Table 1 Action of Antigen on ^{45}Ca Movement in Sensitized and Non-sensitized Rat Peritoneal Cells

Experiment	Incubation time (min)	Total histamine per sample (ng)	Histamine release (%)	^{45}Ca in cells (c.p.m.)*		Number of observations	Change due to antigen (c.p.m.)	^{45}Ca in load solution (c.p.m. × 10^6)
				No antigen	Antigen			
Sensitized								
1	1	180	40	2,511 ± 106	4,065 ± 274	5	1,553	1.0
2	1	100	40	2,948 ± 90	7,624 ± 533	5	4,676	1.2
3	1	350	24	5,042 ± 1,190	8,139 ± 585	3	3,097	1.9
4	1	400	26	5,672 ± 2,180	8,058 ± 1,710	3	2,386	2.7
5	2	700	25	3,120 ± 1,303	4,350 ± 1,113	3	1,230	1.0
Non-sensitized								
1	1	700	0	4,520 ± 257	4,693 ± 126	3	173	1.3

* Mean ± s.e. Cells suspended in a medium containing calcium, 1 mmol l^{-1} at 37° C.

calcium, is not essential for histamine secretion. The reduction in the response to calcium caused by magnesium may be due to competition between the two ions, similar to that described for antigen-antibody-induced secretion of histamine[3].

The Physiological Stimulus and Calcium Movement

The experiments with A23187 suggest that entry of calcium into the mast cell is a sufficient stimulus to the metabolically-dependent mechanism which results in histamine secretion. One possible way in which the antigen-antibody reaction might induce histamine secretion would be by allowing the entry of calcium into the mast cell. Our preliminary observations on the movement of ^{45}Ca suggest that this hypothesis is reasonable. Table 1 shows that when sensitized mast cells with membrane bound antibody are stimulated with antigen in the presence of radioactive calcium, there is an increase in the amount of label associated with the cells. At 37° C this movement of ^{45}Ca stimulated by antigen is almost complete in the first fifteen seconds following stimulation, which corresponds to the rate of histamine release. The technique does not allow a distinction between uptake of calcium or exchange of the label with non-labelled calcium. The effect of antigen does not seem to be a non-specific effect of the antigen protein causing binding of ^{45}Ca to the cell surface because it is not observed with non-sensitized cells having no fixed antibody.

Our experiments suggest that calcium entry into mast cells is the trigger to the secretory response.

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LETTERS TO NATURE

PHYSICAL SCIENCES

Lakes Beneath the Antarctic Ice Sheet

The technique of radio-echo sounding of polar ice sheets is now well established[1-3], and three seasons of radio-echo sounding from long range aircraft of the US Navy have been completed under a joint programme of the Scott Polar Research Institute and the US National Science Foundation.

During the most recent field season (1971–72) the square network of flight lines shown in Fig. 1 was flown over East Antarctica using SPRI Mark IV equipment operating at 60 MHz. The map also includes some flight lines from the 1969–70 season at longitudes beyond 90° E which are relevant to our discussion. During the 1971–72 season the improved radio-echo and navigational equipment gave excellent results over most of the flight lines. A detailed survey of the bedrock echo characteristics over this area has been made during the past year. We conclude that this evidence, in combination with other studies, points to the existence of a number of water pockets or lakes a few kilometres wide under certain parts of the ice sheet.

Our film recording system produces a profile of ice thickness similar to that of marine echo sounding (Fig. 2*a–d*). From an aircraft flying at constant altitude profiles of both top and bottom surfaces are recorded as well as reflexions from within the ice mass. Although the strong echo from the upper surface of the ice shows little variation in strength, the normal bottom echo from inland ice (Fig. 2*a*) shows strong fading along the flight line. The horizontal correlation distance or "fading length" of the echo pattern along the flight path is of the order of 20 m and the fading range (variation of echo strength) approaches ±10 dB about the mean value. Harrison[4] has

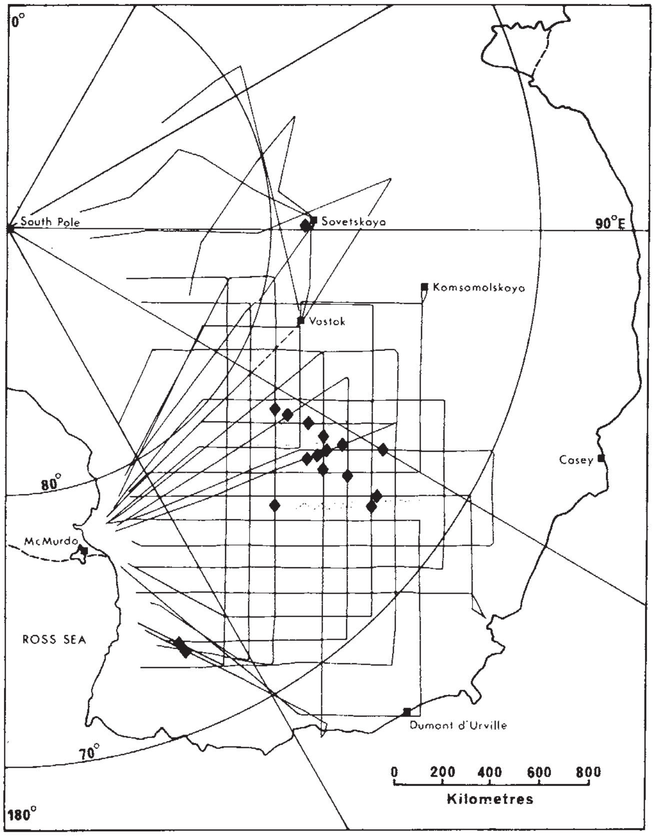

Fig. 1 Flight lines completed in the 1971–72 season of SPRI-NSF radio-echo sounding programme. Some lines from 1969–70 are also included. ◆, Positions of the sub-ice lakes observed on these flights; ■, scientific stations.

shown that these characteristics can be explained in terms of the statistical properties of the ice-rock and ice-air surfaces. To produce fading as seen in Fig. 2 requires a bedrock roughness with a horizontal scale of 20 m or less and a vertical scale comparable to the wavelength of the radio waves (3 m in ice). We note also that the irregular echo returns persist for two or three microseconds after the first arrival, as a result of the broad beamed antenna used for sounding which collects scattered energy returns through angles up to 35° from the vertical. The echo pattern could result either from an irregular distribution of morainal rocks of sufficient size in the basal ice, or from the bedrock roughness mentioned above.

We have noted a number of sites, shown in Table 1, where the normal fading characteristics of the bottom echo change to that which we would expect from an extended smooth surface. Examples are shown in Fig. 2*b*, *c* and *d*. At these sites, the fading length increases to 200 m and more, fading of the echo is much reduced and is absent in some cases, as seen at an enlarged horizontal scale in Fig. 2*d*. At the same time the duration of the bottom echo decreases to a length similar to that of the transmitted pulse (1.0 µs for Fig. 2*b*, *c* and *d*). These characteristics all indicate that specular reflexion is taking place from an extended smooth surface. These surfaces seem to be almost horizontal, with slopes generally less than 1 in 150, except for one case with a slope around 1 in 50.

Table 1 Location and Width of Sub-Ice Lakes

Site No.	Latitude S	Longitude E	Depth of ice cover (m)	Width along flight line (km)
1	76° 42′	122° 45′	3,302	4
2	73° 15′	157° 12′	2,830	5
3	77° 28′	123° 42′	3,600	2
4	74° 08′	124° 35′	4,094	7
5	72° 41′	127° 21′	3,889	4
6	72° 18′	123° 54′	3,254	3
7	77° 59′	122° 43′	3,666	3
8	72° 55′	156° 23′	2,840	2
9	76° 04′	128° 14′	2,969	2
10	75° 56′	127° 21′	3,231	15
11	75° 43′	126° 05′	3,149	4
12	75° 00′	121° 52′	3,057	1
13	75° 54′	122° 06′	3,517	4
14	75° 10′	126° 30′	3,436	3
15	73° 55′	120° 21′	4,047	5
16	76° 42′	136° 23′	3,101	2
17	76° 20′	87° 45′	4,200	7

There is a marked increase in echo strength of 10 to 20 dB as we move from an area of normal fading to one of specular reflexion. The reflexion coefficient of an ice-rock interface is estimated to range from −14 to −20 dB (ref. 2), whereas the reflexion coefficient at an ice–pure water interface would be around −3 dB, provided we are dealing with a thickness of water of the order of a metre or more in depth rather than the usual sub-glacial film of a fraction of a millimetre. Thus the reflexion coefficient suggests that we are dealing with a substantial layer of water, rather than an exceptionally smooth

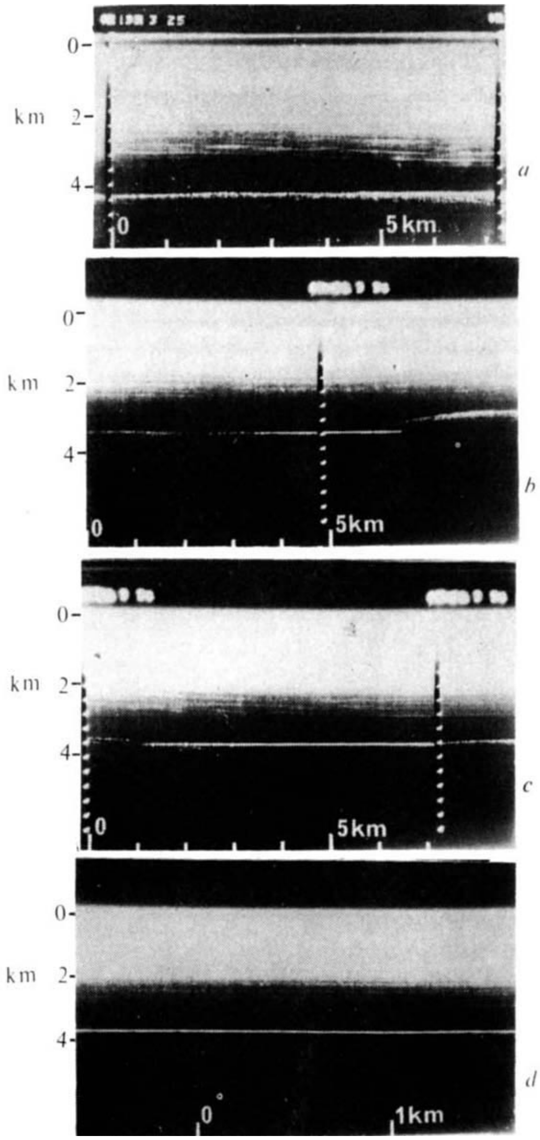

Fig. 2 *a*, Typical strong echo from bedrock, showing normal fading, and some downward extension of the trace due to non-vertical echoes. The column of white dots gives a time reference at 5 µs intervals; *b*, clearly defined example of a smooth reflecting surface under the ice, showing a steep scarp at one edge and a more gradual slope at the other; *c*, further example, with more symmetrical sloping rock margins than shown in Fig. 2*b*; *d*, section from Fig. 2*c* with the horizontal scale expanded four times, illustrating the slow rate and small amplitude of fading.

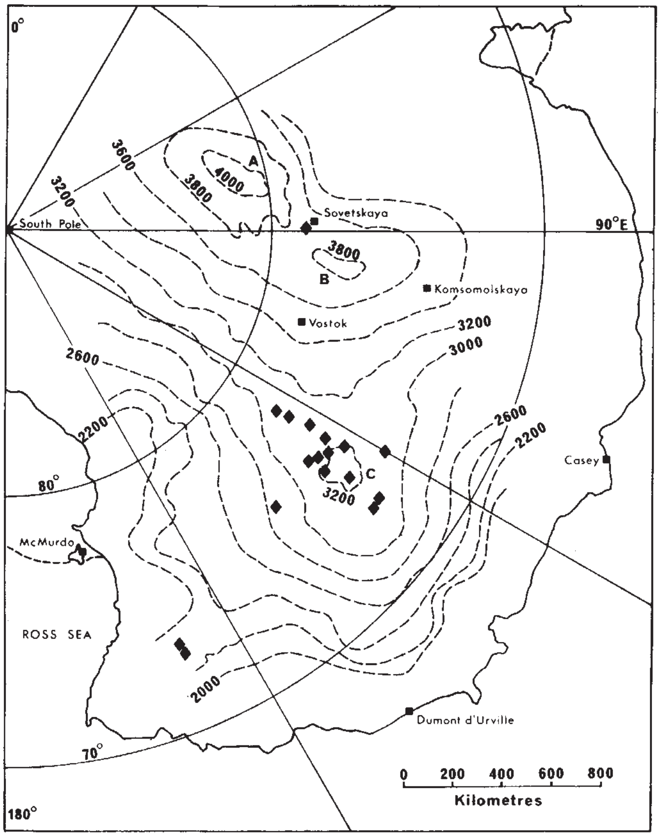

Fig. 3 A map of the surface contours of East Antarctica. The lake sites (as in Fig. 1) are seen to occur in regions of low surface slope.

rock floor beneath the ice. Furthermore, the immediate surroundings of the smooth, near-horizontal sub-glacial echoes, where visible on the records as in Fig. 2*b* and *c*, frequently suggest basins with the surrounding rock sloping down to the level of the smooth reflectors, which we will now term lakes.

The location of the sub-ice lakes is shown by the diamond shapes on the map in Figs 1 and 3, the latter showing their distribution in relation to surface contours of the ice sheet. The surface contours have been determined as part of our sounding programme under the International Antarctic Glaciological Project[5]. The results, which have not yet been published in detail, show that in addition to the highest central dome of the ice sheet (A in Fig. 3), two secondary domes, B and C, exist in the area we have studied. Such domes will also be centres of outflow of the ice, so that in their vicinity surface slopes are low and the velocity of ice movement is small.

Sixteen lakes have been discovered in the 1971–72 records in addition to one from the 1967–68 season near Sovietskaya station, shown in Fig. 1 of ref. 6, for which a tentative explanation in terms of a sub-ice lake was made. The geographical locations of all echoes are shown in Fig. 3. Most are grouped round the centre of outflow of ice at 75° S, 123° E (dome C), while the two near longitude 157° E and the one near Sovietskaya station are near saddles in the ice surface. Further details are given in Table 1.

The existence of meltwater beneath this part of the ice sheet is not in agreement with the computer calculations of Budd, Jenssen and Radok[10] who estimate basal temperatures of −20° C to −30° C over a region covering the main group of specular reflexions. Such calculations are based on earlier estimates of ice thickness, geothermal heat flux and surface accumulation rates. The latest information on these parameters given by the present radio-echo programme and the surface traverse of French scientists, both forming part of the International Antarctic Glaciological Project, indicates that basal melting can occur around dome C when ice depths are about 2,900 m or more (D. Jenssen, unpublished). Similar conclusions seem reasonable for sub-ice lakes at the other two localities. In making these calculations, the major uncertainties arise in estimating the geothermal heat flux, and in assuming that the true temperature distribution can be approximated by a steady-state system. It is satisfactory that calculations based on the newest data appear compatible with our interpretation of the radio-echo observations.

Although the presence of basal water seems reasonable, we have yet to explain why it should accumulate in certain localities since the pressure gradient beneath a glacier normally serves to drive out sub-glacial water. In addition to the other factors discussed in detail by Weertman[8] the flow of water is controlled mainly by two factors: the ice thickness gradient, and the basal slope. Looking at the problem in two dimensions, where x is a distance measured along the line of flow, the direction of flow, F, can be derived from the balance of pressure gradients:

$$F \propto (-\rho_w g \beta_x - \rho_i g \partial H/\partial x)$$

where ρ_i and ρ_w are the respective densities of ice and water, H is the ice depth, β_x is the basal slope and g the acceleration due to gravity. If α_x is the surface slope

$$\partial H/\partial_x = \alpha_x - \beta_x$$

Taking ρ_i and ρ_w such that $(\rho_w - \rho_i)/\rho_i = 1/10$

$$F \propto (-\beta_x - 10\alpha_x)$$

Thus flow in the positive sense due to a negative surface slope α_x can be prevented by a basal slope in the opposite sense and greater by a factor of at least 10, thus forming a lake. Such conditions are most likely to be found in localities where surface slopes are small, such as domes and saddles on the ice sheet. This explains the distribution of sub-ice lakes shown in Fig. 3, taken in conjunction with the above discussion of basal melting. We do not expect to find lakes beneath domes A and B of Fig. 3, since basal temperatures here are calculated as well below freezing point.

Once sub-ice basins have filled to overflowing, there may well be some interconnexion between lakes by a sub-ice film of water, or by sub-ice channels, though according to Weertman[8], the latter is less likely. It is, however, likely that much of the sub-ice water will be refrozen to the base of the ice further out from the centre of the ice sheet. It has been estimated[7] that this effect takes place in Byrd Land and seems likely in Greater Antarctica on the basis of temperature calculations[9,10]. Nevertheless, the possibility remains that the deeper parts of the sub-glacial floor may permit some drainage from sub-ice lakes to the sea.

The presence of lakes beneath an ice sheet at least several million years old presents a different problem to that of the bodies of water that appear to be trapped near the Ross Ice Shelf–Byrd Land boundary described in Robin, Swithinbank and Smith[6]. Whereas the latter may be of a relatively recent origin in geological or glaciological terms, the latest evidence from Hayes *et al.*[11], obtained during deep sea drilling in the Ross Sea by the Glomar Challenger, suggests that the main Antarctic ice sheet changed little in size since a retreat some 5 m.y. ago. It may be wrong to suppose that basal temperature conditions have remained the same over this period, in which case the sub-ice lakes may be much younger than the ice sheet. But we should consider if the sub-ice lakes could be as old as 5 m.y. or more. One must take into account the melting of ice that will occur at the base of the ice if the lakes are to persist over such long periods. The available geothermal and frictional heat will limit such melting to less that a centimetre per year and it is likely to be of the order of 1 mm yr^{-1}. Even such melting over a period of several million years would melt an ice column totalling several thousand metres in thickness. As this will be basal ice which normally carries morainic material, we should expect such material to be deposited in the sub-ice lakes and, in the course of time, to fill them. For the lakes to persist, we must postulate a low rate of deposition of morainic material from the melting ice. Two factors may assist here. The first is the possibility of a low rate of erosion near the centre of the ice sheet and the second is that the rate of transport of the lowest layers of ice across the lakes is very low. Such effects are to be expected near a centre of outflow and may be another reason for the concentration of sub-ice lakes in such areas.

Another question which is raised by the presence of such lakes is that of biological conditions in the water. The survival of any life forms existing in these regions before the glaciation seems unlikely, considering the environmental changes which must have taken place. But once basal melting of the ice commenced, it would provide a slow, steady influx of microorganisms deposited in the past on the surface of the ice. The geothermal heat flux provides a source of energy, and, with the oxygen dissolved in the ice, it is conceivable that the water provides a refuge for any such microorganisms which have survived the downward passage through the ice, which will have taken 10^5 yr or more.

The practical need for knowledge of conditions at the base of the Antarctic ice sheet has been given special emphasis by the recent proposal of Zeller, Saunders and Angino[12] for dumping radioactive wastes on the ice sheet.

It has been indicated that the possibility of a connexion between the sub-ice water and the sea cannot be ruled out, and this must call into question any proposal which assumes the base of the ice to be totally isolated from the habitable world. Further, the extent of basal melting is critically dependent on the heat influx at the base of the ice. The drastic local disturbances caused by the heat output from such dumps, and their effect on the dynamics of the ice sheet, must be better understood before such proposals can be properly assessed.

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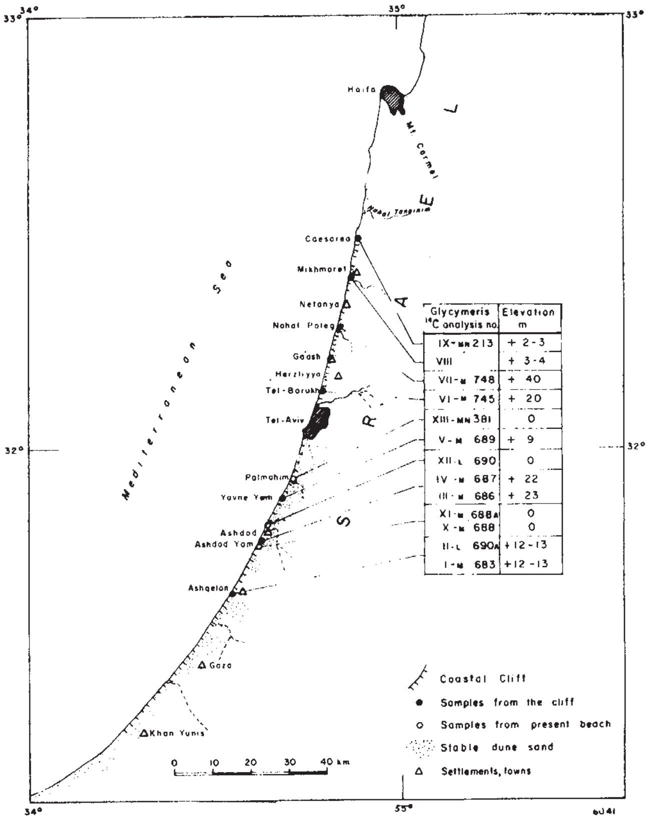
Recent Faulting along the Mediterranean Coast of Israel

Two hypotheses explaining the origin of the present coastline of Israel, one postulating a tectonic, the other merely a wave-abrasion mechanism, have long been the subject of controversy. The arguments supporting a tectonic origin of the coastline are its linearity and the fact that it consists of an almost continuous line of low cliffs from Khan Yunis in the south to Mount Carmel in the north. The chief argument for an abrasional origin was the dominant trend of the waves coming from the west, perpendicular to that part of the coastline.



Glycymeris ^{14}C analysis no.	Elevation m
IX-MN 213	+ 2-3
VIII	+ 3-4
VII-M 748	+ 40
VI-M 745	+ 20
XIII-MN 381	0
V-M 689	+ 9
XII-L 690	0
IV-M 687	+ 22
III-M 686	+ 23
XI-M 688A	0
X-M 688	0
II-L 690A	+12-13
I-M 683	+12-13

Fig. 1 Location map.

Systematic observations made by us since 1961 along the coastline, the adjacent cliffs and the offshore littoral zone from Gaza to Caesarea have revealed the following:

(A) At various localities (Fig. 1), horizons of naturally deposited marine shells are found at different elevations (3 to 40 m), on or near the top of the cliffs. In some places these beds are found as far as several hundred metres landward from the shoreline (Ashdod, Gaza). The beds are dominated by the aragonite-secreting pelecypod *Glycymeris violacescens* (Lmk.) and are found either on the surface or interbedded in the sandy sediment, in places forming a layer up to 1 m thick. Usually the shells overlie either kurkar (cemented aeolianite) or hamra (red loam) of upper Pleistocene to Holocene age. At several localities (such as Ashqelon, Mikhmoret and Caesarea) the beds are found overlying ancient sites of Roman to Crusader times. In some cases, pottery sherds of various ages (the latest of which is Mediaeval-Crusader) are interbedded and imbricated within the *Glycymeris* accumulations. The fact that many of the sherds have been rounded through wave action into pebble-like fragments is of special importance.

(B) Sand dunes which occur along most of the coast of Israel terminate abruptly north of Nahal Tanninim (Fig. 1). Most of these sand dunes are today inactive, partly stabilized by vegetation. In the south (Ashdod, Ashqelon, Gaza) these dunes cover settlements as young as Early Moslem, which were originally built on red loam (hamra) plains. In the central and northern parts of the discussed area, the coastal cliffs are much higher (up to 50 m above sea level) than in the south, and the sand dunes are found on top of the cliffs (Herzliya, Netanya); at Gaash, for example, they cover a Byzantine settlement located 41 m above sea level. These relatively high, near vertical cliffs are only 10 to 20 m from