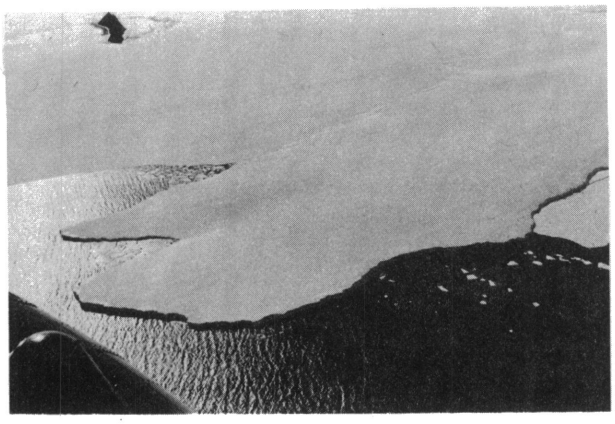

Figure 3. Terminus of Erebus Glacier Tongue, 13 February 1978, with Big Razorback Island in upper left. (Photographed by PH3 Weinger, U.S. Navy.)

stresses. The analysis indicates that deflections of order 5 centimeters are needed to produce significant stresses for the present glacier in the sixth vibration mode (period about 16 ± 1 second). Wave lengths are then about 1½ kilometers. Tilts have been observed of order 1½ (arc) seconds (for the 16-second period waves). This would correspond to amplitudes of order 1 centimeter.

These measurements were taken under relatively calm conditions with sea ice surrounding most of the glacier. Under storm conditions with open water it seems possible that significant bending stresses may be generated and that the ice may fail in fatigue along one of the antinodes. This is the vibration calving theory, constructed to account for the production of large tabular icebergs.

The strain meter data will provide independent information on wave periods and on amplitudes of the oscillation. The longitudinal velocity data will provide information on the flow law of the ice.

We thank personnel of Holmes and Narver Inc., as well as the U.S. Navy, for full logistics support arranged for by the National Science Foundation.

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Green iceberg sampled in the Weddell Sea

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A green and white iceberg (one of several seen during the cruise) was observed and sampled in the eastern Weddell Sea (69°14.5′S.10°11.8′W.) from ARA *Islas Orcadas* cruise 15 in February 1978 (see figure).

The bulk of the iceberg was comprised of bluish-white, opaque ice that was horizontally stratified but had a rougher top surface than a typical tabular iceberg. The "abnormal" portion of the iceberg was a deep green color, appearing almost black in certain light. The iceberg was estimated to be about 20 meters high, 100 meters long, and 40 meters wide and was tilted at an angle of approximately 35°. The green "outcrop" stretched along the entire side that was tilted downward and extended beneath the sea surface. The maximum height of green ice above the surface was approximately 14 meters. Most of the green ice was covered with snow, but several exposed faces, up to 8 meters high, appeared to be the result of recent fractures and showed no obvious signs of weathering. One of these faces was flat and smooth and the ice appeared to be transparent (rather than translucent, as described by Moulton and Cameron, 1976, for a green iceberg observed off the South Shetlands). One got the impression of looking through very clear ice, deep into a dark green interior. There was an abrupt boundary between the green and the white ice. Reconstructing the iceberg's geometry before it tilted would put the green ice on the top surface overriding or abutting the stratified ice. Other green ice observed on this cruise appeared to be on the underside of overturned icebergs (see also Moulton and Cameron, 1976).

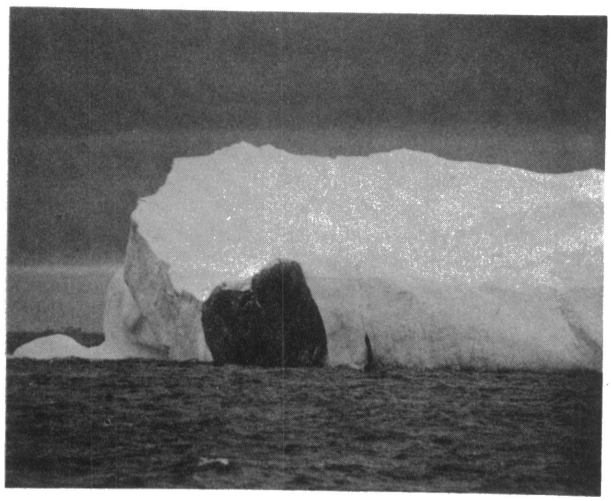
While we were not able to get close enough to the iceberg to collect samples directly from the green outcrop, a piece of ice was netted in the immediate vicinity of this iceberg. Although we do not know with certainty if this ice sample came from the green or the white portion of the berg, or even if it came from that iceberg in particular, what we have found so far indicates that this is an unusual piece of ice. We do know that there were no other icebergs closer than several kilometers, that the closest sea-ice was 150 kilometers away, and that the sea-surface temperature was -0.06°C, well above freezing for surface water.

The sample when recovered weighed about 2 kilograms and was shaped like a goose-neck. Its entire surface was covered with regular hexagonal-shaped depressions about 30 millimeters across. It appeared colorless in daylight as well as under artificial lighting conditions. Close examination showed it to contain many inclusions of particulate material (it took only 30 milliliters of the melted sample to clog a 25-millimeters diameter, glass-fiber filter with a pore size of 0.45 micrometers). Portions of the sample have been sent to various research laboratories for analysis. Collaborating in these studies are Steve Ackley and Tony Gow of the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), John Edmond of MIT, Harmon Craig of Scripps,

Results of analyses of iceberg sample and some comparisons with surface water.[a]

	Iceberg sample	Surface water		Iceberg sample
Temperature (°C)	NM[b]	-0.06	Dissolved nitrogen:	
Salinity (particulate protein nitrogen)	0	33.03	$NO_3 + NO_2$ (μg-at liter^{-1})	3.87
O_2 (ml liter^{-1})	NM[b]	6.57	NO_2 (μg-at liter^{-1})	0.87
pH	6.98	NM[b]	NH_4 (μg-at liter^{-1})	25.83
SiO_4 (μg-at liter^{-1})	0.7	68.0	Total persulphate nitrogen (μg-at liter^{-1})	271.33
PO_4 (μg-at liter^{-1})	2.04	1.55		
PPN[c] (μg-at liter^{-1})	28.8	0.74	Organic nitrogen (μg-at liter^{-1})	241.64
Total dry weight (μg liter^{-1})	4,000	NM[b]		

[a]Samples taken 6 February 1978 at 0600 GMT; water depth, 4,104 meters; air temperature, 0.4°C; weather, overcast.
[b]NM = not measured.
[c]PPN = particulate protein nitrogen.



Green and white iceberg photographed in the eastern Weddell Sea, February 1978. Green portion appears as black portion in foreground.

John Anderson and Dennis Kurtz of Rice University, and Ken Haines, Warren Pulich, Paul McDonald, and Pat Cotter of the University of Texas Marine Science Institute, Port Aransas.

Thin sections examined at the Cold Regions Research and Engineering Laboratory showed a remarkably bubble-free, highly orientated crystalline structure indicative of high-deformation sheared ice and typical of a simple valley glacier. The ice contains a diversified assemblage of particles including a large number of fibers, perhaps of vegetable origin and ranging from colorless to blue, orange, and green; obsidian flakes; a few quartz grains; amorphous aggregates; black, charcoal-like fragments; pieces of shelly material; and diatoms, some of which (approximately 700 per liter) appear to contain protoplasm. This material contains almost 30 microgram-atoms per liter of particulate protein nitrogen. Other particles include a lustrous metallic-looking mineral fragment as well as several malleable metallic particles resembling silver. After filtering, the meltwater contains 26 microgram-atoms per liter of ammonia-nitrogen and 240 microgram-atoms per liter dissolved organic nitrogen. The table summarizes the results of some of our analyses compared with surface-water conditions at the iceberg site.

None of the results so far can be used to postulate an origin for green icebergs, except to say that in this particular sample the color may have been caused by optical effects from the bubble-free ice rather than from the material suspended in it and that it is formed not from shelf ice but from a simple valley glacier. The very high ammonia and nitrate-nitrite and nitrogen values are far higher than reported for the antarctic ice sheet (Parker *et al.*, 1978). We hope the analyses still in progress (mineralogical, physical, and geochemical analyses, ATP and chlorophyll determinations, and bacterial and phytoplankton growth experiments) will help us determine the origin of these interesting icebergs and point the way to future research in this field.

I thank Arnold Gordon (and NSF grant DPP 76-81240) and Ted Baker of Lamont-Doherty Geological Observatory, chief scientist, Captain Badaroux of the Armada Argentina for his good humor and cooperation during the 3 a.m. ice-collecting venture, and John Hattner of Florida State University who displayed great dexterity in collecting the sample.

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