

Book Review of "Exploring the Earth's Crust: History and Results of Controlled-Source Seismology (GSA Memoir 208)" by Claus Prodehl and Walter D. Mooney

Prodehl and Mooney have done an impressive service to the community in providing this compendium of controlled-source seismic studies of the earth's crust carried out to 2005. It is a remarkable piece of work. The book will be a valuable resource for students and researchers in earth sciences for many years to come.

The chapter on the "History of controlled-source seismology" provides an excellent introduction to the data sets and experiments that are discussed in the remainder of the book. It is strange that for such a large book there is no index and, as a result, it is awkward to find material of interest. Consequently this chapter is especially necessary.

The chapter on "The first 100 years (1845-1945)" does for controlled-source seismology what Love's (1927) "Historical Introduction" did for the theory of elasticity and Dewey and Byerly (1969) did for seismometry. Given the importance and ubiquity of the term "Mohorovičić Discontinuity" it would be interesting to know who first used this term and how quickly it was generally accepted. This is not, however, addressed in Prodehl and Mooney other than to say "This boundary [reported by Mohorovičić (1910)] ... was shortly thereafter defined as the crust-mantle boundary and was named the Mohorovičić discontinuity...". (By the way, for those anglophones interested in the history of seismology there is an English translation of Mohorovičić 's 1910 paper (Mohorovičić 1992).)

It is, of course, common knowledge that the crust is defined as the region of the earth above the Mohorovičić Discontinuity (or Moho) and that this is observed seismically from both earthquakes and controlled sources. The notion of the earth's crust was well established before Mohorovičić made his famous observation (Fisher, 1889; Fowler, 1990; Hopkins, 1848; Milne, 1903; 1906; Oldham, 1906; Rutherford, 1907, for example) and soon thereafter his seismic structure was correlated with granitic/basic (crust) and ultra-basic (mantle) rocks (Jeffreys, 1926). The term "Mohorovičić Discontinuity", however, was first introduced in the literature by Macelwane and Sohon (1936; OED Online, 2013). They attributed a figure showing the Mohorovičić Discontinuity (their Plate III) to C.G.Dahm (he used the term in his PhD Thesis two years earlier (Dahm, 1934)) and the Dominion Observatory, Ottawa, Canada. The term grew in popularity through the 1940's and 1950's (Birch, 1952; Bullen, 1947; Ewing and Press, 1955; Gilluly, 1955; Gutenberg, 1943; Gutenberg and Richter, 1939; Hess, 1955a; b; Lovering, 1958; Shepard, 1959; Shor, 1954; Wager, 1958) until it reached celebrity status with Project MOHOLE (Bascom, 1961; Bullard, 1961; Greenberg, 1967). Correlation of seismically observed speeds with laboratory measured speeds of various rock types under suitable temperature and pressure established the Moho as the boundary between felsic/mafic rocks (crust) and ultramafic rocks (mantle) (Adams and Williamson, 1923; Birch, 1952; Birch and Bancroft, 1938). This model is consistent with gravity measurements and isostasy (Hess, 1955b; Woolard, 1960; Worzel and Shurbet, 1955).

Interestingly Jeffreys in his classic work "The Earth", with editions going back to 1924, did not use the term "Mohorovicic Discontinuity" until the fifth edition (Jeffreys, 1970),

although Jeffreys (1963) did acknowledge the term. In contrast, Bullen used the term in all editions of his book going back to 1947 (Bullen, 1947). Holmes in another classic work, "Principles of Physical Geology", did not mention it in the 1945 edition (Holmes, 1945) but mentions it extensively in the 1965 edition (Holmes, 1965). This reader could not find any instance of Gutenberg using the term before 1939.

The bulk of Prodehl and Mooney consists of separate chapters dedicated to the decades from 1940 to 2000 with the final chapter on the early twenty-first century. The chapter on the 1940's gives an intriguing overview of controlled source seismology in Central Europe (using left-over ordinance from the second world war) and the development of the seismic refraction method at sea. Several review papers in the early 1950's summarized the rapidly developing picture of crustal thickness worldwide and the distinct differences between continental and oceanic crust. The chapter on the 1950's highlights seismic refraction work in North America, Eastern Europe, Japan and the Southern Hemisphere. Over half the chapter addresses marine seismology, but strangely no mention of the MOHOLE project.

The core of the book consists of four extensive chapters spanning the decades from 1960 to 2000. Each of these chapters follows a uniform format. First, there is an introduction giving a theme for the decade, for example, the 1970's is appropriately called the "Decade of International Cooperation". Technological developments in each decade are discussed here. This is followed by sections on continental experiments (based on geographical location: Europe, USSR, North America, etc) and marine experiments. Each chapter concludes with a summary of the "State of the Art". The final chapter, covering 2000-2005, follows a similar format.

In the chapters covering 1950 to 2000, there is a series of maps showing the locations of marine seismic refraction experiments worldwide in each decade. It is interesting to see how the marine work transitioned from North Atlantic, to Pacific and Indian Oceans, and to the Southern Ocean and poles as the decades progressed. The reader is left wondering, however, why there are not similar series of maps for the continental work and for multichannel reflection seismology.

The bibliography is daunting with 58 pages and about 40 entries per page. The appendices on the accompanying DVD provide supplementary material including reprints of difficult to obtain manuscripts, record sections, and electronic copies of all figures in the paper. Disappointingly Appendix 3-1 on Mintrop's history of seismology simply gives a link to a web page which is out-of-date. It would have been nice to have an English translation of this paper (Mintrop, 1947). The figures are fascinating. Mintrop (1930), in English, has very similar material.

Prodehl and Mooney essentially focus on experiments that measure the gross structure of the earth above the Moho. They are readily suited to this task since they have spent much of their careers constructing data bases of crustal structure (Mooney *et al.*, 1998; Mooney *et al.*, 2002; Prodehl *et al.*, 2005, for example). There is a large volume of controlled source work, however, that targets the detailed structure of the upper crust, of both continents

and oceans, that is less well covered. The book contains very little on petroleum exploration multi-channel seismology although this is by far the largest controlled-source seismic discipline. This is probably due to the proprietary nature of so much of this work and the fact that it rarely addresses the whole crust, down to the Moho. Also borehole seismology (vertical seismic experiments, oblique seismic experiments, etc), at sea and on land, is touched on only briefly. The book overlooks the first attempt to correlate in situ seismic velocities of ophiolites with the layered structure of oceanic crust (Lort and Matthews, 1972; Matthews *et al.*, 1971) as well as the role of controlled-source seismology in delineating oceanic detachment faults and core complexes (Canales *et al.*, 2004), the building blocks of the revolutionary "Chapman Model" of oceanic crustal structure (Escartin and Canales, 2011; Larsen *et al.*, 2009; Tucholke and Lin, 1994).

Prodehl and Mooney admit that they are unable to report on "all" controlled source seismic projects targeting the structure of the crust, just the "most important" ones. Of course "important" is determined by the subjective judgment of the authors. Other investigators may have their own opinions of what the important projects were. The danger in a comprehensive historical review, such as this, is that the important projects that are not mentioned will be forgotten. Readers should keep this in mind. It is not difficult to think of major projects and prominent scientists in the field of controlled source seismology that are not mentioned in this book.

Whenever a comprehensive overview of a subject is attempted, some work will inevitably be left out. This book is no exception. Nonetheless it is a noble undertaking.

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