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# DEFENCE RESEARCH ESTABLISHMENT OTTAWA

DREO TECHNICAL NOTE NO. 74-16
DREO TN 74-16

# SOME SEA ICE OBSERVATIONS AT HERSCHEL ISLAND IN MID WINTER 1973

by

G.J. Irwin

PROJECT NO.
97-67-05

JULY 1974
OTTAWA

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## ERRATA

Page 4, line 31, "For the invar E = 2.2 x $10^t$psi" should read: "For the invar E = 2.2 x $10^7$psi"

Page 6, line 10, "and high salinity which is constrained at the edge by the shoreline" should read: "and high salinity) which is constrained at the edge by the shoreline"

Because of the poor quality of some photographs a limited number of colour originals will be available for loan upon request.

## ABSTRACT (U)

50//Some observations of sea ice near the shoreline were made during a week's visit to Herschel Island, N.W.T. in January and February 1973. [The observations of leads, hummocks, tidal cracks and ice strains constitute the author's initial acquaintance with ice conditions above the arctic circle.] Apparent expansions and contractions in the level ice sheet of Thetis Bay give positive and negative values of strain averaging 1.7 x 10$^{-4}$. The latter phenomenon may correspond to relative decreases and increases in air temperature from day to day. However, experimental sources of error are found to be significant and improvements in technique are suggested.//

## RÉSUMÉ (U)

Quelques observations de la glace de mer près du littoral étaient faites pendant une visite d'une semaine entre les mois de janvier et février. Les observations des chenaux, des buttes de pression, des fissures de marée, et des déformations de glace constituent la connaissance initiale de l'auteur avec les conditions de la glace au-delà du cercle Arctique. Des dilatations et contractions apparentes dans la glace nivelée de la Baie Thetis donnent des valeurs positives et négatives des déformations vers 1.7 x 10$^{-4}$. Ce phénomène-ci peut être relié aux diminutions et augmentations de la température de l'air de jour en jour. Cependant, les erreurs expérimentales sont déterminées d'être significatives. Ensuite des améliorations de procédure sont suggérées.

# SOME SEA ICE OBSERVATIONS AT HERSCHEL ISLAND IN MID WINTER 1973

## INTRODUCTION

In the course of studies of sea ice in the Canadian Arctic, a trip to Herschel Island, Yukon Territories in January 1973 provided the author with the opportunity of making an initial acquaintance with the arctic winter environment. The behaviour of sea ice at the land-sea interface in the Arctic is a current Canadian Defence interest, thus particular attention was given to sea ice processes and morphology in the vicinity of coastlines between the Mackenzie Delta and Herschel Island. It was at the settlement of Herschel on the east coast of the island that the author joined Dr. P.F. Cooper, Jr. of the Polar Continental Shelf Project who was engaged in ice strain measurements. Knowledge of phenomena affecting arctic shorefast and grounded ice such as leads, tidal cracks and strains is far from complete and is a significant concern to commercial interests in the region. The present visit gave the author a personal impression of the setting within which such problems of sea ice must be solved.

Strain measurements carried out on sea ice using a chaining method are discussed at some length. Despite necessary improvements in the experimental approach an attempt is made to account for the magnitude of strain measured.

Herschel Island, perhaps a glacial ice thrust feature (1), is situated at $69^{\circ}35'$N and $138^{\circ}56'$W, 156 miles north west of Inuvik, N.W.T. and covers an area of 43 square miles in the Beaufort Sea. It is separated from the mainland near the Alaskan border by a narrow channel. At the time of visiting Herschel there were about five useful hours of daylight from 12 noon. There is a two-foot tide in the vicinity and currents flow between ½ and 1 knot west to east.

## THE EXPEDITION

Take-off was from Inuvik in a Cessna 185 on January 28, at dawn, 11:20 a.m. mountain time, with winds at 20 mph and temperature about $10^{\circ}$F. En route it was seen that Ptarmigan Bay (Figure 1) contained about 100 square miles of open water on the south while to the north ice cover was about 9/10. From the cockpit on the approach to Herschel

Island much open water surrounded Collinson Head less than a mile offshore. Thetis Bay, by contrast, was covered by level ice. Figure 2 shows the eastern coastline in more detail.

On January 29 the lead offshore from Collinson Head had closed up during the dark hours adding to an already hummocky ice field (Figure 3). Ice blocks up to 30 inches in thickness and several feet in breadth were piled up to 6 feet on the shallow shore of Collinson Head (Figure 4). The characteristic blue colour of these blocks was indicative of substantial brine drainage.

The very rough ice field at the Head and on the north shore contrasted vividly with the smooth, level ice of Thetis Bay. The bay is well protected from the north shore rip current (1). In addition a longshore clockwise eddy current in the bay probably keeps it free of ice floes in summer (1) and particularly at the time of freeze up. Some grounded hummocks were noted, however, along the south edge of the sandspit at Herschel. Tidal cracks up to 6 inches wide and discontinuous in nature (Figure 5) followed the shoreline of the island, even cutting through the hummocks.

On January 31 traverses were made by snowmobile east along the spit at Herschel and around Collinson Head toward Bell Bluff and west and south along the shore of Thetis Bay. In the vicinity of Collinson Head and the north shore, pressure ridges parallel to the coast line were separated by 100 feet of smooth ice providing a passage for the snowmobile for distances of several hundred yards (Figure 6). The sail height of these ridges was about 6 feet. Arrays of parallel tidal cracks separated by a few yards were most clearly evident along the coastline of Thetis Bay. About 100 yards from the bay shoreline was a line of slightly ridged ice (only inches in height) which probably delineated the trajectory of a "working" tidal crack (Figure 7). This is the crack along which, according to natives of the area, the polar bear treads. As pointed out by Wright and Priestley (2) the number of tidal cracks depends on the rate of increase of both water depth and ice thickness. The outermost crack functions as the working one. In Thetis Bay as many as five active cracks spaced some 10 yards apart were noted. This may be due to the presence of multiple sand bars or underwater spits. Zubov (3) gives a brief description of tidal cracks in fast ice and shows that the steeper the angle of the slope and the less the amplitude of the tide, the closer together will be the exterior crack (a working crack remote from the shoreline) and an adjacent interior working crack (closer to the shoreline). Thus many aspects of the tidal cracks observed should be accountable in the above terms. On February 2, it was found that during the night a functioning tidal crack at Herschel had opened up from a fraction of an inch to 6 inches wide at the top but tapered toward zero at 4 feet depth. With limited means an attempt to measure ice thickness through the crack yielded a value of over four feet. The tapered cross section of the crack was probably a consequence of a hinging effect of the active portion of the ice sheet with the ebb and flow of the tide.

On the return journey to Inuvik, February 2, it was apparent from the air at 2800 ft. that sea ice along the mainland coast was rough (Figure 8) between Herschel Island and Kay Point. From there to the

Mackenzie Delta the ice took on a decidedly smoother character (Figure 9). Extensive open water was seen perhaps ten miles from the shore after passing Kay Point.

## TECHNIQUE OF STRAIN MEASUREMENT WITHIN THETIS BAY

A simple mechanical approach to ice strain measurement at the surface was attempted with Dr. Cooper on the level ice of Thetis Bay about $\frac{1}{4}$ mile south of the sand spit at Herschel. As sketched in Figure 10, invar tape under tension and 150 feet in length was used to detect daily contractions or expansions in the surface of the ice sheet using nails fixed in the ice as indicators. Tension at 15 lbf was maintained in the tape with the use of sensitive spring balances attached to spikes driven into the ice sheet at each end of the tape. Four smooth wooden supports maintained the tape free of the two-inch depth of hard wind-packed snow. On consecutive days lines of measurement were taken at $120^{\circ}$ angles directed approximately east, south-west, and north-west. A carpenter's square laid on the ice served as an aid to measure the minute displacements of the nail indicators at each end of the tape. Measurements of displacement per 24 hour period between afternoons averaged 20/64 inches. In a 150 foot length this gives a strain of $1.7 \times 10^{-4}$. The sign of the displacement occurred as either positive or negative on different days. During the period that the author was present there was an anomalous warm period lasting about three days. Between January 29 to 30, daytime temperatures averaged $10^{\circ}$F with a peak on January 29 of $29^{\circ}$F. As complete data were not made available to the author it can only be surmised that notable changes in air temperature had a direct relationship to deplacements measured even with the presence of the thermally insulating effect of the hard packed two inch snow cover.

## DEPENDENCE OF STRAIN ON TEMPERATURE

The following is speculation on the range of surface ice temperatures and thermal fluctuation required to produce the observed strain measurements in Thetis Bay using likely values of ice sheet thickness and salinity. A graph of thermal strain of sea ice at various temperatures against a range of salinities (Figure 11) was calculated from data due to Malmgren(4). From the graph it can be seen that sea ice may experience large dimensional changes for only a narrow range of temperatures. If the ice thickness in Thetis Bay is assumed to be five feet, an average salinity for the ice sheet can be calculated using an equation due to Cox and Weeks (5):

$$\overline{S} = 7.88 - 1.59(h)$$

$\overline{S}$ is the average salinity and h is the ice thickness in meters. Here $\overline{S} = 5.45^{\circ}/oo$. By interpolation on the graph, and assuming $1^{\circ}$C rise or fall in ice temperature with changing air temperature, the ice temperature corresponding to the observed average strain comes close to $-6^{\circ}$C or $21^{\circ}$F. This appears unrealistically high considering that average daytime temperatures were only 10$^{\circ}$F. With a larger air temperature change, surface ice temperatures according to the graph could occur within the range of 10 and 19$^{\circ}$F. The observed strain is a relative one, i.e. not absolute. Even so, given the average ambient temperature the same range of ice temperatures is deduced. Further speculation is not warranted. However, with complete experimental data adequate comparisons with the results of other workers should be possible.

## EXPERIMENTAL SOURCES OF ERROR

To assess the feasibility of the strain measurement technique used, experimental sources of error are enumerated. The most important are expected to be as follows:

1. Error of measurement.
2. Temperature sensitivity of the invar tape.
3. Changes in tension of the tape causing elastic strains.
4. Friction of wooden supports.
5. Tape not stretched straight, effects of wind, angle tape makes with plane of the ice sheet near the ends where measurement is made, sag of tape giving incorrect "gauge length".

Estimates of these errors are given below:

1. The error of reading both ends of the tape gives a strain error of $\pm 5.5 \times 10^{-6}$.

2. The thermal coefficient if expansion ($\alpha$) for invar is about $2.15 \times 10^{-7}/^{\circ}$F. For a temperature change ($\Delta T$) of 20$^{\circ}$F as occurred on January 29, 1973, the corresponding strain would be $\varepsilon = \alpha\Delta T = 4.3 \times 10^{-6}$.

3. The following expression relates strains ($\alpha$) to changes in tension $(t - t_o)$: $\varepsilon = \dfrac{t - t_o}{AE}$

   where E is Young's modulus,

   A is the cross sectional area of the invar tape,

   $t_o$ and t are the initial and final tension respectively.

   For the invar $E = 2.2 \times 10^{t}$ psi

   $A \simeq 0.044 \text{ (inches)}^2$

   Tension though initially set at 15 lbf, fluctuated within ± 5 lbf. Thus $\varepsilon = \pm 5 \times 10^{-6}$.

4. The coefficient of static (dry) friction of wood on metal is 0.2 to 0.6 (6). For invar of density 0.499 lb/ft$^3$ acting on a ½ inch thickness of four wooden supports, then in the worst case the force of friction is $4.2 \times 10^{-5}$ lbf. Such a small force would have a negligible effect on the measured strain value.

5. Deviations from a straight line in the vertical or horizontal plane were at worst within 10°. This was estimated to introduce a strain error of $4 \times 10^{-6}$.

For a catenary shape of the invar tape between supports the following equation holds:

$$C = \frac{wl^3}{24\ t^2}$$

where:

C is the correction between supports

W is the weight in lb/ft = 0.153 lb/ft

l is the distance between supports ≈ 50 ft

t is the tension = 15 lbf

Thus, C = 0.54 ft. and for the total length, 1.62 ft.

This introduces an error of $1.9 \times 10^{-6}$ in measured strain.

A total percentage is thus calculated as 12% for strains of about $2 \times 10^{-4}$. This error will be correspondingly higher where strains close to zero are measured. In general the technique of strain measurement used is admissible only where fairly large strains are expected.

## RECOMMENDATIONS FOR IMPROVEMENTS IN TECHNIQUE

Such an ideally level ice sheet as that in Thetis Bay should be conducive to accurate strain measurements. Some improvements that might be made in the above technique are suggested.

The measurements in three directions should be taken concurrently. A check on results might be to take a series of measurements in each direction with arrays either as in (a) or (b) of Figure 12 for example. In case (b) several strain ellipses could be constructed. With an extended array of measuring sites a mapping of the strain field throughout the Bay could be achieved. However, a more precise and practical approach would be to use electronic optical (geodimeter) or microwave optical (tellurometer) methods of measurement along a strain triangle similar to the mesoscale method of strain measurement by Hibler et al (7). In fact the strain ellipses give only relative strain. However, with the construction of strain rate ellipses over a sufficient period of time (7) and with a knowledge of the relationship between absolute strain and temperature for the type of sea ice being dealt with, it should be possible to deduce the state of strain in the ice sheet.

A systematic recording of ice temperature profiles and salinity profiles over a known thickness of ice together with a corresponding surface strain measurement over the same period of time might be sufficient to account for the strains recorded. However, other mechanisms may modify measured strain values. At high surface temperature and high salinity a differentially contracting ice sheet may tend to buckle convex downwards with the added component of its own weight. Bending stresses will then contribute to the negative upper surface strains measured. Conversely a differentially expanding ice sheet (especially with falling temperatures and high salinity which is constrained at the edge by the shore line may bend with the concavity downward thus influencing measured positive values of strain. It is therefore advisable to measure vertical deflections in the ice sheet in addition to horizontal strains.

It would be interesting to measure horizontal pressure at a tide crack interface. Thermal expansion of the Thetis Bay ice sheet could produce substantial pressure although there was no external evidence of this in the area visited.

## CLOSING REMARKS

Although the observations made during the trip to Herschel Island present little that is new or unexpected, nevertheless some appreciation of sea ice problems in an arctic setting was gained. Such phenomena as:

1) leads that precede the formation of a hummocky ice field of pressure ridges;

2) tidal cracks which are a direct indication of ice movements;

3) apparent ice strains which are sensitive to ambient air temperatures

are an obvious part of any total description of sea ice coastal behaviour during winter in the region visited. Also ice strains should be measured with more advanced techniques than chaining methods of surveying.

## REFERENCES

1. G. Hattersley-Smith. Beaufort Sea Expedition, Herschel Island, Parry Peninsula, Holman Island. Arctic Section, Defence Research Board (1951).

2. C.S. Wright and R.E. Priestley. British (Terra Nova) Antarctic Expedition 1910-1913 "Glaciology". Harrison and Sons Ltd., London, p.356, (1922).

3. N.N. Zubov. Arctic Ice. "Izdatel'stvo Glavsevmorputi". Translation (1963) by U.S. Navy Oceanographic Office and American Meteorological Soc., pp 158-160, (1943).

4. F. Malmgren. The properties of sea ice "O svoistvakh morskogo i'da" from the Scientific Results of the Maud Expedition 1918-1925, 1(5), (1927). Reference 3.

5. G.F.N. Cox and W.F. Weeks. Salinity variations in Sea Ice AIDJEX Bulletin No. 19, pp 1-17, (1973).

6. Handbook of Chemistry and Physics 53rd ed. Ed. R.S. Weast. Publ. The Chemical Rubber Co. p.F15. (1972-73).

7. W.D. Hibler III, W.F. Weeks, S. Ackley, A. Kovacs, and W.J. Campbell. Mesoscale Strain Measurements on the Beaufort Sea Ice Pack (AIDJEX 1971) AIDJEX Bulletin No. 13, pp 55-76. (1972).

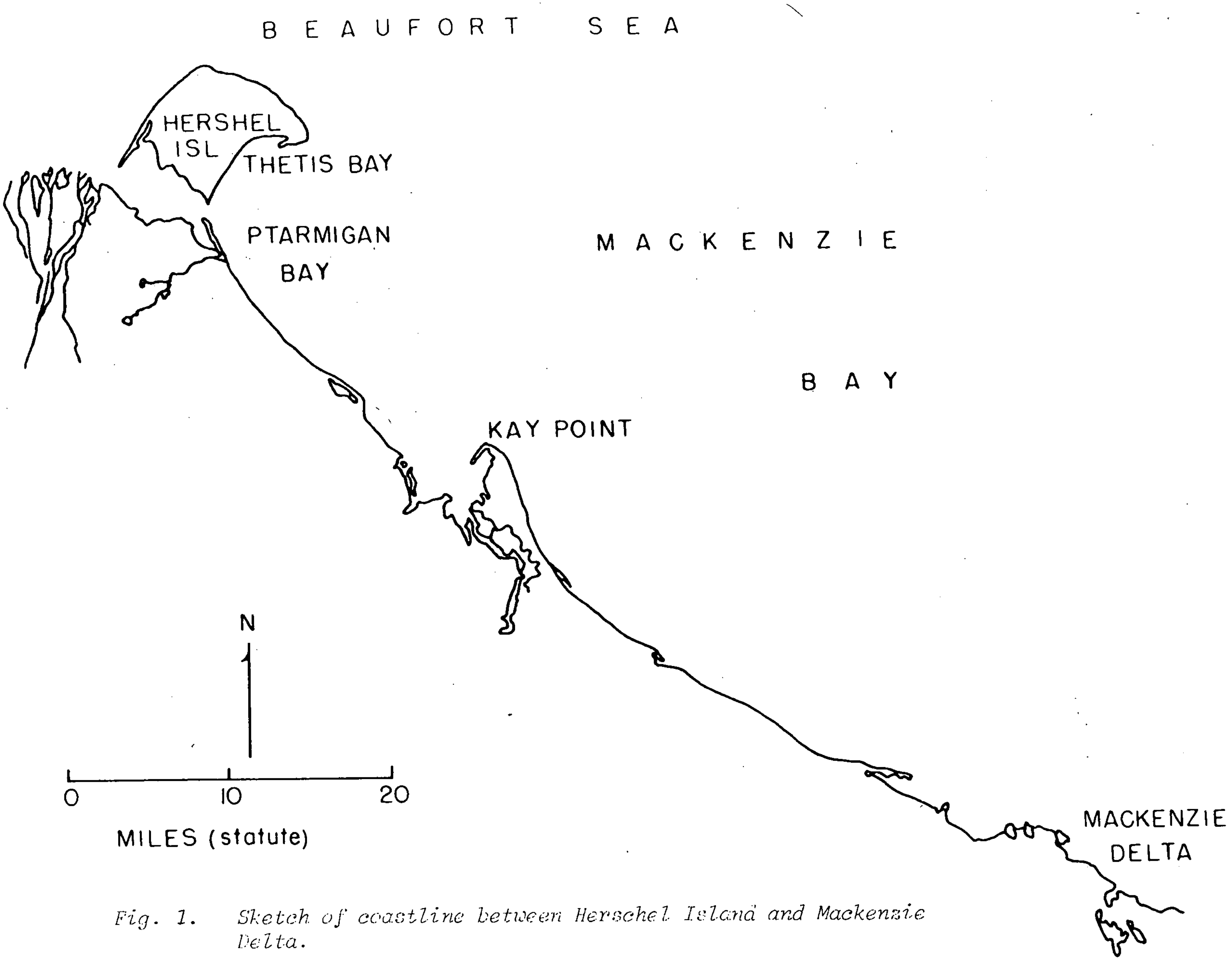

*Fig. 1. Sketch of coastline between Herschel Island and Mackenzie Delta.*

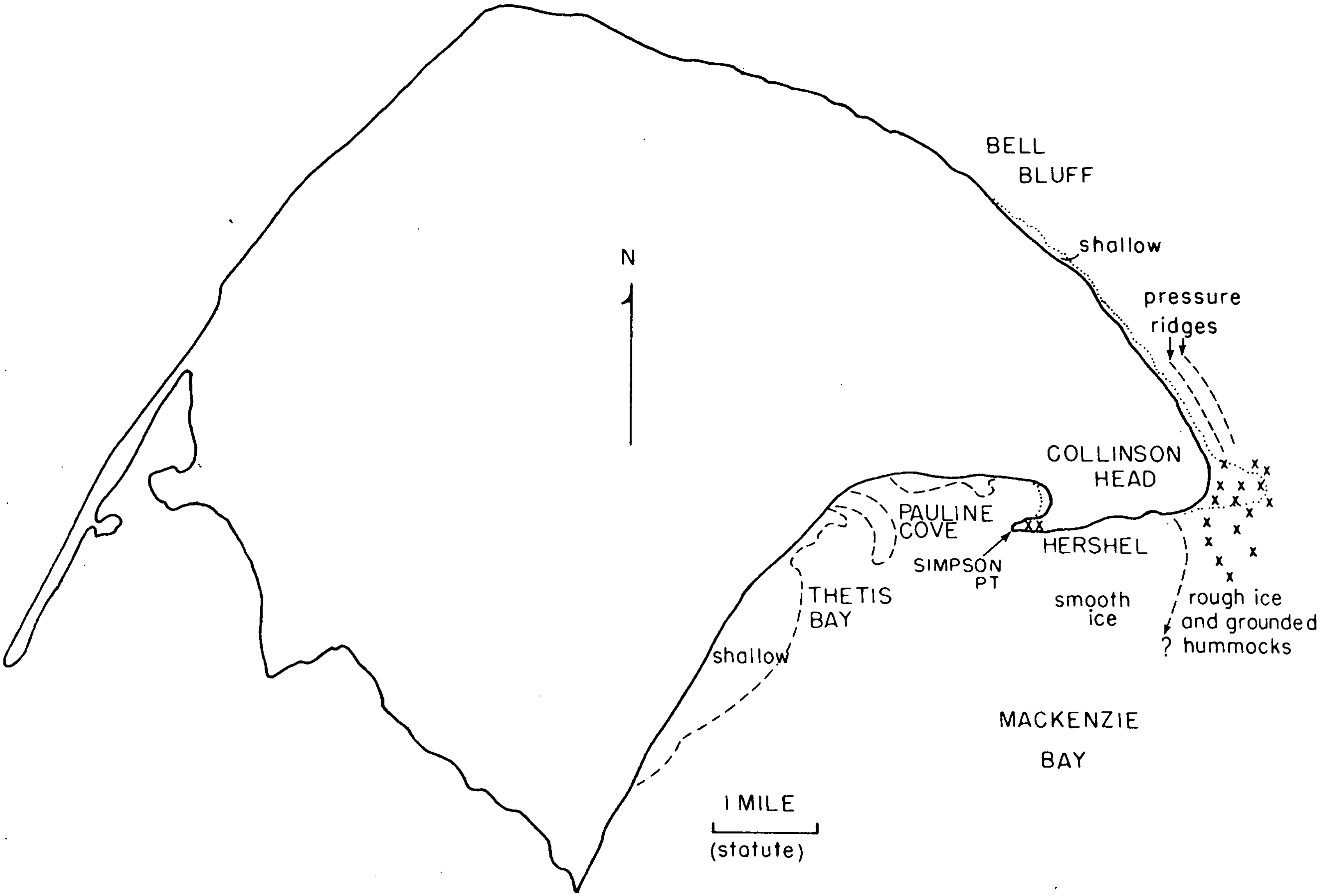

*Fig. 2. Sketch of Herschel Island. Some ice features are indicated diagramatically.*

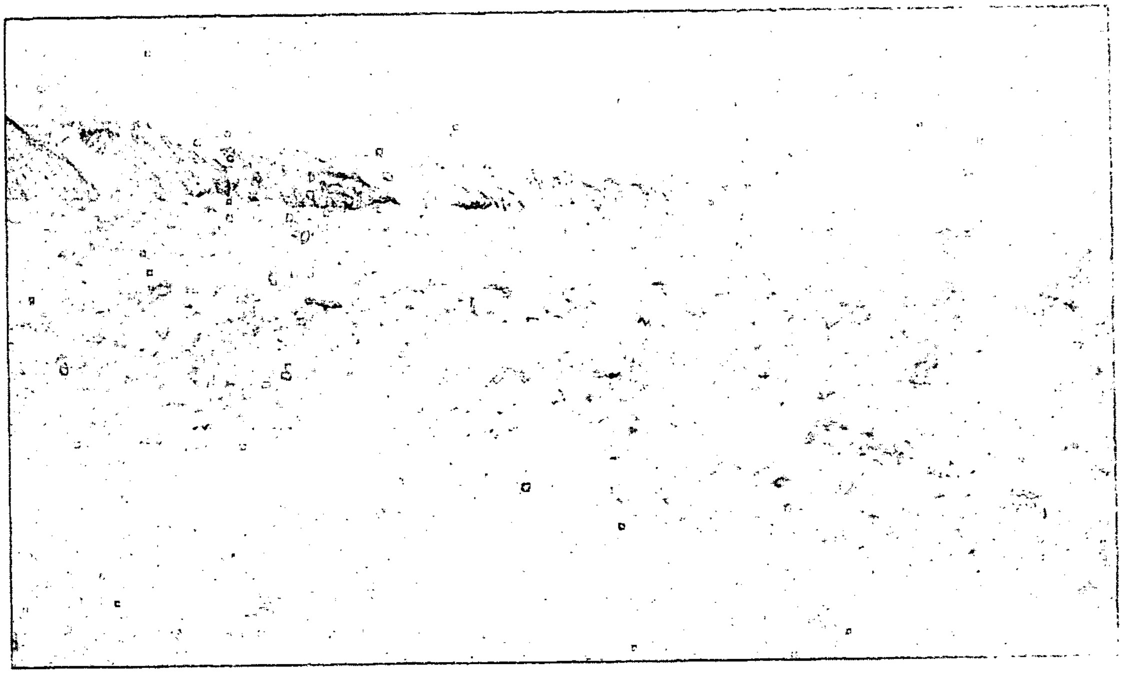

Fig. 3. Rough ice at Collinson Head. Cliffs are about 100 ft. in height.

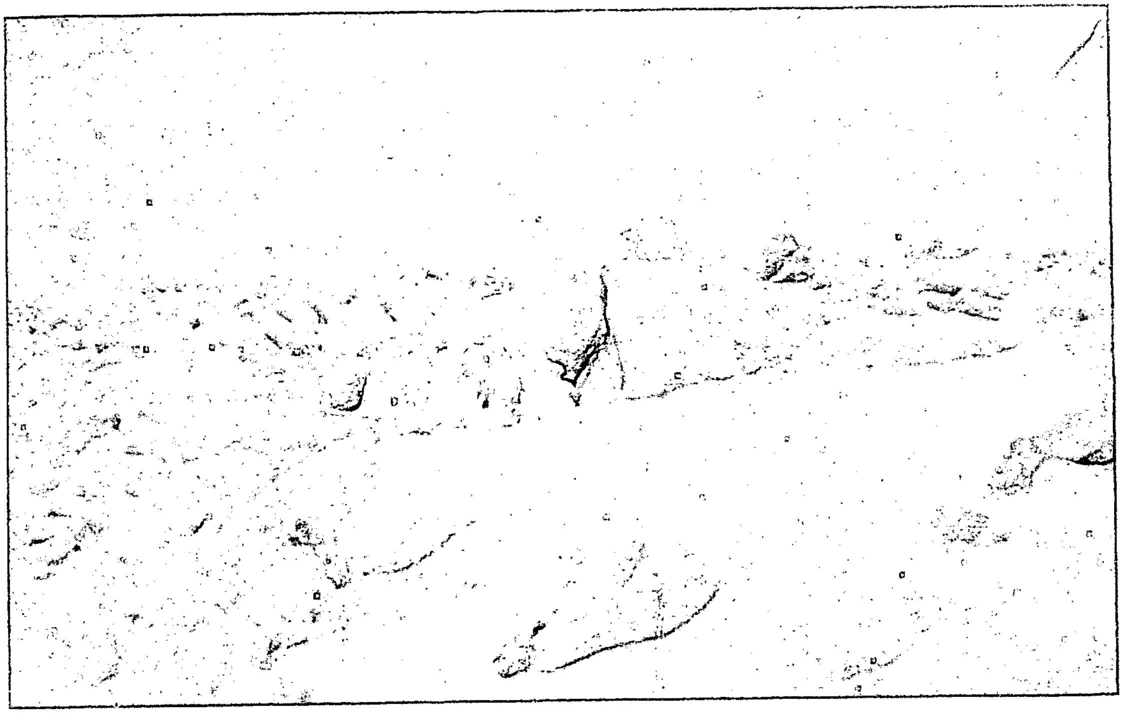

Fig. 4. Typical grounded hummock about six feet in height at Collinson Head.

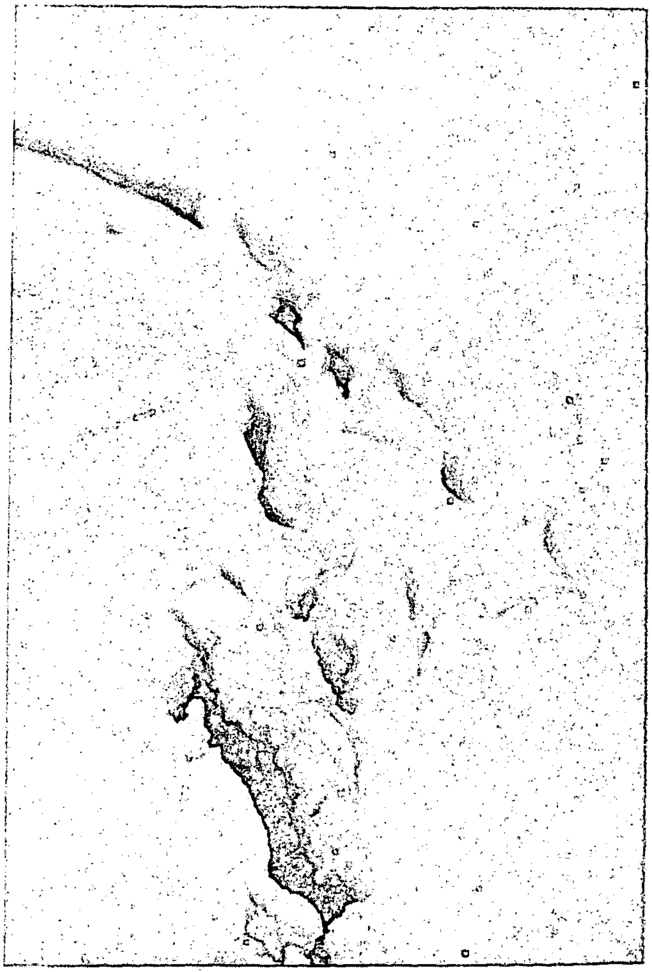

*Fig. 5. Discontinuous tidal cracks beside sand spit at Herschel.*

Fig. 6 Parallel pressure ridges separated by smooth ice as seen on north side of Collinson Head.

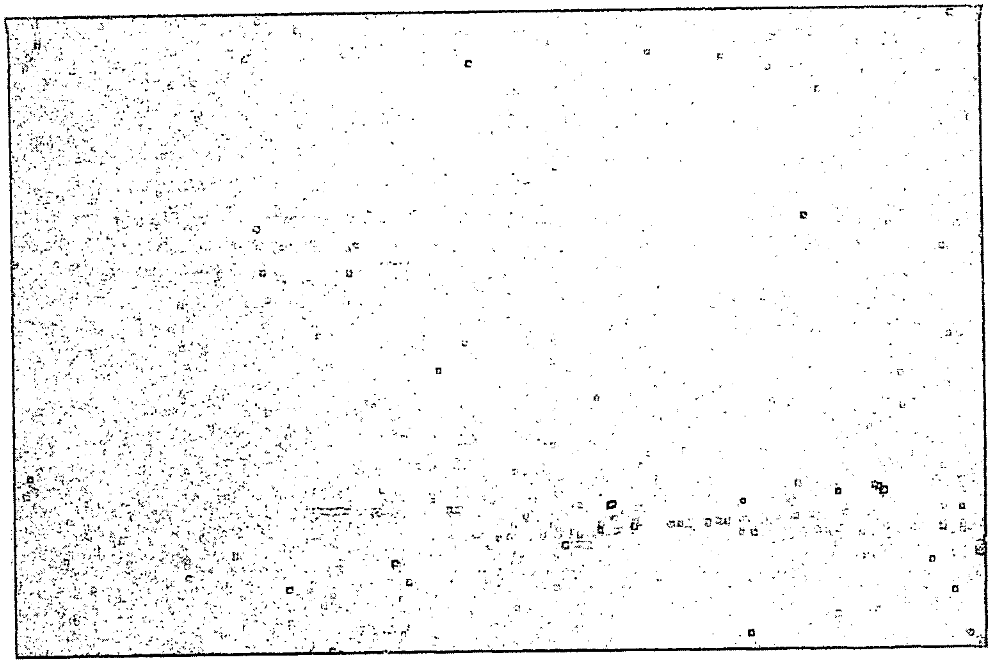

Fig. 7. Slight ridge delineates trajectory of probable working crack in Thetis Bay.

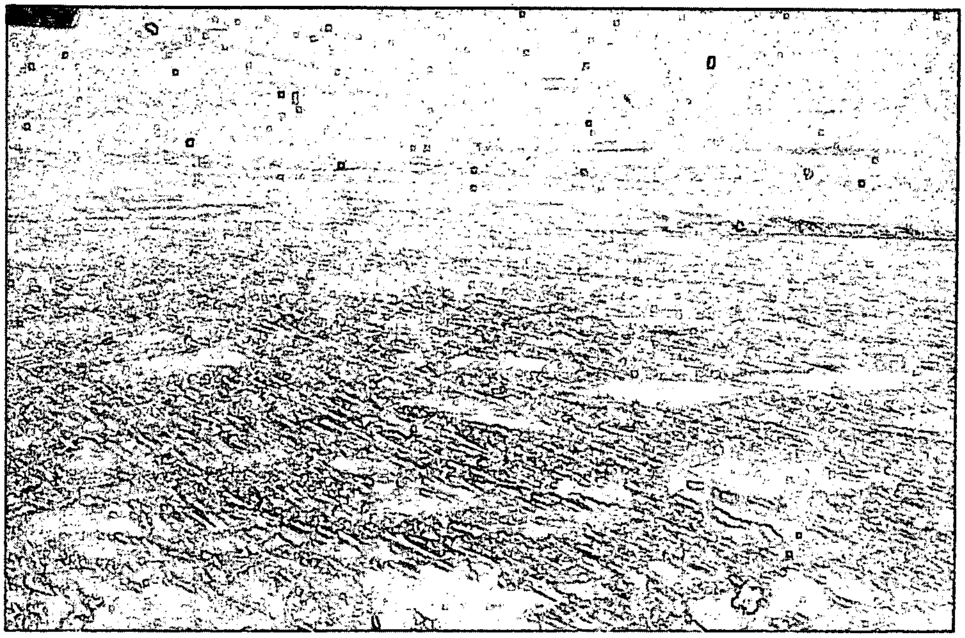

Fig. 8. Typical of rough ice observed during flight from Herschel toward Kay Point along mainland coast.

Fig. 9. Smooth sea ice east of Kay Point. Sand spit promontory at right.

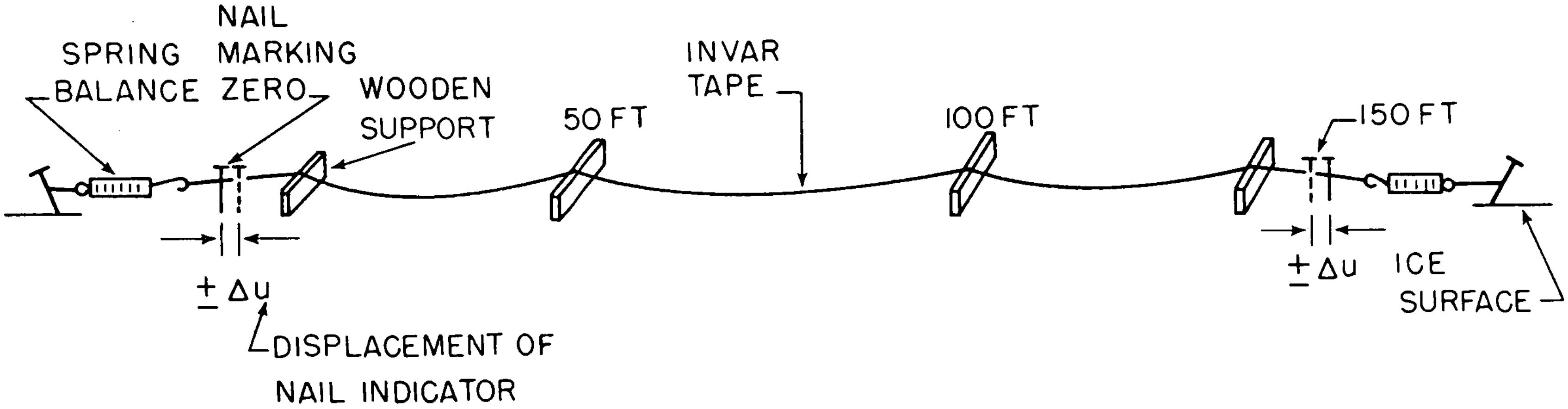

*Fig. 10. Diagramatic sketch of strain measurement technique.*

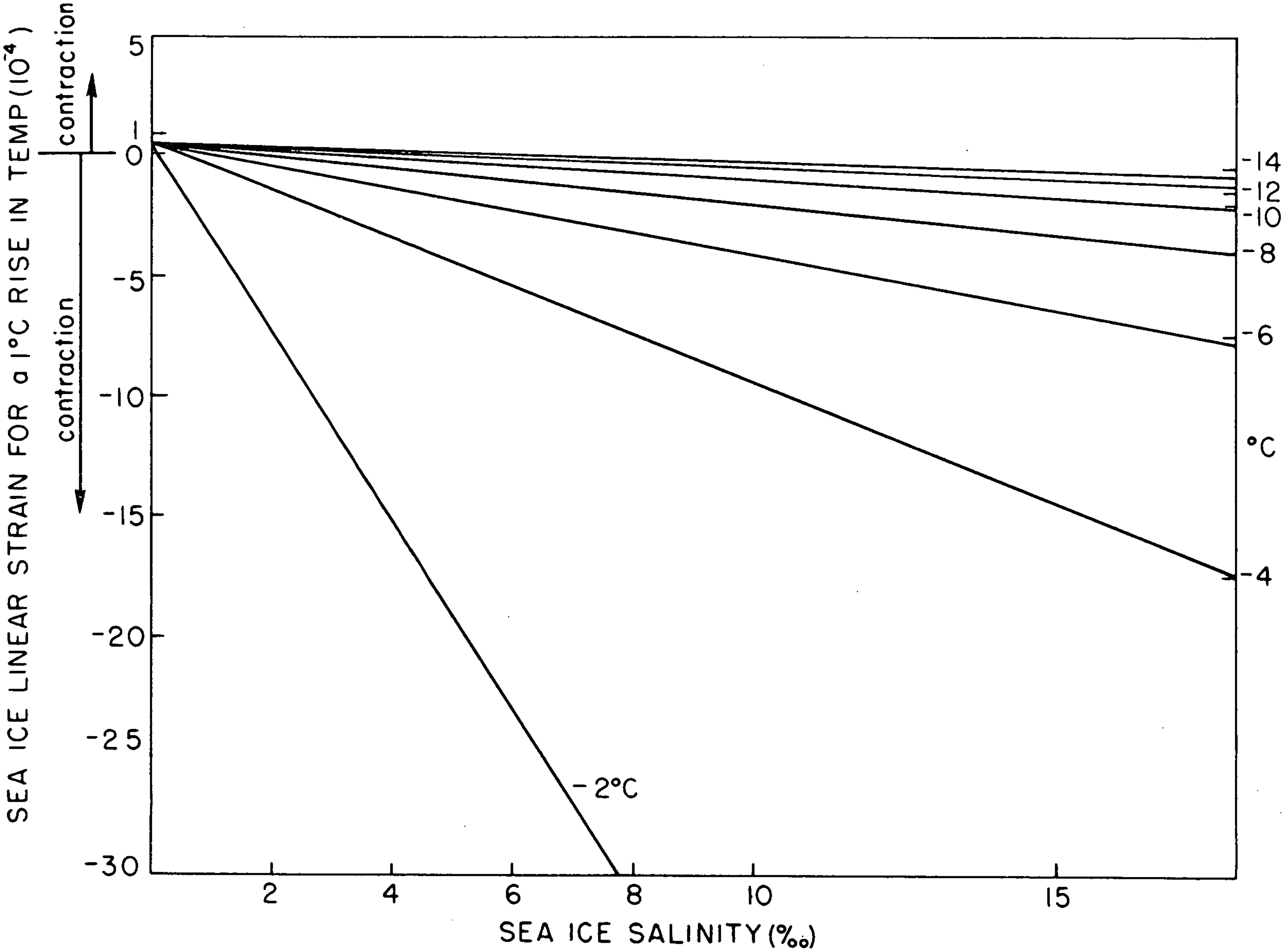

*Fig. 11. Graphical representation of sea ice strain varying with salinity at given ice temperatures. Calculated from data due to Malmgren (4).*

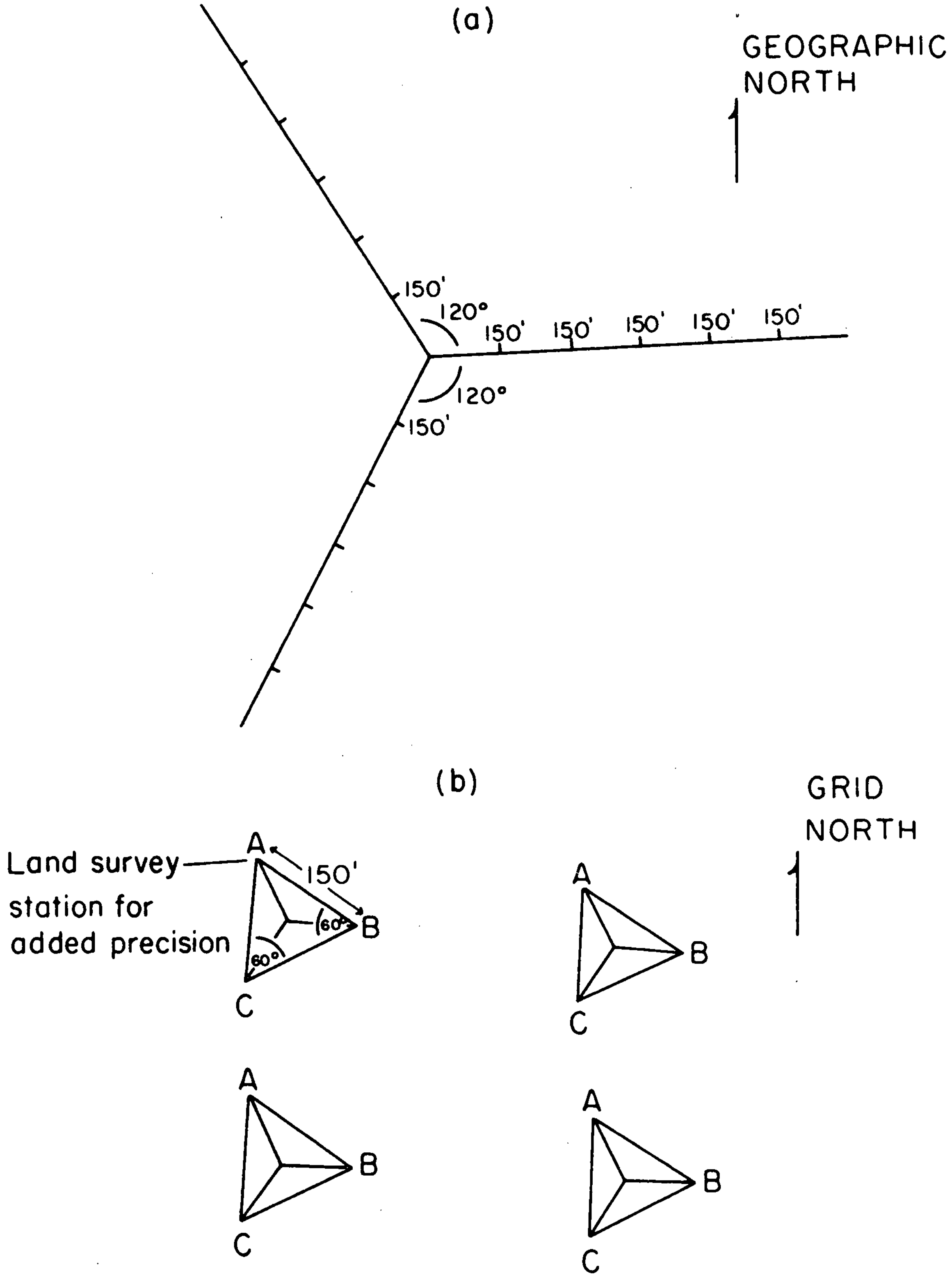

*Fig. 12. Two possible arrays for the measurement of strain, (a) or (b). The latter allows for a mapping of strain field on the basis of strain ellipses.*

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