Polar Record 40 (213): 153–165 (2004). Printed in the United Kingdom. DOI: 10.1017/S0032247403003346

Antarctic sledging preparations and tacit knowledge

Ronald Savitt
Savitt Associates, 2702 NE Bryce Street, Portland, Oregon 97212, USA

Received March 2003

ABSTRACT. The article discusses how organisational structure and culture affected the preparations for sledging in three Antarctic expeditions between 1901 and 1904. The central focus is how expedition leaders sought tacit knowledge, 'the knowledge of how we do things.' Two organisational types were derived from a study of 36 major polar expeditions. These – the industrial organisation and the innovative organisation – were used to analyse how sledging practices evolved in the British National Antarctic Expedition, German South Polar Expedition, and Scottish National Antarctic Expedition. Robert Falcon Scott, in great part as a result of his naval heritage, did not fully understand the need for and the methods required to gain the operational knowledge required for sledging in Antarctica. He applied the traditional command-and-control system based on naval tradition. Erich von Drygalski and William Speirs Bruce applied Fridtjof Nansen's scientific approach, in which the scientific staffs were integrated into sledging operations. In this approach, every variable that could possibly affect the outcome of the research was incorporated into preparations, much as is the case in classical experimental design. While no attempt is made to judge sledging success in the study, the results clearly indicate the importance of knowing how to use the tacit dimension in sledging. The implications go far beyond sledging and suggest the need for managers to have an intimate understanding of how things work.

Contents

Introduction 153
Methodology 153
Knowledge management 155
Finding and using tacit knowledge 155
Organisations and exploration 156
Sledging organisations in three Antarctic expeditions 157
Tacit knowledge and the preparation for sledging 158
Summary and conclusions 162
Implications 162
Acknowledgements 163
References 163

Introduction

Polar explorers played many roles in carrying out their expeditions. Although most did not describe themselves as managers, each was. Almost every explorer described his tasks in developing and allocating human and physical resources. The demands of management often went beyond their immediate backgrounds. Critical to each expedition was the identification and assembly of relevant knowledge. The expedition leader had to understand the potency of such knowledge, sometimes without experiencing it. Knowing what to know was a constant challenge.

This research reflects the renewed interest in polar exploration. Sir Ernest Shackleton's *Endurance* expedition has been the subject of two major management studies (Perkins and others 2000; Morrell and Caparell 2001). Other management studies have focused on corporate governance issues, public versus private ownership, and human resource issues and the effects of confinement on individual performance (Karpoff 2001; Suster 1996). This article examines knowledge management practices used in the preparation for sledging in the early part of the 'Heroic Age,' 1901–04. It looks at how expedition leaders gathered explicit and tacit knowledge, respectively, 'what is known and recorded' and 'what we know how to do' and 'how things are done.' The thesis is that the search for tacit knowledge is a function of the expedition's organisational structure and the impact that structure had on its leader. The more formal and hierarchical the organisation, the less likely tacit knowledge will be sought and applied; the more open and innovative the expedition's organisation, the greater the role of tacit knowledge.

Methodology

This is a study of management practices using historical information. The research employs a 'retrodiction' process that serves 'to work out what might have happened in the past' (Savitt 1980: 52). The research uses grounded theory, a qualitative methodology based on the inductive discovery of theory by the systematic evaluation of data (Haig 1995: 9). The study examines the organisational structures and resulting leadership styles of 36 expeditions, 25 Arctic and 11 Antarctic, from the nearly 140 polar expeditions in the period 1818–1916. Four Antarctic expeditions in the 1901 to 1904 period were held out of the initial analysis; these are the British National Antarctic Expedition (BNAE or *Discovery* Expedition), the German South Polar Expedition (GSPE), the Scottish National Antarctic Expedition (SNAE), and Otto Nordenskjöld's Swedish Antarctic expedition. They became the focus of the second part of the research in which the findings from the first part were applied. Summary data from the 40 expeditions are shown in Table 1. Included are descriptions of the various knowledge bases and their interrelationships among the various expeditions. Direct connections between the Arctic and the Antarctic expeditions are also identified.

Table 1 provides an overview of knowledge flows from the expeditions that were used in the analysis. The Arctic section of the table summarises a sample of important

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

Table 1. Selected polar expeditions with major sledging activities used in the study. Sources for identification of expeditions wtth significant sledge journeys: Cyriax 1963; Pearson 1995; Headland, in press; Mirsky 1970; Vaughan 1999; British Parliamentary Hearings (1818–l879): 'Arctic Blue Books' (Tremaine 45121–45127).

Dates	Expedition	Leader	Knowledge bases
Arctic			**Explicit and tacit knowledge factors**
1819–20	British Northwest Passage expedition	William Edward Parry	First major experiences with sledges
1820–24	Russian exploring expedition	F. von Wrangel	Military column approach
1821–23	British Northwest Passage expedition	William Edward Parry	Application of Eskimo methods
1827	British North Polar expedition	William Edward Parry	Design of sledge and sledge boats
1829–33	British Northwest Passage expedition	John Ross	Longest sledge journey, 400 miles
1836–37	British naval exploring expedition	George Back	Sledges converted to boats
1848–49	British naval Franklin search expedition	James Clark Ross	Man haulage, flat sledges, extensive improvements
1850–51	British naval Franklin search expedition	Horatio Austin	Larger and flatter sleds; improvements to Ross' sledges
1853–55	US Franklin search expedition	Kane	Lessons from disaster with dogs
1857–59	British Franklin search expedition	Francis Leopold McClintock	Classic sledging article used for Scott in 1901–04
1872–74	Austro-Hungarian Exploring Expedition	Karl Weyprecht/Julius Payer	Sledging techniques
1875–76	British Arctic Expedition	George Strong Nares	Sledges 'as cavalry'
1878–80	US Franklin search expedition	Frederick Schwatka	Greenland sledges
1881–82	British exploring expedition	Benjamin Leigh Smith	Sledging application
1881–84	US International Polar Year Expedition	Adolphus W. Greely	Hudson Bay sledges
1888–89	First crossing of Greenland	Fridtjof Nansen	Basic sledging and haulage methods
1891–92	US North Greenland expedition	Robert E. Peary	Peary 'sledging system'
1893–95	US North Greenland expedition	Robert E. Peary	Peary 'sledging system'
1893–96	Norwegian exploring expedition	Fridtjof Nansen	Three years in Arctic with sledges; Nansen sledge
1894–97	Jackson-Harmsworth Expedition	Frederick George Jackson	Variety of haulage methods, Armitage, Bruce, Crean, Koettlitz, and Robertson
1896	First crossing of Spitsbergen	Martin Conway	Sledging techniques
1897	British exploring expedition – Spitsberge	Martin Conway	Sledging and skiing techniques
1898–99	Wellman Polar Expedition	Walter Wellman	Dogs and sledging methods
1899–1900	Italian North Polar expedition	Duke of the Abruzzi	Dogs most useful; Nansen advice is taken
1903–05	Fiala–Ziegler Expedition	Anthony Fiala	Detailed instructions and evaluations for sledge parties
Antarctic			**Tacit knowledge bases**
1892–93	Scottish whaling expedition	Alexander Fairweather	Previous Arctic, Bruce as part of crew
1897–99	Belgian Antarctic expedition	Adrien de Gerlache	Amundsen and Frederick Cook part of crew
1898–l900	British Antarctic expedition	Carsten Borchgrevink	First use of dogs and skis, Bernacchi a member
1901–03	German South Polar Expedition	Erich von Drygalski	Greenland preparatory expedition
1901–04	Swedish South Polar expedition	Otto Nordenskjöld	Previous Arctic experience, limited sledging
1901–04	British National Antarctic Expedition	Robert Falcon Scott	Armitage, Crean, and Koettlitz from Jackson-Harmsworth, and Bernacchi from Borchgrevink's
1902–04	Scottish National Antarctic Expedition	William Speirs Bruce	British whaling 1892–93; Jackson-Harmsworth, Robertson captain of *Scotia*
1903–05	French Antarctic expedition	Jean-Baptiste Charcot	Consulted with Nordenskjöld
1907–09	British Antarctic Expedition	Ernest Shackleton	Shackleton, Frank Wild, Ernest Joyce with BNAE 1901–04
1908–10	French Antarctic expedition	Jean-Baptiste Charcot	1903–05 French expedition
1910–12	Norwegian Antarctic expedition	Roald Amundsen	Belgian 1897–99; Northwest Passage 1903–06
1910–13	British Antarctic expedition	Robert Falcon Scott	Scott, Wilson, Evans and others from 1901–04 BNAE
1911–12	German South Polar expedition	Wilhelm Filchner	Drygalski, Konig from Arctic
1911–14	Australasian Antarctic Expedition	Douglas Mawson	Sledge practices from Nansen; with Shackleton 1907–09
1914–16	Imperial Trans-Antarctic Expedition	Ernest Shackleton	Shackleton, Wild, Joyce, Crean, Marston from earlier expeditions

sledging activities, which became part of the explicit knowledge base used by Antarctic explorers. Where possible, such as in the case of the Jackson-Harmsworth Expedition, the names of individuals who participated in Antarctic expeditions are identified. The Antarctic section provides a list of all of the expeditions in the 'Heroic Age' and indicates sources of tacit knowledge.

Knowledge management

Knowledge management represents those activities that are used to develop 'intellectual assets' or the knowledge of how to do things (Davenport and Klahr 1998). It is composed of three inextricably interrelated activities, the capture, the application, and the creation of usable knowledge (Liebowitz and Beckman 1998: 8). Julius Payer put this in a polar context when he wrote;

> Every Arctic expedition should be guided by the experiences of its predecessors, both in plan and its equipment; and hence we have often to deplore the negligence of almost all polar navigators in failing to inform those who follow them of what they actually saw, of their modes of procedure, or of the mistakes which they committed. It will not, therefore, be labour thrown away, if we state our own experience and record our own observations for the guidance of others, in order to show, with the utmost possible clearness, what future explorers have before them, and how best to meet it. (Payer 1876: I, 62)

Measures of success include what was learned and how well it served others. Knowledge management is affected by the organisation's culture, behaviour, and structure, its openness to new ideas, and its willingness to engage in experimentation. It comes from a Japanese intellectual tradition with its separation of 'subject,' 'mind,' and 'self' from the 'object,' 'body,' and 'other' that characterises western social sciences and 'the Cartesian split between the knower and the known' (Nonaka and Takeuchi 1995: 32). Explicit and tacit knowledge have individual and organisational dimensions. These are (1) tacit and individual knowledge, (2) tacit and organisational knowledge, (3) explicit and individual knowledge, and (4) explicit and organisational knowledge (Baumard 1999: 104). Although appearing static, this is a dynamic process, which is concerned with the transfer of individual tacit knowledge to organisational explicit knowledge.

The challenge for explorers was to learn how to capture the lessons from those who went before them. The task is not as simple as it might seem, especially because not all of the knowledge was readily accessible and because not all those seeking it understood exploration, especially the role of sledging in polar exploration. Finally, some did not understand how and where to seek such knowledge.

The search for knowledge

In preparing for the Antarctic, expedition leaders did not start *de nova* in their effort to answer four critical questions. What did they need to know? Who had the appropriate knowledge? How should the search be conducted? How much of the Arctic experience would be relevant for the Antarctic? They had important starting points including the written records of previous explorers, commercial organisations, their own experiences, the learned and scientific societies, and the national navies, which were storehouses of exploration knowledge. The most important of these was the Royal Geographical Society (RGS), which had been a sponsor of exploration and a participant in Arctic exploration (Cameron 1980). The Society provided a venue for informal contacts. The RGS also collected a wide assortment of value materials for explorers and produced the series of *Hints to travellers*, beginning in 1854. This was an effort 'to promote an authoritative "way of seeing" in the field' (Driver 2001: 49). The RSG established informal protocols that influenced exploration.

The nineteenth-century Arctic sledging literature was an important starting point for those about to go to the Antarctic. Much stemmed from English expeditions between 1818 and 1875 as reported in various narratives and the 'Arctic Blue Books.' Experiences from other Arctic expeditions, including those from Austria, Britain, Germany, Italy, Norway, and the United States, were also readily available (Payer 1876; Conway 1897; Jackson 1898; Drygalski 1897; Abruzzi 1903; Nansen 1890, 1897; Peary 1898). Important British materials were brought together for the British National Antarctic Expedition by the RGS in *The Antarctic manual*; it provided discussions of issues that would confront the expedition (Murray 1901). Included was Francis Leopold McClintock's classic account of Arctic sledge travelling that had first been published in the *Proceedings of the Royal Geographical Society* in 1876 (1876: 242–279; 1901: 293–304). Albert Hastings Markham underlined McClintock's contributions when he wrote that he brought sledging to 'a very perfect state' and stood without rival at the very top of sledge travellers (Markham 1878: 283). As important as it was, *The Antarctic manual* did not include anything about the more recent Arctic sledging experiences, especially those of Fridtjof Nansen (Nansen 1890; 1897).

In spite of all that was available, it is not clear how much of these materials were used. Ship libraries contained collections of Arctic sledging journeys, but it does not appear that they were extensively used in preparing for Antarctic exploration.

Finding and using tacit knowledge

Tacit knowledge is the 'knowledge used by organisational members to perform their work and make sense of their worlds' (Choo 1998: 111). Michael Polyani, a scientist later a philosopher, described it succinctly as 'We know more than we can tell' (Polyani 1966: 4). It represents 'our ability to perform skills without being able to articulate them' (Collins 1985: 56). Tacit knowledge originates from experiencing and doing tasks. Every individual – from pulp and paper mill operators to photocopier repair

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

technicians to dentists – have and use tacit knowledge. The capture and exploitation of tacit knowledge is difficult because 'it can not be articulated fast enough, because it is impossible to articulate all that is necessary for a successful performance, and because language cannot simultaneously serve to describe relationships and characterise the things related' (Nelson and Winter 1982: 81–82). What this means is that many innovations and solutions that occur 'as a result of experience gained in the operation of the firm will remain unused' (Penrose 1980: 54). However, solutions are captured and can be used to improve operations. For that to happen, there must be personal contact among individuals involved in the process, a propensity and ability to share what they have learned, and recognition by the organisation that the management of tacit knowledge is important. How this evolves is determined by the organisation and its culture (Baumard 1998: 197–223).

Tacit knowledge is difficult to manage. The greatest challenge is to collect as much as possible. Managing tacit knowledge implies that the manager understands the process and the wherewithal to capture the process either directly or from those that are part of it. This requires openness to new ideas that are derived in non-traditional ways often built on limited evidence. It is similar to dead reckoning – 'the guesswork, informed guesswork, but guesswork nevertheless' (Gurney 1997: 25. Management thinking supports the view that individual tacit knowledge can be converted into organisational explicit knowledge. There is a substantial literature supporting that view (Choo 1988: 119–126; Nonaka and Takeuchi 1995: 185–193). A more conservative view is held in the scientific literature. 'The individual's knowledge must be acquired by contact with the relevant community rather than by transferring programs of instruction' (Collins 1985: 159).

Sources of tacit knowledge

Expedition leaders clearly understood that drawing upon past experience was necessary. This was particularly important for sledging for two reasons. First, it would play a central role in Antarctic exploration, which required a greater commitment to land-based transportation. Second, not all expedition leaders had sledging experiences and thus they had to develop an understanding as to what it was all about. The written record described what it was to undertake sledge travelling but not how to do it. The latter was achieved in three ways: the direct experience of the leader, individuals selected by the leader, and the absorption of knowledge from the written record. Some Antarctic expedition leaders had tacit knowledge as a result of previous expeditions or experiences that were part of their preparations. For those who did not have such experience, it meant that they had to select individuals who did. They had to be able to judge what others knew and what others could do. Experience was a precursor but not a guarantor of having the appropriate tacit knowledge. Seeking such knowledge is a difficult task under any circumstance but more difficult when organisational cultures are not predisposed to it. Formal organisations often have barriers, including the use of a common language that excludes new ideas, the continuously reinforced stories of how things have worked in the past, the operating procedures, and the 'strategic intent' of the organisation's mission (Von Krogh and others 2000: 22–25).

The absorption of tacit knowledge from the explicit is a challenging task because one never fully knows how much was captured, how well it was captured, and how well it was transferred and presented in explicit materials. Importantly, its application depends on those using it having substantial experience to interpret it. Roald Amundsen wrote: 'Second hand experience out of a book is often as good as first hand, if the reader has had enough experience in the same field to understand and apply what he needs' (Amundsen 1927: 239). Even then challenges abound. Take the case of Roger Daynes, a contemporary sledge maker who was asked to produce sledges for a Shackleton movie. He found that while Shackleton had described the sledges and the materials for building them, missing were the instructions (Shackleton 1909: 148–150). If it had not been for Daynes' Antarctic experiences in making and repairing sledges, he would not have been able to replicate Shackleton's sledges (Roger Daynes, SnowSled, personal communication, 14 March 2000). Tacit knowledge is also embedded in the sledges and equipment, although it is not always visible. Advances in sledge design, sledging equipment, and sledging techniques were made but often went unseen. In a different context Nansen made a relevant point: 'one word of advice:– See everything packed yourself and you will know where it is, don't be afraid of revising your lists too often before starting' (Bain 1897: 113).

Organisations and exploration

Three different organisational types are found in polar exploration: commercial, naval, and scientific expeditions. Each used different procedures. Whalers and sealers dominated the commercial arena; they operated in flotillas, and fleet owners and captains controlled the operations (Davis and others 1989). They had the luxury of a large pool of sailors with extensive experiences who were readily available to take on the risky work. They provided much navigational knowledge to polar exploration, but their commercial focus limited advances in other areas. An important exception was William Scoresby, the younger, who made important contributions to sledging with regards to its use in reaching the North Pole (Vaughan 1999: 151).

Naval expeditions were organised with a strong command-and-control system dominated by an extensive administrative system, the influence of which extended beyond the boundaries of the navy to the industries and suppliers on which the navy depended (Rodgers 1988: 11). Naval hierarchy and culture defined policies, procedures, rewards, and sanctions. They encouraged adherence to a common order and discouraged disagreement

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

Table 2. Characteristics of sledging organisations used in three Antarctic expeditions 1901–04.

Factors	Industrial	Innovative
Organisational structure	Hierarchal	Flat
Organisational size	Large	Small
Leadership background	Royal Navy	Scientific
Operational atyle	Delegation	Shared
Management system	Direct orders	Co-operative
Assumptions about the environment	Clearly stated	Exist with and respond to
Approach to the environment	Force to conquer	Adapt to conditions
Planning orientation	Fixed	Evolutionary
Role of knowledge: planning		
Explicit	Central	Peripheral
Tacit	Minimal	Central
Role of knowledge: operations		
Explicit	Central	Peripheral
Tacit	Recognized	Central

and experimentation; management was monopolistic and authoritarian. Naval exploration 'was the product of a hierarchal service establishment based on discipline and its purpose was war and the keeping of peace and order' (Wallace 1980: 5). Such operations have been characterised as a 'heavy sea borne' tradition, 'where the solution of problems was based on a technology with a great use of labour force' (Ellis 1986: 98). Except for expedition leaders, the line officers and crews were often explorers by chance and defined by their times. Many sought an 'ordinary naval career and sailed for an unknown world of ice and snow full of the robust confidence of the Victorian age' (Kirwin 1959: 79). These expeditions used the 'rules of engagement' of the times, which were often inconsistent with 'exploration for its own sake' that was carried out by men 'who made it their life task to extend the limits of the unknown, which were completely captivated by the lure of the Arctic' (Mirsky 1970: 9). What they had were the advantage of massive resources, formal organisations, and the desire to complete the map of the world (Peter Speak, personal communication, 14 November 2001).

Scientific expeditions took their form from the principles of the scientific method with its central focus on experimentation. Scientific explorers were concerned with the unknown, but their focus went beyond 'geographical knowledge' and 'a science of position,' although geographic discovery was part of their work (Driver 2001: 2). This approach was clearly exhibited by Nansen. He applied scientific reasoning to understanding the reasons for and the consequences of the *Jeannette* disaster. Using that example, he developed a theory of polar currents in the Arctic Ocean, which recognised the advantages of adapting to the environment rather than confronting it. This principle was used in the design of the hull of *Fram*, which allowed it to be pushed upwards on the ice (Nansen 1897: 103). The principle was carried over to sledging (Amundsen 1927: 103). Because the ship and the sledge were core elements, he took great care to understand the impact of each on the other and ultimately on the success of the expedition. This varies little from the principles of experimental design, in which all of the external and internal variables affecting an experiment's outcome are identified and evaluated before the experiment takes place (Ferber 1949: 246).

From a casual glance scientific organisations appear similar to naval expeditions; what differed, however, was how they carried out the work of exploration. This is seen in the make-up and operations of the scientific party. It was holistic; the members were integrated into the expedition. The organisation, as with contemporary scientific-based commercial organisations, was fluid and 'without boundaries to the demands placed on the individuals and implicates all members in the concern's success' (Samson 1990: 32). Because of limited resources, scientific expeditions were managed differently. Nansen made this a central issue. He abhorred 'the sacrifice of money and lives in an Arctic voyage which does not start from a thorough knowledge of all that has been done and suffered in these regions, and is not guided by practical talent for combining unconnected data, constructing reasonable theories, and even divining what lies behind the mists and beyond the immeasurable ice fields' (Astral 1896: 260–261).

Sledging organisations in three Antarctic expeditions

Two distinct organisational types not dissimilar to those found in the management literature were identified from the 36 polar expeditions examined in the first phase of the research. These are the industrial organisation and the innovative organisation. Their characteristics are summarised in Table 2 and were used in evaluating how tacit knowledge was managed in developing the sledging journeys in three expeditions, the BNAE, the SNAE, and the GSPE. Although the original intent of the research was to include Nordenskjöld's Swedish expedition as well, it was excluded from the analysis. While there were extensive sledging journeys, there was insufficient information except in the area of sledging provisions to include it in the discussion (Nordenskjöld 1920). It is

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

not clear what planning went into the expedition as a whole; it had major disasters including the loss of the ship (Nordenskjöld and Anderson 1905: 528–536). What evidence is available does not provide much insight into how the expedition was organised and suggests major shortcomings. Musing about the Arctic and Antarctic differences, Nordenskjöld wrote, 'we were so perfectly unprepared for the eventuality' that they were not similar (Nodrenskjöld and Anderson 1905: 284). Additional research regarding this expedition is in order.

The industrial organisation

Sledging organisations on the BNAE were similar to the industrial organisation found in the management literature (Mintzberg and others 2002: 221–222). This form originated in the Industrial Revolution and is characterised by specialisation operations defined by standardised procedures through a vertical hierarchy. Co-operation among units rather than integration describes this organisation. Senior officers issued directives that were administered by middle-level officers and carried out by the crew. There were clearly stated behavioural rules and operating procedures as can be in seen 'sledging orders.' It was the command-and-control system of contemporary times and can be represented by a triangle with authority originating from the apex and flowing to the broad base where actions are performed. Communications flow downward through clearly defined channels; reports about results move upward, however, although most knowledge remains at the operations level, and as a result there is limited conversion of tacit knowledge to explicit knowledge for further use (Choo 1998: 119–121).

British sledging parties were derived from the naval organisation from which they originated. There was a formal structure with a clear division of labour between the officers and the men. These remained clear in spite of the proximity in which they lived and worked. The crew's primary responsibility was to haul the sledges while the officers supervised and provided directions. While they both shared the difficulties of hauling sledges, officers had administrative responsibilities that ranged from planning to recording the day's activities and winding the chronometer (Savours 1999: 210). Although camaraderie was high, class distinctions limited the relationships between officers and crew and affected what the officers learned from the men, a point frequently seen in their journals (McClintock and Mecham 1852–54). The command system for sledging was developed by McClintock (Markham 1878: 283). Sledges were conceived as naval vessels and operated similarly to ships. They also included heraldic banners and employed man haulage reflecting the seaman's historical use of ropes (Markham 1903). Naval sledging accomplished a great deal in the Arctic (Cyriax 1963). These practices remained dormant for the last 25 years of the nineteenth century. With the start of Antarctic exploration in the new century, the Royal Navy had a great deal of catching up to do, especially with regard to equipment, haulage methods, and sledging organisation (Pearson 1995: 9). As it moved forward, the culture of the naval organisation affected how new knowledge was brought into preparations for the Antarctic. For example, the use of dogs and the advances in sledging practice were dismissed out of hand (Mackinnon 1985: 135).

The innovative organisation

The innovative organisation has its roots in scientific method and is based on process and experimentation and is best seen in the SNAE and the GSPE. The administrative structure is limited; there are still positions of authority but these are defined in terms of 'adhocracy,' the co-ordinated efforts of participants who share common knowledge and responsibilities for the process (Mintzberg and others 2002: 223–224). There was little of the vertical, command-and-control structure of naval-oriented expeditions (Lüdecke 1995: 244–246). The innovative sledging organisation with its holistic orientation came from Nansen. Amundsen implemented Nansen's approach, which was 'the fastest, most economical, and most effective system to transcend the ice' (Amundsen 1927: 241). It included not simply a better designed sledge but skiing and the use of dogs. Tents, cookers, clothing, food for dogs, and dogs for food as well as the streamlined, light-weight sledge were all part of the system. Men on skis could not travel as fast as dogs alone but could control the speed of the sledge and minimise the wear and tear on the dogs and the rate at which resources were used. Skis provided an effective way for men to travel in conjunction with sledges rather than pulling, sitting on, or trudging beside them (Nansen 1890: 73). This system went beyond the artefacts to the individual practices, such as how to stow equipment on the sledge. It represented the optimum combination of resources and procedures that would provide the most effective and efficient sledging journey.

Experimentation is a key element of the innovative model. It is not that experiments do not arise naturally as the result of operations in all sledging journeys, but it is the explicit preparation for experimentation that focuses on the importance of the tacit knowledge. It begins with the formation of *a priori* hypotheses of what might happen given certain conditions in a specific environment with an appreciation of independent and dependent variables that might affect sledging. Past knowledge is continually tested through practice, falsifying what does not work and sustaining what does. The environment is assumed to be in constant flux, and success requires understanding the nature of such changes and adapting to them.

Tacit knowledge and the preparation for sledging

Tacit knowledge was handled differently by Scott and Drygalski and Bruce. Scott's environment was shaped by naval practices, while for Drygalski and Bruce it was shaped by the scientific method. Differences also came from personal experiences with sledging. Scott had none. Drygalski and Bruce had substantial sledging experiences.

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

Drygalski had undertaken a Greenland expedition in 1891–93, and Bruce had participated in the Jackson-Harmsworth Expedition of 1894–97. These were instrumental in their attitudes toward tacit knowledge and the manner in which it was assessed, gathered, and applied.

Scott and the industrial organisation

The *Discovery* Expedition was a classic naval operation complicated in great part by the clash of interests among sponsoring groups (Markham 1986). Scott faced the enormous task of building an organisation capable of carrying out the expedition with little time and experience. He began in July 1900 and realised after his visit to Drygalski in December that 'All of the arrangements which were being so busily pushed forward in Germany were practically at a standstill in England; many of them in fact, had not yet been considered' (Scott 1905: I, 33). Naval procedures were in force. A number of officers had been selected early in the process but did not join the expedition until later, and as a result did not have the opportunity to develop their knowledge of important matters (Scott 1905: I, 37). Scott was commander, although he had not been able to make certain key decisions. What differences there might have been if he had had more discretion and a longer planning period are difficult to assess. Given his naval background, the differences would probably have been minor. Scott was prepared for naval exploration but not necessarily an integrated expedition.

Scott had the overwhelming challenge of bringing together all of the equipment, supplies, and men as well as developing both the explicit and tacit knowledge for the expedition. As a naval officer, his immediate efforts were to bring him up-to-date with navigational matters. These became the focal point of his search for knowledge, at the cost of not devoting the same efforts in understanding sledging. Scott's need to develop a familiarity with the previous sledging practices was hampered by the lack of polar experience (Markham 1901: 335–346). He faced the daunting tasks of identifying what knowledge he needed and how to collect it. Writing after early sledging journeys, Scott noted: "It is strange to look back on these first essays at sledging, and see how totally hampered we were by the want of experience" (1905: I, 226).

Late in 1900, Scott at the insistence of Sir Clements Markham went to see Nansen in Oslo and Drygalski in Berlin to learn about sledges and sledging. Markham recognised the need to catch up because 'our dockyards had also lost the tradition of clothing, sledge equipment, and sledges, which had been brought to perfection as supplied to the Franklin search expeditions' (Markham 1921: 450). Scott wrote: 'Since 1853 whatever improvement has been made in sledging methodology has been developed abroad, and it is abroad therefore that the modern traveller must look for all that is latest and best in this respect' (Scott 1905: I, 409). Yet he had difficulties in carrying this through. In 1900, Scott made notes of the 'many interesting scraps of conversation with Nansen' regarding provisions but little about the integrated approach that Nansen was urging him to adopt (Scott 1900). Nansen, according to Scott, provided instructions about a number of things, including the use of dogs, the design of sledges, dog harnesses, and the number and types of sledges to take.

Scott engaged in 'learning by reading' when in April 1902 he wrote, 'I find time to read up Arctic literature, of which, I am woefully ignorant; most unfortunately, our library is deficient in this respect, as owing to the hurry of our departure many important books were omitted' (Scott 1905: I, 306). As did many others, he relied extensively on codified knowledge as seen by the extensive collection of books on *Discovery*. The library catalogue contains what was thought to be important knowledge, including the narratives and research reports of several polar expeditions (Anon 1901: 32–34). Nevertheless it had limits, prompting one scholar to note that 'Whoever selected the Polar Library for the *Discovery* was determined that members of the expedition should not greatly counteract their inexperience by reading. Scott regretted the deficiency of their shelves in the works of the only two polar travellers, Nansen and [Robert] Peary, who had anything to teach; *The First Crossing of Greenland* being the only book of either of these explorers that they possessed' (Hayes 1928: 151). Missing was Nansen's *Farthest north*, with its complete description of sledges, dogs, and skis. Only by chance had Edward Wilson taken notes on some parts of this work, primarily sledge foods. 'It is inconceivable that (Sir Clements) Markham an admirer of Nansen, had not suggested the book to William Shackleton (not a relative of Ernest Shackleton) when he had called for advice, and yet somehow the book had not been obtained' (Yelverton 2002: 159). Roland Huntford suggested that Scott was not engaged in learning about sledging in spite of his post-expedition writings (1997: 140). David Yelverton, on the other hand, indicated that he focused on individual elements such as clothing and dogs but not the large picture (2001: 36). Both are probably correct. Whatever the reasons, Scott did not appear to appreciate the central role of sledging in exploration and the need to gain as much experience as possible in preparations for the expedition. What resulted was a great amount of 'on the job learning,' which can also be dangerous and wasteful of resources.

Scott recognised the importance of sledging and actively sought advice, although he did not seem to get beyond McClintock. Nansen urged Scott to meet with the sledge builders to learn more about them, but when it came time to place the orders he let Nansen take responsibility. Scott wrote of the visit 'much as I should have liked to linger longer and increase my knowledge in this province, I was forced to curtail my visit to the shortest possible time' (Scott 1905: I, 411). This is a statement that is somewhat unsettling in terms of what he might have learned from Nansen. Based on what Scott seemingly did not ask, it is reasonable to suggest that he either did not understand the importance of tacit knowledge or was

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

not able to ask pertinent questions. Nansen urged Scott to meet with the Duke of the Abruzzi who was in Norway and who had recently returned from two years in the Arctic. The Duke had his sledges and dogs intact, and could have provided important knowledge about their use as well as let Scott experiment with them. He also had experience with the German silver runners advocated by Nansen. Although Scott met the Duke and discussed the silver runners, which Scott apparently used with some regret, it is not clear what else Scott learned about sledging (Scott 1905: II, 411). It is not known whether Scott took the opportunity to review the Duke's draft manuscript on his book, especially the extensive discussion of sledging (Abruzzi 1903).

On the same trip Scott met with Drygalski in Berlin, but he once again did not seem to learn much about his sledging experiences in Greenland (Drygalski: 1897). Scott recorded little from the visit and it appears little was learned. Although Scott saw that he needed to convert Arctic experience to the Antarctic, he did not become fully engaged in that process. He relied on tradition but did not go beyond it. For example, his experiments with dogs were 'better than expected but served to strengthen the fine old British tradition which Sir Clements Markham set such store by, that the best polar draught animals are the human members of the expedition' (Mill 1905: 72).

Whatever can be said about Scott's difficulties with tacit knowledge does not take away from what he learned about sledging from the *Discovery* expedition. His sledging narrative is one of the most comprehensive in all polar literature. Chapters 10 and 11 offer detailed descriptions of sledges, sledge practices, sledge equipment, and insights including those with dogs (Scott 1905: I). There is irony in Scott's views on explicit and tacit knowledge. On the one hand, 'The popular accounts of former expeditions were not written with a view to supply the minute detail that was required, and no memory could be expected to retain these details after the lapse of such a time: the art was lost' (Scott 1905: I, 410). And on the other, the critical reference point is the British Arctic heritage and not the advances in exploration since the last expedition. He wrote, 'It may be fairly claimed that polar sledging is an English production; it is the direct outcome of that feverish energy in exploration which has distinguished our race for so many centuries and has led them to the performance of such glorious pioneer work within the Arctic Circle' (Scott 1905: I, 403). Contrast this to Markham's mandate for going to visit Nansen!

Scott collaborated with others to acquire sledging knowledge. A key choice was Albert Armitage (Walton 1985). Armitage was familiar with Nansen sledges from his experiences with the Jackson-Harmsworth Expedition (Jackson 1898: 115). He took responsibility for the *Discovery* sledges and consulted with Nansen much as Scott. 'In regards to the sledge equipment, I should like, in the first place, to accept my great indebtedness to both Dr Nansen and Mr Crichton-Somerville for the aid that they gave me in selecting the sledges and furs' (Armitage 1905: 304). He applied several lessons from the Arctic, including ordering dogs from a single supplier so as to minimise differences among breeds. He wrote that 'I realized the primary importance of an efficient sledging outfit, and I strove to glean from every source such information as should serve to see us properly provided in this respect' (Scott 1905: I, 410). Although Armitage wrote extensively about sledges, it is difficult to determine how much he understood about Nansen's system, because he always returned to the sledge.

> Perhaps the most important part of the sledge-traveller's outfit is the sledge itself. Our sledges had been made in Christiania to compromise all those modifications and improvements which had been suggested by the experience of Nansen, and on the whole it is doubtful if we could have provided ourselves with sledges more suitable to our various purposes. The main differences between these sledges and those used by other explorers were a decrease in breadth and an increase in runner surface. (Armitage 1905: 421–422)

It is not clear whether he fully appreciated Nansen's system beyond the sledges themselves.

Scott depended on others including Dr Reginald Koettlitz who had also participated in the Jackson-Harmsworth Expedition and Dr Edward Wilson. These were important choices but what knowledge they contributed is not clear. Regardless of these efforts, Scott always seems at some distance from sledging. He indicates surprise about significant matters that should have concerned him. 'Yesterday, I was pleasantly astonished to find that Wilson had some notes on Nansen's "Farthest North," giving extracts of his sledges, weights, &c., and these may be of great use in calculating our own weights' (Scott 1905: I, 306). Surprise betrays the preparations that should have gone into the plan.

It was not that Scott was adverse to new ideas; it was that he was unable to place them within the context of process. He took skis but they were introduced *de nova* and separate from sledging. Very few of the crew had any experience with skis and while he understood that they had a role in sledge journeys, at the beginning they were used for entertainment (Scott 1905: I, 125). Louis Bernacchi, a scientist on *Discovery*, described their experience as one 'with constant collisions and falls' (2001: 31–32). It is not that the English did not recognise the importance of skis; rather that little effort was given to build on past knowledge. In the Antarctic in 1898 Bernacchi 'tried running with the Norwegian *ski*, those long snow-shoes used so successfully on Arctic expeditions' (Bernacchi 1901: 81). Learning to ski prior to departure would have been appropriate.

In the end Scott's actions were defined by the Royal Navy. He should not be blamed 'as if it were a personal failing, for following his upbringing' (Stroud 1986: 1653). What he was never able to do was to bring the appropriate knowledge into play. He relied on naval experience from where it had left off in the Arctic. The British were novices

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

in the Antarctic, when they could have been experts by combining past efforts with new methods, and as a result they kept on 'repeating the fundamental legacy of McClintock – man haul sledging' (Hays 1928: 163). In spite of the fact that the *Discovery* Expedition was the best equipped that the British had ever sent south, there was a 'conspicuous lack of knowledge and understanding about polar matters' (Smith 2000: 40).

Drygalski

The German South Polar Expedition was greatly influenced by Drygalski, who like Scott had to navigate through political machinations, but who unlike Scott had the advantage of being involved early in the planning stages (Drygalski 1900). He attacked the planning from a scientific perspective. Bruce described him as 'a scientist, and one, who, from practical experiences, has an intimate knowledge of the work he has to undertake' (Bruce 1901: 461). Nansen wrote he 'has planned and equipped his expedition with the scientific thoroughness peculiar to the German nation' (Nansen 1901: 313). Drygalski applied Nansen's method, starting with the design of *Gauss*, and carried it throughout his organisation and ultimately into his sledging. His staff was brought into the planning early and were given the responsibility of using their initiative (Drygalski 1989: 11). They had approximately 18 months for preparation, some of which was used to study previous expeditions. The organisation was characterised by independence, which ensured depth of knowledge for each member, and interdependence, which ensured the sharing of knowledge among all members. 'A great deal of thought and consideration went into this therefore, but in the end the expedition recruited members conceived and refined their tasks entirely in their own terms, while remaining conscious of the overall coherence of the whole project' (Drygalski 1989: 17). Their scientific backgrounds reinforced their awareness of capturing and using knowledge.

Drygalski wrote of his plan as a shell, the interior of which was a knowledge problem that could only be solved by bringing together the correct combination of individuals. These were to shape the expedition and not be shaped by its plan. 'The guiding principle for the expedition as a whole was the same as for each one of us taking part: that of freedom – freedom to make decisions on the spot, within the overall scheme' (Drygalski 1989: 33). It dominated the expedition's operations (Lüdecke 2001). With regard to sledging, Drygalski transferred tacit knowledge from his Greenland expedition to the Antarctic. 'I can only suggest that they too [critics] should take a tour by sledge in the Antarctic, and hope that they will come through the winter storms as safely as we did, luckily without anyone losing his life' (Drygalski 1989: 188–189).

Drygalski used Nansen sledges with dog teams and found the sledges were not up to his expectations. The German silver runners did not work out to his satisfaction and the sledges were not as successful on the rough ice surfaces as they had hoped. The light weight of the Nansen sledge had come at the cost of strength. Drygalski noted actions taken to remedy problems. They 'removed the German silver strips on the runners, which had broken on the journey out, replaced them with a, new trim from tin cans' (Drygalski 1989: 239). He converted tacit knowledge to explicit and provided recommendations to subsequent explorers regarding sledge matters, especially the design and composition of runners. Further, he offered important insights about applying the scientific method in operations. In the broadest context, he wrote 'Data obtained on journeys by sledges or in boats remains largely random, dependent on the moment, and may well be quite different at other times or at the same time in other years' (Drygalski 1989: 204). Throughout Drygalski illustrated the interconnections among factors, starting with the need for a clear understanding of past evidence, the integration of personal experiences, the independence and interdependence of expedition members, and continual experimentation.

Bruce

Bruce's Scottish National Antarctic Expedition represents the penultimate example of the innovative model. His efforts resulted in one of the most successful scientific Antarctic expeditions although not always acknowledged as such (Aldridge 1999: 64). Given his background and preparation, nothing but success should have been expected. He was totally 'prepared for the work of a polar scientist and explorer' and only 'a limited number of men had experience of both the far north and far south' (Speak 1992b: 285). Bruce's holistic perspective began in Edinburgh with Patrick Geddes, a biologist turned city planner, who 'was an energetic and charismatic figure who advocated a holistic approach to learning' (Swinney 2002: 288). Although he had not planned to become a polar explorer, he took to it easily. He participated in at least 10 expeditions. In retrospect, his early experiences almost seemed planned to support an eventual Antarctic expedition, with his participation at the Ben Nevis Observatory, which served as an opportunity to get training and experience in techniques that might prove useful in participating in expeditions (Swinney, in press). He participated as naturalist on the Jackson-Harmsworth Expedition, where he experienced dogs and sledges and made the acquaintance of D.W. Wilton, who was later to accompany him on *Scotia* (Pitman 1982: 12; Bruce 1902: 542).

Bruce wrote Sir Clements Markham in response to the announcement regarding the formulation of a British Antarctic expedition. In the letter he described who he was and what he would bring to the proposed expedition. 'For the past seven years I have been training myself with a view of making myself more efficient for Polar Service. I have spent one summer in the Antarctic Regions, three summers and one winter in the Arctic Regions, and more than a year on the summit of Ben Nevis in charge of the Observatory. I am a "ski" runner & have taken part in

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

sledging operations' (Bruce 1899). Given the politics of the British expedition as well as Bruce's limited standing in the exploration community, he organised a Scottish expedition. His initial plans were made known in 1900 when he discussed its scientific mission as well as the means by which scientific discovery would be carried out (Bruce 1900). His basic premise was that if scientific work were to be successful 'Modern polar exploration must be conducted in this manner' (Bruce 1911a: 239). As with Drygalski, he saw the benefits of small but highly integrated group to conduct research on the continent, including the briefest though pertinent discussion of how the landing party would operate. 'In the spring sledge journeys with dogs will be undertaken for topographical and other purposes. I have seen fast land floe-ice in the Antarctic that could be travelled over with dogs, sledges, and ski' (Bruce 1901: 461–467).

Bruce's planning was based on experience and continual experimentation. He also relied on the experiences of others. He had respect for the *Belgica* expedition, both for its scientific contributions and for the improvement of expedition equipment. 'Every successful expedition, and even unsuccessful expeditions in less degree and different manner, is of immense value for the planning equipment and work of a subsequent expedition' (Bruce n.d.a.: 13). Bruce spent a great deal of time and effort in learning how his equipment worked. He left little to chance and made sea trips with *Scotia*. 'The first trip was partly an experimental one to find out how our apparatus and provision scales worked' (Brown and others 1906: 138). Peter Speak, Bruce's biographer, concluded: 'The very considerable success of the operation owed much to the careful planning and experimentation' (Speak 1992a: 138). His understanding of the role of tacit knowledge was great and he enshrined it in his expedition. His own words best describe this: 'The members of the Expedition must be so prepared that they can distinguish the important from the unimportant and the necessary from the merely desirable' (Bruce 1901: 465). As did Drygalski, he brought his staff early in the development process in order 'to stimulate interest, by having a personal share in the responsibility of equipping the expedition, I selected several of my staff a considerable time before the expedition started' (Bruce n.d.b.: 6).

Summary and conclusions

The analysis of the preparation for sledging establishes the important differences between organisational characteristics and the ways in which tacit knowledge is viewed and managed. Scott operated within the naval culture and hence greatly relied upon the Arctic experiences. Although he recognised the importance of advances in sledging developed by others, it was difficult for him to move beyond the familiar environment. The naval culture was powerful in defining how things were to be done, which was based on a long tradition of sledging; and at the end of the day it was generally impervious to change. The formal structure had been well honed for carrying out a certain type of exploration, one that had singularity of purpose and dramatic resources to back up the plans. Naval expeditions did open up the Arctic, but recent research documents that they were not as effective in terms of reaching their goals as private expeditions and at the same time they suffered more tragedy (Karpoff 2001).

Would Scott have been more successful it he had been a scientist like Bruce or Drygalski? The answer is not an unconditional yes. Even if he were like them, it is difficult to believe that he would have been able to change naval culture dramatically. Its was simply too strong; the management hierarchy would have had to bend if not give away to a very different system. Even if Bruce had been on the expedition, it is doubtful that he would have been able to affect operations. While his own work would have been carried out in the scientific manner, he would have had difficulty in rolling back naval traditions. It was not that Scott was unaware of the role of the new knowledge; he was unable to collect and apply it. It is more than fair to suggest that his difficulties with tacit knowledge carried over to his later expedition on *Terra Nova*.

Bruce and Drygalski developed their expeditions around the principles of tacit knowledge, but that was to be expected. Their success in no small part was due to their ability to control the environment surrounding the development and operations of their expeditions. They were able to carry out their tasks without the encumbrance of a complex organisation; generally each part of their expedition was under their control rather than committees. While they were not free agents, they simply had more freedom to create their expeditions. Would they have been able to repeat their success? Drygalski never had the opportunity for another Antarctic expedition. Bruce planned an expedition to cross the Antarctic; however, it never came to pass (Bruce 1911a: 352–357). Because his plans were never fully developed, it is difficult to know if they would have been as successful as the SNAE (Bruce 1911b). What can be said is that he would have more actively engaged in the application of tacit knowledge.

There is no reason to expect that only scientists can manage tacit knowledge. Amundsen was not a scientist, but rather someone who saw value in personal experiences, and he applied the Nansen system with great success (Amundsen 1913: chapter 13). What well may be the case is the predisposition of the explorer toward tacit knowledge rather than a one-to-one correlation to science and the environmental conditions that support its capture and use. What we have at hand are individual traits, much like leadership, that are difficult to codify, define, and measure.

Implications

These findings suggest that expedition leaders must have a central position in the development of knowledge for key processes, although it is not realistic to expect that

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

they must be fully capable of undertaking all expedition processes. They must be conversant with the key processes and those that should arise from direct experiences or the experiences of others. Critically important are the need for substantial planning and experimentation with key processes, and the ability to experiment and capture additional tacit knowledge. Success in the management of tacit knowledge demands a clear understanding of the processes. Experimentation is a key factor in determining what works and what does not work. Tacit knowledge generated from experimentation must be quickly captured, communicated, and transformed into explicit knowledge if it is to have value. What constrains the understanding of the process is the organisation's culture and structure. The less open an organisation is to change, in the sense of having to confront and implement new knowledge, and the greater the hierarchy of the organisation, the greater the chance that tacit knowledge will be given minimum importance or even none at all.

Acknowledgements

I am indebted to the anonymous reviewers for their comments. I want to thank the following for their encouragement and assistance: Philip N. Cronenwett, Sarah I. Hartwell, Robert Headland, Jenny Mai Handford, Cornelia Lüdecke, John Reid, Shirley Sawtell, Peter Speak, Geoffery N. Swinney, and William Mills. Support was provided by the John L. Beckley Endowment, School of Business Administration, University of Vermont.

References

Abruzzi, Duke of the (Luigi Amedo di Savoia). 1903. *On the 'Polar Star' in the Arctic sea*. 2 vols. London: Hutchinson & Co.

Aldridge, D. 1999. *The rescue of Captain Scott*. East Linton: Tuckwell Press.

Amundsen, R. 1913. *The South Pole, an account of the Norwegian Antarctic expedition in the Fram 1910–1912.* London: John Murray.

Amundsen, R. 1927. *My life as an explorer*. London: William Heinemann.

Anon. 1901. *Catalogue of the books of the 'Discovery' 1901* London: Murray.

Armitage, A.B. 1905. *Two years in the Antarctic: being the narrative of the British National Antarctic Expedition*. London: Edward Arnold.

Astral, A. 1896. Arctic expeditions from the earliest times. In: Waldman, W.C. *Fridtjof Nansen 1861–1893.* London: Longmans, Green, and Co: 224–262.

Bain, J.A. 1897. *Life and adventures of Nansen, the great Arctic explorer*. London: Walter Scott Publishing Co.

Baumard, P. 1999. *Tacit knowledge in organisations*. London: Sage.

Bernacchi, L. 1901. *To the south polar regions*. London: Hurst and Blackett.

Bernacchi, L. 2001. *Saga of the 'Discovery.'* Royston: Rooster Books.

Brown, R.N., R.C. Mossman, and J.H.H. Pirie. 1906. *The voyage of the 'Scotia': being the record of a voyage of exploration in the Antarctic seas*. London: William Blackwood and Sons.

Bruce, W.S. 1899. Letter to Clements Markham, 16 April 1899. Cambridge: Scott Polar Research Institute MS 441/7/2.

Bruce, W.S. 1900. The proposed Scottish National Antarctic Expedition. *Scottish Geographical Magazine* 16 (7): 352–357.

Bruce, W.S. 1901. The German South Polar Expedition. *Scottish Geographical Magazine* 17 (9): 461–467.

Bruce, W.S. 1902. Scottish National Antarctic Expedition. *Scottish Geographical Magazine* 18 (10): 536–543.

Bruce, W.S. 1911a. *Polar exploration*. London: Williams & Nargate.

Bruce, W.S. 1911b. The new Scottish national expedition. *Scottish Geographical Magazine* 36 (4): 192–195.

Bruce, W.S. n.d.a. *Fragments of a manuscript on preparation for an expedition*. Edinburgh: University of Edinburgh Library, Special Collections box 1651 92/9.

Bruce, W.S. n.d.b. [possibly 1916]. *Fragments of a manuscript on Antarctica*. Edinburgh: University of Edinburgh Library, Special Collections 77/3.

Cameron, I. 1980. *To the farthest ends of the Earth; the history of the Royal Geographical Society*. London: MacDonald and Jane's.

Choo, C.W. 1998. *The knowing organisation: how organisations use information to construct meaning, create knowledge and make decisions*. New York: Oxford University Press.

Collins, H.M. 1985. *Changing order: replication and induction in scientific practice*. London: Sage Publications.

Conway, W.M. 1897. *The first crossing of Spitzbergen*. London: J.M. Dent & Co.

Cyriax, R.J. 1963. Arctic sledge travelling by officers of the Royal Navy, 1819–1849. *The Mariner's Mirror* 49 (2): 127–142.

Davenport, T.H., and P. Klahr. 1998. Managing customer support knowledge. *California Management Review* 40 (3): 195–208.

Davis. L.E., R. Gallman, and T.D. Hutchins. 1989. Productivity in American whaling: the New Bedford fleet in the nineteenth century. In: Galenson, D.W. (editor). *Markets in history: economic studies of the past*. Cambridge: Cambridge University Press: 97–143.

Driver, F. 2001. *Geography militant*. Oxford: Blackwell Publishers.

Drygalski, E. 1897. *Grönland-Expedition der Gesellshaft für Erdkunde zu Berlin 1891–1893.* Berlin: W. Kuhl.

Drygalski, E. 1900. *Plan und Aufgaben der Deutshen Südpolar-Expedition*. Leipzig: Verlag von S. Hirzel.

Drygalski, E. 1989. *The southern ice continent, the German South Polar Expedition aboard the Gauss 1901–1903.* Bluntisham: Bluntisham Books.

Ellis, R.D. 1986. *An evaluation of the British Royal Navy Arctic exploration techniques 1812–1876.* Unpublished MPhil thesis. Cambridge: Scott Polar Research Institute, University of Cambridge.

Ferber, R. 1949. *Statistical techniques in market research*. New York: McGraw-Hill.

Gurney, A. 1997. *Below the convergence, voyages toward Antarctica 1699–1839.* London: Penguin Books.

Haig, B.D. 1995. Grounded theory as scientific method. *Philosophy of education, 1995 Yearbook*. 1–9.

Hayes, J.G. 1928. *Antarctica: a treatise on the southern continent*. London: Richards Press.

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

Headland, R.K. In press. Unpublished revision of *Chronological list of Antarctic expeditions and related historical events*.

Huntford, R. 1997. *Nansen: the explorer as hero*. New York: Barnes and Noble.

Jackson, F.G. 1898. Three years' exploration in Franz Josef Land. *Geographical Journal* 11 (2): 113–130.

Karpoff, J.M. 2001. Public versus private initiatives in the Arctic exploration. *Journal of Political Economy* 109 (1): 38–79.

Kirwin, L.P. 1959. *The white road.* London: Hollis and Carter.

Liebowitz, J., and T. Beckman. 1998. *Knowledge organisations: what every manager should know.* Boca Raton, FL: St Lucia Press.

Lüdecke, C. 1995. Die deutsche Polarforschung seit der Jahrhundertwende und der Einfluss Erich von Drygalskis. *Berichte zur Polarforschung* 158.

Lüdecke, C. 2001. Das Prinzip der Freiheit: Erich von Drygalski leitet die erste deutsche Antarktisexpedition. *Naturwissenschaftliche Rundschau*. 54 (12): 643–648.

Mackinnon, C.S. 1985. The British man-hauled sledge tradition. In: Sutherland, P.D. (editor). *The Franklin era in Canadian Arctic history, 1845–1859.* Ottawa: National Museum of Man (Mercury Series, Anthropological Survey of Canada Paper 131): 129–140.

Markham, A. 1878. *The great frozen sea: a personal narrative of the voyage of the Alert during the Arctic expedition of 1875–6*. London: Daldy, Isbister & Co.

Markham, C.R. 1901. Address to the Royal Geographical Society. *Scottish Geographical Magazine* 17 (7): 335–347.

Markham, C.R. 1903. Arctic sledge travelling. *Geographical Journal* 22 (3): 299–305.

Markham, C.R. 1921. *The lands of silence: a history of Arctic and Antarctic exploration*. Cambridge: Cambridge University Press.

Markham, C.R. 1986. *Antarctic obsession: a personal narrative of the origins of the British National Antarctic Expedition 1902–1904.* Edited by C. Holland. Bluntisham: Bluntisham Books and Erskine Press.

McClintock, F.L. 1876. On Arctic-sledge travelling. *Proceedings of the Royal Geographical Society* 242–279.

McClintock, F.L. 1901. On Arctic sledge travelling. In: Murray, G. (editor). *The Antarctic manual*. London: Royal Geographical Society: 293–304.

McClintock, F.L., and G.F. Mecham. 1852–54. Journals of sledge and cart journeys made during the British (Franklin search) expedition. Cambridge: Scott Polar Research Institute MS 216/1 [original document in Public Record Office, Adm 7/189].

Mill, H.R. 1905. *The siege of the South Pole*. New York: Frederick A. Stokes Company.

Mintzberg, H., J. Lampel, J. B. Quinn, and S. Ghoshal. 2002. *The strategy process: concepts, contexts, cases*. Fourth edition. Upper Saddle, NJ: Prentice Hall.

Mirsky, J. 1970. *To the Arctic! The story of northern exploration from earliest times to the present*. 3rd edition. Chicago: University of Chicago Press.

Morrell, M., and S. Capparell. 2001. *Shackleton's way; leadership lessons from the great Antarctic explorer*. New York: Viking.

Murray, G. (editor). 1901. *The Antarctic manual*. London: Royal Geographical Society.

Nansen, F. 1890. *The first crossing of Greenland.* 2 vols. London: Longmans, Green, and Co.

Nansen, F. 1897. *Farthest north*. 2 vols. Westminster: Archibald Constable and Company.

Nansen, F. 1901. The present condition and problems of polar exploration. *The Pall Mall Magazine* 25 (September to December): 297–314.

Nelson, R.R., and S.G. Winter. 1982. *An evolutionary theory of economic change*. Cambridge, MA: Belknap Press of Harvard University Press.

Nonaka, I., and H. Takeuchi. 1995. *The knowledge-creating company, how Japanese companies create the dynamics of innovation*. New York: Oxford University Press.

Nordenskjöld, O. 1920. *Wissenshaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901–1903. Band I Geographie, Hygiene und Erdmagnetismus*. Stockholm: Lithographishes Institut des Generalstabs.

Nordenskjöld, O., and G. Anderson. 1905. *Antarctica or two years amongst the ice of the South Pole*. London: Hurst & Blackett.

Payer, J. 1876. *New lands within the Arctic circle*. 2 vols. London: Macmillan and Co.

Pearson, P. 1995. Sledges and sledging in polar regions. *Polar Record* 31 (176): 3–24.

Peary, R.E. 1898. *Northward over the great ice*. London: Methuen.

Penrose, E. 1980. *The theory of the growth of the firm*. Oxford: Basil Blackwell.

Perkins, D., M.P. Holtman, P.R. Kessler, and C. McCarthy 2000. *Leading at the edge: leadership lessons from the extraordinary saga of Shackleton's Antarctic expedition*. New York: AMACOM.

Pitman, J. 1982. *Manuscripts in the Royal Scottish Museum Edinburgh Part 2: William Bruce papers and diary of A. Forbes Mackay*. Edinburgh: National Scottish Museum (Natural History 8).

Polanyi, M. 1966. *The tacit dimension*. New York: Doubleday & Company.

Rodgers, N.A.M. 1988. *The wooden ship: an anatomy of the Georgian navy*. London: Fontana Press.

Samson, K.J. 1990. *Scientists as entrepreneurs: organisational performance in scientist-started new ventures*. Norwell: Kluwer Academic Publishers.

Savitt, R. 1980. Historical research in marketing. *Journal of Marketing* 44 (Fall): 52–58.

Savours, A. 1999. *The search for the North West Passage*. New York: St Martin's Press.

Scott, R.F. 1900. Journal of a visit to Norway and Berlin in preparation for the British national expedition, 1901–1904. Cambridge: Scott Polar Research Institute MS 352/2.

Scott, R.F. 1905. *The voyage of the 'Discovery'*. 2 vols. London: John Murray.

Shackleton, E. 1909. *The heart of the Antarctic*. 2 vols. London: William Heinemann.

Smith, M. 2000. *Tom Crean*. Seattle: The Mountaineers Books.

Speak, P. 1992a. William Speirs Bruce and the Scottish National Antarctic Expedition. *Scottish Geographical Magazine* 108 (3): 138–148.

Speak, P. 1992b. William Speirs Bruce: Scottish nationalist and polar explorer. *Polar Record* 28 (167): 285–292.

Stroud, M. 1986. Scott – 75 years on. *British Medical Journal* 293: 1652–1653.

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press

Suster, J. 1996. *Bold endeavours lessons from polar and space exploration*. Annapolis: Naval Institute Press.

Swinney, G.N. 2002. Some new perspectives on the life of William Speirs Bruce (1867–1921). *Archives of Natural History* 28 (2): 285–311.

Swinney, G.N. In press. William Speirs Bruce, the Ben Nevis Observatory and Antarctic meteorology. *Scottish Geographical Journal* 118 (4).

Vaughan, R. 1999. *The Arctic: a history*. Stroud, Gloucestershire: Sutton Publishing.

Von Krogh, G., K. Ichijo, and I. Nonaka. 2000. *Enabling knowledge creation: how to unlock the mystery of tacit knowledge and release innovation*. Oxford: Oxford University Press.

Wallace, H.N. 1980. *The navy, the company and Richard King*. Montreal: McGill-Queen's University Press.

Walton, D.W.H. 1985. Profile: Albert Borlase Armitage. *Polar Record* 22 (140): 511–518.

Yelverton, D.E. 2000. *Antarctica unveiled: Scott's first expedition and the quest for the unknown continent*. Boulder: University Press of Colorado.

https://doi.org/10.1017/S0032247403003346 Published online by Cambridge University Press