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SUMMARY AND DISCUSSION OF SURVEY CONTROL FOR ICE FLOW STUDIES ON ROOSEVELT ISLAND, ANTARCTICA

by James L. Clapp

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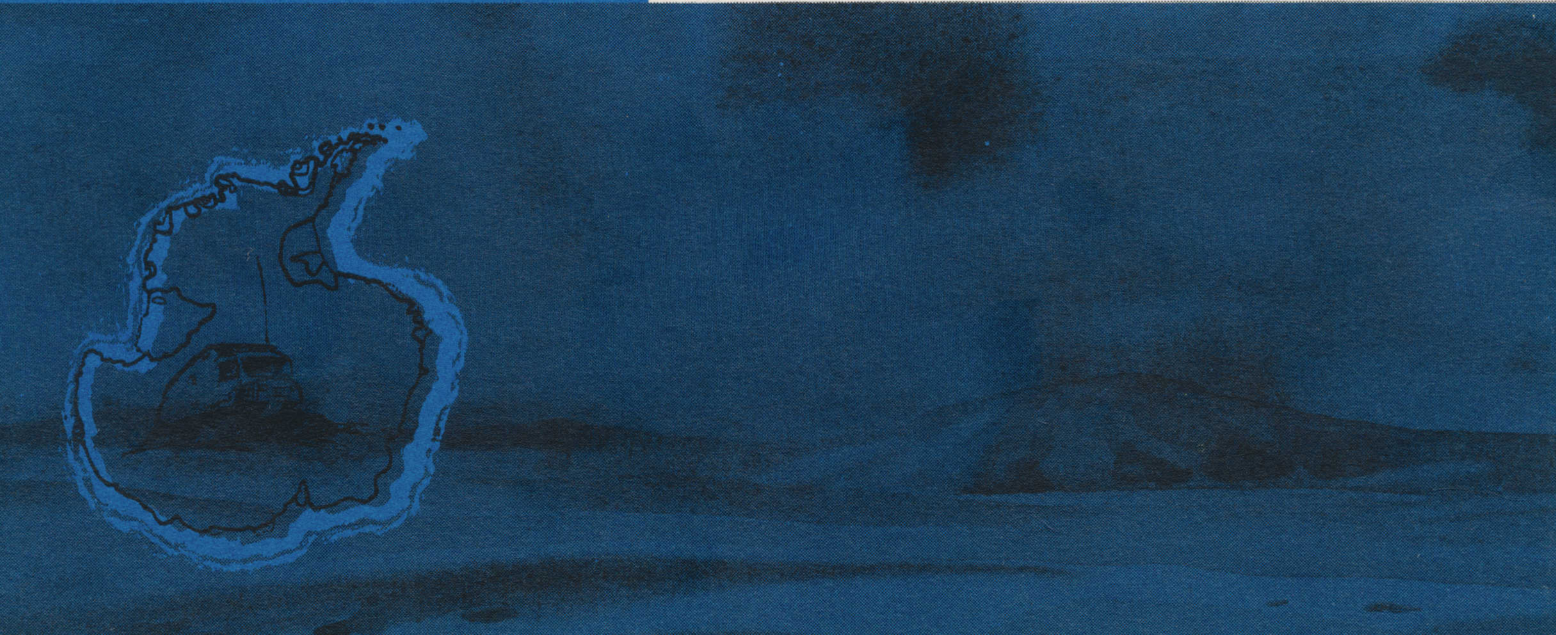

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ABSTRACT

The engineering results of the 1961-62, 1962-63 investigations upon Roosevelt Island, Antarctica are presented with interpretation and conclusions. First, the methods employed to establish absolute horizontal and vertical control on 351 points distributed over the surface of the ice cap are described and results given. The probable error in the horizontal position of these points was ±0.5' of latitude and ±2.0' of longitude. The probable error in their vertical position was ±3.5 meters. Second, the methods employed to establish relative horizontal and vertical control on a strain rate network consisting of 102 control points covering a span of approximately 70 km are described and results given. The maximum probable error in the horizontal location of a control point was ±0.33 meters. The maximum probable error in the vertical location of a control point was ±92 cm. Third, strain rates and relative displacements are presented for 86 lines representing an area from the crest of the ice cap to the southwest edge. The strain rates and the displacements parallel to the fall line are greater than those perpendicular to the fall line. The strain rates and displacements tend to increase as the distance from the crest of the ice cap increases.

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Chapter I

INTRODUCTION

Purpose

The primary subjects of this report are: (1) the methods used to establish horizontal and vertical control for geophysical and glaciological exploration and an analysis of the precision and accuracy provided by these methods; (2) the methods used to determine strain rates on Roosevelt Island and the results of these measurements; and (3) the methods used to prepare a small scale topographic map of the area under investigation.

1. Background Information

Inasmuch as a significant portion of the earth's land surface is covered to a great depth by ice sheets, and in the geological past an even greater area was thus buried, it is of concern to man to learn as much as possible of the rheological nature of ice. During the past ten years much knowledge has been gained in this area, from laboratory studies (e.g. Butkovich and Landauer[1], 1958; Glen[2], 1955; Jellinek and Brill[3], 1956; Steinemann[4], 1956) and field observations (e.g. Glen[5], 1956; Gerrard et al.[6], 1952; Haefeli and Brentani[7], 1955; Haefeli[8], 1952). However, the studies have not been in complete agreement. Further, when the available data has been applied to the theoretical explanation of the behavior of glaciers and ice caps, the results have, to some degree, disagreed with field observations. Field measurements made in the past have been confined, for the most part, to valley glaciers. This is due to the fact that major ice caps, such as Greenland and Antarctica, are, because of their enormous size, extremely difficult to examine as a whole. For this reason, the most promising approach to the study of the motion of ice sheets would appear to be the investigation of small ice caps, which can be considered as models of the major ice caps.

In 1960 a proposal to investigate the ice flow on a small ice cap was submitted to the National Science Foundation by Dr. George P. Woollard, Dr. Charles R. Bentley, and Mr. Mario B. Giovinetto, all of the University of Wisconsin Geophysical and Polar Research Center. The proposal was accepted and funds were made available for the research.

Roosevelt Island was selected as the site for the proposed research. As can be seen in Figure 1, Roosevelt Island is located between 78°40'S - 80°10'S and 160°W - 164°W. It is approximately oval in shape, some 120 kilometers long and 70 kilometers wide. The ice dome rises to an elevation of approximately 450 meters above the surrounding Ross Ice Shelf. The ice mass of which the dome consists is grounded on a rise in the ocean floor. The remainder of the shelf is supported on the water surface.

Roosevelt Island was chosen as the site of the proposed research because: (1) It is situated at a latitude sufficiently high to guarantee continuously cold conditions, thus eliminating the effect of summer melts. (2) It is small enough to permit the desired investigations to be carried out in detail. (3) It is large enough not to be significantly influenced by the movement of the Ross Ice Shelf. (4) The topography of the subsurface ice-rock interface is generally regular. (5) Meteorological data extending back fifty years is available from nearby stations at the Bay of Whales and Kainan Bay. (6) It is logistically supportable from the main United States base at McMurdo Sound, about 450 miles to the east. Item (4) was, of course, unknown until the initial phase of the investigation was completed.

The original proposal for the research on Roosevelt Island had four basic objectives: (1) to determine the mass budget of the Roosevelt Island ice cap; (2) to determine the physical conditions within the ice which govern its flow, including the nature of the ice-rock interface with regard to its effect upon the ice flow; (3) to relate (1) and (2) with theoretical and laboratory investigations of the nature of the ice; (4) to apply the results of (1), (2) and (3) to major ice caps.

In order to achieve these objectives it is necessary to conduct a series of related measurements to determine such things as: (1) the surface topography by means of altimetry; (2) the rate of accumulation of mass and its distribution over the surface of the ice cap by means of repeated measurements on a series of stakes placed at regular intervals; (3) the ice thickness and the nature of the ice-rock interface by means of seismic and gravity studies; (4) the ice movement at the surface by means of repeated measurements upon a series of horizontal and vertical control points; (5) the mean annual surface isotherms by means of temperature measurements in ten-meter auger holes; (6) temperature measurements made at intervals down fifty-meter drilled holes.

This report is fundamentally concerned with the geodetic methods and techniques required by the above measurements. These include: (1) horizontal and vertical control for the determination of the rate of accumulation of mass and its distribution over the surface of the ice cap; (2) horizontal and vertical control for the seismic studies of the thickness of the ice and the nature of the ice-rock interface; (3) horizontal and vertical control for the investigation and representation of the surface topography of the ice cap; (4) the methods and techniques used to measure the ice movement and the results of these measurements.

Field parties were engaged in measuring these quantities on Roosevelt Island during the 1961-1962 and 1962-1963 season. For field work in Antarctica a season extends from early November to late February. Inasmuch as the sun does not appear during the winter months, all field operations must be conducted during the relatively short Antarctic summer. The party during the 1961-1962 season comprised Mario B. Giovinetto, chief of party and glaciologist; Manfred Hochstein, chief geophysicist; Jerry Clark, assistant geophysicist; William Unger, assistant geophysicist; Raymond Logie, mechanic; William Heilman, assistant engineer; Hugh Kieffer, general assistant; and the author, chief engineer.

Following a reconnaissance flight, the party was airlifted from McMurdo Sound to Roosevelt Island in early October, 1961. These flights, as well as the delivery of over fifty tons of supplies including vehicles, scientific equipment, food and shelter, were carried out by the U. S. Navy Air Development Squadron 6 (VX-6). Upon arrival on Roosevelt Island a temporary base camp, Camp Wisconsin, was established at 79°16'S and 162°15'W. Later in the season Camp Wisconsin became semipermanent with the erection of a Jamesway building. When construction of the temporary camp was completed the first stage of the field operations, a topographic reconnaissance, was begun.

At completion of the topographic reconnaissance, geophysical investigations were conducted in the areas where it was desired to investigate the surface movement. The purpose of these investigations was to make certain that the topography of the ice-rock interface was regular and therefore that it would not have a significant effect on the strain rates in the ice mass. When these investigations were finished work began on the investigation of surface movement, the geophysical exploration of the island, and the investigation of mass accumulation.

During the 1962-1963 season the field party comprised Charles R. Bentley, Manfred Hochstein, Edgar Doss, Richard Heidemann, David Tranter, L. Kreiling and Michael Boman. During this second season the work begun in 1961-1962 was extended, the accumulation measured, and the control points for movement studies relocated.

Chapter II

SURVEY CONTROL FOR TOPOGRAPHIC RECONNAISSANCE AND GEOPHYSICAL EXPLORATION

INTRODUCTION

Any effort to coordinate reconnaissance and exploratory measurements over an area as large as Roosevelt Island requires that horizontal and vertical control be provided for the points investigated. For the topographic reconnaissance and geophysical exploration conducted on Roosevelt Island this control can be considered in two categories: the primary control, which deals with the absolute location of points upon the earth's surface, and the secondary control, which deals with the location of points relative to each other. This chapter is concerned with the application of solar observations, seismic studies, and barometric leveling to provide the primary control, and the application of calibrated odometer measurements, grid bearing observations, and barometric leveling to provide the secondary control. This chapter will discuss the methods used to provide this control.

The first section deals with the primary horizontal control and will explain the Line of Position method and the method of Sun's Profile at Local Noon, which were used to determine the absolute position of points upon Roosevelt Island. In addition, this section will include the results of all the astronomic positions obtained upon the ice cap. The second section is concerned with the primary vertical control and explains the two methods used to establish sea level datum upon Roosevelt Island. The first of these was single base altimetry ties to Little America III and Little America V. The second was the application of seismic-determined ice thickness and the laws of flotation. The third section explains the requirements for the secondary control. The fourth section covers the use of calibrated odometers and magnetic compasses to provide local navigation and secondary horizontal control. The section also includes an analysis of the results of these measurements. The fifth section deals with the use of semi-leap-frog altimetry to provide secondary vertical control and an analysis of the accuracy of these measurements. The sixth and last section in Chapter II summarizes the control obtained for the topographic reconnaissance and geophysical traverses.

1. Horizontal primary control

The establishment of accurate values of latitude and longitude in Antarctic regions is considerably more difficult than in lower latitudes. The most obvious obstacle is the weather, not only because it is generally cold and windy, but also because many days are overcast, making observations on a celestial body impossible. On Roosevelt Island, during the ninety-five days of the 1961-1962 field season, fifty-eight days, or 61 percent of the working time, the sun was obscured by cloud cover, fog, or blowing snow. Inasmuch as other subjects to be investigated were of equal importance, it was not always possible to wait for satisfactory observing conditions. A second factor, which adversely affects the results of celestial observations in Antarctic regions, is that of instrument settlement. Since, for field observations, the instrument must be set up on the snow surface settlement will occur.

Although some daylight star observations have been made at permanent stations, this technique does not lend itself to field observations due to the time required to locate the star. Therefore, the only celestial body practically visible during the field season is the sun. This imposes difficulties not generally associated with solar observation for position. These are caused by the fact that at high latitudes the sun remains low in the sky where the refraction corrections are of questionable value. The daily variation in the sun's altitude on Roosevelt Island was approximately between 10° and 33°, which is just sufficient for astronomical observation.

The initial step in the determination of accurate values of latitude and longitude on Roosevelt Island was the construction of Reference Point Susan, a stable, semi-permanent marker in the vicinity of Camp Wisconsin. This point would later serve as the primary datum for all secondary horizontal control. The point was constructed by driving three eight-foot 2 x 4 timbers into the ice, flush with the surface. These were placed in a triangular arrangement on three-foot centers. A cap was then constructed on the butt ends of these timbers. The cap was built so that the tripod of the Kern DKM-2 theodolite could be easily set up over the reference point etched into the center of the cap. The weight of the instrument was then supported by the eight-foot 2 x 4's. Finally, a portable platform for the observer was constructed so that observations could be made without the weight of the observer affecting the stability of the setup. These efforts were made in order to reduce the problem of differential settlement and to provide a semi-permanent station. Both these objectives were fulfilled. As a possible aid in relocation, the construction of this reference point is shown in Figure 2.

Two different types of solar observations were used to determine the position of Point Susan. One was the Line of Position method, which is frequently used for aircraft or ship navigation. A line of position is the locus of points at which the altitude of a celestial body will be the same at a particular instant of time. It is perpendicular to the direction to the celestial body and for all practical purposes can be considered a straight line through the position of the observer. Therefore, the intersection of two lines of position determined from assumed positions will establish the location of the true position of the observer. The observations required for this method are the altitude of the celestial body and the time of observation. The instruments used for the solar observations made upon Roosevelt Island were a Kern DKM-2 theodolite equipped with a solar eye piece, stopwatches, and a short wave radio.

The principle difficulty with this technique was obtaining accurate values of time. This was due to the fact that it was frequently impossible to receive any time signal due to radio blackouts caused by magnetic storms. This condition is rather frequent in the Antarctic. During the 1962-1963 season this problem was nearly eliminated by using a Hamilton Chronometer as a primary time standard when WWV signals could not be received. A second difficulty was cloud cover, which frequently prevented observations altogether.

In order to determine the position of Point Susan, six lines of position were determined. The observations required for these lines of position were taken at six different times in order that the lines of position would cover a full 360°. This was done for two reasons: to attempt to average out large errors due to refraction, and to obtain the maximum number of strong intersections.

The second technique used to establish the location of Point Susan was a profile of the sun at local noon, hereafter referred to as PSLN. The same instruments were used as in the Line of Position method. The PSLN method requires that observations be taken on the sun for altitude and time during the period the sun crosses the observer's meridian. A plot of the altitude versus time permits an accurate determination of the maximum altitude and the time at which it occurs. The latitude can then be calculated from the observed altitude and the longitude from the time of local noon. The problems encountered with this procedure were, again, difficulty in obtaining WWV signals and cloud cover.

Two main advantages are offered by this form of computation. First, any significant error in an observed altitude will be readily apparent in the plot of altitude versus time. Therefore, that observation can be eliminated. Second, by plotting the curve on a large scale, distorted to emphasize changes in altitude, accurate values of the maximum altitude and the time of its occurrence can be obtained.

Figure 3 shows the positions obtained for Point Susan by the sun's profile method and by the Line of Position method. The maximum variation in latitude is 0° 02.1', or approximately two nautical miles. The maximum variation in longitude is 0° 11.3', or approximately 2.1 nautical miles. Table I lists the values of latitude and longitude obtained for Point Susan by both methods. The averages of these values, latitude 79° 15.8'S ± 0.4' and longitude 162° 17.5'W ± 1.7', establishes the datum used for all horizontal control on Roosevelt Island. The probable errors are well within the limits imposed by the gravity portion of the geophysical explorations since, at this latitude, the change in gravity is approximately 0.5 mg. for a 1' change in latitude.

2. Vertical primary control

In addition to being the reference point for all secondary horizontal control, Point Susan was also the bench mark for all secondary vertical control. It was therefore necessary to establish the elevation of Point Susan relative to mean sea level. Since there was no existing control available, and since a level loop to the sea at the Bay of Whales, which was the closest point, was not possible due to field time requirements, the elevation of Point Susan had to be established by less direct means. Two different methods were used. The first was a series of single base altimetry ties to points of known elevation on the Ross Ice Shelf. The second was based upon the assumption of hydrostatic equilibrium of points located in the immediate vicinity of Roosevelt Island on the Ross Ice Shelf.

In early December of the 1961-1962 season, air support was provided by the Navy Air Development Squadron VX-6 for altimetry ties to Little America III and Little America V. These ties were made by single base altimetry with the base instruments at Point Susan and the field instruments airlifted to points of known elevation upon the Ross Ice Shelf. These reference points were Little America III at 78° 10'S and 162° 10'W. The aircraft used was a U. S. Navy "Otter". The ties were made in two separate loops in order to reduce the possibility of cumulative errors. Two altimeters were used for both the base and field readings and the average of the two readings was used in the reduction in order to hold the effects of instrument drift to a minimum. In addition to altimeter readings, both stations read and recorded values for wet and dry bulb temperature and wind velocity and direction. These values were then used to compute corrections for the deviation of the atmosphere from the standard atmosphere and for the differential pressure over the area.

The results of the altimeter ties to Little America III and Little America V are shown in Table II. These results were used during the 1961-1962 and 1962-1963 seasons and for the initial data reduction. They were, however, discarded when a more accurate tie was calculated from the results of the 1962-1963 season.

The fact that the Ross Ice Shelf is floating was used as a basis for the calculation of the final absolute elevation of Point Susan. During the course of field operations the thickness of the ice shelf was measured at the ten points shown in Figure 4. The results of these investigations indicated an ice thickness varying from 569 meters at 71 to 354 meters at CW30 + 6. From the above data the elevations of the points above sea level were calculated based upon the work of A. P Crary[9]. The assumption was made that there was local compensation under these points; that is, that rises and depressions in the surface elevation were reflected by a corresponding increase or reduction in the ice thickness. In order to take into account the possibility of region compensation, whereby local surface features are not reflected by a corresponding decrease in the submerged portion of the shelf ice, the elevation was calculated at all points at which ice thickness measurements were conducted. Inasmuch as the possibility of the point being on a depression is as great as its being on a rise, averaging should tend to remove any errors introduced by the assumption of local equilibrium.

Table III lists the results of these computations. The elevations obtained for the seismic points agree closely. This agreement would tend to support the assumption of local hydrostatic equilibrium. The elevations at these seismic points were tied to Point Susan by the semi-leap-frog method of altimetry, fixing the elevation of Point Susan as 563.0 ± 3.5 meters. The probable error of 3.5 meters is highly satisfactory. The semi-leap-frog method of altimetry will be discussed in a later section entitled "Relative vertical control".

3. Requirements for secondary control

As has been mentioned earlier, the first phase of the field work to be undertaken after the base camp was established was a topographic reconnaissance of the ice cap. The primary purposes were: (1) to locate the point of maximum surface elevation where theory predicts the ice movement should be a minimum; (2) to locate the section of the ice cap most nearly approaching the conditions depicted by the theory, that is, having a uniformly increasing slope from the point of maximum elevation to the edge of the ice cap; (3) to select the section in (2) which has the maximum strain rate, that is, the section which has the maximum surface slope; and (4) to assure that the sub-surface rock under the selected section has a regular surface in order that the ice flow not be significantly influenced by topographic features at the ice-rock interface.

In order to satisfy the requirements listed above, reconnaissance traverses were conducted from base camp as shown in Figure 5. These traverses covered a total distance of approximately 350 kilometers, with a maximum difference of elevation of approximately 450 meters. The elevation and location of about two hundred points were determined. This, coupled with a limited seismic investigation of the ice-rock interface, provided the necessary information for the selection of the section of the ice cap for the strain rate investigation. This will be discussed in Chapter III.

In addition to the topographic reconnaissance traverses, geophysical traverses were conducted over a major portion of the ice cap as shown in Figure 6. These traverses were carried out in order to determine the ice thickness, gravity anomalies, magnetic anomalies, surface elevation, and mass accumulation. A total distance of about one thousand kilometers was covered by the traverses and the position and elevation of about 350 points was established.

Transportation for both the reconnaissance and geophysical traverses was provided by two Trackmaster over snow vehicles. One or more one-ton sleds containing equipment and supplies were generally pulled by each vehicle. The duration of the traverses ranged from one day to three weeks.

4. Horizontal secondary control

The horizontal control for both the topographic reconnaissance and the geophysical traverses was established relative to Point Susan. In order to provide a reference direction, solar observations were made at Point Susan to determine the true azimuth of a reference line. To obtain a reference direction a second semi-permanent point was constructed. This point, hereafter referred to as the Reference Mark, was set at a distance of about three kilometers from Point Susan. This was done so that it would be a sufficient distance to provide an adequate back sight, yet close enough to be visible on a clear day. The Reference Mark was set in the direction of maximum surface slope from Point Susan in order that the maximum component of displacement due to ice flow would be in the direction of the line. Thus, movement in the ice mass would produce a minimum change in the azimuth of the reference line. This will be discussed in greater detail in Chapter III. The Reference Mark was constructed by driving a twelve foot 4 x 4 timber to within four feet of the surface. A four-meter stadia board was then bolted to the protruding end of the 4 x 4. The top of the stadia board was secured by guy wires to 2 x 4 stakes. This provided a target which made it unnecessary to occupy the reference point for sights from Point Susan. At a distance of about two hundred meters from Point Susan a flag was set just off the reference line to aid in sighting the Reference Mark during periods when visibility was limited. Figure 7 shows the Reference Mark as it was during the 1961-1962 season. At the end of the 1962-1963 season the stadia board and cross piece was removed.

The results of these observations are shown in Table IV. The large probable error of ±3.5' was due to several factors. First, the difficulty in obtaining good observations due to operator fatigue introduced by the unfavorable working conditions. Second, the refraction correction at low altitudes is quite large and somewhat unreliable. Third, errors in time tend to be critical. An analysis of these error sources indicates that when the observed altitude is about 30° an error of one minute in the observed altitude, either due to an observation error or refraction, will cause an error in the calculated bearing of the sun of approximately forty minutes of arc. An error of one minute of time will cause no significant error in the calculated bearing of the sun. Therefore, the conclusion may be drawn that the large probable error of ±3.5' in the azimuth of the reference line is principally due to uncertainties in the observed altitudes. However, for the purpose of secondary control, the results of these observations provide sufficient accuracy.

The direction of the legs of all reconnaissance and geophysical traverses were established with respect to this reference line. This was accomplished by measuring the angle between the reference line and the initial leg of the traverse. All subsequent changes in direction were measured as angles to the right or left from the back leg of the traverse. For the reconnaissance traverses these angles were measured with a Brunton compass. For the geophysical traverses they were measured, in most cases, with a K and E transit. This technique required that the traverse legs be run in straight lines. A system of trailmarking flags was used to insure that the legs were straight. The flags were red or black cloth pieces eighteen inches square attached to ten-foot bamboo poles. At frequent intervals, typically an hour or thirty minutes depending on the visibility, the lead vehicle would stop to set a flag in line with the preceding two flags. Since the speed of the Trackmasters was limited to about two kilometers an hour, the flags were spaced at a maximum interval of two kilometers. On days of good visibility this provided a clear backsight for an observer equipped with field glasses.

While the lead vehicle was moving ahead the correct heading was usually maintained by visual backsight. During periods of reduced visibility this was accomplished through the use of a magnetic compass.

In order to establish the positions of points on these traverses relative to Point Susan, it was necessary to know the distance along the traverse course as well as the direction of the course. The distances were measured with vehicle odometers. In order to calibrate the Trackmaster odometers a base line of approximately 3000 meters was measured with the Tellurometers from Point Susan to the Reference Mark. Then each vehicle was driven over the line four times, twice in each direction. On the first pass the vehicle was operated in low range at 2000 rpm. The second pass was made in low range at 2200 rpm. The third pass was made in high range at 1500 rpm. The last pass was made in high range at 1600 rpm. Odometer readings were taken and recorded at the beginning and end of each pass. The difference in these readings gave the indicated odometer mileage. The odometers could be read directly to 0.1 odometer miles and estimated to the nearest 0.01 odometer miles with an estimated reading error or ±0.02 odometer miles. This reading error would correspond to approximately +20 meters.

From these values of indicated mileage and the Tellurometer-determined true distance, calibration factors were calculated for each range and engine rpm. When conducting traverse operations the vehicle driver attempted to hold the indicated rpm between the limits used in the calibration.

During traverse operations periodic checks were made to determine if the calibration factor had changed due to wear and damage. The results of these checks are indicated in Table V. It should be noted that the errors indicated by these checks compare favorably with the estimated reading error of ±20 meters, indicating that the accuracy of the system is limited by the reading error. The relatively high accuracy of this system of measuring distances is due to several factors, principally; (1) the fact that a tracked vehicle with a direct linkage from the drive sprocket to the odometer was used; (2) the fact that little if any slippage occurs between the track and the snow surface; (3) the fact that the topography of the ice caps precludes any significant changes in surface slope. The greatest single source of error in the system was the reading error. This can be greatly reduced by calibrating the tenths dial of the odometer and installing an index mark for reading. This would reduce the reading error to approximately ±5 meters.

In order that gross errors of either direction or distance be detected in the position of points located by the above methods, it was desirable to obtain Line of Position fixes at the end of each day's operation and at all changes in direction. This was not always possible. Since it requires at least four hours elapsed time to obtain a strong intersection of the Lines of Position, it frequently was not practical to delay progress on the traverse to obtain a complete position fix. In such cases, one Line of Position was obtained and its intersection with the direction of the traverse was assumed to locate the position of the observer. An additional problem was that imposed by the weather, as it was frequently impossible to obtain any observations. Figure 8 shows the location and relative strength of the fixes obtained on the topographic reconnaissance traverse, and Figure 9 shows those values obtained on the geophysical traverse.

The method used for the horizontal adjustment of these traverses consisted of fitting the observed directions and distances to the position located by solar observations. This was accomplished by plotting the position of the points located by solar observations at a large scale and estimating the correction to be applied to the observed distances and directions so that they would fit these fixed points. In cases where two or more fixed points affected the location of the course, the angular error was proportioned according to the strength of the fix. The strength of the fix was classified A, B, or C, where A indicates two or more lines of position intersecting at strong angles, B indicates two or more lines of position intersecting at relatively weak angles, and C indicates weak fixes due to such factors as low altitude at the time of observation, single line of position, sun obscured at time of observation, etc.

In order to evaluate the accuracy provided by this method of maintaining horizontal control, five closed traverses were analyzed. Latitudes and departures were calculated for the respective sides and the error of closures calculated. The results of this analysis are shown in Table VI. The average precision of 1/127 is well within that required and is consistent with the probable errors of the reference direction.

5. Secondary vertical control

In addition to the horizontal location of reconnaissance and geophysical points, it was necessary to establish their elevation. This was usually accomplished by semi-leap-frog altimetry carried out simultaneously with the establishement of the horizontal control. Point Susan was used as a bench mark for all the secondary vertical control and all elevations were measured relative to it.

The instruments used to measure the difference in elevation with respect to Point Susan were: four Wallace and Tiernan altimeters calibrated to read to $\pm$ 1 meter, two sling-type psychrometers, thermometers, and watches. This technique provided an operation speed of about 3.3 kilometers an hour when the stations were established at about 3 kilometer intervals. When a half kilometer spacing was used this was reduced to 2.5

kilometers an hour. The reduction of these operations was based upon the average readings at the field and base stations. These values were corrected for instrument temperature and instrument drift. The indicated difference in elevation thus obtained was corrected for the variation from the standard atmospheric temperature and humidity.

Not all the vertical control was established by the semi-leap-frog altimetry method. On most geophysical lines a modified single base method was used for expediency. The base vehicle remained at a known station for a series of field readings and then closed upon the field vehicle. In addition, differential levels were obtained on a few lines. These will be discussed in Chapter III.

The elevations of most points on the geophysical traverses were established by at least two independent measurements. Since points on the reconnaissance traverses served a temporary function, their elevations were established only once. Figure 10 shows the system of traverses used to obtain the elevation of geophysical points. The loops were adjusted by two different methods, the method used depending upon the available data. On the lines where elevations were determined by multiple measurements, the average difference in elevation was calculated between adjacent stations. These lines are shown by the multiple lines in Figure 10. On other lines, where a closed loop existed, the error of closure of the loop was computed and distributed over the number of stations, weighing those stations established by multiple observations. As indicated in Figure 10, some lines could not be adjusted by either of these methods since they were observed only once and did not form part of a closed loop. In these cases no adjustments were made.

Two different evaluations were made of the elevations determined by the above methods. The first was an analysis of the error of closure of the various loops. This analysis indicates an average perimeter length of 50 kilometers with 36 stations in the loop. The average error of closure for the loops was 5.0 meters. The error of closure per kilometer of traverse was 0.10 meters, and the error of closure per station was 0.15 meters. The probable error per observation was ± 0.47 meters. Table VII summarizes the results of these loops. A second analysis was possible on the K line and a short portion of the M line, where elevations were also established by differential leveling. This second analysis indicates an error per kilometer of 0.22 meters and an error per station of 0.42 meters. The probable error per observation was ±0.72 meters. Table VIII is a summary of this comparison. A comparison of the values obtained for the error per station and the error per kilometer for the two analysis indicates quite favorable agreement. The fact that the values obtained by the second analysis are somewhat larger than those obtained from the first is probably due to the fact that the altimetry versus differential levels analysis was carried out over much shorter intervals. This would indicate that errors present are random in nature and that all large systematic errors have been eliminated.

From the probable errors listed in Tables VII and VIII, a value of ±0.5 meters per observation was assigned to the elevations determined. This value, which indicates a remarkable accuracy for altimetry surveys, also supports the conclusion that large systematic errors have been eliminated. Further, this reflects the relatively stable atmospheric conditions present over the snow surface upon the ice cap. This may be easily appreciated when one compares this surface with a typical surface at the middle latitudes, where unequal heating causes local variations in pressure.

6. Summary of survey control for traverses

Using the techniques and methods discussed above, horizontal and vertical control was established for a total of 351 points. Table IX gives the elevation, the probable error in elevation, and the latitude and longitude of points established on the topographic reconnaissance traverses. The elevations are based upon the elevation of Point Susan, and the probable errors are relative to Point Susan. Although many more points were located on these traverses, only those permanently marked are included in Table IX. All the points included in Table IX are marked by a fifty-five gallon drum.

Table X gives the bearing of the geophysical lines, the probable error in the bearings, the distance between adjacent stations, accumulated distances along the lines, and latitudes, longitude, elevation, and probable error in elevation of all points on the geophysical traverses. The bearings of the lines are relative to the reference line and are not true bearings due to the extreme convergence of meridians. The probable errors in these bearings are derived from the adjustments necessary to make a plot of the traverses fit the position established by solar observations. All distances listed were measured with vehicle odometers. The values of latitude were obtained from a plot of the traverses. The elevations are based upon an elevation of 563.0 meters for Point Susan. The probable errors in elevation were derived from a probable error per observation of ±0.5 meters.

Profiles of the geophysical lines revealed the typical surface configuration of an ice cap. The east side of both the K line and the L line showed a slight depression in the ice shelf just prior to the rise at the toe of Roosevelt Island. On the K line this depression is quite gradual, amounting to a drop of about 13 meters in a distance of 20 kilometers. On the L line the depression is more abrupt, having a drop of some 20 meters in a horizontal distance of 5.5 kilometers. This same feature was observed at the juncture of the Ross Ice Shelf with the Antarctic continent by N. A. Ostenso and E. Thiel during the 1956 field season.[10] The nature of the profiles confirmed that Roosevelt Island is a typical ice cap and may be considered as a model of a larger feature.

A topographic map of Roosevelt Island is shown in Figure 11. It was prepared from the data presented in Tables IX and X. Roosevelt Island is seen to be oval in shape with a length of approximately 155 kilometers and a width of approximately 60 kilometers. There are three dominate features of the topography: (1) the regular nature of the surface, (2) the "s" shaped summit running in a northwest to southeast direction, and (3) the slight emboyment in the northwest portion of the ice cap. The maximum elevation of the dome is 565 meters above sea level, a rise of about 495 meters above the surrounding Ross Ice Shelf. The surface slope is approximately zero in the vicinity of the crest and increases uniformly until it reaches a maximum of 3.4% near the edge of the ice cap. At this point there is an abrupt change in slope as the ice cap merges with the ice shelf.

Chapter III

STRAIN RATE MEASUREMENTS

INTRODUCTION

One of the principal goals of the research activities on Roosevelt Island is to obtain accurate values for the surface strain rates, and to determine their distribution over the ice cap. This requires that the displacement of selected points be measured relative to time. Since all of the surface of the ice cap is subject to varying degrees of strain, and no fixed points are practically available in the vicinity of Roosevelt Island, the measurements required for this portion of the investigation had to be made on a relative basis. That is, the displacements of points were measured relative to one base point and a single reference direction. This chapter is subdivided into eight sections. The first is concerned with the selection of the section of the ice cap over which the strain rates were to be determined; the second with the selection of the base point and the reference direction; the third with the systems of control points established to determine strain rates; the fourth with the field methods and techniques used to obtain vertical control for these control points; the fifth with the adjustment and results of the vertical control; the sixth with the field methods and techniques employed to obtain horizontal control for the control points; the seventh with the reduction and adjustment of the horizontal control; and the eighth with the results of this portion of the research.

1. Selection of the Section for Strain Rate Study

As has been indicated previously, one of the primary objectives of the reconnaissance phase of operations on Roosevelt Island was to locate the section of the ice cap most nearly approaching the conditions depicted by the theories of ice flow; that is, having a uniformly increasing slope from the point of maximum elevation to the edge of the ice cap. In addition, it was desired that the subsurface rock under this section have a regular surface so that the ice flow not be influenced by topographic features at the ice-rock interface.

The theoretical surface profile of a two dimensional ice sheet lying on a horizontal bed is, according to J. F. Nye:[11]

$$\left(\frac{h}{H}\right)^{2 + 1/m} \quad \left(\frac{x}{L}\right)^{1 + 1/m} = 1$$

where h is the height of the upper surface above the ice-rock interface at a distance x from the center, H is the height of the upper surface above the ice-rock interface at the center, and L is the distance from the center of the ice sheet to its edge. The constant m in this equation has a value between 2.0 and 2.5. Figure 12 shows the profile of the K line as established by the reconnaissance traverses, and the theoretical profile through this section based upon Nye's equation. For this theoretical profile a value for H of 760 meters was used. This value was obtained from seismic reflection studies. Station K60 was taken as the center of the section. This gave a value for L of 35 kilometers for the northeast portion. A value for m of 2.5 was used for both halves of the profile.

As can be seen from Figure 12, the surface profile of the ice cap on the K line closely follows that depicted by Nye's equation. Based on this, the section represented by the K line was selected for the location of the strain network. Seismic investigations conducted after the network was established, indicated that the ice-rock interface was quite regular, having the form indicated in Figure 12.

2. Selection of the Base Point and Reference Direction

After the section on which the strain rate studies were to be carried out was selected, it was necessary to establish a base point and a reference direction. These were required since the displacements were to be measured on a relative basis. The selection of the location of the base point and the reference direction was based upon the theoretical work of J. Weertman on the equilibrium profile of ice caps.[12] Weertman gives for the effective velocity the equation:

$$\mu = \beta\tau \, (\tau^2 + \tfrac{1}{4}\sigma b^2)^{\frac{1}{2}(m-1)}$$

where μ is the effective velocity, β a constant, τ the shear stress at the bottom of the ice mass, and m a constant between 2.0 and 2.5. The shear stress τ is given by the equation:

$$\tau = -\rho g h \, (dh/dx)$$

where ρ is the density, g the acceleration of gravity, h the elevation of the surface with respect to the ice-rock interface, dh/dx the surface slope. Therefore, the conclusion may be drawn that where the surface slope approaches zero, the effective velocity of the ice cap will approach a minimum.

Based upon the above analysis, Point Susan was selected as the base point of the network established to determine the strain rates upon the surface of the ice cap. As can be seen by reference to the profile of the K and M lines, Point Susan is situated in the region of minimum surface slope. Therefore, the effective velocity of Point Susan should be a minimum.

In order to conduct the strain rate measurements on a relative basis, it is necessary to have a reference direction as well as a reference point. Since the effective velocity of the ice mass will approach a minimum as the surface slope approaches zero, as has been shown above, the most desirable position of a reference direction is in the direction of the maximum slope. If this condition is met, then the slope perpendicular to the reference direction will approach zero since it will parallel the contours. This will provide the desirable relationship that the effective velocity perpendicular to the direction of the reference direction will approach a minimum, and the maximum effective velocity will be in the direction of the reference direction. This will produce the minimum change in direction due to the theoretical deformation of the ice mass. In addition to the above requirement for the reference direction, it is desirable that the reference direction be established near the summit of the ice cap since the surface slope in this region is a minimum in all directions. The direction established by the line from Point Susan to the Reference Mark discussed in Chapter II met both of those requirements, and, in addition, both points were already established in a semi-permanent manner, and the true bearing of the line had already been determined. Therefore, the line defined by Point Susan and the Reference Mark was taken as the reference direction.

3. System of Control Points

The basic plan for the investigation of the surface strain rates required a system of control points reaching across the ice cap in the general vicinity of the K line. It was desired that the position of these points be established relative to each other with an accuracy of ±10 cm. In the past, efforts to measure angles on an ice cap met with only limited success. Both the German Greenland Expedition of 1929-1931, under Alfred Wegener, and the French Greenland Campaigns of the Expeditions Polaires, under Paul Emile Victor, found that the measurement of angles, under the climatic and meteorological conditions associated with an ice cap, requires a great deal of time and provides only limited accuracy. In contrast, the geodetic work for the International Greenland Expedition, conducted by Walther Hofmann in the summer of 1959, was quite successful. In this work a chain of quadrilaterals was established by pure distance measurements.[13]

Based upon the above, the decision was made to employ a chain of quadrilaterals to establish the horizontal positions of control points upon Roosevelt Island. This was accomplished by measuring all four sides and both diagonals of the figure by electronic means. In addition to eliminating the necessity of measuring angles, this provides a control on the accuracy of the measurement since one of the six distances must serve as one side of the adjacent quadrilateral. Therefore, a check could be maintained upon the closure of the quadrilaterals. The basic control network consists of twenty-nine quadrilaterals, made up of sixty points, and arranged in the form of a half-cross as shown in Figure 13. The long axis of the cross runs across the ice cap in a northeast to southwest direction in the general vicinity of the K line. The half cross portion of the network roughly follows the summit of the ice cap running southeast from Point Susan. In addition to this basic network, two small grid systems were established at the northern and southern extremes of the ice cap with a portion of the network on the Ross

Ice Shelf. This was done in order to determine the strain rate and the velocity of the ice shelf with respect to Roosevelt Island. This is necessary in order that the effect of the ice shelf upon Roosevelt Island may be determined. These secondary networks are not, therefore, of direct concern to the basic problem of establishing the strain rates upon the ice cap.

The control points are designated by a letter and a number. The letter represents the line on which the point is located, while the number represents the individual points on the line as shown in Figure 13. All control points were marked in the field by four-foot bamboo stakes driven to within 10 cm of the snow surface. The center of the stake designates the point. Guide poles about twelve feet high were set at all control points in such a manner that the stake marking the control point is usually one meter magnetic south of the guide pole. The guide poles were provided with flags in order to simplify the process of relocating the control points. In most cases each guide pole was provided with two different colored flags. In general the flagging was consistent for each line with regard to color and arrangement. Table XI provides a summary of the flagging system.

During the 1961-1962 season the quadrilaterals I through XVII were set and the horizontal and vertical positions of the control points measured. During the 1962-1963 season these quadrilaterals were remeasured and quadrilaterals XVIII through XXXVI set and measured. Current plans call for all the quadrilaterals to be remeasured during the 1965-1966 season. Therefore, a complete result will not be available until some time after the 1965-1966 season.

The initial step in establishing the quadrilaterals was the marking of the control points. Since it was anticipated that the strain rates would be small, it was desired to obtain a spacing between adjacent control points of about 5 kilometers. In order to achieve this spacing it was necessary to select the positions of the control points with care since each corner of the quadrilateral had to be visible from the other three corners. This was accomplished by using two field parties, each equipped with a Trackmaster. Each party would position itself so that it was at the approximate desired distance and direction from a previously established point. Then these new sites were checked to insure that all corners of the quadrilateral were visible. This was accomplished by sighting on the other corners, those previously established being marked with guide poles and flags, and the new points being defined by the location of the vehicles. This was a time-consuming operation, particularly in the vicinity of the summit of the ice cap where as much as five hours were required to set a quadrilateral. In this area it was desired that the A and B lines, as defined in Figure 13, be positioned on opposite sides of the summit. Therefore, it was difficult to provide a line of sight between all corners of each quadrilateral. As can be seen in Figure 13, it was necessary to position the control points in this area so that the sides of the quadrilaterals were considerably shorter than desired. This was also the case at the edges of the ice cap where the line of sight was restricted by undulations in the surface.

4. Methods Employed to Obtain Vertical Control on the Strain Rate Network

It was desired to establish vertical control as well as horizontal on the control points in the strain rate network. Vertical control was desired because (1) the differences in elevation between control points are needed in order that the measured distances could be reduced to horizontal; (2) the change in elevation of the control points relative to time are needed in order to obtain the vertical component of the ice movement.

Since the vertical component of the ice motion is small, the second goal for the vertical control governs the accuracy requirements. For the purpose of obtaining these vertical movements, it was desired that the vertical position of the control points be established to a relative accuracy of ± 1.0 meters. Neither trigonometric nor barometric leveling techniques could provide this accuracy in these regions. Trigonometric leveling is unsatisfactory because of the severe effects of refraction, and barometric leveling because of its inherent high probable error. Therefore, the vertical control for the strain rate measurements upon Roosevelt Island was established by differential leveling.

Point Susan was considered as the reference bench mark for this portion of the control. (The methods employed to establish the elevation of Point Susan with respect to mean sea level have been covered in Chapter II.) The elevations of all control points on the strain rate network were based on the elevation of Point Susan.

The equipment used in the differential leveling of the strain rate network was a Zeiss Ni2 automatic level, two 3.8 meter level rods, and motor toboggans and Trackmasters for transportation. The procedure used varied with the number of men and vehicles available. However, most of the leveling was done by a two-man party equipped with two motor toboggans. The sight was taken by setting a target on the rod in coincidence with the line of sight, and taking and recording the readings at the rod. The rear member of the party would then move ahead. Back sights and foresights were approximately balanced by estimation. This had to be done since the motor toboggans were not provided with odometers. Figure 14 shows the instrument man moving ahead on a motor toboggan. A six-inch section of 2 x 4 timber driven flush with the snow surface was used as a turning point. The highest point on the bamboo stakes marking the control points was used for the elevation of the point. All control points were included in the level loops as turning points.

In order that frequent field checks be available, the leveling was done in a series of eleven loops. Four of these loops were run in the 1961-1962 season and the rest in the 1962-1963 season. Figure 15 shows the location of the loops in relation to the strain network.

The leveling of the strain rate network was hampered to a great extent by factors associated with the Antarctic regions, particularly reduced visibility, which frequently limited the length of sight possible or eliminated leveling operations altogether. Table XII summarizes the effect of limited visibility upon leveling operations during the 1961-1962 and 1962-1963 field seasons. The basic time unit considered in Table XII is the working day. This was selected since once the plan for the day's operations had been established, it was frequently impossible to alter it due to vehicle and personnel commitments. In the table "unrestricted" means visibility conditions which impose no length of sight limitations upon line of sight operations. "Restricted" refers to visibility conditions which impose a limitation on the length of sights which could be used. "Non-operational" means visibility conditions which, due to blowing snow, fog, and haze, render operations dependent upon a line of sight impossible. This classification system is somewhat arbitrary in that some days had portions of two, or even all three divisions. In these events, the day was classified as restricted. As can be seen in Table XII, the visibility was such that leveling operations were restricted or impossible 123 days out of the 189 days during which field work was being done on Roosevelt Island. This is 65 per cent of the field season.

Visibility limitations were not the only difficulties encountered in the line of sight. On bright clear days, which have been classified as unrestricted, a severe inversion layer occurs at a height of approximately one meter above the snow surface. This is thought to be caused by the large percentage of the sun's energy reflected at the snow surface. This reflected energy tends to heat the atmosphere immediately above the surface, thus causing a temperature reversal. Under these conditions it was necessary for the level party to shorten the length of sights so that the line of sight was always above the inversion. Thus it is seen that the leveling operations were limited by both extremes of visibility conditions. The ideal conditions of leveling were overcast skies with unlimited visibility at the surface. Due to the relatively short duration of the Antarctic field season it was impossible to perform all leveling operations under these ideal conditions.

One other significant source of error, typical to the region, is settlement of both the instrument and the turning point between back sight and foresight. Since this will be a systematic error, efforts were made to control it. Settlement, although present in any differential leveling operation, is more critical when operations are being conducted over a snow surface. This is the case since the settlement can be extreme in areas where the snow is soft. The Zeiss Ni2 automatic level was selected for use on Roosevelt Island not only because of the operational speed which it permits, but also because of its characteristics with regard to settlement. Since the line of sight is maintained as a horizontal line by gravity, any error due to settlement will be only as large as the algebraic value of the settlement. There will be no rotation of the line of sight which would introduce large errors. Therefore, errors due to settlement of the instrument should be no larger than the amount of settlement. Since the absolute value of the settlement must be small, the use of the Zeiss Ni2 should effectively reduce the settlement errors to a minimum.

Errors due to settlement of the turning point will be similar to those introduced by settlement of the instrument. They will not, however, be as critical since settlement of the turning point will not produce a rotation of the line of sight regardless of what type of instrument is used. In order to reduce the settlement of the turning point to a minimum, a six-inch, light-colored wooden 2 x 4 was used as a turning point. This large turning point was used to reduce the bearing pressure of the point. The light color was used to prevent heating of the turning point by absorbing the sun's energy and thus causing settlement due to melting.

When personnel and transportation requirements permitted, the leveling was conducted with three man parties: two rod men and an instrument man. This arrangement permitted the taking of the back sight and foresight in rapid succession and thereby reducing the effects of settlement. Although this was an ideal solution, it was not frequently used due to the fact that it requires three vehicles. Transportation was critical in all phases of the field work and it was not practical to tie up the major portion of the vehicles available in one part of the total work.

When a two-man leveling party was used, the leveling operation proceeded with a velocity of about 2 kilometers per hour. When the three-man party was used, the velocity increased to about 2.7 kilometers per hour. These velocities varied with other conditions, such as visibility and degree of surface slope. They are, however, an indication of the speed at which differential leveling can be carried out using these procedures.

5. Adjustment and Results of Vertical Control

The errors of closures of the level loops are given in Table XIII. These ranged from a maximum of 1.811 meters in Level Loop III to a minimum of 0.023 meters in Level Loop X. The average error of closure was 0.444 meters. It was assumed that these errors of closure were due to accidental errors and they were therefore distributed equally over the turning points in the loops. The error per turning point varied from a maximum of 1.36 cm in Level Loop III to a minimum of 0.04 cm in Level Loop VI. The average error per turning point was 0.395 cm. A total distance of approximately 244 kilometers was leveled, including 1055 turning points. The average error per kilometer was 1.85 cm, ranging from a maximum of 5.81 cm in Level Loop III to a minimum of 0.15 cm in Level Loop VI. Inasmuch as the maximum distance from Point Susan on the main portion of the strain rate network is about 50 kilometers, the maximum probable error with respect to Point Susan is ±92 cm. This is within the desired accuracy of ±1.0 meter.

Table XIV lists the elevations obtained for the control points. Since the ice cap is undergoing strain continuously, these elevations are listed along with the date they were established. The elevations obtained in Level Loops I, II, III, IV, V, VI and VII are based upon control point R2, which was tied to Point Susan by barometric leveling. The elevations obtained in Level Loops X and XI are based upon T8 for which an elevation of 100.00 meters was assumed. The elevations listed for stations F10, F11, F12, F13, F14, G10, and G11 are approximate elevations obtained by barometric leveling.

In all, the elevations of eighty-six control points are listed. These elevations were obtained by differential leveling with Point Susan as a bench mark, with the exception of the three special cases explained above. The probable error in elevation with respect to Point Susan of any control point in the main portion of the strain rate network is less than one meter.

6. Field Methods Employed to Obtain Horizontal Control on the Strain Rate Network

The basic plan for the establishment of horizontal control on the strain rate network called for the measurement of all four sides and both diagonals of a quadrilateral. It was desired to obtain the relative horizontal position of the control points to within ±10 cm. The Tellurometer was selected as the instrument best suited for this purpose. Tellurometers had been used for measurements over snow surfaces in Arctic Canada, Jungfraujoch, Zugspitzplatt, Munich, and Greenland by the International Greenland Expedition.[14] In these operations it proved a reliable and accurate instrument. Based upon the results of these investigations, three Tellurometers model MRA2 were selected for the establishment of horizontal control.

The use of this model Tellurometer to measure distances in a polar area offers several advantages. First, since the surface topography of an ice cap is extremely regular, the measurement of distances with the Tellurometer becomes almost independent of the surface relief. This is the case since the electromagnetic waves of the Tellurometer are disturbed chiefly by steep slopes or cliffs which are, of course, not found on the ice cap. Second, the electromagnetic waves experience a high degree of absorption when directed over the soft snow surface. This reduces the signal strength and therefore reduces the maximum range from about 40 kilometers to about 20 kilometers. Although this loss of range is somewhat of a disadvantage, it is more than offset by the fact that this strong absorption also almost completely eliminates reflections from the surface. Measurements conducted on varying carrier frequencies show a minimal change in travel time. This allows a significant improvement in the accuracy with which one is able to determine the effective travel time of the electromagnetic energy. Third, extremely high humidity, even fog, which is quite frequent on Roosevelt Island, does not disrupt distance measurements with the Tellurometer. On the contrary, it improves the probable accuracy by creating a near homogeneous atmosphere through which the electromagnetic energy must pass. This allows accurate determination of the refractive index of the atmosphere and therefore a reliable correction may be applied to the measured travel time. Fourth, the Tellurometer model MRA2 is equipped with a thermostatically controlled crystal oven which provides frequency stabilization down to -40°F. Fifth, the Tellurometer model MRA2 has provision for remoting the reflector from the basic unit. This allows the operator to work in more comfortable conditions than if he had to operate the instrument in the open.

In addition to three Tellurometer models MRA2, the following equipment was used: two Wallace and Tierman sling type psychrometers to obtain the vapor pressure; two Wallace and Tiernan altimeters to measure the atmospheric pressure; two 3.8 meter level rods to measure the height of the Tellurometer reflector above the stations; two Trackmaster over-snow vehicles for transportation and instrument towers.

The procedures used to measure the necessary distances on the strain rate network were as follows: Two parties, each equipped with a Tellurometer and associated instruments, would occupy the control points at the ends of the line to be measured. Each Trackmaster was equipped with a platform constructed atop the A-frame of the vehicle. The Tellurometer reflectors were mounted upon tripods by the use of specially constructed adapters. Brackets were constructed on the Trackmasters to hold the adapters when the vehicles were in motion. The tripods were set on the platforms atop the Trackmasters. The measuring points of the reflectors were brought over the control points by using a plumb line. Figure 16 shows an operator positioning the reflector over a control point. Due to the small amount of tolerance permitted by the slot in the platform, it was frequently necessary to relocate the vehicles in order to align the slot in the platform with the control point. As soon as the operator was satisfied that the measuring point of the adapter was centered over the control point, he would point the reflector directly at the second station. Care was taken to insure that the vertical orientation of the reflector was such that the broadcast energy was not directed toward the snow surface. The adapters were connected to the main Tellurometer unit by a 22 foot coaxial cable. The main unit was permanently positioned inside the vehicle. Therefore, when the reflectors were positioned upon the adapters, the unit could be operated from within the vehicle.

Although this arrangement was somewhat cumbersome and time consuming to set up, it was necessary. First, the Tellurometer is a line of sight instrument. Since the surface topography of the ice cap is extremely regular it was impossible to position the control points upon rises in the surface elevation. This restricted the line of sight to less than 1.5 kilometers, particularly in the area around the crest of the ice cap. In addition, the maximum range was reduced by the extreme absorption of the snow surface and use of the coaxial cable, both of which tended to weaken the signal strength. Therefore, it was necessary to raise the reflectors as far as possible above the snow surface in order to provide a longer line of sight and to reduce the effect of absorption of the electromagnetic energy at the surface. When this was done the indicated crystal current was generally in the range of 0.3 to 0.4 milliamps. Second, inasmuch as the measurement procedure required approximately forty-five minutes, during which time the operator had to remain relatively still, the operator fatigue was significant enough to adversely affect the results. Therefore, it was necessary to remote the principal unit to the interior of the vehicle where the operator could take the necessary readings in relative comfort.

The principal disadvantage of this technique was that it required plumbing over a distance of about 3.5 meters. This was a considerable problem particularly when the operator was working alone and a wind was blowing. It is hoped that in future operations optical plummets can be obtained.

After the Tellurometer units were set up in the above manner, the operators established contact at a preselected carrier frequency. This carrier frequency was selected in the middle of the carrier frequency range covered by the instruments to insure that contact could be established. Since each Tellurometer model MRA2 can function as either the measuring station or the reflecting stations, the same party was always the measuring station. This was done in order to avoid the possibility of both stations attempting to assume the same function.

Once contact was established, the operators measured and recorded the instrument height above the control points. This was accomplished by measuring and recording the difference in elevation from the top of the bamboo stake marking the control point, to the measuring mark on the adapter. This measurement was taken directly upon a level rod held against the adapter. When this was completed the operators proceeded to take and record the meteorological data necessary to compute the refractive index of the atmosphere. This consisted of wet and dry bulb thermometer readings and the barometric pressure. Sling type psychrometers were used for the humidity measurements and proved to be unsatisfactory. Thermometers were frequently broken due to difficulties in handling the sling arrangement in heavy mittens. At one time during the 1962-1963 season, measurements had to be taken only on the dry bulb due to the destruction of all available thermometers. Pressure observations were made upon the Wallace and Tiernan altimeters. These meteorological observations were made at both ends of the line before and after each complete set of Tellurometer readings. The average values were then used in all calculations.

After these preliminary measurements were completed, the operators took the Tellurometer readings from the relative comfort of the vehicle interiors. For each distance measured, two sets of course readings were taken at two different carrier frequencies. These readings were reduced on site in order to assure that no ambiguities existed. If an ambiguity was encountered it was resolved before the parties left the control points. Fine readings were taken at ten to twelve different carrier frequencies in order to reduce the influence of the existing surface reflections. Care was taken to insure that the reading obtained at either the highest or lowest carrier frequency was not a maximum or a minimum. If either of these was a maximum or a minimum, another reading was taken at respective higher or lower carrier frequency. This was done in order that the shape of the ground swing curve would be defined within its maximum limits.

The average time required for the measurement of a line using the above procedures was about forty-five minutes. This varied widely, particularly when an ambiguity occurred. The minimum time required for the measurement of any line during the two seasons was twenty-two minutes. During this measurement a second man performed as recorder at the measuring station. This significantly reduced the time required.

More significant than the actual time of measurement was the travel time required to move to a new line when a measurement had been completed. The operational velocity of the Trackmaster over the rough surface of the ice cap was limited to about four kilometers per hour. Attempts to drive faster than this caused vehicle breakdown and damage to equipment in the vehicles. Since only two field parties were used for the great majority of the work done to establish horizontal control, at least one of the parties had to move to a new station for each measurement. Since the average length of a side of a quadrilateral was 4.5 kilometers, the average travel time for each measurement was about 1.1 hours. The average time required for each side measured, including the necessary travel time, was 1.9 hours. Each new quadrilateral includes five new sides as the first side is the closing side of the previous quadrilateral. Therefore, the average time required to measure a quadrilateral was 9.5 hours. The work on the quadrilaterals was conducted so that two quadrilaterals would be measured before stopping for meals and rest. In order that work not be slowed while operations were in progress, meals were prepared at the stationary vehicle in situations where only one party had to move to a new station.

In summary, the procedures discussed above were those used for obtaining the necessary field data to establish control upon the strain rate network. They provided a relatively smooth operation in spite of environmental restrictions. The speed of the operation was approximately one quadrilateral, or five sides, per ten-hour period. The two areas in which the procedure can be improved are setting up over the control point and travel time requirements. The accuracy provided by these procedures will be discussed in the following section.

7. Reduction and Adjustment of Horizontal Control on the Strain Rate Network

This section will be concerned with the reduction of the Tellurometer measurements and the adjustment of the quadrilaterals. The first step in the reduction was the analysis of the Tellurometer fine readings. A plot of fine readings versus the carrier frequency at which the fine reading was obtained was constructed for each line measured. When the indirect ray path consists predominantly of a single reflection, this plot will approximate a sinusoidal curve commonly called ground swing. On lines where the difference between the direct path and the reflected path is small, a full cycle of ground swing will not develop. Since this was the case for all measurements conducted on Roosevelt Island, it was necessary to inspect these curves carefully in order to select the zero axis of the curve. The zero axis thus selected was considered as the true fine reading and was then combined with the course reading to yield the mean transit time. On occasion, lines with small ground swings produced a single reading which was significantly different from the remainder of the readings. These were considered to be produced by the in-phasing of a number of reflections and were therefore disregarded.

The lines measured upon Roosevelt Island rarely produced a ground swing with an amplitude of greater than 1.0 mμs, a value which can be considered as resulting from the uncertainty of the readings and real changes in the transit time. This small swing is probably the result of two factors: the fact that the surface has a strong tendency to absorb the electromagnetic energy rather than reflect it; and that due to the regularity of the surface, the difference in distance between the direct and indirect was small.

The velocity of electromagnetic energy was taken as 299,792.5 ±0.1 km/s as determined by Froome.[15] The refractive index was calculated using Essen's formula:[16]

$$(n-1)10^6 = \frac{4730}{459.5 + t} \left(P + \left(\frac{8540}{459.5 + t}\right) e\right)$$

where t is the air temperature in degrees Fahrenheit, P is the barometric pressure in inches of mercury, and e is the vapor pressure in inches of mercury. The meteorological conditions were measured on thermometers reading directly to one degree, and Wallace and Tiernan surveying altimeters reading directly to one meter. The average conditions at the ends of the line were taken as representative of the conditions throughout the length of the line. This is justified by the fact that the regular surface of the ice cap is likely to produce homogeneous meteorological conditions in the lower air layers. Also, the variation in vapor pressure is relatively insignificant in polar regions.

The above conditions generally prevailed on the ice cap. However, during calm and sunny days a sharp inversion developed, as has been pointed previously. On such days, not only were the meteorological observations questionable, but, more significantly, the Tellurometers produced unreliable readings due to refraction and reflection at the inversion. Therefore, on such days, it would have been best if no Tellurometer measurements were taken. This was not always possible however, due to the limited field season.

The final factor considered in the reduction of the Tellurometer distances was the reduction to horizontal. This was calculated according to the relationships:

$$C_h = \frac{h^2}{2s} \qquad D = s - Ch$$

where C_h is the slope correction, h is the difference in elevation, s is the slope distance, and D is the horizontal distance. The distances were not reduced to sea level since the desired results of the measurements were the strain rates which can be determined from distance differences.

The adjustment of the quadrilaterals was accomplished by operating upon the angles computed from the measured sides. Both the geometric and trigonometric properties of the quadrilateral were considered. All measured sides were weighted one since they had been measured by identical means under similar conditions and were approximately the same length. Since the chain of quadrilaterals was developed using a side common to two quadrilaterals, the adjustment was designed to hold previously adjusted values constant. This was done since a simultaneous adjustment of the entire chain of quadrilaterals would not compensate for movement during the period of measurement. The computations associated with the reduction of the Tellurometer measurements and the computation of the unadjusted angles of the quadrilateral were carried out on an IBM 1604 electronic computer. It should be noted that for the adjustment following the final remeasurement of the network a least squares adjustment operating upon the lengths will be used. The adjustments were made by hand in order that maximum control could be maintained upon the accumulation error.

8. Results of Strain Rate Measurements

In the process of establishing horizontal control upon the strain rate network 53 quadrilaterals, consisting of 102 stations, were measured. This required 271 measurements over a total distance of about 1000 kilometers. Table XV presents an evaluation of the individual quadrilaterals with regard to their errors of closure, precision, and probable error in the length of a side. For the quadrilaterals measured in the 1961-1962 season, the average error of closure was ±0.177 meters, the average precision was 1/149,000, and the probable error in the length of a side was ±0.030 meters. For the measurements made during the 1962-1963 season the average values obtained for similar quantities were ±0.456 meters, 1/62,000, and ±0.077 meters. The difference in accuracy, indicated by a comparison of these values for the two seasons, is due to several factors: (1) The sides of many quadrilaterals established during the 1962-1963 season were relatively short. (2) For a portion of the measurements taken during the 1962-1963 season, psychrometers were not available at both ends of the line being measured. (3) For the quadrilaterals established on the shelf ice during the 1962-1963 season, elevations were obtained by barometric leveling rather than by differential leveling. (4) During the 1962-1963 season less care was taken in setting up over the control point.

The results of the measurements upon the strain rate network are presented in Table XVI and Table XVII. Table XVI lists the adjusted distances for all lines being measured and the bearing of the line relative to the reference line. Table XVII lists the coordinates of the control points for both the 1961-1962 and 1962-1963 seasons. These coordinates are relative, based upon an assumed direction and base point location.

Chapter IV

DISPLACEMENTS AND STRAIN RATES

INTRODUCTION

The final products of the strain rate measurements discussed in Chapter III are the displacements of the control points and the magnitude and orientation of the strain rates. This chapter discusses the calculations and presentation of these qualities. The first section will be concerned with the displacements, and the second with the strain rates.

1. Displacements

The displacements of the control points relative to Point Susan were calculated from the coordinates obtained from the 1961-1962 and 1962-1963 measurements. These displacements are presented as vectors in Figure 17. As can be seen by referring to Figure 17, these displacements tend to be rotated toward the northwest. Although this would coincide with the expected effect of the movement of the shelf ice, the magnitude of the rotation is more than could be expected. In addition, inasmuch as the summit of the ice cap nearly coincides with the A line, it is highly unlikely that the displacements of points B4 and B5 could be in the direction indicated. This is the case since the elevation of the points on the B line are generally 16 meters lower than the corresponding point on the A line. It is to be expected, therefore, that the displacement of points B4 and B5 should be in the direction of the fall line, that is, away from the A line.

An inspection of Figure 17 indicates that both of the above discrepancies between the theory of ice flow and the measured displacement vectors could be produced by a rotation of the axes used for the calculation of the coordinates for the 1962-1963 season. Since the directions of the axes were established by the assumption that the displacement of the Reference Mark was along the north-south axis, any deviation of displacement of the Reference Mark from this assumption could produce a corresponding rotation of the axes. Based upon the premise that such a deviation from the original assumption is present, a displacement of the Reference Mark was calculated which would largely remove the northward component of the displacements of the points on the F and G lines. This resulted in an indicated displacement of the Reference Mark of 1.93 meters in a direction of N 23°28' W. When this displacement of the Reference Mark is used, it produces a clockwise rotation of the coordinate axes of 0°00'56". This rotation of the axes produces the displacement vectors shown in Figure 18.

With reference to Figure 18, the effect of the rotation of the axes of 0°00'56" is to swing the displacement vectors of the control points on the F and G lines to a direction more nearly parallel to the fall line, as depicted by the theory. In addition, it clearly reveals a realistic effect exerted on the displacements of control points F9 and G9 by the motion of the shelf ice. However, the pattern of displacements in the vicinity of the crest of the ice cap does not appear to be valid. There is no apparent physical basis for the down-slope component of displacement of points on the A line to increase with the distance from point C-1. Further, the head end of these displacement vectors clearly indicates a rotation of axes.

During the 1961-1962 field season, quadrilateral XVII, which contains control points C-1, RM, BB13, and A13, was measured several months after the remainder of the quadrilaterals in the vicinity of the summit had been measured. An analysis of the displacement of the Reference Mark over this period, based on quadrilateral XVII, indicated a displacement of 0.30 meters in a direction of N 11°11' W. Assuming a uniform displacement with respect to time, this provides a clockwise rotation of the coordinate axes of 0°00'25" for the 1962-1963 measurements. Figure 19 presents the displacement vectors of the control points resulting from this rotation.

With reference to Figure 19, the displacement vectors, based on a direction of N 11°11' W for the displacement of the Reference Mark, provide a pattern closely fitting the theory. The displacement of points in the vicinity of the summit tend to be in the direction of the fall line and proportional to the surface slope and distance from the base point. Although the displacement vectors of points on the F and G lines still retain a significant northern component, it is smaller than for displacements based on the original assumption. This northern component can be attributed to the effect of the Ross Ice Shelf. Table XVIII gives the revised coordinates of the control points for the 1962-1963 season, based on a displacement of the Reference Mark of 1.80 meters in a direction of N 11°11' W, and the magnitude and direction of the displacements of the respective points.

Two possibilities exist for the removal of the uncertainties introduced by the failure of the Reference Mark to move along the coordinate axes. The first is a series of daylight star observations on the azimuth of the reference line from which the relative direction of the displacement of the Reference Mark with respect to the base point may be determined. This will, therefore, firmly establish the direction of the coordinates axes.

The second is the remeasurement of the D and E lines during the 1965-1966 season, which would provide displacement vectors on both sides of the crest and any rotation of the axes should be readily apparent.

A graphical presentation of the displacements on the F and G lines versus the distance from the summit of the ice cap is presented in Figure 20. The displacements are those calculated based on a direction of N 11°11' W for the displacement of the Reference Mark. The curves for the two lines agree quite well with the exception of the final portion. This is possibly due to the fact that the last point on the F line is more exposed to the effect of the ice shelf since it is further on the shelf.

2. Strain Rates

The strain rates along each line in the control net were calculated from the adjusted distances. These are summarized in Table XIX. This includes only those lines which were measured in both the 1961-1962 and 1962-1963 seasons. A graphical representation of the relation of strain rates, surface slopes, and coordinates for control points on the A and B lines is presented in Figure 21.

With reference to Figure 21, it can be seen that the strain rates parallel to the slope are significantly larger than the strain rates perpendicular to the slope. Further, both sets have a slight tendency to increase as the distance from the base point increases. Of equal significance is the fact that neither the strain rates perpendicular to the slope nor those parallel to the slope indicate any strong tendency to approach zero in this region.

A graphical representation of the relation of strain rates, surface slopes, and coordinates of the control points on the F and G lines is presented in Figure 22. With reference to Figure 22, it can be seen that, again, the strain rates parallel to the slope are significantly larger than those perpendicular to the slope. Further, the strain rates parallel to the slope tend to assume the shape of the slope versus distance curve, with the exception of the extreme points which are located on the periphery of the ice cap.

Of further interest is the shape of the curve representing the strain rates perpendicular to the slope. In the vicinity of the summit the values closely approach those for the A-B lines. They remain relatively constant at +0.100 mm/m/yr. until a point about two-thirds of the total distance to the edge of the ice cap is reached. At this point the strain rates decrease until a maximum compression is reached just prior to the edge of the ice cap. At this point the curve again reverses and an expansion of 0.16 mm/m/yr. is obtained for the last line in the network. This compression is probably due to the pressure exerted by the Ross Ice Shelf.

Chapter V

CONCLUSIONS

Based upon the detailed information presented in the preceding four chapters, the following specific and general conclusions are drawn:

1. The accuracy of distances measured by calibrating the Trackmaster odometer is limited by the reading error.

2. The horizontal control on the geophysical traverses was established with an average precision of 1/130, based upon an average error of closure of 956 meters over an average perimeter distance of 101,400 meters.

3. The vertical error of closure on the geophysical traverses, as established by barometric leveling, ranged from a maximum of ±10.2 meters to a minimum of ±0.5 meters with the average being ±5.0 meters for the eleven loops.

4. The vertical error per station on the geophysical traverses, as established by barometric leveling, ranged from a maximum of ±0.51 meters to a minimum of ±0.03 meters with the average being ±0.15 meters for the eleven loops.

5. The vertical error per kilometer on the geophysical traverses, as established by barometric leveling, ranged from a maximum of ±0.43 meters to a minimum of ±0.02 meters with an average of ±0.10 meters for the eleven loops.

6. The probable vertical error per observation on the geophysical traverses, as established by barometric leveling, ranged from a maximum of ±1.00 meters to a minimum of ±0.20 meters with the average being ±0.47 meters.

7. The average error per station of the barometric leveling, as derived by comparison with elevations established by differential levels, is ±0.42 meters.

8. The average error per kilometer of the barometric leveling, as derived by comparison with elevations established by differential levels, is ±0.22 meters.

9. The probable error per observation of the barometric leveling, as derived by comparison with elevations established by differential levels, is ±0.72 meters.

10. The velocity of operation of the geophysical and reconnaissance traverses was about three kilometers an hour, exclusive of geophysical explorations.

11. The section of the ice cap selected for the location of the strain rate network has a regular profile which closely approximates the equilibrium profile predicted by J. F. Nye.[11]

12. The base point of the strain rate network is located in the vicinity of the crest of the ice cap.

13. There is a slight depression in the ice shelf just prior to the rise at the toe of Roosevelt Island similar to the junction of the Ross Ice Shelf and the Antarctic Continent, as reported by N. A. Ostenso and E. Thiel.[10]

14. The vertical error of closure on the strain rate network, as determined by differential leveling, ranged from a maximum of 1.811 meters to a minimum of 0.023 meters with the average being 0.444 meters over an average distance of 22 kilometers.

15. The vertical error per turning point on the strain rate network, as determined by differential leveling, ranged from a maximum of 1.36 cm to a minimum of 0.04 cm with the average being 0.395 cm.

16. The vertical error per kilometer on the strain rate network as determined by differential leveling, ranged from a maximum of 5.81 cm to a minimum of 0.16 cm with the average being 1.85 cm.

17. During the 1961-1962 and 1962-1963 seasons, line of slight operations were rendered impossible twenty-nine percent of the time by visibility conditions, and severely limited thirty-six percent of the time.

18. During days of unlimited visibility lines of sight were affected by extreme refraction when directed within one meter of the firn surface.

19. The use of a Zeiss Ni2 automatic level eliminated large errors in differential leveling due to instrument settlement.

20. The average time required to measure a line on the strain rate network was forty-five minutes when using the Tellurometer model MRA2.

21. The average travel time required to move to a new line on the strain rate network was 1.1 hours.

22. The average time required to measure a complete quadrilateral was 9.5 hours.

23. The electromagnetic waves used by the Tellurometer model MRA2 experience a high degree of absorption directed over the firn surface reducing the maximum range to approximately 20 kilometers and imposing the requirement to elevate the units.

24. The absorption of the electromagnetic waves by the firn surface reduces reflections from the surface to such a degree that the observed ground swing is seldom more than 1.0 mus.

25. The Tellurometer model MRA2 requires no additional insulation against temperatures on the order of -20°F. If such insulation is provided, the instrument will overheat and the pattern frequency will drift.

26. The average error of closure of the strain rate quadrilaterals was ±0.177 m for the 1961-1962 measurements and ±0.456 m for the 1962-1963 measurements.

27. The average precision of the strain rate quadrilaterals was 1/149,000 for the 1961-1962 measurements and 1/62,000 for the 1962-1963 measurements.

28. The probable error in the length of a side on the strain rate quadrilaterals was ±0.030 m for the 1961-1962 measurements and ±0.077 for the 1962-1963 measurements.

29. The degree of precision of a quadrilateral measurement is inversely proportional to the length of sides in the quadrilateral.

30. The displacement of the Reference Mark is in a direction of N 11° 11' W assumed on N 37° 35' E true.

31. Displacements are generally in a direction radial from the base point.

32. The displacements increase according to a higher order equation as the distance from the summit increases.

33. The strain rates parallel to the fall line tend to increase according to a higher order relationship as the distance from the summit of the ice cap increases. This relationship holds until just prior to the edge of the ice cap where the strain rate decreases to essentially zero.

34. The strain rates perpendicular to the fall line remain relatively constant at a value of +0.100 mm/m/yr until about two-thirds of the distance to the edge of the ice cap. At this point they decrease to a minimum of approximately -0.250 mm/m/yr. They then increase to a value of +0.150 mm/m/yr on the shelf ice. This compression may be a local effect of surface or subsurface topography.

FOOTNOTES

1. Butkovich, T. R. and Landauer, J. K. 1958 "The Flow Law for Ice," Union Geodesique at Geophysique Internationale. Association Internationale d'Hydrologie Scientifique. Symposium de Chamonix, 16-24 Sept. 1958, pp. 318-327.

2. Glen, J. W. 1955 "The Creep of Polycrystalline Ice," Proceedings of the Royal Society, Ser. A, Vol. 228, No. 1175, pp. 519-538.

3. Jellinek, H. H. G., and Brill, R. 1956 "Viscoelastic Properties of Ice," Journal of Applied Physics, Vol. 27, No. 10, pp. 1198-1209.

4. Steinemann, S. 1956 "Flow and Recrystallization of Ice," Union Geodesique at Geophysique Internationale. Association Internationale d'Hydrologie Scientifique, Assemblee Generale de Rome 1954, Tom. 4, pp. 449-462.

5. Glen, J. W. 1956 "Measurement of the Deformation of Ice in a Tunnel at the Foot of an Ice Fall," Journal of Glaciology, Vol. 2, No. 20, pp. 735-745.

6. Gerrard, J. A. F., Perutz, M. F. and Roch, A. 1952 "Measurement of the Velocity Distribution Along a Vertical Line Through a Glacier," Proceedings of the Royal Society, Ser. A, Vol. 213, No. 1115, pp. 546-558.

7. Haefeli, R. and Brentani, F. 1955 "Observations in a Cold Ice Cap," Journal of Glaciology, Vol. 2, No. 18, pp. 571-581.

8. Haefeli, R. 1952 "Some Observations or Glacier Flow," Journal of Glaciology, Vol. 1, No. 9, pp. 496-500.

9. Crary, A. P. 1958 "Final Results, Study of Ice Thickness and Water Depths, Ross Ice Shelf Traverse," Little America Data Memorandum 18-K.

10. Ostenso, N. A. and Thiel, E. 1961 "The Contact of the Ross Ice Shelf and the Continental Ice Sheet, Antarctica," Journal of Glaciology, Vol. 3, No 29, p. 825.

11. Nye, J. F. 1959 "The Motion of Ice Sheets and Glaciers," Journal of Glaciology, Vol. 3, No. 26, p. 497.

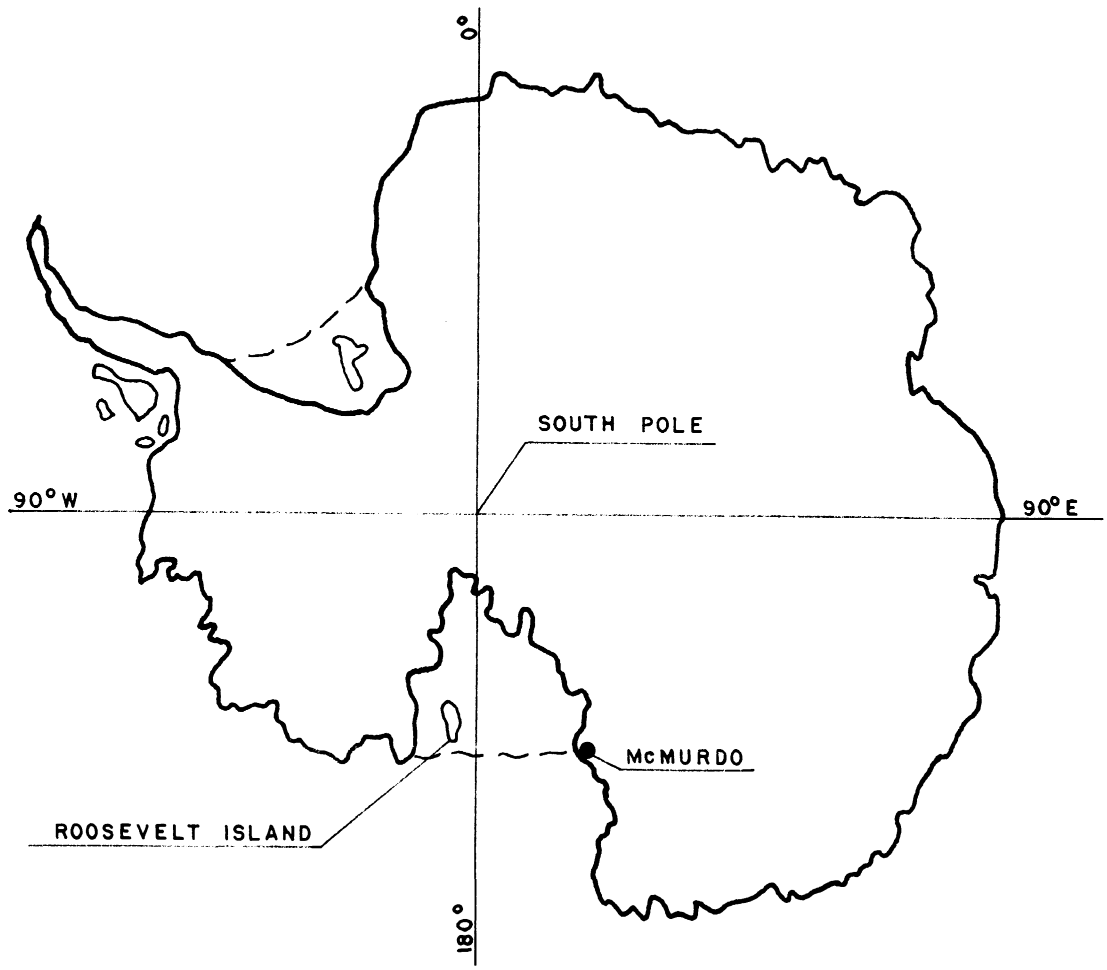
12. Weertman, J. 1961 "Equilibrium Profile of Ice Caps," Journal of Glaciology, Vol. 3, No. 30, p. 955.

13. Hofmann, Walther 1961 "Tellurometer Measurements on the Greenland Ice Cap During the International Glaciological Greenland Expedition (EGIG) Summer 1959," Publication No. 54 of the I.A.S.H. Snow and Ice Commission, pp. 469-475.

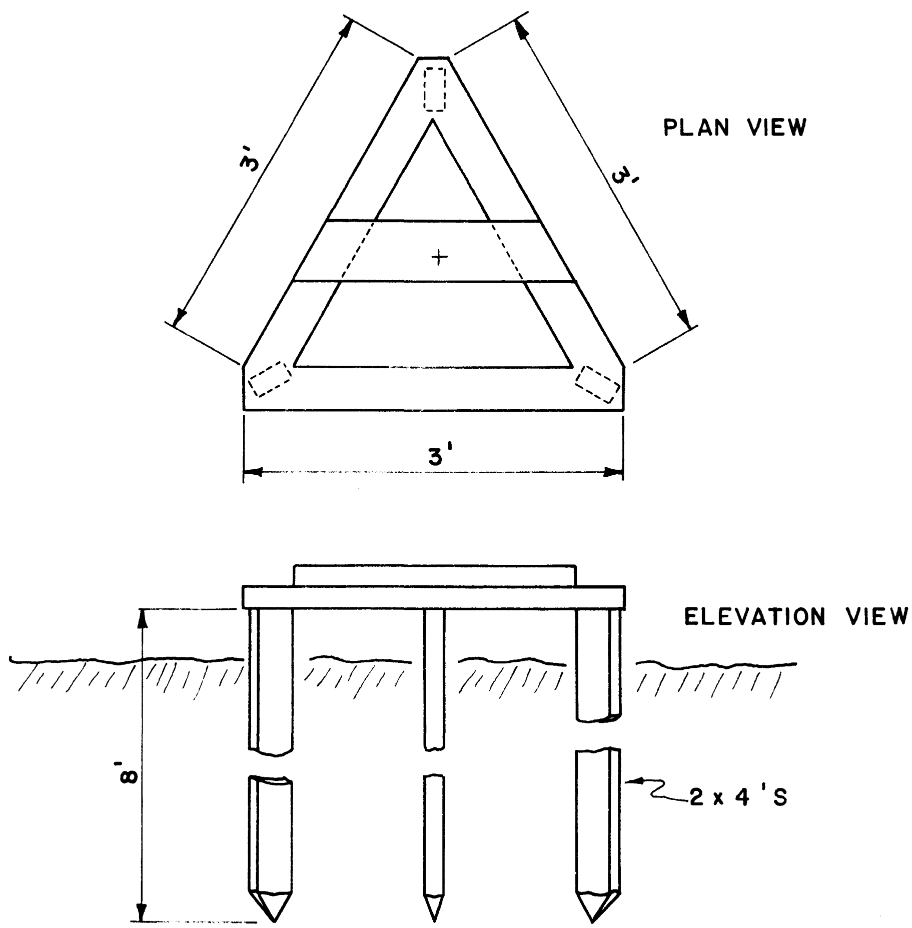
14. Ibid.

15. Laurila, S. 1960 Electronic Surveying and Mapping, Columbus: The Ohio State University, p. 228.

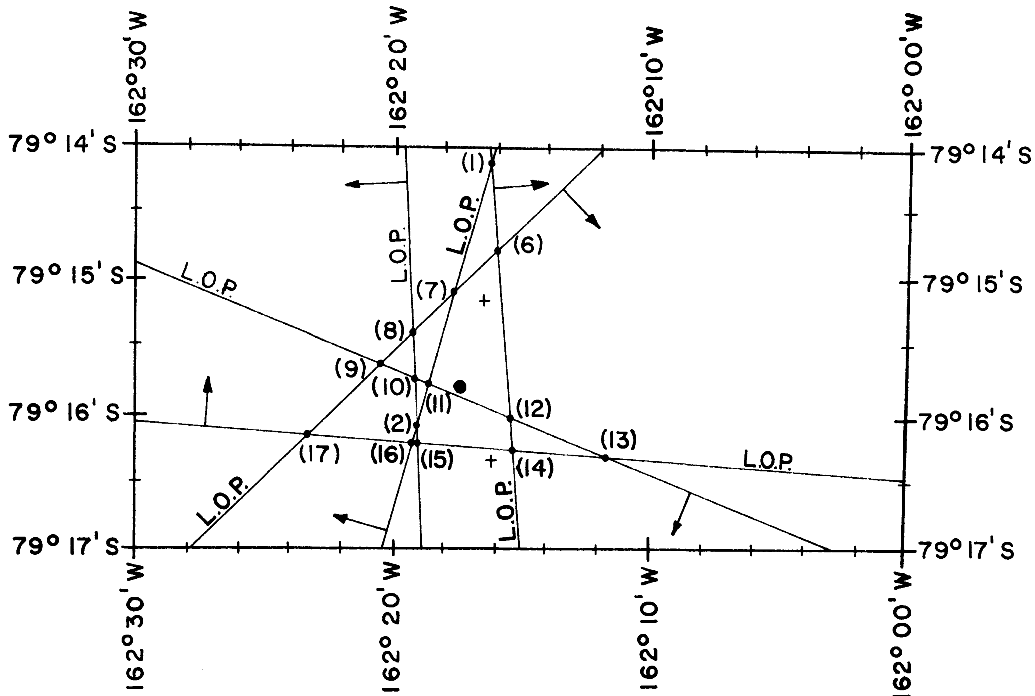
16. Operators' Manual for the Operation and Part I Maintenance of the Tellurometer Micro-Distancer Model MRA2 (Tellurometer Limited, Cape Town, Union of South Africa).



ANTARCTICA
FIGURE I



CONSTRUCTION OF POINT SUSAN
FIGURE 2

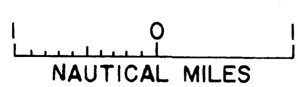


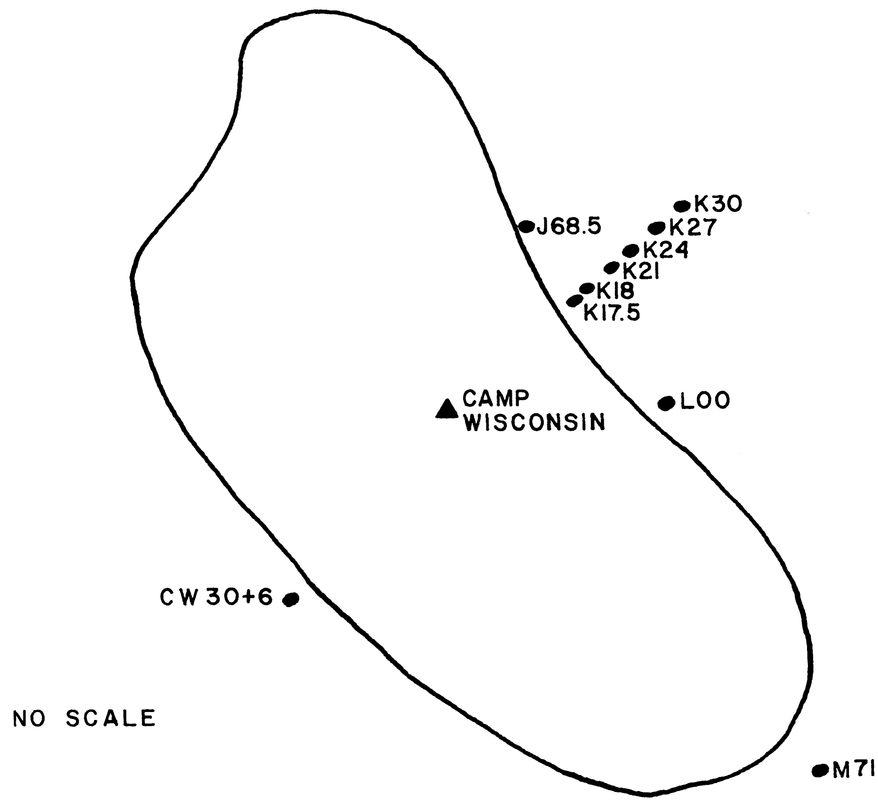
LOCATION OF POINT SUSAN
FIGURE 3

KEY

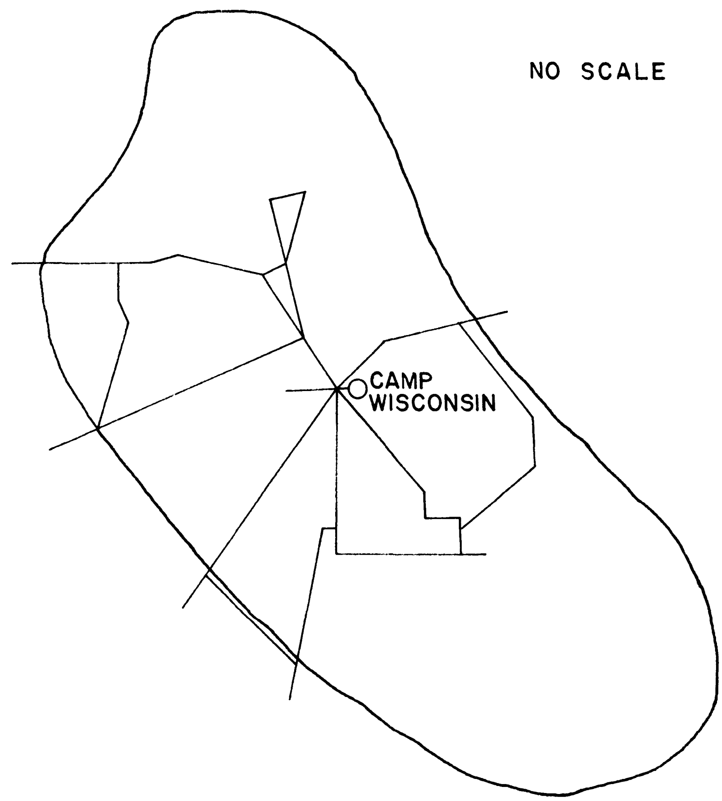
• INTERSECTION OF L.O.P.
+ FIX FROM SUN PROFILE
● AVERAGE POSITION
↓ DIRECTION OF SUN

AVERAGE POSITION=
79° 15.8'S ± 0.4'
162° 17.5'W ± 1.7'

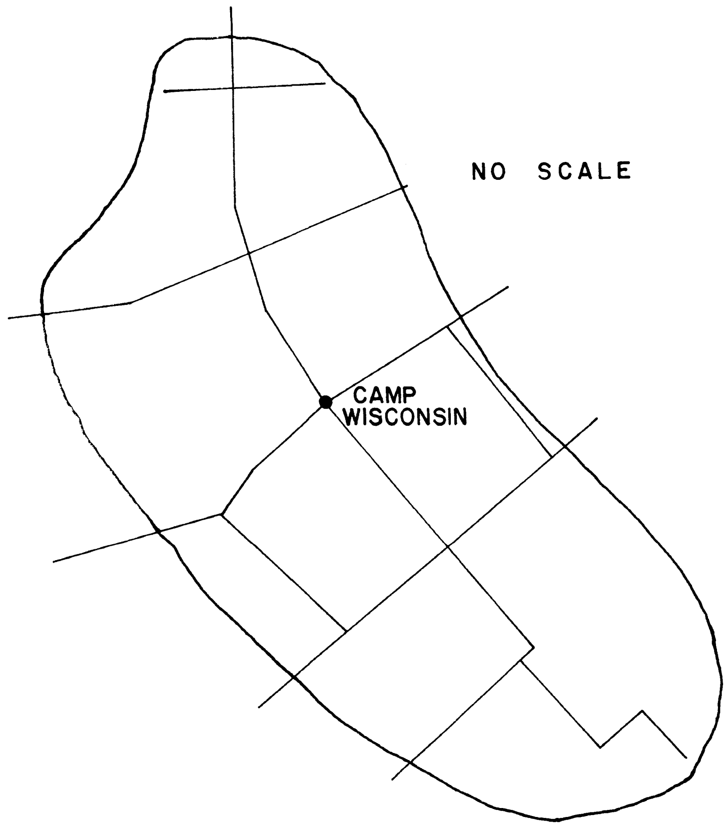




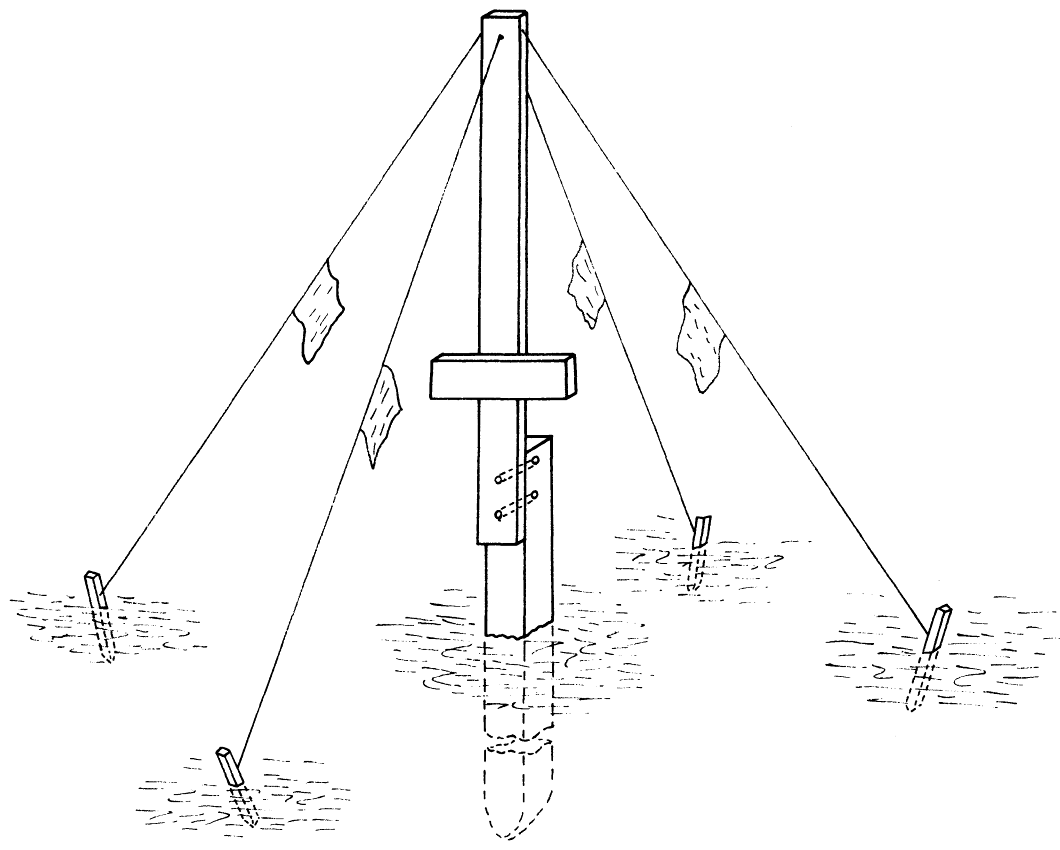
LOCATION OF POINTS USED FOR
SEISMIC TIE TO SEA LEVEL
FIGURE 4



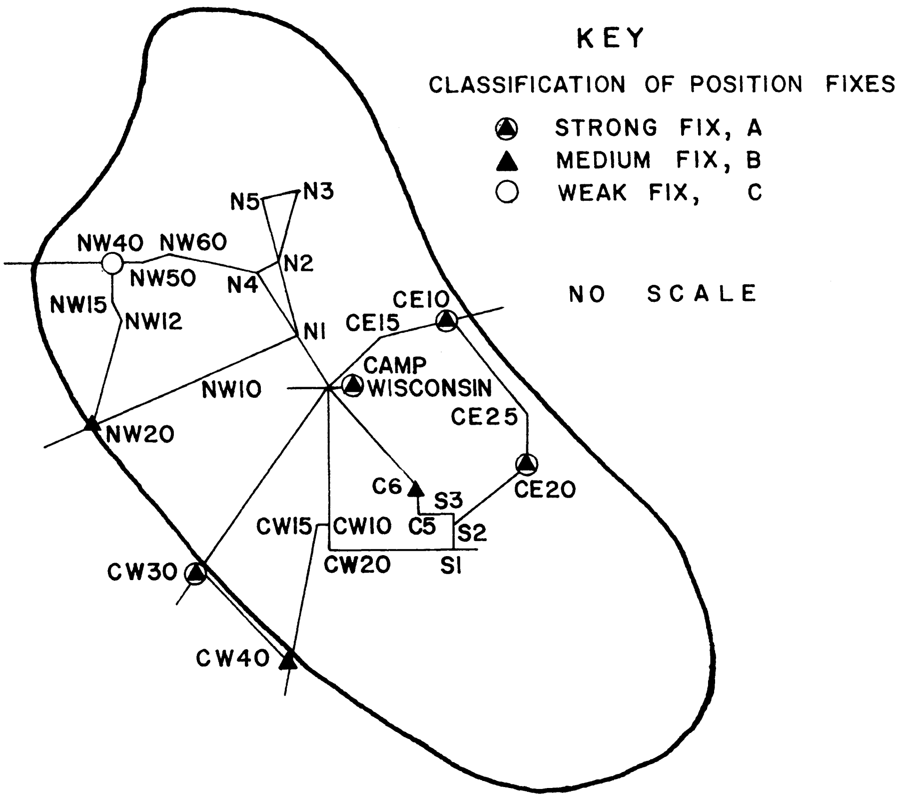
1961 – 1962 RECONNAISSANCE TRAVERSES
FIGURE 5



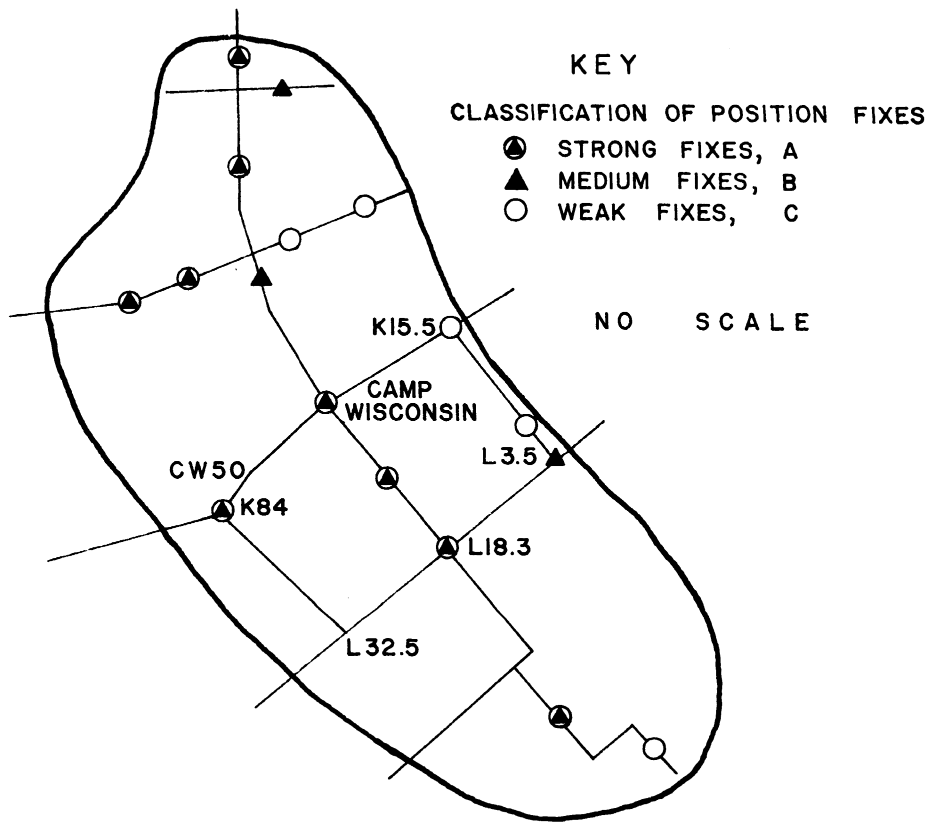
GEOPHYSICAL TRAVERSES, 1961-62-63
FIGURE 6



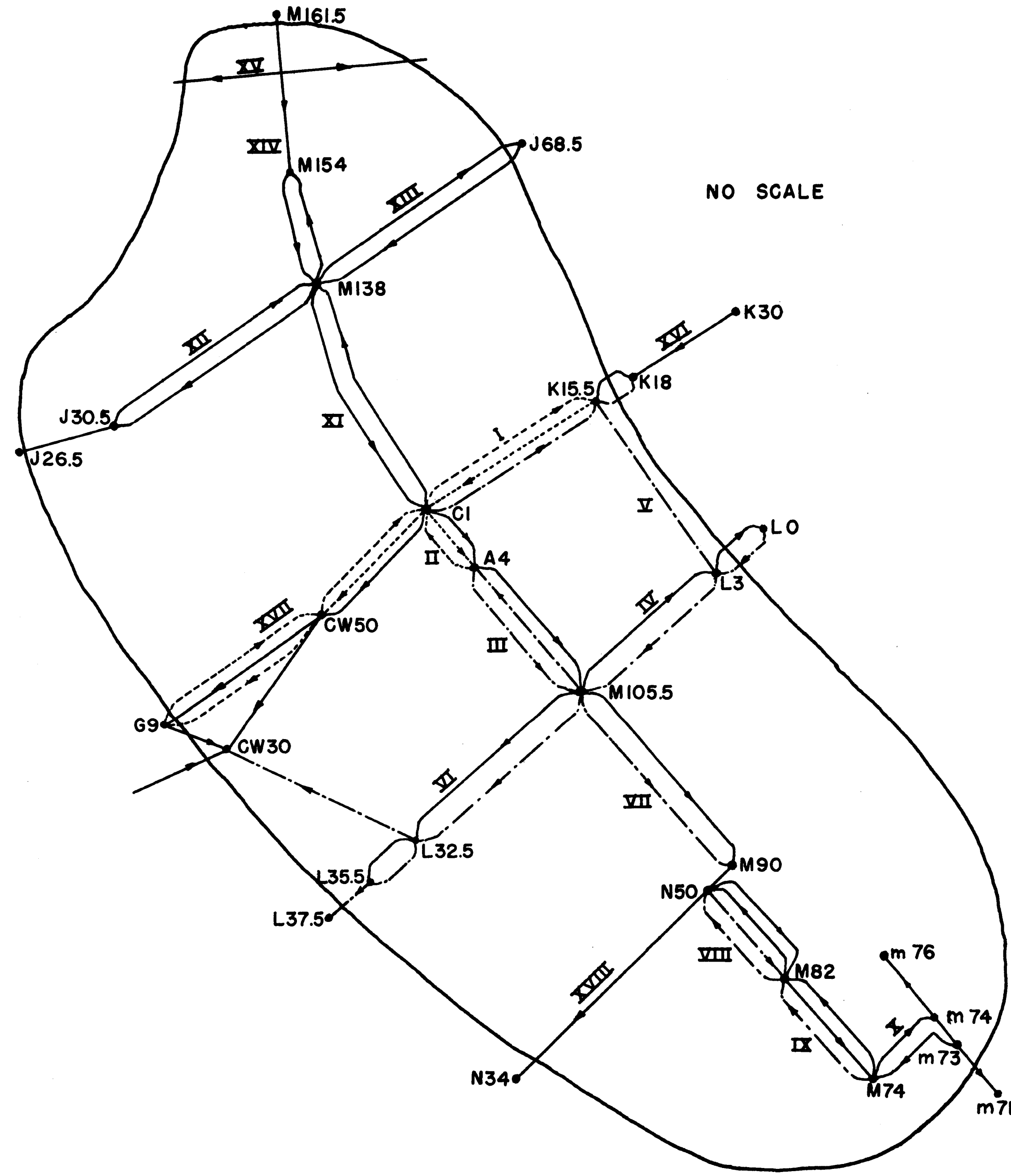
REFERENCE POINT
FIGURE 7



FIXES ON RECONNAISSANCE TRAVERSES
FIGURE 8



FIXES ON GEOPHYSICAL TRAVERSES
FIGURE 9



VERTICAL CONTROL LOOPS ON ROOSEVELT ISLAND
FIGURE 10

KEY

—·— ALTIMETER READINGS 1961-62

—— ALTIMETER READINGS 1962-63

------ LEVELED 1961-62-63

• TRAVERSE STATIONS

XXX LINE NUMBER

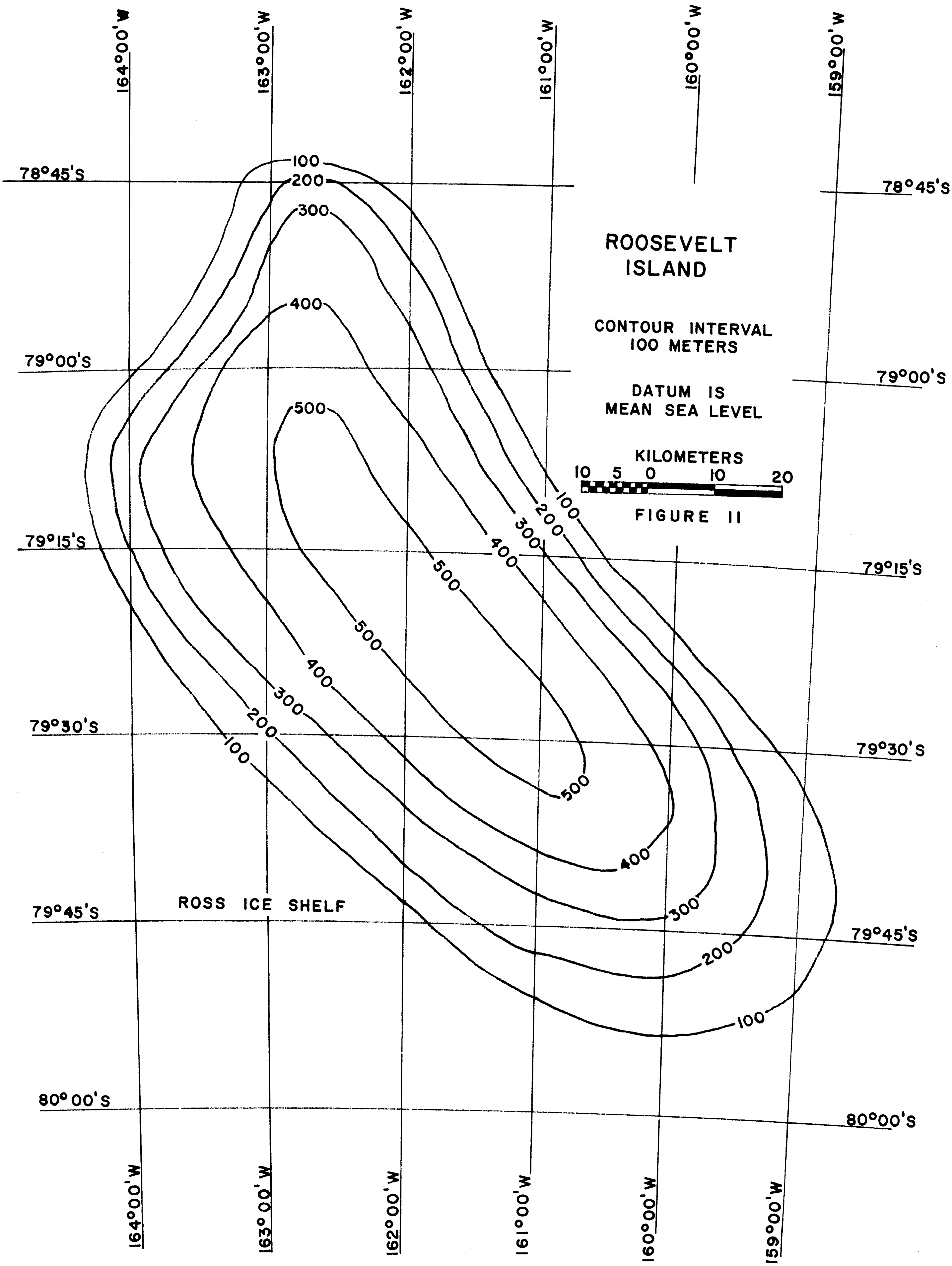
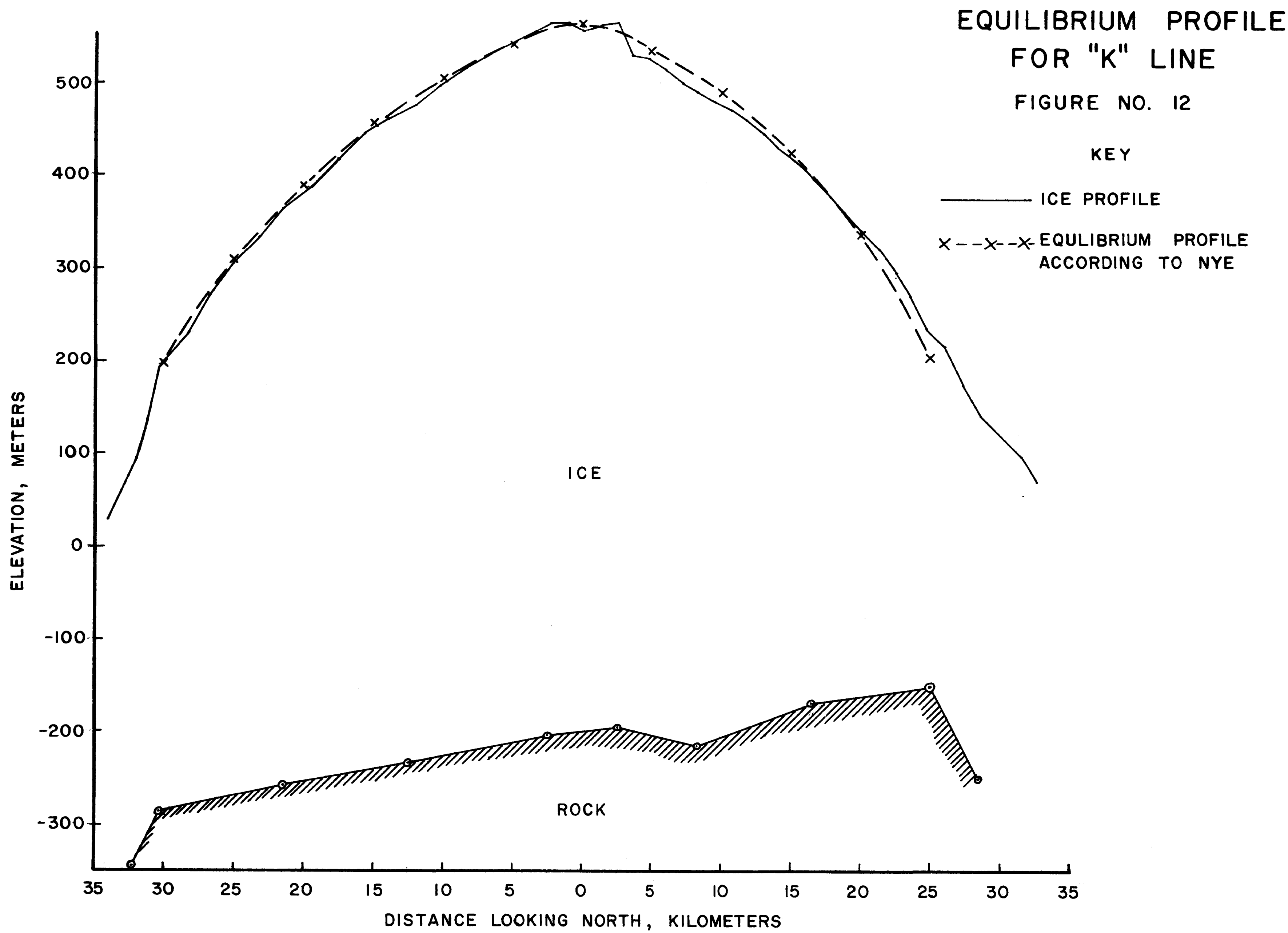

164°00'W
163°00'W
162°00'W
161°00'W
160°00'W
159°00'W
78°45'S
79°00'S
79°15'S
79°30'S
79°45'S
80°00'S
100
200
300
400
500
ROOSEVELT ISLAND
CONTOUR INTERVAL 100 METERS
DATUM IS MEAN SEA LEVEL
KILOMETERS
10 5 0 10 20
ROSS ICE SHELF

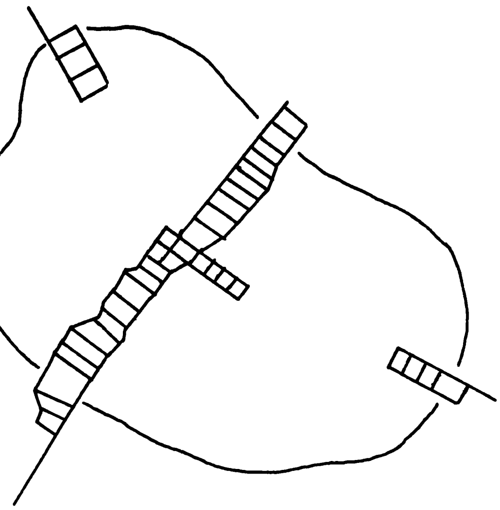
FIGURE 11



EQUILIBRIUM PROFILE
FOR "K" LINE
FIGURE NO. 12
KEY
ICE PROFILE
EQULIBRIUM PROFILE ACCORDING TO NYE
ICE
ROCK
ELEVATION, METERS
500
400
300
200
100
0
-100
-200
-300
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
DISTANCE LOOKING NORTH, KILOMETERS

SYSTEM OF QUADRILATERALS ROOSEVELT ISLAND

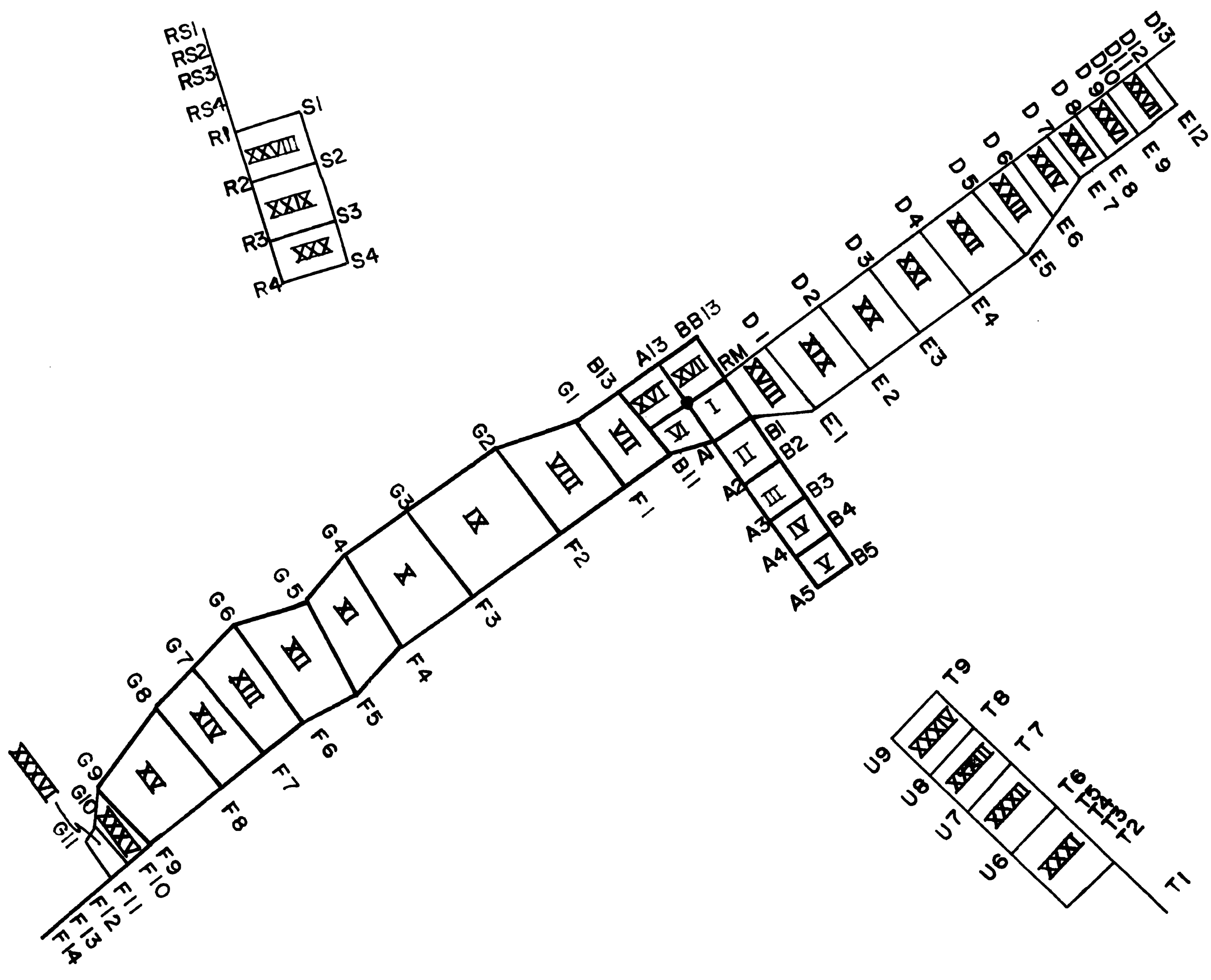
FIGURE 13



KEY

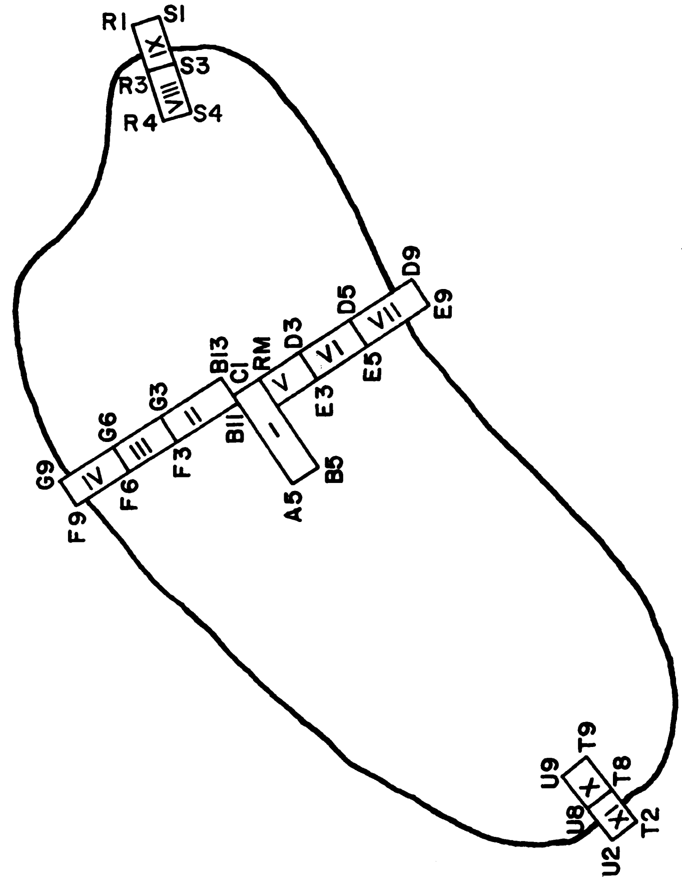
- ● POINT SUSAN
- XXXX QUADRILATERAL NUMBERS
- A9 REFERENCE POINTS
- ▬ QUADRILATERALS SURVEYED IN BOTH 1961-62 AND 1962-63 SEASONS
- — QUADRILATERALS SURVEYED IN 1962-63 SEASON

NO SCALE



TRANSPORTATION ON LEVELING OPERATION

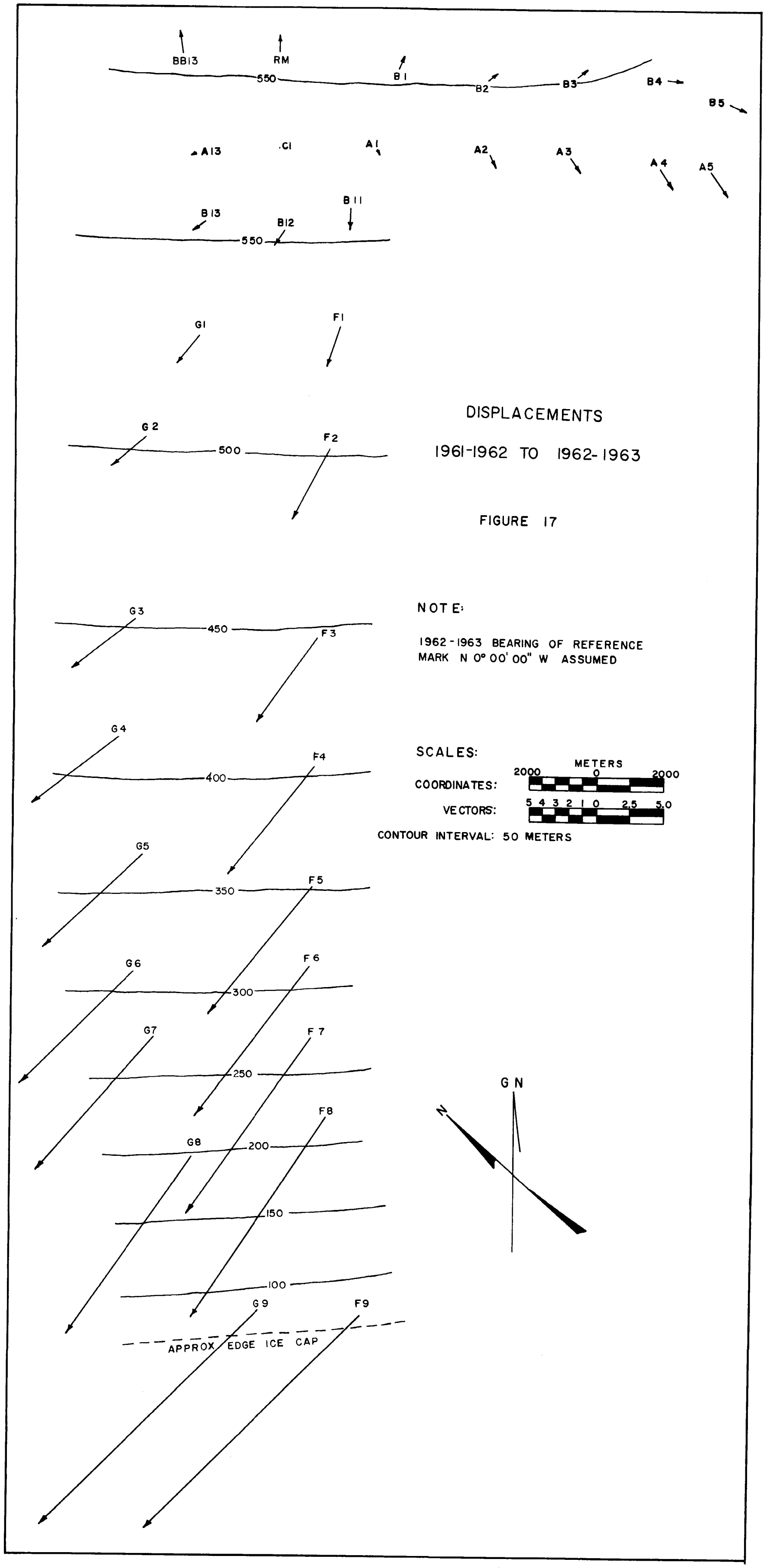
Figure 14

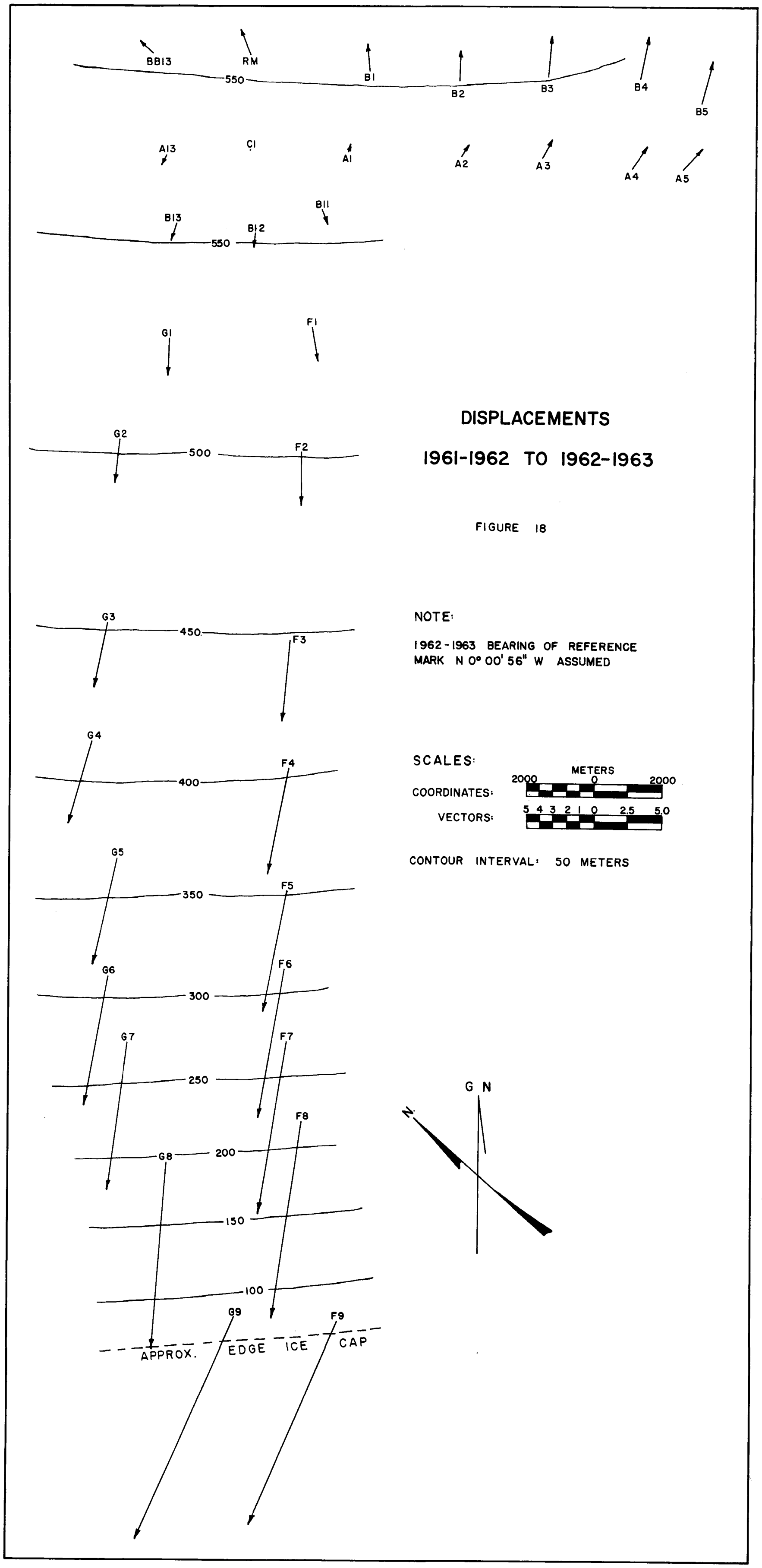


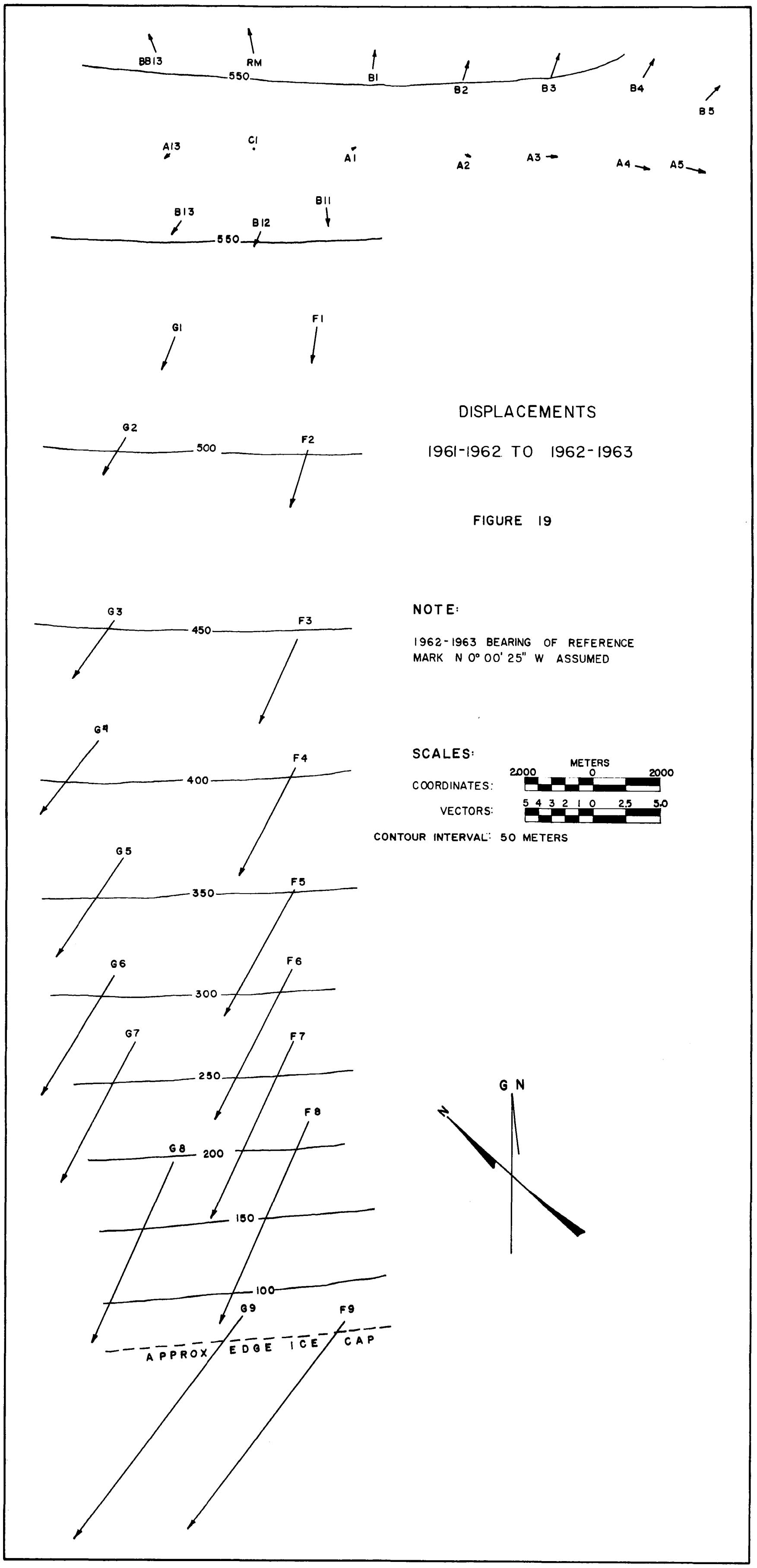
LEVEL LOOPS ON STRAIN NET
FIGURE 15

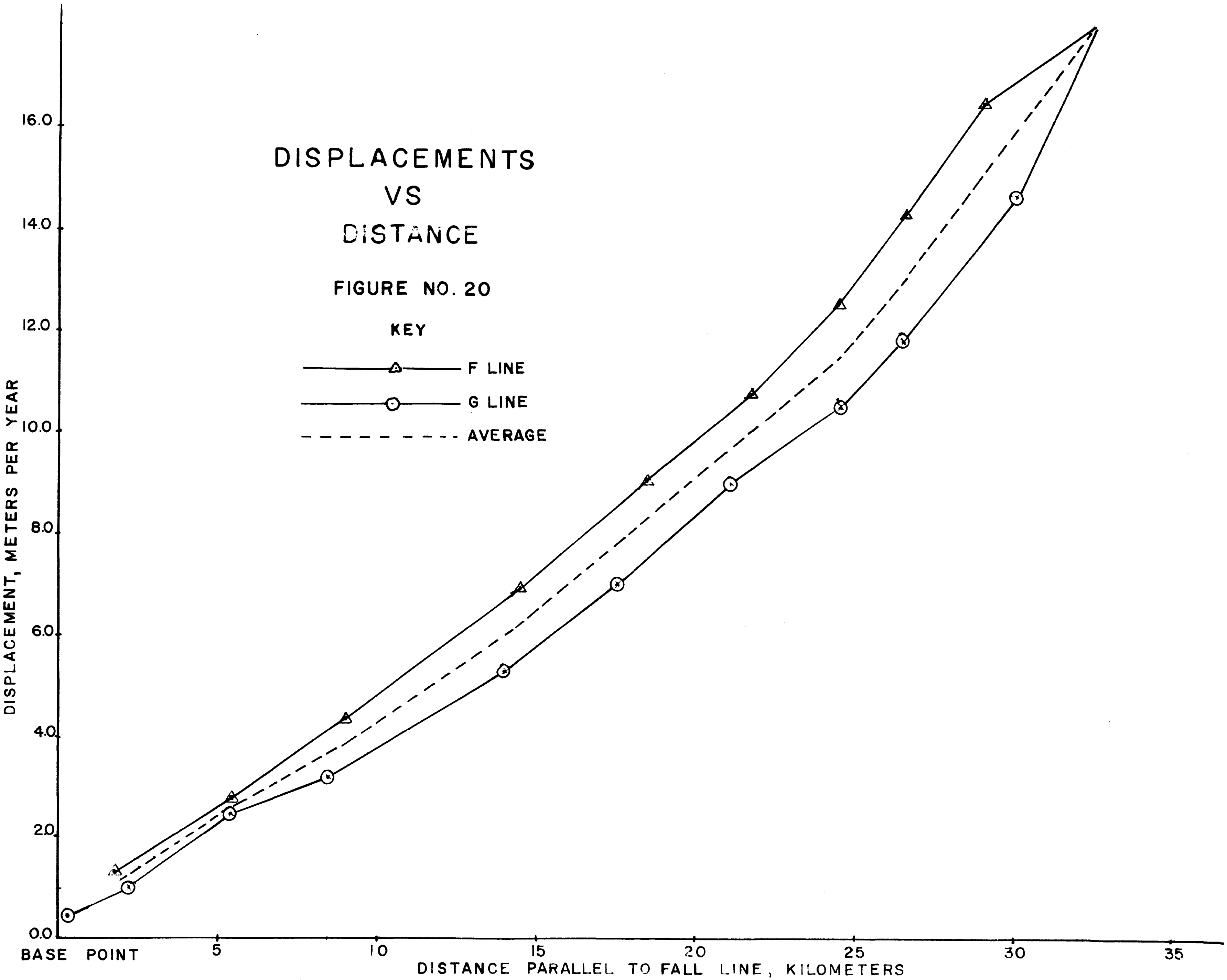
OCCUPYING CONTROL POINT

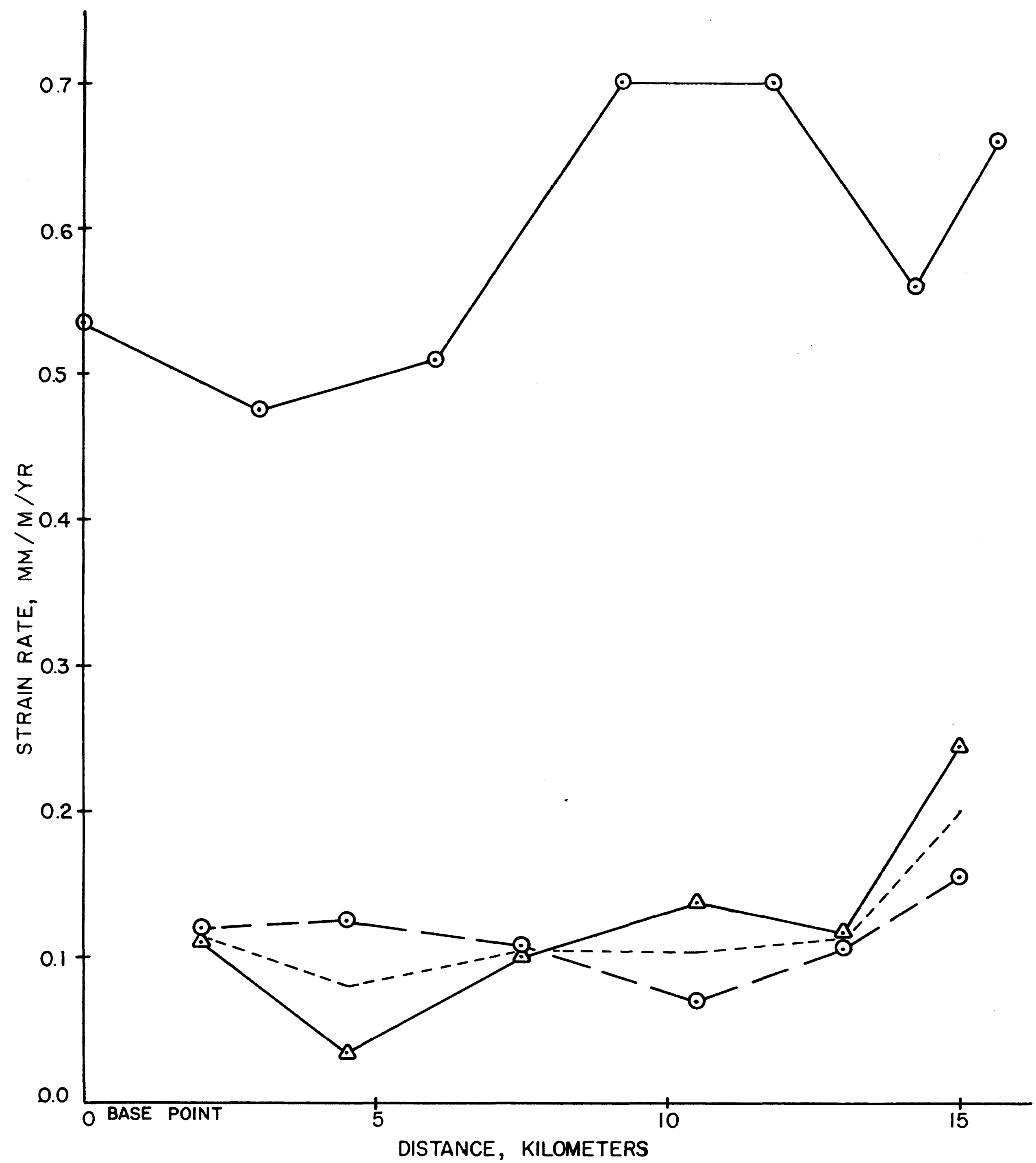
Figure 16


DISPLACEMENTS
1961-1962 TO 1962-1963
FIGURE 17
NOTE:
1962-1963 BEARING OF REFERENCE MARK N 0° 00' 00" W ASSUMED
SCALES:
METERS
2000 0 2000
COORDINATES:
VECTORS:
5 4 3 2 1 0 2.5 5.0
CONTOUR INTERVAL: 50 METERS
GN
N
BB13
RM
B1
B2
B3
B4
B5
550
A13
C1
A1
A2
A3
A4
A5
B13
B12
B11
G1
F1
G2
F2
500
G3
F3
450
G4
F4
400
G5
F5
350
G6
F6
300
G7
F7
250
G8
F8
200
150
100
G9
F9
APPROX EDGE ICE CAP


BB13
RM
B1
B2
B3
B4
B5
550
A13
C1
A1
A2
A3
A4
A5
B13
B12
B11
550
G1
F1
DISPLACEMENTS
1961-1962 TO 1962-1963
FIGURE 18
G2
F2
500
G3
F3
450
NOTE:
1962-1963 BEARING OF REFERENCE MARK N 0° 00' 56" W ASSUMED
G4
F4
400
SCALES:
METERS
2000 0 2000
COORDINATES:
VECTORS:
5 4 3 2 1 0 2.5 5.0
CONTOUR INTERVAL: 50 METERS
G5
F5
350
G6
F6
300
G7
F7
250
F8
G8
200
150
100
G9
F9
APPROX. EDGE ICE CAP
G N
N


BB13
RM
550
B1
B2
B3
B4
B5
A13
C1
A1
A2
A3
A4
A5
B13
B12
B11
550
G1
F1
DISPLACEMENTS
1961-1962 TO 1962-1963
FIGURE 19
G2
500
F2
G3
450
F3
NOTE:
1962-1963 BEARING OF REFERENCE MARK N 0° 00' 25" W ASSUMED
G4
400
F4
SCALES:
METERS
2000 0 2000
COORDINATES:
5 4 3 2 1 0 2.5 5.0
VECTORS:
CONTOUR INTERVAL: 50 METERS
G5
350
F5
G6
300
F6
G7
250
F7
F8
G8
200
150
100
G9
F9
APPROX EDGE ICE CAP
G N
N


DISPLACEMENTS
VS
DISTANCE
FIGURE NO. 20
KEY
F LINE
G LINE
AVERAGE
DISPLACEMENT, METERS PER YEAR
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
BASE POINT
5
10
15
20
25
30
35
DISTANCE PARALLEL TO FALL LINE, KILOMETERS



STRAIN RATES VS DISTANCE

A – B LINES

FIGURE NO. 21

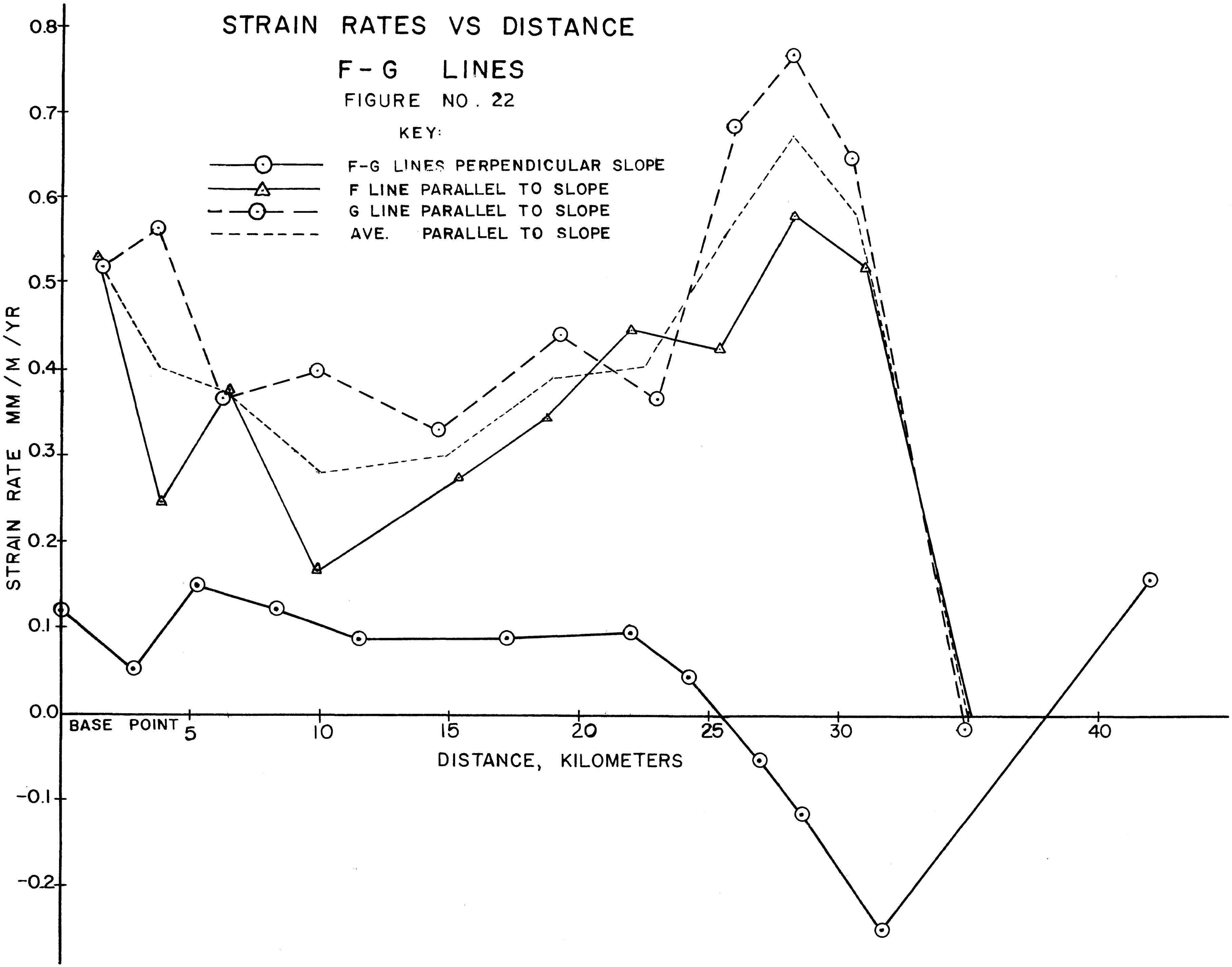

STRAIN RATES VS DISTANCE
F-G LINES
FIGURE NO. 22
KEY:
F-G LINES PERPENDICULAR SLOPE
F LINE PARALLEL TO SLOPE
G LINE PARALLEL TO SLOPE
AVE. PARALLEL TO SLOPE
STRAIN RATE MM / M / YR
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
BASE POINT
5
10
15
20
25
30
40
DISTANCE, KILOMETERS

TABLE I

POSITION FIXES AT POINT SUSAN

Fix No.	Latitude	Longitude
1	79°14.2'S	162°16.3'W
2	79°15.8'S	162°18.5'W
3	79°16.0'S	162°15.2'W
4	79°15.2'S	162°16.5'W
5	79°16.4'S	162°16.3'W
6	79°14.8'S	162°15.9'W
7	79°15.2'S	162°17.8'W
9	79°15.7'S	162°20.4'W
10	79°15.8'S	162°19.1'W
11	79°15.9'S	162°18.5'W
12	79°16.0'S	162°15.3'W
13	79°16.3'S	162°12.0'W
14	79°16.3'S	162°15.2'W
15	79°16.3'S	162°18.8'W
16	79°16.2'S	162°19.2'W
17	79°16.2'S	162°23.1'W
Ave.	79° 15.8' S ± 0.4'	162° 17.5' W ± 1.7'

TABLE II

ELEVATION AT POINT SUSAN BY ALTIMETRY

Field Station	Field Station Elevation Meters	Difference in Elevation to Point Susan Meters	Elevation of Point Susan Meters
Little America V	43	+512	555
Little America III	28	+523	551
		Average	553

TABLE III

ELEVATION OF POINT SUSAN FROM SEISMIC STUDIES

Seismic Point	Ice Thickness Meters	Ice Density	Calculated Elevation of Seismic Point above Sea Level Meters	Difference in Elevation to Point Susan Meters	Elevation of Point Susan Meters
K17.5	470	0.857	67	500	567
K18	444	0.858	63	502	565
K21	476	0.859	67	499	566
K24	499	0.862	69	494	563
K27	517	0.861	72	490	562
K30	505	0.861	70	489	559
L0.0	330	0.845	51	493	544
J68.5	430	0.856	62	498	560
M71	569	0.866	76	490	566
CW30 + 6	354	0.850	53	503	556

Average Elevation of Point Susan = 563 ± 3.5 meters

TABLE IV

AZIMUTH OF REFERENCE LINE

Observation		Azimuth of Reference Line with Respect to North
1		48°46'
2		48°37'
3		48°54'
4		48°41'
5		48°49'
6		48°45'
7		48°52'
8		48°44'
	Average	48°46' ± 3.5'

TABLE V

ODOMETER CALIBRATION CHECKS

From Point	To Point	Indicated Odometer Distance Meters	Tellurometer Distance Meters	Error in Meters	Precision
Susan	A1	2,900	2,896	-4	1/725
A1	A2	3,330	3,330	0	- - -
A2	A3	2,350	2,385	+35	1/68
A3	A4	2,680	2,679	-1	1/2,700
A4	A5	1,500	1,506	+6	1/250
M160	M160.5	860	857	-3	1/287
M160	M160.5	852	857	+5	1/171
M160	M161	1,683	1,707	+24	1/70
M160	M161	1,689	1,707	+18	1/95
M160	M161.5	2,511	2,474	-37	1/67
Susan	R.M.	2,806	2,805	-1	1/2,800
Susan	R.M.	2,844	2,805	-39	1/72

TABLE VI

HORIZONTAL CLOSURE OF GEOPHYSICAL TRAVERSES

	Loop	Perimeter Distance Meters	Error Closure Meters	Vector	Precision
1.	Susan-RM-K15.5-L3.5-L18.5-A5-Susan	111,452	1457	N 57 22 E	1/80
2.	Susan-CW50-K84-L32.5-L18.3-A5-Susan	116,440	457	S 59 34 E	1/255
3.	Susan-CE15-CE10-CE25-CE20-S2-S3-C5-C6-Susan	108,624	877	S 48 19 E	1/124
4.	Susan-CW20-S1-S3-C5-C6-Susan	97,786	1303	N 28 49 E	1/75
5.	Susan-CW30-CW40-CW15-CW10-Susan	93,669	1077	N 21 22 W	1/87
6.	N1-NW20-NW10-NW15-NW40-NW50-NW60-N4-N1	80,450	562	S 48 17 W	1/143
	Average	101,400	956		1/127

TABLE VII

ANALYSIS OF ALTIMETER ELEVATIONS

Loop	Description	Distance Kilometers	Number Stations	Vertical Error Closure Meters	Error per Station Meters	Error per Kilometer Meters	Probable Error per Observation Meters
II	Susan-A4	23.4	12	0.5	0.05	0.02	0.21
III	A5-M105.5	32.0	22	2.2	0.10	0.07	0.47
IV	Susan-K15.5-L3.5	76.5	62	8.5	0.14	0.11	0.25
VI	Susan-K84-L32.5-M105.5	79.0	61	6.3	1.10	0.08	0.37
VII	M105.5-M90	52.0	36	3.4	0.10	0.07	0.20
VIII	M90-M82	29.4	22	1.6	0.08	0.05	1.00
IX	M82-M74	28.0	20	10.2	0.51	0.36	0.97
X	M74-NE1	10.0	20	4.3	0.22	0.43	0.56
XI	Susan-M154	92.6	62	8.5	0.14	0.09	0.42
XII	M138-J30.5	62.0	42	1.1	0.03	0.02	0.31
XIII	M138-J68.5	66.0	42	8.0	0.19	0.12	0.41
	Average	50.1	36	5.0	0.15	0.10	0.47

TABLE VIII

ANALYSIS OF ALTIMETRY VS. LEVELS

Station	No. Station from Susan	Kilometers from last Station	Difference in Elev. by Levels	Difference in Elev. by Altimeter	Error	Error per Station	Error per Kilometer	Probable Error per Observation
K2	3	6.4	-46.3	-47.9	+1.6	+0.53	+0.25	
K5	6	5.3	-57.2	-58.3	+1.1	+0.37	+0.21	
K7	8	3.7	-41.9	-43.9	+2.0	+1.00	+0.54	
K10	11	5.4	-80.9	-81.1	+0.2	+0.07	+0.04	
K12	13	3.6	-67.0	-66.6	-0.4	-0.20	-0.01	
K14	16	3.6	-81.7	-84.0	+2.3	-0.77	+0.63	
K15	17	1.8	-53.3	-53.4	+0.1	-0.10	-0.06	
K15.5	18	0.9	-37.1	-36.8	-0.3	-0.30	-0.33	
A1	1	2.9	0.0	0.0	0.0	0.00	0.00	
A2	2	3.4	+ 0.6	+ 0.3	-0.3	-0.30	-0.01	
A3	3	2.3	+ 0.3	+ 0.7	-0.4	-0.40	-0.20	
A4	4	2.7	+ 0.2	+ 1.2	+1.0	+1.00	-0.37	
A5	5	1.5	- 0.3	- 0.7	-0.4	-0.40	-0.27	
	Average					0.42	0.22	±0.72

TABLE IX

HORIZONTAL AND VERTICAL CONTROL ON RECONNAISSANCE TRAVERSES

Station	Elevation Meters	P.E. in Elevation Meters	Latitude South	Longitude West
C-2	563.0	±1.2	79°20.2'	161°56'
C-3	562.3	1.4	79°23.1'	161.39'
C-4	556.3	2.5	79°27.0'	161.20'
S-1	535.0	3.0	79°30.7'	161.11'
CW-20	389.5	5.0	79°30.9'	162°18'
CW-30	101.5	3.0	79°29.3'	163.26'
CW-40	93.0	4.0	79°37.4'	162.37'
CW-50	395.0	2.2	79°23.1'	162.53'
CE-10	189.5	3.0	79°09.3'	160.56'
CE-20	289.5	3.5	79°20.4'	160.30'
N-1	565.0	3.5	79°07.0'	162.36'
N-2	530.5	4.0	79°06.0'	162°50'
N-3	494.5	4.5	79°01.8'	162.51'
NW-20	137.0	5.0	79°16.9'	164°01'
NW-30	125.5	5.5	79°06.1'	164°09'

TABLE X

HORIZONTAL AND VERTICAL CONTROL
FOR GEOPHYSICAL TRAVERSES

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
I	46	78°45.3'	163.23'	85.5	± 3.3
I	46.5	78°45.2'	163°20'	98.5	3.3
I	47	78°45.2'	163°18'	107.0	3.3
I	47.5	78°45.1'	163°15'	112.5	3.2
I	48	78°45.1'	163°13'	122.0	3.2
I	49	78°45.0'	163°09'	141.0	3.2
I	50 M159	78°44.8'	163°04'	144.5	3.1
I	51	78°44.7'	163°00'	146.5	3.2
I	52	78°44.6'	162°56'	156.5	3.2
I	53	78°44.5'	162.51'	167.0	3.2
I	54	78°44.5'	162°47'	167.0	3.3
I	54.35	78°44.5'	162°45'	167.0	3.3
I	54.70	78°44.4'	162°44'	169.0	3.3
I	55	78°44.4'	162°43'	165.0	3.4
I	55.5	78°44.3'	162°41'	161.5	3.4
I	56	78°44.3'	162°39'	157.0	3.4
I	56.5	78°44.2'	162°37'	145.5	3.5
I	57	78°44.2'	162°34'	133.0	3.5
S	S3	78°43.8'	162°59'	155.0	3.5
J	26.5	79°15.8'	164°16'	56.8	3.3
J	27	79°15.7'	164°14'	60.3	3.3
J	27.5	79°15.5'	164°12'	79.2	3.3
J	28	79°15.4'	164°09'	100.3	3.2
J	28.5	79°15.3'	164°07'	118.7	3.2
J	29	79°15.1'	164°05'	140.9	3.2
J	29.5	79°15.0'	164°03'	156.1	3.1
J	30	79°14.9'	164°02'	179.0	3.1
J	30.5	79°14.7'	163°58'	198.8	3.0
J	31	79°14.5'	163°57'	214.8	3.0
J	32	79°14.0'	163°53'	257.4	3.0
J	33	79°13.5'	163°49'	286.9	2.9
J	34	79°13.0'	163°45'	312.7	2.9
J	34.7	79°12.6'	163°42'	330.7	2.8
J	35	79°12.4'	163°41'	----	---
J	36	79°11.8'	163°38'	356.9	2.7
J	37	79°11.3'	163°34'	376.7	2.7
J	38	79°10.7'	163°30'	392.4	2.6
J	39	79°10.2'	163°26'	407.2	2.6
J	40	79°09.6'	163°22'	423.4	2.5

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
J	41	79°09.0'	163°19'	436.8	± 2.5
J	42	79°08.4'	163°15'	446.1	2.4
J	43	79°07.9'	163°11'	459.2	2.4
J	44	79°07.4'	163°07'	468.4	2.3
J	45	79°06.8'	163°04'	479.4	2.3
J	46	79°06.2'	163°00'	487.9	2.2
J	47	79°05.6'	162°56'	495.0	2.2
J	48	79°05.1'	162°52'	501.0	2.1
J	49	79°04.5'	162°49'	504.6	2.1
J	50-M138	79°03.9'	162°46'	508.0	2.0
J	51	79°03.3'	162°41'	505.7	2.1
J	52	79°02.7'	162°37'	500.0	2.1
J	53	79°02.1'	162°32'	486.3	2.2
J	54	79°01.6'	162°29'	471.8	2.2
J	55	79°01.1'	162°24'	454.5	2.3
J	56	79°00.5'	162°20'	437.8	2.3
J	57	78°59.9'	162°16'	418.2	2.4
J	58	78°59.5'	162°12'	395.8	2.4
J	59	78°58.9'	162°08'	375.3	2.5
J	60	78°58.2'	162°04'	351.1	2.5
J	61	78°57.7'	162°00'	322.9	2.6
J	62	78°57.1'	161°56'	293.2	2.6
J	63	78°56.6'	161°61'	263.3	2.7
J	64	78°55.9'	161°47'	226.7	2.7
J	65	78°55.3'	161°42'	180.3	2.8
J	66	78°54.7'	161°38'	155.6	2.8
J	67	78°54.1'	161°34'	106.4	2.9
J	67.5	78°53.8'	161°32'	74.7	2.9
J	68	78°53.5'	161°30'	71.7	3.0
J	68.5	78°53.2'	161°27'	66.1	3.0
K	30	78°56.75'	160°05'	74.5	2.9
K	29	78°57.5'	160°10'	74.7	2.9
K	28	78°58.25	160°14'	73.8	2.8
K	27	78°58.75'	160°18'	73.3	2.8
K	26	78°59.5'	160°23'	72.7	2.7
K	25	79°00.0'	160°27'	71.1	2.7
K	24	79°00.75'	160°31	69.9	2.6
K	23	79°01.5'	160°36'	67.0	2.6
K	22	79°02.0'	160°40'	65.4	2.5
K	21	79°02.75'	160°44'	64.3	2.5

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
K	20	79°03.5'	160°49'	63.1	±2.4
K	19	79°04.0'	160°53'	61.6	2.4
K	18	79°04.75'	160°58'	62.2	2.3
K	17	79°05.5'	161°02'	65.7	2.3
K	16	79°06.0'	161°05'	65.4	2.2
K	15.5	79°06.25'	161°07'	98,5	2.2
K	15	79°06.5'	161°10'	134.7	2.1
K	14	79°07.0'	161°14'	188.0	2.1
K	13	79°07.25'	161°17'	226.6	2.0
K	12	79°08.25'	161°21'	269.7	2.0
K	11	79°08.75'	161°25'	304.5	1.9
K	10	79°09.5'	161°29'	336.7	1.9
K	9	79°10.0'	161°33'	364.1	1.8
K	8	79°10.5'	161°37'	388.9	1.7
K	7	79°11.0'	161°41'	417.6	1.6
K	6	79°11.5'	161°45'	445.1	1.5
K	5	79°12.25'	161°49'	459.5	1.4
K	4	79°13.0'	161°53'	478.9	1.3
K	3	79°13.5'	161°56'	497.7	1.2
K	2	79°14.0'	162°01'	516.7	1.1
K	1	79°14.5'	162°05'	530.8	0.8
K	Ref Mk	79°15.0'	162°09'	544.8	0.5
K	Susan	79°16.0'	162°15'	563.0	0.0
K	PP #2	79°16.0'	162°17'	564.5	0.5
K	60	79°16.0'	162°18'	558.5	0.8
K	61	79°16.2'	162°19'	560.5	1.1
K	62	79°16.6'	162°21'	561.5	1.2
K	63	79°17.1'	162°24'	534.0	1.3
K	64	79°17.6'	162°26'	524.0	1.4
K	65	79°18.0'	162°28'	513.0	1.5
K	66	79°18.5'	162°31'	502.0	1.6
K	67	79°19.0'	162°33'	489.5	1.7
K	68	79°19.5'	162°36'	481.5	1.8
K	69	79°20.0'	162°38'	470.0	1.9
K	70	79°20.4'	162°41'	459.5	1.9
K	71	79°20.9'	162°43'	446.0	2.0
K	72	79°21.4'	162°46'	432.0	2.0
K	73	79°21.8'	162°48'	416.0	2.1
K	74	79°22.3'	162°51'	401.0	2.1
K	CW50	79°22.7'	162°53'	395.0	2.2

TABLE X (cont)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
K	75	79°23.2'	162°55'	377.0	± 2.2
K	76	79°23.8'	162°57'	358.0	2.3
K	77	79°24.3'	162°59'	342.0	2.3
K	78	79°24.8'	163°02'	319.0	2.4
K	79	79°25.3'	163°04	296.0	2.4
K	80	79°25.8'	163°06'	269.0	2.5
K	81	79°26.3'	163°08'	236.0	2.5
K	82	79°26.8'	163°10'	215.0	2.6
K	83	79°27.3'	163°13'	174.0	2.6
K	84	79°27.9'	163°14'	142.0	2.7
K	CW30	79°29.3'	163°20'	101.5	3.0
K	M1	79°29.8'	163°25'	70.8	3.1
K	M2	79°30.3'	163°29'	61.3	3.2
K	M3	79°30.9'	163°34'	60.4	3.3
K	M4	79°31.5'	163°38'	57.8	3.4
K	M5	79°32.0'	163°42'	58.5	3.5
K	M6	79°32.6'	163°47'	60.9	3.6
K	M7	79°33.1'	163°52'	60.9	3.8
K	M8	79°33.6'	163°56'	59.5	4.0
K	M9	79°34.2'	164°01	59.5	4.2
K	M10	79°34.6'	164°05'	58.5	4.4
K	M11	79°35.2'	164°10'	59.5	4.6
K	M12	79°35.8'	164°15'	60.5	4.8
L	0.0	79°14.5'	160°08'	71.6	3.0
L	0.5	79°14.75'	160°10'	79.1	3.0
L	1.0	79°15.0'	160°12'	66.1	2.9
L	1.5	79°15.5'	160°13'	66.1	2.9
L	2.0	79°15.75'	160°15'	68.1	2.8
L	2.5	79°16.25'	160°17'	66.6	2.8
L	3.0	79°16.5'	160°19'	49.6	2.7
L	3.5	79°16.75'	160°21'	112.1	2.7
L	4.5	79°17.75'	160°25'	184.9	2.6
L	5.5	79°18.5'	160°29'	234.8	2.6
L	6.5	79°19.5'	160°33'	288.8	2.5
L	7.5	79°20.25'	160°37'	323.8	2.5
L	8.5	79°20.5'	160°39'	354.9	2.4
L	9.5	79°21.75'	160°42'	387.5	2.4
L	10.5	79°22.0'	160°46'	415.7	2.3

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
L	11.5	79°22.75'	160°50'	441.5	± 2.3
L	12.5	79°23.5'	160°53'	463.9	2.2
L	13.5	79°24.75'	160°57'	485.4	2.2
L	14.5	79°25.0'	161°01'	505.1	2.1
L	15.5	79°25.75'	161°04'	522.3	2.1
L	16.5	79°26.5'	161°08'	538.6	2.0
L	17.5	79°27.0'	161°11'	548.9	2.0
L	18	79°27.5'	161°13'	554.3	1.9
L	18.3	79°27.75'	161°15'	554.8	1.9
L	19	79°28.25'	161°17'	548.3	2.0
L	20	79°29.0	161°21'	535.8	2.0
L	21	79°29.75'	161°25'	519.8	2.1
L	22	79°30.5'	161°29'	503.3	2.1
L	23	79°31.25'	161°33'	484.8	2.2
L	24	79°31.75'	161°36'	466.3	2.2
L	25	79°32.5'	161°40'	447.3	2.3
L	26	79°33.25'	161°43'	424.3	2.3
L	27	79°34.0'	161°46'	400.3	2.4
L	28	79°34.75'	161°51'	360.3	2.4
L	28.5	79°35.0'	161°53'	354.8	2.5
L	29	79°35.5'	161°54'	339.8	2.5
L	29.5	79°35.75'	161°56'	311.8	2.6
L	30	79°36.0'	161°58'	301.3	2.6
L	30.5	79°36.5'	162°00'	285.8	2.7
L	31	79°36.75'	162°01'	276.3	2.7
L	32	79°37.25'	162°05'	246.3	2.8
L	32.5	79°37.75'	162°07'	229.3	2.8
L	33	79°38.0'	162°09'	213.3	2.9
L	34	79°38.75'	162°12'	203.8	2.9
L	35	79°39.5'	162°16	145.3	3.0
L	36	79°40.0'	162°20'	106.3	3.0
L	37	79°40.75'	162°24'	66.3	3.1
L	37.5	79°41.0'	162°26'	66.8	3.1
M	74	79°49.3'	159°08'	118.6	3.6
M	75	79°48.6'	159°13'	132.2	3.6
M	76	79°48.0'	159°17'	149.8	3.5
M	77	79°47.4'	159°21'	163.0	3.5
M	78	79°46.7'	159°25'	183.2	3.5

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
M	79	79°46.1'	159°29'	197.3	± 3.4
M	80	79°45.5'	159°33'	218.2	3.4
M	81	79°44.8'	159°37'	235.3	3.4
M	82	79°44.1'	159°41'	260.5	3.3
M	83	79°43.5'	159°46'	285.7	3.3
M	84	79°42.7'	159°51'	308.3	3.2
M	85	79°42.0'	159°55'	329.1	3.2
M	86	79°41.4'	160°00'	348.6	3.1
M	87	79°40.6'	160°04'	366.2	3.1
M	88	79°39.9'	160°08'	384.4	3.1
M	89	79°39.2'	160°13'	402.1	3.0
M	90A	79°38.5'	160°17'	417.6	3.0
M	90	79°37.8'	160°14'	408.6	2.9
M	91	79°37.2'	160°18'	412.9	2.9
M	92	79°36.5'	160°21'	433.3	2.8
M	92.1	79°36.4'	160°22'	437.9	2.8
M	93	79°35.75'	160°26'	449.6	2.7
M	94	79°35.25'	160°30'	461.1	2.7
M	95	79°34.5'	160°34'	473.8	2.6
M	96	79°34.0'	160°38'	486.6	2.6
M	97	79°33.25'	160°42'	496.2	2.5
M	98	79°32.75'	160°46'	507.1	2.5
M	99	79°32.0'	160°50'	515.1	2.4
M	100	79°31.0'	160°50'	521.3	2.4
M	100.5	79°31.25'	160°55'	525.7	2.3
M	101.5	79°30.5'	160°59'	533.7	2.2
M	102.5	79°29.75'	161°03'	540.9	2.2
M	103.5	79°29.25'	161°07'	546.5	2.1
M	104.5	79°28.5'	161°11'	550.8	2.0
M	105.5	79°27.75'	161°15'	554.8	1.9
M	106.5	79°27.0'	161°18'	555.3	1.9
M	107.5	79°26.25'	161°22'	558.3	1.8
M	108.5	79°25.5'	161°26'	560.3	1.8
M	109.5	79°24.75'	161°29.5'	549.8	1.7
M	110.5	79°24.25'	161°33'	560.8	1.6
M	111.5	79°23.5'	161°37'	562.3	1.5
M	C3	79°23.0'	161°39'	562.3	1.4
M	112.5	79°22.5'	161°41'	565.3	1.3
M	113.5	79°21.75'	161°44'	561.8	1.2
M	A5	79°21.0'	161°49'	563.8	1.1

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
M	A4	79°20.25'	161°54'	564.1	± 1.0
M	A3	79°19.5'	161°58'	563.9	0.8
M	A2	79°18.25'	162°02'	563.6	0.7
M	A1	79°17.25'	162°09'	562.7	0.5
M	123	79°16.0'	162°15'	563.0	0.0
M	124	79°15.3'	162°17'	562.0	0.5
M	125	79°14.5'	162°19'	560.5	0.7
M	126	79°13.7'	162°22'	559.0	0.8
M	127	79°13.0'	162°25'	558.0	1.0
M	128	79°12.2'	162°27'	557.5	1.1
M	129	79°11.4'	162°29'	557.0	1.2
M	130	79°10.6'	162°32'	555.5	1.3
M	131	79°09.9'	162°34'	554.0	1.4
M	132	79°09.2'	162°36'	553.0	1.5
M	132.1	79°09.1'	162°36.5'	-----	---
M	133	79°08.3'	162°38'	548.0	1.6
M	134	79°07.4'	162°39'	542.0	1.7
M	135	79°06.5'	162°40.5'	524.5	1.8
M	135.5	79°06.1'	162°41'	531.0	---
M	136	79°05.6'	162°43'	526.0	1.9
M	137	79°04.8'	162°44'	517.0	2.0
M	138	79°03.9'	162°46'	508.0	2.0
M	139	79°03.0'	162°48'	496.0	2.1
M	140	79°02.1'	162°49'	486.0	2.1
M	141	79°01.3'	162°51'	474.0	2.2
M	142	79°00.4'	162°52'	464.5	2.2
M	143	78°59.5'	162°54'	454.5	2.3
M	143.5	78°59.0'	162°54.5'	-----	---
M	144	78°58.6'	162°55'	443.5	2.3
M	145	78°57.7'	162°55.5	434.5	2.4
M	146	78°56.8'	162°56'	424.5	2.4
M	147	78°55.9'	162°56.5'	412.5	2.5
M	148	78°55.0'	162°57'	398.0	2.5
M	149	78°54.0'	162°58'	383.5	2.6
M	150	78°53.1'	162°58.5'	368.0	2.6
M	151	78°52.2'	162°59'	349.5	2.7
M	152	78°51.3'	163°00'	331.0	2.7
M	153	78°50.3'	163°01'	314.0	2.8
M	154	78°49.4'	163°01.5'	295.0	2.8
M	155	78°48.5'	163°02'	272.0	2.9

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
M	156	78°47.6'	163°02.5'	238.0	± 2.9
M	157	78°47.7'	163°03'	218.5	3.0
M	158	78°45.7'	163°03.5'	185.0	3.0
M	159	78°44.8'	163°04'	144.5	3.1
M	159.5	78°44.4'	163°04.5'	121.0	3.1
M	160	78°43.9'	163°05'	96.0	3.1
M	160.5	78°43.3'	163°04.5'	55.5	3.2
M	161	78°42.9'	163°04'	51.0	3.2
M	161.5	78°42.4'	163°03.5'	42.0	3.3
N	50	79°38.5'	160°17'	417.9	3.0
N	49	79°39.2'	160°21'	413.7	3.1
N	48	79°40.0'	160°24'	401.0	3.2
N	47	79°40.7'	160°28'	384.3	3.3
N	46	79°41.5'	160°32'	362.0	3.4
N	45	79°42.2'	160°35'	335.0	3.5
N	44	79°43.0'	160°39'	318.5	3.6
N	43	79°43.7'	160°43'	297.9	3.7
N	42	79°44.5'	160°46'	276.9	3.8
N	41	79°45.2'	160°50'	259.4	3.9
N	40	79°45.9'	160°54'	234.4	4.0
N	39	79°46.7'	160°58'	216.1	4.1
N	38	79°47.4'	161°02'	184.6	4.2
N	37	79°48.1'	161°05'	159.4	4.3
N	36	79°48.8'	161°09'	132.6	4.4
N	35	79°49.5'	161°13'	100.4	4.5
N	34	79°50.2'	161°17'	61.4	4.6
O	L32.5	79°37.75'	162°07'	229.3	2.8
O	1	79°37.1'	162°11'	219.0	3.0
O	2	79°36.5'	162°15'	221.0	3.2
O	3	79°36.0'	162°19'	225.0	3.4
O	4	79°35.5'	162°22'	232.0	3.6
O	5	79°34.8'	162°27'	230.0	3.8
O	6	79°34.2'	162°31'	230.0	4.0
O	7	79°33.7'	162°35'	229.0	3.8
O	8	79°33.1'	162°39'	230.0	3.6
O	9	79°32.5'	162°42'	228.0	3.4

TABLE X (con't)

Line No.	Station No.	Latitude South	Longitude West	Elevation Meters	P.E. in Elevation Meters
O	10	79°31.9'	162°46'	232.0	± 3.2
O	11	79°31.3'	162°50'	222.0	3.0
O	12	79°30.7'	162°54'	212.0	2.8
O	13	79°30.1'	162°58'	201.0	2.6
O	14	79°29.5'	163°02'	191.0	2.4
O	15	79°28.9'	163°06'	182.0	2.2
O	16	79°28.4'	163°10'	174.0	2.0
O	17	79°27.8'	163°14'	157.0	1.5
	G9	79°27.8'	163°33'	82.0	1.0
P	K15.5	79°06.25'	161°10'	98.5	2.2
P	1	79°07.0'	161°04'	95.6	2.3
P	2	79°07.75'	161°01'	103.2	2.4
P	3	79°08.5'	160°58'	112.8	2.5
P	4	79°09.5'	160°54'	117.3	2.6
P	5	79°10.25'	160°51'	106.4	2.7
P	6	79°11.00'	160°48'	105.0	2.8
P	7	79°11.5'	160°45'	109.1	2.9
P	8	79°12.5'	160°41'	115.6	3.0
P	9	79°13.25'	160°38'	125.2	3.1
P	10	79°13.75'	160°35'	136.3	3.0
P	11	79°14.5'	160°31'	132.9	2.9
P	12	79°15.25'	160°28'	120.9	2.8
P	13	79°16.0'	160°25'	118.0	2.7
P	14	79°16.75'	160°21'	112.1	2.7
m	71	79°49.8'	158°49'	63.3	4.0
m	T2	79°49.6'	158°50'	63.8	4.0
m	T4	79°49.2'	158°53'	64.3	4.0
m	72	79°48.9'	158°54'	65.1	3.9
m	T7	79°48.6'	158°56'	108.9	3.9
m	73	79°48.5'	158°57'	119.3	3.8
m	T8	79°48.2'	158°58'	127.1	3.8
m	74	79°47.9'	159°01'	135.0	3.7
m	T9	79°48.5'	159°03'	144.2	3.8
m	76	79°49.3'	159°07'	156.8	3.8
	NE 1	79°48.5	159°04'	129.9	3.7

TABLE XI

SYSTEM OF FLAGS ON THE STRAIN RATE NETWORK

Control Points	Guide Pole Location	Flags Color and Arrangement
A1	1 meter magnetic north	two flags: red over black
A2		
A3		
A4		
A5		two flags: black over black
B1		two flags: black over red
B2		one flag: red
B3		two flags: black over red
B4		
B5		
B11	1 meter magnetic north	one flag: red
B11	1 meter magnetic south	one flag: black
B12	1 meter magnetic north	one flag: red
B12	1 meter magnetic south	one flag: black
B13	1 meter east	one flag: red
B13	1 meter west	one flag: red
A13	1 meter magnetic north	two flags: red over black
BB13		two flags: black over red
F1		two flags: black over blue
F2		
F3		
F4		
F5		
F6		
F7		
F8		
F9		
F10		
F11		
F12		
F13		
F14		
G1	1 meter magnetic north	two flags: blue over black
G2		
G3		
G4		
G5		
G6		
G7		
G8		
G9		
G10		
G11		

TABLE XI (con't)

Control Points	Guide Pole Location	Flags Color and Arrangement
D1	1 meter magnetic north	two flags: red over blue
D2		
D3		
D4		
D5		
D6		
D7		
D8		
D9		
D10		
D11		
D12		
D13		
E1	1 meter magnetic north	two flags: blue over red
E2		
E3		
E4		
E5		
E6		
E7		
E8		
E9		
E12	1 meter magnetic north	two flags: blue over red
R1	1 meter magnetic north	two flags: black over blue
R2		
R3		
R4		
S1	1 meter magnetic north	two flags: blue over black
S2		
S3		
S4		
T1	1 meter magnetic north	two flags: black over blue
T2		
T3		
T4		
T5		
T6		
T7		
T8		
T9		
U2	1 meter magnetic north	two flags: blue over black
U6		
U7		
U8		
U9		

TABLE XII

VISIBILITY ON ROOSEVELT ISLAND

Season	Total No. of Days	Unrestricted		Restricted		Non-Operational	
		Days	%	Days	%	Days	%
1961-62	95	40	42	32	34	23	24
1962-63	94	26	28	36	38	32	34
Total	189	66	35	68	36	55	29

TABLE XIII

SUMMARY OF VERTICAL CONTROL ON STRAIN RATE NETWORK

Loop	Year	Control Points in Loop	Number of Turning Pts.	Distance km	Error Closure meters	Error per T.P. cm	Error per km cm
I	1961-62	Susan, A1, A2, A3, A4, A5, B5, B4, B3, B2, B1	50	29.03	0.130	0.26	0.45
II	1961-62	Susan, B13, G1, G2, G3, F3, F2, F1, B11, B12, B13	136	37.98	0.895	0.66	2.36
III	1961-62	G3, G4, G5, G6, F6, F5, F4, F3	133	31.14	1.811	1.36	5.81
IV	1961-62	G6, G7, G8, G9, F9, F8, F7, F6	171	29.69	0.767	0.45	2.58
V	1962-63	Susan, R.M., A13, D1, D2, D3, E3, E2, E1, BB13	132	36.49	0.068	0.05	0.19
VI	1962-63	D3, D4, D5, E5, E4, E3	119	26.53	0.043	0.04	0.16
VII	1962-63	D5, D6, D7, D8, D9, E9, E8, E7, E6, E5	147	21.05	0.733	0.50	3.48
VIII	1962-63	S3, S4, R4	36	7.10	0.145	0.40	2.04
IX	1962-63	S3, S2, S1, R1, R2, R3	63	7.41	0.079	0.13	1.07
X	1962-63	T8, T9, U9, U8	22	8.02	0.023	0.10	0.29
XI	1962-63	U8, U7, U6, U2, T2, T3, T4, T5, T6, T7, T8	46	9.59	0.185	0.40	1.93
Total			1055	244.03	4.879	4.35	20.36
Average			95	22.18	0.444	0.395	1.85

TABLE XIV

VERTICAL CONTROL ON STRAIN RATE NETWORK

Control Point	Elevation Above MSL meters	Date Elev. Established	Level Loop No.	Remarks
Susan	563.00	1 Dec 1961	I	
Reference Mark	544.85	1 Dec 1961		
A1	562.68	1 Dec 1961	I	
A2	563.56	1 Dec 1961	I	
A3	563.86	7 Jan 1962	I	
A4	564.06	7 Jan 1962	I	
A5	563.82	7 Jan 1962	I	
A13	565.40	7 Jan 1962	V	
B1	547.35	1 Dec 1961	I	
B2	549.24	1 Dec 1961	I	
B3	549.56	1 Dec 1961	I	
B4	551.28	7 Jan 1962	I	
B5	556.45	7 Jan 1962	I	
B11	556.79	27 Jan 1962	II	
B12	552.83	27 Jan 1962	II	
B13	554.50	5 Feb 1962	II	
BB13	546.00	5 Feb 1962	V	
F1	532.54	27 Jan 1962	II	
F2	501.59	27 Jan 1962	II	
F3	447.80	28 Jan 1962	II	
F4	401.98	28 Jan 1962	III	
F5	350.96	28 Jan 1962	III	
F6	308.93	28 Jan 1962	III	
F7	262.47	29 Jan 1962	IV	
F8	208.45	29 Jan 1962	IV	
F9	80.71	30 Jan 1962	IV	
F10	70.00*	-------	--	Altimetry
F11	65.00*	-------	--	Altimetry
F12	60.00*	-------	--	Altimetry
F13	60.00*	-------	--	Altimetry
F14	60.00*	-------	--	Altimetry
G1	529.88	4 Feb 1962	II	
G2	504.03	4 Feb 1962	II	
G3	451.72	3 Feb 1962	II	
G4	416.36	3 Feb 1962	III	
G5	369.91	3 Feb 1962	III	
G6	314.17	2 Feb 1962	III	
G7	276.32	1 Feb 1962	IV	
G8	195.54	1 Feb 1962	IV	
G9	82.80	30 Jan 1962	IV	
G10	60.00*	-------	--	Altimetry
G11	60.00*	-------	--	Altimetry

*Approximate

TABLE XIV (con't)

Control Point	Elevation Above MSL meters	Date Elev. Established	Level Loop No.	Remarks
D1	516.72	20 Dec 1962	V	
D2	459.55	20 Dec 1962	V	
D3	417.56	20 Dec 1962	V	
D4	336.66	21 Dec 1962	VI	
D5	269.71	21 Dec 1962	VI	
D6	188.03	2 Feb 1963	VI	
D7	134.71	2 Feb 1963	VII	
D8	97.64	2 Feb 1963	VII	
D9	67.08	2 Feb 1963	VII	no closure
D10	65.76	2 Feb 1963	VII	no closure
D11	65.08	2 Feb 1963	VII	no closure
D12	66.88	2 Feb 1963	VII	no closure
E1	520.33	23 Dec 1962	V	
E2	473.67	23 Dec 1962	V	
E3	427.89	21 Dec 1962	V	
E4	350.25	21 Dec 1962	VI	
E5	282.43	21 Dec 1962	VI	
E6	209.17	2 Feb 1963	VII	
E7	135.42	2 Feb 1963	VII	
E8	97.21	2 Feb 1963	VII	
E9	65.53	2 Feb 1963	VII	
E12	65.00*	--------	---	
R1	37.95	9 Jan 1963	IX	Based on R2 Elev
R2	77.00	9 Jan 1963	IX	Altimetry
R3	126.20	9 Jan 1963	IX	Based on R2 Elev
R4	172.47	9 Jan 1963	VIII	Based on R2 Elev
S1	39.07	9 Jan 1963	IX	Based on R2 Elev
S2	78.39	9 Jan 1963	IX	Based on R2 Elev
S3	137.00	9 Jan 1963	IX	Based on R2 Elev
S4	178.76	9 Jan 1963	VIII	Based on R2 Elev
T1	50.07	20 Jan 1963	XI	Based on T8 Elev
T2	50.12	20 Jan 1963	XI	Based on T8 Elev
T3	50.19	20 Jan 1963	XI	Based on T8 Elev
T4	51.02	20 Jan 1963	XI	Based on T8 Elev
T5	50.91	20 Jan 1963	XI	Based on T8 Elev
T6	50.31	20 Jan 1963	XI	Based on T8 Elev
T7	82.41	20 Jan 1963	XI	Based on T8 Elev
T8	100.00	20 Jan 1963	X	Assumed Elevation
T9	116.55	21 Jan 1963	X	Based on T8 Elev
U2	48.69	20 Jan 1963	XI	Based on T8 Elev
U6	49.03	20 Jan 1963	XI	Based on T8 Elev
U7	82.23	20 Jan 1963	XI	Based on T8 Elev
U8	96.58	20 Jan 1963	X	Based on T8 Elev
U9	113.02	21 Jan 1963	X	Based on T8 Elev

*Approximate

TABLE XV

ANALYSIS OF QUADRILATERAL CLOSURES

Quad. No.	Error of Closure 1961-62 meters	Precision 1961-62 1 n / n	P.E. in Length of Side 1961-62 meters	Error of Closure 1962-63 meters	Precision 1962-63 1 n / n	P.E. in Length of Side 1962-63 meters
I	0.079	148,000	0.012	0.407	29,000	0.035
II	0.162	66,000	0.042	0.146	73,000	0.063
III	0.050	193,000	0.028	0.021	459,000	0.042
IV	0.102	102,000	0.032	0.211	50,000	0.069
V	0.701	10,000	0.057	0.375	22,000	0.062
VI	0.053	182,000	0.084	0.318	29,000	0.027
VII	0.098	158,000	0.033	0.578	27,000	0.167
VIII	0.117	142,000	0.034	0.146	114,000	0.057
IX	0.081	274,000	0.028	0.566	39,000	0.205
X	0.042	467,000	0.010	0.190	98,000	0.047
XI	0.614	30,000	0.050	0.201	91,000	0.047
XII	0.187	87,000	0.022	0.746	22,000	0.073
XIII	0.222	64,000	0.028	0.743	19,000	0.069
XIV	0.095	158,000	0.021	0.188	80,000	0.057
XV	0.076	239,000	0.017	0.382	48,000	0.175
XVI	0.055	169,000	0.008	0.025	372,000	0.003
XVII	0.282	40,000	0.002	0.308	36,000	0.034
XVIII				0.347	45,000	0.064
XIX				0.252	76,000	0.094
XX				0.529	31,000	0.090
XXI				0.071	272,000	0.060
XXII				1.213	13,000	0.091
XXIII				0.346	42,000	0.073
XXIV				1.360	7,000	0.109
XXV				0.853	6,000	0.074
XXVI				0.179	21,000	0.038
XXVII				0.492	10,000	0.079
XXVIII				0.508	7,000	0.056
XXIX				1.277	4,000	0.063
XXX				0.535	13,000	0.051
XXXI				0.445	15,000	0.046
XXXII				0.121	35,000	0.057
XXXIII				0.232	17,000	0.060
XXXIV				0.386	21,000	0.291
XXXV				1.224	6,000	0.073
Ave.	0.177	149,000	0.030	0.456	62,000	0.077

TABLE XVI

SUMMARY OF QUADRILATERAL DATA

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative C1-RM 1962-63
C1-RM	2802.75	N 0° 00' 00.0"	2804.02	N 0° 00' 00.0"
C1-A1	2896.78	S 89° 58' 09.7" E	2896.90	S 89° 57' 47.5" E
A1-RM	4031.80	N 45° 55' 45.9" W	4032.99	N 45° 54' 52.0" W
RM-B1	3542.08	S 82° 45' 15.1" E	3542.55	S 82° 45' 02.0" E
A1-B1	2436.94	N 14° 39' 58.0" E	2438.29	N 14° 39' 57.1" E
C1-B1	4230.54	N 56° 09' 29.3" E	4231.45	N 56° 09' 01.3" E
A1-A2	3330.62	S 87° 13' 41.6" E	3330.94	S 87° 13' 06.7" E
A2-B1	3699.45	N 47° 05' 36.5" W	3700.52	N 47° 04' 18.5" W
B1-B2	2666.43	S 83° 19' 10.7" E	2666.70	S 83° 18' 39.9" E
A2-B2	2209.27	N 1° 35' 32.6" W	2210.71	N 1° 35' 04.8" W
A1-B2	3854.09	S 57° 54' 44.4" W	3855.02	S 57° 54' 20.6" W
A2-A3	2209.27	S 88° 18' 34.0" E	2385.96	S 88° 18' 25.5" E
A3-B2	3343.05	N 47° 01' 37.6" W	3344.13	N 47° 00' 28.4" W
B2-B3	2622.04	N 87° 03' 47.2" E	2622.21	N 87° 03' 46.6" E
A3-B3	2419.30	N 4° 05' 25.2" E	2420.88	N 4° 05' 27.6" E
A2-B3	3468.11	N 47° 30' 21.3" E	3469.42	N 47° 29' 34.1" E
A3-A4	2679.66	S 84° 00' 33.8" E	2679.95	S 84° 00' 01.3" E
A4-B3	3669.27	N 42° 47' 14.5" W	3670.83	N 42° 47' 01.6" W
B3-B4	2709.30	S 88° 42' 19.0" E	2709.56	S 88° 41' 31.1" E
A4-B4	2640.44	N 4° 41' 43.3" E	2641.84	N 4° 41' 46.2" E
A3-B4	3719.23	N 50° 46' 29.9" E	3720.13	N 50° 46' 03.5" E
A4-A5	1506.01	S 87° 52' 55.6" E	1506.36	S 87° 52' 02.7" E
A5-B4	2980.22	N 25° 37' 23.1" W	2982.02	N 25° 36' 41.3" W
B4-B5	1950.84	S 68° 45' 27.7" E	1951.12	S 68° 44' 45.9" E
A5-B5	2049.97	N 14° 58' 03.4" E	2051.24	N 14° 57' 21.8" E
A4-B5	2800.66	N 46° 35' 12.1" E	2801.48	N 46° 34' 36.0" E
C1-B12	2422.46	S 3° 56' 56.1" E	2425.51	S 3° 55' 45.7" E
A1-B12	3644.95	S 48° 30' 04.5" W	3646.02	S 48° 30' 07.3" W
A1-B11	1916.65	S 23° 51' 02.1" W	1917.79	S 23° 50' 24.7" W
B11-B12	2064.06	S 71° 17' 15.9" W	2064.55	S 71° 18' 26.2" W
C1-B11	2753.24	S 50° 24' 44.2" E	2754.22	S 50° 23' 08.0" E
C1-A13	2499.82	S 86° 30' 28.8" W	2500.19	S 86° 30' 24.2" W
A13-B13	2045.17	S 9° 35' 58.2" E	2045.70	S 9° 34' 50.6" E
C1-B13	3056.79	S 44° 48' 20.3" W	3057.94	S 44° 48' 32.4" W
B12-B13	2334.16	N 83° 54' 10.9" W	2334.39	N 83° 53' 36.1" W
A13-B12	3494.85	S 49° 36' 49.6" E	3495.22	S 49° 35' 48.5" W
B11-B13	4295.95	S 84° 27' 58.0" W	4296.72	S 84° 28' 46.6" W
B13-G1	3426.89	S 3° 02' 09.9" W	3428.31	S 3° 02' 47.5" W
B11-G1	5881.01	S 49° 16' 57.2" W	5882.49	S 49° 17' 21.0" W
B11-F1	3512.22	S 4° 32' 29.1" W	3513.64	S 4° 33' 16.5" W
F1-G1	4192.75	S 85° 24' 54.2" W	4193.32	S 85° 25' 40.7" W

TABLE XVI (con't)

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative C1-RM 1962-63
B13-F1	5050.91	S 52° 19' 35.4" E	5052.27	S 52° 18' 20.2" E
G1-G2	3295.16	S 27° 00' 12.2" W	3295.79	S 27° 01' 06.3" W
F1-G2	6550.65	S 60° 02' 34.3" W	6551.78	S 60° 03' 20.9" W
F1-F2	3693.51	S 4° 22' 53.0" W	3695.10	S 4° 24' 03.9" W
F2-G2	5409.00	N 85° 38' 07.6" W	5409.48	N 49° 18' 45.8" W
F2-G1	5137.51	N 49° 20' 17.8" W	5138.51	N 49° 18' 45.8" W
G2-G3	5484.79	S 3° 43' 03.7" W	5486.46	S 3° 44' 18.9" W
F2-G3	7659.66	S 48° 38' 16.7" W	7661.01	S 48° 39' 13.5" W
F2-F3	5605.50	S 3° 37' 21.8" W	5607.51	S 3° 38' 35.3" W
F3-G3	5420.99	N 85° 21' 39.0" W	5421.54	N 84° 20' 03.1" W
G3-G2	7839.90	N 39° 59' 50.8" W	7841.87	N 39° 58' 05.0" W
G3-G4	3545.70	S 7° 19' 37.8" W	3547.04	S 7° 21' 06.2" W
F3-G4	6564.41	S 62° 57' 43.2" W	6565.52	S 62° 59' 51.2" W
F3-F4	3835.77	S 0° 35' 08.8" W	3837.61	S 0° 36' 49.9" W
F4-G4	5869.83	N 81° 39' 32.2" W	5870.37	N 81° 37' 39.6" W
F4-G3	6911.11	N 50° 47' 51.2" W	6912.64	N 50° 45' 39.5" W
F4-G5	3609.66	S 11° 40' 48.9" E	3611.42	S 11° 39' 26.7" E
F4-G5	5742.50	S 62° 08' 29.4" W	5742.91	S 62° 09' 27.5" W
F4-F5	3615.04	S 0° 36' 56.4" W	3616.50	S 0° 38' 11.3" W
F5-G5	5123.50	N 79° 31' 32.5" W	5123.78	N 79° 29' 45.0" W
F5-G4	7295.78	N 52° 15' 09.3" W	7297.66	N 52° 13' 02.7" W
G5-G6	3470.05	S 4° 38' 54.5" W	3471.67	S 4° 39' 38.4" W
F5-G6	5889.16	S 64° 35' 15.5" W	5889.28	S 64° 36' 01.2" W
F5-F6	2346.80	S 0° 47' 54.4" W	2348.56	S 0° 49' 04.2" W
F6-G6	5289.72	S 88° 02' 34.9" W	5289.47	S 88° 04' 26.7" W
F6-G5	5983.27	N 56° 46' 46.6" W	5984.84	N 56° 44' 19.7" W
G6-G7	2108.56	S 16° 25' 08.2" E	2109.92	S 16° 24' 00.0" E
F6-G7	5182.30	S 64° 50' 25.1" W	5181.83	S 64° 51' 17.0" W
F6-F7	2159.54	S 1° 08' 08.4" E	2161.35	S 1° 07' 03.0" E
F7-G7	4733.64	S 89° 27' 58.4" W	4733.09	S 89° 30' 17.5" W
F7-G6	5684.83	N 69° 37' 34.7" W	5685.71	N 69° 35' 10.0" W
G7-G8	3695.65	S 18° 34' 48.6" E	3698.54	S 18° 33' 20.4" E
F7-G8	5022.59	S 45° 04' 14.4" W	5022.66	S 45° 04' 14.8" W
F7-F8	2425.09	S 10° 53' 55.5" E	2426.82	S 10° 52' 21.7" E
F8-G8	4180.25	S 73° 48' 24.6" W	4179.06	S 73° 49' 43.3" W
F8-G7	5693.78	N 65° 45' 51.4" W	5694.72	N 65° 42' 43.7" W
G8-G9	4989.42	S 24° 14' 41.6" E	4989.35	S 24° 09' 09.8" E
F8-G9	6043.68	S 18° 58' 45.4" W	6047.13	S 19° 02' 01.2" W
F8-F9	5975.96	S 10° 21' 56.7" E	5975.76	S 10° 18' 28.7" E
F9-G9	3045.21	N 86° 55' 33.2" W	3045.87	N 86° 56' 08.5" W
F9-G8	6936.42	N 47° 12' 09.4" W	6933.40	N 47° 08' 51.2" W
BB13-RM	2877.85	S 89° 53' 42.0" E	2878.21	S 89° 53' 25.1" E
A13-BB13	2985.24	N 7° 22' 02.9" W	2986.99	N 7° 21' 37.8" W

TABLE XVI (con't)

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative C1-RM 1962-63
A13-RM	3867.71	N 40° 10' 22.1" E	3869.20	N 40° 09' 49.7" E
01-A13	2499.82	S 86° 30' 28.8" W	2500.19	S 86° 30' 24.2" W
C1-BB13	4021.14	N 45° 42' 06.5" W	4022.49	N 45° 41' 12.1" W
B1-E1			3882.70	N 22° 42' 14.2" E
E1-RM			5912.32	S 57° 58' 47.9" W
RM-D1			3597.02	N 8° 03' 37.7" E
D1-E1			4528.62	S 84° 35' 37.1" E
B1-D1			5012.73	N 36° 54' 06.1" W
E1-E2			4764.14	N 7° 44' 17.0" E
D1-E2			6705.29	N 50° 10' 41.6" E
D1-D2			5407.67	N 7° 42' 33.9" E
D2-E2			4550.80	S 76° 28' 10.5" E
D2-E1			6912.53	S 33° 10' 48.3" E
E2-E3			3901.36	N 3° 40' 45.1" E
D2-E3			5463.99	N 58° 49' 23.6" E
D2-D3			3625.43	N 7° 16' 39.6" E
D3-E3			4284.91	S 79° 40' 48.0" E
D3-E2			6119.43	S 40° 23' 20.7" E
E3-E4			5260.04	N 8° 22' 37.3" E
D3-E4			6670.84	N 48° 18' 55.8" E
D3-D4			5401.17	N 7° 10' 40.1" E
D4-E4			4404.73	S 77° 54' 37.2" E
D4-E3			7076.03	S 30° 01' 31.0" E
E4-E5			3541.28	N 6° 51' 43.0" E
D4-E5			5394.42	N 61° 15' 56.0" E
D4-D5			3637.03	N 6° 57' 48.6" E
D5-E5			4408.08	S 76° 39' 47.6" E
D5-E4			5957.55	S 40° 27' 42.2" E
E5-E6			3722.34	N 17° 38' 32.6" W
D5-E6			4049.11	N 51° 19' 21.2" E
D5-D6			3650.39	N 7° 20' 23.4" E
D6-E6			2906.81	S 67° 58' 33.6" E
D6-E5			6009.88	S 39° 30' 03.8" E
E6-E7			2819.34	N 15° 39' 21.6" W
D6-E7			2525.76	N 49° 57' 55.2" E
D6-D7			1807.94	N 7° 36' 07.4" E
D7-E7			1702.93	S 84° 21' 37.6" E
D7-E6			3786.29	S 40° 25' 50.8" E
E7-E8			1008.89	N 22° 55' 59.8" W
D7-E8			1508.12	N 59° 39' 35.2" E
D7-D8			1018.51	N 8° 41' 25.4" E
D8-E8			1173.54	S 77° 56' 56.1" E
D8-E7			1937.19	S 52° 41' 27.0" E
E8-E9			626.90	N 5° 36' 59.8" E
D8-E9			1267.00	N 72° 36' 01.4" E

TABLE XVI (con't)

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative C1-RM 1962-63
D8-D9			794.52	N 6° 26' 20.9" E
D9-E9			1192.83	S 69° 51' 50.9" E
D9-E8			1480.14	S 45° 39' 27.6" E
E9-E12			1080.53	N 11° 25' 35.0" E
D9-E12			1483.26	N 64° 04' 28.5" E
D9-D12			1099.44	N 6° 01' 42.3" E
D12-E12			1297.20	S 69° 56' 35.1" E
D12-E9			1808.57	S 33° 44' 15.3" E
D8-D10			1157.88	N 6° 20' 12.9" E
D8-D11			1530.49	N 6° 14' 18.9" E
D8-D13			2241.64	N 6° 18' 08.4" E
G9-G10			1886.81	S 49° 40' 23.2" E
F9-G10			1920.85	S 56° 34' 12.9" W
F9-F10			832.13	S 6° 31' 32.9" W
F10-G10			1526.16	S 81° 16' 32.4" W
F10-G9			3108.64	N 71° 26' 18.0" W
G10-G11			648.56	S 3° 39' 00.2" E
F10-G11			1710.22	S 59° 04' 55.3" W
F10-F11			513.74	S 2° 11' 13.4" E
F11-G11			1531.05	S 76° 11' 38.0" W
F11-G10			1553.88	N 79° 32' 54.7" W
F11-F12			900.41	S 2° 11' 41.0" W
F11-F13			1283.62	S 2° 11' 59.3" W
F11-F14			1646.27	S 2° 11' 16.1" W

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative R1-R2 1962-63
R1-R2			808.65	N 0° 00' 00.0"
R1-S1			882.18	S 86° 32' 43.8" W
R2-S1			1232.12	N 45° 37' 02.6" E
R2-RS1			2473.33	S 2° 43' 48.0" W
R2-RS2			2146.65	S 2° 27' 42.0" W
R2-RS3			1706.42	S 2° 30' 31.9" W
R2-RS4			1289.46	S 1° 01' 11.5" W
S1-S2			882.42	N 0° 37' 48.3" E
R2-S2			871.12	N 88° 38' 50.6" W
R1-S2			1202.50	N 46° 24' 14.2" W
R2-R3			1666.02	N 4° 38' 47.0" E
R3-S2			1923.86	S 31° 31' 17.8" W
S2-S3			1933.13	N 5° 48' 50.9" W

TABLE XVI (con't)

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative R1-R2 1962-63
R3-S3			1234.59	N 76° 44' 18.5" W
R2-S3			2217.21	N 28° 45' 26.6" W
R3-R4			2235.87	N 2° 02' 53.8" E
R4-S3			2334.47	S 33° 17' 49.8" W
S3-S4			1839.20	N 16° 03' 37.8" W
R4-S4			1799.81	S 84° 08' 17.0" W
R3-S4			2670.35	N 39° 49' 56.3" W

Side	Horiz. Length meters 1961-62	Bearing Relative C1-RM 1961-62	Horiz. Length meters 1962-63	Bearing Relative T2-T6 1962-63
T1-T6			2418.78	N 0° 00' 05.9" W
T2-T6			1782.12	N 0° 00' 00.0"
T3-T6			1206.01	N 0° 00' 24.7" E
T4-T6			604.90	N 0° 01' 12.3" E
T5-T6			286.56	N 0° 03' 03.6" W
T2-U2			1618.28	N 83° 46' 30.9" W
T6-U2			2273.63	S 45° 02' 14.0" W
U2-U6			1857.22	N 8° 12' 22.0" E
T6-U6			1363.46	N 80° 13' 20.0" W
T2-U6			2420.80	N 33° 42' 49.5" W
T6-T7			808.52	N 0° 00' 34.8" E
T7-T6			1462.42	S 66° 45' 48.4" W
U6-U7			805.56	N 5° 54' 23.5" E
T7-U7			1280.69	N 79° 54' 45.2" W
T6-U7			1629.80	N 50° 40' 30.5" W
T7-T8			1009.56	N 0° 06' 22.9" W
T8-U7			1483.82	S 58° 02' 54.5" W
U7-U8			759.25	N 24° 41' 18.2" E
T8-U8			946.71	S 84° 13' 00.2" W
T7-U8			1313.92	N 45° 54' 46.8" W
T8-T9			2309.68	N 0° 03' 38.2" E
T9-U8			2583.82	S 21° 26' 14.0" W
U8-U9			2870.77	N 18° 54' 33.4" W
T9-U9			1900.26	N 80° 35' 14.2" W
T8-T9			3220.56	N 35° 32' 40.6" W

TABLE XVII

COORDINATES

Station	Coordinates Relative to C1 C1-RM Assumed North 1961-1962 N	E	Coordinates Relative to C1 C1-RM Assumed North 1962-1963 N	E
C1	1,000,000.00	1,000,000.00	1,000,000.00	1,000,000.00
RM	1,002,802.75	1,000,000.00	1,002,804.02	1,000,000.00
A1	999,998.46	1,002,896.80	999,998.14	1,002,896.90
B1	1,002,356.00	1,003,513.79	1,002,356.98	1,003,514.23
A2	999,837.40	1,006,223.51	999,836.50	1,006,223.92
B2	1,002,045.81	1,006,162.12	1,002,046.37	1,006,162.78
A3	999,767.02	1,008,608.14	999,766.02	1,008,608.84
B3	1,002,180.16	1,008,780.71	1,002,180.73	1,008,781.54
A4	999,487.35	1,011,273.17	999,485.90	1,011,274.11
B4	1,002,118.94	1,011,489.32	1,002,118.88	1,011,490.40
A5	999,431.70	1,012,778.15	999,429.85	1,012,779.43
B5	1,001,412.12	1,013,307.61	1,001,411.60	1,013,308.81
B11	998,245.48	1,002,121.79	998,243.86	1,002,121.72
B12	997,583.29	1,000,168.83	997,582.18	1,000,166.07
B13	997,831.21	997,845.87	997,830.52	997,844.93
A13	999,847.74	997,504.82	999,847.66	997,504.46
BB13	1,002,808.34	997,122.01	1,002,810.04	997,121.79
F1	994,744.28	1,001,843.70	994,741.31	1,001,842.70
G1	994,409.13	997,664.36	994,407.05	997,662.73
F2	991,061.57	1,001,561.53	991,057.11	1,001,559.15
G2	991,473.20	996,168.22	991,470.96	996,165.53
F3	985,467.27	1,001,207.34	985,460.94	1,001,202.84
G3	985,999.95	995,812.58	985,996.18	995,807.79
F4	981,631.70	1,001,168.12	981,623.54	1,001,161.72
G4	982,483.21	995,360.38	982,478.30	995,353.91
F5	978,016.87	1,001,129.28	978,007.27	1,001,121.55
G5	978,948.30	996,091.16	978,941.37	996,083.63
F6	975,670.30	1,001,096.58	975,658.95	1,001,088.02
G6	975,489.66	995,809.94	975,481.18	995,801.54
F7	973,511.18	1,001,139.38	973,498.01	1,001,130.17
G7	973,467.08	996,405.94	973,457.11	996,397.26
F8	971,129.83	1,001,597.90	971,114.76	1,001,587.94
G8	969,964.06	997,583.49	969,950.84	997,574.23
F9	965,251.41	1,002,673.16	965,235.44	1,002,657.23
G9	965,414.71	999,632.34	965,398.27	999,615.72
F10			964,408.71	1,002,562.66
G10			964,177.22	1,001,054.16
F11			963,895.34	1,002,582.26
G11			963,529.98	1,001,095.45

TABLE XVII (con't)

Station	Coordinates Relative to C1 C1-RM Assumed North 1961-1962		Coordinates Relative to C1 C1-RM Assumed North 1962-1963	
	N	E	N	E
F12			962,995.59	1,002,616.75
F13			962,612.67	1,002,631.54
F14			962,250.30	1,002,645.59
D1			1,006,365.50	1,000,504.37
E1			1,005,938.82	1,005,012.84
D2			1,011,724.29	1,001,229.80
E2			1,010,659.58	1,005,654.30
D3			1,015,320.52	1,001,889.06
E3			1,014,552.90	1,005,904.65
D4			1,020,679.36	1,002,363.93
E4			1,019,756.92	1,006,670.97
D5			1,024,289.56	1,002,804.88
E5			1,023,272.73	1,007,094.07
D6			1,027,910.03	1,003,271.23
E6			1,026,819.99	1,005,965.92
D7			1,029,702.08	1,003,510.41
E7			1,029,534.73	1,005,205.10
D8			1,030,708.89	1,003,664.30
E8			1,030,463.88	1,004,811.97
D9			1,031,498.40	1,003,753.40
E9			1,031,087.77	1,004,873.33
D10			1,031,859.70	1,003,792.10
D11			1,032,230.32	1,003,830.62
D12			1,032,591.76	1,003,868.87
E12			1,032,146.88	1,005,087.39
D13			1,032,936.97	1,003,910.48

Station	Coordinates Relative to C1 C1-RM Assumed North 1961-1962		Coordinates Relative to R1 R1-R2 Assumed North 1962-1963	
	N	E	N	E
RS1			498,338.12	499,882.20
RS2			498,663.98	499,907.80
RS3			499,103.86	499,925.30
RS4			499,519.39	499,977.05
R1			500,000.00	500,000.00
S1			499,946.84	499,119.42
R2			500,000.00	500,000.00

TABLE XVII (con't)

Station	Coordinates Relative to C1 C1-RM Assumed North 1961-1962		Coordinates Relative to R1 R1-R2 Assumed North 1962-1963	
	N	E	N	E
S2			500,829.21	499,129.13
R3			502,469.19	500,134.96
S3			502,752.40	498,933.30
R4			504,703.63	500,214.87
S4			504,519.82	498,424.48

Station	Coordinates Relative to C1 C1-RM Assumed North 1961-1962		Coordinates Relative to T2 T2-T6 Assumed North 1962-1963	
	N	E	N	E
T1			299,363.34	300,000.69
T2			300,000.00	300,000.00
U2			300,175.47	298,391.26
T3			300,576.11	299,999.86
T4			301,177.22	299,999.79
T5			301,495.56	300,000.26
T6			301,782.12	300,000.00
U6			302,013.68	298,656.35
T7			302,590.64	300,000.14
U7			302,814.95	298,739.24
T8			303,600.20	299,998.26
U8			303,504.80	299,056.37
T9			305,909.87	300,000.71
U9			306,220.64	298,128.03

TABLE XVIII

DISPLACEMENTS

Point	Coordinates Based on RM Displacement of 1.80 m at N 11° 11' W		Displacement	
	N	E	Length m	Direction
C1	1,000,000.000	1,000,000.000		
RM	1,002,804.525	999,999.654	1.80	N 11° 11' W
A1	999,998.490	1,002,896.903	0.10	N 73° 18' E
B1	1,002,357.411	1,003,513.945	1.42	N 6° 05' E
A2	999,837.258	1,006,223.936	0.45	S 71° 58' E
B2	1,002,047.118	1,006,162.533	1.37	N 17° 23' E
A3	999,767.060	1,008,608.870	0.73	N 86° 52' E
B3	1,002,181.794	1,008,781.281	1.73	N 19° 17' E
A4	999,487.271	1,011,274.174	1.00	S 85° 26' E
B4	1,002,120.271	1,011,490.147	1.57	N 31° 58' E
A5	999,431.400	1,012,779.500	1.38	S 77° 28' E
B5	1,001,413.210	1,013,308.640	1.50	N 43° 23' E
B11	998,244.114	1,002,121.934	1.38	S 5° 50' E
B12	997,582.205	1,000,166.368	1.18	S 22° 53' W
B13	997,830.255	997,845.195	1.16	S 35° 11' W
A13	999,847.357	997,504.474	0.51	S 42° 39' W
F1	994,741.534	1,001,843.341	2.77	S 7° 28' W
G1	994,406.771	997,663.406	2.54	S 21° 56' W
F2	991,057.297	1,001,560.232	4.46	S 16° 56' W
G2	991,470.500	996,166.561	3.17	S 31° 35' W
F3	985,461.083	1,001,204.597	6.77	S 23° 53' W
G3	985,995.675	995,809.483	5.28	S 35° 57' W
F4	981,623.685	1,001,163.946	9.04	S 27° 29' W
G4	982,477.739	995,356.031	6.99	S 38° 30' W
F5	978,007.406	1,001,124.212	10.73	S 28° 11' W
G5	978,940.897	996,086.181	8.92	S 33° 56' W
F6	975,659.080	1,001,090.974	12.54	S 26° 34' W
G6	975,480.675	995,804.513	10.49	S 31° 10' W
F7	973,498.151	1,001,133.385	14.34	S 24° 24' W
G7	973,456.645	996,400.475	11.78	S 27° 37' W
F8	971,114.952	1,001,591.439	16.22	S 23° 28' W
G8	969,950.550	997,577.870	14.63	S 24° 12' W
F9	965,235.767	1,002,661.447	19.22	S 36° 50' W
G9	965,398.221	999,619.916	20.64	S 36° 59' W
BB13	1,002,809.686	997,121.447	1.46	N 22° 32' W

TABLE XIX

STRAIN RATES

Line	Horiz. Length 1961-62 meters	Change in Length 1961-62 to 62-63 mm	Elapsed Time days	Strain Rate mm/m/yr
C1-RM	2802.75	+1270	343	+0.476
C1-A1	2896.78	120	390	0.038
A1-RM	4031.80	1180	390	0.277
RM-B1	3542.08	470	393	0.130
A1-B1	2436.94	1340	391	0.517
C1-B1	4230.54	910	393	0.202
A1-A2	3330.62	320	402	0.106
A2-B1	3699.45	1060	392	0.307
B1-B2	2669.43	270	392	0.109
A2-B2	2209.27	1440	391	0.699
A1-B2	3854.09	930	392	0.259
A2-A3	2385.67	290	402	0.133
A3-B2	3343.05	1080	391	0.346
B2-B3	2622.04	170	391	0.069
A3-B3	2419.30	1580	391	0.699
A2-B3	3468.11	1310	391	0.403
A3-A4	2679.66	290	400	0.118
A4-B3	3669.27	1560	390	0.455
B3-B4	2709.30	260	390	0.103
A4-B4	2640.44	1400	389	0.567
A3-B4	3719.23	900	390	0.259
A4-A5	1506.01	350	399	0.249
A5-B4	2980.22	1800	389	0.646
B4-B5	1950.84	280	389	0.154
A5-B5	2049.97	1270	389	0.663
A4-B5	2800.66	820	389	0.313
C1-B12	2422.46	1050	342	0.407
B12-A1	3644.95	1070	345	0.277
A1-B11	1916.65	1140	345	0.562
B11-B12	2064.06	490	345	0.224
C1-B11	2753.24	980	346	0.338
A13-B13	2045.17	530	342	0.244
B13-C1	3056.79	1150	341	0.354
C1-B12	2422.46	1050	342	0.407
B12-B13	2334.16	230	340	0.092
A13-B12	3494.85	370	341	0.099
B11-B13	4295.95	770	332	0.163
BB13-RM	2877.85	360	334	0.115
BB13-A13	2985.24	1750	334	0.539
A13-RM	3867.71	1490	334	0.354
A13-C1	2499.82	370	273	0.111
BB13-C1	4021.14	1350	334	0.309
B13-G1	3426.89	1420	337	0.377
B11-G1	5881.01	1480	332	0.229

TABLE XIX (con't)

Line	Horiz. Length 1961-62 meters	Change in Length 1961-62 to 62-63 mm	Elapsed Time days	Strain Rate mm/m/yr
B11-F1	3512.22	+1420	333	+0.368
F1-G1	4192.75	570	335	0.125
B13-F1	5050.91	1360	335	0.248
G1-G2	3295.16	630	333	0.174
F1-G2	6550.65	1130	331	0.157
F1-F2	3693.51	1590	334	0.396
F2-G2	5409.00	480	331	0.087
F2-G1	5137.52	990	334	0.177
G2-G3	5484.79	1670	334	0.280
F2-G3	7659.66	1350	336	0.162
F2-F3	5605.50	2010	335	0.330
F3-G3	5420.99	550	335	0.093
F3-G2	7839.90	1970	335	0.231
G4-F3	6564.41	1110	334	0.156
F3-F4	3835.77	1840	335	0.441
F4-G4	5869.83	540	333	0.084
F4-G3	6911.11	1530	334	0.204
G4-G5	3609.66	1760	331	0.444
F4-G5	5742.50	410	332	0.065
F4-F5	3615.04	1460	333	0.368
F5-G5	5123.50	280	332	0.050
F5-G4	7295.78	1880	332	0.234
G5-G6	3470.05	1620	330	0.425
F5-G6	5889.16	120	331	0.018
F5-F6	2346.80	1760	331	0.682
F6-G6	5289.72	- 250	331	-0.043
F6-G5	5983.27	+1570	330	+0.239
G6-G7	2108.56	1360	328	0.581
F6-G7	5182.30	- 470	329	-0.082
F6-F7	2159.54	+1810	330	+0.763
F6-G7	4733.64	- 550	330	-0.106
F7-G6	5684.83	+ 880	330	+0.141
G7-G8	3695.65	2890	328	0.524
F7-G8	5022.59	70	327	0.012
F7-F8	2425.09	1730	329	0.642
F8-G8	4180.25	-1190	328	-0.256
F8-G7	5693.78	+ 940	327	+0.148
G8-G9	4989.42	- 70	394	-0.015
F8-G9	6043.68	+3450	394	+0.616
F8-F9	5975.96	- 200	395	-0.036
F9-G9	3045.21	+ 460	394	+0.163
F9-G8	6933.40	-3200	395	-0.470