Glacier science and environmental change

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This book is a welcome contribution to glacier science because it goes beyond what available textbooks cover. It would be an excellent book to serve as the nucleus of several advanced undergraduate and graduate seminars. Knight states that his purpose is to provide a view of the current understanding of key issues that relate the study of glaciers to the broader field of environmental change. He succeeds by pulling together 92 papers on various aspects of glacier science into a single volume. The range of topics covered and of scientists contributing is impressive, as are the 57 pages of references that will provide a wonderful resource for the student and professional scientist.

The book is divided into five sections, each of which has a keynote paper followed by a series of shorter articles covering themes of major importance, as well as local case studies that document recent research. As of January 2007, more than 450 pages of papers were supplemented by many additional colour photographs and diagrams on the publisher's website (http://www.blackwellpublishing.com/knight/). The papers do not have abstracts, but many are short enough that one is not needed, and most of the long papers cover such a broad range of topics that an abstract would not be very meaningful. Many of the papers provide a glimpse of the research questions that are now being asked, and I was left with a wide variety of ideas for future research.

The first section, 'Glaciers and their coupling with hydraulic and sedimentary processes', which is introduced by Boulton, covers the coupling of glaciers with atmosphere, ocean and lithosphere. Boulton's paper concentrates on processes at the glacier bed, covering small-to-large scale patterns and processes of deposition and erosion. There is a short discussion of tunnel valleys, eskers and subglacial water, and the nature of subglacial groundwater flow is introduced here. It is the theme of five of the shorter papers, including two on the Scandinavian Ice Sheet and three on the Laurentide Ice Sheet. In his introduction, Knight makes the point that he has attempted to bring into focus controversial issues by inviting papers with authors on both sides of various arguments. In this first section of the book, differing views of the importance of the subglacial groundwater system in distributing glacial meltwater, the origin of streamlined forms, hummocky topography and the nature of tunnel channels are all covered. Several papers argue for a megaflood origin of many of these features. Benn & Evans follow these articles with a paper arguing that the importance of megafloods has been greatly overemphasized (although they obviously took place).

Another aspect of glacier-substrate interaction is the chemical changes that take place in water as it moves through the glacial and subglacial system. Four short papers discuss various aspects of this, followed by three papers on glacial landforms. Justice is not given to a landforms approach to understanding the distribution of glacial landforms, but papers in later sections contribute to the topic.

Andrews has written the lead paper for the section entitled 'Glaciers, oceans, atmosphere and climate'. Beginning with Meier's simple picture of glacier response to climate change, Andrews outlines the complexities of this relationship at the historic time scale, the Little Ice Age time scale and that of the last glacial cycle. Clearly there is much to learn about the relationship between glaciers, oceans and atmosphere, and Andrews points out that only relatively incomplete studies of small glacier-atmosphere interactions exist, and that there are none for large ice sheets.

There follow 15 papers of various lengths on topics including modern glacier studies, extent of Arctic sea ice, palaeo-ice streams, the ocean climate record and the effects of glaciers on the continental shelves. Longer papers on modelling the extent and thickness of ice on Iceland during the Last Glacial Maximum, and on modelling ice sheets in general, provide an excellent summary of what can be done with glacier models. The paper by Bond presents relationships between the ocean record and ice sheets from a historical perspective, concluding that in many cases we do not know whether changes in the ocean record were produced by changes in the ice sheets, or if changes in ocean and atmospheric dynamics caused rapid glacier advances and basal meltwater releases from ice sheets.

Sugden takes a historical approach in introducing the section entitled 'Changing glaciers and their role in earth science evolution'. He points out that, after many years of separation between the quantitative glaciological community and the less quantitative glacial geomorphology-sedimentology community, studies of palaeoglaciology are beginning to integrate both approaches. Remote-sensing, real-time monitoring of glaciers, hugely increased computing power, high-resolution ice-core records, an improving ability to date events with various geochemical methods and increased interaction with ocean and atmosphere scientists have all contributed to our understanding of glaciers and landscape. These themes are apparent in the selection of papers that follow. One by Klemm et al. provides a rational explanation of the 'inversion' approach of using landform assemblages to reconstruct past glaciological conditions.

A major change that has taken place in the last two decades, the improved accessibility to high-resolution satellite images and digital elevation models, has, among other things, allowed the recognition of large-scale ice streams in the Pleistocene record. It is predicted by Clark et al. that the availability of high-resolution satellite images will allow completion of geomorphological mapping of Britain and Ireland in a decade. The section also contains a series of short papers on the Little Ice Age and more recent glacier fluctuations around the world. Some localities seem under-represented, but some areas not included in this section are included in others (e.g. Iceland).

The fourth section of the book is introduced by an article entitled 'Glacier composition, mechanics and dynamics', written by Jacka. This paper takes a somewhat different approach than the other keynote papers, in that the paper integrates nearly all of the conclusions of papers in the section into the overview paper, thus providing an excellent summary of what is covered in most papers in this section. Jacka provides a basic introduction to glacier motion, including the effects of composition and temperature on the rate and nature of ice movement. At least three of the papers in this section concentrate on variations of Glen's flow law. The papers examine ice movement, at various scales, and, in particular, Cuffey's paper relates ice sheet form and behaviour to the micro-physical behaviour of ice. These papers are followed by several that concentrate on basal motion and effects of basal debris in cold-based and warm-based glaciers. Fast ice motion is considered by two fairly long papers in the section, and these papers relate back to several papers in the first section of the book. It is clear that, even though we have learned a lot in the more than 50 years since the publication of Glen's flow law,
we understand very little of the details of ice motion, especially at the base of glaciers.

In the keynote paper of the final section, entitled 'The practice of glaciology', Alley & Anandakrishnan chose not to summarize the papers in their section, but instead to speculate on further advances that may take place in the practice of glaciology. Among these are improved characterization of glacier beds using radar, active and passive seismic methods, and perhaps new technology as it develops.

They point out that marked improvements have taken place in modelling by including multiple stresses, but conclude that further advances will be necessary before truly predictive models of glaciers can be developed. In addition, they point out that, unlike the field of climate modelling, where models are developed by communities of scientists, glacier modelling is done by small research groups and individuals. They suggest that laboratory studies will continue to be important, but also point out that laboratory efforts are frustrated by the necessity of high strain rates that do not represent real-world conditions. Forensic glaciology is another approach that has promise: basically studying properties of the ice and deducing its history from them.

Alley & Anandakrishnan predict improvements in drilling methods and that automated analyses of ice cores will take place in the future. They point out the need for long-term planning at critical core sites. Like several other papers in the volume, they predict that the technology for remotely sensing conditions at the base of the ice will improve, and that remotely operated vehicles will be used to explore ice shelves and grounding lines further.

Following an overview paper by Bamber on advances in the uses of active radar remote sensing and laser altimetry, several papers describe the use of various remote-sensing techniques on glaciers, glacier beds and glacial landscapes. This section includes several short papers on ice sheet modelling and several on glacier monitoring, including an overview paper by Haeberli on the Global Terrestrial Network for Glaciers (GTN-G). This is a hierarchical strategy of monitoring at scales ranging from regional to global and including in situ measurements, remote observations and numerical modelling. The 'Practice of glaciology' section is rounded out by several papers of a more geological nature on a variety of subjects, including the interpretation of glacial sediments, laboratory experiments on the entrainment and deformation of glacial sediment and the use of cosmogenic nuclides to estimate the extent of past glaciation.

My overall impression is that I learned a lot reading this book. I learned about areas of interest that are peripheral to mine and yet in many ways contribute to my understanding of glacial deposits. Many of the top glacier scientists of the world have written about what they think is important and interesting, so the book provides new ideas for the professional and advanced undergraduate and graduate students.

A common thread throughout all of the sections is the importance of the glacier bed, and how little we know about it. Understanding more about the nature and processes at the glacier bed is fundamental to glacier modelling and many other aspects of glaciology, glacial geomorphology and sedimentology. Perhaps the next decade will provide answers if glaciologists and those who study glacial sediments and landforms can work together interactively. This book should stir that kind of response!

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