

EARLY DISCOVERERS

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SOME NOTES ON SEA ICE OBSERVED BY CAPTAIN JAMES COOK, R.N., DURING HIS CIRCUMNAVIGATION OF ANTARCTICA, 1772-75*

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ABSTRACT. This paper is derived from notes on ice conditions made during a study of Captain James Cook's voyage around Antarctica in 1772-75. The original notes comprised a detailed examination of the day-to-day remarks on ice in Cook's Journal, together with comments in the light of present-day knowledge.

RÉSUMÉ. Cette communication est basée sur les notes concernant les conditions de la glace faites au cours d'une étude sur le voyage du capitaine James Cook autour du pôle Sud en 1772-75. Ces notes contenaient un examen détaillé des remarques concernant la glace que le capitaine Cook avait faites au jour le jour dans son Journal, ainsi que des commentaires à la lumière de nos connaissances actuelles.

ZUSAMMENFASSUNG. Dieser Artikel stammt von Aufzeichnungen über die Eisverhältnisse, die anlässlich des Studiums einer in den Jahren 1772-75 gemachten Fahrt des Kapitäns James Cook um die Antarktis herum. Die Aufzeichnungen umfassten ursprünglich die in allen Einzelheiten durchstudierten täglichen Wiedergaben über Eis in Cook's Journal zusammen mit Kommentaren im Hinblick auf heutige Kenntnisse.

CAPTAIN JAMES COOK's second voyage, which included the first circumnavigation of Antarctica, and the first crossing of the Antarctic Circle, was an epic feat of seamanship and endurance. Navigation among the often immense icebergs and the heavy pack ice of Antarctica is difficult enough in a full-powered vessel—what it must have been like in a sailing ship of 462 tons can only be conjectured. By nature and by his training Cook was economical of words and, as a seaman, wrote up his Journal in such a way that, while giving all essential information, there were few frills. He must have had considerable ice experience in his earlier years—on his voyages to the Baltic and, no doubt, when surveying the St. Lawrence River and the coasts of Newfoundland. If so, he seldom mentions it; any references to northern ice conditions are indirect. Only very occasionally did Cook enlarge on the subject of Antarctic ice but such comments as he did make were extremely pertinent. For one who was normally so accurate in recording detail it is surprising to find so little reference to the dimensions of the icebergs or "ice islands", the term by which Cook refers to them throughout in his Journal.

1772-73

Cook sailed south from Cape Town on 22 November 1772, and sighted his first Antarctic iceberg on 10 December in lat. $50^{\circ} 27' S.$, long. $20^{\circ} 45' E.$ The ships (*Resolution* and *Adventure*) continued on their southerly course, passing many icebergs ("Islands of Ice") until they were stopped by an "immense field of ice" in lat. $54^{\circ} 55' S.$, long. $22^{\circ} 13' E.$ This northern limit was some 120 miles† north of the mean limit suggested by Mackintosh and Herdman¹ but only 60 miles north of the position where the pack was found on 12 December 1938.

Hoping to find a break in the pack, Cook continued along the ice edge generally in a

* Substance of a lecture given to the Society on 23 January 1957.

† All references to miles denote nautical miles; 100 nautical miles are equivalent to 185.26 kilometres.

south-easterly direction. He was much hampered by bergs and loose ice and after sailing some 90 miles without finding a break, Cook decided to "run 30 or 40 Leagues to the East before I haul again to the South, for here nothing can be done". On 23 December they were in lat. $55^{\circ} 26' S.$, long. $31^{\circ} 33' E.$ and course was altered to the south. The ships now passed through several narrow fields of ice (conditions typical of the summer break-up of the pack ice) in about $58^{\circ} S.$ and by the 26th, although little further progress had been made to the south, they were in long. $27^{\circ} 37' E.$ By now the ice met was old and rotten in places, and rafted in others, but did not hinder the ships so that on the 27th they were some 240 miles almost due south of their position on 19 December, and in clear water. Two days later dense fields of pack ice were sighted to the north and there can be little doubt that Cook had now worked his ships around the end of a wide tongue or belt of pack ice.

Many years later the pelagic whaling fleet of the 1930s confirmed the existence, in the early summer of most years, of this wide tongue of pack ice stretching out in an unbroken mass far to the east from the Weddell Sea. In early January the area of clear water south of this tongue may stretch to within 100 miles of the Antarctic Continent and by mid-February only a narrow fringe of pack remains around the coast. If Cook had not been so anxious to look for Bouvet's "Cape Circumcision" he might well have gone south and so sighted or even reached the Antarctic Continent.

Observations over the years since Cook's time provide a better understanding of the reasons for this tongue of ice and for the presence—especially noted by Cook—of the very large number of icebergs in this eastern part of the Atlantic sector of the Southern Ocean. We now know² that there is a westward-moving drift of surface water (the East Wind Drift) around most of the coasts of Antarctica which, in the Weddell Sea, is diverted north and then north-east by the long eastern coasts of Graham Land and the submarine ridge known as the Scotia Arc.³ The very cold Weddell surface water thus joins the West Wind Drift, which persists around Antarctica, in all seasons, in the region of the prevailing westerly winds.

The influence of this wide belt of very cold water can be shown to stretch eastwards to long. $30^{\circ} E.$ and, in winter, northwards for over 1,000 miles from Antarctica. This stream also carries away from the Weddell Sea the very many icebergs which derive from the ice shelf in this area.

Cook penetrated to lat. $59^{\circ} 18' S.$, long. $111^{\circ} 09' E.$, in his search for Bouvet's discovery. Being now well south and to the west of the position assigned by Bouvet, and not knowing that the longitude reported was much in error, he assumed that the reported "land" was "nothing but Mountains of Ice surrounded by field Ice . . ." and turned east again to search for the land lately discovered by the French and reported to lie in long. 57° or $58^{\circ} E.$

On the passage east the drift of loose pack ice led Cook to make some measurements on the surface current. The speed and direction of drift to the north-west thus observed supported Cook's inference that the large body of pack ice they had met a few days earlier could not have melted in so short a time, but had probably drifted "northward". Further current observations a week or so later again showed a north-westerly set, and the speed observed, $\frac{1}{3}$ knot, compares well with observations made in this area in recent years.

Cook now had some comments to make on sea ice and in his Journal, following on the current observations, he continues: ". . . Some curious and interesting experiments are wanting to know what effect cold has on Sea Water in some of the following instances: does it freeze or does it not, if it does, what degree of cold is necessary and what becomes of the salt brine? for all the Ice we meet with yields Water perfectly sweet and fresh . . ." This no doubt refers to the practice of watering ship by collecting pieces of ice floating in the sea and melting them down in coppers on board.

J. R. Forster⁴ discusses this problem at some length, quoting experimental work by Nairne and Higgins which would appear reasonably conclusive to anyone but J. R. Forster. Nevertheless he does suggest that sea ice can be formed *in situ*.

The ships continued south and crossed the Antarctic Circle a few days later, in long. $39^{\circ} 35' E.$,* but, on reaching lat. $67^{\circ} 15' S.$ they were again held up by impenetrable pack ice. Cook was now only 75 miles from the Antarctic Continent and his account of the ice which stopped the ships as comprising “. . . high Hills or Islands, smaller pieces packed together and what Greenland men properly call field Ice, . . .” is a good description of the types of ice often met with close packed around the coasts of Antarctica, especially in the deep bays and indentations, at this time of year.

1773-74

SECOND ICE EDGE CRUISE—IN THE PACIFIC SECTOR OF THE SOUTHERN OCEAN

Leaving New Zealand in late November 1773, Cook reached lat. $62^{\circ} 10' S.$, in about long. $171^{\circ} W.$, early in December before sighting any icebergs. Pack was not seen until the ship reached lat. $66^{\circ} S.$ several days later, when more icebergs and much loose ice were met. Weather conditions were poor, with fog and strong winds and the ship was several times embayed in loose ice before a shift of wind to the south-west enabled them to get clear.† Not liking these conditions of weather and ice, and having decided that land to the south was unlikely, Cook stood away north-east to clear the ice and then set his course eastwards.

That the summer break-up of the pack ice had begun is borne out by Cook's remarks two days later regarding ice collected by his boats when watering ship: “. . . it was none of the best for our purpose, being composed chiefly of frozen snow, was pores and had imbibed a good deal of salt water, this however dreaned of after it had laid some time, after which the ice yielded sweet water. . . .” Rotten ice of this type is common at this season on the ice edge, especially in the central and eastern parts of the Pacific Sector, where the advance and retreat of the pack is small, and Cook's assumption that this ice was merely frozen snow was not entirely correct. There is little doubt that the snowfalls of winter, in freezing conditions, do consolidate the pancake ice into large areas of solid pack, in waters where the range of growth and dispersal are small. Little is known about the movements of pack ice in this Sector other than the fact that the range of these movements is small, especially in the Bellingshausen Sea, and that, so far as we know at present, the coasts of Antarctica here are never clear of ice. No one has yet penetrated to the Continent by sea over the greater part of this Sector.

Steering generally east but making any southing possible Cook crossed the Antarctic Circle for the second time, on 21 December, in about long. $143^{\circ} W.$ Weather conditions were poor—there being a thick fog, accompanied by a strong gale, rain and sleet. It is not surprising that the ship “Came close aboard a large Island of ice” and that “being a good deal imbarass'd with loose ice we with some difficulty wore (ship) and stood to the NW untill noon”. Most of the icebergs sighted this day were of the weathered type and Cook, commenting on their rugged appearance, with many peaks, mentions for the first time that all those he had seen previously were quite flat on top.

Remaining south of the Circle the ship made good progress to the east and again met pack, in the form of a large field of closely packed floes, in lat. $67^{\circ} 19' S.$, long. $138^{\circ} 15' W.$ ‡

The search of the area to the north occupied Cook for the next fortnight and on 11 January, having discounted the possibility that any large area of land lay between him and Otaheite, he

* Claimed to be the first crossing of the Antarctic Circle which undoubtedly it was.

† This concentration of loose ice and icebergs is very typical of break-up conditions and it is of considerable interest to find that the edge of the loose ice (and, presumably, the pack ice) lay only 20-30 miles north of the mean position suggested by Mackintosh and Herdman⁷ for this month.

‡ Sixty miles, approximately, south of the mean limit for December as suggested by Mackintosh and Herdman.⁷ It should be noted, however, that there is only one other report of pack ice recorded for this month between the meridians of 160° and $80^{\circ} W.$ —and that was in 1841.

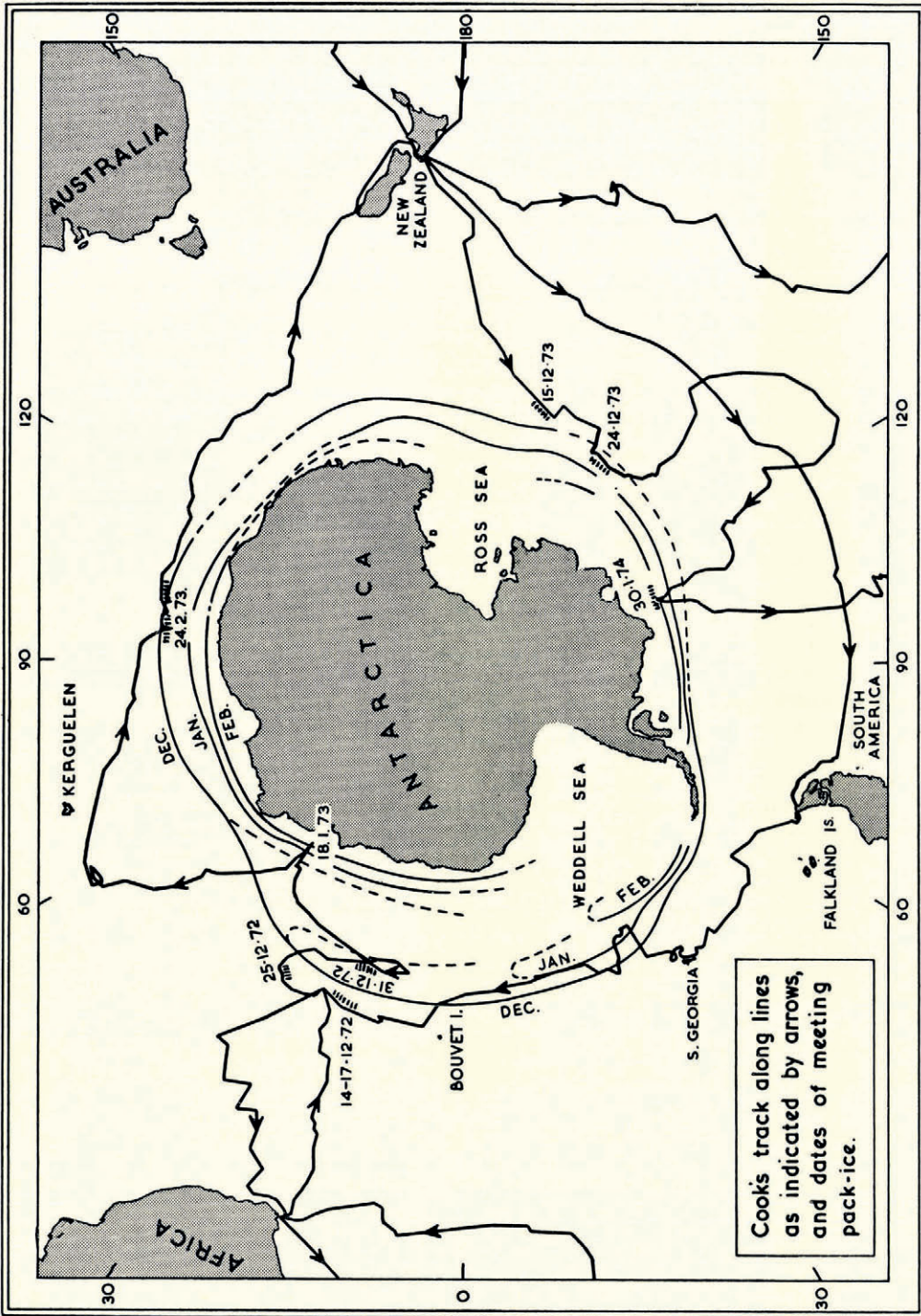


Fig. 1. Cook's track and positions of meeting pack ice, shown in relation to the mean northern limit of the pack ice for the months of December, January and February (Mackintosh and Herdman¹)

hauled round and stood back south-east again. Icebergs were reported in lat. $62^{\circ} 36' S.$, long. $109^{\circ} 32' W.$ and the Antarctic Circle was crossed for the third time on 26 January, in long. $109^{\circ} 31' W.$ Lat. $70^{\circ} S.$ was reached with the ship still in open water but ice blink was seen in the sky and a field of closely packed ice stretching east and west as far as they could see was found later the same day. We cannot better Cook's own description: ". . . The outer or Northern edge of this immense Icefield was composed of loose or broken ice so close packed together that nothing could enter it, about a Mile in began the firm ice, in one compact solid body and seemed to increase in height as you traced it to the South; In this field we counted Ninety Seven Ice Hills or Mountains, many of them vastly large . . ."

Cook continues his Journal with some remarks on Greenland ice in relation to that which he was now meeting, and advances a theory (which he was to modify later in the voyage) about the formation of "Ice Islands" and "Ice Hills". His words are worth quoting in full: ". . . Such Ice Mountains as these are never Seen in Greenland, so that we cannot draw a comparison between the Greenland Ice and this now before us: Was it not for the Greenland Ships fishing yearly among such ice (the ice hills excepted) I should not have hesitated one moment in declaring it as my opinion that the Ice we now see extended in a solid body quite to the Pole and that it is here, i.e., to the South of this parallel, where the many Ice Islands we find floating about in the Sea are first form'd, and afterwards broke off by gales of wind and other causes,* be this as it may, we must allow that these numberless and large Ice Hills must add such weight to the Ice fields, to which they are fixed, as must make a wide difference between the Navigating this Icy Sea and that of Greenland: I will not say however it was impossible. . . ."

By noon the next day (30 January) Cook had managed to work his ship further to the south and east, to lat. $70^{\circ} 48' S.$, in long. $106^{\circ} 34' W.$ and, finally, to lat. $71^{\circ} 10' S.$, in long. $106^{\circ} 54' W.$,† the highest latitude yet reached by any ship in this area. Here he decided that any further progress to the south would be very dangerous and that it would only be prudent, if he wished to complete his whole voyage as planned, to turn back. The Journal reads: ". . . I will not say it was impossible to get anywhere in among this Ice, but I will assert that the attempting of it would be a very dangerous enterprise and what I believe no man in my situation would have thought of. I whose ambition leads me not only farther than any other man has been before me but as far as I think it possible for man to go, was not sorry at meeting with this interruption, as it in some measure relieved us from the dangers and hardships, inseparable with the Navigation of the South Polar Regions. Since therefore we could not proceed one Inch further South, no other reason need be assigned for our Tacking and stretching back to the North . . ." Cook now thought that there was "no probability of finding Land in these high latitudes, at least not this side Cape Horn", so he turned north to spend the winter in the Tropics, intending to be back in the neighbourhood of Cape Horn by November.

1774-75

THIRD ICE EDGE CRUISE—IN THE ATLANTIC SECTOR OF THE SOUTHERN OCEAN

Delayed by repairs to *Resolution* it was 16 December before Cook sighted Tierra del Fuego. He spent some time among the islands off the south coast and at Staten Island, so that January was well advanced before the discovery of South Georgia. Eleven days (13-24 January) were spent in circumnavigating the island. Cook was surprised to find an island of this size, and in these latitudes, covered with snow and ice in mid-summer.

* The break-up of shelf ice "by gales of wind and other causes" is, as we now know, how the tabular berg or Cook's "Ice Island" originates. Where Cook erred was in the assumption that ice masses of this size were formed in the open sea.

† About 120 miles from the land—a coast delineated only by aerial survey, and so rather conjectural.

From South Georgia Cook steered east-south-east and then south.

The first iceberg of the season was seen on 27 January when the fog, which had persisted for several days, lifted slightly. A "gentle" northerly gale the next day then brought clear weather and the sea around them was found to be "strewed with large and small ice". Later in the same day they fell in "all at once with a vast number of large Ice islands, and a Sea strewed with loose ice . . ." Cook then stood back to the west, observing that all the icebergs around them were flat-topped and of equal height. Much loose ice was around, which was described as "what broke off from these isles". The ship was now in lat. $60^{\circ} 04' S.$, long. $29^{\circ} 23' W.$ and it seems much more likely that the "loose ice" was the northern edge of the pack ice. The mean northern limit of ice for January lies very close to this position and at this time of year the edge is likely to be more scattered than compact. The tabular bergs reported were obviously fairly new and in the very cold surface water here in January (between 0° and $-1^{\circ} C.$)⁵ there is little chance that any reasonable quantity of "loose ice" could accumulate from pieces broken off new tabular bergs.

Little progress was made during the next two days, there was not much wind and the ship was surrounded by many bergs and much "loose ice". One iceberg was noted by Cook as being the largest seen during the voyage, but unfortunately he did not give any indication of its size.*

Standing north-east to clear all this ice Cook sighted land on 31 January. This was an outlying large rock of one of the group now known as the South Sandwich Islands.† On 6 February Cook was well east of the group and not having seen any more land concluded "that what we had seen which I named Sandwich Land was either a group of Isles & c^a or else a point of the Continent, for I firmly believe that there is a tract of land near the Pole, which is the source of most of the ice which is spread over this vast Southern Ocean: . . ." The Journal continues with the following remarks on the distribution of ice which are well worth recording in their original form. ". . . and I think it is also probable that it (the land) extends farthest to the North opposite the Southern Atlantick and Indian Oceans because ice has always been found farther to the North in these Ocean than anywhere else, which I think could not be if there was no land to the South. I mean a land of some considerable extent, for if we suppose that there is none and that ice may be formed without it will follow of course that the cold ought to be every where nearly equal round the Pole, as far as 70° or 60° of Latitude, or so far as to be out of the influence of any of the known Continents, consequently we ought to see ice every where under the same Parallel or near it, but the contrary has been found. It is but few ships which have met with ice going round Cape Horn and we saw but little below the sixtieth degree of Latitude in the Southern Pacific Ocean. Where as in this Ocean between the Meridian of 40° West and 50° or 60° East We have found ice as far North as 51° . Bouvet found some in 48° and others have seen it a much lower latitude."[‡]

Cook continued his search for Bouvet's "Cape Circumcision" to the longitude of $19^{\circ} 18' E.$, meeting few icebergs on the way, and investigated the "appearance of land" he had noted when on the ice edge here, outward-bound, in December 1772. Sailing now over a clear sea he decided that "it could not be doubted but that the Ice hills had deceived us as well as Mr. Bouvet", and so set his course northwards, "having no business farther South".

The main purpose of the voyage having been achieved, Cook summed up. That there might be "a Continent or large tract of land near the Pole" he did not deny; on the contrary

* In the course of the years since Cook's visit a number of very large tabular bergs has been reported in this sector of the Southern Ocean. One was over 100 miles long.

† Cook discovered the southern part of the group. The remaining three northern islands were discovered by Bellingshausen, 45 years later, in 1819.

‡ Ice reported in lat. $48^{\circ} S.$ would undoubtedly be icebergs and it is almost certain that the northern limits reported by Cook refer also to icebergs. He does not, at this time, appear to have differentiated between icebergs and pack ice.

he thought that the "excessive cold, the many islands and vast floats of ice" were proof that land existed, and that it might extend farthest to the north in the Atlantic and Indian Ocean sectors. This suggestion was based on the more northerly distribution of ice and the lower temperatures experienced compared with similar latitudes in the Pacific sector, coupled with the assumption, to which Cook still strongly adhered, that all sea ice was "first formed at or near land". As we now know this far-reaching northerly distribution of ice in the Atlantic and western Indian Ocean sectors depends on the cold surface current flowing away north-eastwards from the Weddell Sea.

Cook then discusses the formation of "Ice Islands" and, in general, his remarks so nearly agree with our present knowledge that it is worth quoting them in full: they are ". . . It is very certain that we saw not a River or stream of Water on all the coast of Georgia, or on any of the Southern lands, nor did we ever see a stream of Water run from any of the Ice Islands. How are we then to suppose that there are large rivers in these Countries, the Vallies are covered many fathoms deep with everlasting snow and at the sea they terminate in Ice cliffs of vast heights. It is here where the Ice Islands are formed, not from streames of Water but from Consolidated snow which is allmost continually falling or drifting down from the Mountains, especially in Winter where the frost must be intense during that season, that these Ice cliffs must so accumulate as to fill up all the Bays be they ever so large is a fact which cannot be doubted as we have seen it so in summer; also during that season the snow may fix and consolidate to ice to most of the other coasts and there also form Ice cliffs. These cliffs accumulate by continued falls of snow and what drifts from the Mountains till they are no longer able to support their own weight and then large pieces break off which we call Ice islands. Such as have a flat even surface must be of the Ice formed in the bays and before the flat Vallies, the others which have a spired unequal surface must be formed on or under the side of a Coast, composed of spired Rocks and precepices, or some such uneven surface, for we cannot suppose that snow alone, as it falls, can form on a plain surface, such as the Sea, such a variety of high spired peaks and hills as we have seen on many of the Ice isles. It is certainly more reasonable to suppose that they are formed on a Coast whose Surface is some thing similar to theirs."

This summary on the origins of icebergs is not so very far from the truth especially with regard to tabular icebergs, which derive mainly from the vast areas of shelf ice in the Ross and Weddell Seas. Some of the smaller irregular icebergs have, no doubt, their origin in the individual glaciers but the majority of Cook's "spired" icebergs were, undoubtedly, weathered tabular bergs. These, as they move north-eastwards into warmer waters, melt below the water line. Thus losing stability, normally they cant to expose a much worn outline but, occasionally, the whole iceberg overturns before finally breaking up.

Whereas his observations on icebergs agree well with our present-day knowledge, Cook's remarks on the formation of pack ice lead one to the conclusion that he was reluctant to abandon the idea that sea water did not freeze. He allowed that the surface temperature might be below freezing point (*i.e.* of fresh water) which was correct, as was his assumption that saline water would not freeze when agitated. He was also correct in assuming that the pack ice builds up from further snowfalls but he was quite wrong in his belief that pack ice had its beginning in snow which froze as it fell on the cold calm water in winter. In other words Cook believed that the sea might be frozen over without being actually frozen itself.

More than half a century was to pass before Ross penetrated to the ice shelf that now bears his name and found one of the sources of the tabular iceberg, and it was not until much later that the processes underlying the formation of the Antarctic pack ice were fully understood.⁶

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