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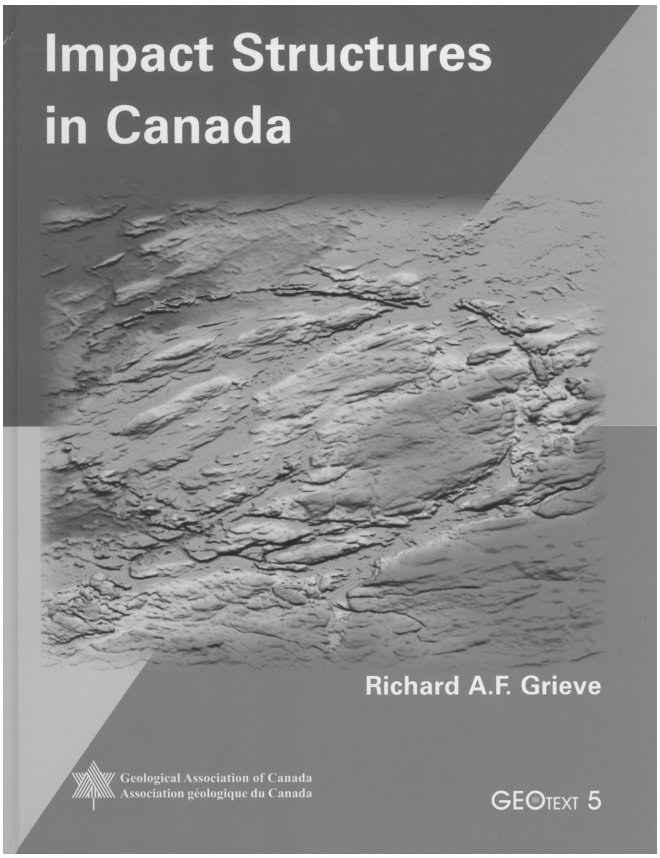
Book Review

Impact structures in Canada, by Richard A. F. Grieve. Geological Association of Canada, 2006, 210 p., $60 (Canadian dollars), hardback (ISBN 1-897095-11-2).

Cratonic regions of the world provide rich libraries of remnant impact craters, and Canada is one of the richest among them. For nearly six decades, Canadian scientists have harnessed this natural resource to produce some of the best geologic descriptions of impact craters in the world. As described in *Impact structures in Canada*, this initiative began at the Dominion Observatory under the direction of C. S. Beals in the 1950s. Success was achieved early in the program with a comprehensive geophysical and drilling campaign at Brent crater, which remains one of the best-characterized simple craters in the world.

Craters in Canada have a broad distribution of ages, ranging from 1 to 1850 Ma, providing a detailed measure of specific events that shaped the Earth over nearly 2 billion years, and broader insights into processes that shaped Earth throughout its entire 4.5-billion-year history. Although the record of cratering in Canada is rich, impact structures have been partially eroded. Rather than being a detriment, however, this created a special opportunity to explore subsurface components of impact craters, providing important information about the structural evolution that occurs as a function of crater size. It also provided an opportunity to study the distribution of shock-metamorphosed products, ranging from shatter cones to multi-kilometer-thick impact-melt sheets. These studies have, in turn, led to empirical scaling relationships that are applied to impact sites throughout the world and on other planetary surfaces.

This book synthesizes the results of those studies in an accessible way. The volume begins with a 22-page introduction about impact craters and impact-cratering processes. The introduction is very broad, addressing a series of important issues: the spatial, temporal, and size distribution of craters; cratering rate; crater morphology; processes associated with the excavation and modification of craters, including the deposition of impactites; subsolidus shock effects; impact melting; distribution of shock metamorphism; and gravity, magnetic, and seismic signatures of impact sites. I particularly like the discourse in this chapter, because Grieve explains the development of many concepts and how they were influenced by geologic evidence recovered from impact sites. He also identifies several issues that still need to be addressed. The introduction is so complete that it has become the first paper I recommend to new students.



The bulk of the book (over 150 pages) is a series of 29 chapters that describe each Canadian crater in alphabetical order. These chapters are concise yet thorough summaries of the morphology, geology, geochemistry, geophysics, and age of each crater. They are abundantly illustrated. For example, the description of the Brent crater in the first chapter is augmented with 17 figures (e.g., a LANDSAT image, surface topographic map, surface geology map, geologic cross section, residual Bouguer gravity map, and nine photomicrographs of impact melts and breccias in core samples) and 6 additional tables of data.

It is perhaps an interesting historical exercise to compare the wealth of information in Grieve's book with the dearth of information in a previous catalogue of Canadian craters (Fryer and Titulaer 1972, Catalogue of terrestrial crateriform structures, Part 1, Canada, published by the International Astronomical Union and European Space Research Organisation, ESRO SP-92, Paris). The comparison illustrates the huge contribution made by Grieve, other

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Canadian scientists, and their international collaborators. Unlike the nearly blank pages in the older volume, the new volume provides abundant geologic data and a clear link between geologic observations and existing models of impact cratering processes.

The summary of 29 known craters (i.e., those with geologic evidence of shock metamorphism) is followed by a chapter describing other possible impact structures in Canada, and thus provides a starting point for additional work. The book ends with a lengthy bibliography that generates my only criticism of the entire book. Papers with more than three authors are not organized chronologically in the bibliography. Rather, they are mixed with two-author papers and organized alphabetically based on the spelling of the second author. Consequently, Grieve et al. (1991) occurs in the list before Grieve and Cintala (1981), Grieve and Garvin (1984), and Grieve and Head (1983), because the second author in Grieve et al. (1991) is Bottomley. Grieve et al. (1991) also occurs before Grieve et al. (1981) in the bibliography, because the second author in the latter paper is Robertson. Thus, one has to work a little to find some references. Nonetheless, this is a first-rate book and should be available to anyone studying impact cratering processes.

Between the book's introductory chapter and the 29 chapters describing known Canadian craters is a chapter that summarizes the history of impact crater studies in Canada. It is a bittersweet chapter. The work by scientists at the Dominion Observatory and their collaborators was pioneering. They provided geologic ground-truth to a field that had been largely an astronomical one (with a few exceptions, like the work of D. M. Barringer in Arizona). Thus began the definition of impact cratering as a geologic process. Over a period of years, studies of impact cratering processes moved to the Geological Survey of Canada (GSC), where it was led by the book's author. The group was one of the world's most productive impact cratering teams and, in the opinion of this writer, had the highest international reputation of any GSC group. Yet, the team was dissolved in 1998 when Canada decided to terminate its internally funded study of impact craters. Fortunately, many of the team's resources were transferred to the University of New Brunswick and are now under the direction of John Spray. This book is one of the transitional components of that move. In the author's own words, the book is designed, in part, "to ensure that the intellectual assets of the impact program, initiated by C. S. Beals, are not lost to the community." I wish him and the growing program at the University of New Brunswick the greatest success in this endeavor.

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