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Appointment with the Titanic

> . . . at a little before 11.40, one of the look-outs in the crow's nest struck three blows on the gong . . . following this immediately afterwards by a telephone message to the bridge "Iceberg right ahead." Almost simultaneously with the three gong signal Mr. Murdoch, the officer of the watch, gave the order "Hard-a-starboard," and immediately telegraphed down to the engine room "Stop. Full speed astern." The helm was already "hard over," and the ship's head had fallen off about two points to port, when she collided with an iceberg well forward on her starboard side. [1]

1.1 The Titanic iceberg

An autumn blizzard swept across the southern part of the Greenland Ice Sheet tens of thousands of years ago, perhaps as long as 90 000 years ago at the end of the last interglacial period [2], dumping a thick layer of snow on the ice surface. Over the following few years more snow accumulated, compressing the underlying snowflakes. Each summer, as the upper part of the snow layer reached melting point, its crystals became slick and slid into spaces in the crystal lattice, thus increasing the snow density. At the end of each summer some of this snowpack froze together to become firn, eventually becoming incorporated into the glacier ice beneath.

Thus began the life of the iceberg that on the night of 14 April 1912 AD scraped along the starboard side of RMS *Titanic* on its maiden voyage across the North Atlantic, leading to the sinking of the ship, the loss of over 1000 lives and the emergence of the iceberg as an iconic sign of concealed threat. Icebergs have also become an archetypal marine hazard because of this collision. However, there are far more elements to their significance.

They are notable signs of polar environmental change and potential freshwater sources. They have impacts on coastal and marine ecology, and marine and coastal geology. They leave evidence of climate change as they melt, and they have played a role in human culture because of their threat, their role in the great age of polar exploration, their beauty and their rarity, at least for most of humanity.

In this book I will explore these many aspects of the iceberg phenomenon, travelling to both polar regions, into the past and future, and encountering a range of scientific and social science disciplines on my journey. Part I of the book will concentrate on the science of icebergs, while Part II will deal more with their impacts on the environment and human society. However, in this chapter the Titanic example will act as an exemplar of the iceberg phenomenon.

1.1.1 The origin of the iceberg

No one knows for certain from where the Titanic iceberg originated. It must have calved from a glacier in the Arctic, almost certainly from the Greenland Ice Sheet (GrIS), sometime in the period 1907–12, as few Arctic icebergs survive for more than a few years after calving [3, 4]. However, there is a mix of more recent observational evidence, hypothesis and modelling which is consistent with the iceberg having calved from west Greenland, and most probably from the south-western part of the GrIS.

The conventional view of iceberg motion in the north-west (NW) Atlantic is of an anticlockwise circulation around the Labrador Sea and Baffin Bay, with some icebergs drifting into the Labrador Sea proper from the west Greenland Current, and notable short circuits of the iceberg route south and north of the Davis Strait (Figure 1.1). Icebergs join this pathway, largely driven by the ocean circulation [3], all along the route from southern Greenland around to the marine-terminating glaciers of Baffin Island. Recent iceberg modelling work suggests that most of the icebergs from southern and mid-west Greenland enter the shorter routes across to the Labrador Current, rather than travel the complete Baffin Bay circuit [4]. This was particularly true for the decade prior to 1912, according to the model, as the majority of modelled icebergs that flowed south, to the east of Newfoundland, in these years came from south-west Greenland [5].

A coupled ocean-iceberg model hindcast [4] of the calving location of the Titanic iceberg suggests that the iceberg calved from the Greenland coast, south-west of South Dome (Figure 1.1). There are a range of equally plausible candidate glaciers along the south-west Greenland coast, most with marine-terminations currently 50–100 km inland from their fjord's connection with the Labrador Sea. Despite global warming, the calving fronts of these glaciers are likely to have been at most a few kilometres closer to the ocean in 1912 [6]. However, all of the candidate glaciers are ice outlets from the southern section of the GrIS, near South Dome. This is the part of the GrIS with the maximum accumulation rate, because it lies on the edge of the North Atlantic storm belt, but also the maximum summer melt rate,

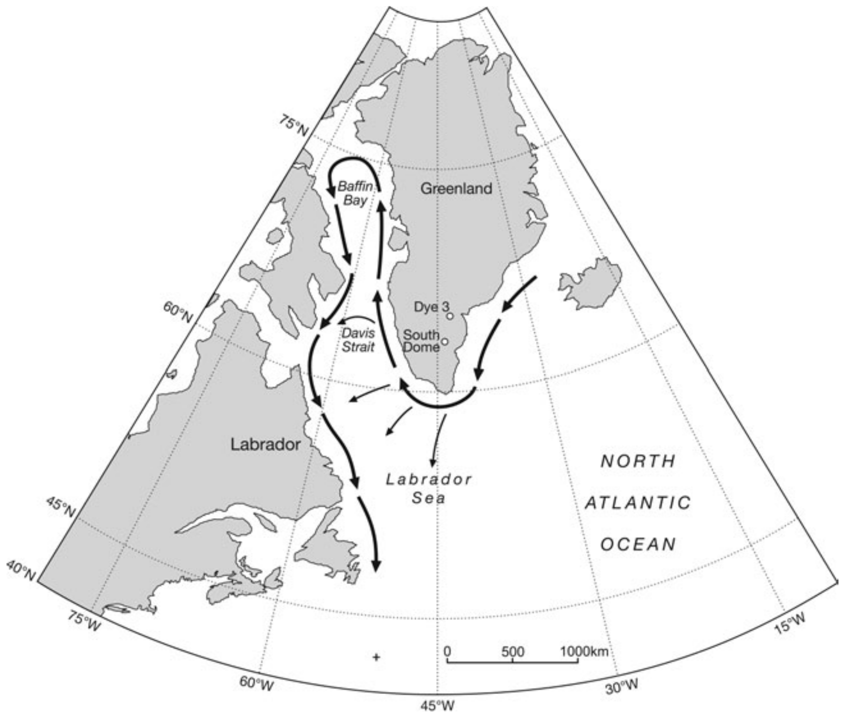

Figure 1.1 Map of the Greenland and Labrador area with arrows showing the direction of ocean currents likely to be carrying icebergs towards 40°N. The position of the RMS *Titanic* at the point of impact is shown by a '+'. The positions of the South Dome and Dye 3 ice cores are shown by 'o'. Based on limited observed iceberg drift patterns (after [4, Fig. 2], with permission from John Wiley and Sons).

as it is the part of the ice sheet furthest south, with relatively warm seas and land masses nearby. Nevertheless, the ice sheet at South Dome accumulates at a rate of ~0.55 m yr^{-1} [7], so the ice that eventually calves as a c. 250 m thick iceberg will only have required 500 years or so of accumulation to reach this depth. However, as we will see, the Titanic iceberg's ice is likely to have been consolidated far earlier than 1400 AD.

The ice at the base of the GrIS at the Dye3 ice core, the nearest deep ice core to southern Greenland, although on the northern flank of the South Dome, is over 100 000 years old [2]. As ice in an ice sheet slowly flows downhill towards the coast, it is possible that the ice in the Titanic iceberg is this old, or even older as ice flows slowly at only a few metres per year on average in this region [8]. However, this is unlikely. The ice feeding into marine-terminating glacier outlets will tend to have predominantly come from circumscribed ice streams feeding into the glaciers from further inland or the ice from the nearby uplands. The flowing ice also thins, due to surface and basal melting, and the effect of differential acceleration down-slope, from a thickness of 2–3 km at the South Dome to a few hundred metres at the calving front. It is therefore uncertain where in the ice sheet the ice in the Titanic iceberg originated, either horizontally or from what depth.

What is known is that the ice accelerates as it enters the ice streams leading into the marine-terminating glaciers, with speeds of several hundreds to several thousands m yr^{-1} [8] over the last 100 km or so (Figure 1.2). The Titanic iceberg's ice is therefore likely to have been somewhere between 1000 and 100 000 years old, and so most likely dating from the last glacial period.

Once ice reaches the marine-termination of its glacier the processes leading to the final trigger for an iceberg to calve are multiple and not known in detail [9]. They will also vary from place to place, and potentially over time [10]. However, the contributing processes are likely to be a mix of impacts from the interaction of water with the calving front: through ice sheet meltwater weakening the ice from within or subglacially, from subsurface melting from ocean water flowing up-fjord or from variation in the tides and ice melange in the fjord in front of the ice front altering stress patterns in the calving front.

Icebergs tend to begin life tabular or irregular in shape (see Chapter 2 for more details). However, most Greenland bergs are likely to be irregular, as the fjords into which they calve are not normally wide – they are typically 3–4 km in south-west Greenland. This is because the stresses imposed on the calving front by the frictional effect of the nearby side boundaries and the basal friction from the point at which the ice is grounded (for many marine-terminating glaciers just 5–10 km from the calving front [11]) are sufficient to mean parts of the calving front break off, rather than the entire width [12]. While the Titanic iceberg will have spent some months subject to the reshaping effects of the ocean and atmosphere, it is believed to have been irregular in shape (Figure 1.3).

1.1.2 Titanic rendezvous

It is sometimes suggested that a maritime disaster was very likely in the spring of 1912, as there were far more icebergs than normal in the NW Atlantic shipping lanes [13, 14]. There were certainly numerous reports of icebergs and "field ice" in the vicinity of the *Titanic* in the days leading up to the collision [1], the latter being a term implying a significant extent of iceberg and/or sea-ice fragments. It is also known that the sea-ice extent off Newfoundland was greater than normal that spring (Figure 1.4), although not exceptionally so [15]. However, just as the sea-ice extent was anomalously high, but not extreme, so was the 1912 iceberg number.

Following the sinking of the *Titanic* the International Ice Patrol (IIP) was set up by the US Coast Guard, to monitor iceberg numbers in the NW Atlantic

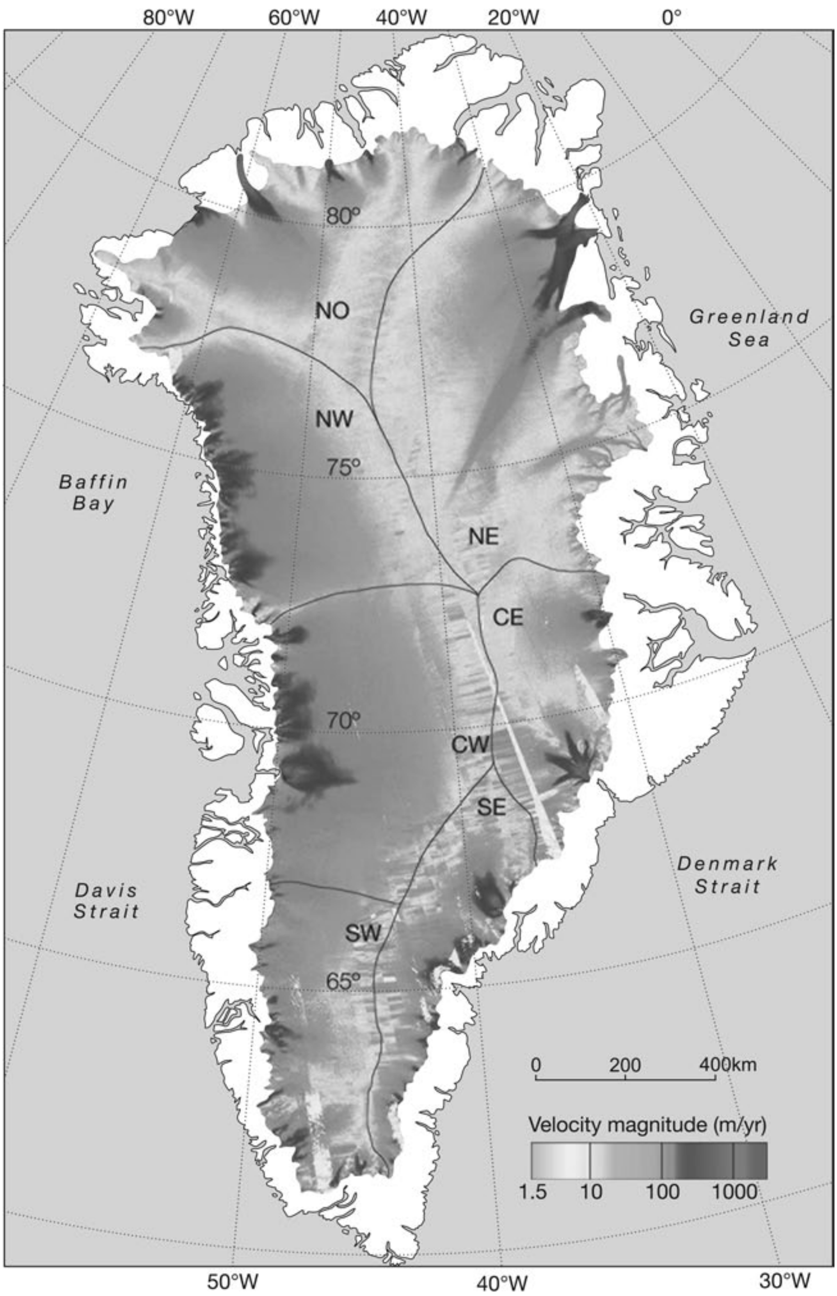

Figure 1.2 Ice velocity field of the GrIS derived from satellite radar interferometry of 2008–9. The velocity scale is logarithmic, at 150 m pixel resolution. After Figure 2 of [8], with permission of John Wiley and Sons.

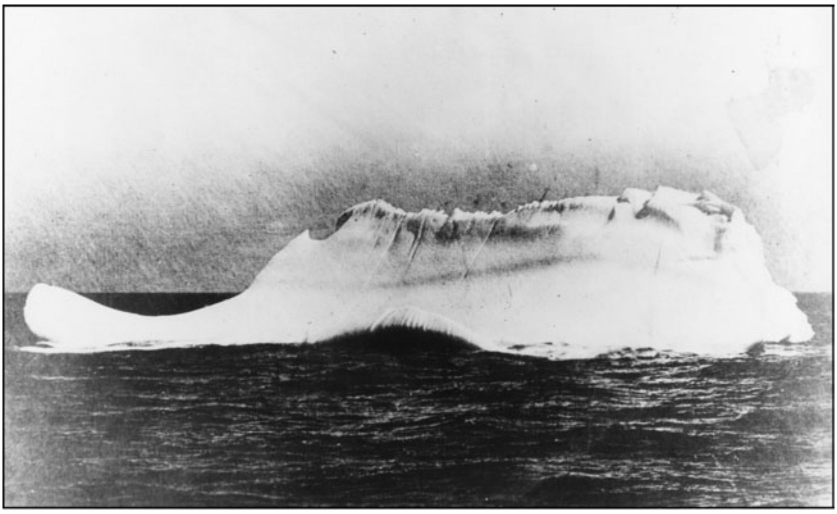

Figure 1.3 Iceberg believed to have been responsible for the sinking of RMS *Titanic*. The visible dimensions are roughly 120 m long and 30 m high. The streak visible in the photograph is believed to be red paint from the *Titanic*'s side. From a photograph taken by Captain de Carteret of the SS *Minia* (reproduction permission given by the US Coast Guard Historian's Office).

and give ice warnings to shipping [16]. There were records of previous year's iceberg sightings, however, and these have been combined into a long-term database, starting in 1900, of the monthly number of icebergs greater than 5 m in dimension (i.e. not "growlers") passing south of 48°N (Figure 1.5, [17]). There have been changes in IIP observing practice over the years, which we will explore in depth in Chapters 3 and 8, but for our purpose here we will assume that the yearly totals are robust. In 1912 there were 1038 icebergs crossing 48°N, according to this dataset, with 395 in April, the peak month for observed icebergs that year [5]. Figure 1.5 shows that the 1912 value is a significant number, but far from the maximum in the series; 14 years since 1900 have exceeded this total, on occasion by over a factor of 2. Just three years before, in 1909, there had been a comparable number observed (1041). Even for April there have been four years with sometimes more than double the 1912 monthly value, and several years with numbers approaching the 1912 value. Thus, the number of icebergs in 1912 was anomalously high, but it was not an extreme year in the context of the twentieth century as a whole.

Coupled iceberg-ocean modelling suggests that the Titanic iceberg calved in late summer to autumn 1911 [5]. It collided with the *Titanic* at 11.40 pm, local time (0310 GMT) on the night of 14/15 April 1912 near 41°47'N, 49°55'W (Figure 1.1, [18]). This means the iceberg had some 6 months or so in the ocean to move and

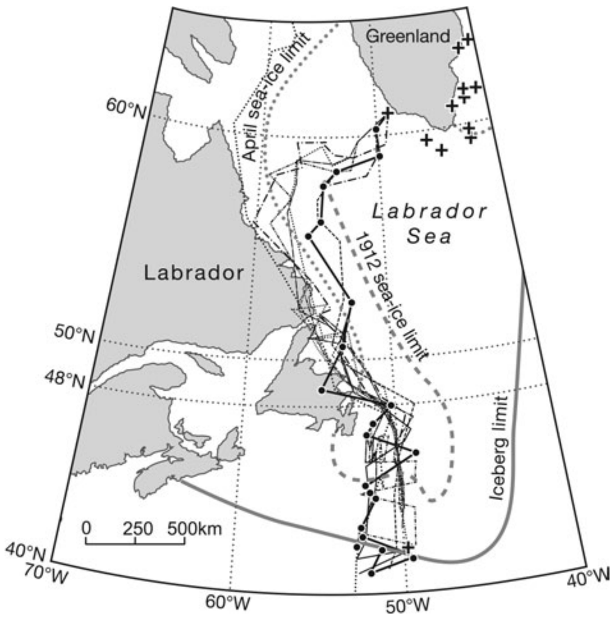

Figure 1.4 Ice conditions in the Labrador Sea in spring 1912. The average sea-ice limit for April 1979–2013 is shown dotted, a typical Newfoundland maximum sea-ice limit for the early twentieth century is dashed and denoted as 1912 (from [15]) and the maximum iceberg limit for 1900–2000 is shown, in addition to the 48°N latitude circle. Also shown are trajectories of representative modelled icebergs [5] reaching the general area of the sinking of the *Titanic* between mid-January and mid-July, 1912. The iceberg most closely matched to the time and place of the *Titanic*'s sinking (marked by an '+') is shown in bold, with filled circles periodically. The real land boundary is shown, rather than the model's representation of this; icebergs appear to cross the Labrador and Newfoundland coasts, where there are differences in these boundaries.

melt. We have seen that the Titanic iceberg is likely to have calved from a glacier in south-west Greenland. Icebergs from this area generally enter the anticlockwise circulation of the sub-polar ocean gyre (Figure 1.1), passing eventually into the southward flowing Labrador Current, along the Labrador coast. Modelling suggests that this was the case in 1912 (Figure 1.4) and that most icebergs modelled to be in the general area of the *Titanic* in the first half of 1912 took that path. Only a small proportion are predicted to have come from further north, in Baffin Bay (Figure 1.5). Icebergs largely move with the ocean currents, although we will see in Chapter 3 that there are more forces involved than just ocean drag, some of which can cause icebergs to roll over if buoyantly unstable. However, Figure 1.4 shows a flow largely driven by the mean ocean circulation.

Icebergs also melt as they move, however. Reports from the few survivors of the sinking of the *Titanic* that saw the colliding iceberg [1] claimed that it was 50–100

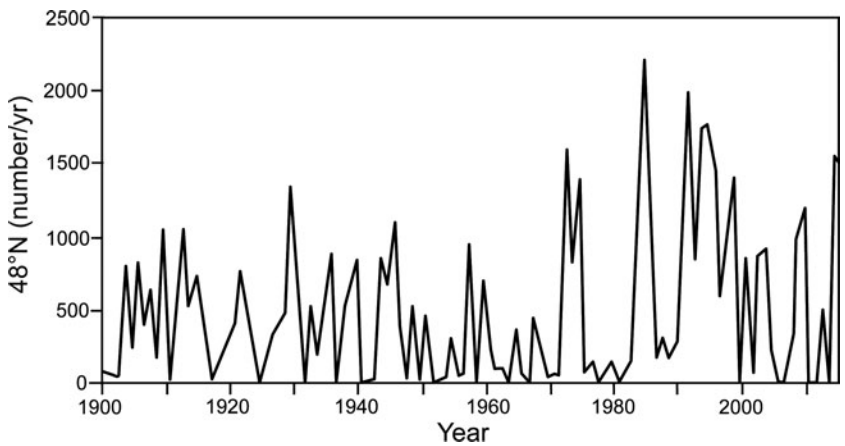

Figure 1.5 Total number of icebergs >5 m in diameter crossing latitude 48°N in the NW Atlantic each year 1900–2014, as recorded by the IIP. Note that the year is defined as an ice-year, beginning in October of the year before the notional record and extending to September of the ordinal year.

feet high (15–31 m) and some 400 feet long (122 m). The rescue ship, RMS *Carpathia*, reported steaming through ice up to 200 feet high on the three-and-a-half-hour journey to the collision site, and the next day, and the dimensions of the iceberg widely believed to have been responsible for the collision fit with the survivors' estimates (Figure 1.3). The vertical dimensions of the Titanic iceberg will have actually been greater than seen, as the density of glacial ice is about 15% lower than that of seawater and so ~85% of an iceberg is below the surface. Thus, the Titanic iceberg is likely to have been 90–185 m deep, while being some 125 m long, ignoring any possible underwater projection. The height can be tied down even more through considering the implications of the stability constraint mentioned above. Essentially, as an iceberg predominantly melts from the side [3], its centre of gravity will eventually become too high for the iceberg to remain upright and so it will roll over. Assuming the length of the Titanic iceberg to be as reported – ~125 m – the stability constraint means that the iceberg could not have been more than ~100 m deep. It likely protruded some 17 m (~60') above the waterline. An iceberg of depth 100 m and width 125 m will have had a mass of ~1.5 Mt.

The iceberg modelled to be in the vicinity of the *Titanic* sinking (Figure 1.4) began life in early autumn 1911 as an iceberg 500 m in length by 300 m in depth, with a mass of ~75 Mt. By the time it reached ~42°N in mid-April 1912 it had reduced in mass to 2.1 Mt, remarkably close to the reconstructed mass of 1.5 Mt for the Titanic iceberg.

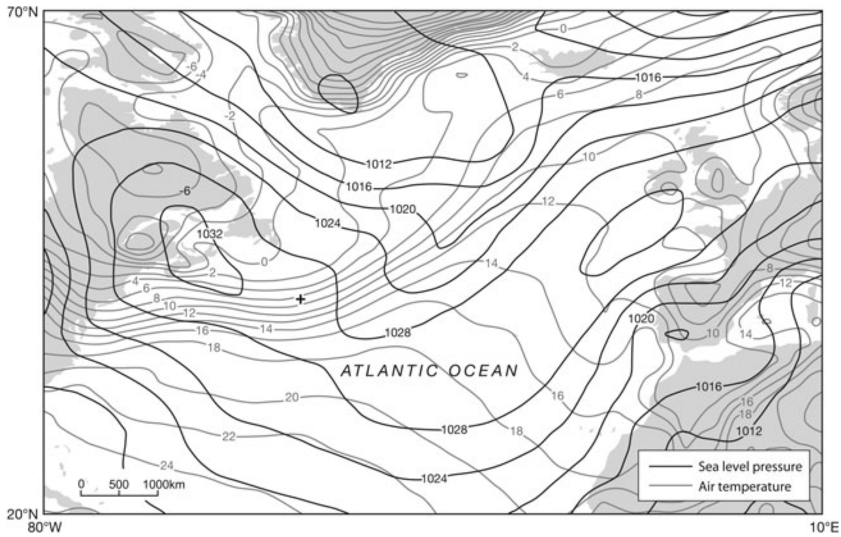

Figure 1.6 Sea-level pressure (hPa) and air-temperature (°C) chart for 0000 GMT, 15 April 1912, taken from the ensemble mean of the twentieth century reanalysis [19]. The location of the Titanic is shown by an '+'. After Figure 1 of [5].

As the iceberg and the *Titanic* travelled towards their fateful encounter, the atmosphere and ocean set the stage on which the drama would be played out. Near-surface air temperatures during March and April 1912 were anomalously cold over eastern Canada and out over the whole western North Atlantic from 35 to 55°N, by more than 2°C relative to the 1981–2010 mean. In early April high pressure had dominated the North Atlantic. By the time of the collision a ridge connecting high pressure cells on either side of the Atlantic had formed (Figure 1.6), leading to the cold air over eastern Canada being transported out over the Atlantic by NW winds. These conditions assisted the southward transport of ice in the Labrador Current and delayed its melting, leading to sea-ice and icebergs being found further south than normal, even for the early twentieth century. As we saw earlier in the chapter, the presence of extensive ice was widely reported prior to, and following, the collision [1]. Despite these warnings, and a moonless, if cloud-free, night, the *Titanic* was steaming towards New York normally, rather than at reduced speed [18].

At 11.40 pm Frederick Fleet, a lookout in the crow's nest, sighted a large iceberg dead ahead. He immediately contacted the bridge, where the orders to put the ship's engines to full astern and turn the ship to starboard were quickly given. Nevertheless, the iceberg still struck the ship aft of the bow. In the enquiry immediately after the accident, it was stated that "the ship brushed along a submerged spar of the iceberg along her starboard side, opening several varying sized holes along her length and an inrush of water" [20]. Six compartments were flooded, two more than the design specifications of the ship allowed while still remaining afloat. The ship sank in less than 4 hours, leading to the loss of 1512 lives; only 710 were rescued from the lifeboats by the *Carpathia*.

Why did the *Titanic* sink so quickly? The mid-2000s analysis of the rivets used to fix the steel plates of the ship together suggested that those used in the front and rear fifths of the vessel were of secondary quality, with a greater slag content than the highest-quality rivets available [21]. This made the heads of these rivets more susceptible to stresses, leading them to pop off under the impact of the collision and cause major hull failure. It seems likely that the *Titanic* tragedy occurred as a result of a combination of the ship travelling too quickly for the conditions and quality compromises made during construction.

1.1.3 The fate of the iceberg

Despite probably losing some 95% of its mass before colliding with the *Titanic*, our iceberg was still a substantial hazard for shipping following the collision (Figure 1.3). Occasionally, icebergs have been found a surprisingly long way south or east in historical times in the North Atlantic; however, in 1912 the Titanic iceberg was only 1–200 km at most from the much warmer waters of the North Atlantic Drift [22], in which it would have quickly melted completely. The resulting input of freshwater into the upper ocean will have locally changed the seawater's salinity by a small amount, as will have been happening throughout the passage of the iceberg from the Greenland coast to its ultimate disappearance somewhere around 40°N in the western Atlantic. For all but the largest icebergs this effect will be very localised, but we will see in Chapter 4 that the net effect of all icebergs' meltwater can be significant in modifying the ocean circulation and sea-ice characteristics, and in Chapter 7 how on occasions in the past massive armadas of icebergs have almost certainly changed regional, and possibly global, climate for centuries.

Icebergs do not just release freshwater when they melt. The Titanic iceberg, as with all icebergs, will have carried both life and sediments with it through its journey, slowly letting these out into the ocean over time. The origins of these and their impacts on the environment will be dealt with more fully later. Most of these "foreign" elements would have been carried by the iceberg since it calved. However, some life forms, for example, polar bears, can use icebergs as a means of transport, getting on and then off during the iceberg's lifetime. Similarly, the Titanic iceberg might have collected sediment on route, through collisions with the rocks of the fjord walls on its way to the open ocean or by scraping across the sea floor leaving its home fjord, or during passage along the Labrador or Newfoundland coasts.