Polarforschung 51 (1): 43—53, 1981

Geodetic Surveying on the Filchner/Ronne Ice Shelf and in the Atka Bay 1979/80

By D. Möller and H. Gerdau *

Summary: Over a period of more than three weeks, Doppler satellite observations were carried out at the Filchner Station and at the ice edge of the Filchner/Ronne Ice Shelf in order to derive essential information about drift velocity and direction of the ice shelf for the future wintering station, planned to be constructed in the antarctic summer 1980/81.
For the relative control of the two satellite stations and as a basis for future deformation analysis, a traverse 20 km in length and at 2 km intervals was determined by comparative measurements using different distance measuring instruments.
For the determination of possible ice movements in the vicinity of the Filchner Station, and at the ice edge, deformation figures and alignment lines were measured twice at an interval of three weeks.
Doppler Satellite observations at one point and the first measurements in a deformation triangle were carried out at a distance of 5 km from the ice edge of Atka Bay within two days.

Zusammenfassung: Über einen Zeitraum von mehr als drei Wochen wurden bei der Filchner-Station und an der Eiskante des Filchner-Ronne-Schelfeises Doppler-Satellitenmessungen durchgeführt, um die für den im Südsommer 1980/81 geplanten Bau einer zukünftigen Überwinterungsstation wesentlichen Informationen über die Schelfeisgeschwindigkeit und -richtung abzuleiten.
Für die Relativkontrolle der beiden Satellitenstationen und als Grundlage für zukünftige Deformationsanalysen wurde eine 20 km lange Traverse mit einem durchschnittlichen Punktabstand von 2 km mit unterschiedlichen Entfernungsmeßgeräten bestimmt.
Für die Bestimmung eventueller relativer Eisbewegungen wurden in der Nähe der Filchner-Station und an der Eiskante Deformationsfiguren und Alignements zweimal im Abstand von 3 Wochen gemessen.
Innerhalb von 2 Tagen wurden in ca. 5 km Abstand von der Eiskante der Atka-Bucht für einen Festpunkt Doppler-Satellitenmessungen und die ersten Messungen in einem Deformationsdreieck durchgeführt.

1. MEASUREMENTS ON THE FILCHNER/RONNE ICE SHELF

1.1 *Pegging out of a route to the planned summer camp (Filchner Station)*

After having established a suitable landing place (see FUCHS et al., 1981) on the ice shelf where the front is relatively low (less than 10 m) at 50° west and 77° south (Fig. 1), a route of 20 km from the edge to the planned summer camp had to be reconnoitred, pegged out and marked for all sledge convoys and helicopter flights.

Taking into account the radio echo sounding results (KOHNEN, 1981), the visual helicopter reconnaissances by Reinwarth and Möller, the Landsat photographs compiled by Hofmann which disclosed large crevasses and considering the expected drift direction of the ice shelf, the initial direction of the route to the camp was established perpendicularly to the ice shelf front with azimuth of about 130°.

Considering that neither navigation devices nor distance recorders were available for the expedition vehicles the route could only be pegged out with lower accuracy. The direction transfer was carried out by a visual rearward extending at distances of approximately 200 to 250 m. The distances were measured by an odometer which had been calibrated on a geodetically determined line of about 1.2 km in length. The main points marked at a distance of about 1 km by red flags served at the same time as accumulation stakes to be used for the subsequent work as well (REINWARTH, 1981). The distances can be taken from Fig. 2.

A check of the pegging out work in the form of a comparison with the geodetic traverse surveyed at a later date revealed a longitudinal error amounting to 47 m in 20 km (without odometer calibration 992 m)

* Prof. Dr. Dietrich Möller and Dipl.-Ing. Horst Gerdau, Institut für Vermessungskunde der Technischen Universität, Pockelstr. 4, D-3300 Braunschweig.

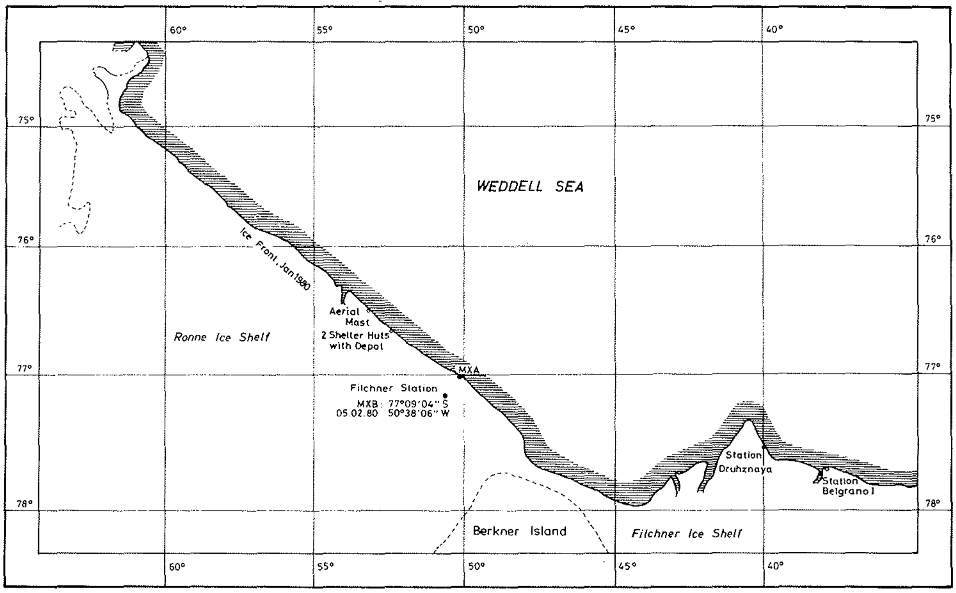

Fig. 1: Ice front of the Filchner/Ronne Ice Shelf from Belgrano I to the peninsula.

Abb. 1: Eiskante des Filchner-Ronne-Schelfeises von Belgrano I bis zur Halbinsel

and a lateral error of 0.36° equivalent to about 125 m in 20 km.

This shows that the applied procedure was adequate for the purpose intended, but for journeys of several hundred kilometres navigation devices are absolutely necessary for vehicles.

1.2 *Determination of the ice shelf drift velocity*

Within the scope of this exploratory expedition, the main geodetic task was the determination of the drift velocity of the Ronne Ice Shelf in order to ensure that the wintering station, planned to be constructed in the antarctic summer 1980/81, can be used for at least 10 years without getting prematurely lost at the ice edge. As there existed no information whatsoever on the ice shelf movements within the area, attempts had to be made to extrapolate the annual drift velocity from the measurements carried out during the few weeks available for this work. Based on the results of the measurements taken on the Ross Ice Shelf (DORRER et al., 1971) a drift velocity of the order of 1 km/year is to be expected. Considering that no reliable information is available yet as to whether the ice front of the Ronne Ice Shelf is stationary (KOHNEN, 1981), the summer camp 1979/80 and thus the main station was established at a distance of 20 km from the edge.

On account of the great distances (> 300 km) from the station to visible fixed points on rock, the application of conventional terrestrial geodetic measuring methods for point determination had to be dispensed with. The positions were determined therefore by means of Doppler satellite survey methods which, contrary to astronomical methods, are not dependent on visibility and are more accurate.

The measurements were taken with two Geoceiver Satellite Surveyor Magnavox MX 1502 set up at the Filchner Station and at a distance of about 350 m from the ice shelf edge. Except for some short interruptions for logistic reasons, the instruments were operated for 27 days at the ice edge and for 22 days at the Filchner Station. Using uncorrected field measurements, for the Filchner Station (MXB) and annual drift velocity of 1056 m/year at an azimuth of 59.6° was extrapolated as a provisional result and for the station at the ice edge (MXA) 1256 m/year at an azimuth of 48.0° (see Fig. 3) was obtained.

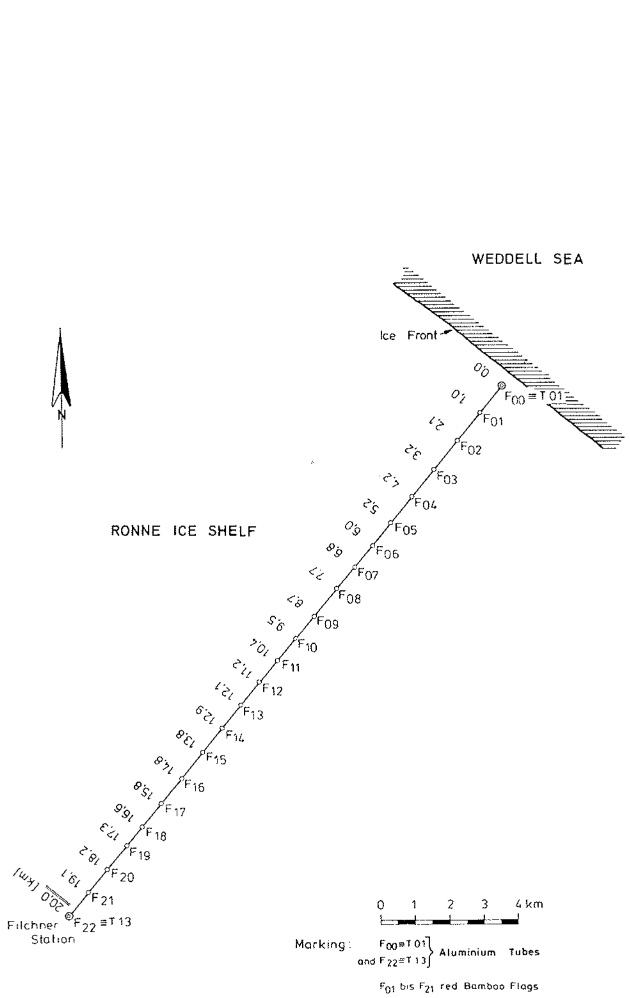

Fig. 2: Transport route 1979/80 from the ice front to the Filchner Station.

Abb. 2: Transportroute 1979/80 von der Eiskante zur Filchner-Station

Based on these findings, considering the uncertainty of the ice shelf stability and in view of the meteorological conditions getting more and more favourable with increasing distance from the ice shelf front, the erection of the future German wintering station in the area of the Filchner Station has been recommended.*

1.3 *Establishment of a geodetic traverse extending from the ice edge to the Filchner Station*

For the relative control of the two Magnavox stations, as well as a basis for the later determination of different ice shelf movements between the ice edge and Filchner Station, a traverse parallel to the transport route was marked at 2 km intervals and measured. The „fixed" points T 01 near MXA and T 13 near MXB are identical with the route points F 00 and F 22 respectively and all other T-points are located at a distance of approximately 50 m southeast of the transport route (see Figs. 2, 4). The marking of the traverse points as well as of all other geodetic „control points" was carried out by means of 3 m aluminium poles which were drilled or rammed flush with the snow and, at the end of the expedition, were extended with poles 1 or 2 m in length in order to ensure that repeated measurements can be carried out in the antarctic summer of 1980/81 for deformation analyses. The measurements were taken with the electronic tacheometer WILD TC 1, all distances and elevation differences having been measured by forward and

* During the expedition 1980/81 H. Gerdau and M. Köhler from the Institut für Vermessungskunde der Technischen Universität Braunschweig succeeded in repeating the Magnavox measurements over 2 days at both stations in January 1981. A comparison of the 1979/80 measurements with the measurements taken in 1981 furnished the following reliable data:

MXB: 1042 m/year under the azimuth of 52°,5
MXA: 1078 m/year under the azimuth of 57°,7.

The agreement of the extrapolated values with these results meets with expectations. The difference of only 14 m for the drift velocity of the Filchner Station permits one to assume a steadiness in the ice shelf movement at 20 km edge distance. The greater differences occuring in the vicinity of the ice shelf edge are plausible. Considering that the shortterm measurements, made in the antarctic summer 1979/80, were carried out in an inhomogeneous crevassed area, it had to be expected that the extrapolated velocities would furnish too great values as compared to the measurements taken over a full year, the more so as at the time of the repetition measurements in 1981 the ice edge was still stable.

backward sight. In view of the extreme refraction conditions, the measurement of heigths was repeated on another day by a trigonometric levelling from the centre with average sighting distances of 1 km to improve the accuracy. Further comparative measurements were taken on the traverse using a laser rangefinder Rangemaster II of Messrs. Keuffel & Esser and three microwave rangefinders SIAL MD 60 of Messrs. Siemens-Albis.

The essential results of the traverse measurements are summarized as follows:

- The distance between the Magnavoxstations MXA and MXB, obtained by the Doppler measurements, as compared with the distance calculated from the traverse measurement, shows the plausible difference of 2 m.
- The Rangemaster measurements taken on different days and at different distances differ by a maximum of 7.5 cm, at a distance of 12.1 km.
- The 3 SIAL instruments reveal under the same meteorological conditions mean distance errors of $\leqq \pm 1$ cm with distances up to 10 km. The maximum difference in distance ascertained under different external conditions and on different days amounted to 5 cm at a distance of 5.8 km.
- A comparison of SIAL distances with Rangemaster distances with ranges up to 6 km measured under the same meteorological conditions results in an average difference of 1.3 cm.
- The traverse lengths from T 1 to T 13 (20 km) measured once with the WILD TC 1 and, under different external conditions via only one intermediate point, with the Rangemaster II differed by 9.8 cm.
- With the Rangemaster as well as with the SIAL instruments transhorizonmeasurements were possible.
- Contrary to the prevalent opinion, both long-distance measuring instruments proved to be very well usable on the ice shelf.
- The height profile (see Fig. 5) was derived from the direct (tape) measurement of the ice shelf edge height above the — tide dependent — sea level and the trigonometric levelling.

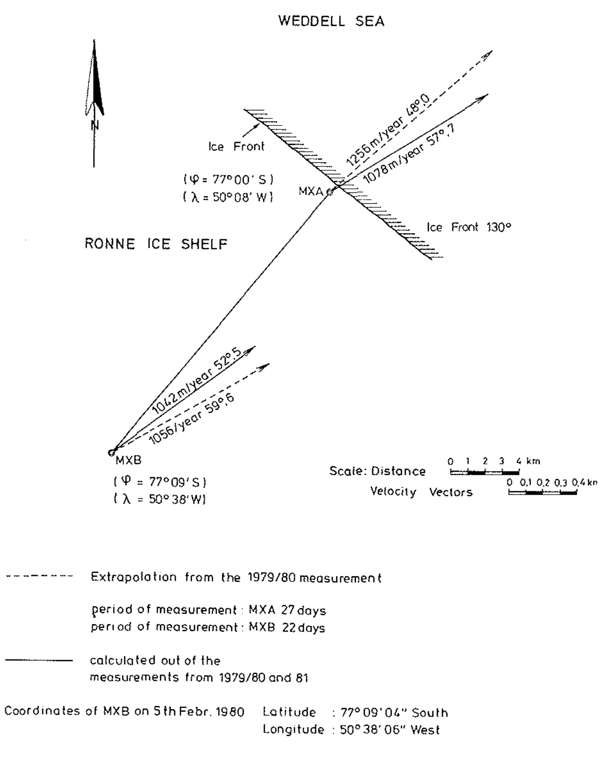

Fig. 3: Movement of the Filchner/Ronne Ice Shelf (preliminary results).

Abb. 3: Bewegung des Filchner-Ronne-Schelfeises (vorläufige Ergebnisse).

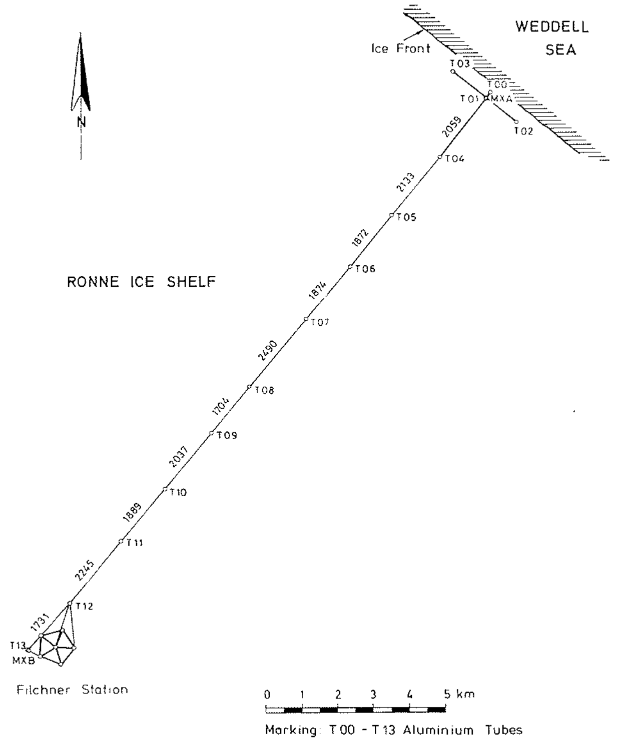

Fig. 4: Geodetic traverse 1979/80 from the ice front to Filchner Station with deformation figures.

Abb. 4: Geodätische Traverse 1979/80 von der Eiskante zur Filchner-Station mit Deformationsfiguren.

— The average difference between the results of the trigonometric levelling over a distance of 2 km and the trigonometric levelling with a sighting distance of 1 km amounts to 0.4 m and + 0.2 m respectively per difference in elevation.
— Sample measurements with sighting distances of 200 to 250 m verify the results of the data used in the cm-range.

The originally planned extension of the traverse towards the south was dispensed with in this summer campaign primarily for logistic reasons.

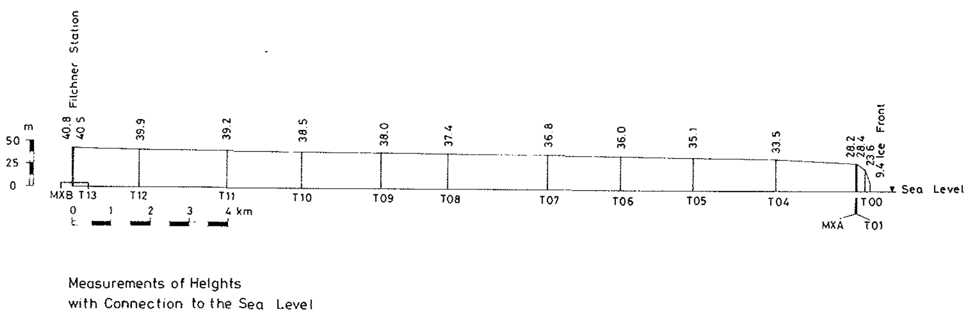

Fig. 5: Longitudinal profile of the geodetic traverse 1979/80.

Abb. 5: Höhenprofil der geodätischen Traverse 1979/80.

1.4 *Measurements to determine possible relative ice velocities*
For the determination of possible ice movements in the vicinity of the Filchner Station a deformation pentagon (see Fig. 6) with a radius of 500 m was pegged out, marked and at the request of the planning group for the wintering station measured twice at an interval of a few weeks. However there was reason to assume that information on significant and representative movements in this homogeneous ice shelf area could only be expected after a repetition of the measurement a year later.

In addition, the pentagon side P 20 — P 22, pegged out at right angles to the supposed main drift direction, was established as an alignment line with 5 intermediate points i. e. the changes in the position of the intermediate points were determined by means of precision angle measurements. In the line P 20 — P 23 five intermediate points were also intercalated in order to determine changes in the distance, if need be, by repeated distance measurements.

All observations were carried out with forced-centring on tripods via special targets in the ends of aluminium poles.

The targets for the intermediate points 31—35 and 41—45 were directly centred by force in the aluminium poles protruding from the snow.

The alignment measurements were taken from both endpoints of the line with the WILD T 3. The relative changes in position (lateral displacements) of the intermediate points 31—35 ascertained over a period of 18 days amounted to a maximum of 2.8 mm with the greatest difference obtained from the two-sided observations being 2.7 mm, i. e. no significant changes are ascertainable. The same applies to the changes in length of the partial distances 100 m long between the points 41 and 45 which amounted to 3.2 mm at the most.

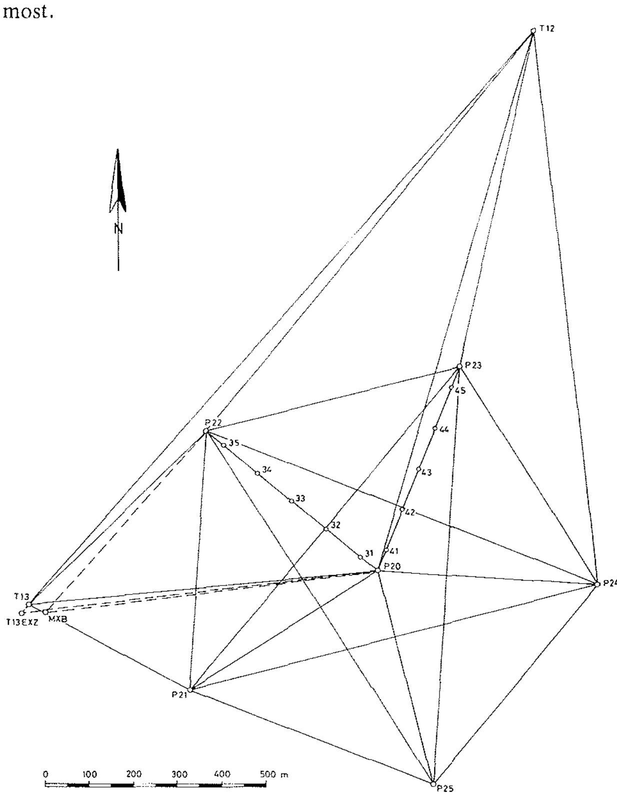

Fig. 6: Deformation pentagon 1979/80 Filchner Station with connection to the traverse.

Abb. 6: Deformationspentagon 1979/80 Filchner-Station mit Verbindung zur Traverse.

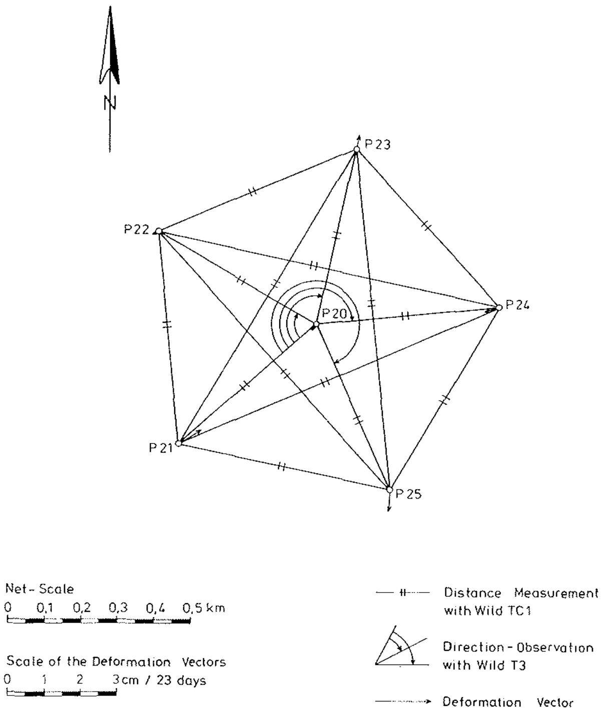

Fig. 7: Deformation in the pentagon 1979/80 Filchner Station.

Abb. 7: Deformation im Pentagon 1979/80 Filchner-Station.

While all pentagon sides were measured twice with the WILD TC 1, the angle in the central point was additionally measured with the WILD T 3. For the orientation of the pentagon a WILD gyro attachment GAK 1 was used.

The average errors of position amounting to ± 1.2 mm for the reference measurement and to ± 1.7 mm for the repetition measurement taken approximately three weeks later can be looked upon as being excellent.

The field evaluations had, however, already disclosed between the two measuring periods a scale difference in the distances of 10 ppm respectively 1 mm/100 m which was at first attributed to the great variations in temperature. However, a laboratory calibration of the TC 1 carried out under the corresponding temperature conditions resulted in an increase of this error to 17 ppm and not in the expected elimination.

The deformation analyses reveal because of the high internal measuring accuracies significant changes in position between the two measuring periods — maximally 15 mm for point 25 using a rigid scale (after laboratory calibration) for reference and repetition measurement and maximally 8 mm respectively for point 21 using a free scale for one measuring period (see Fig. 7). It probably would be wrong to extrapolate these values since already the releasing of a tension condition in the snow-field may cause a sudden displacement of this order.

Representative data on this area can be expected at the earliest after a year.

The levelling errors of closure for the relative measurement of heights of the pentagon points amount to 1 cm on an average.

1.5 *Deformation distances at the ice edge*

At the beginning and end of the period of measurements, the profile T 2 — T 1 — T 3 (nearly parallel to the ice front) was measured by the rangefinder Rangemaster II and the electronic tacheometer WILD TC 1. These measurements were carried out to obtain a comparator base for the odometer and to get information about the deformations near by the ice edge. At T 1 a final measurement with the WILD gyro-attachment GAK 1 was carried out.

1.6 *Survey of the Filchner Station*

On a bad weather day, permitting only short sighting distances, the Filchner Station with all its installations was surveyed with the WILD TC 1. The siteplan is shown in Fig. 8.

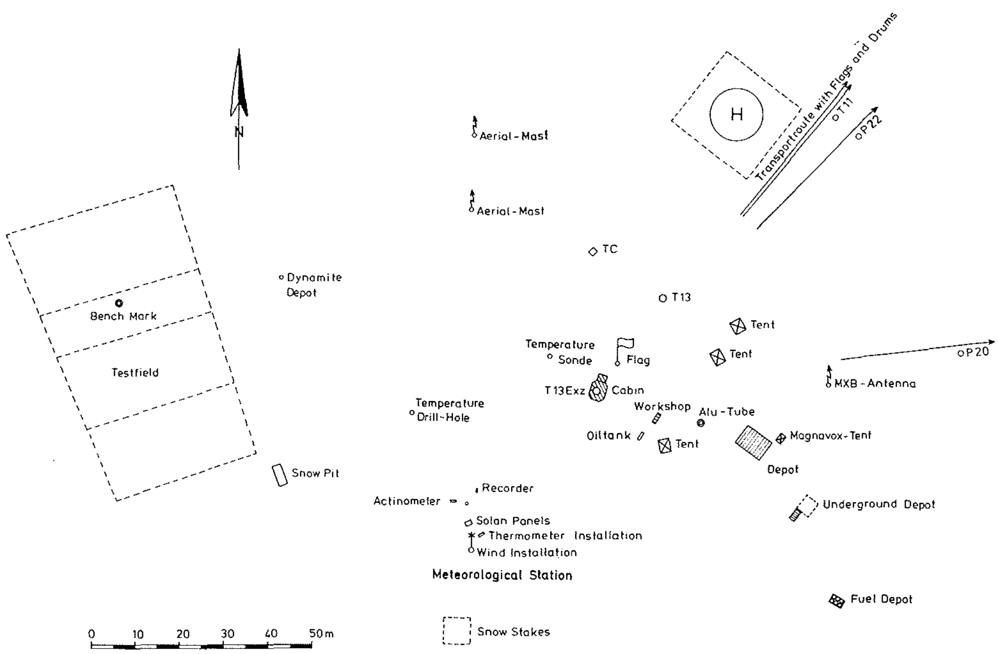

Fig. 8: Site plan of the Filchner Station.

Abb. 8: Lageplan der Filchner-Station.

2. MEASUREMENTS IN THE ATKA BAY

In view of the pack ice conditions in the Weddell Sea, generally known and dreaded since Filchner 1911, another suitable landing place has — in spite of the extremely favourable situation in summer 1979/80 — been looked for around Cap Norvegia on the return voyage from the Filchner Ice Shelf. It was found in Atka Bay, the height of the ice edge also amounting to less than 10 m. In view of the fact that only two days were available to do the field work, that only small vehicles and helicopters could be operated and that a notably slower drift velocity than that of the Filchner/Ronne Ice Shelf could be expected, one Doppler-point was fixed and the first measurements in a deformation triangle with 750 m lateral length were carried out at a distance of only 5 km from the ice edge on the ice shelf. After repetition measurements, scheduled for summer 1980/81, the desired information about drift velocity as well as about possible relative movements (see Figs. 9, 10) will be obtained.

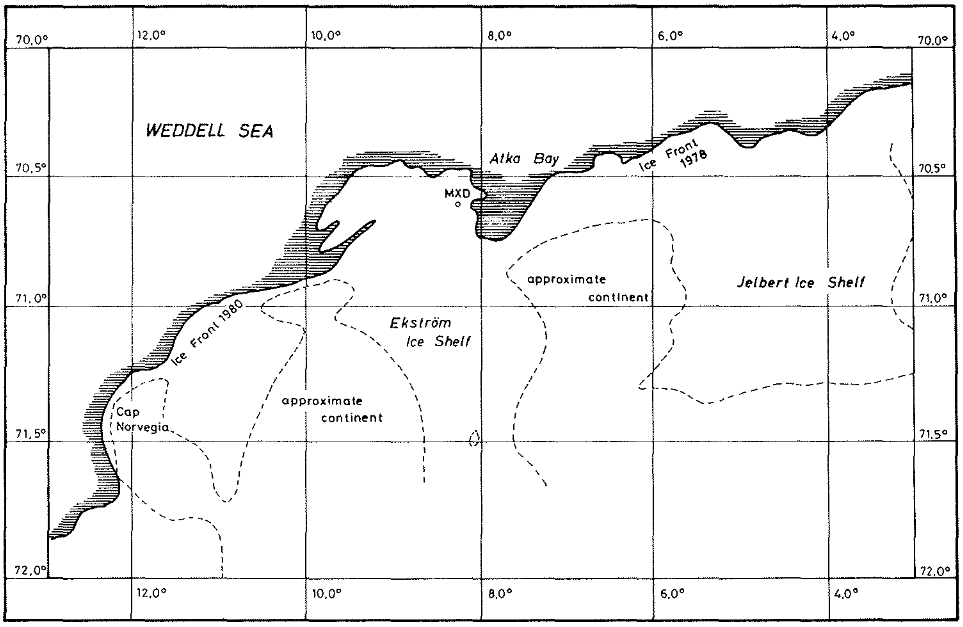

Fig. 9: Ice front of Atka Bay and surroundings.

Abb. 9: Schelfeiskante der Atka-Bucht und Umgebung.

The Doppler measurements were carried out — as described under section 1 — with a Magnavox instrument for the point MXD.

The measurements of the deformation triangle with central point and two intermediate points along the radial rays were taken with the WILD TC 1 and WILD T 3, the system was oriented by means of gyroscopic measurements.

The accuracy of the distance measurements amounts to $\pm$ 5.2 mm/km, the accuracy of the direction measurements in the central point to $\pm$ 0.2 mgon.

The levelling errors of closure for the relative altimetry amount to 7 mm on an average.

Considering that the obtained data are the foundation for later deformation and drift analyses, a recommendation for the establishment of a summer station on the ice shelf of Atka bay has been made to the German National Committee for SCAR.

3. FINAL REMARKS

For subsequent measurements, at the end of the measuring campaign the aluminium poles MXA, MXB, T 01, T 04, T 12, T 13 and P 20 on the Filchner/Ronne Ice Shelf were extended by 2 m, all other points by 1 m. All points of the deformation triangle in Atka Bay were extended by 1.5 m aluminium poles, the alignment points by 1 m.

The geodetic instrumental equipment proved its worth, only for the frequency control of the TC 1 field comparisons are intended.

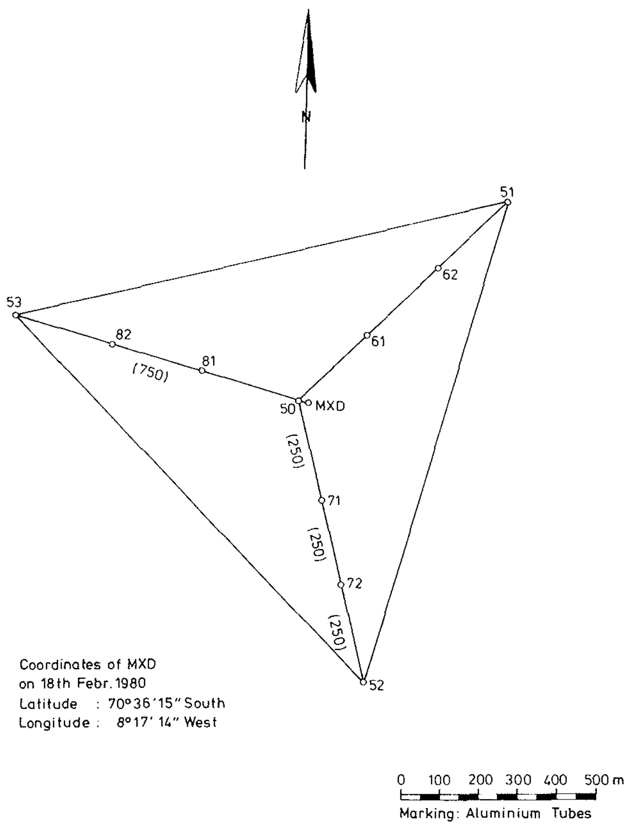

Fig. 10: Deformation triangle 1979/80 Atka Bay.

Abb. 10: Deformationsdreieck 1979/80 Atka-Bucht.

In future expeditions the dynamics of the whole Filchner/Ronne Ice Shelf are be determined by repeated three-dimensional Doppler satellite positioning of points at 100 km intervals.

The relative movement of the ice is to be obtained from deformation pentagons at locations of special glaciological interest.

For the performance of these works, navigation devices for the tracked vehicles and the helicopters with sufficient radius of action are absolutely necessary on safety grounds.

4. ACKNOWLEDGEMENTS

The authors are greatly indebted to their expedition comrades Reinwarth, Schneppenheim, Suhrmeyer, Hag, Menssen, Heldt, and Wenzel for their selfless co-operation in the geodetic field work as well as to Köhler for his control calculations and deformation analyses.

Last, but not least, our sincere thanks are due to Messrs. Siemens-Albis for the loan of the 3 SIAL-instruments and to Messrs. Keuffel & Esser for a repair set which we were fortunately able to return unused.

Literature

Dorrer, E., Hofmann, W., Nottarp, K. & W. Seuffert (1971): Geodätische Geschwindigkeitsbestimmungen auf dem Ross-Schelfeis in der Antarktis. — Dt. Geod. Kommission b. d. Bayer. Akad. Wiss., Reihe B, Nr. 181, München.

Fuchs, G., Gerdau, H., Henning, K., Klapdor, N., Kohnen, H., Möller, D., Reinwarth, O. & L. Suhrmeyer (1981): Survey and mapping of the ice front along the Antarctic coast between 8°W and 62°W. — Polarforschung 51 (1): 17—19.

Kohnen, H. & P. H. Hag (1981): Radio echo sounding investigations on the Filchner/Ronne Ice Shelf 1979/80. — Polarforschung 51 (1): 55—60.

Reinwarth, O. (1981): Glazialmeteorologische Arbeiten auf dem Filchner-Ronne-Schelfeis während der Standorterkundungsexpedition 1979/80. — Polarforschung 51 (1): 61—75.