tion might have penetrated into the interior of the ice core. The outer annulus had a thickness of approximately 1 cm and the second annulus had a thickness of about 1.5 cm. The innermost cylinder had a diameter of roughly 5 cm. The individual annuli and the central portion of the core were separately melted and analyzed for NO_3^- using the cadmium reduction method (Strickland and Parsons, 1968). The outermost annulus showed a concentration of 17 μgN/liter, the second annulus 9 μgN/liter, and the interior cylinder 8 μgN/liter.

Our results are summarized and compared with the data from analyses performed by Harrower and published by Wilson et al. (1978) in table 3. Note that our trimmed core values range from 7 to 32 μg/liter NO_3-N and that the exterior trimmings always exceed the interior values. None of the extremely high values obtained in the preliminary core analysis could be duplicated. It is probable that the high values obtained from the outer core trimmings have been caused by contamination from drilling fluids. Our concentric study indicates that there was little penetration of the contaminants into the interior of the core, at least in the case of the section from 543.3 m.

The data suggest that the exterior ≥ 1 cm of the Vostok ice core has been contaminated with NO_3^- despite the lack of apparent contamination from the low NH_4-N values reported by Wilson et al. (1978). Segments cut from core ends which showed evidence of core rotation also showed elevated NO_3^- values. Our data suggest that the very high values reported by Wilson et al. most probably resulted from surface contamination of the core and that any trimming which they may have done was inadequate to remove it. Their suggestion that the very high NO_3^- values are indicative of a period of high solar activity approximately 4,600 years BP thus cannot be confirmed at this time.

Table 3. Nitrate ($NO_3^- -N$) and ammonium ($NH_4^+ -N$) values for Vostok core segments (see text for details)

Depth in Meters	NO_3^- Wilson et al. (1978)	NH_4^+ Wilson et al. (1978)	NO_3^- μg/liter Ranges in This Study	
			Interior	Exterior
47	11	36	15-23.5	25-29.5
119.5	11	6	9-11	13-13.5
170.6	528	26	7-30*	50-80
304.3	24	31	6-6.5	—
408.5	192	17	24-30	32-44
525	133	16	14-21	23-23.5
665	53	16	10-14	83-88
796	48	16	14-17.5	28.5-33.5
884	14	8.5	11-14	28.5-29
949	184		13.5-32*	

* Indicates segments were cut from end pieces of core sections that showed evidence of core rotation and/or fracturing.

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Saline discharge at the terminus of Taylor Glacier

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At intervals of one to a few years, during the "nonsummer" months, some thousands of cubic meters of saline water flow out from either a crevasse at the northern corner of the terminus of Taylor Glacier or a source beside the glacier near this crevasse. This fluid freezes to form a saline icing (frozen outwash fan, cone, or ice platform), which extends over an ice-marginal stream delta and onto the moat ice of western Lake Bonney. When the discharge issues from the crevasse (the glacier discharge site), an ice-marginal debris-covered mound is also partially covered. The icing is colored various shades of orange due to small amounts of hydrated iron oxides and silt. When the icing is fresh this coloration is not apparent, but develops as surface ablation and oxidation proceed. During the summers and years between such discharge events, the icing ablates completely. However, salty orange subglacial layers and crevasse infillings persist around the glacier discharge site.

The subglacial layers of orange ice are exposed as laterally persistent bands several meters long in the ice-marginal debris-covered mound. These layers form part of a thick sequence of stagnant ice and basal debris that dips upglacier beneath the discharge site, and probably developed by regelation in a basal position. From this it is inferred there has been a long record of activity involving saline material under Taylor Glacier.

The crevasse infillings occasionally contain iron-stained euhedral gypsum crystals 2-4 mm long that crystallized in place (Stephens and Siegel, 1969). Median septa of bubbles are evident in some infillings. These indicate freezing of saline water in crevasses during or after past discharge events. Leaching and freezing-out have removed some soluble salts, such as halite, thenardite, and gypsum from the infillings.

Early photographs of the glacier terminous (Taylor, 1922) show that there has been activity similar to that of the present day since at least 1911. There have been at least eight and probably ten separate, major discharge events since 1956 (table 1). (Major events are defined as those which produce a frozen saline icing whose volume is greater than about 10^3 m^3). The chemistry of each of these events is very similar to each other as determined from published (Hamilton et al., 1962; Black et al., 1965) and present analyses of samples of saline ice, fluid, and salts from the 1958, 1962, 1972, 1975, 1976, and 1978 events (see also table 2). On the basis of the record in table 1, a discharge of some $(6 \pm 1) \times 10^3$ m^3 of saline water is predicted in the austral winter or spring of 1979.

Minor events involving a few tens of cubic meters may occur during some intervening years and ablate before being observed. One such event of about 100 m^3 may have occurred in 1977 from the glacier discharge site.

In November 1976 a saline spring (0 to 1 liters per second) was operating lateral to the glacier discharge site in a small area adjacent to the stream delta. The discharge events of 1975 and 1976 also came from this area, defined as the lateral discharge site. Table 2 compares three analyses of the spring waters with a partial analysis of the 1978 discharge fluid and seawater. The eutectic temperature for the original salt system involved is colder than −21°C. Bicarbonate concentrations and pH were affected by loss of carbon dioxide during (1) degassing of the upwelling spring water as it reached the surface, and (2) loss from the sample bottles after warming during transhipment. The loss of CO_2 resulted in the precipitation of calcium carbonate, as calcite and aragonite.

Ionic ratios and enrichments indicate that the salt in the discharge waters is similar to seawater that has been concentrated 2.4 to 3.1 times. Depletion of potassium and sulphate has occurred; the former possibly by ion exchange and the latter by gypsum precipitation. Also, the marked enrichment of calcium and carbonate may have occurred by aqueous basal or subglacial chemical weathering. An iron-stained, marble-rich metasediment belt is exposed on either side of the glacier 3 km up from the terminus.

Isotope δD and $\delta^{18}O$ values (G. L. Lyon, N. Z. Institute of Nuclear Sciences) were corrected for Mg^{2+}, Ca^{2+}, and K^+ by the method of Sofer and Gat (1972). These values are indicative of ice formed from high altitude polar precipitation (Epstein et al., 1963; Picciotto, 1967; Lorius et al., 1969). Thus the waters of the discharge events

Table 1. Known record of discharge events[1]

Year	Type[2]	Years Since Previous Event	Source of Information	Age Relative to Recurring Cracks in Moat ice[3]	Volume of Saline Icing[4] (m^3)
1911	G?	?	Taylor, 1922	nk	?
⋮					
1957	L?[5]	?	Black, 1969[5]; USN aerial photo	nk	?
1958	L	1?	Hamilton *et al*, 1958	nk	ca. 5000?
1961	G and/or L	3	Black *et al*, 1965	nk	?
1962	G	1	Black *et al*, 1965	nk	3000-6000
1967	G and/or L	5?	R. L. Armstrong, photograph	nk	ca. 3000?
1968	G	1	Black, 1969	nk	ca. 5000?
1971	G (and L?)	3	Y. Yusa, photographs	nk	3000±1000
1972	G	1		younger	5000±1000
1975	L	3	P. H. Robinson, photographs	younger?	3000±1000
1976	L (and G)	1		older	6000±1000
1978	G	(1) 2		young	3500± 500

[1] Any further information for the years preceding 1967 would be gratefully received. However, the record is believed to be complete since 1958.

[2] Discharge from crevasse on glacier, G; from lateral source, L: see text.

[3] See text. Not known- = nk.

[4] Average volume from 1969 to 1976 is 2000 ± 500 $m^3.y^{-1}$.

[5] "Brownish to yellowish discoloration seen from the air on the north side of the glacier near the terminus."

Table 2. Analysis of saline spring and glacier discharge waters; concentration expressed as ppm; cations determined by atomic absorption; chloride by Mohr titration; sulphate gravimetrically; bicarbonate from carbonate precipitate and sample

	Samples				
	5-53A[1]	5-53B[1]	5-72[2]	7-01B[3]	Seawater[4]
Temperature, °C, ±0.3	−7.5	−5.3	−5.1	−5.5	—
Na	32100	28000	27500	nd	10561
K	730	605	595	nd	380
Mg	4200	3500	3800	nd	1272
Ca	2400	2100	2200	nd	400
Cl	59200	51500	49800	45100	18980
SO_4	nd	nd	4980	4440	2648
[HCO_3 (minimum)]	1500	1300	1500	nd	140
Electric conductivity at 25°C [$m.mhs.cm^{-1}$]	127	115	112	99	53
Freezing point depression (±0.2°C): ( ) denotes precipitation had occurred	(−7.9)	(−5.6)	nd	−5.5	−1.9
Total dissolved salts (%) (calculated)	8.8	8.0	8.2	—	3.5
Density (calculated)[$Mg.m^{-3}$] (25°C)	1.10	1.09	1.09	—	1.02
$\delta D_{corrected}$ ±2%	−311	−308	—	—	0
$\delta^{18}O_{corrected}$ ±0.2%	−39.2	−38.7	—	—	0
Ca/Na	0.074	0.075	0.078	—	0.038
Mg/Na	0.13	0.12	0.14	—	0.12
K/Na	0.023	0.022	0.022	—	0.036
Mg/Ca	1.8	1.7	1.8	—	3.18
So_4/Cl	—	—	0.100	0.098	0.140
HCO_3/Cl	>0.026	>0.026	>0.030	—	0.0075

Isotope analyses by G. L. Lyon and corrected for Mg^{2+}, Ca^{2+} and K^+ content.

[1] Nitrate in stream from spring, determined by specific ion electrode.

[2] Molar balance with 4%: Σcations 1.42; Σanions 1.47.

[3] pH 6.2 ± 0.2 measured 24 hours after sampling.

[4] Sverdrup et al., 1942.

are considered to be melted Taylor Glacier ice. This is confirmed by the lack of ^{18}O enrichment, a condition expected in connate or other ground waters.

A basal ice source for the discharge waters may result in direct discharge of saline waters into Lake Bonney by subterranean flow. Such flow can only occur where there is permeable material or gaps in the confining permafrost. Electrical resistivity measurements (McGinnis and Jensen, 1971) suggest such a gap adjacent to the glacier discharge site and also the presence of a wedge of permeable aquafrost that thins upglacier from the terminus of the glacier.

Preliminary calculations using geothermal gradients (Decker and Bucher, 1977), the subglacial profile and ice thickness (Stern, 1978), englacial and basal temperatures, and ice velocity suggest that the glacier is overriding a saline depression of about 5 × 10^5 m^2, located 1 to 2 km up from the terminus. It is known that Taylor Valley has been inundated with seawater at least as far west as Lake Bonney. The salts in the lake have been derived from seawater (Angino et al., 1964; Nakai et al., 1978). Presumably this marine incursion(s) occurred during a period when Taylor Glacier had retreated so that the subglacial depression near the present terminus was also filled with seawater. Evaporation to dryness preceded readvance of the glacier, the base of which is now melting on contact with the salt.

Water depths were measured in January 1979 beneath a recurring crack system in the moat ice of Lake Bonney in the bay adjacent to the discharge sites. A break in slope of the lake bed was found to occur beneath these cracks at a depth of 2-4 m.

Freezing rates from the moat ice at Lake Vanda (Cutfield, 1974) indicate that the moat ice at Lake Bonney will thicken to 2 to 4 meters between June and October. It is believed that the recurring cracks occur when accumulated tensile and compressive forces exceed the strength of the ice after this has thickened and frozen to the lake bed.

Observations over a number of years of the relationship between the crack system and the development of the saline icing (table 1) suggest that the discharge events occur consistently around August, (i.e., June to October) as well. This is in good agreement with the observations of October 1978, when an event was still in progress, but drawing to an end.

That the discharges always occur at one or both of the same two sites indicates that a bedrock col or permanent subglacial channel(s) exist between the saline water source and the discharge sites. Autumn and winter freezing of infiltrated freshwater in the surface sediments around the northwestern shore of Lake Bonney could prevent a normal subterranean flow. This would result in damming saline water before eventual bursting in the late winter or early spring. However, the actual mechanisms of storage and release of saline water are likely to be affected by glaciological and climatic variations which are poorly known.

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Gas studies: Ice from Allan Hills meteorite site and Byrd Station

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We are in the process of analyzing ice samples taken near Allan Hills (figure 1), one of two blue ice regions in Antarctica where meteorites lie exposed on the surface. This site was discovered in 1976 (Cassidy, 1977; Nagata, 1977) The other site—located near the Queen Fabiola (or Yamato) Mountains—was found in 1969 by a Japanese glaciological party (Nagata, 1975).

During the past three field seasons, W. A. Cassidy and his associates (Cassidy, 1978) have recovered more than 600 meteorites from the approximately 100-square-kilometer Allan Hills blue ice area. The rare-gas isotopic contents of ten Allan Hills meteorites have been measured (H. W. Weber and L. Schultz, 1978) and no paired falls have been found. This indicates that a large fraction of the meteorites are from different falls. The terrestrial ages of about 20 specimens have been measured as being

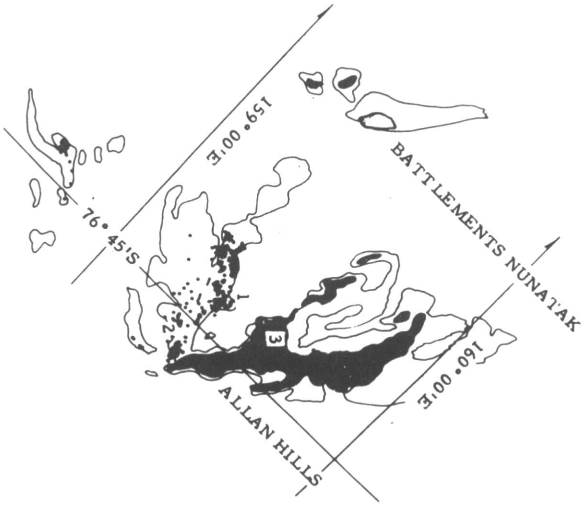

Figure 1. Locations of meteorite finds at the Allan Hills site. Rock outcrops are shaded and bare ice patches are outlined. Monocline in ice surface runs from southwest of Allan Hills toward Battlements Nunatak but flattens out before reaching nunatak. (Surrounding features can be located on USGS Convoy Range map ST 57–60/1/.)