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GEOLOGICAL SURVEY

COLUMBIA GLACIER STAKE LOCATION, MASS BALANCE,
GLACIER SURFACE ALTITUDE, AND ICE RADAR DATA
1978 MEASUREMENT YEAR

by

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ICE RADAR DATA 1978 MEASUREMENT YEAR

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INTRODUCTION

Surveys were made to determine balance, motion, topography and ice depth at Columbia Glacier, Chugach Mountains, Alaska, for the 1978 Measurement Year (MY) as part of an intensive research program by the U.S. Geological Survey to investigate the stability of calving glaciers. The set of systematic measurements reported here is part of the basic data required for glacier dynamic analyses, computer models, and predictions of glacier activity. The 1978 MY (September 1, 1977, through August 31, 1978) was chosen, rather than the traditional Hydrologic Year, to avoid stormy fall weather. The data in this report are the first year-long, glacier-wide set of balance and kinematic measurements available for Columbia Glacier.

Columbia Glacier is a relatively large glacier, nearly 1,100 square kilometers (km^2) in area, is approximately 68 kilometers (km) long, extends from about 3,700 meters (m) altitude to several hundred meters below sea level, and calves into Prince William Sound. Parts of the glacier, notably the terminus area, are highly crevassed.

Well controlled surveys of glacier surface altitude, stake location, ice radar, and mass balance were made at approximately 60 points for the measurement year. The measurement points are shown in figure 1. The data in this report include the coordinates of all surveyed points, balance stake readings, snow and firn densities, and delay times for ice radar reflections. All corrections for atmospheric refraction and glacier surface roughness have been incorporated.

Many persons in addition to the authors participated actively in this work, and part of the credit as well as the responsibility for the

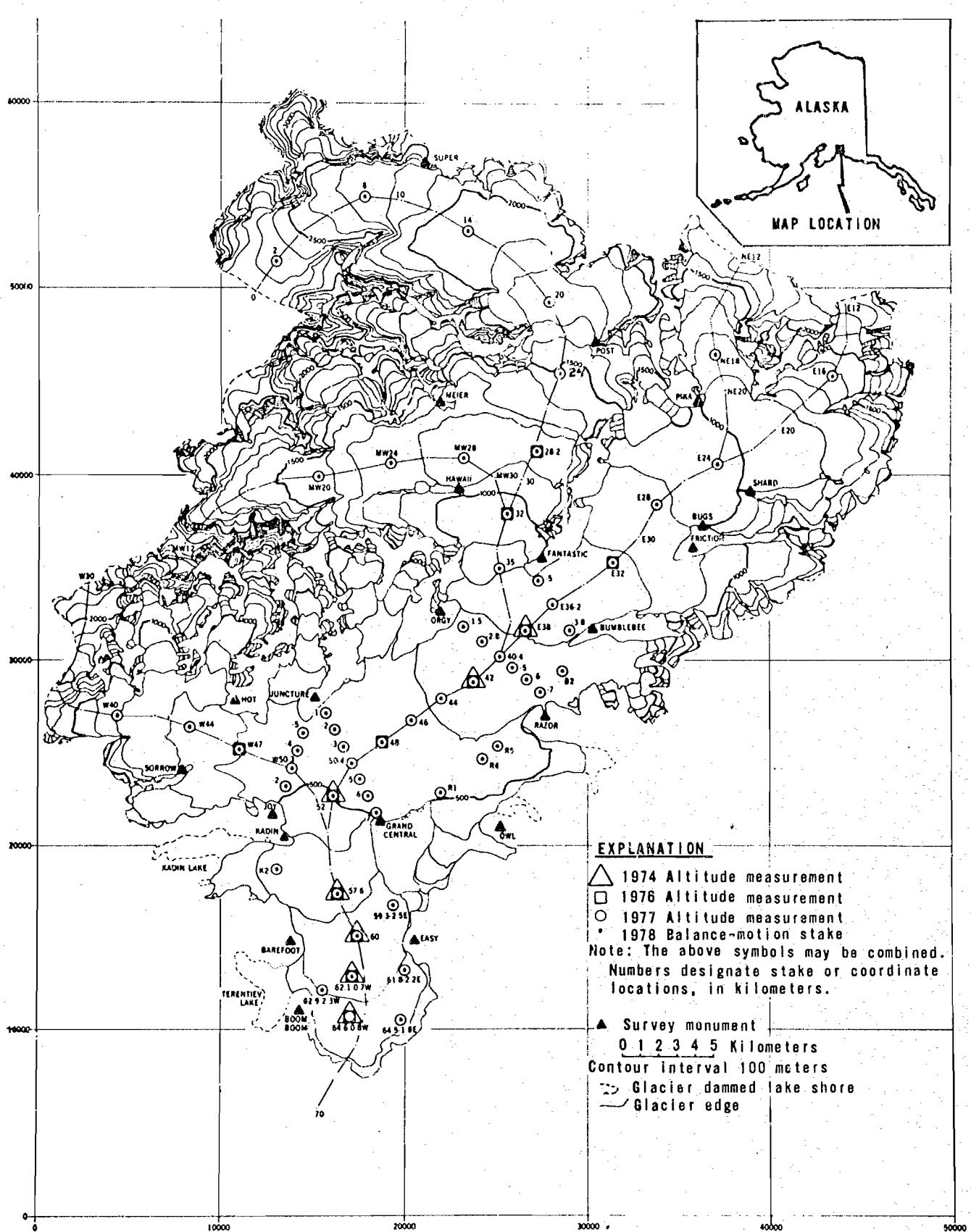


Figure 1.--Coordinate system, survey stations, stakes, and measurement locations used for the 1978 surveys of Columbia Glacier. The square grid represents the local sea-level coordinates in meters. The longitudinal profile coordinate system is shown by dots every 2 km connected by lines drawn along the centerline of the trunk glacier and main tributaries; values are in kilometers.

accuracy of the results is theirs. They include: Robert Bindshadler, C. S. Brown, Leslie Gitomer, R. M. Krimmel, M. F. Meier, Austin Post, E. A. Senear, Mary Shields, W. G. Sikonia and R. D. Watts. Three helicopter pilots made hundreds of landings on extremely rough ice; we thank John McCamish, Jim Sheffers, and Walter Lasher for their safe and skillful flying.

SURVEY CONTROL

The metric, sea-level-scale coordinate system used at Columbia Glacier is based on the Universal Transverse Mercator (UTM) System. The UTM plane is not at a fixed altitude relative to sea level; therefore a sea-level-scale coordinate system is used because it allows simpler equations for geodetic surveys than the UTM system. The origin of the local sea-level coordinate system for Columbia Glacier is the intersection of UTM coordinates 480,000 m Easting and 6,754,000 m Northing. At Columbia Glacier the scale change from UTM to sea level involves dividing UTM distances by 0.999600. UTM coordinates of any point listed in this report may be calculated by:

$$\text{UTM Easting} = (0.999600) X_0 + 480,000$$

$$\text{UTM Northing} = (0.999600) Y_0 + 6,754,000$$

The sea-level coordinates of the survey monuments are presented in table 1. Two new monuments, Owl and Pika, were installed in 1978. Several additional stations served as temporary distance-measuring transponder sites, but no permanent monuments were left. The altitude of the monument at each permanent station is given. Temporary cones were used for better visibility at several monuments. The altitude of the top of the alternative points may be obtained by adding H_t , which is listed in table 1, to the monument altitude.

The scale of the survey network was established in 1974 with a laser distance-measuring system. Subsequent distance measurements (table 2) with two different microwave systems and the same laser unit indicate that the 1974 net⁺ scale is approximately 0.999890 times the actual scale. High in the east branch of Columbia Glacier, the triangulation extension of the 1974 scale is 0.999400 times the microwave-measured distance. Even though these small discrepancies of net scale

were discovered in 1978, we did not measure a sufficient number of distances to recalculate all the survey monument coordinates. Moreover, recalculation of monument coordinates is disruptive during a year of intensive study, and the systematic errors are insignificant compared to the annual motion of this very active glacier.

SURVEY CALCULATIONS

Surveys were made using foresight, triangulation, and resection techniques. Foresight surveys require one horizontal angle, one vertical angle, and the slope distance. Triangulation requires horizontal and vertical angles from two instrument stations. Resection, a backsight technique, requires two horizontal angles between three known points, and three vertical angles from a surveying instrument located near the point being surveyed.

In this report the horizontal distance at sea level (D_{ho}) between a surveying instrument and a target is a spherical Earth arc length (fig. 2) calculated by:

$$D_{ho} = \frac{D_{he}}{400} \times \tan^{-1} \left(\frac{D_t \cos V_t}{Z_i + r_e + D_t \sin V_t} \right)$$

where D_{he} is the Earth's circumference, D_t is the measured slope distance to the target, V_t is the measured vertical angle to the target, positive up from the horizontal, Z_i is the instrument altitude above sea level, and r_e is the Earth's radius. The approximate values, $D_{he} = 40 \times 10^6$ m (the original definition of the meter) and $r_e = 40 \times 10^6 / 2\pi$, yield results within one part per million (ppm) of results using more precise Earth circumference and radius values.

The altitude of each target was calculated using the equation:

$Z_t = Z_i + D_{hi} \sin V_t + \Delta Z_f$ (fig. 2), where Z_i is the instrument altitude, D_{hi} is the horizontal distance to the target at the instrument altitude, which is simply $D_{ho} \left(\frac{Z_i + r_e}{r_e} \right)$, and ΔZ_f is the correction in vertical distance due to effects of Earth curvature and refraction. ΔZ_f

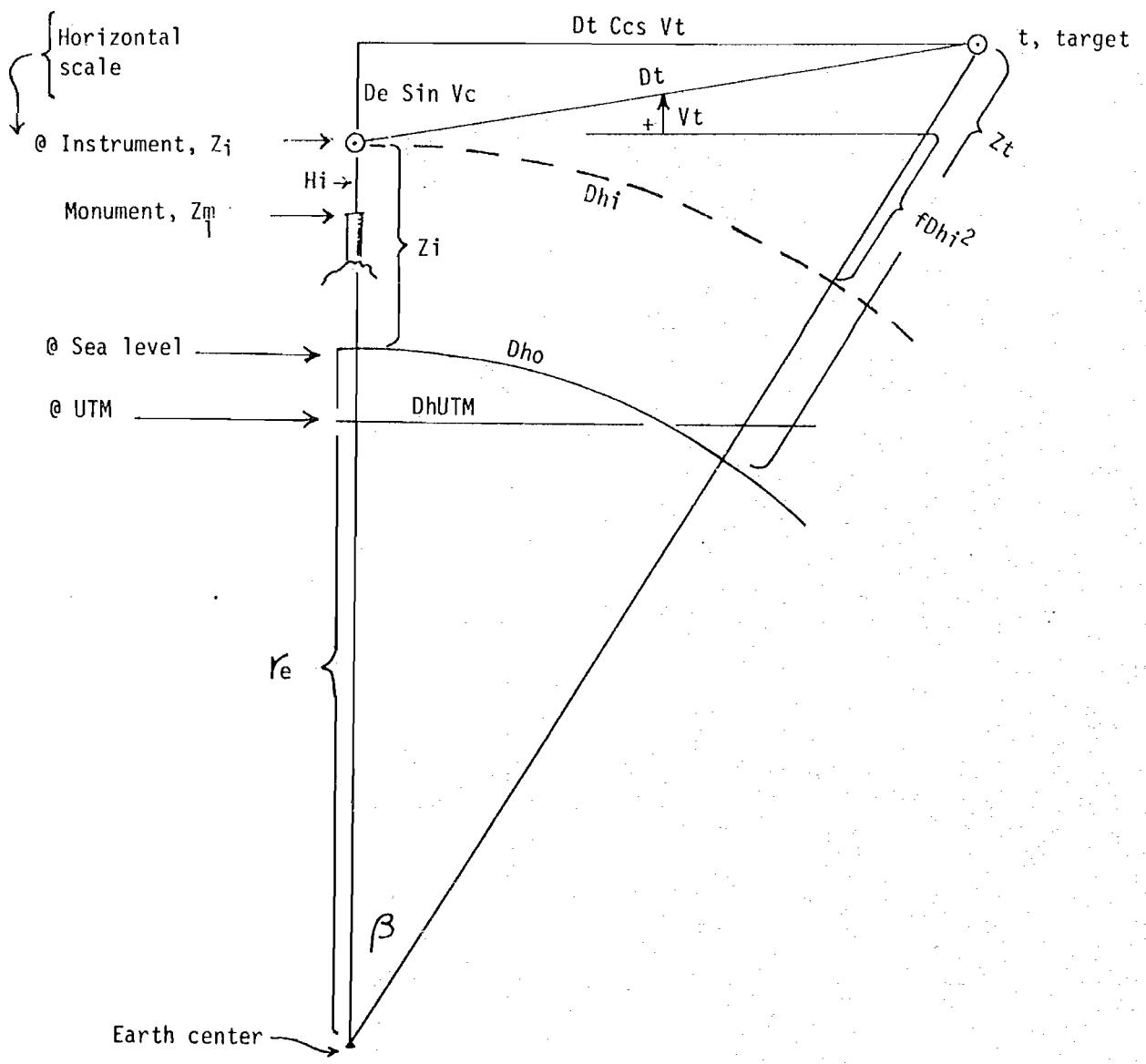


Figure 2.--Geometry of horizontal distances, altitudes, vertical angles, and curvature-refraction correction.

can be calculated quite precisely, if the horizontal distance is less than 500 km, by using the equation: $\Delta Z_f = f D_{hi}^2$

ΔZ_f ranges from 0.18 to 0.24 m at a distance of 2 km to about 4.50 to 6.00 m at 10 km (fig. 3), the normal distance of surveying at Columbia Glacier.

The curvature-refraction coefficient, f , was monitored continually during the field surveys by measuring the vertical angle to a reference point of known altitude. The coefficient, f , (dimension, meter per meter² or "per meter") is calculated by the equation:

$$f = \frac{Z_A - Z_i - D_{hiA} \tan V_A}{2 D_{hiA}}$$

where Z_A is the altitude of the reference stations; Z_i is the instrument altitude; D_{hiA} is the horizontal arc distance at the instrument altitude between the instrument and the reference point (similar to the geometry of fig. 2); and V_A is the vertical angle measured to the reference point.

All calculations were made in the field, often at the survey point, and later checked in the office using a series of integrated subroutines programmed for the Hewlett Packard HP-67* pocket calculator. The programs are included as tables 3-9 in this report. The resection XY coordinate equation was developed by S. M. Hodge (U.S. Geological Survey, Tacoma). All other calculations were developed by Mayo and Trabant. The programs are evolving rapidly, and there have been significant changes from the earlier versions.

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

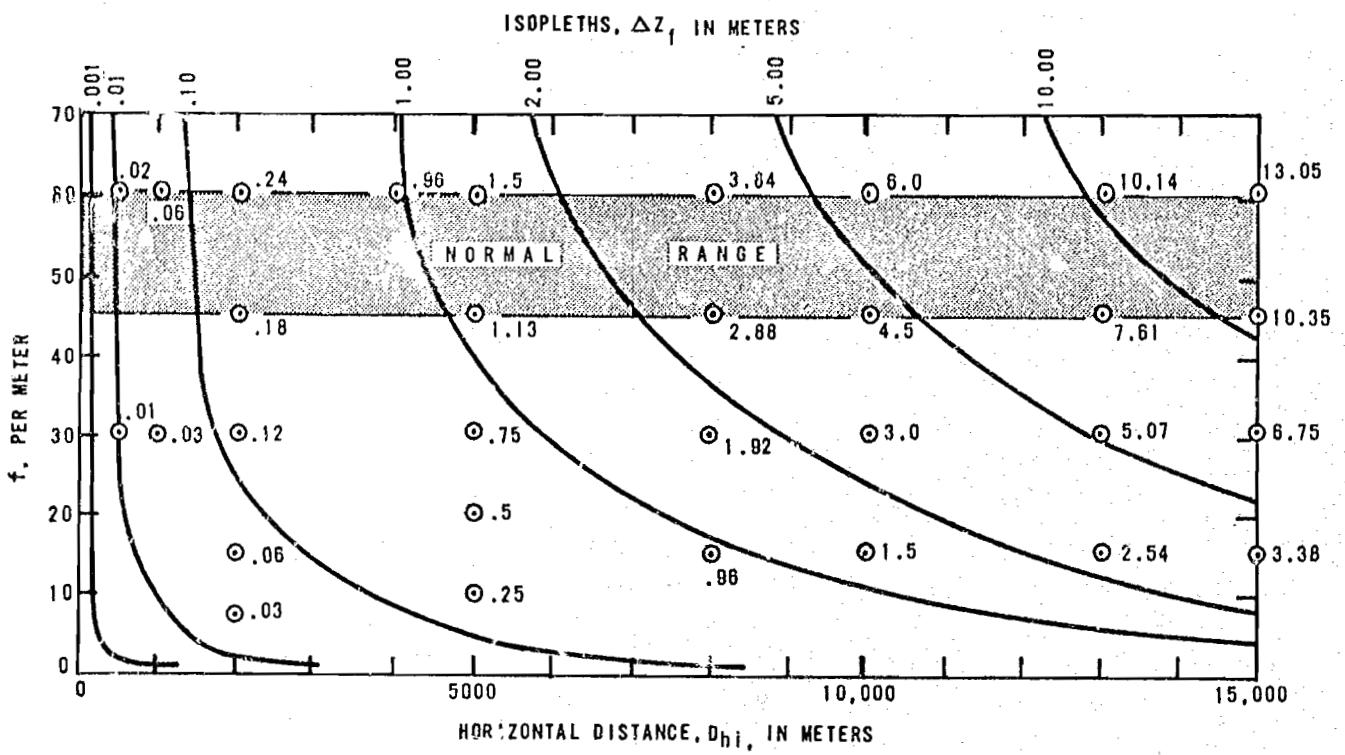


Figure 3.--Earth curvature and atmospheric refraction correction, ΔZ_f , as a function of the curvature-refraction coefficient, f , and horizontal distance, D_{hi} .

COLUMBIA GLACIER DATA

All survey data for Columbia Glacier (table 10) are calculated relative to the survey monument coordinates (table 1). In most instances, the data involve only the 1978 MY. However, glacier surface surveys made prior to 1977-78 are included if they were close to stations reoccupied in 1978. An explanation of the information in tables 10 and 11 follows.

Position names

The surveyed points have designations which follow the curvilinear longitudinal coordinate system (fig. 1). This system originates at the ice divide between Columbia and Yale Glaciers and provides kilometer locations down the centerline of Columbia Glacier. A stake installed in 1977 at the 52-km location is designated as 77-52. A stake designated as 77-40-5 indicates that a 1977 stake was located 5 km along a precisely defined cross-glacier profile 40 km down the longitudinal profile. U.S. Geological Survey Open-File Report 78-264 lists the coordinates of the curvilinear longitudinal and cross-profile system. Where the cross profile has not been precisely defined, the approximate location is listed as follows: A stake designated as 77-61.8-2.2E was installed in 1977 and is located 61.8 km down the longitudinal profile (X' coordinate) and 2.2 km east of center (Y' coordinate).

The glacier surface was surveyed at three points in the vicinity of $X_0 Y_0$ coordinates designated by the longitudinal profile system or at the origin point of a stake for the purpose of measuring altitude changes of the glacier surface. Three altitude measurements at the 42-km longitudinal profile point, for example, are designated 42-P, 42-Q, and 42-R.

The locations of the ice radar transmitter and receiver follow the same location-naming convention described for stakes but are preceded by

the notebook reference to the radar survey. A point named 78T94 40.0-6.9 indicates the year of the measurement (1978), the person's field notes (T for Trabant), and the notebook page number (94) followed by the distance down the longitudinal profile (40.0 km) and either the distance along a defined cross-glacier profile (6.9 km in this case) or the Y' coordinate as for stakes. Both the transmitter and receiver positions used for a single ice radar measurement are given the same name. In some instances only the midpoint (MP) between the transmitter and receiver was surveyed and the transmitter-receiver antenna separation (S) was measured directly.

Balance data

Each balance (b') measurement reported (table 10) is the height of the glacier surface on the stake, measured from the stake bottom. Therefore, the altitude of the glacier surface at the stake may be calculated by adding the stake Z coordinate to the stake b' reading. The material at the surface is indicated by a letter in parentheses. The balance nomenclature from Mayo, Meier, and Tangborn (1972) was used for the 1978 Measurement Year data at Columbia Glacier:

- (s) snow which has not yet survived a complete ablation season;
- (f) the top of the 1978 new firn increment, that is, the 1978 "summer surface";
- (i) the top of old ice;
- (F) a new term: old firn; 77(F) is the top of 1977 firn.

Ice radar data

A monopulse radar transmitter redesigned by R. D. Watts (U.S. Geological Survey, Denver) was centered to a 60-m resistively loaded dipole antenna. The antenna was inside a clear, flexible plastic tubing which provided mechanical strength. The receiver consisted of a similar antenna, a 0.5-volt "clipper" to protect amplifiers from over-voltage

input, a variable linear amplifier, another "clipper" and finally a Sony-Tektronix 465 oscilloscope to measure the travel delay time. The strongest return signal was obtained by orienting the antennas parallel with assumed ice depth contours. Data from 1970 surveys are presented in table 11.

Five checks were used to verify that the correct delay time was measured and that an observed wave was actually a reflected radar pulse. First, the oscilloscope sweep must trigger on the first pulse received directly from the transmitter. The voltage of the first pulse accelerates during the first quarter of the voltage rise, whereas later voltage rises decelerate from zero to the wave crest. Second, transmitted and reflected waves must be opposite in sign. Third, the wavelength of the transmitted and reflected signal must be the same. Fourth, the same number of waves must be present with the same relative strength in the transmitted and reflected signals. And lastly, the repetition rate and output signal strength of the transmitter must be checked to verify that the transmitter is operating normally. If the ice depth is shallower than about 300 m, all these checks could be made with one oscilloscope setting; thicker ice measurements require a series of adjustments of both the amplifier and the oscilloscope to make the checks. All delay times reported are definitive, thoroughly checked reflections.

ACCURACY OF SURVEYS

Error analyses are complex because only part of the total error in a survey results in imprecisions of calculations made from the survey results. For example, the coordinates of survey monuments may be in error by more than a meter because of hemispheric-scale measurement errors, yet these same coordinates are accurate within a few centimeters relative to each other within the Columbia Glacier basin. Furthermore, the altitude change at a specific point on the glacier such as the 8-km "index point" can be measured more precisely than the altitude of sta-

tion SUPER; that is, all errors in the coordinates of a survey monument do not propagate through to measurements of glacier change as surveyed from that monument.

Systematic errors such as net scale and net position are relatively unimportant and may be omitted from errors in motion analyses. The significant errors include (1) definition of curvature-refraction corrections, (2) clarity of survey targets to the surveyor, (3) angle and distance measurement precision for each target survey, and (4) the problems associated with defining the surface of a rough glacier (fig. 4) and the position of loose stakes.

Curvature-refraction coefficient, f , was defined within about $\pm 1 \times 10^{-9}$ or ± 0.03 m vertical error at 5 km. The clarity of the surveyors' target was enhanced by use of brilliant orange oilcloths. In general, the surveyor could define the target within ± 0.05 m. Angle measurements included a direct and indirect sighting to each target. In general, the first set of horizontal angles in a long series of measurements such as a net survey differ from the mean of the set by about ± 0.00109 (grad)* and the vertical by only ± 0.00059 . This same relative accuracy of surveying applies to single target surveys. An error of $\pm .00109$ at 5 km distance is 0.08 m.

Triangulation surveys were used over most of the glacier, and the estimated standard error of measurement at 5-km distances is $\sqrt{(0.03)^2 + (0.05)^2 + (0.08)^2}$ which is ± 0.10 m. Foresight surveys involving microwave-measured slope distances may have larger errors. Table 2 shows the size of errors that may be associated with distance measurements. An error of 100 ppm is ± 0.5 m at 5 km distance.

*Grad, an angular quantity equal to 0.9 degree. Surveying instruments used at Columbia Glacier and all calculations in this report utilize grad angles.

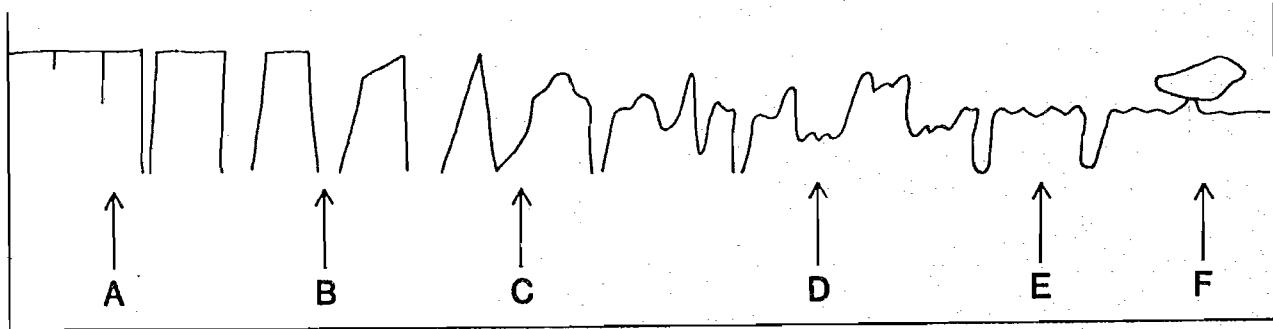


Figure 4.--Schematic cross section of part of Columbia Glacier illustrating the complexities of defining the glacier surface altitude at a point. This is somewhat simplified, because this type of complexity extends in a third dimension on the actual ice surface. The "average surface altitude" at any of the defined points (A-F) is uncertain and is reported as "surface definition" in table 10.

Stakes in the ice cannot be placed exactly vertically, and melting snow and ice around the stake leaves a hole in which the stake can move. The stake position uncertainty is about ± 0.10 m.

In most crevassed areas, the seracs have flat tops, which we chose as the glacier surface. In very rough areas, we attempted to choose a surface in the middle of the roughness amplitude. To do this, we surveyed three points (P, Q, and R) around each point where altitudes were to be compared. These three points help average the rough surface and allow calculations of the index point altitude when the point itself is not accessible. For each triangle, the observer on the glacier estimated how well the triangle represented the surface. The accuracy estimate follows the criteria that the plane defined by the three surveyed points represents the average ice surface within the reported error limit and that the actual glacier surface is no better defined than the above criteria.

An exceptionally large uncertainty was encountered during the 77-08-30 survey of stake 77-E28. The survey was made during a period with a strong atmospheric inversion which produced mirage conditions. No theodolite backsights were made to measure the amount of refraction; therefore the curvature-refraction correction could have varied ± 2 m. An $f = 0$ used to calculate the stake position indicates that the location increased 0.5 m in altitude during the 1978 MY. An $f = -80$, which is also possible (light path is more curved than the earth surface), would lead to the conclusion that the ice thinned 1.5 m during the year. The data reported (table 10) represents the results of $f = 0$.

REFERENCES

M. F. Meier and others, 1978, Columbia Glacier progress report, December 1977: U.S. Geological Survey Open-File Report 78-264, 56 p.

Mayo, L. R., Meier, M. F., and Tangborn, W. V., 1972, A system to combine stratigraphic and annual mass-balance systems--A contribution to the International Hydrological Decade: *Journal of Glaciology*, v. 11, no. 61, p. 3-14.

Table 1.--Columbia Glacier survey monuments, local sea-level coordinates in meters.

STATION		X ₀	Y ₀	ALTITUDE Z	AUXILIARY *H _t
Super Post	1977	21119.02	56760.91	2511.79	-0.95b
	1977	30412.32	47061.23	1831.78	-1.28b
					-0.24c
Meier	1977	21866.42	43860.04	1431.17	
Hawaii	1977	23001.45	39311.77	1230.77c	-0.70b
Pika	1978	36092.70	44130.25	1250.50	-0.83b
Shard	1977	38558.48	39212.93	1059.57	
Bugs	1977	36354.29	37275.01	1027.31c	-0.70b
Fantastic	1977	27415.57	35545.72	1075.23	-0.94b
Bumblebee	1977	30160.14	31697.66	808.05	-0.95b
Orgy	1977	21991.53	32591.43	1072.10	-1.05b
Razor	1974	27587.07	27004.03	822.69	-0.03b
Owl	1978	24965.91	21034.82	652.87	1.49p
Juncture	1974	15030.30	27939.73	828.70	-0.79b
Sorrow	1977	7854.73	24055.94	785.30c	1.51p
Hot	1977	10756.73	27746.74	906.97	-0.71b
Joy	1974	12770.57	21672.61	935.41	-0.98b
Grand Central	1977	18604.04	21258.91	639.64	-0.30c
Kadin	1977	13466.48	20448.24	545.34	-0.37c
Easy	1977	20547.28	14807.32	461.13	-0.02b
Boom Boom	1974	14285.07	10973.43	506.02	1.48p
Rain	1978T	11044.4	11715.2	709.5	
Pickle	1978T	23825.2	18387.7	967.8	
Anger	1978T	3158.4	25359.8	1565.8	
A.J.	1978T				
Battery	1978T	28724.3	36959.6	1564.1	
Cornice	1978T	24419.1	47332.6	2541.5	

*H_t, Height of target from monument altitude

c, cone top

p, pipe top if monument is not at pipe top

b, base of pipe, rock surface

1978T, temporary distance measuring transponder station

Table 2.--Comparison of 1977 and 1978 microwave- and laser-measured distances with distances calculated from the 1974 laser-controlled survey coordinates. Triangulation calculations using the 1974 laser-controlled net were used for the comparison. All but the last listed comparison were measurements using microwave equipment. An error of 100 ppm is equal to 0.1 meter per kilometer.

Survey monuments	Apparent error in survey net scale	
	meters	ppm
1977 Grand Central - Orgy	-1.18	-100
1978 Razor - Owl	-0.79	-121
1977 Grand Central - Kadin	-0.56	-109
1977 Easy - Boom Boom	+0.59	+ 80
1977 Meier - Fantastic	-1.24	-124
1977 Hot - Grand Central	-0.48	- 47
1977 Hawaii - Post	+0.85	+ 79
1977 Hot - Sorrow	+0.21	+ 45
1977 Fantastic - Bugs	-0.53	- 58
1977 Bugs - Shard	+1.87	+637
1977 Grand Central - Boom Boom	-0.12	- 11
1977 Grand Central - Razor	-0.92	- 86
1978 Grand Central - Kadin	-0.56	-108
1978 Grand Central - Kadin	-0.47	- 90
1978 Grand Central - Kadin	-0.53	-102
1978 Grand Central - Kadin	-0.47	- 90
1978 Grand Central - Kadin (Laser-measured)	-0.72	-138

User sequencing of programs in tables 3-9. The necessary results of all calculations are automatically stored for use by subsequent programs connected by solid arrows.

FORESIGHT TECHNIQUE

Instrument Location Known

Table 3

A,1i,B,2	△—	△—△—
△—△—△—△—△—		

Monument Coordinates

Table 4

HVDIA	$f_A \ominus A$	XYZ _L	HD/f/V _D _L
D _L	HVDI _t	/V _t	/A _{it}

Data Entry/Reduction
and Predictor

Table 5

HVDIA	$\ominus A$	XYZ _L	HD/f/V _D _L	ppm	TEL
D _L	M _{oxy}	HVDI _t	/V _t	/A _{it}	/XYfZ _t

Foresight Result

TRIANGULATION TECHNIQUE

Instrument Location Known

Table 3

A,1i,B,2	△—	△—△—
△—△—△—△—△—		

Monument Coordinates

Table 4

HVDIA	$f_A \ominus A$	XYZ _L	HD/f/V _D _L
D _L	HVDI _t	/V _t	/A _{it}

Data Entry/Reduction
and Predictor

Manually Record
 $\ominus A_1$ $\ominus A_2$
 F_{A1} F_{A2}
 V_{t1} V_{t2}
 A_{i11} A_{i12}
 Reenter

Table 3

A,1i,B,2	△—	△—△—
△—△—△—△—△—		

Monument Coordinates

Table 6

X _{Zi1}	XYZ _{i2}	$\ominus A_1$	$\ominus A_2$	V _{i1}	V _{i2}
X _t	Y _t	f_1/Z_{t1}	f_2/Z_{t2}	\bar{Z}_1	

Triangulation Result

REJECTION TECHNIQUE

Instrument Location Unknown

Table 7

A ₁	B	A _z	C	A ₃
V _A	V _B	V _C	B _{iA}	A _{iC} _Σ

Data Entry/Reduction

Table 3

A,1i,B,2	△—	△—△—
△—△—△—△—△—		

Monument Coordinates

Table 8

X _i	Y _i	$\ominus A$
----------------	----------------	-------------

Rejection

Table 9

A	B	C	$\leftarrow \frac{D_h}{Z_i}$	Z _i
AB	BC	CA	$\leftarrow \frac{f}{Z_i}$	

Instrument Altitude Backsight

Table 3.--HP-67 program to enter survey monument coordinates for foresight, triangulation, and resection calculations. All program instructions in this report utilize the following conventions:

- Underline denotes data to be keyed into the calculator before program execution.
- C - Cap denotes the result of a calculation which is displayed by the program execution, or data which is recalled and displayed.
- Box identifies the user-controlled subroutine to be used.
- ↑ - Arrow indicates to press the **Enter** key.
- R/S - Press the run/stop key to continue program execution.

INSTRUCTIONS FOR FORESIGHT SURVEY COORDINATES

1. **[A]** - Programs calculator so that coordinates of the azimuth reference station "A" are entered. Stores 1 in I-register.
2. H_t, **[C]** through **[fe]**, H_t - H_t is the target height above the monument. Subroutine enters coordinates of the station selected and adds H_t to the monument altitude.
3. **[B]** - Programs calculator to enter coordinates of the surveying instrument. Stores 4 in I-register.
4. H_i, **[C]** through **[fe]**, H_i - H_i is the height of the instrument above the monument. Subroutine enters the coordinates of the station selected and adds H_i to the monument altitude.

INSTRUCTIONS FOR TRIANGULATION COORDINATES

1. Use Table 4 programs to calculate f (curvature-refraction coefficient), V_t (vertical angle to target), and Ait (horizontal angle from azimuth reference station "A" to the target) for both instrument locations; then use coordinate entry program as follows:

Table 3.--HP-67 program to enter survey monument coordinates for foresight, triangulation, and resection calculations--Continued.

2. **[A]** - Programs calculator to enter coordinates of first instrument.
3. $\underline{H_i}$, **[C]** through **[fe]**, $\underline{H_i}$ - Enters coordinates of first instrument.
4. **[B]** - Programs calculator to enter coordinates of second instrument.
5. $\underline{H_i}$, **[C]** through **[fe]**, $\underline{H_i}$ - Enters coordinates of second instrument.

INSTRUCTIONS FOR RESECTION COORDINATES

1. **[A]** - Programs calculator to enter coordinates of station "A" - See resection instructions also.
2. $\underline{H_t}$, **[C]** through **[fe]**, H_t - Enters coordinates. Leaves 4 in I-register, so station "B" entry can follow.
3. For station "B", simply $\underline{H_t}$, **[C]** through **[fe]**, $\underline{H_t}$. Leaves 7 in I-register, so station "C" entry can follow.
4. For station "C", simply $\underline{H_t}$, **[C]** through **[fe]**, $\underline{H_t}$.

Table 3.--HP-67 program to enter survey monument coordinates for foresight, triangulation, and resection calculations. Station coordinates in program are in centimeters--Continued.

	A,1	i,B,2	SUPER	Post	MEIER	
	HAWAII	FANTASTIC	PiKA	SHARD	BUGS	

EXAMPLE
Program
Card

GRAD, DSP2.

001	*LELA	046	7	891	4	136	2	181	1
002	1	047	5	892	3	137	GSB1	182	2
003	GT00	048	GT02	893	1	138	1	183	3
004	*LBLB	049	*LELG Post	894	1	139	0	184	3
005	4	050	3	895	7	140	7	185	GSB1
006	*LBLG	051	0	096	GT02	141	5	186	1
007	STOI	052	4	097	*LBLa Hawaii	142	2	187	0
008	0	053	1	098	2	143	3	188	5
009	R/S	054	2	099	3	144	GT02	189	3
010	*LBL1	055	3	100	0	145	*LBLc PiKa	190	5
011	EEX	056	2	101	0	146	3	191	7
012	2	057	GSB1	102	1	147	6	192	GT02
013	CHS	058	4	103	4	148	0	193	*LBLd Bugs
014	x	059	7	104	5	149	9	194	3
015	STOI xyz	060	0	105	GSB1	150	2	195	6
016	ISZI	061	6	106	3	151	7	196	3
017	R↓	062	1	107	9	152	0	197	5
018	ETH	063	2	108	3	153	GSB1	198	4
019	*LBL2	064	3	109	1	154	4	199	2
020	GSB1	065	GSB1	110	1	155	4	200	5
021	DSZI	066	1	111	7	156	1	201	GSB1
022	ST+i z	067	8	112	7	157	3	202	3
023	ISZI	068	3	113	GSB1	158	8	203	7
024	R/S	069	1	114	1	159	2	204	2
025	*LBLC SUPER	070	7	115	2	160	5	205	7
026	2	071	6	116	3	161	GSB1	206	5
027	1	072	GT02	117	0	162	1	207	0
028	1	073	*LBLd Meier	118	7	163	2	208	1
029	1	074	2	119	7	164	5	209	GSB1
030	9	075	1	120	GT02	165	6	210	1
031	0	076	8	121	*LBLb FANTASTIC	166	5	211	0
032	2	077	6	122	2	167	0	212	2
033	GSB1	078	6	123	7	168	GT02	213	6
034	5	079	4	124	4	169	*LBLd Shard	214	6
035	6	080	2	125	1	170	3	215	1
036	7	081	GSB1	126	5	171	8	216	GT02
037	6	082	4	127	5	172	5	217	R/S
038	6	083	3	128	7	173	5		
039	9	084	8	129	GSB1	174	6		
040	1	085	6	130	3	175	4		
041	GSB1	086	0	131	5	176	8		
042	2	087	0	132	5	177	GSB1		
043	5	088	4	133	4	178	3		
044	1	089	GSB1	134	5	179	9		
045	1	090	1	135	7	180	2		

Table 4.--HP-67 program to calculate f , θ_A , theodolite angles to a position "L" to be located, slope distance to "L", and the vertical and horizontal angles to a target, V_t and Ait--Continued.

Prerequisite - Theodolite and station "A" coordinates entered.

1. \underline{HDA}_j , \uparrow , \underline{VDA}_j , \uparrow , \underline{HIA}_j , \uparrow , \underline{VIA}_j , \boxed{A} , $\lceil HDA \rceil$, R/S, $\lceil VDA \rceil$, R/S, $\lceil HIA \rceil$, R/S, $\lceil VIA \rceil$. Enter both opening and closing shots to "A" before calculating Ait. During review of data, if an error is discovered, CLX, key-in correct value, resume data review with R/S.
2. \boxed{B} , $\lceil f_A \rceil$. f_A is calculated using only the last set of observations to "A". Exponent is displayed automatically to identify that f is being displayed. $f = 69.0 \times 10^{-9}$ is the largest possible value.
3. \boxed{C} , $\lceil \theta_A \rceil$. Calculated from station coordinates.
4. $\underline{X_L}$, \uparrow , $\underline{Y_L}$, \uparrow , $\underline{Z_L}$, D, $\lceil X_L \rceil$, R/S, $\lceil Y_L \rceil$, R/S, $\lceil Z_L \rceil$
If coordinate is incorrect, CLX, key in correct value, continue with R/S.
5. \boxed{E} , $\lceil HD_L \rceil$, R/S, $\lceil f \rceil$ which may be changed by, CLX, key in correct value, R/S, $\lceil VD_L \rceil$.
6. $\boxed{f_A}$, $\lceil D_L \rceil$
7. $\underline{HD_t}_j$, \uparrow , $\underline{VD_t}_j$, \uparrow , $\underline{HI_t}_j$, \uparrow , $\underline{VI_t}_j$, \boxed{fb} , $\lceil V_t \rceil$, R/S, $\lceil Ait \rceil$. V_t and Ait may be recalculated and displayed by: \boxed{fc} , $\lceil V_t \rceil$, R/S, $\lceil Ait \rceil$.

Table 4.--HP-67 program to calculate f , θ_A , theodolite angles to a position "L" to be located, slope distance to "L", and the vertical and horizontal angles to a target, V_t and Ait .

INSTRUCTIONS

These programs are specific to surveying instruments which read out in grad angle units, horizontal circle positive clockwise, and vertical circle with zero at the zenith.

HVD1A - Four instrument readings to a chosen reference station "A".

HDA - Horizontal direct reading to "A".

VDA - Vertical direct reading to "A".

HIA - Horizontal inverted reading to "A".

VIA - Vertical inverted reading to "A".

f_A - Earth curvature-atmospheric refraction coefficient calculated from vertical angles to "A".

θ_A - Azimuth from theodolite to "A" with the geometric sign convention that east is zero and counterclockwise is positive.

XYZL - Coordinates of any third location "L".

HD_L - Horizontal direct theodolite reading to "L".

f - Curvature-refraction coefficient used to calculate vertical angle to "L"; 60×10^{-9} is a typical value.

VD_L - Vertical direct theodolite reading to "L".

D_L - Slope distance to "L".

HVDIt - Instrument readings to a survey target "t".

V_t - Vertical angle to "t" with the sign convention that horizontal is zero and positive up.

Ait - Horizontal angle clockwise from "A" to "t" measured by a surveying instrument "i".

Table 4.--HP-67 program to calculate f , θ_A , theodolite angles to a position "L" to be located, slope distance to "L", and the vertical and horizontal angles to a target, V_t and Ait --Continued.

HVDIA	f_A	θ_A	XYZL	HD/F VOL
DL	HVDIT	/Vt	/Ait	

Grad

001	*LBLA	046	DSP2	051	0	136	STO1	VD _t	131	7
002	P _{ZS}	047	RND	092	0	137	GSB0		182	Pi
003	STO3	VIA4	048	STOE f _A	093	+	138	STO2	HIt	183
004	GSB0		049	R/S	094	*LBL8	139	GSB0		184
005	X _{ZI}		050	*LBLC	095	FIX	140	STO3	VIt	185
006	CLX		051	RCL2 Y _A	096	DSP4	141	P _{ZS}		186
007	RCL6 HD _{A3}		052	RCL5 Y _L	097	RND	142	*LBL6		187
008	STO4 HO _{A3}		053	-	098	RTN	143	P _{ZS}		188
009	X _{ZI}		054	RCL1 X _A	099	EEX	144	RCL1 VD _t		189
010	STO6 HD _{A4}		055	RCL4 X _I	100	2	145	GSB2 Vt		190
011	GSB0		056	-	101	GSB6	146	RCL3 VIt		191
012	STO7 VD _{A4}		057	+P Dho _A	102	RCL6 f	147	GSB3 Vt		192
013	GSB0		058	R ₄	103	ENG	148	GSB3		193
014	X _{ZI}		059	GSB8	104	DSP2	149	R/S		194
015	CLX		060	STO8 θ _A	105	R/S	150	P _{ZS}		195
016	RCL8 HIt _{A3}		061	RTN	106	STOE f	151	RCL0 HD _t		196
017	STO5 HIt _{A3}		062	*LBL0	107	GSB7	152	RCL4 HD _{A3}		197
018	X _{ZI}		063	FIX	108	GSB8	153	GSB4		198
019	STO8 HIt _{A4}		064	DSP2	109	R ₄	154	RCL0 HDE		199
020	GSB0		065	STO9 Z _L	110	-	155	RCL6 HO _{A4}		200
021	STO9 VIA4		066	RT	111	R/S	156	GSB4		201
022	P _{ZS}		067	RT	112	*LBL6	157	+		202
023	R/S		068	R/S	113	GSB5 DHil	158	RCL2 HIt		203
024	*LBLB		069	STO7 X _L	114	GSB6	159	RCL5 HIt _{A4}		204
025	GSB0 θ _A		070	R1	115	7	160	GSB4		205
026	R1 Dho _A		071	R/S	116	8	161	+		206
027	GSB1 Scale		072	STO8 Y _L	117	.	162	RCL2 HIt		207
028	X		073	R1	118	5	163	RCL8 HIt _{A4}		208
029	STOC DHia		074	R/S	119	CHS	164	P _{ZS}		209
030	F _{ZS}		075	GSBD	120	EEX	165	GSB4		210
031	RCL7 VDA		076	*LBL6	121	9	166	+		211
032	GSB2 VA		077	GSB5	122	CHS	167	4		212
033	RCL9 VIA		078	R ₄ θ _L	123	*LBL7	168	= Ait		213
034	GSB3 VA		079	CHS	124	X FDhil ²	169	R/S		214
035	TAN		080	RCL0 θ _A	125	- ΔZ	170	*LBL0		215
036	X		081	+	126	RCLC DHil	171	GSB8		216
037	CHS		082	P _{ZS}	127	+P	172	P _{ZS}		217
038	RCL3 ZA		083	RCL6 HD _A	128	STOA DL	173	R1		218
039	RCL6 ZL		084	P _{ZS}	129	DSP2	174	R/S		219
040	-		085	+ HDL	130	RTN	175	P _{ZS}		220
041	+		086	0	131	*LBL6	176	RTN		221
042	RCLC DHia		087	*LBL4	132	P _{ZS}	177	*LBL1		222
043	X ²		088	-	133	GSB0	178	RCL6 ZL		223
044	÷		089	X _{0?}	134	STO0 HD _t	179	2		224
045	ENG		090	4	135	GSB0	180	EEX		

Table 5.--HP-67 program to calculate the theodolite horizontal and vertical direct readings, and distance to any XYZ coordinate; reduce tellurometer data; and calculate the coordinates of a target surveyed by foresight.

INSTRUCTIONS

HDA - Table 4

HIA - Table 4

θA - Table 4

XYZL - Table 4

HD_L - Table 4

f - Table 4

VD_L - Table 4

ppm - Parts per million correction for tellurometer distance.

TELL - Tellurometer reading, distance/0.03.

D - Slope distance, including ppm correction as measured by tellurometer.

Move - Difference between D_t and D_L (table 4), positive indicates that distance must be increased.

D_t - Slope distance between optic center of surveying instrument, i, and survey target, t, including distance measurement offset corrections.

HVDIt - Table 4

V_t - Table 4

Ait - Table 4

XYfZt - Sea-level-scale coordinates of survey target, t, with review of curvature-refraction coefficient, f.

Prerequisite - Theodolite and station "A" coordinates.

1. HDA, t, HIA, A, HDA, R/S, HIA, R/S, θA. Both opening and closing shots to "A" are required and are automatically updated in series shots.

Table 5.--HP-67 program to calculate the theodolite horizontal and vertical direct readings, and distance to any XYZ coordinate; reduce tellurometer data; and calculate the coordinates of a target surveyed by foresight--Continued.

2. XYZ_L , same as table 4
3. HD_L , f , VD_L , same as table 4. Subroutines **A**, **B**, and **C** take the place of previous program (table 4) if f is not calculated.
4. ppm format (.000152), **D**, ppm
5. **TELL**, **E**, **D**. Manually add offset corrections.
6. **D_t**, **[fa]**, **Move**
7. $\text{HVDI}_t/V_t/Ait$ - Same as table 4.
8. Coordinates of "t" are calculated only if both V_t and Ait have been displayed correctly by automatically executed subroutine **fc**. To correct or enter already calculated values of V_t and Ait : **fc**, incorrect **V_t**, CLX, correct **V_t**, R/S, incorrect **Ait**, CLX, correct **Ait**, R/S, **X_t**, R/S, **Y_t**, R/S, **f**, if f is incorrect, CLX, correct **f**, R/S, **Z_t**.

Table 5.--HP-67 program to calculate the theodolite horizontal and vertical direct readings, and distance to any XYZ coordinate; reduce tellurometer data; and calculate the coordinates of a target surveyed by foresight--Continued.

	HDI _A CA / θ _A	XYZ _L	HD _t /E _t /VD _t	PPM	TELL/D	
	D _t	HVO _t	V _t /A _t	X _{YFZ_t}		

GRAD

001	*LBLA	046	RCL4 X _t	091	*LBLB	136	2	181	GSB6
002	DSP4	047	-	092	-	137	÷	182	÷ D _t
003	P _t S	048	→P D _t	093	0	138	DSP4	183	→R ΔX
004	RCL6 HD _{A1}	049	GSB6	094	3	139	RND	184	RCL4 X _t
005	ST05	050	X	095	X	140	R/S V _t	185	+
006	RCL6 HD _{A1}	051	STOCDH _t	096	RCLI	141	STOD	186	DSP2
007	ST04	052	R↓	097	1	142	COS	187	R/S X _t
008	GSB3	053	CHS	098	+	143	X	188	R↓ AY
009	ST06 HD _{A2}	054	RCL6 θ _A	099	X	144	GSB7	189	RCL5 Y _t
010	GSB3	055	+	100	DSP2	145	RCL6 D _t	190	+
011	ST08 HD _{A2}	056	P _t S	101	RND	146	RCL6 V _t	191	R/S)
012	P _t S	057	RCL6 HD _{A3}	102	R/S	147	SIN	192	RCL6 V _t
013	RCL2 Y _t	058	P _t S	103	*LBLA	148	X	193	TAN
014	RCL5 Y _t	059	+ HD _t	104	STOB D _t	149	+	194	GSB2 F
015	-	060	DSP4	105	CHS	150	÷	195	RCL6 D _t
016	RCL1 X _A	061	θ	106	RCLA D _t	151	TAN ⁻¹	196	X
017	RCL4 X _t	062	*LBLD	107	+	152	EEX	197	+
018	-	063	-	108	DSP2	153	5	198	RCL6 D _t
019	→P	064	X<0?	109	R/S MOVE	154	X	199	X
020	X _t Y	065	4	110	*LBL6	155	STOC D _t	200	RCL6 Z _t
021	ST00 θ _A	066	0	111	DSP4	156	P _t S	201	+
022	R/S	067	0	112	GSB3	157	RCL6 HD _t	202	R/S Z _t
023	*LBL2	068	+	113	P _t S	158	RCL4 HD _{A1}	203	*LBL3
024	RCL6 f	069	RTN	114	ST00 HD _t	159	GSB0	204	R1
025	ENG	070	EEX	115	GSB3	160	RCL6 HD _t	205	R/S
026	DSP2	071	Z	116	ST01 VD _t	161	RCL6 HD _{A2}	206	RTN
027	R/S	072	RCL5 Z _t	117	GSB3	162	GSB0	207	*LBL6
028	ST0E f	073	RCL6 Z _t	118	ST02 HI _t	163	+	208	RCL6 Z _t
029	FIX	074	-	119	GSB3	164	RCL2 HI _t	209	GSB7 F
030	RTN	075	RCLCDH _t	120	ST03 VI _t	165	RCL5 HI _{A1}	210	+
031	*LBLB	076	X _t	121	P _t S	166	GSB0	211	LSTX F
032	DSP2	077	GSB2 f	122	*LBLC	167	+	212	÷
033	ST09 Z _t	078	X	123	RCLB D _t	168	RCL2 HI _t	213	RTN
034	R↑	079	-	124	EEX	169	RCL8 HI _{A2}	214	*LBL7
035	GSB3	080	RCL6 D _t	125	2	170	P _t S	215	6
036	ST07 X _t	081	→F	126	P _t S	171	GSB0	216	3
037	GSB3	082	STOA D _t	127	RCLI VD _t	172	+	217	6
038	ST08 Y _t	083	R↓ V _t	128	- V _t	173	4	218	6
039	GSB3	084	-	129	RCL3 VI _t	174	÷	219	1
040	GSBB	085	DSP4	130	P _t S	175	RND	220	9
041	*LBLC	086	R/S	131	3	176	R/S A _t	221	8
042	RCL8 Y _t	087	*LBLD	132	0	177	CHS	222	RTN
043	RCL5 Y _t	088	STOI PPM	133	0	178	RCL6 θ _A	223	R/S
044	RCL7 X _t	089	DSP6	134	- V _t	179	+	160	RCLCDH _t
045	RCL7 X _t	090	R/S	135	+	180	RCLCDH _t		

Table 5.--HP-67 program to calculate the theodolite horizontal and vertical direct readings, and distance to any XYZ coordinate; reduce tellurometer data; and calculate the coordinates of a target surveyed by foresight--Continued.

HDIA/ θ _A	XYZ _L	HD/ E/V _D _L	PPM	TEL/ D
D _c / MOVE	HVDI _t / V _t /A _t / XYZ _t			

GRAD

001	*BLA	046	RCL4 X _t	091	*LBL E	136	2	181	GSB6
002	DSP4	047	-	092	-	137	-	182	-
003	F _S	048	*P D _H _L	093	0	138	DSP4	183	→R ΔX
004	RCL5 H _A	049	GSB6	094	3	139	RND	184	RCL4 X _t
005	ST05	050	X	095	X	140	R/S V _E	185	+
006	RCL6 H _A	051	STOCDH _L	096	RCLI	141	STOD	186	DSP2
007	ST04	052	R↓	097	1	142	COS	187	R/S X _t
008	GSB3	053	CHS	098	+	143	X	188	R↓ ΔY
009	ST06 HD _{AZ}	054	RCL0 θ _A	099	X	144	GSB7	189	RCL5 Y _t
010	GSB3	055	+	100	DSP2	145	RCLB D _E	190	+
011	ST08 H _{AZ}	056	F _S	101	RND	146	RCLD V _E	191	R/S Y _t
012	F _S	057	RCL6 HD _{AZ}	102	R/S	147	SIN	192	RCLD V _t
013	RCL2 Y _t	058	F _S	103	*LBL A	148	X	193	TAN
014	RCL5 Y _t	059	+ HD _L	104	STOB D _E	149	+	194	GSB2 F
015	-	060	DSP4	105	CHS	150	-	195	RCLC A _H _{AZ}
016	RCL1 X _A	061	0	106	RCLA D _L	151	TAN ⁻¹	196	X
017	RCL4 X _t	062	*LBL D	107	+	152	EEX	197	+
018	-	063	-	108	DSP2	153	5	198	RCLC D _H _{AZ}
019	+P	064	XCBT	109	R/S MOVE	154	X	199	X
020	XZY	065	4	110	*LBL D	155	STOCDH _L	200	RCL6 Z _t
021	ST00 θ _A	066	0	111	DSP4	156	F _S	201	+
022	R/S	067	0	112	GSB3	157	RCLB HD _E	202	R/S Z _t
023	*LBL2	068	+	113	F _S	158	RCL4 HD _A	203	*LBL3
024	RCLC f	069	RTN	114	ST00 HD _E	159	GSB0	204	RT
025	ENG	070	EEX	115	GSB3	160	RCLB HD _E	205	R/S
026	DSP2	071	2	116	ST01 VD _E	161	RCL6 HD _{AZ}	206	RTN
027	R/S	072	RCL5 Z _L	117	GSB3	162	GSB0	207	*LBL6
028	STOE f	073	RCL6 Z _t	118	ST02 H _I _t	163	+	208	RCL6 Z _t
029	FIX	074	-	119	GSB3	164	RCL2 H _I _t	209	GSB7 fe
030	RTN	075	RCLOC DH _L	120	ST03 VI _E	165	RCL5 H _A _I	210	+
031	*LBLB	076	X ²	121	F _S	166	GSB0	211	LSTX fe
032	DSP2	077	GSB2 f	122	*LBL D	167	+	212	-
033	ST09 Z _L	078	X	123	RCLB D _E	168	RCL2 H _I _t	213	RTN
034	RT	079	-	124	EEX	169	RCL8 H _A _Z	214	*LBL7
035	GSB3	080	RCLOC DH _L	125	2	170	F _S	215	6
036	ST07 X _t	081	+F	126	F _S	171	GSB0	216	3
037	GSB3	082	ST0A D _L	127	RCLI VD _E	172	+	217	6
038	ST08 Y _t	083	R↓ V _L	128	- V _t	173	4	218	6
039	GSB3	084	-	129	RCL3 VI _E	174	-	219	1
040	GSB6	085	DSP4	130	F _S	175	RND	220	9
041	*LBLC	086	R/S	131	3	176	R/S A _H _E	221	8
042	RCL8 Y _t	087	*LBL D	132	0	177	CHS	222	RTN
043	RCL5 Y _t	088	ST01 PPM	133	0	178	RCL0 θ _A	223	R/S
044	-	089	DSP6	134	- V _E	179	+		
045	RCL7 X _L	090	R/S	135	+	180	RCLOC DH _L		

Table 6.--HP-67 program to calculate the coordinates of a target surveyed by triangulation.

XYZ_{i1} - Coordinates of instrument, station 1 if entered by coordinate entry program, table 3.

XYZ_{i2} - Coordinates of instrument station 2 if entered by coordinate entry program.

θ_{A1} - First theodolite reference station "A" azimuth.

θ_{A2} - Second theodolite reference station "A" azimuth.

V_{t1}, Ait₁ - Vertical and horizontal angles to target "t" measured by first instrument.

V_{t2}, Ait₂ - Angles to same "t", but measured by the second instrument.

X_t, Y_t - Coordinates of "t".

f₁ - f measured or assumed for first theodolite.

Z_{t1} - Altitude of "t" calculated using f₁ and V_{t1}.

f₂, Z_{t2} - Same using data from second theodolite.

\bar{Z}_t - Inverse distance weighted average of Z_{t1} and Z_{t2}.

Prerequisites - θ_{A1} , θ_{A2} , V_{t1}, Ait₁, V_{t2}, and Ait₂ must be previously calculated. Coordinates of both theodolites may have been entered by coordinate entry program. If not,

1. X_{i1} , †, Y_{i1} , †, Z_{i1} , \boxed{A} , $\boxed{X_{i1}}$, R/S, $\boxed{Y_{i1}}$, R/S $\boxed{Z_{i1}}$. If a coordinate is incorrect, CLX, key in correct value, R/S to continue.
2. Subroutines \boxed{A} , \boxed{B} , \boxed{C} , \boxed{D} , and \boxed{E} may also be used to recall data in storage, as a check. CF3, \boxed{A} , $\boxed{X_{i1}}$, R/S, $\boxed{Y_{i1}}$, R/S, $\boxed{Z_{i1}}$
3. XYZ_{i2} - Same as first instrument.
4. $\boxed{\theta_{A1}}$, †, $\boxed{\theta_{A2}}$, \boxed{C} , $\boxed{\theta_{A1}}$, R/S, $\boxed{\theta_{A2}}$
5. $\boxed{V_{t1}}$, †, $\boxed{Ait_1}$, \boxed{D} or \boxed{E} for 2, $\boxed{V_{t1}}$, R/S, $\boxed{Ait_1}$.
6. \boxed{fa} , $\boxed{X_t}$. The following subroutines are called by R/S, or

Table 6.--HP-67 program to calculate the coordinates of a target surveyed by triangulation--Continued.

7. \boxed{fb} , $\boxed{Y_t}$
8. $\boxed{f_1}$, \boxed{fc} , $\boxed{Z_{t1}}$
9. $\boxed{f_2}$, \boxed{fd} , $\boxed{Z_{t2}}$
10. \boxed{fe} , $\boxed{Z_t}$

Table 6.--HP-67 program to calculate the coordinates of a target surveyed by triangulation--Continued.

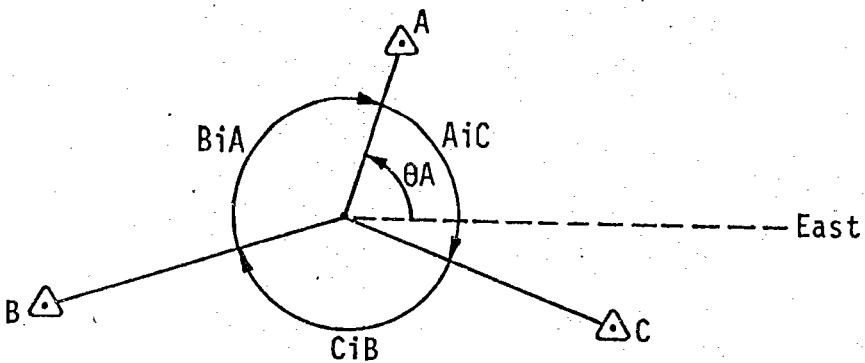
X_{ij}	XYZ_{ij}	Θ_{ij}/Θ_{AZ}	V_{ij}/A_{ij1}	V_{ij2}/A_{ij2}
X_t	Y_t	f_1/Z_{t1}	f_2/Z_{t2}	\bar{Z}_t

001	*LBLH	046	R/S	091	-	136	+R AX	181	RCL5 Y ₁₂
002	F3?	047	RCL7 Θ _{A2}	092	P±S	137	RCL1 X _{j1}	182	-
003	GT00	048	R/S	093	STO2 Θ _{t1}	138	+	183	P±S
004	RCL1 Y _{A1}	049	*LBL4 Θ _{A2}	094	P±S	139	P±S	184	RCL8 X _t
005	R/S	050	STO7	095	RCL5 Y ₁₂	140	STO8 X _t	185	P±S
006	RCL2 Y _{A1}	051	X _{A2} Y	096	RCL2 Y _{j1}	141	P±S	186	RCL4 X ₁₂
007	R/S	052	R/S	097	-	142	R/S X _t	187	-
008	RCL3 Z _{A1}	053	STO0 Θ _{A1}	098	RCL4 X ₁₂	143	*LBL6	188	+P D ₁₂₂
009	R/S	054	RCL7 Θ _{A2}	099	RCL1 X _{j1}	144	X _{A2} Y ΔY	189	P±S
010	*LBL0	055	R/S	100	-	145	RCL2 Y _{j1}	190	STO7
011	STO3 Z _{A1}	056	GT04	101	+P	146	+	191	P±S
012	R/T	057	*LBLD	102	P±S	147	P±S	192	RCL6 Z ₁₂
013	GSB1	058	F3?	103	STO4 D _{H12}	148	STO9 Y _t	193	RCL6 Y _t
014	STO1 X _{j1}	059	GT05	104	P±S	149	P±S	194	+
015	GSB1	060	RCL8 V _t	105	R↓ Θ _{t2}	150	R/S Y _t	195	RCL6 Y _t
016	STO2 Y _{j1}	061	R/S	106	- T ₁₂	151	*LBL6	196	÷
017	GSB1	062	RCL8 A _{t1}	107	LSTX	152	P±S	197	X
018	GT00	063	R/S	108	2	153	RCL3 D _{H12}	198	STO1 D _{H122}
019	*LBL1	064	*LBL5	109	0	154	P±S	199	RCL0 F ₂
020	R/T	065	STO8 A _{t1}	110	0	155	RCL3 Z _{j1}	200	X
021	R/S	066	X _{A2} Y	111	+	156	6	201	RCL9 Y ₁₂
022	RTN	067	R/S	112	RCL7 Θ _{A2}	157	4	202	TAN
023	*LBLB	068	STO8 V _t	113	-	158	EEX	203	+
024	F3?	069	RCL8 A _{t2}	114	RCLB A _{t2}	159	, 5	204	RCL1
025	GT03	070	R/S	115	+	160	STOE Y _t	205	X
026	RCL4 X _{t2}	071	GT05	116	P±S	161	+	206	RCL6 Z ₁₂
027	R/S	072	*LBL6	117	STO5 Z _t	162	LSTX Y _t	207	+
028	RCL5 Y ₁₂	073	F3?	118	SIN	163	÷	208	STO5 Z ₁₂
029	R/S	074	GT06	119	RCL4 D _{H12}	164	X	209	R/S
030	RCL6 Z ₁₂	075	RCL5 V _{t2}	120	X	165	STO1 D _{H121}	210	*LBL6
031	R/S	076	R/S	121	X _{A2} Y	166	X	211	RCL6 Z _{t1}
032	*LBL3	077	RCLB A _{t2}	122	COS	167	RCL8 V _{t1}	212	RCL0 Z ₁₂
033	STO6 Z _{j1}	078	R/S	123	Z	168	TAN	213	-
034	R/T	079	*LBL6	124	0	169	+	214	P±S
035	GSB1	080	STO8	125	0	170	RCL1 S _{H121}	215	RCL7 D _{H122}
036	STO4 X _{j2}	081	X _{A2} Y	126	+	171	X ΔZ	216	X
037	GSB1	082	R/S	127	RCL5 Z _t	172	RCL3 Z _{A1}	217	RCL3 D _{H121}
038	STO5 Y ₁₂	083	STO5 V _{t2}	128	-	173	+	218	RCL7 D _{H122}
039	GSB1	084	RCL8 A _{t2}	129	STOE Z _{t1}	174	STOC Z _{t1}	219	P±S
040	GT03	085	R/S	130	SIN	175	R/S	220	+
041	*LELC	086	GT06	131	÷	176	*LBL6	221	÷
042	DSP4	087	*LBL6	132	STO3 D _{H121}	177	STO5 F ₂	222	RCL0 Z ₁₂
043	F3?	088	DSP2	133	RCL2 Θ _{t1}	178	P±S	223	+
044	GT04	089	RCL0 Θ _{A1}	134	P±S	179	RCL9 Y _t	224	R/S Z _t
045	RCL0 Θ _{A1}	090	RCL8 A _{t1}	135	X _{A2} Y	180	P±S		

Table 7.--HP-67 program to calculate the horizontal and vertical angles used for resection. All angles in grad.

INSTRUCTIONS

Relative positions and naming conventions for monuments and angles used by this program are:



Monuments are surveyed in the sequence, A_1 , B , A_2 , C , A_3 .

A_1 - First set of horizontal and vertical direct and inverted theodolite readings to monument "A".

B - Theodolite readings to monument "B".

A_2 - Second set of theodolite readings to "A".

C - Theodolite readings to monument "C".

A_3 - Third set of theodolite readings to "A".

V_A , V_B , V_C - Mean vertical angles to stations "A", "B" and "C"; horizontal is zero and angles are positive above horizontal.

BiA , AiC - Mean horizontal angles.

Σ - Total of mean horizontal angles AiC , CiB and BiA . Should be close to 400.0000 grad.

Table 7.--HP-67 program to calculate the horizontal and vertical angles used for resection. All angles in grad--Continued.

1. $\underline{HDA_1}$, \uparrow , $\underline{VDA_1}$, \uparrow , $\underline{HIA_1}$, \uparrow , $\underline{VIA_1}$, \boxed{A} , $\underline{HDA_1}$, R/S, $\underline{VDA_1}$, R/S, $\underline{HIA_1}$, R/S, $\underline{VIA_1}$. If any are incorrect, CLX, key in correct value, R/S to continue.
2. Theodolite angles to stations B, A₂, C and A₃ are entered in the same manner as those to A₁.
3. \boxed{fa} , \underline{VA}
4. \boxed{fb} , \underline{VB}
5. \boxed{fc} , \underline{VC}
6. \boxed{fd} , \underline{BiA}
7. \boxed{fe} , \underline{AiC} , R/S, Σ

Table 7.--HP-67 program to calculate the horizontal and vertical angles used for resection. All angles in grad--Continued.

	A_1	B	A_2	C	A_3	
	V_A	V_B	V_C	$B:A$	$A:C/\Sigma$	

GRAD, DSP4

001	*LBLA	046	2	091	÷	V_B	136	*LBLLe
002	STO1	047	X \neq I	092	RND		137	0
003	CLX	048	GSB0	093	RTN		138	P \neq S
004	X \neq I	049	GSBD	094	*LBLb		139	RCL2
005	GSB0	050	*LBLE	095	5		140	P \neq S
006	GSBA	051	STO1	096	GSB4		141	RCL8
007	*LBLD	052	CLX	097	STOB	V_B	142	GSB5
008	F39	053	1	098	R/S		143	P \neq S
009	GT01	054	6	099	*LBLc		144	RCL4
010	*LBL2	055	X \neq I	100	1		145	RCL0
011	RCL1	056	GSB0	101	3		146	GSB5
012	R/S	057	GSBE	102	GSB4		147	RCL2
013	R1	058	*LBLa	103	STOC	V_C	148	RCL6
014	ISZI	059	1	104	R/S		149	GSB5
015	GT02	060	GSB4	105	*LBLd		150	RCL4
016	*LBL1	061	9	106	0		151	RCL8
017	GSB3	062	GSB4	107	RCL0		152	P \neq S
018	GSB3	063	+	108	RCL4		153	GSB5
019	GSB3	064	1	109	GSB5		154	4
020	*LBL3	065	7	110	RCL2		155	÷
021	R1	066	GSB4	111	RCL6		156	RND
022	STO1	067	+	112	GSB5		157	STO1 A:C
023	R/S	068	3	113	RCL8		158	R/S
024	STO1	069	÷	114	RCL4		159	0
025	ISZI	070	RND	115	GSB5		160	STO1
026	SF3	071	STOA	116	P \neq S		161	RCL4 HD _B
027	RTN	072	R/S	117	RCL0		162	P \neq S
028	*LBLB	073	GSBb	118	P \neq S		163	RCL2 HD _C
029	STO1	074	*LBL4	119	RCL6		164	P \neq S
030	CLX	075	STO1	120	GSB5		165	GSB5
031	4	076	R↓	121	4		166	RCL6 HI _B
032	X \neq I	077	RCL1 VD	122	÷		167	P \neq S
033	GSB0	078	CHS	123	RND		168	RCL4 HI _C
034	GSBB	079	EEX	124	STOD	B:A	169	P \neq S
035	*LBLC	080	2	125	R/S		170	GSB5
036	STO1	081	+	126	GSBe		171	2
037	CLX	082	ISZI	127	*LBL5		172	÷ C:B
038	8	083	ISZI	128	-		173	RCLD B:A
039	X \neq I	084	RCL1 VI	129	X<0?		174	RCLE A:C
040	GSB0	085	3	130	4		175	+
041	GSBC	086	0	131	0		176	+
042	*LBLD	087	0	132	0		177	R/S Σ
043	STO1	088	-	133	+			
044	CLX	089	+	134	+			
045	1	090	2	135	RTN			

Table 8.--HP-67 program to calculate the instrument XY coordinates by resection.

Prerequisites - horizontal angles AiB and BiC , and coordinate XYZ_A , XYZ_B and XYZ_C .

X_i , X coordinate of surveying instrument axis

Y_i , Y coordinate of surveying instrument axis

θ_A , azimuth of "A" monument from theodolite; east is zero, positive azimuth angles are counterclockwise from east

1. $[A]$, X_i , R/S, $[Y_i]$, R/S, θ_A or

2. $[B]$, $[Y_i]$

3. $[C]$, θ_A

X_i and Y_i are automatically stored for subsequent instrument altitude backsight program (table 9).

Table 8.--HP-67 program to calculate the instrument XY coordinates by resection--Continued.

	X_i	Y_i	Θ_A	
GRAD				
001	*LBLA			091 RCLB HDA3
002	*LBLB			092 ST09
003	RCLD B:A			093 RCL1 Y:
004	RCLC A:C			094 P±S
005	ST08			095 R/S
006	XZY			096 *LBLC
007	ST+G B:C			097 *LBLG
008	TAN			098 RCL2 YA
009	1/X			099 P±S
010	ST01			100 RCL1 Y:
011	RCL1 XA			101 P±S
012	RCL4 XB			102 -
013	-			103 RCL1 XA
014	X			104 P±S
015	RCL4 XB			105 RCL0 X:
016	RCL7 XC			106 P±S
017	-			107 -
018	RCL0 B:C			108 -P
019	TAN			109 XZY ΘA
020	1/X			110 DSF4
021	ST06			111 RND
022	X			112 R/S ΘA
023	+			
024	RCL8 YC			
025	RCL2 YA			
026	-			
027	+			
028	RCL2 YA			
029	RCL5 YB			
030	-			
031	RCLI COT B:A			
032	X			
033	RCL5 YB			
034	RCL8 YC			
035	-			
036	RCL8 COT B:C			
037	X			
038	+			
039	RCL1 XA			
040	RCL7 XC			
041	-			
042	+			
043	÷			
044	ENT1			
045	ST08 'K'			
				089 RCL6 HDA3
				096 ST07

Table 9.--HP-67 program to calculate f and instrument altitude by back-sight at a resection location.

INSTRUCTIONS

Prerequisites - Vertical angles V_A , V_B , and V_C ; monument coordinates XYZ_A , XYZ_B , and XYZ_C ; and instrument coordinates X_i and Y_i .

A - Abbreviated notation for: (1) Dh_A , the horizontal distance between the instrument and "A". (2) Zi_A , the instrument altitude calculated using Dh_A , V_A , and a curvature-refraction coefficient, f, to "A".

B - Abbreviated notation for Dh_B and Zi_B as above.

C - Abbreviated notation for Dh_C and Zi_C as above.

AB - Abbreviated notation for (1) f_{AB} , the curvature-refraction coefficient calculated using Dh_A , Dh_B , V_A , and V_B , and (2) Zi_{AB} , the instrument altitude which results when f_{AB} is used. This calculation is very sensitive to all monument coordinate and observational errors. Maximum possible value is 69×10^{-9} . This f value is used as a guide to choosing the final f value.

BC and CA - Abbreviated notation as above.

Zi - Surveying instrument axis altitude.

1. \boxed{A} , $\boxed{Dh_A}$, R/S, \boxed{f} (60×10^{-9} , an assumed normal value is used on the first run and may be changed by: CLX, key in new value, R/S, to continue), $\boxed{Zi_A}$.
2. \boxed{B} , $\boxed{Dh_B}$, R/S, \boxed{f} , R/S, $\boxed{Zi_B}$.
3. \boxed{C} , $\boxed{Dh_C}$, R/S, \boxed{f} , R/S, $\boxed{Zi_C}$.
4. $\boxed{f_a}$, $\boxed{f_{AB}}$, R/S, $\boxed{Zi_{AB}}$.

Table 9.--HP-67 program to calculate f and instrument altitude by backsight at a resection location--Continued.

5. $\boxed{f_b}$, $\boxed{f_{BC}}$, R/S, $\boxed{Z_{iBC}}$.
6. $\boxed{f_c}$, $\boxed{f_{CA}}$, R/S, $\boxed{Z_{iCA}}$.
7. Choose an f value which reduces the scatter of Z_i values. The Z_i with the shortest Dh value will be the least affected by changes in f and therefore the most accurate.
8. \boxed{A} , $\boxed{Dh_A}$, R/S, \boxed{f} , CLX and key in chosen \boxed{f} , R/S, $\boxed{Z_{iA}}$.
9. \boxed{B} , $\boxed{Dh_B}$, R/S, chosen \boxed{f} , R/S, $\boxed{Z_{iB}}$.
10. \boxed{C} , $\boxed{Dh_C}$, R/S, chosen \boxed{f} , R/S, $\boxed{Z_{iC}}$.
11. Select the Z_i value by inspecting all of the above results.
12. Selected $\boxed{Z_i}$, \boxed{E} , $\boxed{Z_i}$. Stores Z_i and prepares calculator storage registers for foresight programs. X_i , Y_i , Z_i and last used f are automatically stored for use by foresight programs. HDA_3 and HIA_3 stored for calculating theodolite angles to any XYZ location and for calculating Ait horizontal angle even if a closing reading to monument "A" is not possible.

Table 9.--HP-67 program to calculate f and instrument altitude by back-sight at a resection location--Continued.

A	B	$C \leftarrow Dh/Zi$	Zi
AB	BC	CA	f/Zi

Grad, CF1, SF2

001	*LBLH	046	÷	Re	091	RTN	136	RCL3	Za	181	GSB6	
002	1	047	+		092	*LBLLE	137	GSB5	182	COS		
003	2	048	LSTX	Re	093	RND	138	RCL9	Zc	183	X	
004	STO1	049	÷	Scale	094	STO6	Zi	139	GSB7	184	GSBD Dha	
005	GSB1	050	X		095	P2S	140	RCL9	Zc	185	X ²	
006	STO3	Dha	051	FIX	096	RCL8	HDA3	141	GT08	186	GSB0 VA	
007	GSB2	052	RND		097	STO5	HDA3	142	*LBL5	187	COS	
008	RCL1	VA	053	P2S	098	RCL6	HIA3	143	RCL1	Dha	188	X
009	GSB3	054	F1?		099	STO4	HIA3	144	GSB0	Vb	189	-
010	GT08	055	R/S	Dhi	100	RCL0	XL	145	TAN	190	÷	
011	*LBLLE	056	P2S		101	RCL1	Yi	146	X	191	ENG	
012	1	057	RTN		102	P2S		147	-	192	RND	
013	5	058	*LBL2		103	STO5	Yi	148	GSBD	Dha	193	R/S f
014	STO1	059	ENT1		104	R↓		149	GSB0	VA	194	RCL1 VA
015	GSB1	060	P2S		105	STO4	XL	150	TAN	195	COS	
016	STO4	Dha	061	6	106	RCL6	Zi	151	X	196	X ² I	
017	GSB2	062	EEX		107	R/S		152	+	197	7	
018	RCL1	Vb	063	8	108	GT0E		153	R1	198	-	
019	GSB3	064	CHS		109	*LBLa		154	STO1	199	X ² I	
020	GT08	065	F2?		110	CF0		155	R↓	200	RCL1 Dha	
021	*LBLC	066	STO5	f	111	1		156	RTN	201	X ²	
022	1	067	CLX		112	4		157	*LBL6	202	X	
023	8	068	RCL1	f	113	STO1		158	X ² I	203	X	
024	STO1	069	ENG		114	RCL6	Zb	159	7	204	RCL1 Dha	
025	GSB1	070	F1?		115	GSB5		160	+	205	GSB0 VA	
026	STO5	Dhc	071	R/S	116	RCL3	Za	161	X ² I	206	TAN	
027	GSB2	072	FIX		117	GSB7		162	RCL1	Vb	207	X
028	RCL1	Vc	073	STO5	f	118	RCL3	Za	163	RTN	208	+
029	GSB3	074	X		119	GT08		164	*LBLD	209	CHS	
030	GT0C	075	RTN		120	*LBLb		165	X ² I	210	RTN	
031	*LBL1	076	*LBL3		121	CF0		166	F0?	211	*LBL8	
032	P2S	077	P2S		122	1		167	GSB6	212	+	
033	RCL1	Yabc	078	TAN	123	5		168	8	213	FIX	
034	DSZI	079	+		124	STO1		169	-	214	R/S	
035	RCL1	Yi	080	X	125	RCL9	Zc	170	X ² I			
036	-	081	CHS		126	GSB5		171	RCL1	Dha		
037	RCL1	Xabc	082	ISZI	127	RCL6	Zb	172	RTN			
038	RCL6	Xi	083	ISZI	128	GSB7		173	*LBL6			
039	-	084	RCL1	Zabc	129	RCL6	Zb	174	3			
040	+P	Dha	085	+	130	GT08		175	+			
041	RCL2	Zi	086	STO2	131	*LBL6		176	RTN			
042	2	087	P2S		132	SF0		177	*LBL7			
043	EEX	088	F1?		133	1		178	-			
044	7	089	R/S	ZL	134	3		179	RCL1	Dhb,		
045	P1	090	SFI		135	STO1		180	X ²			

Table 10.--Columbia Glacier survey results 1978 measurement year.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6'	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-2	77-08-28	13022.1	51481.9	2643.8	2.8(s) 9.6(s)		
Stake 77-2	77-11-16	—	—	—	2.8(77f)		
Stake 77-2	78-08-23	13083.2	51542.7	2632.0	12.7(s) .52(s)		
Glac. Surf. 2-P	78-08-23	13025.8	51483.2	2646.6			±0.05
Glac. Surf. 2-Q	78-08-23	13011.8	51461.5	2647.1			
Glac. Surf. 2-R	78-08-23	13001.6	51482.8	2647.3			
Stake 77-2	78-09-01	—	—	—	13.4(s) 12.7(78f)		
	78-09-09	—	—	—	13.7(s)		
Stake 77-8	77-08-28	17804.5	54952.7	2223.6	2.8(s)		
Stake 77-8	78-08-23	—	—	—	12.5(s)		
Glac. Surf. 8-P	78-08-23	17808.2	54952.8	2226.3			±0.10
Glac. Surf. 8-Q	78-08-23	17796.7	54936.8	2226.7			
Glac. Surf. 8-R	78-08-23	17789.6	54953.6	2227.4			
Stake 77-8	78-08-23	18079.5	54986.3	2210.4		.58(s)	

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Glac. Surf. 10-P	78-08-23	19777.8	54739.2	2135.0			±0.10
Glac. Surf. 10-Q	78-08-23	19793.1	54783.2	2133.1			
Glac. Surf. 10-R	78-08-23	19811.6	54774.1	2132.6			
Stake 77-14	77-08-28	23436.0	53156.8	1918.8	3.0(s)	.62(s)	
Stake 77-14	78-08-24	23602.6	53068.6	1911.8	7.9(s)		
39 Glac. Surf. 14-P	78-08-24	23428.2	53168.0	1920.4			±0.10
Glac. Surf. 14-C	78-08-24	23427.6	53141.1	1920.6			
Glac. Surf. 14-R	78-08-24	23454.0	53150.4	1920.4			
Stake 77-20	77-08-28	27904.2	49256.8	1761.0	2.9 (s)		
Glac. Surf. 20-P	78-08-25	27909.2	49254.1	1765.6			±0.20
Glac. Surf. 20-Q	78-08-25	27882.2	49258.9	1765.6			
Glac. Surf. 20-R	78-08-25	27899.3	49283.4	1764.9			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 5' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-24	77-08-28	28444.2	45467.4	1477.9	2.9(s)		
Stake 77-24	78-08-25	28085.6	44546.0	1420.5	4.9(s)		
Glac. Surf. 24-P	78-08-25	28441.4	45464.9	1486.8			±0.40
Glac. Surf. 24-Q	78-08-25	28474.1	45517.0	1484.7			
Glac. Surf. 24-R	78-08-25	28493.3	45490.2	1484.0			
04	Glac. Surf. 28.2	76-08-20	27186.7	41345.5	1108.7		
	Stake 77-28.2	77-08-29	27192.1	41371.1	1103.8	5.2(s)	
	Glac. Surf. 28.2-Q	77-08-29	27226.1	41382.6	1109.0		±0.30
	Glac. Surf. 28.2-R	77-08-29	27208.8	41349.1	1110.6		
	Stake 77-28.2	77-08-31	—	—	—	5.2(s)	
	Stake 77-28.2	77-11-16	—	—	—	6.9(s)	
	Stake 77-28.2	78-08-26	27061.7	40945.0	1099.0	6.5(s)	
	Glac. Surf. 28.2	78-08-26	27164.2	41333.4	1110.0		
	Glac. Surf. 28.2-P	78-08-26	27190.1	41370.5	1106.7		±0.30
	Glac. Surf. 28.2-Q	78-08-26	27226.9	41374.4	1109.7		
	Glac. Surf. 28.2-R	78-08-26	27198.7	41351.9	1109.6		
	Stake 77-28.2	78-09-01	—	—	—	6.4(s)	

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Glac. Surf. 32-P	76-08-15	25460.7	37990.1	959.0			±0.20
Glac. Surf. 32-Q	76-08-15	25436.5	37973.9	958.3			
Glac. Surf. 32-R	76-08-15	25464.0	37950.4	957.1			
Stake 77-32	77-08-29	25453.8	37967.4	951.2	6.9(s)		
Glac. Surf. 32-P	77-09-03	25620.2	37988.4	963.0			±0.30
Glac. Surf. 32-Q	77-09-03	25601.4	37897.4	960.7			
Stake 77-32	77-11-16	—	—	—	8.6(s)		
Stake 77-32	78-08-26	25164.5	37045.5	920.4	6.9(l) .60(l)		
Glac. Surf. 32-P	78-08-26	25613.3	37993.6	964.3			
Stake 77-35-2	77-08-31	24840.4	35079.5	822.2	5.5(s)		
Glac. Surf. 35-P	78-08-26	25145.4	35100.0	831.2			±0.20
Glac. Surf. 35-Q	78-08-26	25088.3	35100.2	832.6			
Glac. Surf. 35-R	78-08-26	25119.4	35186.1	841.0			
Glac. Surf. 35-P2	78-08-26	24839.9	35080.1	828.9			
Stake 77-35-2	78-08-28	25174.7	34104.5	759.5	4.5(l)		

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b'	Density ρ	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-40-1.5	77-08-31	23217.2	31849.2	650.4	7.2(s)		
Stake 77-40-1.5	78-08-28	22995.1	31626.5	648.5	4.4(l)		
Glac. Surf. 40-1.5-P	78-08-28	23321.7	31886.0	653.5			±1.00
Glac. Surf. 40-1.5-Q	78-08-28	23227.7	31841.9	653.6			
Glac. Surf. 40-1.5-R	78-08-28	23283.9	31817.3	654.5			
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Stake 77-40-2.8	77-08-31	24243.2	31035.7	667.5	7.1(s)		
Stake 77-40-2.8	78-08-28	23878.7	30623.4	661.5	4.5(l)		
Glac. Surf. 40-2.8-P	78-08-28	24403.7	31255.0	677.2			
Glac. Surf. 40-2.8-Q	78-08-28	24350.3	31296.2	676.9			
Glac. Surf. 40-2.8-R	78-08-28	24306.1	31238.0	675.4			
Glac. Surf. 40-2.8-P	78-09-06	24262.5	31051.5	673.3			±0.30
Glac. Surf. 40-2.8-Q	78-09-06	24212.3	30961.9	671.9			
Glac. Surf. 40-2.8-R	78-09-06	24182.9	31033.7	673.0			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-40-4	77-08-31	25163.0	30256.3	662.5	7.2(s)		
Stake 77-40-4	78-08-28	24833.1	29785.3	657.4	4.5(l)		
Glac. Surf. 40-4-P	78-08-28	25162.7	30256.2	667.8			±0.30
Glac. Surf. 40-4-Q	78-08-28	25171.6	30235.4	667.6			
Glac. Surf. 40-4-R	78-08-28	25179.6	30265.0	668.2			
Stake 77-40-5	77-08-31	25915.4	29595.7	6422	7.2(s)		
Stake 77-40-5	77-11-16	—	—	—	7.3(s)		
Stake 77-40-5	78-08-28	25689.4	29239.9	640.7	5.0(l)		
Glac. Surf. 40-5-P	78-08-28	25795.7	29680.6	648.1			±0.30
Glac. Surf. 40-5-Q	78-08-28	25912.0	29599.0	647.8			
Glac. Surf. 40-5-R	78-08-28	25865.4	29539.2	647.9			
Stake 40-6	77-08-31	26665.1	28933.6	645.4	7.2(s)		
Stake 40-6	78-08-28	26619.1	28861.3	644.8	5.0(l)		
Glac. Surf. 40-6-P	78-08-28	26658.5	28938.3	650.7			±0.20
Glac. Surf. 40-6-Q	78-08-28	26672.5	28886.1	650.5			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-40-7	77-08-31	27414.0	28272.6	634.5	7.1(s)		
Stake 77-40-7	78-08-28	27414.7	28270.2	635.1	5.0(e)		
Glac. Surf. G70	74-07-30	23851.5	28644.1	640.0			
Glac. Surf. G70-P	76-08-21	23876.8	28696.5	641.3			± 0.30
Glac. Surf. G70-Q	76-08-21	23828.7	28637.4	638.5			
Glac. Surf. G70-R	76-08-21	23903.7	28565.9	637.6			
Glac. Surf. 42-P	76-08-21	23683.6	28863.8	643.8			± 0.30
Glac. Surf. 42-Q	76-08-21	23637.6	28854.5	642.3			
Glac. Surf. 42-R	76-08-21	23618.4	28780.1	640.1			
Stake 77-42	77-08-31	23745.9	28837.3	636.9	7.1(s)		
Glac. Surf. 42-P	77-09-03	23647.0	28829.9	642.2			± 0.30
Glac. Surf. 42-Q	77-09-03	23710.9	28712.0	638.7			
Stake 77-42	78-08-28	23354.5	28486.9	621.3	3.7(e)		
Glac. Surf. 42-P	78-08-29	23748.8	28844.9	642.6			± 0.30
Glac. Surf. 42-Q	78-08-29	23731.5	28843.0	642.4			
Glac. Surf. 42-R	78-08-29	23756.2	28829.7	642.1			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-44	77-09-01	21966.7	27933.4	612.0	7.3(s)		
Stake 77-44	78-08-02	21563.5	27652.3	603.6	4.8(l)		
Glac. Surf. 44-P	78-08-02	21966.2	27936.2	617.1			± 0.15
Glac. Surf. 44-Q	78-08-02	21945.0	27878.0	616.3			
Glac. Surf. 44-R	78-08-02	21991.0	27898.0	616.5			
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Stake 77-46	77-09-01	20346.6	26758.4	594.9	8.1(s)		
Stake 77-46	78-09-02	19948.7	26534.6	595.1	6.0(l)		
Glac. Surf. 46-P	78-09-02	20346.2	26759.1	601.7			± 0.15
Glac. Surf. 46-Q	78-09-02	20325.8	26733.3	602.2			
Glac. Surf. 46-R	78-09-02	20295.9	26749.0	601.3			
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Stake 77-48	77-09-01	18712.0	25605.6	549.0	9.3(l)		
Glac. Surf. 48-P	77-09-01	18556.5	25729.3	560.3			± 0.30
Glac. Surf. 48-Q	77-09-01	18694.8	25470.3	548.8			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-48	78-08-29	18404.5	25253.7	528.5	6.0(s)		
Glac. Surf. 48-P	78-08-29	18711.4	25605.4	557.3			±0.30
Glac. Surf. 48-Q	78-08-29	18698.6	25603.9	557.2			
Glac. Surf. 48-R	78-08-29	18706.5	25596.1	557.2			
Stake 77-50-1	77-08-27	15719.5	27118.8	538.7	7.6(s)		
Glac. Surf. 50-1-P	77-08-27	15710.1	27132.2	545.6			±0.30
Glac. Surf. 50-1-Q	77-08-27	15693.7	27117.6	545.8			
Stake 77-50-1	78-09-01	15675.9	27067.1	538.1	4.5(s)		
Glac. Surf. 50-1-P	78-09-01	15709.2	27130.7	542.7			±0.30
Glac. Surf. 50-1-Q	78-09-01	15724.7	27066.5	542.5			
Stake 77-50-2	77-08-27	16171.5	26255.9	536.5	7.7(s)		
Stake 77-50-2	78-09-01	15972.7	25962.0	531.0	4.0(s)		
Glac. Surf. 50-2-P	78-09-01	16167.5	26254.9	542.9			±0.80
Glac. Surf. 50-2-Q	78-09-01	16152.9	26304.5	541.7			
Glac. Surf. 50-2-R	78-09-01	16084.1	26198.9	542.5			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-50-3	77-08-27	16627.9	25361.6	541.6	2.8(i)		
Stake 77-50-3	78-06-08	16407.5	25020.8	531.3	8.2(s)		
Glac. Surf. 50-3-P	78-09-01	16610.2	25365.6	546.2			+0.10
Glac. Surf. 50-3-Q	78-09-01	16645.7	25356.9	547.7			
Glac. Surf. 50-3-R	78-09-01	16634.3	25395.3	547.2			
Stake 77-50-3	78-09-02	16339.3	24909.2	528.8	3.9(i)		
Stake 77-50-4	77-08-27	17073.8	24455.2	520.9	7.3(l)		
Stake 77-50-4	77-08-31	-	-	-	7.2(l)		
Stake 77-50-4	78-06-08	16842.6	24102.3	505.8	7.9(s)		
Glac. Surf. 50-4-P	78-06-08	17023.7	24574.7	535.7			+0.10
Glac. Surf. 50-4-Q	78-06-08	17177.2	24567.0	533.8			
Stake 77-50-4	78-09-01	16766.7	23988.4	500.2	5.0(i)		
Glac. Surf. 50-4-P	78-09-01	17074.3	24457.9	525.6			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-50-5	77-08-27	17475.3	23542.1	512.7	7.4(i)		
Stake 77-50-5	78-09-01	17146.9	23183.0	510.6	5.3(i)		
Glac. Surf. 50-5-P	78-09-01	17527.3	23567.1	516.0			±0.10
Glac. Surf. 50-5-Q	78-09-01	17429.5	23609.9	514.3			
Glac. Surf. 50-5-R	78-09-01	17420.2	23514.6	515.0			
Stake 77-50-6	77-08-27	17981.9	22666.2	531.6	7.3(i)		
Stake 77-50-6	78-08-30	17804.2	22518.6	535.6	2.1(i)		
Glac. Surf. 50-6-P	78-08-30	17981.0	22675.2	535.5			±0.05
Glac. Surf. 50-6-Q	78-08-30	17972.8	22655.3	536.2			
Glac. Surf. 50-6-R	78-08-30	17954.4	22667.3	535.5			
Stake 77-50-7	77-08-27	18319.2	22008.6	528.7	7.3(s)		
Stake 77-50-7	77-08-29	—	—	—	7.3(s)		
Stake 77-50-7	78-08-30	18313.0	21997.9	530.1	3.3(i)		
Glac. Surf. 50-7-P	78-08-30	18319.0	22008.4	533.9			±0.05
Glac. Surf. 50-7-Q	78-08-30	18310.2	22015.0	534.2			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date	Sea level coordinates			Balance	Density	Surface Definition
	Y - M - D	X ₀ meters	Y ₀ meters	Z meters	b' meters	P Mg/m ³	meters
Glac. Surf. G44	74-07-29	16070.0	22771.1	483.9			
Glac. Surf. G45	74-07-29	16000.2	22646.6	483.0			
Glac. Surf. 52-P	76-08-19	15979.8	22667.0	480.8			±0.15
Glac. Surf. 52-Q	76-08-19	15942.9	22666.4	481.2			
Glac. Surf. 52-R	76-08-19	16044.9	22621.9	482.1			
Stake 77-52	77-08-25	16095.0	22710.0	470.4	9.3(s)		
Glac. Surf. 52-P	77-08-25	16081.9	22720.2	479.5			±0.10
Glac. Surf. 52-Q	77-08-25	16012.8	22634.6	477.7			
Stake 77-52	78-09-01	16018.8	21870.7	454.3	7.0(6)		
Glac. Surf. 52-P	78-09-01	16081.0	22720.1	476.8			±0.10
Glac. Surf. 52-Q	78-09-01	16057.2	22804.7	475.4			
Glac. Surf. 52-R	78-09-01	16127.4	22750.2	478.1			
Glac. Surf. G8	74-07-29	16705.5	17263.4	302.4			
Glac. Surf. 57.6-P	76-08-20	16689.5	17263.1	298.5			±0.50
Glac. Surf. 57.6-Q	76-08-20	16731.6	17223.6	296.8			
Glac. Surf. 57.6-R	76-08-20	16725.4	17283.1	298.0			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-57.6	77-08-25	16719.5	17260.8	278.4	11.8(i)		
Tape 78-57.6T	78-06-10	16942.7	16666.2	261.2	12.6(i)		
Stake 77-57.6	78-09-02	17020.8	16482.1	256.7	5.6(i)		
Tape 78-57.6T	78-09-02	17010.0	16482.0	250.2	6.5(i)		
Glac. Surf. 57.6 JT	78-09-02	16942.5	16666.5	270.3			
Glac. Surf. 57.6-P	78-09-02	16719.5	17260.0	287.2			± 0.80
Glac. Surf. 57.6-Q	78-09-02	16720.3	17235.4	287.3			
Glac. Surf. 57.6-R	78-09-02	16676.1	17196.6	287.3			
Stake 77-59.3-2.5E	77-08-25	19365.6	16756.6	225.7	13.3(i)		
Stake 77-59.3-2.5E	78-06-06	19407.5	16753.8	226.8	11.1(i)		
Stake 77-59.3-2.5E	78-09-03	19421.7	16753.2	227.4	5.3(i)		
Glac. Surf. 59.3-P	78-09-03	19351.0	16780.7	235.7			± 0.10
Glac. Surf. 59.3-R	78-09-03	19378.7	16789.2	234.6			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date	Sea Level coordinates			Balance	Density	Surface Definition
	Y - M - D	X ₀ meters	Y ₀ meters	Z meters	b' meters	P Mg/m ³	meters
Glac. Surf. G56	74-07-29	17253.9	15080.0	271.6			
Glac. Surf. G60	74-07-29	17254.9	14798.6	264.9			
Glac. Surf. 60-P	76-08-20	17307.2	15195.5	270.9			±0.50
Glac. Surf. 60-Q	76-08-20	17354.3	14971.0	267.5			
Glac. Surf. 60-R	76-08-20	17399.1	14909.4	266.5			
Stake 77-60	77-08-24	17392.0	15029.9	252.1	11.8(i)		
Glac. Surf. 60-Q	77-08-24	17233.3	15002.6	261.2			±0.50
Glac. Surf. 60-R	77-08-24	17351.8	14978.5	260.5			
Stake 77-60	77-08-31	—	—	—	11.6(i)		
Stake 77-60	78-06-09	17552.0	14376.9	SURFACE 241.8			
Stake 77-60	78-09-03	17593.1	14171.0	226.2	6.0(i)		
Glac. Surf. 60-P	78-09-03	17395.0	15033.7	258.1			±0.50
Glac. Surf. 60-Q	78-09-03	17504.2	14375.6	237.3			
Glac. Surf. 60-R	78-09-03	17488.4	14234.2	232.3			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date	Sea level coordinates			Balance	Density	Surface Definition
	Y - M - D	X _o meters	Y _o meters	Z meters	b' meters	P Mg/m ³	meters
Glac. Surf. G52	74-07-29	17103.2	12840.1	210.5			
Glac. Surf. 62.2-7-P	76-08-20	17121.2	12849.6	206.6			±0.30
Glac. Surf. 62.2-7-Q	76-08-20	17076.7	12854.6	205.7			
Glac. Surf. 62.2-7-R	76-08-20	17127.1	12809.0	205.5			
Stake 77-62.2-7	77-08-24	17116.9	12818.6	195.9	9.8(G)		
Stake 77-62.2-7	78-06-07	17085.8	12108.0	177.9	7.9(W)		
Glac. Surf. 62.2-7-P	78-06-07	17145.2	12812.8	198.5			±0.30
Glac. Surf. 62.2-7-Q	78-06-07	17096.0	12872.7	203.1			
Glac. Surf. 62.2-7-R	78-06-07	16966.7	12802.7	194.7			
Stake 77-62.2-7	78-09-03	17060.6	11889.1	172.6	4.6(W)		
Glac. Surf. 62.2-7-JP	78-09-03	17102.2	12128.8	182.6			
Glac. Surf. 62.2-7-JQ	78-09-03	17139.9	12092.6	181.7			
Glac. Surf. 62.2-7-JR	78-09-03	16969.9	12037.2	180.3			
Glac. Surf. 62.2-7-P	78-09-03	17152.5	12872.5	199.5			±0.50
Glac. Surf. 62.2-7-Q	78-09-03	17061.2	12876.5	196.6			
Glac. Surf. 62.2-7-R	78-09-03	17139.5	12927.3	195.9			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-61.8-2.2E	77-08-24	20000.3	13428.1	172.3	13.4(0)		
Stake 77-61.8-2.2E	78-06-06	20008.7	13416.1	173.8	10.2(0)		
Stake 77-61.8-2.2E	78-09-03	20016.3	13411.4	173.7	5.1(4)		
Glac. Surf. 61.8-2.2E-P	78-09-03	20000.8	13427.9	180.3			±0.40
Glac. Surf. 61.8-2.2E-Q	78-09-03	19987.4	13398.3	179.5			
Stake 77-62.9-2.3W	77-08-21	15524.0	12111.2	167.9	15.2(2)		
Stake 77-62.9-2.3W	78-06-07	15541.8	12005.4	163.7	13.1(2)		
Stake 77-62.9-2.3W	78-09-03	15543.8	11959.8	164.3	7.7(2)		
Glac. Surf. 62.9-2.3WP	78-09-03	15581.6	12168.0	177.7			±1.00
Glac. Surf. 62.9-2.3WQ	78-09-03	15513.4	12110.8	176.4			
Glac. Surf. 62.9-2.3WR	78-09-03	15599.4	12061.4	171.5			
Glac. Surf. 646	74-07-29	16851.3	10773.3	191.2			
Glac. Surf. 646-8W-P	76-08-20	16966.7	10763.3	176.9			±0.40

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Glac. Surf. 64.6-8W-P	77-09-02	17032.0	10759.6	164.6			
Glac. Surf. 64.6-8W-Q	77-09-02	16840.4	10621.2	167.6			
Glac. Surf. 64.6-8W-R	77-09-02	16733.9	10842.6	168.4			
Glac. Surf. 64.6-8W-P	78-09-03	16767.4	10745.0	165.0			
Stake 77-64.5-1.8E	77-08-24	19779.9	10628.0	124.6	14.6(6)		
Stake 77-64.5-1.8E	77-08-31	—	—	—	13.9(6)		
Stake 77-64.5-1.8E	77-11-16	—	—	—	12.6(5)		
Stake 77-64.5-1.8E	78-06-06	19787.1	10609.3	124.5	10.3(6)		
Glac. Surf. 64.5-1.8E-Q	78-06-06	19767.0	10634.3	136.5			
Glac. Surf. 64.5-1.8E-R	78-06-06	19800.6	10640.4	135.4			
Stake 77-64.5-1.8E	78-06-28	—	—	—	10.2(6)		
Stake 77-64.5-1.8E	78-08-06	—	—	—	8.0(6)		
Stake 77-64.5-1.8E	78-08-31	—	—	—	6.4(6)		
Stake 77-64.5-1.8E	78-09-03	19790.9	10598.6	124.9	6.3(6)		
Glac. Surf. 64.5-1.8E-P	78-09-03	19763.4	10655.7	134.7			±0.50
Glac. Surf. 64.5-1.8E-Q	78-09-03	19779.9	10639.6	133.6			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates X_0 meters	Y_0 meters	Z meters	Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
Stake 77-E24	77-08-30	37089.9	40605.7	947.1	5.1(s)		
Stake 77-E24	77-11-16	—	—	—	6.8(s)		
Stake 77-E24	78-08-27	37031.4	40569.5	946.5	4.8(s)		
Glac. Surf. E24-Q	78-08-27	37091.9	40601.0	951.3			±0.05
Glac. Surf. E24-R	78-08-27	37037.7	40612.7	951.5			
Stake 77-E24	78-09-01	—	—	—	4.8(i)		

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Stake 77-E28	77-08-30	33774.1	38423.0	881.8	5.3(s)	Note: Survey error of +1.4 to -2.0 possible range due to unusual refraction.
Stake 77-E28	77-11-16	—	—	—	6.0(s)	
Stake 77-E28	78-08-27	33732.4	38385.0	883.3	3.9(s)	
Glac. Surf. E-28-Q	78-08-27	33772.1	38419.4	887.6		±0.05
Glac. Surf. E-28-R	78-08-27	33724.6	38416.1	886.8		
Glac. Surf. E32-P	76-08-20	31423.9	35256.4	780.3		±0.10
Glac. Surf. E32-Q	76-08-20	31237.9	35309.2	779.5		
Glac. Surf. E32-R	76-08-20	31283.4	35221.4	778.9		

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance ' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-B2	77-08-31	28709.1	29470.5	626.5	7.2(s)		
Stake 77-B2	78-08-28	28712.9	29468.5	629.3	5.2(i)		±0.05
Stake 77-B2	78-09-08	—	—	—	5.0(i)		
Stake 77-E16	77-08-30	43479.0	45282.5	1348.1	5.1(s)		
Stake 77-E16	77-11-16	—	—	—	7.1(s)		
Stake 77-E16	78-08-06	—	—	—	7.0(s)		
Stake 77-E16	78-08-27	43385.2	45194.1	1339.5	6.2(s)		
Glac. Surf. E16-P	78-08-27	43511.5	45323.3	1355.5			±0.10
Glac. Surf. E16-Q	78-08-27	43489.4	45279.5	1353.5			
Glac. Surf. E16-R	78-08-27	43473.5	45792.5	1352.6			
Glac. Surf. E20-P	78-08-27	40482.4	42642.4	1040.9			±0.05
Glac. Surf. E20-Q	78-08-27	40455.2	42635.0	1040.2			
Glac. Surf. E20-R	78-08-27	40481.3	42610.5	1040.1			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-E32	77-08-31	31241.9	35234.5	774.6	5.9(s)		
Glac. Surf. E32-Q	77-08-31	31356.3	35225.5	781.6			±0.10
Glac. Surf. E32-R	77-08-31	31325.9	35299.0	782.4			
Stake 77-E32	78-08-27	31198.0	35169.0	774.1	4.3(i)		
Glac. Surf. E32-P	78-08-27	31422.1	35256.3	781.2			±0.20
Glac. Surf. E32-Q	78-08-27	31356.2	35225.3	780.2			
Glac. Surf. E32-R	78-08-27	31325.9	35298.9	780.9			
Stake 77-E36-5	77-08-31	27273.5	34261.5	711.7	6.1(s)		
Stake 77-E36-5	78-08-28	27270.6	34249.3	709.1	4.2(i)		
Glac. Surf. E36-5-Q	78-08-28	27272.2	34260.9	716.1			±0.05
Glac. Surf. E36-5-R	78-08-28	27279.9	34256.4	716.0			
Stake 77-E36-2	77-08-31	28077.5	32993.2	708.4	5.0(s)		
Stake 77-E36-2	78-08-28	28023.4	32930.3	707.5	2.5(i)		
Glac. Surf. E36-2-P	78-08-28	28075.6	32994.7	711.2			±0.40
Glac. Surf. E36-2-Q	78-08-28	28018.6	32978.3	710.1			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-E36-3.8	77-08-31	29042.0	31473.8	701.0	6.2(s)		
Stake 77-E36-3.8	78-08-28	29036.1	31465.2	701.6	4.0(i)		
Glac. Surf. E36-3.8-P	78-08-28	29041.3	31474.7	706.0			+0.15
Glac. Surf. E36-3.8-Q	78-08-28	29047.6	31465.3	705.5			
Glac. Surf. R110	74-07-29	26479.1	31861.0	691.0			
Glac. Surf. E37.8	76-08-21	26497.9	31862.5	690.3			
Glac. Surf. E38-P	76-08-21	26434.0	31691.2	688.9			+0.10
Glac. Surf. E38-Q	76-08-21	26405.2	31682.6	688.8			
Glac. Surf. E38-R	76-08-21	26436.9	31640.6	688.4			
Stake 77-E38	77-08-31	26555.4	31694.4	683.0	6.1(s)		
Glac. Surf. E38-P	77-09-03	26385.9	31678.5	689.8			+0.10
Glac. Surf. E38-Q	77-09-03	26454.5	31588.5	689.1			
Stake 77-E38	78-06-09	26454.8	31329.0	682.3	7.1(c)		
Glac. Surf. E38-P	78-06-09	26614.1	31730.2	690.3			
Glac. Surf. 74R110	78-08-29	26480.7	31858.6	688.8			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-E38	78-08-29	26417.8	31218.8	681.6	4.0(2)		
Glac. Surf. E38-P	78-08-29	26554.7	31693.3	687.0			±0.15
Glac. Surf. E38-Q	78-08-29	26564.0	31671.6	686.7			
Glac. Surf. E38-R	78-08-29	26540.6	31684.5	686.8			
Glac. Surf 74R110	78-08-29	26480.7	31858.6	688.8			
Stake 77-K2	77-08-25	13107.0	18725.7	305.4	11.2(2)		
Glac. Surf. K2-P	77-08-25	13119.0	18719.7	316.8			
Glac. Surf. K2-P	78-06-10	13119.8	18780.5	314.7			
Stake 77-K2	78-09-02	13070.3	18726.6	303.1	6.9(2)		
Glac. Surf. K2-P	78-09-02	13117.4	18718.5	310.8			±0.05
Glac. Surf. K2-Q	78-09-02	13092.2	18707.2	310.9			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance 6' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-MW20	77-08-29	15590.6	40058.4	1413.1	5.4(3)		
Glac. Surf. MW20-P	77-08-29	15379.9	39938.9	1429.1			±0.15
Glac. Surf. MW20-Q	77-08-29	15316.2	39895.2	1432.6			
Glac. Surf. MW20-P	78-08-24	15352.2	39921.7	1430.7			±0.15
Glac. Surf. MW20-Q	78-08-24	15317.5	39877.3	1432.9			
Glac. Surf. MW20-R	78-08-24	15303.8	39901.5	1432.6			
Glac. Surf. MW20-PS	78-08-24	15599.9	40073.1	1418.0			
Glac. Surf. MW20-QS	78-08-24	15590.5	40038.6	1420.2			
Glac. Surf. MW20-RS	78-08-24	15573.9	40065.8	1419.0			
Glac. Surf. MW20A	78-08-25	15805.7	40080.8	1413.3			
Stake 77-MW20	78-09-02	15902.9	40189.2	1403.5	11.4(3)		
Stake 77-MW24	77-08-29	19247.6	40676.6	1235.5	5.3(3)		
Stake 77-MW24	77-11-16	—	—	—	8.3(3)		
Stake 77-MW24	78-08-24	19487.7	40667.7	1228.7	8.8(3)		
Glac. Surf. MW24-P	78-08-24	19216.3	40658.8	1239.6			±0.05
Glac. Surf. MW24-Q	78-08-24	19239.3	40703.4	1240.0			
Glac. Surf. MW24-R	78-08-24	19282.2	40667.6	1239.5			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	X ₀ meters	Sea level coordinates Y ₀ meters	Z meters	Balance b' meters	Density ρ Mg/m ³	Surface Definition meters
Stake 77-MW28	77-08-29	23223.4	40923.3	1156.4	5.3(s)		
Stake 77-MW28	77-11-16	—	—	—	8.6(s)		
Stake 77-MW28	78-08-24	23486.6	40811.8	1146.3	7.2(s)		
Glac. Surf. MW28-P	78-08-24	23218.9	40931.2	1161.8			± 0.15
Glac. Surf. MW28-Q	78-08-24	23250.2	40868.5	1159.9			
Glac. Surf. MW28-R	78-08-24	23270.7	40924.5	1159.8			
Stake 77-NE18	77-08-30	36995.1	46440.1	1129.9	4.9(s)		
Glac. Surf. NE18-Q	77-08-30	36987.0	46419.9	1134.5			± 0.10
Glac. Surf. NE18-R	77-08-30	37012.2	46419.2	1133.7			
Stake 77-NE18	77-11-16	—	—	—	6.0(s)		
Stake 77-NE18	78-08-27	37038.4	46328.8	1126.5	4.0(l)		
Glac. Surf. NE18-P	78-08-27	36997.4	46423.5	1134.2			
Stake 77-R1	77-09-01	21984.0	22924.2	524.0	8.6(s)		
Stake 77-R1	78-08-29	22018.4	22807.0	515.3	2.2(l)		
Glac. Surf. R1-P	78-08-29	21997.2	22915.4	529.3			± 0.50
Glac. Surf. R1-Q	78-08-29	22085.1	23015.7	532.4			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-R4	77-09-01	24162.7	24608.8	573.3	8.3(s)		
Stake 77-R4	78-08-29	24178.9	24559.4	571.6	4.5(l)		
Glac. Surf. R4-P	78-08-29	24163.1	24609.3	579.4			±0.20
Glac. Surf. R4-Q	78-08-29	24203.1	24557.0	575.6			
Stake 77-R5	77-09-01	25104.9	25428.2	551.4	8.2(l)		
Stake 77-R5	78-08-10	—	—	—	5.5(l)		
Stake 77-R5	78-08-29	25129.6	25409.4	552.9	4.5(l)		
Glac. Surf. R5-P	78-08-29	25103.5	25427.4	558.1			±0.20
Glac. Surf. R5-Q	78-08-29	25128.9	25435.8	557.3			
Stake 77-W40	77-09-01	4381.3	27007.5	769.4	6.0(s)		
Stake 77-W40	78-09-02	4487.1	26999.5	764.7	6.9(s)		
Glac. Surf. W40-P	78-09-02	4379.7	27006.8	774.6			±0.20
Glac. Surf. W40-Q	78-09-02	4395.0	27027.0	775.2			
Glac. Surf. W40-R	78-09-02	4394.6	26989.3	773.7			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance b' meters	Density P Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-W44	77-09-01	8285.1	26391.4	645.9	7.2(s)		
Stake 77-W44	78-09-02	8376.0	26316.7	643.8	6.9(e)		
Glac. Surf. W44-P	78-09-02	8271.8	26382.6	650.6			±0.05
Glac. Surf. W44-Q	78-09-02	8288.1	26393.4	650.9			
Glac. Surf. W44-R	78-09-02	8288.1	26374.1	650.6			
Glac. Surf. W47-P	76-08-13	10944.5	25056.8	584.7			±0.05
Glac. Surf. W47-Q	76-08-13	10823.6	25076.4	586.9			
Glac. Surf. W47-R	76-08-13	10950.9	24925.3	581.7			
Stake 77-W47	77-09-01	10945.6	25058.4	577.2	7.6(s)		
Glac. Surf. W47-Q	77-09-03	11019.3	25168.7	586.0			
Glac. Surf. W47-R	77-09-03	11043.5	25103.0	584.2			
Stake 77-W47	78-09-01	11072.5	25011.3	573.9	6.2(e)		
Glac. Surf. W47-P	78-09-01	11023.4	25171.0	582.6			±0.05
Glac. Surf. W47-Q	78-09-01	10950.6	25042.1	582.9			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance ' meters	Density ρ Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-W50-2	77-08-22	13494.5	23269.5	525.6	9.1(6)		
Glac. Surf. W50-2-P	77-08-22	13557.5	23146.7	528.8			
Glac. Surf. W50-2-Q	77-08-22	13546.2	23205.2	530.4			
Stake 77-W50-2	78-09-01	13593.7	23196.4	520.0	5.8(1)		
Glac. Surf. W50-2-P	78-09-01	13541.8	23216.6	528.7			±0.15
Glac. Surf. W50-2-Q	78-09-01	13547.9	23299.6	529.3			
Glac. Surf. W50-2-R	78-09-01	13493.1	23295.7	531.1			
Stake 77-W50-3	77-08-23	—	—	—	9.1(5)		
Stake 77-W50-3	77-08-25	13812.6	24217.1	515.6	9.0(5)		
Stake 77-W50-3	78-09-01	13940.2	24125.3	513.5	7.0(1)		
Glac. Surf. W50-3-P	78-09-01	13858.4	24165.5	521.6			±0.10
see next page for additional data							
Stake 77-W50-4	77-08-25	14155.7	25123.6	515.3	8.3(5)		
Glac. Surf. W50-4-Q	77-08-25	14185.6	25077.2	522.8			
Glac. Surf. W50-4-R	77-08-25	14211.9	25109.7	523.0			

Table 10.--Columbia Glacier survey results 1978 measurement year--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Balance <i>b</i> meters	Density <i>P</i> Mg/m ³	Surface Definition meters
		X ₀ meters	Y ₀ meters	Z meters			
Stake 77-W50-4	78-09-06	14239.7	250624	513.0	6.7(i)		
Glac. Surf. W50-4-P	78-09-06	14160.0	25118.9	520.9			±0.10
Glac. Surf. W50-4-Q	78-09-06	14166.9	25133.6	521.1			
Glac. Surf. W50-4-R	78-09-06	14150.9	25131.9	521.2			
Glac. Surf. W50-5-P	77-08-26	14479.4	26051.5	527.6			
Stake 77-W50-5	77-08-27	14458.3	26071.0	519.7	8.2(3)		
Glac. Surf. W50-5-Q	77-08-27	14469.2	26071.2	527.8			
Stake 77-W50-6	78-08-31	14463.0	26064.1	519.5	6.4(i)		
Glac. Surf. W50-5-P	78-08-31	14468.0	26074.0	525.8			±0.15
Glac. Surf. W50-5-Q	78-08-31	14448.2	26081.2	526.0			

additional data

Glac. Surf. W50-3-P	77-08-25	13751.9	24146.7	526.4
Glac. Surf. W50-3-Q	77-08-25	13855.6	24151.4	524.4

Table II.--Columbia Glacier 1978 surface ice radar measurements.

Point surveyed	Date Y - M - D	Sea level coordinates			Separation m	Ice Radar delay time μs
		X _o meters	Y _o meters	Z meters		
78M103A 2	78-09-09	13000.0	51640.0	2645.0		
78M103A 2	78-09-09	13083.2	51542.7	2644.7		8.8
78M102D 14 MP	78-09-09	23602.6	53058.6	1912.1	100	no return
78M102C 20 MP	78-09-09	27904.2	49256.8	1761.0	100	no return
78T98 34.7-1.0W	78-09-08	24123.1	35318.5	832.0		
78T98 34.7-1.0W	78-09-08	24177.6	35195.5	827.1		8.0, 10.4
78T92G 34.8-0.4E	78-09-06	25481.5	35274.1	849.6		
78M99A 34.8-0.4E	78-09-06	25479.5	35357.7	856.1		5.2
78M99B 35.1-0.1W	78-09-06	25105.4	34887.9	812.8		
78M99B 35.1-0.1W	78-09-06	25113.8	35071.5	829.5		no return

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.

Point surveyed	Date	Sea level coordinates			Separation m	Ice Radar delay time μs
	Y - M - D	X _o meters	Y _o meters	Z meters		
78M100A 36.4-0.5W	78-09-06	24852.5	34967.5	820.7		
78M100A 36.4-05W	78-09-06	24906.6	34810.4	809.9		no return
78T99 40.3-1.6	78-09-08	23193.3	31735.7	653.4		
78T99 40.3-1.6	78-09-08	23172.7	31526.5	650.2		4.9
78T98 40.2-2.6	78-09-08	24055.1	30933.9	671.1		
78T98 40.2-2.6	78-09-08	23899.7	31079.0	667.2		9.7
78T97 40.4-3.4	78-09-08	24462.2	30343.7	664.4		
78T97 40.4-3.4	78-09-08	24559.5	30375.5	664.9		no return
78T96 40.3-4.2	78-09-08	25003.3	29773.1	655.9		
78T96 40.3-4.2	78-09-08	25247.3	29866.6	655.3		7.9
78T96 40.2-5.0	78-09-08	25744.1	29382.5	648.0		
78T96 40.2-5.0	78-09-08	25881.0	29446.0	647.5		7.6

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Separation m	Ice Radar delay time μs
		X meters	Y meters	Z meters		
78T95 40.3-5.6	78-09-08	26081.6	28963.9	645.9		
78T95 40.3-5.6	78-09-08	26195.1	29067.1	648.1		7.5
78T95 40.0-6.1	78-09-08	26808.8	28787.1	649.5		
78T95 40.0-6.1	78-09-08	26712.1	28892.3	650.3		6.6
78T94 40.0-6.9	78-09-08	27282.5	28439.7	645.7		
78T94 40.0-6.9	78-09-08	27410.0	28280.2	639.4		2.65
78M94C 55.9-2.5W	78-09-04	13735.8	18027.8	314.9		
78M94C 55.9-2.5W	78-09-04	13536.8	18288.5	314.5		3.35
78T35 59-2.7E MP	78-06-07	19404.6	16753.1	237.9	90	2.85
78M94B 59.5-1.8W	78-09-04	15711.8	14615.2	245.8		
78M94B 59.5-1.8W	78-09-04	15579.5	14708.7	247.9		3.7

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Separation m	Ice Radar delay time μ s
		X meters	Y meters	Z meters		
78M94A 61.3-3.3W	78-09-04	14421.0	13090.5	200.0		
78M94A 61.3-3.3W	78-09-04	14539.5	13048.0	202.0		2.45
78T35 61.8-2.2E MP	78-06-07	20008.7	13411.6	183.9	100	2.1
78T36 62.4-0.2W MP	78-06-07	17506.0	12548.0	204.3	100	6.59
78T36 62.7-2.3W MP	78-06-07	15541.3	12005.2	176.8	100	2.3
78T35 64.5-1.8E MP	78-06-07	19787.1	10609.3	134.8	100	2.0
78M93 64.6-1.8W	78-09-04	16174.1	10893.0	146.2		
78M93 64.6-1.8W	78-09-04	15888.4	10974.4	161.7		2.51
78H21 64.8-1.0W	78-09-04	16731.9	10735.0	163.4		
78H21 64.8-1.0W	78-09-04	16717.8	10515.5	164.3		4.9

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.

Point surveyed	Date Y - M - D	Sea level coordinates			Separation m	Ice Radar delay time μs
		X meters	Y meters	Z meters		
78H20	65-1.2W	78-09-04	16455.0	10409.1	156.4	
78H20	65-1.2W	78-09-04	16481.8	10592.6	164.4	3.9
78T93	B2	78-09-06	28808.6	29525.4	634.0	
78T93	B2	78-09-06	28716.7	29468.9	634.8	6.6
78T92F	E36-1.1	78-09-06	27869.0	33754.3	717.8	
78M98A	E36-1.1	78-09-06	27815.0	33818.8	717.7	8.3
78T92D	E36-1.7	78-09-06	28078.3	32956.2	711.0	
78M97A	E36-1.7	78-09-06	28021.4	33002.1	709.5	9.4
78T92E	E36-2.7	78-09-06	28573.2	32507.0	723.6	
78M97B	E36-2.7	78-09-06	28501.8	32591.7	724.0	8.1
78T92C	E36-3.4	78-09-06	28748.3	31900.1	713.3	
78M96B	E36-3.4	78-09-06	28804.1	31797.1	711.7	4.95

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.

Point surveyed	Date Y - M - D	X meters	Sea level coordinates Y meters	Z meters	Separation s m	Ice Radar delay time μs
78T92B E36-3.6	78-09-06	28898.9	31608.0	709.5		
78M96A E36-3.6	78-09-06	28962.4	31536.5	708.4		3.43
78M101A R1.7	78-09-09	25516.3	23520.5	530.9		
78M101A R1.7	78-09-09	22548.8	23526.1	531.1		no return
78M101A R1.7	78-09-09	22627.4	23561.3	532.0		
78M102A R2.4	78-09-09	23037.8	23691.4	548.9		
78M102A R2.4	78-09-09	23058.0	23775.5	552.9		4.2
78T58 R3.9	78-08-10	24235.5	24833.0	586.0		
78T58 R3.9	78-08-10	24275.4	24727.2	583.5		4.55
78T58 R5 MP	78-08-10	25129.6	25407.4	552.9	100	4.95
78S57 W44	78-09-09	8376.0	26316.7	643.8	127	10.95

Table 11.--Columbia Glacier 1978 surface ice radar measurements--Continued.!

Point surveyed	Date Y - M - D	X _o meters	Sea level coordinates Y _o meters	Z meters	Separation s m	Ice Radar delay time μs
78M91D W50-2 MP	78-09-01	13593.7	23196.4	520.0	100	3.9
78530 W50-3	78-09-01	13858.4	24165.5	521.6		
78530 W50-3	78-09-01	13940.2	24125.3	522.5		no return
78M90A W50-4 MP	78-08-31	14239.7	25062.4	513.0	100	6.4
78M89B W50-5 MP	78-08-31	14463.0	26064.1	528.5	100	4.45