

tightlipped. In one page, Bessels recounts the rapid deterioration of Hall's health and his death following his return from the sledge journey, ultimately concluding that the unfortunate Hall had suffered a stroke. Bessels' narrative sheds no additional light on the mysterious circumstances of Hall's death or who may have been implicated in that death if it was murder. As for his personal feelings toward Hall, Bessels' narrative only infrequently questions Hall's skills as leader, and he is guarded in his comments, making only isolated criticisms. Bessels found Hall "weak" in simply accepting Budington's opinion that farther northward progress in *Polaris* was not possible (p. 143). When Hall concluded that *Polaris* should abandon the push to the north, Bessels confided that "the success of the expedition [was] sacrificed to the whim of an individual" (p. 149). Although these unflattering comments about his commander reflect Bessels' disappointment, nothing would suggest that murder was contemplated. Similarly, Bessels makes no mention of any verbal disagreements he had with Hall.

In contrast to his restrained opinions in regard to his fellow participants, Bessels' descriptions of the natural world around him were far more unreserved and revealing. He was an astute observer, and his narrative reflects his inquisitive nature and the breadth of his scientific knowledge. Within each chapter, his narrative interweaves scientific details and descriptions of everything from birds, mammals, flora, and peoples, to extensive commentary even on geology and glaciology. Bessels also supplied a 115-page appendix to the narrative of physical observations (which constituted an extract from the longer, separate volume of physical observations published in English in 1874). Bessels intended to publish his natural history and ethnographic observations in a second volume of scientific observations, but the U.S. Government never provided the funding, so this narrative serves as the only record of those observations. Interestingly, notwithstanding the enmity between Bessels and Hall, the death of Hall and the disaster that struck *Polaris*, the narrative reflects Bessels' faithful continuation of his scientific responsibilities with a 19th century wit and humor that runs through the narrative.

Bessels also provides additional details about the wintering at Port Foulke, to which Tyson was not a witness. Importantly, this aspect of the narrative demonstrates that Bessels was obsessed with making a name for himself in geographical discovery, and it contradicts the notion that Bessels simply wished to return home after Hall's death. Following the separation of the *Polaris* crew and the ship's wintering at Port Foulke, Bessels attempted to organize another attempt by sledge, with several Inuit to assist, to achieve a farthest north and perhaps even best the highest latitude achieved by the British Arctic Expedition of 1875–76. The trip ended in bitter disappointment, as the sledge party failed to reach as far north as *Polaris* Bay, the seat of their previous winter quarters; however, the attempt speaks to Bessels' single-minded determination for geographical achievement.

William Barr's informative introduction provides the background to the *Polaris* expedition, its principal actors, and, just as importantly, the broader historical context within which the *Polaris* expedition was set. At that time, the pursuit of science and a spirit of nationalism motivated European and American nations to actively enter the polar arena, hoping to make new scientific discoveries and leave their own geographic mark in the far North. The extensive notes for each chapter also serve to provide background to Bessels' comments and references and place them in their proper 19th century context.

Perhaps the most intriguing aspect of William Barr's translation is the epilogue, which includes the publication of tantalizingly new information regarding a possible motive for Hall's murder by Bessels. Correspondence recently identified by Arctic historian Russell Potter suggests that immediately before the departure of *Polaris* from New York, Hall and Bessels were both vying for the affection of Miss Vinnie Ream, an attractive young singer. Hall, in the company of Bessels, visited Miss Ream on several occasions while in New York, and both appear to have been captivated by her. The infatuated Bessels sent an affectionate letter to her at the time of departure, while at the same time, Miss Ream was sending friendly letters, gifts, and a flag to Hall. Could a love interest have been the motive for Bessels to murder Hall? Perhaps more facts will be uncovered to answer that question.

In summary, William Barr's translation should appeal to those with more than a passing interest in Arctic history and to those seeking more details about the *Polaris* expedition and its naturalist and scientist, Emil Bessels.

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**GEOCRYOLOGY: CHARACTERISTICS AND USE OF FROZEN GROUND AND PERMAFROST LANDFORMS.** By STUART A. HARRIS, ANATOLI BROUCHKOV and CHENG GUODONG. Boca Raton, Florida: CRC Press, 2018. ISBN 978-1-138-05416-5. xliii + 765 p., maps, b&w and colour illus., references, subject index. Hardbound. US\$229.95. Also available as an ebook.

With increased development of resources in cold regions of the world, these remote areas that witness recent climate warming receive growing attention by the public and by governments with territories located at high latitudes or at high elevations. Information on their natural environment is much needed in order to address issues associated with life and work in the frigid domain. The book by Harris, Brouchkov, and Cheng provides pertinent information for such needs. Geocryology, which is the main title of the book, is defined as the study of the effects of sub-zero temperatures on the surface layers of the Earth's crust (p. 1). The book is divided into three parts that reflect

its subtitle *Characteristics and Use of Frozen Ground and Permafrost Landforms*: Part I - characteristics of permafrost, Part II – permafrost landforms, and Part III – use of permafrost areas. In addition to permafrost regions, areas with only seasonal frost are also given consideration where appropriate.

Part I begins by introducing a plethora of terms, which are helpfully highlighted in bold italics. Most of these terms are defined in Chapter 1, each given a brief description or a reference to later chapters for explanation or elaboration. Knowledge of cryogenic processes (from dictionary: cryo = freezing; genic = related to production) is fundamental to understanding how landforms develop under intense coldness. Chapter 2 adopts a qualitative approach to explain the temperature and moisture conditions under freeze and thaw and describes the resulting processes of cryosuction, needle ice formation, frost heaving and thaw settlement, ground cracking, upheaving of objects, sorting of earth materials, and weathering, with additional mention of karst and seawater in permafrost areas. Chapter 3 lists regional and local factors that affect the distribution of permafrost, from climatic and locational considerations to terrain and vegetation influences. The distribution of permafrost follows in Chapter 4, which includes a good summary of the techniques used to map permafrost (and several of its related properties, such as ice and carbon contents) and their limitations.

Part II occupies 294 of the 635 pages that constitute the main body of the book. In a number of chapters, one interesting approach is to use temperature to summarize the occurrence of different landforms. Using the freezing index and the thawing index (both in degree-days per year) as the axes, the distribution of a particular geomorphic feature is mapped on the temperature field by locating the positions of its reported sites on the graph. Chapter 5 describes the formation of frost cracks and the development of ice-wedges, together with soil wedges that infill the cracks. Chapter 6 introduces different kinds of massive ground ice, mostly found below ground except icing or aufeis, which is formed above the ground surface. The origin of underground ice is discussed, including the burial of glaciers, the creation of ice through cryosuction, ice injection, and through the growth of ice wedges that may lead to the formation of *yedoma*, a Russian term for ice complex. It is acknowledged (p. 190) that our understanding of the processes involved in the transformation to yedoma remains incomplete. This chapter ends with sections on perennial ice caves and ice blocks found in bedrock. Chapter 7 presents an assemblage of mound features connected with the accumulation of ground ice, though their genesis varies. They include such structures as icing blister, frost mound, *palsa*, *lithalsa*, peat plateau, and *pingo*. The making of these features, as well as several types of hummocks, is discussed.

Proceeding from lowlands to terrain with increased gradients, the next chapter concerns mass wasting or the downslope transfer of sediments and soils (p. 267).

Although gravity is the driving force, freeze-thaw processes facilitate the detachment and downslope movement of materials in cold regions. Chapter 8 describes the processes and features resulting from slow movement or creep and from fast movement or debris flow, slides, and slumps. Also presented is the downslope movement of snow as avalanches and as slush flow. Chapter 9 deals with blocky materials that produce such landforms as block fields, talus slopes, rock glaciers, and block streams. The discourse on rock glaciers is notably thorough. Implicit in these two chapters is the significant role of gravity that is superimposed by cryogenic processes to shape the slopes in permafrost areas. One major geomorphic agent not considered is running water, in its capacity to change slope morphology through erosion and deposition.

Cryogenic patterned ground is frequently encountered in permafrost regions. Chapter 10 describes the forms and possible modes of formation for nets, circles, mudboils, and stripes. Citing a field experiment conducted in a non-permafrost area near St. Andrews in Scotland that produced sorted nets (p. 394–395), the authors convey the message that the occurrence of these micro-features does not necessarily imply the presence of permafrost. The last chapter in Part II (chapter 11) emphasizes the role of heat in causing ice melt, leading to ground subsidence and thermokarst, and to slumping of river banks and retreat of shorelines. Apart from the sections on river ice and sea ice, the mechanical aspect of erosion is underrepresented. It would be an enhancement for this chapter, as well as for the book, to pay more attention to river flow and fluvial activities of erosion, sediment transport, and deposition, all of which play a part in the evolution of the geocryological landscape. Under open water conditions, rivers influence water supply and sewage disposal and affect the stability of structures built on and across permafrost terrain; thus, they have direct relevance to several topics covered in Part III.

Chapter 12, the first chapter in Part III, pertains to the mechanics of frozen soils. It introduces the physical principles requisite for subsequent chapters, and it also complements chapter 2, which describes cryogenic processes. Chapter 13 presents the techniques employed to ensure the stability of buildings in permafrost regions, covering issues that pertain to the types of foundation, the materials used, and the devices to maintain cold ground. Chapter 14 reviews problems imposed by permafrost on roads, railways, and airfields, including their related surfaces and tracks, embankments, bridges, and icing issues. Examples drawn from several countries show that the methods to meet these challenges are evolving quickly, especially from the experience of building railway lines in Siberia and across the Tibetan Plateau. Chapter 15 concerns oil and gas, with additional comments on gas hydrates. The experiences in Alaska and in Siberia illustrate the problems and solutions associated with various phases of operation, from exploration to production and delivery of the products. Chapter 16 surveys different methods of mining in permafrost, including historical notes on how

gold, diamonds, iron, and other base metals are extracted from the ground. The question of waste disposal eludes satisfactory answers, as is demonstrated by the situation with toxic wastes from a gold mine at Yellowknife, Northwest Territories, Canada. The remaining chapters pertain to human settlements and livelihood in permafrost regions. Chapter 17 examines important issues of water supply and the disposal of liquid and solid wastes and gives examples of several types of foundation built on permafrost for electric transmission lines. The final chapter (18) is more concerned with natural vegetation zones than with the agriculture and forestry of its title. The brevity of comments on these economic activities makes the content not entirely compatible with the chapter heading.

This book by Harris, Brouchkov, and Cheng shares the same main title of *Geocryology* with a book written by the late Professor Lincoln Washburn (1979). The present book not only provides an update with almost four decades of new scientific knowledge, but also includes a substantial section on geotechnical engineering in permafrost regions, which greatly enlarges the scope of Washburn's treatise. With three co-authors who come from different countries to share their research experience and expertise, this book makes available geocryological information not published originally in the English language. As expected, the book is well endowed with case studies and illustrative examples taken mostly from northern Canada, Alaska, Siberia, and Tibet in China. These are a major attraction of this publication.

This book is marred by some editorial deficiencies. Although it is not necessary to use the same units of measurement throughout (SI units being the standard for scientific publications nowadays), some of the conversions are wrong (e.g., p. 4 and p. 20, latent heat of fusion is stated as  $640 \text{ g.cal/cm}^3$ , which does not equal the correct value of  $3.347 \times 10^8 \text{ Jm}^{-3}$ ). Note that almost all the units labeled as  $\text{cm}^2/\text{a}^{-1}$ ,  $\text{mm}/\text{a}^{-1}$ , or such like, are erroneous. Furthermore, it is wearisome to look for diagrams incorrectly referred to in the text (e.g., p. 161 and p. 180 refer to Fig. 1.25 as showing yedoma, but this figure on p. 34 is a chart and not a picture). Some diagrams mentioned in the text are missing (e.g., "Fig. 1" that is purported to accompany Eq. 12.10, on p. 449). On the other hand, Equations 3.8 and 3.9 on p. 102

repeat themselves as Equations 3.10 and 3.11 on pages 114 and 115, and editorial oversight results in the repetition of an entire paragraph on p. 181. There are misleading statements (e.g., p. 90 states that "ground heat flux is substantially (usually  $0-7^\circ\text{C}$ ) warmer," but heat flux is not measured as temperature). Student readers should also be aware of oversimplifications. For example, on page 52 we read that "since snow is translucent, melting occurs throughout the snowpack during daylight hours." This may apply to very shallow snowpack, but as radiation extinguishes exponentially in the snow, most of the radiation energy will not penetrate and would not provide the energy for internal melt of the snow cover during daylight hours.

These blemishes need not detract from the usefulness of the book. Overall, it is comprehensive and places geomorphology and geotechnical engineering under a single cover. As cold regions in general, and circumpolar areas in particular, are highly sensitive to changes due to natural and human-related causes, this book offers materials valuable to understanding and confronting present and future environmental changes. Without rendering quantitative treatment on many topics (except Chapter 12 on soil mechanics), the descriptive approach makes the book easily accessible to a general readership, and it will appeal to undergraduate students who are not mathematically inclined. Those who wish to pursue specific topics at greater depth can consult relevant articles listed in the very extensive bibliography, which covers 119 pages.

#### REFERENCE

- Washburn, A.L. 1979. *Geocryology: A survey of periglacial processes and environments*, 2nd ed. London: Edward Arnold. 406 p.

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