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BOOK REVIEW

Review of *Principles of Glacier Mechanics*

Roger LeB. Hooke. Cambridge University Press. 3rd edition. 2020. 513+xii pp. ISBN: 978-1-108-42734-0 (hardback), 978-1-108- 44607-5 (paperback)

The first edition of Roger Hooke's book on glacier mechanics, published over 20 years ago, and resident in one of my offices, was a relatively slim volume. In this, its third edition, it has doubled in length and will sit comfortably on its shelf alongside the books by Cuffey and Paterson and by van der Veen. It provides a complete text on glacier mechanics for glaciological students. As Hooke notes in his various prefaces, the book is intended for practicing glaciologists and is aimed at a numerate but also practically minded audience.

The book consists of 16 chapters, of which the first two are introductory, and the 14 following substantive ones each finish with a useful summary. Exercises on these substantive chapters (excluding Chapter 7 on basal processes) are gathered in 10 pages at the end of the book, and as their extent indicates, they are adequate for a course based on the book, though the lecturer might well want to add some others. There is an extensive reference list with upwards of 600 entries, occupying 41 pages, and it is a fairly eclectic list displaying a catholic taste. It is difficult to assess an index, but searches for the following (no doubt nonrandom) keywords was satisfactory: drumlin, till, Glen's flow law, LGM, GRIP, Dansgaard-Oeschger events, ice core, regelation; but there was no EPICA or δ^{18}O. The following more abstruse items were not there: Agassiz, viscoelastic, thermal runaway, sublimation; but fracture mechanics was.

The subjects of the substantive chapters, following the first two on motivation and basic mechanical concepts, are mass balance, flow and fracture, glacier velocity fields, ice sheet temperatures, basal processes, en- and subglacial hydrology, stress and velocity distribution (two related chapters), numerical modelling, simple applications, ice streams and ice shelves, foliation, response to climate change, and ice cores.

The first chapter is a rather apologetic answer to the question: why study glaciers? It sets the tone, almost at a high school level: here is why you are doing this subject. The second chapter, also introductory, tells us some basic facts about glacier size and constitution, and it also introduces tensors. As gently as possible, but it is hard to find a way to do this that is not overly abstract.

Having passed this early hurdle, the first substantive chapter is on mass balance. There is a nice early part on the transformation of snow to ice, before the nuts and bolts of mass balance are described. The treatment is largely descriptive, equations are kept to a minimum, and, in keeping with the book's ethos, radiative transfer is not discussed.

Next, Chapter 4 concerns ice flow and fracture. There is an extended discussion of the atomic structure of ice, and a detailed description of the different ways in which creep can occur. As with other chapters, a feature of this book is the depth of the discussion. We hear, for example, about the other stable phases of ice, and about the role of pre-melting on creep as the melting temperature is approached. This chapter also describes fracture mechanics and elaborates on this to discuss the concepts of damage mechanics.

Chapter 5 is about the velocity field in a glacier. The basic mechanics (the shallow ice approximation) is introduced in a simplistic way for two-dimensional flow, but it is then elaborated to three-dimensional velocity profiles and the calculation of a shape factor. One of a number of diverting topics is a section on the commonly "concave upwards" cross-sectional profile in the accumulation area and the "convex upwards" profile in the ablation area. Convex and concave are wretched terms, as their meanings to mathematicians and geomorphologists are almost exactly contradictory; the surface bulges upwards in the ablation area and is depressed downwards in the accumulation area. Hooke provides an equation-free explanation of this, which I remark on as it is something I have been perplexed by.

Chapter 6 describes the temperature structure in ice sheets. First we creep gently up on the energy equation for the ice temperature, and then there follows a raft of simple approximate solutions. One of the things I like about the discussion of basal conditions is the idea that the transition from frozen to thawed base will be patchy and gradual, rather than the abrupt no-slip to sliding, which is sometimes adopted. There is also a description of certain geomorphic features, which may be associated with such transitions, such as patterned ground and ribbed moraine.

Chapters 7 and 8, a hundred pages between them, deal with the important topics of subglacial processes: glacier sliding and water flow. This is an area in which recent developments have come thick and fast, and Hooke is up to the task. The chapter on sliding deals fairly rapidly with Weertman's description of sliding, details some of the complications, taking the Iken route through cavitation, and then spends most of the chapter discussing till and its rheology in forensic detail; this discussion is very welcome. Towards the end, there is a little material on frost heave-related processes and subglacial bedforms, though at a cursory level.

The chapter on hydrology is again wide ranging. It starts with veins and lenses, passes to Röthlisberger channels and linked cavities, and cuts a dashing path through jökulhlaups, surges, eskers, and other large-scale geomorphic features such as tunnel valleys and cirques. As elsewhere, the discussion is always lucid and makes a habit of reverting to observations where possible. This book is not the place to find technically advanced theories of these and other phenomena, nor even necessarily up-to-date ones, but the material is always stimulating and well serves its aim of introducing the general-purpose glaciological student to the theoretical intricacies of the phenomena he describes.

At this point, halfway through the book, we have been taken on a tour of many of the most interesting glaciological phenomena, and we have toyed with some of their complexities. The contents of the second half look less promising from this perspective. The next four chapters deal with stress, deformation, and numerical modeling, and as their titles indicate they are of a much more theoretical nature. They deal with such things as tensors and coordinate transformations, but with an old-style approach similar to that in Paterson's original book; indeed, approximate calculations of stress in glaciers are dealt with in a similar way. In the same vein, the chapter on numerical methods is a helicopter view and eschews detail.

Chapter 13 is on ice streams and ice shelves and reverts to the earlier style, fact-filled exposition with a sprinkling of theory. Chapter 14 is on foliation, and Chapter 15 describes the response of glaciers to climate change. This has a short preamble dealing with Pleistocene climate, the 40 ky to 100 ky transition and Dansgaard–Oeschger events, but spends most of the time on Nye's kinematic wave theory, and subsequent variants of it. The final Chapter 16 is on ice cores; it details how the cores are extracted and analyzed, what they contain, and what this means for paleoclimatic studies. As throughout the book, a number of interesting outtakes are provided, the last (by no means atypical) a comment on the dramatic lowering of atmospheric lead levels during the Black Death in Europe in the mid-1300s.

As mentioned earlier, a sequence of problems follows the main text, and these could be used if the book is used for a course, but the chapters have variable numbers of such exercises (and some have none). Also as mentioned earlier, the reference list is extensive, selective but eclectic and wide ranging, both in time and content (Amundsen 1912, for example). The book is very well written, is very readable, is not cluttered with over-citation, and has remarkably few typographical errors—a handful that I noticed. If used for a course, I think it suits physical geography/environmental studies better than Earth sciences/geophysics, but that is just my opinion, and it will also depend on the numeracy of the audience, although you could skip a good deal of the theory altogether. And now to the punch line: would I buy this book? Yes. Should *you* buy this book? Yes.

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