

# **Absolute Gravity and Crustal Deformation in Yellowstone Caldera**

## D. C. McAdoo<sup>1</sup>, A. A. Tikku<sup>2</sup>, F. Klopping<sup>3</sup>, D. Winester<sup>4</sup>, W. Stone<sup>5</sup>, M. Schenewerk<sup>6</sup>, T. Niebauer<sup>3</sup> and J. M. Brown<sup>3</sup>

<sup>1</sup> NOAA Laboratory for Satellite Altimetry, E/RA31, Silver Spring, MD 20910; dave.mcadoo@noaa.gov <sup>2</sup> Lamont-Doherty Earth Observatory, P.O Box 1000, Palisades, NY 10964; ani@ldeo.columbia.edu <sup>3</sup> Micro-G Solutions Inc., 515 Briggs St. P.O. Box 636, Erie, CO 80516; fjklopping@microgsolutions.com <sup>4</sup> NOAA/NGS, N/NGS6, SSMC3, 1315 East-West Highway, Silver Spring, MD 20910; Daniel.Winester@noaa.gov <sup>5</sup> NOAA/NGS, P.O. Box 129, Albuquerque, NM 87103; stone-ngs@cabq.gov 6 NOAA/NGS, N/NGS6, SSMC3, 1315 East-West Highway, Silver Spring, MD 20910; mschenewerk@kc.rr.com,

### Abstract

The Yellowstone Caldera is an active volcanic area at the end of the Snake River Plateau-Yellowstone hotspot chain and has been the focus of a number of geodetic surveys designed to measure crustal motion and mass flux. Major episodes of volcanic activity in the Yellowstone Caldera were 2.0, 1.2, and 0.6 Ma ago. The caldera is still active today as evidenced by seismicity, high heat flow and the presence of numerous thermal hot springs and geysers, in addition to measurable uplift and subsidence of the caldera on the order of 10-20 cm from GPS and leveling. In September 2000 we collected the first absolute gravity measurements in Yellowstone, with coincident GPS measurements. Our 12 baseline observations (8 with the portable A-10 and four with the FG-5) were distributed throughout the caldera. This October (2001) we reoccupied 3 of these FG-5 sites. One of our objectives was to establish benchmarks on bedrock to minimize water table level fluctuations; six of our sites meet this criterion. Four of the sites coincide with relative gravity stations established by the University of Utah. These relative gravity stations can now be tied to absolute gravity stations. Assessing the relative contributions of magmatic and hydrothermal processes can now begin. FG-5 data collected close by Old Faithful in 2000 show a 15 microgal signal over 2 days. This October we collected a second, 3.5 day-long time series of FG-5 observations at Old Faithful revealing a short-period, 9-microgal amplitude signal. A coincident 3.5 day-long time series of GPS heights at Old Faithful showed roughly comparable shortperiod fluctuations of several cm in amplitude. Despite noise in the two signals, some correlation exists between the gravity and topography (as well as eruption times). This Old Faithful gravity signal is similar in amplitude to that obtained at the Wakarewarewa Geyser flat in New Zealand.

45° 00' -

44° 30' -

44° 00'

**GPS setup at Station 3 (2000)** (photo by W. Stone)



The A-10 has nominal accuracy of ~10 microGal vs 7-33 microGal (at best, using looping techniques) for relative gravity.

<u>FG-5</u> has has system accuracy of ~ 1 microGal but is much more difficult to deploy in field.

Yellowstone Absolute Gravity Sites





(one of the first field deployments of A-10)



In 2000, we obtained absolute gravity and GPS data at twelve sites in Yellowstone ncluding five sites (1,10,3,4,5) which form a transect across the Sour Creek resurgent dome (SC) from Canyon southeast past I This transect has been used since 1923 as leveling (now GPS) line to study inflation and deflation of the Sour Creek resurgent dome (e.g. Pelton and Smith, 1979,1982; Dzurisin et al., 1999).

\*Note two gravity sites (12 and 6) lie along the eastern boundary of the Elephant Back (EB) fault zone. Wicks et al. (1998) inferred from InSAR data that region nearly coincident with the **EB** fault zone may act as a conduit between the Mallard Lake (ML) and Sour Creek (SC) resurgent domes.

\*This year (October, 2001), we obtained more FG-5 absolute gravity at three sites, 9 Mammoth. 10 Canvon and 11 Old Faithful At Old Faithful we collected a 3.5 day long time series of GPS data as well the FG-5 gravity at a site 70 meters from the geyser.

## Station 9, Mammoth, a quiet FG-5 gravity site



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# **LAMONT-DOHERTY**

**Old Faithful (station 11) Time Series** 



(b) 2001 Old Faithful FG-5 gravity



276.5 277.0 Julian Day -Year 2001 278.0

Interpretation of gravity-height change ratios for volcanic calderas (from Brown et al, 1991)



**Objective:** to assess relative contributions of magmatic and hydrothermal processes in the Yellowstone caldera

In 2000 we collected the first absolute gravity (using A-10 and FG-5 meters) measurements along with coincident GPS measurements at 12 sites spanning the caldera. Some repeat FG-5 and GPS observations were made this fall.

FG-5 data collected in 2000 and 2001 at Old Faithful reveal large, short-period microgravity (~8-15 mGals) and crustal motion (several cm in the vertical) signals associated with hydrothermal activity in the Upper Geyser Basin.

## **Comparing Gravity and GPS Height Time Series**

Old Faithful gravity (black), GPS heights (red=1hr blue=3hr), Eruption Times (vert lines)



ignificant linear correlation (Pearson's r > 0.4) exists between smoothed 3 our GPS height estimates (in blue) and FG-5 gravity (15-min drop sets); (below) a 'pea rginal significance in the gravity PSD and gravity-height coherences occurs at periods  $\sim 1.5$  hours i.e., near the mean time interval between eruptions



\* Old Faithful gravity and GPS adds to our physical understanding of geysers. We can detect both mass motion beneath the geyser and inflation/deflation of the crust

## **Old Faithful**



(photo by A. Tikku)



