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RESULTS FROM AN ABSOLUTE GRAVITY SURVEY IN THE UNITED STATES

M. A. Zumberge[1,2] and J. E. Faller[3]

Joint Institute for Laboratory Astrophysics
University of Colorado and National Bureau of Standards

J. Gschwind

Geodetic Survey Squadron, Defense Mapping Agency

Abstract. Using the recently completed JILA absolute gravity meter, we made an absolute gravity survey which covered 12 sites in the United States. Over a period of 8 weeks, the instrument was driven a total distance of nearly 20,000 km to sites in California, New Mexico, Colorado, Wyoming, Maryland, and Massachusetts. The time spent in carrying out a measurement at a single location was typically 1 day. A measurement accuracy of around 1×10^{-7} m/s^2 (10 μGal) is believed to have been obtained at each of the sites.

1. Introduction

We have recently completed an absolute gravity survey at 12 sites in the United States (see Figures 1 and 2). Eight sites had been previously occupied by other absolute instruments, and four were new sites chosen because they were near locations in which other measurements relevant to the study of geodynamics were made.

The new instrument (see Figure 3), described elsewhere in detail [Zumberge et al., 1982; Faller et al., 1979], consists of a freely falling corner cube reflector whose downward acceleration is measured interferometrically with a stabilized He-Ne laser. This technique for making gravity measurements has been used successfully by several other researchers [Arnautov et al., 1979; Cannizzo et al., 1978; Faller, 1965; Guo et al., 1983; Hammond and Faller, 1967; Hammond and Iliff, 1978; Murata, 1978; Sakuma, 1974]. We have made a considerable effort to minimize the size and complexity of the instrument to facilitate its rapid deployment without sacrificing accuracy. In our recently completed survey, which was the instrument's first trial involving a series of successive measurements at a number of different locations, an accuracy of 10^{-7} m/s^2 (10 μgal) is believed to have been obtained while the necessary site occupation time was generally less than 1 day.

2. The Instrument

Figure 4 illustrates the principle of the instrument's operation. A Michelson interferometer determines the position of a corner cube, which is allowed to fall freely inside a vacuum chamber. By accurately measuring the arrival times of a subset of the interference fringes, the acceleration of the falling object is calculated. This provides a measure of the local acceleration due to gravity in terms of the laser wavelength and the frequency of the rubidium standard, which is used in the timing electronics.

To minimize nongravitational forces on the falling object, it is surrounded by a servocontrolled motor-driven chamber which moves vertically inside the main vacuum system. The dropping chamber effects the release of the falling object and then tracks it (without physically coming into contact with it) during the measurement. As a result, the falling corner cube is shielded from drag due to the imperfect vacuum. The falling chamber also provides an electrically conducting shell surrounding the dropped object so that external electrostatic fields do not affect the measurement. In addition, the purely mechanical character of the release removes the necessity for having any sort of magnetic support or release mechanism that might result in a residual magnetic force during the measurement.

At most sites that were visited, the entire operation of unloading, assembling the instrument, acquiring the data, disassembly, and re-

Fig. 1. Sites of absolute gravity measurements: 1, Boulder, Colorado (JILA); 2, Denver, Colorado; 3, Holloman AFB, New Mexico; 4, Vandenberg AFB, California; 5, Lick Observatory, California; 6, Owens Valley Observatory, California; 7, Pasadena, California (Kresge Lab); 8, Pinyon Flat Observatory, California; 9, Goldstone Observatory, California; 10, Sheridan, Wyoming; 11, Great Falls, Montana; 12, Gaithersburg, Maryland (NBS); 13, Hanscom AFB, ~~Massachusetts (AFGL)~~.

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[1] Also at Time and Frequency Division, National Bureau of Standards.

[2] Now at Institute of Geophysics and Planetary Physics, University of California, San Diego.

[3] Also at Quantum Physics Division, National Bureau of Standards.

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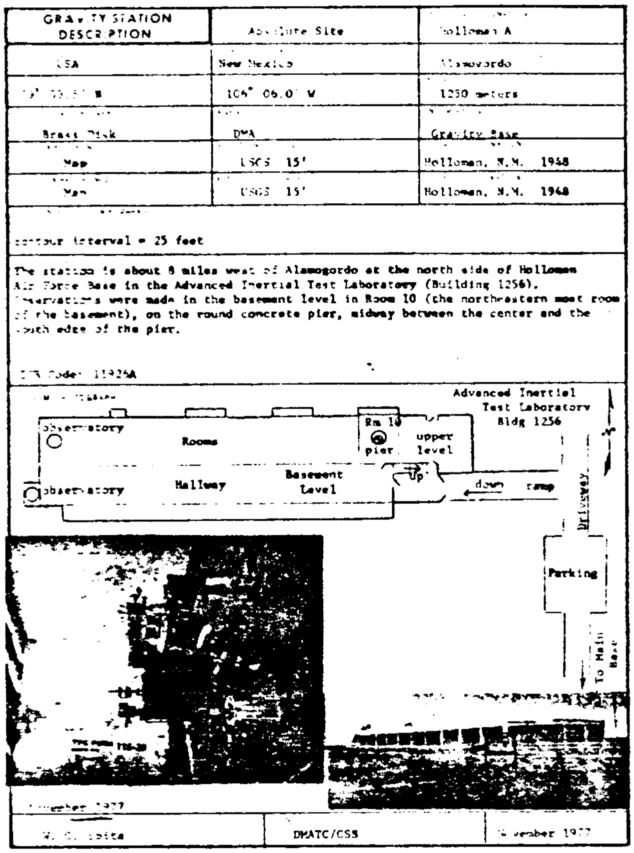


GRAVITY STATION DESCRIPTION	Absolute Site	Holloman A
USA	New Mexico	Alamogordo
[illegible] N	106° 06.0' W	1250 meters
Brass Disk	DMA	Gravity Base
Map	USGS 15'	Holloman, N.M. 1948
Map	USGS 15'	Holloman, N.M. 1948

contour interval = 25 feet

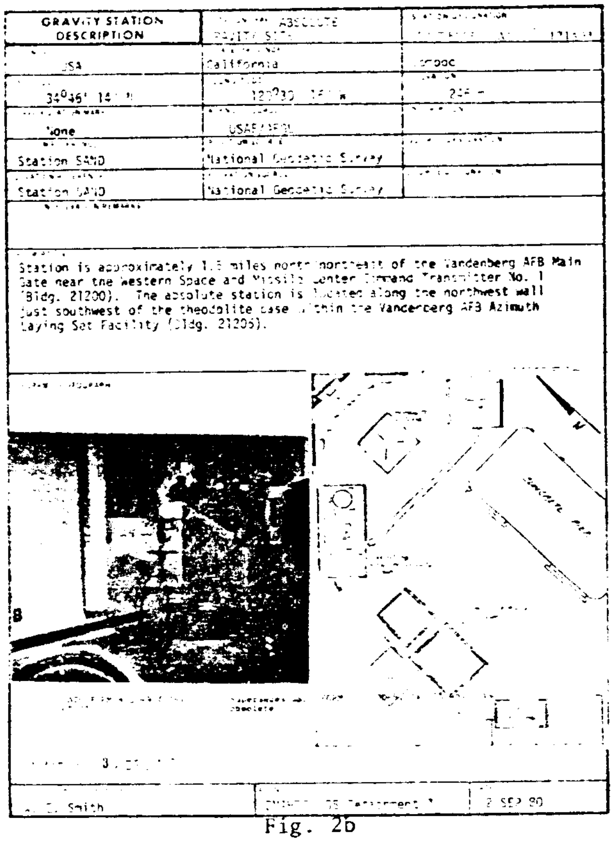
The station is about 8 miles west of Alamogordo at the north side of Holloman Air Force Base in the Advanced Inertial Test Laboratory (Building 1256). Observations were made in the basement level in Room 10 (the northeastern most room of the basement), on the round concrete pier, midway between the center and the south edge of the pier.

[illegible] Code: 11925A

November 1977

W. C. Smith	DMATC/CSS	November 1977

Fig. 2a



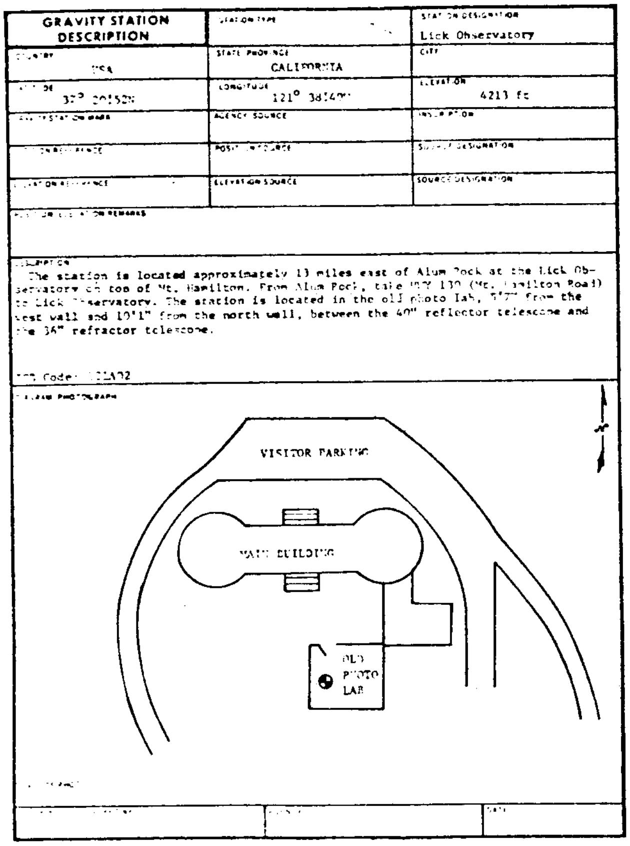
GRAVITY STATION DESCRIPTION	ABSOLUTE GRAVITY SITE	[illegible]
USA	California	Lompoc
34°46' 14" N	120°33' [illegible] W	2[illegible] m
None	USAF/AFGL	
Station SAND	National Geodetic Survey	
Station SAND	National Geodetic Survey	

Station is approximately 1.5 miles north northeast of the Vandenberg AFB Main Gate near the Western Space and Missile Center Command Transmitter No. 1 (Bldg. 21200). The absolute station is located along the northwest wall just southwest of the theodolite base within the Vandenberg AFB Azimuth Laying Set Facility (Bldg. 21205).

3 [illegible]

[illegible] Smith	[illegible] Department	2 SEP 80

Fig. 2b



GRAVITY STATION DESCRIPTION	STATION TYPE	STATION DESIGNATION Lick Observatory
COUNTRY USA	STATE PROVINCE CALIFORNIA	CITY
LATITUDE 37° 20.52'N	LONGITUDE 121° 38.47'W	ELEVATION 4213 ft
GRAVITY STATION MARK	AGENCY SOURCE	INSCRIPTION
POSITION REFERENCE	POSITION SOURCE	SOURCE DESIGNATION
ELEVATION REFERENCE	ELEVATION SOURCE	SOURCE DESIGNATION

POSITION LOCATION REMARKS

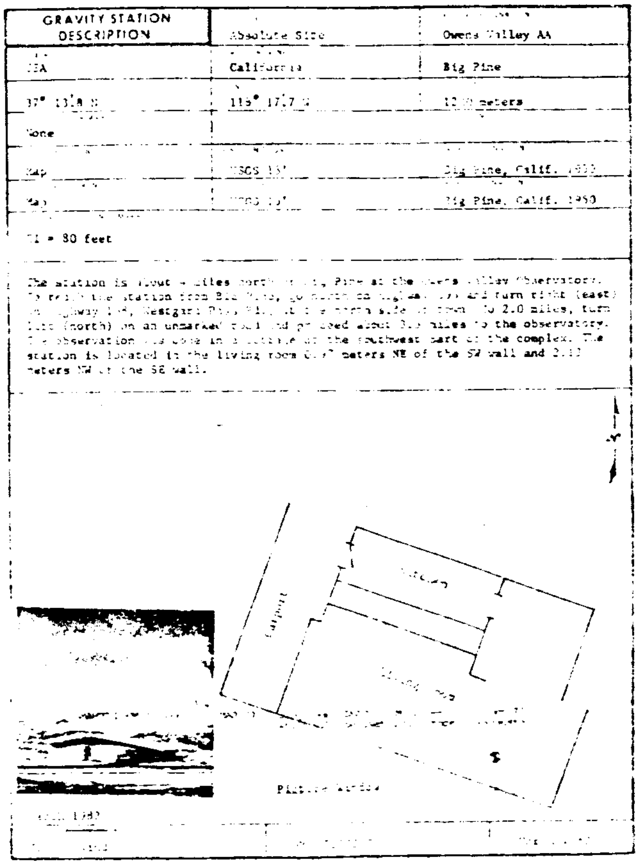
DESCRIPTION

The station is located approximately 13 miles east of Alum Rock at the Lick Observatory on top of Mt. Hamilton. From Alum Rock, take HWY 130 (Mt. Hamilton Road) to Lick Observatory. The station is located in the old photo lab, 5'7" from the west wall and 10'1" from the north wall, between the 40" reflector telescope and the 36" refractor telescope.

[illegible] Code: [illegible]A02

[illegible] PHOTOGRAPH

Fig. 2c



GRAVITY STATION DESCRIPTION	Absolute Site	Owens Valley AA
USA	California	Big Pine
37° 13.8' N	118° 17.7' W	12[illegible] meters
None		
Map	USGS 15'	Big Pine, Calif. 1950
Map	USGS 15'	Big Pine, Calif. 1950

CI = 80 feet

The station is about [illegible] miles north of Big Pine at the Owens Valley Observatory. To reach the station from Big Pine, go north on highway 395 and turn right (east) on highway 168, Westgard Pass Rd., at the north side of town. Go 2.0 miles, turn left (north) on an unmarked road and proceed about [illegible] miles to the observatory. The observation was done in a cottage at the southwest part of the complex. The station is located in the living room [illegible] meters NE of the SW wall and 2.1[illegible] meters NW of the SE wall.

[illegible] 1982

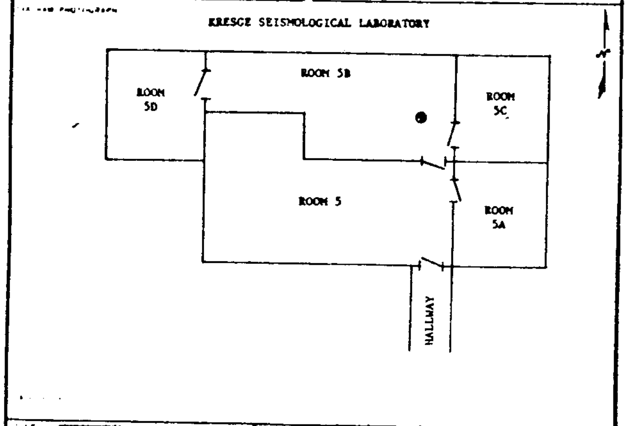
Fig. 2d

Fig. 2. Station descriptions for the sites.

GRAVITY STATION DESCRIPTION	Absolute Site	Pasadena AA
USA	California	Pasadena
34° 08.'92 N	118° 10.'22 W	305 meters
None		
Map	USGS 7½'	Pasadena, Calif. 1966
Map	USGS 7½'	Pasadena, Calif. 1966

CI = 40 feet

The station is located in Pasadena at the Kresge Seismological Laboratory. To reach the station from highway 134 in Pasadena, go north on San Rafael Blvd. about 0.3 miles and turn right (east) at the entrance to the complex. The station is in the lower level of the lab in room 5B, 1.20 meters west of the east wall and [illegible].56 meters north of the south wall.



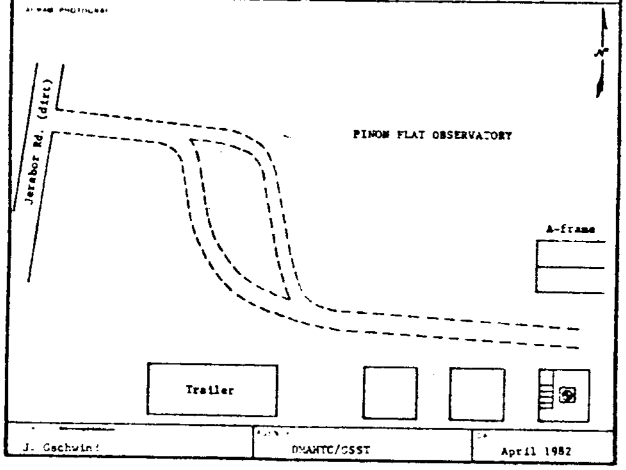
J. Gschwind	DMAHTC/GSST	April 1982

Fig. 2e

GRAVITY STATION DESCRIPTION	Absolute Site	Pinon Flat AA
USA	California	Palm Desert
33° 36' N	116° 27' W	1250 meters
None		
Map	USGS 15'	Palm Desert,Calif. 1959
Map	USGS 15'	Palm Desert,Calif. 1959

CI = 80 feet

The station is about 10 miles SSW of Palm Desert and 1 mile north of Pinon Flat Camp at the Pinon Flat Observatory. To reach the station, go SSW from Palm Desert on highway 74. Turn right (north) on Pinon Drive about 0.5 miles west of the fire station at Pinon Flat Camp. Go about 1.1 miles, turn right (east) on Jerabor Rd. and continue about 1.1 miles to the entrance of the observatory. Observations were done in the easternmost of three 4X4 meter wooden buildings on a 60X60 cm. granite pier projecting about 60 cm. above the floor which is 1.5 meters below ground level.



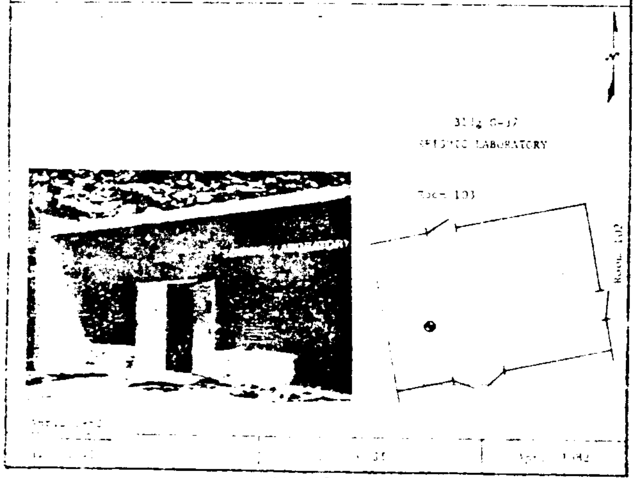
J. Gschwind	DMAHTC/GSST	April 1982

Fig. 2f

GRAVITY STATION DESCRIPTION	Absolute Site	Goldstone AA
USA	California	Barstow
35° [illegible]	116° 48.'3 W	[illegible] meters
None		
Personal Communication	NASA	Mr. Ben Caudian
Map	USGS 15'	Goldstone Lake,Calif. 1948

Per Mr. Ben Caudian, NASA, the coordinates of the Echo antenna are 35° 18' [illegible] 116° 48.'3 W. Since the site is approximately [illegible] meters north of the antenna, the coordinates are 35° 18.'[illegible] N, 116° 48.'3 W.

The station is located about 25 miles [illegible] of Barstow at Camp Irwin Military Reservation in the seismic laboratory (Bldg. G-37) near the Echo antenna of the NASA Goldstone Deep Space Complex. To reach the station, proceed [illegible] on Barstow Rd. from Barstow to Camp Irwin. Turn left [illegible] on NASA Rd. and [illegible] miles to a NASA guard station. Continue 2.[illegible] miles and turn right [illegible]) on Echo Rd. to the Echo Antenna Complex. The station is about 300 meters north of the Echo antenna in the seismic laboratory 1.36 meters NE of the SW wall and 1.[illegible] meters NW of the [illegible] wall.



[illegible]	[illegible]	[illegible] 1982

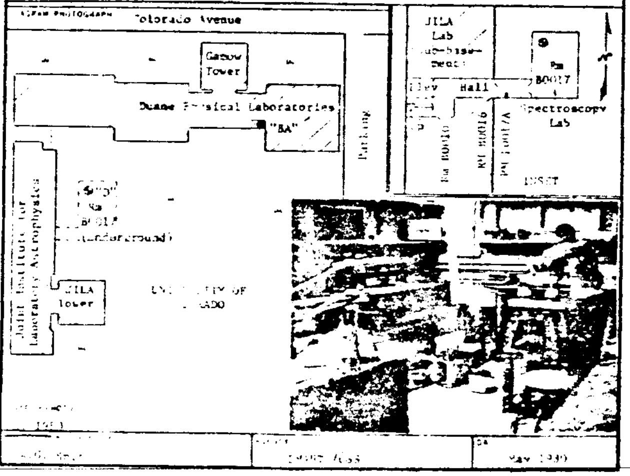
Fig. 2g

GRAVITY STATION DESCRIPTION	STATION TYPE Absolute Site	STATION DESIGNATION Boulder D
COUNTRY USA	STATE/PROVINCE Colorado	CITY Boulder
LATITUDE 40° 00.'5 N	LONGITUDE 105° 16.'1 W	ELEVATION 1633 meters
GRAVITY STATION MARK Brass disk	AGENCY SOURCE USAF	INSCRIPTION Gravity Station
POSITION REFERENCE Map	POSITION SOURCE USGS 7 1/2'	SOURCE DESIGNATION Boulder, Colo 1966
ELEVATION REFERENCE Map	ELEVATION SOURCE USGS 7 1/2'	SOURCE DESIGNATION Boulder, Colo 1966

POSITION/ELEVATION REMARKS

DESCRIPTION The station is in the southern part of Boulder at the University of Colorado, 0.5 miles west of 28th Street, south of Colorado Avenue and Folsom Stadium, in the Joint Institute for Laboratory Astrophysics (JILA) building. Observations were made in the sub-basement in Room B0017 (the Spectroscopy Lab) near the northwest corner, 1.5 meters south of the north wall, 2.0 meters east of the west wall, on the tile floor.

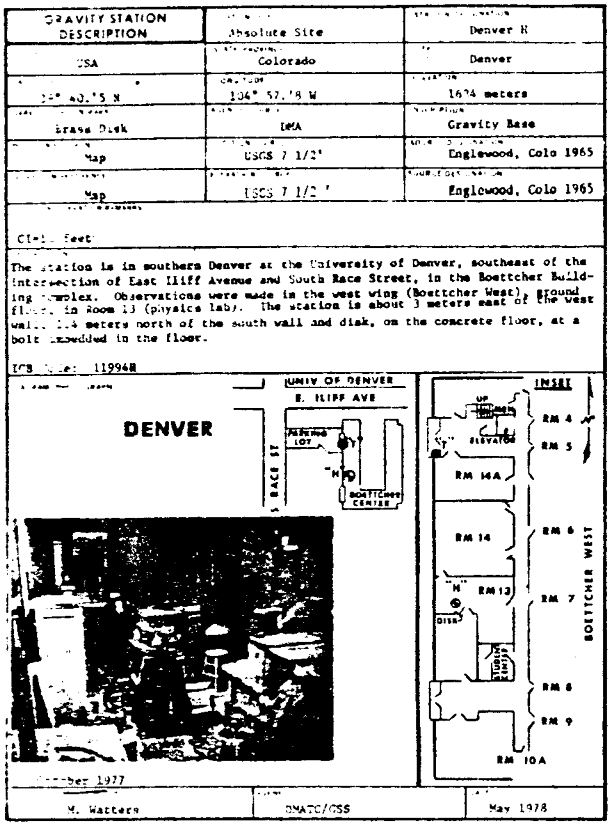
[illegible] Code: 15505D



[illegible]	[illegible]	May 19[illegible]

Fig. 2h

Fig. 2. (continued)



GRAVITY STATION DESCRIPTION	Absolute Site	Denver H
USA	Colorado	Denver
39° 40.'5 N	104° 57.'8 W	1674 meters
Brass Disk	DMA	Gravity Base
Map	USGS 7 1/2'	Englewood, Colo 1965
Map	USGS 7 1/2'	Englewood, Colo 1965

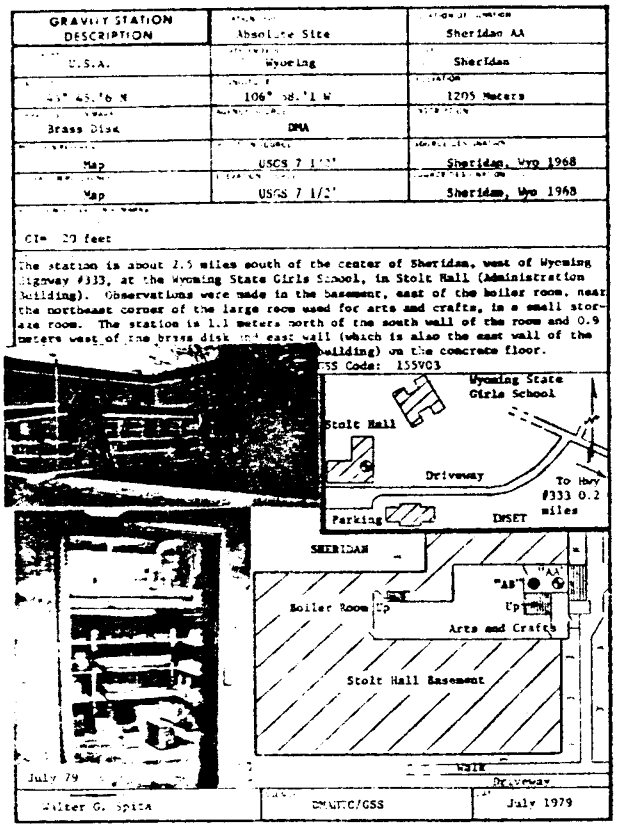
CI=10 feet

The station is in southern Denver at the University of Denver, southeast of the intersection of East Iliff Avenue and South Race Street, in the Boettcher Building complex. Observations were made in the west wing (Boettcher West), ground floor, in Room 13 (physics lab). The station is about 3 meters east of the west wall, 1.4 meters north of the south wall and disk, on the concrete floor, at a bolt imbedded in the floor.

IGB Code: 11994H

M. Watters	DMATC/GSS	May 1978

Fig. 2i



GRAVITY STATION DESCRIPTION	Absolute Site	Sheridan AA
U.S.A.	Wyoming	Sheridan
44° 45.'6 N	106° 58.'1 W	1205 Meters
Brass Disk	DMA	
Map	USGS 7 1/2'	Sheridan, Wyo 1968
Map	USGS 7 1/2'	Sheridan, Wyo 1968

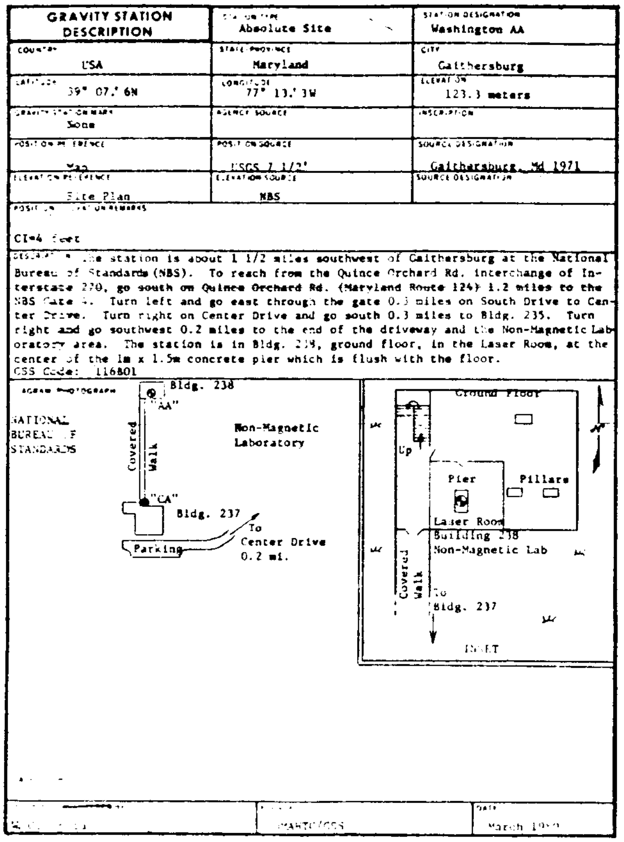
CI= 20 feet

The station is about 2.5 miles south of the center of Sheridan, west of Wyoming Highway #333, at the Wyoming State Girls School, in Stolt Hall (Administration Building). Observations were made in the basement, east of the boiler room, near the northeast corner of the large room used for arts and crafts, in a small storage room. The station is 1.1 meters north of the south wall of the room and 0.9 meters west of the brass disk and east wall (which is also the east wall of the building) on the concrete floor.

GSS Code: 155VC3

Walter G. Spitz	DMATC/GSS	July 1979

Fig. 2j



GRAVITY STATION DESCRIPTION	STATION TYPE Absolute Site	STATION DESIGNATION Washington AA
COUNTRY USA	STATE-PROVINCE Maryland	CITY Gaithersburg
LATITUDE 39° 07.' 6N	LONGITUDE 77° 13.' 3W	ELEVATION 123.3 meters
GRAVITY STATION MARK None	AGENCY SOURCE	INSCRIPTION
POSITION REFERENCE Map	POSITION SOURCE USGS 7 1/2'	SOURCE DESIGNATION Gaithersburg, Md 1971
ELEVATION REFERENCE Site Plan	ELEVATION SOURCE NBS	SOURCE DESIGNATION

POSITION/ELEVATION REMARKS

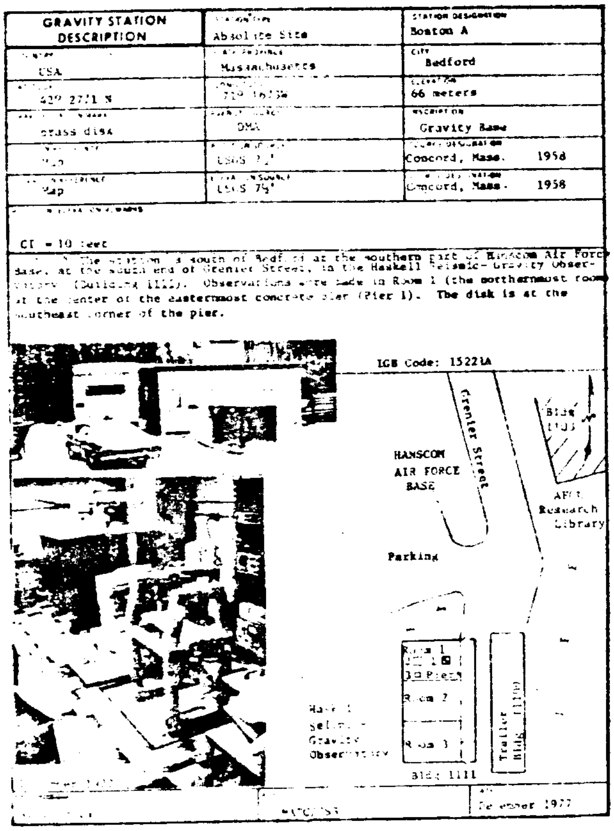
CI=4 feet

DESCRIPTION The station is about 1 1/2 miles southwest of Gaithersburg at the National Bureau of Standards (NBS). To reach from the Quince Orchard Rd. interchange of Interstate 270, go south on Quince Orchard Rd. (Maryland Route 124) 1.2 miles to the NBS Gate 4. Turn left and go east through the gate 0.3 miles on South Drive to Center Drive. Turn right on Center Drive and go south 0.3 miles to Bldg. 235. Turn right and go southwest 0.2 miles to the end of the driveway and the Non-Magnetic Laboratory area. The station is in Bldg. 238, ground floor, in the Laser Room, at the center of the 1m x 1.5m concrete pier which is flush with the floor.

GSS Code: 116801

	DMATC/GSS	DATE March 19

Fig. 2k



GRAVITY STATION DESCRIPTION	STATION TYPE Absolute Site	STATION DESIGNATION Boston A
USA	Massachusetts	CITY Bedford
42° 27.'1 N	71° 16.'3W	ELEVATION 66 meters
brass disk	DMA	INSCRIPTION Gravity Base
Map	USGS 7½'	Concord, Mass. 1958
Map	USGS 7½'	Concord, Mass. 1958

CI = 10 feet

The station is south of Bedford at the southern part of Hanscom Air Force Base, at the south end of Grenier Street, in the Haskell Seismic-Gravity Observatory (Building 1111). Observations were made in Room 1 (the northernmost room) at the center of the easternmost concrete pier (Pier 1). The disk is at the southeast corner of the pier.

IGB Code: 15221A

	DMATC/GSS	December 1977

Fig. 2l

Fig. 2. (continued)

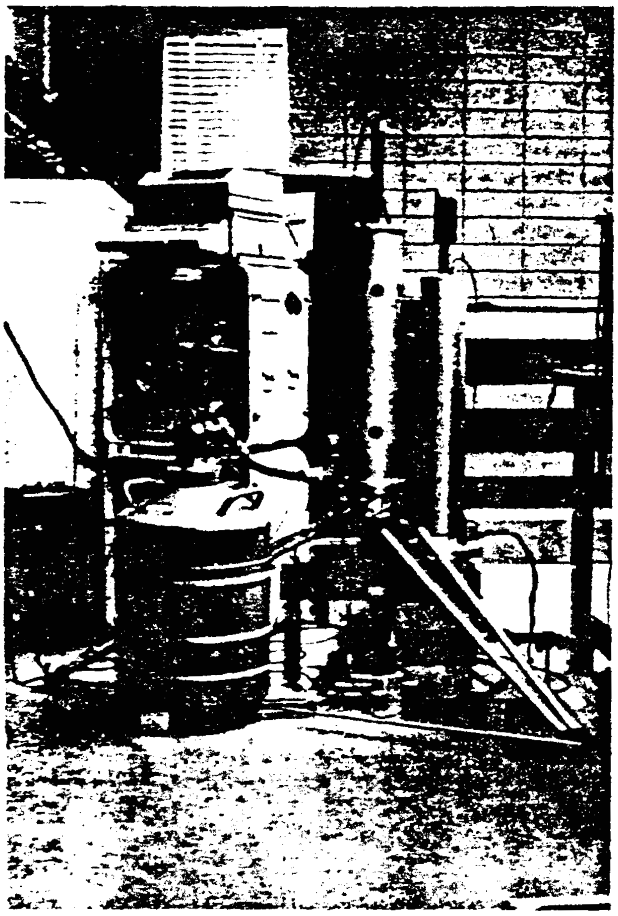


Fig. 3. Photograph showing instrument at the Denver site. Normally, the large dewar (seen in foreground) is left in the truck.

loading required less than 1 day. The vacuum chamber was pumped continuously, even during transport in a small truck. This eliminated the pump-down time that would otherwise have been necessary preceding each measurement. At three sites, mechanical problems inside the dropping chamber needed attention, and as a result, the vacuum was lost. This usually meant an overnight delay to obtain a good vacuum after the problem was corrected.

When no such difficulties were encountered, the operation proceeded smoothly and rapidly. After unloading, two half-racks of electronics containing all of the necessary data acquisition and control electronics were connected and interfaced with the mechanical components, which included an interferometer base, a long-period isolator [Rinker and Faller, 1983], and an evacuated dropping chamber. These three components required minimal mechanical alignment. Under normal conditions, the time needed to get the instrument setup and running was 2 hours. Although gravity data were available immediately following the instrument's assembly, they were generally rejected because of known instrumental biases that can result from temperature transients. To insure quality gravity measurements, the instrument had to remain passive for an hour or so after its initial setup and testing. During this time, the laser, the long-period isolator, and the pressure in the vacuum chamber equilibrated with the new temperature environment.

The period over which actual measurements were taken varied among the sites from several hours to as long as 1 day. Since a data set of 150 drops can be taken in 10 min, the statistical uncertainty is outweighed by systematic effects after a few hours of measurements. Disassembly and reloading required approximately 1 hour, as did the transfer of the absolute value from the measurement height to the floor using a relative gravimeter.

3. Results

Table 1 lists the results from the absolute gravity survey. Included in this list are earlier data from two measurements at a site in Denver, Colorado, and the original measurements from our lab at JILA. The result from one of the 12 sites, Great Falls, Montana, has been omitted. Floor motions at this site, evidenced by analysis of both the long-period isolator signal and time shifts related to the dropped object's position in its fall as well as other unfavorable characteristics of the surroundings resulted in a measurement uncertainty that we believe is at least an order of magnitude larger than obtained elsewhere.

The uncertainty stated for each site is a one sigma estimate of the absolute accuracy based on a root summed square incorporation of four terms. The first is a 4×10^{-8} m/s^2 (4 μGal) uncertainty from instrumental effects which include nongravitational forces, optical path effects, and timing accuracy. The second term is a 5×10^{-8} m/s^2 (5 μGal) uncertainty from possible errors in the laser wavelength. Analysis of the data to date indicates that the laser we used in the March 1982 Denver measurement and the Kresge lab measurement may be the source of a 1 to 2×10^{-7} m/s^2 (10 to 20 μGal) systematic error. Results from these sites have accordingly been assigned larger uncertainties.

The next term in the uncertainty comes from the transfer done with a relative gravity meter from the effective absolute measurement height

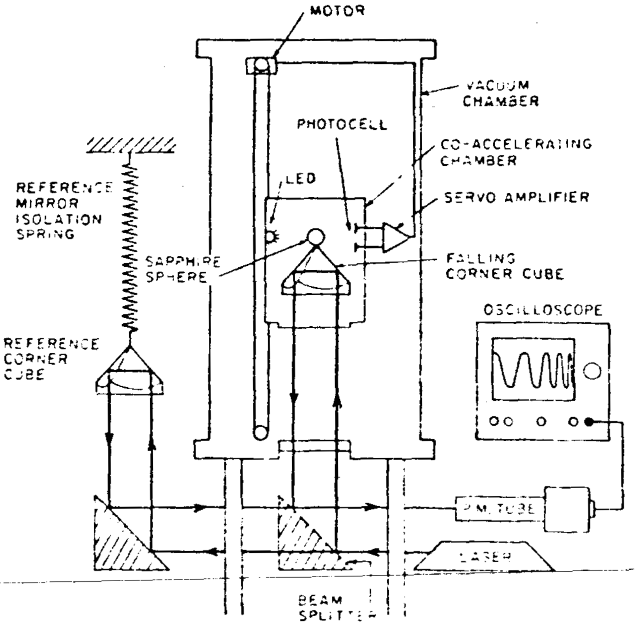


Fig. 4. Schematic of absolute gravimeter.

TABLE 1. Gravity Values Transferred to the Floor

Date	Site	Result, m/s^2 (10^8 μGal)	Uncertainty, 10^{-8} μ m/s^2 (μGal)	Gradient, 10^{-6}/s^2 (μGal/cm)
April 4-10, 1981	JILA	9.79 608 562	7	2.39
May 2-4, 1981	JILA	9.79 608 569	6	
June 6-12, 1981	JILA	9.79 608 566	7	
July 1-6, 1981	JILA	9.79 608 573	7	
Dec. 11-15, 1981	JILA	9.79 608 569	10	
Feb. 1-25, 1982	JILA	9.79 608 557	12	
April 14-15, 1982	JILA	9.79 608 573	9	
Dec. 16-17, 1981	Denver	9.79 598 322	12	2.92
March 1, 1982	Denver	9.79 598 302	12	
March 21, 1982	Holloman AFB	9.79 139 615	8	2.99
March 26, 1982	Vandenberg AFB	9.79 628 137	9	3.44
March 27, 1982	Lick Observatory	9.79 635 503	9	4.42
March 29, 1982	Owens Valley	9.79 444 410	8	2.93
April 1, 1982	Kresge Lab	9.79 560 457	13	2.65
April 7, 1982	Pinyon Flat	9.79 284 081	11	2.88
April 9, 1982	Goldstone	9.79 444 216	9	2.47
April 16, 1982	Sheridan	9.80 208 952	9	2.58
April 28-29, 1982	NBS, Gaithersburg	9.80 103 259	9	3.25
May 1, 1982	Hanscom AFB, AFGL	9.80 378 697	8	3.07

The JILA results differ slightly from previously published values because a more recent gradient measurement has been used in the transfer to the floor.

of 1.1 m to the site floor. This 5×10^{-8} m/s^2 (5 μGal) contribution is a pseudoerror in cases where the data will be used to look for changes in gravity with time using the same instrument because subsequent measurements will be done at the same height. It also exaggerates the overall error when comparisons are made with results from other absolute instruments, since the effective measuring heights are usually comparable. Nevertheless, this error term has been included because it is a valid source of uncertainty when the absolute data are used in conjunction with relative gravity surveys whose measurements heretofore have been made at the floor level.

The last term used to calculate the uncertainties in Table 1 is the statistical error based on the random scatter in the measurements at a particular site. The statistical uncertainty or standard error E is calculated from

$$E = \sigma/\sqrt{N-1}$$

where σ is the standard deviation in the results of sets of 150 drops and N is the number of data sets taken; σ varies among the sites from 4×10^{-8} m/s^2 (4 μGal) to 1.5×10^{-7} m/s^2 (15 μGal), and N ranges from 5 to 22.

4. Discussion

It should be noted that uncertainties from instrumental effects are based on the exhaustive search made in our JILA laboratory for systematic errors. The environments encountered at some of the sites were less favorable than that of the laboratory. This was especially true in regards to temperature stability. Temperature transients are known to cause temporary shifts in the measured value of g when the temperature changes are rapid. Our feeling is that an overall uncertainty estimate of around 1×10^{-7} m/s^2 (10 μGal) at each of the sites is reasonable. However, only through a continued program of instrumental evaluation, both in the lab and in the field, can this estimate of the accuracy be substantiated.

Only two sites have been visited more than once by the JILA absolute gravity meter: the JILA lab in Boulder and the absolute site in Denver. The two Denver measurements disagree by 2×10^{-7} m/s^2 (20 μGal) and are separated in time by only 2.5 months. The disagreement is close to a significant level and is probably due to errors in the particular laser used that have subsequently been identified.

Data gathered over a year's time from our laboratory site provide an indication of the instrument's long-term stability. Figure 5 is a plot of gravity averages in our lab. Over the 1-year period in which these data were obtained, the apparatus was repeatedly disassembled, modified, and transported (in one case, to another conti-

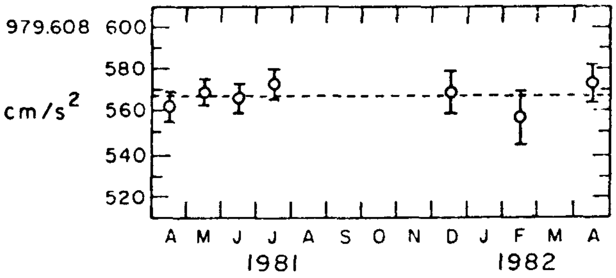


Fig. 5. Absolute gravity measurements at JILA over a 1-year period. One vertical division is 10^{-7} m/s^2 (10 μGal).

TABLE 2. Intercomparison Results of Absolute Gravity Measurements

	JILA		AFGL		IMGC	
	1981	1982	1979	1980	1977	1980
			Holloman AFB			
Result, cm/s^2		979. 139 615	979. 139 600	979. 139 600		979. 139 584
Date		March 21	July 6	May 14 and 31		June 2-3
Gradient, μGal		2.99	2.85	2.85		3.14
$g-\bar{g}$ h=1 m		+12	+11	+11		-34
			Vandenberg AFB			
Result, cm/s^2		979. 628 137		979. 628 190		
Date		March 26		June 3-4		
Gradient, μGal		3.44		3.21		
$g-\bar{g}$ h=1 m		-38		+38		
			Lick Observatory			
Result, cm/s^2		979. 635 503		979. 635 503		
Date		March 27		June 6-8		
Gradient, μGal		4.42		4.15		
$g-\bar{g}$ h=1 m		-13		+13		
			JILA			
Result, cm/s^2	979. 608 568	979. 608 565		979. 608 585		979. 608 498
Date	April-Dec.	Feb.-April		Oct. 18-23		May 26-27
Gradient, μGal	2.39	2.39		2.28		2.32
$g-\bar{g}$ h=1 m	+10	+6		+38		-54
			Sheridan			
Result, cm/s^2		980. 208 952	980. 208 912	980. 208 964		980. 209 007
Date		April 16	July 18-19	Oct. 13-16		June 12-14
Gradient, μGal		2.58	2.32	2.44		2.56
$g-\bar{g}$ h=1 m		-17	-31	+9		+40
			NBS			
Result, cm/s^2		980. 103 259		980. 103 257		
Date		April 28-29		March 13-14		
Gradient, μGal		3.25		3.25		
$g-\bar{g}$ h=1 m		+1		-1		
			AFGL			
Result, cm/s^2		980. 378 697	980. 378 685	980. 378 685	980. 378 659	
Date		May 1	2 yr ave.	1 yr ave.	Oct. and Dec.	
Gradient, μGal		3.07	2.97	2.97	3.02	
$g-\bar{g}$ h=1 m		+17	+5	+5	-26	
			Denver			
Result, cm/s^2	979. 598 322	979. 598 302	979.598 277		979. 598 268	
Date	Dec. 16-17	March 1	April 27-29		Oct. 16-19	
Gradient, μGal	2.92	2.92	2.92		2.94	
$g-\bar{g}$ h=1 m	+30	+10	-15		-25	

Each entry consists of the reported floor value in Gal without a Honkasalo correction [Honkasalo, 1964], the date of the measurement, the gradient in μGal/cm used to transfer to the floor from the effective measuring height of the particular instrument, and a comparison term in μGal. The comparison term was calculated by transferring all of the values to the nominal height of 1 m using the reported gradients and then differencing each result from the mean of all the adjusted results at that site. This decreases the contribution to the discrepancies from differences in the measured gradients. AFGL's value at JILA is transferred to the common site using -16 μGal. JILA's value at AFGL is transferred to the common site using -28 μGal. The AFGL gradient was used in transferring this value to the 1-m nominal height.

nent and back). The standard deviation of these averages is only 6 × 10^{-8} (6 μGal). This high degree of repeatability indicates that the problem of drift that is almost always present in relative gravity meters is not present in the absolute meter.

Table 2 compares the results obtained by the JILA instrument with those of the Air Force Geophysics Laboratory (AFGL) and the Istituto di Metrologia "G. Colonnetti" (IMGC) [Marson and Alasia, 1978, 1980]. All three instruments report typical accuracies of 1×10^{-7} m/s^2 (10 μGal), so most of the intercomparisons between any two instruments should agree within about 1.4×10^{-7} m/s^2 (14 μGal). This is true at some sites but not at others. Some of the differences could be due to real gravity changes because simultaneous measurements have rarely been made. Our method of transferring the measured values to a common reference height of 1 m could also contribute slightly to the calculated differences, but we do not have enough gradient data to compute the transfers in any better way. It is more likely, however, that the discrepancies are due to systematic errors in one or more of the instruments that are as yet unrecognized. The results of the AFGL instrument have been biased by some 8×10^{-7} m/s^2 (80 μGal) since February 1981 due to unknown reasons (J. Hammond, personal communication, 1982), so the comparisons made with that instrument since that date have been omitted.

Compared with both the IMGC and the AFGL instruments, the JILA instrument is in its infancy. However, the rate with which it can acquire data is sufficiently high that a large number of experiments have already been done with it to detect systematic errors and to date we have found no error sources that could account for the discrepancies seen at some of the sites.

5. Conclusions

Because of its sensitivity to both vertical position and mass distribution, gravity data can provide a powerful and unique contribution to the study of crustal dynamics. In the past, inadequacies in the long-term stability of existing relative gravity meters and the difficulties involved with transporting and operating absolute gravity meters have raised questions concerning their usefulness to investigations of tectonic motions. The success of this survey with the JILA absolute gravity meter, however, demonstrates that the accuracy needed to detect small changes in gravity resulting from tectonic motions is now available in an easily portable and durable type of apparatus.

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J. E. Faller, Joint Institute for Laboratory Astrophysics, University of Colorado, Boulder, CO 80309.

J. Gschwind, Geodetic Survey Squadron, Defense Mapping Agency, Washington, DC 20305.

M. A. Zumberge, Institute of Geophysics and Planetary Physics, University of California, San Diego, La Jolla, CA 92093.

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