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Geodetic Survey Stations Near Mount Spurr Volcano, Alaska

by

R.S March, L.R. Mayo, and D.C. Trabant

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DONALD PAUL HODEL, Secretary

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Dallas L. Peck, Director

For additional information write to:

U.S. Geological Survey
Cold Regions Hydrology Project Office
101 12th Avenue, Box 11
Fairbanks, Alaska 99701

CONTENTS

ILLUSTRATIONS

TABLES

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ABSTRACT

As part of a study to measure snow and ice volume and assess the glaciovolcanic hazards at Mount Spurr, Alaska, geodetic survey control has been extended to 7 new permanently marked triangulation stations around Mount Spurr, thus greatly improving the opportunity for spatial control of observations of the volcano. Coordinates for the geodetic stations are given in both the UTM grid system and a local sea-level scale geodetic coordinate system used to simplify geodetic calculations and based on the UTM grid. The measurements used to define the station coordinates are reported.

Introduction

Mount Spurr, Alaska (fig. 1) has been identified by the U.S. Geological Survey as being among those volcanoes in the United States with the greatest potential for eruption in the next 50 years (L. Laird, 1980, written communication). In the wake of the 1980 eruption of Mount St. Helens, Mount Spurr was chosen as one of several volcanoes for geologic and hydrologic studies. Our part in this effort is to measure the snow and ice volume on Mount Spurr by drainage basin and make a preliminary assessment of some of the hydrologic hazards related to the interaction of the volcano with its glaciers. This study requires geodetic coordinates of glacier measurements. Previous monumented control extended only along the south side of Mount Spurr. This report describes the expanded network of geodetically controlled survey monuments near Mount Spurr that we installed for spatial control of measurements on the mountain and makes the coordinates of those monuments available to other researchers working in the area.

Geodetic Coordinate Systems

A local sea-level scale coordinate system, based on the Universal Transverse Mercator (UTM) grid and similar to those used by the authors elsewhere (Mayo and others, 1979; Trabant and Mayo, 1979), was adopted. The origin of the local Mount Spurr net is at UTM coordinates 520,000 meters Easting, 6,770,000 meters Northing in Zone 5. The conversion between the UTM system and our local sea-level system is defined by:

$$\text{UTM Easting} = (\text{scale factor})X_0 + 520{,}000 \quad (1)$$

$$\text{UTM Northing} = (\text{scale factor})Y_0 + 6{,}770{,}000 \quad (2)$$

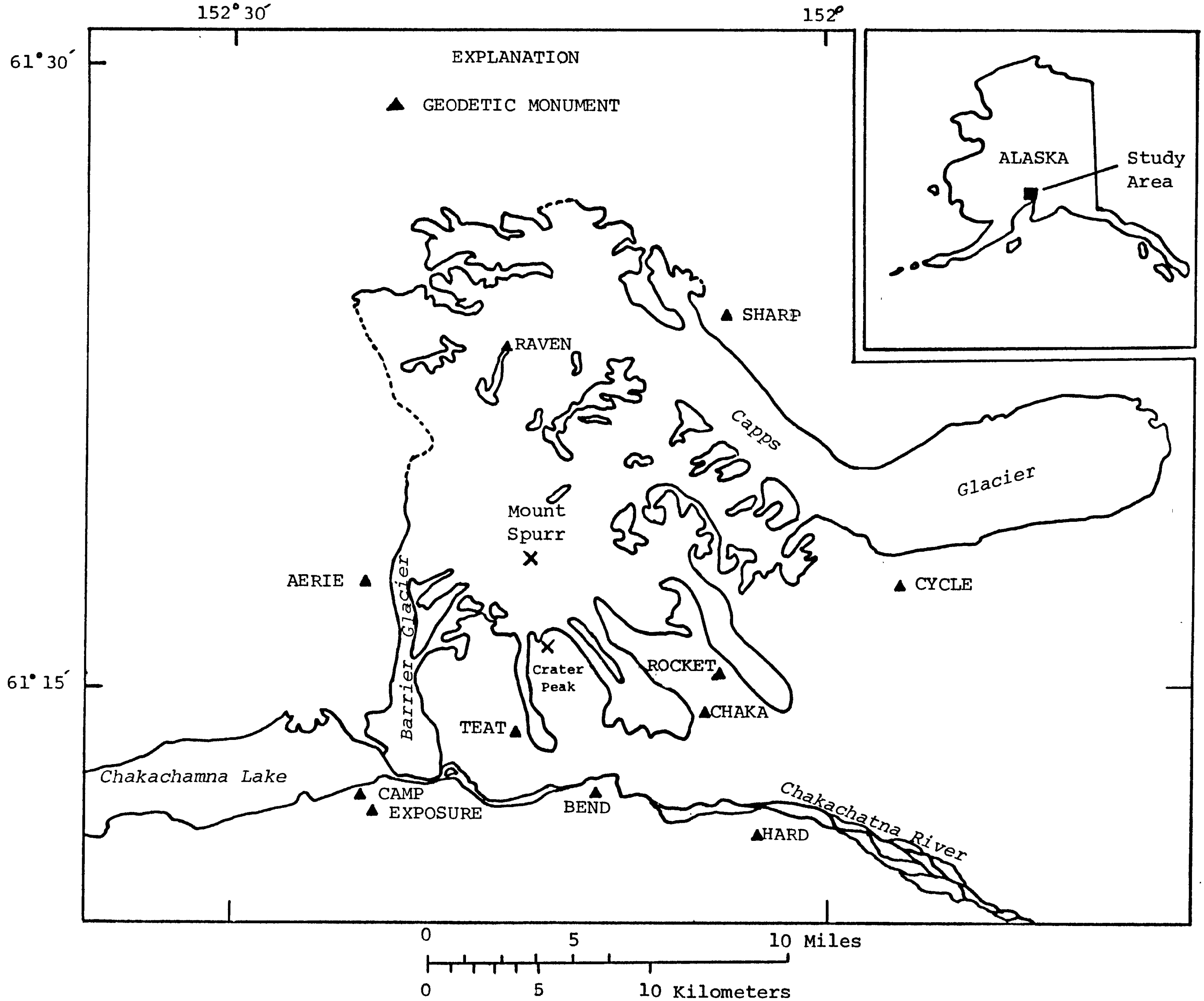

Figure 1. Map showing location of study area and geodetic control network.

where X_0 and Y_0 are our local sea-level coordinates in meters and the scale factor is a variable which is approximated by:

$$\text{scale factor} = 0.9996\,(\sin[100+(500{,}000-\text{UTM Easting})10^{-5}])^{-1} \qquad (3)$$

where the trigonometric function is evaluated in grad. This approximation for the variable scale factor represents an improvement over those previously used by the authors as it is valid throughout a UTM zone. Altitudes, measured relative to sea level, are the same in both the local coordinate system and the UTM system.

1953 National Geodetic Stations

Previously established U.S. National Geodetic Survey (NGS) control stations along the south side of Mount Spurr offered line of sight visibility only to a limited portion of the mountain. Therefore it was necessary to add new control stations that would enable optical surveys of more of the mountain.

Three second order NGS stations (BEND, TEAT, and CHAKA), originally surveyed in 1953, were recovered in 1981 and used as references from which to control new monument locations. A USGS party resurveyed station BEND's altitude in 1978 (value in Table 4) at about 0.9 meters lower than the 1953 surveyed altitude. This change was probably caused by crustal motion during the 1964 Good Friday Earthquake in south-central Alaska. Although it would have been preferable to use this recently resurveyed station as the starting point for the 1981 survey, weather prevented, it and instead, station TEAT was used as the altitude reference or vertical starting point for the local net. We assume the altitude change between 1953 and 1978 at BEND to be an area wide lowering of the land surface and could therefore be applied as a -0.9 meter correction to the altitude of nearby stations that have not been resurveyed since the 1964 earthquake. A map of the tectonic uplift and subsidence associated with the 1964 earthquake (Plafker, 1969, pl.1) shows that Cook Inlet east of Mount Spurr subsided about 0.3 meters. Local residents at the village of Tyonek estimated subsidence of 0 to 0.5 meters. At least one other second order NGS station in the area subsided an amount comparable to that at station BEND in a period bounding the 1964 earthquake. Station BARRIER, 6.1 kilometers west-northwest of station TEAT, subsided 0.6 meters between 1953 and 1978. A -0.9 meter correction (to agree with the altitude change at station BEND) was applied to the 1953 altitude for station TEAT and the resultant altitude (Table 4) used throughout. The 1953 NGS horizontal position of both station TEAT and station CHAKA (Table 4) were assumed correct and used as the baseline from which to extend horizontal control to the new monuments. CHAKA's altitude (Table 4) was recalculated with newly measured vertical angles between it and TEAT (Table 2).It was found to be 0.8 meters lower than the 1953 measured value, which agrees with the slope for the 1964 earthquake deformation.

1981 Monument Survey

The 1981 survey (fig. 2) consisted of measured horizontal angles between stations (table 1), simultaneously measured vertical angles between theodolites located over stations (table 2), and electronically measured slope distances between instruments over stations (table 3). Station positions were calculated by either foresight, intersection, or resection techniques. Slope distances were reduced to sea level, and the earth curvature-atmospheric refraction coefficient between stations was

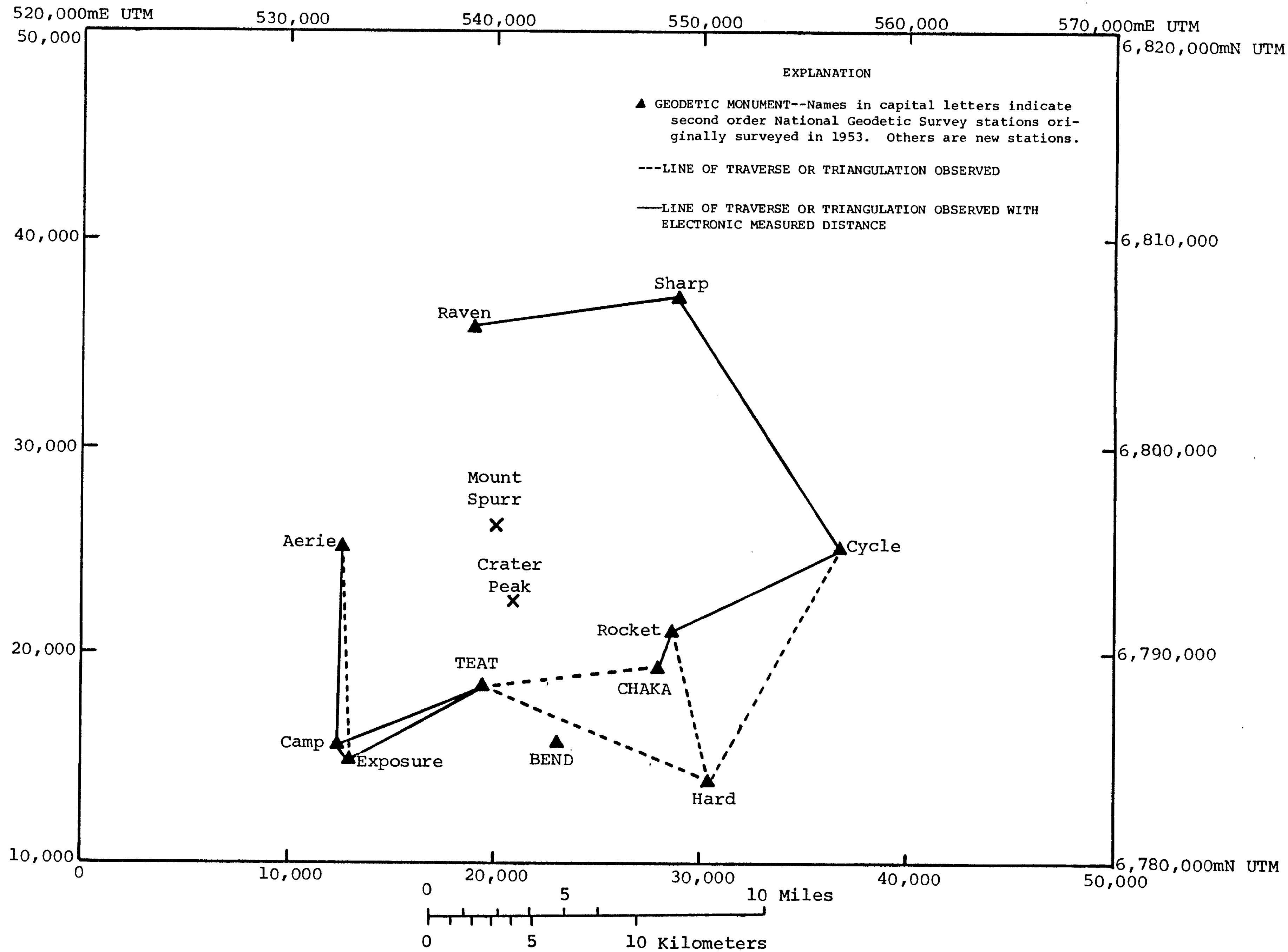

Figure 2. Map showing 1981 Survey Net.

calculated by a procedure developed by Mayo and others (1979). Where redundant measurements were made (stations Aerie, Camp, and Exposure), adjustments were made to the measured angles and distances (tables 1 and 3) to obtain a best fit solution. Elsewhere no adjustments were possible.

New stations, Aerie, Camp, Exposure, Hard, and Sharp, were marked permanently with 44.5 millimeter diameter aluminum rods cemented about 0.6 meters into bedrock. In the case of stations Rocket and Cycle where no bedrock occurs, the aluminum rods were sharpened and pounded into loose volcaniclastic material. The monuments extend about 0.8 meters above the surface so that they can be seen and used as backsight references. The station name and the year of installation are stamped into the top of the monument.

No permanent marker was left at station Raven as it is located on a snow and ice covered ridge. However, the site offers exceptional visibility of the north flank of the mountain and could be temporarily re-occupied at any time by foresight from station Sharp. An alternative and perhaps faster method of relocating station Raven would be to use the angles listed in table 5 and the map-measured distances to calculate the approximate location of the six reference peaks. These peaks could then be used as resection targets from the vacinity of station Raven. (In the field there is only an area of about 100 meters by 20 meters that can be occupied.) The targets can be identified readily in the field by turning the appropriate angle referenced to station Sharp, then by making slight horizontal adjustments to center on the peaks. The new instrument coordinates would then be calculated by resection equations.

The monument coordinates are listed in table 4. We estimate that the standard error in the horizontal position of the new stations relative to station TEAT and station CHAKA is ±0.1 meter. Exceptions to this are station Hard, whose position was determined by resection with an estimated standard error of ±0.3 meters, and stations Sharp and Raven, whose estimated standard error in horizontal positions are ±3.0 meters due to partial failure of our electronic distance measuring equipment. (Both of these positions could be upgraded to an accuracy of ±0.1 meters by remeasuring the distance from station Cycle to station Sharp.) The estimated standard error in the vertical position between two stations is less than ±0.1 meter throughout.

Monument coordinates are reported to 0.01 meter to avoid rounding errors when determining vertical refraction coefficients.

Table 1. Measured and adjusted horizontal angles from the July 1981 survey. Pre-existing NGS stations are listed in all capitals.

Location			Measured Horizontal Angle grad	Standard Error grad	Adjusted Horizontal Angle grad
CHAKA	TEAT	Exposure	174.3685	±.0004	not adjusted
TEAT	Camp	Exposure	85.8094	±.0008	85.8089
Camp	Exposure	TEAT	105.7794	±.0004	105.7792
Exposure	TEAT	Camp	8.4121	±.0003	8.4119
Exposure	Camp	Aerie	239.7734	±.0008	239.7735
Camp	Exposure	Aerie	36.1641	±.0004	36.1640
TEAT	CHAKA	Rocket	125.0103	±.0002	not adjusted
CHAKA	Rocket	Cycle	252.8451	±.0001	not adjusted
Rocket	Cycle	Sharp	92.0226	±.0002	not adjusted
Cycle	Sharp	Raven	128.5625	±.0008	not adjusted
TEAT	Hard	Rocket	60.3898	±.0013	not adjusted
Rocket	Hard	Cycle	47.7304	±.0013	not adjusted
TEAT	Hard	BEND	391.1934	±.0005	not adjusted

Table 2. Measured height of instrument above monument, H_i; vertical foresight angle, V_F; vertical backsight angle, V_B; July 1981. Pre-existing NGS stations are listed in all capitals.

Station	H_i meters	V_F grad	std. error	Station	H_i meters	V_B grad	std. error
TEAT	1.34	5.5575	±.0001	Exposure	0.78	-5.6140	±.0001
Exposure	0.72	-36.0366	±.0001	Camp	0.78	36.0282	±.0001
Camp	0.78	-0.1625	±.0001	TEAT	1.34	0.1043	±.0003
Exposure	0.72	5.0049	±.0001	Aerie	1.00	not measured	
Camp	0.77	9.6478	±.0006	Aerie	1.00	not measured	
CHAKA	1.45	-1.9377	±.0002	TEAT	0.22	not measured	
CHAKA	1.45	-0.5300	±.0001	Rocket	1.29	0.5130	±.0001
Rocket	1.29	-0.1988	±.0001	Cycle	1.27	0.1227	±.0002
Cycle	1.27	2.0976	±.0001	Sharp	0.95	-2.2197	±.0008
Sharp	0.95	2.2155	±.0002	Raven	1.04	-2.2937	±.0001
CHAKA	1.58	-1.7425	±.0002	Hard	0.86	1.7004	±.0002

Table 3. Measured slope distances between instruments listed in Table 2, the sea-level scale horizontal distance, and the adjusted sea-level scale horizontal distance measured in July 1981. Pre-existing NGS stations are listed in all capitals.

Stations	Slope Distance meters	Std. Error meters	Sea-Level Hor. Dist. meters	Adjusted Sea-Level Hor. Dist. meters
TEAT - Exposure[1]	7398.87	±.05	7369.20	7369.38
Exposure - Camp[1]	1179.74	±.03	995.58	995.55
Camp - TEAT[1]	7526.03	±.05	7525.15	7525.23
Camp - Aerie[1]	9564.14	±.06	9451.60	not adjusted
CHAKA - Rocket[1]	1860.18	±.03	1859.83	not adjusted
Rocket - Cycle[1]	8983.37	±.06	8981.99	not adjusted
Cycle - Sharp[2]	14448.06	±3.00	14437.06	not adjusted
Sharp - Raven[3]	9778.09	±2.00	9769.50	not adjusted

[1] Distances measured with a model CA 1000 Tellurometer*, a microwave instrument.

[2] Distance measured with a model CA 1000 Tellurometer*. Data scatter in excess of normal instrument accuracy (note large error) is attributed to a weak battery. Soon thereafter the instrument failed completely due to the battery.

[3] Distance measured with a Racal-Decca* model 520 microwave instrument.

* The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S.G.S.

Table 4. Coordinates of control stations in the Mount Spurr area. Pre-existing NGS stations are listed in all capitals. Their horizontal coordinates are as determined in 1953. The altitude of station BEND (accepted by NGS) is from a 1978 USGS survey. The altitude of station TEAT is the post-earthquake, corrected value and the altitude of station CHAKA is as determined by our 1981 survey (see explanation on page 4).

	UTM Zone 5		Local sea-level		Altitude
Station	Easting meters	Northing meters	X_0 meters	Y_0 meters	Z meters
BEND	543187.11	6785741.69	23196.09	15747.78	874.78
CHAKA	548070.73	6789323.67	28081.53	19331.11	978.17
TEAT	539402.97	6788402.09	19410.51	18409.24	719.33
Camp	532407.24	6785637.01	12412.10	15643.13	735.72
Exposure	532968.60	6784815.30	12973.67	14821.09	1368.29
Aerie	532647.57	6795081.86	12652.52	25091.67	2184.36
Rocket	548596.90	6791106.78	28607.90	21114.90	963.09
Cycle	556666.99	6795042.66	36680.94	25052.19	940.42
Sharp	548769.20	6807121.30	28780.26	37135.57	1430.21
Raven	539086.30	6805851.14	19093.72	35865.08	1776.23
Hard	550281.47	6783896.39	30293.09	13901.72	820.30

Table 5. Horizontal and vertical direct and indirect theodolite observations in grad from an instrument 1.04 meters above station Raven to six unnamed peaks for future use in calculating the coordinates of an instrument placed near station Raven.

Station	Horizontal Direct grad	Vertical Direct grad	Horizontal Indirect grad	Vertical Indirect grad
Sharp	118.9392	-------	318.9408	--------
Peak A	12.4910	94.9098	212.4902	305.0897
Peak B	37.2588	99.0772	237.2576	300.9221
Peak C	48.9802	100.0466	248.9794	299.9502
Peak D	77.8274	100.1256	277.8307	299.8716
Peak E	97.5887	100.0966	297.5875	299.9023
Peak F	146.1999	98.2346	346.1973	301.7648
Sharp	118.9386	-------	318.9398	--------

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