UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Hydrogen Gas Monitoring at Long Valley Caldera, California

by

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Introduction

The Long Valley caldera is an elliptical depression 20 km N-S by 30 km E-W located at the eastern edge of the Sierra Nevada Mountains, which formed during the eruption of the Bishop tuff 0.7 m.y. ago. Resurgence of the central part of the caldera occurred about 0.6 m.y. ago. Long Valley lies at the south end of the Mono Basin volcanic area which extends to Mono Lake, 80 km to the north. The most recent activity in Mono Basin occurred about 200 years ago (Bailey et al., 1976). During the past 150 years, the region has experienced considerable seismic activity (Rinehart and Smith, 1982). In May 1980, a major seismic swarm, including four magnitude 6.0 earthquakes affected an area which included the southern margin of the caldera. Since then, eight additional earthquake swarms have occurred in this same area. The energy released by these swarms has been approximately equivalent, however, the swarms have become more shallow with time beginning at a depth of 9.0 $\pm$ 1 km during the May 1980 swarm to a depth of 3.0 $\pm$ 0.5 km during the swarm which occurred from May 7-9, 1982 (A. Ryall and R. Cockerham, 1982, personal commun.). These swarms have also been accompanied by a characteristic tremor signal which bears many similarities to volcanic tremor. Because of the seismic activity in May 1980, the USGS issued an Earthquake Watch for the Mammoth Lakes area, which remains in effect.

In 1980 the USGS reoccupied a levelling survey line along highway 395 which crosses the resurgent dome of the Long Valley caldera (Savage and Clark, 1982). Since the previous survey of this line in 1978, the resurgent dome experienced an uplift of 25 cm, half centered on the Hilton Creek fault which intersects the south caldera margin, and half centered on the resurgent dome at Casa Diablo fumarole field.

In early May 1982, it became apparent that the occurrence of the seismic activity and the uplift of the resurgent dome might be more significant than previously suspected. On May 7, 1982 the latest seismic swarm struck the area. Seismic activity again included spasmodic tremor. Location of the swarm defined a restricted epicentral area slightly north of the southern margin of the caldera (fig. 1). Reassessment of changes in fumarolic activity together with seismic activity and uplift of the resurgent dome lead to issuing of a Notice of Potential Volcanic Hazard on May 28, 1982 as an addition to the earlier Earthquake Watch which reads in part:

"The discovery in recent months of ground deformation and new fumarolic activity, apparently associated with this seismicity, indicates that the outbreak of volcanic activity (at Long Valley) also is a possibility but by no means a certainty."

Surficial hydrothermal activity is abundant at Long Valley. There are numerous hot springs and fumaroles with temperatures near boiling, particularly in the southwestern quarter of the caldera (see fig. 5 in Bailey et al., 1976). The activity at these springs has been observed to change in the past, often in relation to seismic activity (Sorey and Clark, 1981). It is reasonable to expect that in the future the shallow hydrothermal system will continue to respond to seismic and/or volcanic activity.

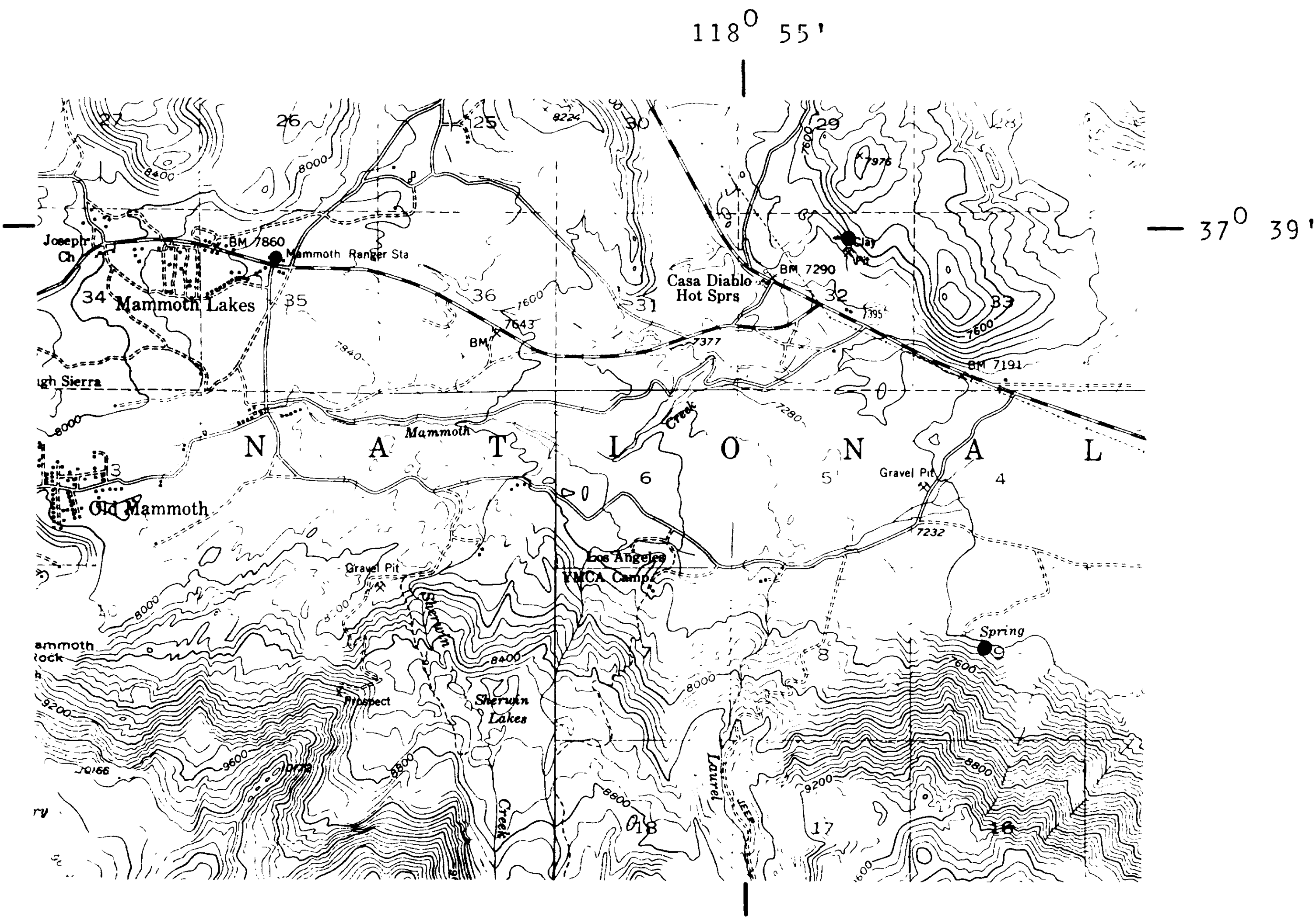


Figure 1. Topographic map showing locations of hydrogen probe stations (●) and Mammoth Ranger Station (•). Base Map: Mount Morrison 15' (USGS).

In response to the need for closer, systematic monitoring of the Long Valley as a means of detecting changes that might precede volcanic activity in the area, we have begun a systematic program to study hydrothermal activity and gas emissions. In this report we describe the initial effort to monitor hydrogen gas as one component of the gas phase that might be given off by an ascending body of magma. Hydrogen is a component of most magmatic gases, and there is now evidence for the release of hydrogen from magmas at shallow crustal depths prior to volcanic eruptions (Sato and McGee, 1981). Hydrogen may also be produced in tectonically active areas by hydration reactions of rock-forming minerals with ground waters at depths where frictional stress results in moderately elevated temperatures. Because hydrogen is extremely mobile and relatively non-reactive once formed, it should ascend to the surface easily through incipient fractures developed in tectonic fault zones. For these reasons, anomalous hydrogen emissions in the Long Valley area may be a good geochemical indication of tectonic or magmatic events.

Monitoring Stations

Two hydrogen gas monitoring sites have been established in Long Valley near the community of Mammoth Lakes, CA (see figs. 1 and 2). One is located on U.S. Forest Service land near Laurel Spring (R28E, T4S, Section 9). The site is situated at an elevation of 2210 m in an aspen grove about 200 m due east of Laurel Spring. The hydrogen sensor is buried to a depth of 1.5 m in a deposit of till and colluvium which rests against an outcrop of granite rock. A fault has been mapped at this location (Bailey and Koeppen, 1977). Also, the inferred rim fault of the Long Valley caldera passes through the area just north of the Laurel Spring site.

The second monitoring site is located at an elevation of 2285 m near Casa Diablo Hot Spring (R28E, T3S, Section 32) on land owned by Magma Energy Company of Los Angeles, CA. The hydrogen sensor is positioned within a fumarole in the upper clay pit excavation. The maximum temperatures of fumaroles in the Casa Diablo area range from 87° to 94° celsius. Gas collected from the Clay Pit fumarole is dominantly air (Table 1). The area is extensively altered to clay (kaolin) and partially silicified rocks. The clay pits are aligned along faults which abound the western margin of the resurgent dome of the Long Valley caldera (Bailey et al., 1976). The original rocks were rhyolites erupted about 0.6 m.y. ago. Casa Diablo is located 3.6 km NNW of the Laurel Spring site (see figs. 1 and 2).

Methods and Initial Results

Hydrogen gas is detected using an electrochemical sensor developed at the USGS. The sensor is basically a fuel cell that produces an electric current in proportion of the amount of hydrogen available for electrochemical oxidation by oxygen. The oxygen is supplied at a rate of a few liters a day from a high-pressure cylinder. A more complete description of the hydrogen sensor can be found in Sato and McGee, 1981.

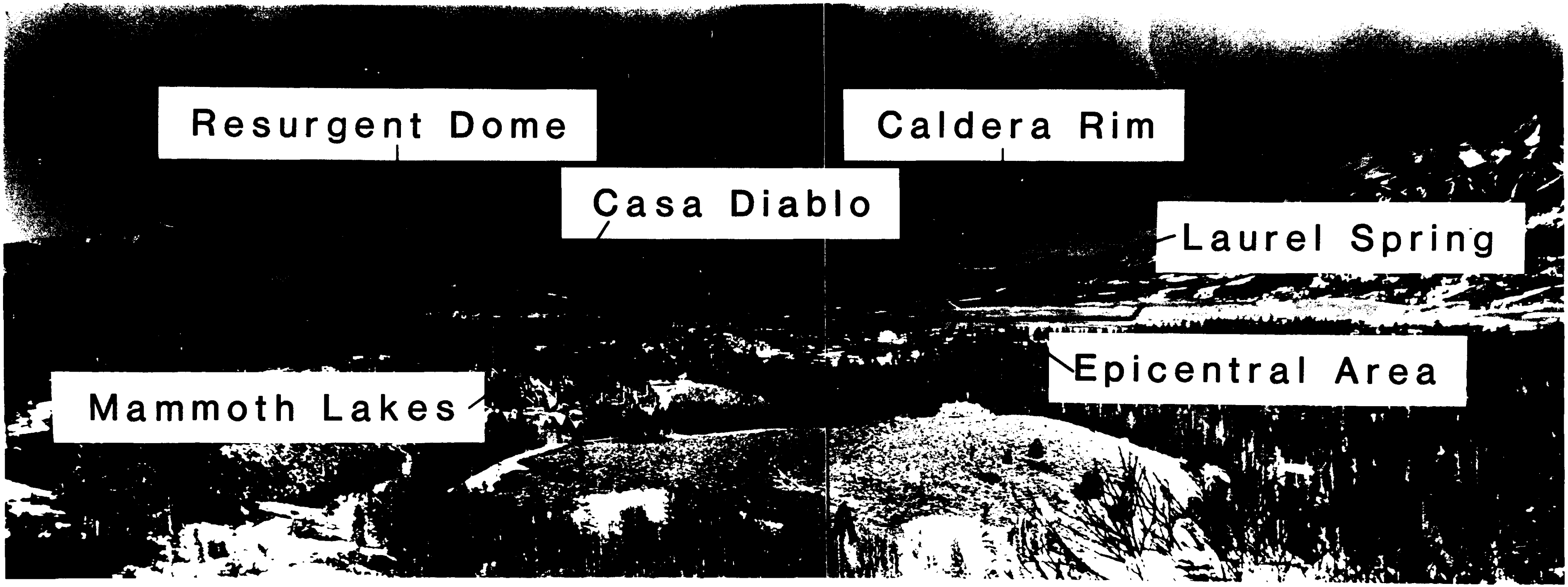


Figure 2. Mammoth Lakes area, south margin of Long Valley Caldera. View to the east from Twin Lakes area showing locations of Mammoth Lakes community; Casa Diablo fumarole area; Laurel Spring; the Epicentral Area of 1980-1982 seismic activity and the Resurgent Dome of the Long Valley Caldera. (Photo by TC taken May 4, 1982).

Table 1. Gas Composition of Clay Pit Fumarole at Casa Diablo

Vol. %	820506-1	820506-2
$O_2 + N_2 + Ar$	99.2	99.4
CO_2	.82	.62
<u>ppm V</u>		
CO	< .5	< .5
CH_4	2.8	3.0
H_2S	< .5	< .5
COS	+	+
SO_2	< .5	< .5
CS_2	< .5	< .5
He	8	8
H_2	3	5
Ne	20	20

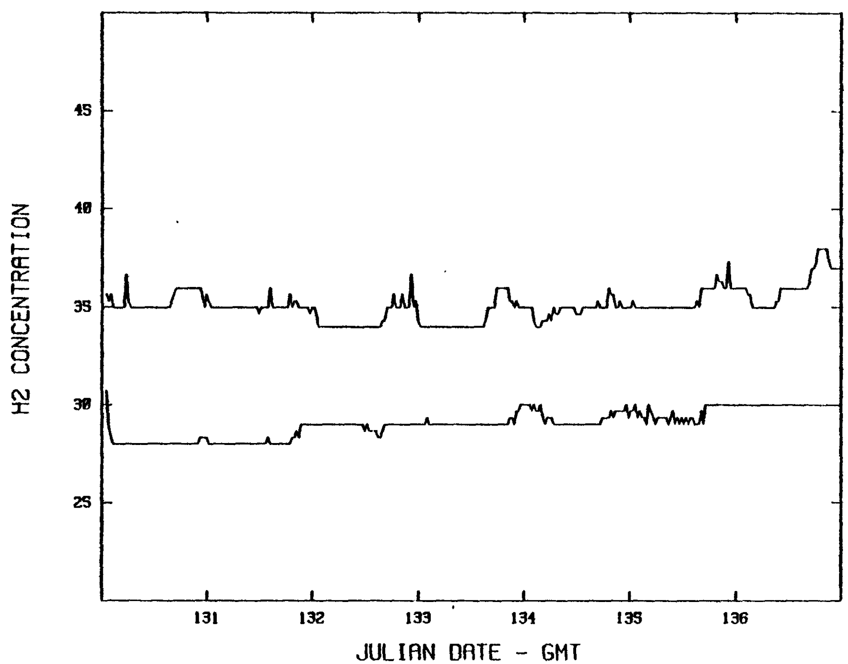
+ Indicates detected but <.5 ppmV

Samples were collected 5-6-82 and analyzed 6-7-82. Both samples contain water. The reported analyses are on a water-free basis.
Analyst - Paul Greenland, USGS, Hawaiian Volcano Observatory

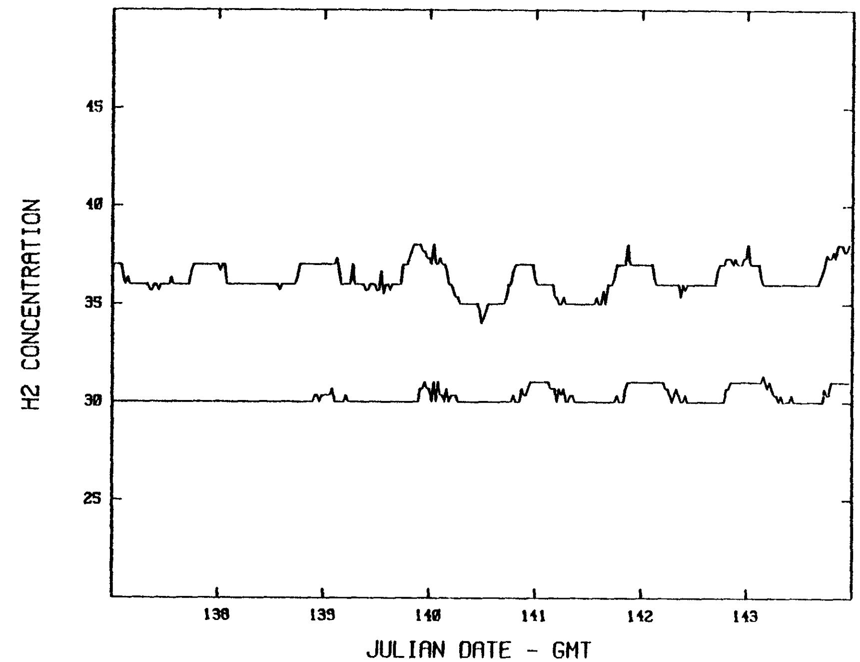
Data on hydrogen emissions are transmitted from each monitoring site using an analog data telemetry system similar to one previously described (McGee and Sato, 1979; McGee, 1979), except that neither a clock nor a multiplexer are used. The version used here converts the low voltage signal from H_2 sensor into an audio frequency which in turn is used to modulate a VHF FM radio transmitter. The output from the telemetry system is thus a single continuous tone, the pitch of which is proportional to hydrogen concentration. The data from each station are received and decoded at the U.S. Forest Service Visitor Center in Mammoth Lakes, CA using VHF FM receivers and discriminators. The discriminators convert the audio tones back into voltages which are proportional to the hydrogen signals from each monitoring location. These voltages are in turn fed to the input of a satellite data collection platform. The data collection platform scans its inputs every 10 minutes and stores the readings in memory until the allocated time window for digital data transmission to a GOES satellite. There are two GOES (Geostationary Operational Environmental Satellite) satellites in Earth-Synchonous orbits approximately 35,500 km above the Equator at longitudes 75° and 35° W. These satellites are operated by the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce. Data are transmitted to one of the satellites every 3 hours. With a 10 minute sampling interval, that means that 18 data points from each monitoring site are transmitted to the satellite at the end of each 3 hour period (144 data points per day). The data are then retransmitted by the satellites to a ground receiving station and stored in a computer memory for data distribution. A small computer terminal and a brief telephone call to the computer center are all that is necessary for us to extract the current data for analysis. Data for the period from May 10 to July 19, 1982 are shown in Figure 3. Since the date of installation, we have observed only minor diurnal variation, which is probably caused by daily microbarometric fluctuations (McCarthy, 1972).

Acknowledgements: We would like to thank the U.S. Forest Service for considerable assistance and cooperation during and preceeding the station installations. We are also grateful to Magma Energy Co. for allowing us to install our equipment on their property.

Figure 3. Hydrogen data for the period May 10 to July 19, 1982 from Long Valley Caldera. The upper curve represents data from the Casa Diablo monitoring site and the lower curve represents data from the Laurel Spring monitoring site. Numerical values for the vertical axis are proportional to hydrogen concentration.



LONG VALLEY HYDROGEN DATA



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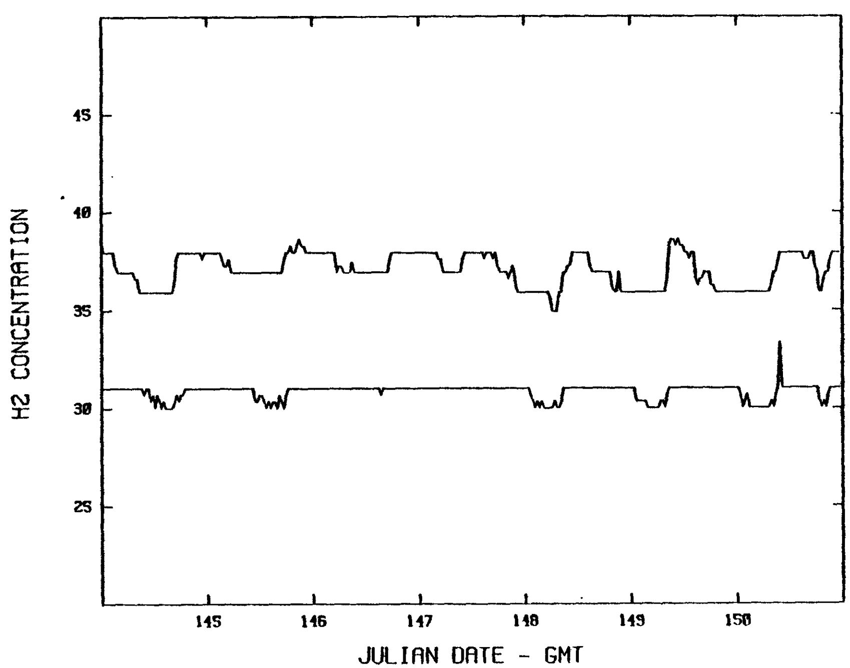

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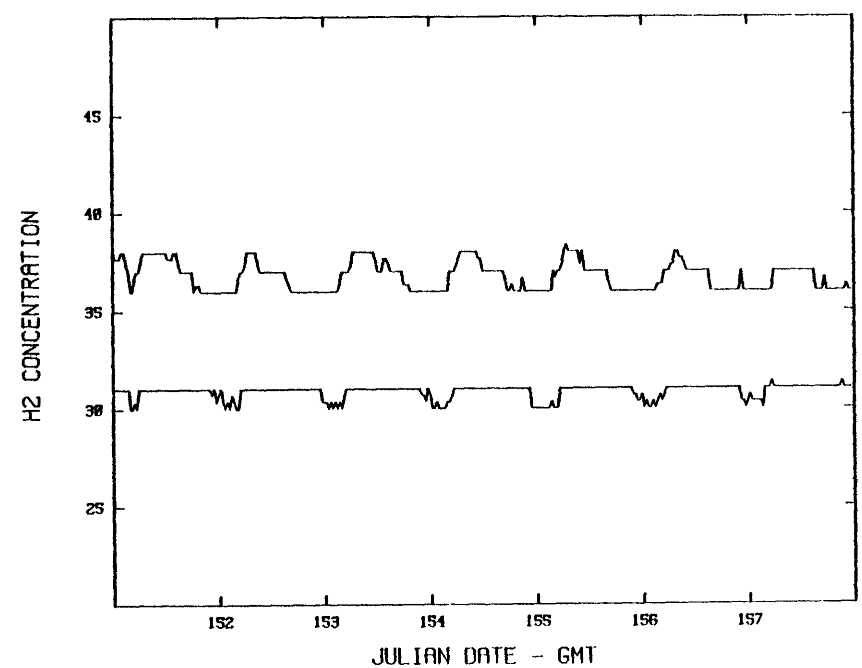

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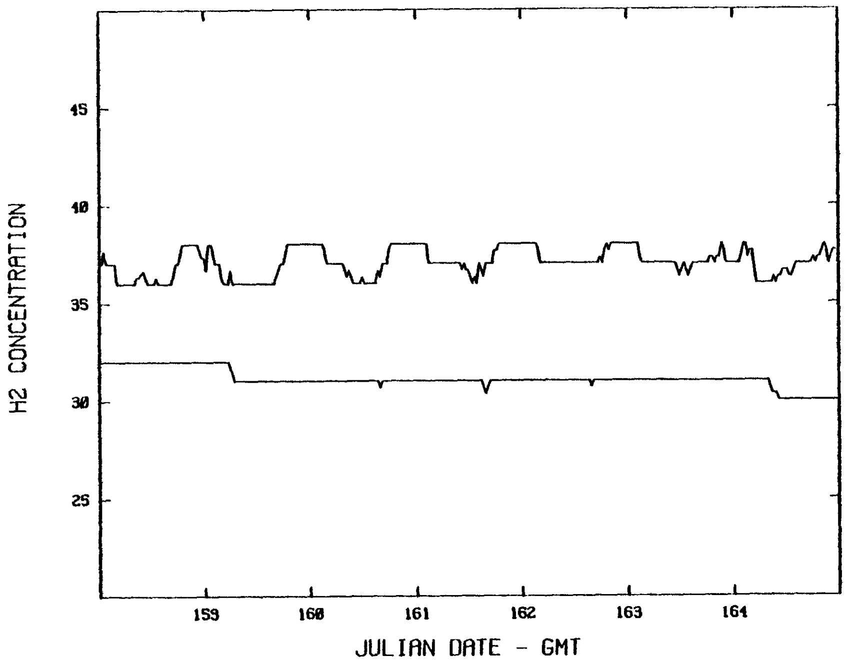

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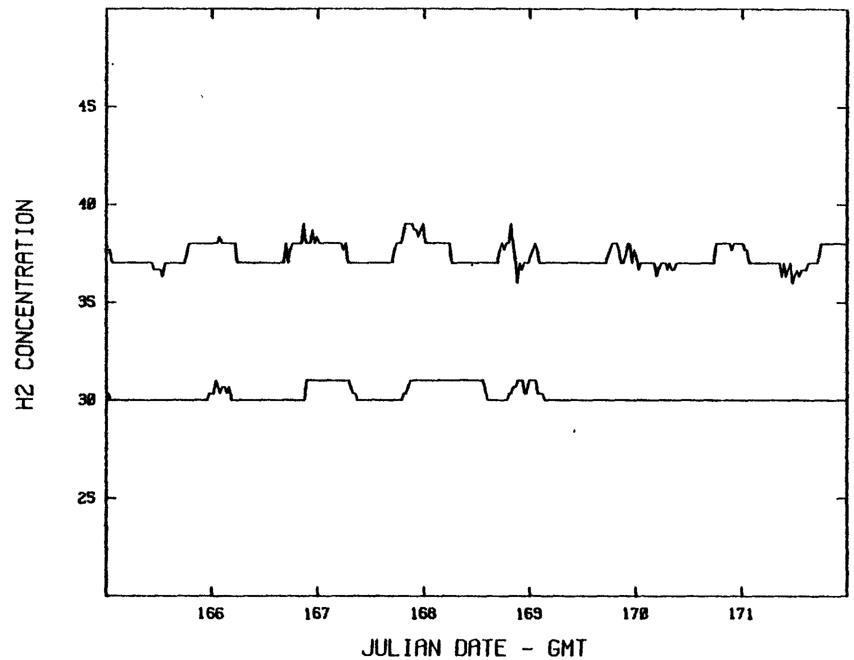

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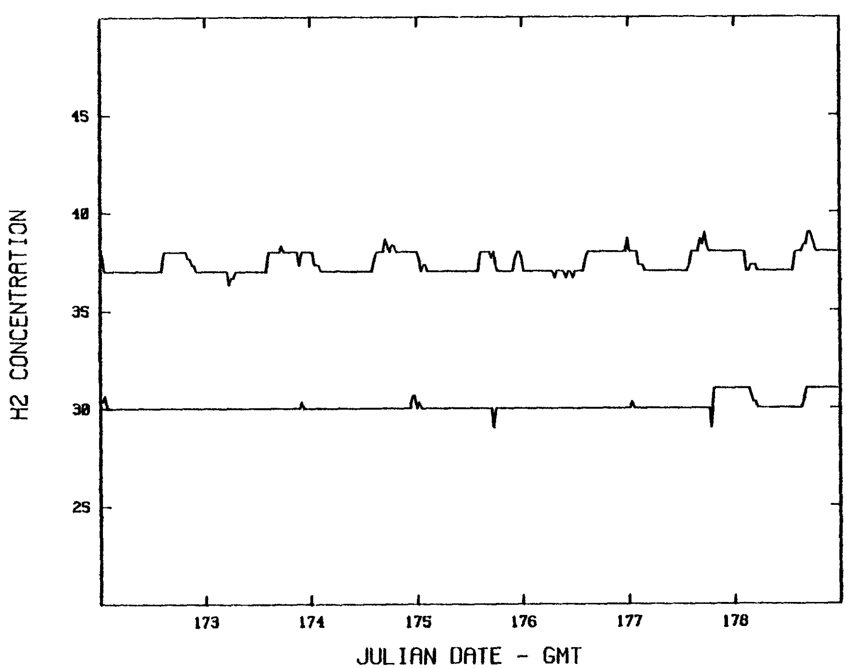

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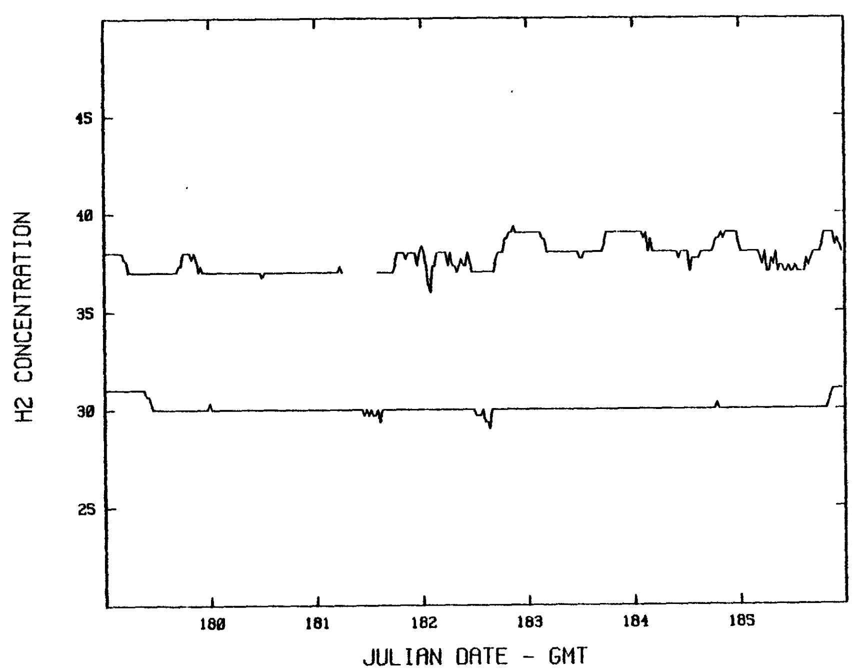

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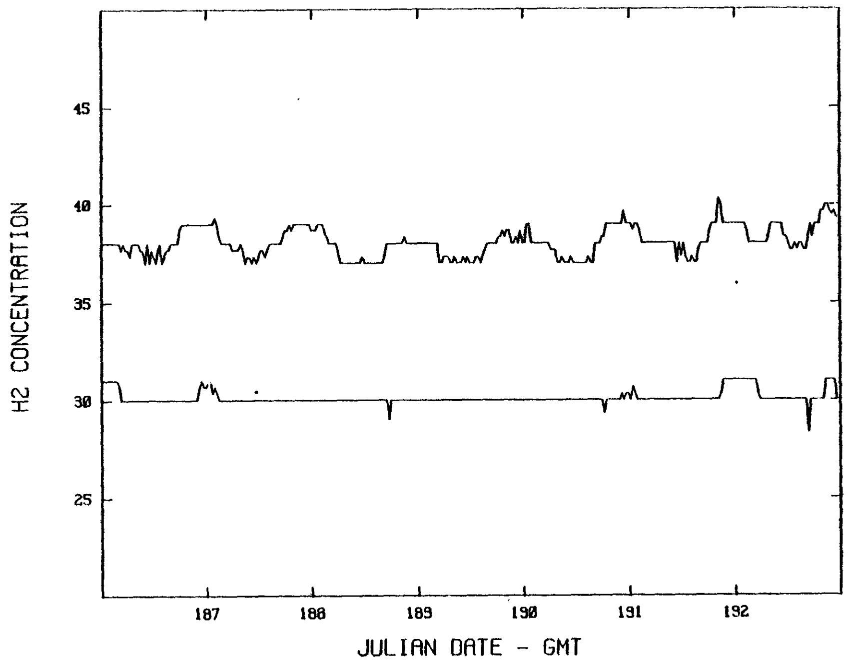

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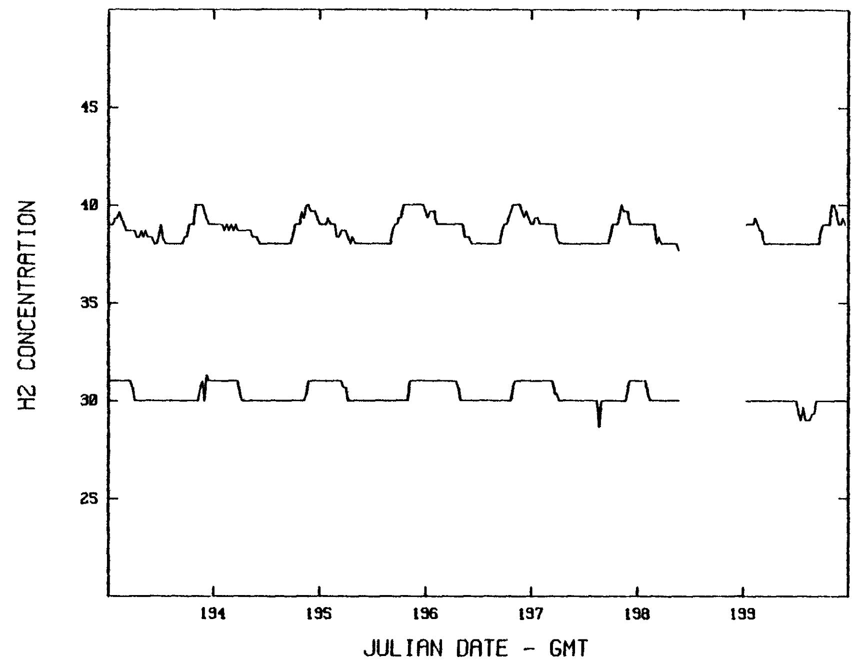

LONG VALLEY HYDROGEN DATA

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