0 relations can thus distinguish zones of current gas flux from fossil signatures.

Radon measurements were made with the Terradex Track Etch system (*14*), which is designed to give integrated readings that minimize the effects of diurnal and barometric pressure. Detector cups were buried at a depth of 40 cm for approximately 30 days before being recovered for analysis by the manufacturer. Mercury was detected by using the Jerome Instrument 301 Au-film Hg^0 detector (*15*) on air-dried soil samples (<80 mesh fraction) from the base of Rn detector holes.

Sample sites (Fig. 1) were generally near roads and trails and were chosen after careful consideration of the local geology and structure because experience at other active volcanoes (*2, 12*) has demonstrated that they may exert a strong influence on geochemistry. Most of the recent eruptions (IC in Fig. 1), uplift, and seismicity have occurred in the central and western portion of the caldera; sample spacing reflects this distribution.

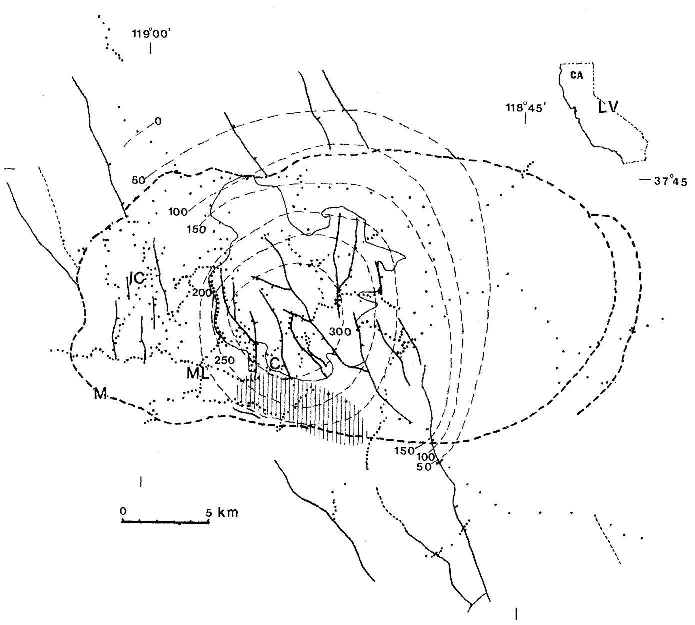
The results for Hg^0 (Fig. 2) were statistically separated (*2*) into three overlapping populations: background, peak, and an intermediate "threshold" group. The background mean of 6.2 ppb Hg^0 (65 percent of the total data) is similar to that reported previously on the basis of much less complete data (*2, 7*). The peak group had a mean of 260 ppb (>40 × background) and represented about 15 percent of the total data (*16*). Most of the caldera and its surrounding area had background Hg^0 concentrations. Three clusters of anomalously high (above threshold) Hg^0 concentrations were identified in the caldera (areas 1, 2, and 3 in Fig. 2). Area 1 occurs over the resurgent dome and the site of greatest recent uplift; it includes most of the obvious geothermal features. Area 2 is less well defined and is largely related to faults. Areas 1 and 2 overlie the principal magma bodies (a and b in Fig. 2), recently identified by their anomalous seismic signals (*17*). Area 3 lies outside the region of that study but is centered on Mammoth Mountain, a volcanic center with extensive present-day fumarolic activity (*4*).

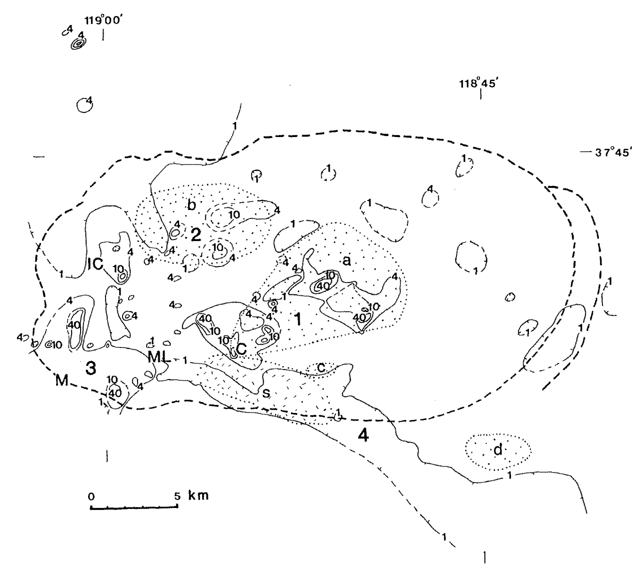
A zone of anomalously low (that is, consistently below background) Hg^0 (area 4 in Fig. 2) lies over the seismicity in the southern moat and outside the caldera. It is significant because my data and those of a 1982 study (*2*) indicate that areas previously identified as containing Hg^0 above background levels (in some cases peak values) (*7*) are now depleted in Hg^0 to below background levels. This "flush zone" was larger in 1983 than in 1982.

The data for Rn also form three overlapping populations. The background mean was 82 T/mm^2 per 30 days, but that group constituted only 5 percent of the total set. A large continuous region of anomalous Rn (above threshold and >3× background) (Fig. 3) overlies and surrounds the resurgent dome and extends to the southeast. It cuts across geological boundaries. This southeast-trending region is approximately coincident with the seismicity recorded since 1978.

An Rn peak (>9× background) occurs in the southern moat, where deformation rates during 1982 and 1983 were most intense (*18*), over the surface projection of a dike postulated to have risen since 1978 (*19*). Smaller Rn peaks are generally related to faults active since 1978.

There are clear spatial relations between Hg^0, Rn, and various geophysical parameters. The two largest Hg^0 anomalies lie over the main magma bodies; the





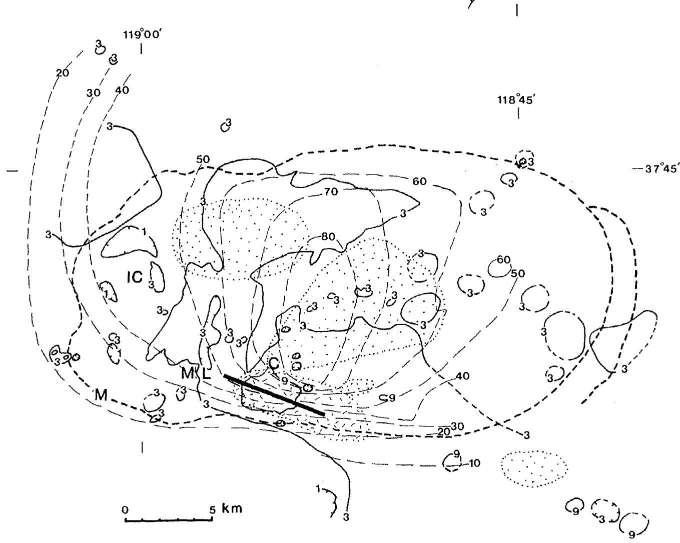


Fig. 1 (top left). Long Valley Caldera (bold dashed lines) with principal faults (bold continuous lines), cumulative 1975–1982 uplift in millimeters (light dashed lines), January 1983 seismic swarm (vertical ruling), outline of the resurgent dome (light continuous line), and Hg^0 and Rn sample sites (dots). Abbreviations: ML, site of Mammoth Lakes Village; IC, Inyo craters; M, Mammoth Mountain; and C, Casa Diablo fumarole. Outline of California shows caldera location (LV). Fig. 2 (top right). Map of the caldera showing geometrically contoured Hg^0 anomalies (continuous lines, dashed where less certain), magma bodies (stippled areas a to d) (*17*), and seismic swarm (hatched area). Hg^0 contours are 1× background (6.6 ppb), 4× (threshold, 26.4 ppb), 10× (peak, 66 ppb), and 40× (264 ppb). Boldface numbers indicate broad Hg^0 highs (1 to 3) and an extensive Hg^0 low (4). Fig. 3 (bottom left). Map of the caldera showing geometrically contoured Rn anomalies (continuous lines, dashed where less certain), magma bodies (stippled areas), seismic swarm (hatched area), surface projection of dike (continuous heavy line) (*18*), and 1982–1983 uplift (light dashed lines) (*19*) in millimeters. Radon contours are 1× background (82 T/mm^2 per 30 days), 3× (threshold, 246 T/mm^2), and 9× (peak, 738 T/mm^2).

third largest is centered on an obvious geothermal feature and volcanic center. An Rn peak and Hg^0 flush zone lies over the area of the greatest rate of deformation, the epicentral region of the January 1983 seismic swarm, and a postulated dike. This suggests that ground gas anomalies are reflecting deep-seated perturbations and not near-surface hydrology (*20*). The magma bodies are postulated to reach to 4.5 km (average depth, approximately 8 km) below the caldera floor (*17*) and the dike to 3 km (*19*). The near-surface hydrologic system extends to depths of 0.5 to 1.5 km and is dominated by flow from northwest to southeast (*20*).

Geophysical, geodetical, and geochemical data indicate that magmatic resurgence has taken place in Long Valley. Various gas signatures indicate an addition of magmatic gas to the geothermal system (*21*). The data are consistent with a model of dike emplacement triggering an increase in the flux of rising gases. Some gases may be directly magmatic but most are probably swept from pore spaces by the convection-induced "plume." The relatively mobile and/or inert gases H, He, and Rn create the surface anomalies observed, but Hg^0 is apparently fixed at depth. Mixing with cold, oxidized, or strongly acidic surface waters would promote HgS precipitation (*13*), or relatively sulfur-rich plume gases could cause formation of Hg^0 complexes. At Kilauea caldera (*3*), strongly acidic caldera soils were high in Rn and low in Hg^0, but peripheral areas had less acidic soil, lower Rn, and high Hg^0. Casa Diablo, the principal caldera fumarole, has both Hg^0 and Rn peak values. Apparently Hg^0 does not have a sufficient rise time to be fixed. The broad-scale Rn and Hg^0 anomalies reflect a steady-state convective geothermal pattern over older degassed magma. The Hg^0 anomaly of the Inyo craters (*2, 7*) is associated with background Rn or negative anomalies, indicating that no active plume exists there.

One may conclude that combined Hg^0 and Rn analysis offers an additional tool for understanding the process of magmatic resurgence taking place at depth. The large-scale geothermal signature of Hg^0 and Rn has been significantly perturbed. The model proposed can explain these perturbations in terms of a plume of gas over the newly intruded dike postulated on the basis of geophysical and geodetical evidence. A relatively small area of the caldera has been confirmed as the site of rising, possibly gas-rich, new magma.

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Cytosolic-Free Calcium Transients in Cultured Vascular Smooth Muscle Cells: Microfluorometric Measurements

Abstract. *Microfluorometric recordings were made of changes in the concentration of cytosolic-free calcium in cultured rat vascular smooth muscle cells treated with quin 2, an intracellularly trapped dye, under several conditions. Nitroglycerin decreased calcium in both the presence and absence of extracellular calcium and strongly and progressively decreased the extent of transient increases in calcium induced by repeated applications of caffeine in the absence of extracellular calcium. Therefore nitroglycerin probably decreases cytosolic-free calcium by accelerating the extrusion of calcium through the sarcolemmal membrane.*

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Contraction of vascular smooth muscle seems to be regulated by changes in the concentration of cytosolic Ca^{2+}. However, changes in Ca^{2+} during contractile activity of vascular smooth muscle cells (VSMC's) have not been measured, except in a few studies in which the Ca^{2+} indicator aequorin was administered intracellularly by microinjection or by making cells hyperpermeable (*1, 2*). We report here the successful recording of Ca^{2+} transients for a given small area (<1 μm^2) in the cytosol of VSMC's by using the fluorescent, Ca^{2+}-sensitive dye quin 2, applied physiologically as the acetoxymethyl ester (quin 2/AM) (*3*). Nitroglycerin induces vasodilation, but the effect of nitroglycerin on the calcium homeostasis of VSMC's is debatable (*4–9*). Using the microfluorometry of quin 2, we investigated the effect of nitroglycerin on the concentration of cytosolic Ca^{2+} in VSMC's.

Primary cell cultures of rat aortic medial VSMC's were established (*10*). On days 5 to 6, just before reaching confluence, the cultured cells on Lux chamber slides were incubated with growth medium containing 50 μM quin 2/AM (DOTITE) for 60 minutes at 37°C and then washed three times with physiological saline solution (PSS) at 25°C to remove dye in the extracellular space. The "normal" PSS (pH 7.4 at 25°C) consisted of 135 mM NaCl, 5 mM KCl, 1mM $CaCl_2$, 1mM $MgCl_2$, 5.5 mM glucose, and 10 mM Hepes. A high-potassium version of this solution was prepared by replacing NaCl with KCl isosmotically. Unless otherwise indicated, the experiments were carried out in normal PSS at 25°C, and high cellular viability (>95 percent)