Notes to D. C. Agnew, *History of Seismology*

(on CDROM in published version)

1. The most thorough account of the early history of seismology remains Davison (1927) though it is largely restricted to the nineteenth century. Dewey and Byerly (1969) cover instrumentation during the same period in detail. Stoneley (1967) is a brief account of seismology since 1900. Howell (1990) provides a historical treatment of current seismological topics. Ben-Menahem (1995) is a chronology of seismology up to the present, with an emphasis on theoretical developments. The most recent summary account is Oldroyd (1996); this is especially valuable for its philosophical reflections and for being part of a larger, and thoughtful, account of the history of the earth sciences.

2. Guidoboni (1998a) and Oeser (1992) summarize classical views about earthquakes,. The main sources for what we know about these views are Aristotle's *Meteorologica*, Book II, Chapters 7-8 (Lee 1952), and Seneca's *Naturales quaestiones*. A typical classification of earthquake types is in the Pseudo-Aristotelian work *De Mundo* (Forster 1914). Shute (1979) offers a discussion of ancient thought on earthquakes, but is not always clear in distinguishing between waves as felt and waves as evidence of propagation. Freeland (1990) discusses the structure of the type of argument that Aristotle uses for earthquakes and other meteorological theories.

3. The standard Western-language account of Chinese earthquake theories is in Needham (1959); a fuller one, marred by Marxist categorizing, is Tang (1988). Sleeswyk and Sivin (1983) is the best discussion of Zhang Heng's seismoscope, though the mechanism they propose to make the instrument more sensitive (amplification by a double pendulum) would also make it an unreliable indicator of direction.

4. Guidoboni (1998a,b) discusses medieval and early-modern ideas on earthquakes, providing a Continental bias which neatly complements the British emphasis of Davison (1927), who provides a full account of Michell's paper (though the original (Michell 1761) is well worth reading). Other views of 18th-century earthquake theories, as seen by interested naturalists not greatly involved in seismic research (John Flamsteed, Benjamin Franklin, Immanuel Kant, and John Winthrop) are provided by Willmoth (1987), Dean (1989), Reinhardt and Oldroyd (1983), Brasch (1916), and Clark (1965); the latter, with Andrews (1973) shows the intermixture of theological and naturalistic reasoning that marked much eighteenth-century discussion. The standard historical account of the Lisbon earthquake remains Kendrick (1957), though it says little about the scientific impact; Johnston (1996) summarizes what is known scientifically. The wave theories of Michell and Drijhout, and more especially how these were represented pictorially, are discussed by Keller (1998).

5. Davison (1927) remains the best overview of nineteenth-century developments in descriptive seismology; Tams (1952) reviews German-language studies. Musson (1999) describes the more recent history of intensity scales. The Humboldtean style is mentioned by Goetzmann (1966), and described most fully in Cannon (1978); the more general passion for statistics is discussed

by Hacking (1990). The role of earthquakes in Lyell's geological thinking is illustrated in Lyell (1830), recently reprinted with an introduction which describes the role of his ideas in geological thought; later editions of the same work contain more seismological examples. Two of the earthquakes mentioned (1819 and 1855), have been studied, with full attention to the historical literature, by Bilham (1998), and by Grapes and Downes (1997) respectively.

6. The fullest accounts of early studies in elastic-wave propagation are Todhunter and Pearson (1886) and Whittaker (1951), though neither is completely satisfactory; Whittaker's attention is on optics, and Todhunter and Pearson's account is weakened by Pearson's polemics on whether isotropic materials have two elastic constants or only one (admittedly a concern of many of the investigators he describes).

7. Dean (1991) and Muir Wood (1988) discuss Mallet's work in some detail; the article on him in the *Dictionary of Scientific Biography* gives some idea of his amazing range of interests. Benedetti *et al.* (1998) is a modern account of the 1857 earthquake.

8. Dewey and Byerly (1969) describe early seismic measurements most broadly. The first ''seismometer'', so named, was built by Forbes in 1841; see Musson (1993). Palmieri's instrument is described most fully by Nazzaro and Tramma (1985); the best illustrations are in Ferrari (1992), who also pictures many of the other Italian instruments, including the tromometers. Ferrari (1994) outlines the work of de Rossi and Bertelli, discussed more fully in Ferrari (1990)—though he leaves open the ultimate fate of their efforts. Gasparini (1990) discusses the connections with the beginning of the Italian seismological service.

9. The development of seismic recording is part of a general trend towards ''objective'' measurement, discussed by Hankins and Silverman (1995) and Daston and Galison (1992). The particular event that promoted this for seismology—foreign researchers in Japan—is discussed by Jones (1980) and Bartholomew (1989), though neither gives much space to seismic studies. Dewey and Byerly (1969) and Muir Wood (1988) discuss the early instrumental developments in more detail, though only the latter conveys the intense rivalry which characterized the British effort. Herbert-Gustar and Nott (1980) provide a full biography of Milne, though it is somewhat uncritical as far as his scientific contributions are concerned. Milne's own writings (for example Milne 1886) indicate the wide range of his interests. The term ''new seismology'' is due to Dutton (1904); see also Clerke (1905).

10. There is no good historical treatment of the earliest period of global seismology, though again Muir Wood (1988), Ferrari (1992) and Dewey and Byerly (1969) describe different aspects, especially the earliest instruments. McConnell (1986) has good illustrations of many early seismometers. The importance of damping for seismometers was in fact shown by J. Perry and W. Ayrton in 1877, but their paper was neglected. Von Rebeur-Paschwitz (1889, 1893, 1895) summarizes his horizontal-pendulum work, which ended with his early death in 1895. The most readily available treatment of Golicyn is the article in the *Dictionary of Scientific Biography*.

11. Brush (1979) describes early ideas about the Earth's interior; many of the debates are

described in detail in Kushner (1990), who has described the birth of the British school of geophysics in Kushner (1993). For invocations of anisotropy and inhomogeneity to explain early seismic data see, for example, Rudzki (1905) and Oldham (1907).

12. Brush (1980) describes some of the earliest developments in seismogram interpretation; studies in Japan are described in Kawasumi (1937). Oldham (1900, 1906) are two early and important papers. Wiechert's activities are outlined by Schröder (1988); Pyenson (1985) is a more nuanced treatment, though it tends to focus on fundraising and the travails of running a distant station rather than on what science was being done. Angenheister (1974) is a useful supplement to Pyenson's treatment of the Samoa Observatory. Mohorovičić's work is described by Bonini and Bonini (1978).

13. The establishment of international seismological institutions is outlined in the accompanying article by Adams; for the International Seismological Summary, see Bullen (1970) and Stoneley (1970), and for the International Seismological Association and its Central Bureau, see Rothé (1981). Udias and Stauder (1996) provide a general review of Jesuit activities in seismology; for the Jesuit Seismological Association see Geschwind (1998). Predecessors to this ecclesiastical involvement were the Italian seismological observatories described by Todesco (1997). Pyenson (1985, 1989, 1990, 1993) describes a number of seismological efforts in his larger study of science and imperialism.

14. The development of the southern California local network is described by Goodstein (1984) and Geschwind (1996). Louderback (1942) and Bolt (1985, 1989) describe network development elsewhere in California and the western USA.

15. Mintrop's research for Wiechert is described in Meyer (1974), including a photograph of the falling weight as it (still) lies in the woods outside Göttingen; see also Keppner (1993). American developments in exploration geophysics are described in Sheriff and Geldart (1982) and Bates *et. al* (1982).

16. Brush (1980) gives the history of seismological studies of the outer and inner core; see also Lehmann (1987) and Bolt (1987) on the latter. For the development of the JB tables see Jeffreys (1939), Stoneley (1967), and Bullen (1963, 1970). Steinhart and Meyer (1961) review early explosion-seismology studies of continental structure; Cornell (1994) provides a very detailed account of Tuve's motivations for undertaking his program. The marine counterpart is described by Bullard (1975 a,b) and Menard (1986).

17. Davison (1927) describes Montessus de Ballore's cataloging efforts. The best discussion of the improvement of instrumental locations with time is in Ambrayses and Melville (1982). Frankel (1991) and Frohlich (1987) describe the discovery of deep-focus earthquakes, and some of the subsequent work on them. Goodstein (1984) discusses the birth of the magnitude scale: a term we actually owe to H. O. Wood. Gutenberg and Richter (1941, 1954) are the best references on their own work; the later edition also includes much information about early seismic stations.

18. The reviews of Kawasumi (1937) and Honda (1962) cover the substantial Japanese contribution to earthquake mechanism studies, though Terada and Matusawa (1926) and Hasegawa (1930) should also be consulted for Shida's work. Aki (1979) has a description of the magma theory. That Byerly had access to Nakano's paper may be inferred from his own early papers (summarized in Byerly 1955 and Udias 1989) and from Byerly *et. al* (1949). Scheidegger (1957) is a very useful comparison of techniques. The depth of confusion over source mechanism interpretation is nicely captured in the reviews of Hodgson and Stevens (1964) and Stauder (1962).

19. Surface-wave studies through the mid-1950's are summarized in Bullen (1963) and Ewing *et. al* (1957). Bullard (1975b) and Oliver (1996) have some material on Ewing's program. Ben-Menahem (1990) includes accounts of Haskell's work.

20. Bolt (1976) is a standard reference on nuclear-explosion seismology. Ziegler and Jacobson (1995) describe US nuclear monitoring efforts through 1949 in detail (many later developments are classified). The advent of the VELA-UNIFORM project is outlined in Bates *et. al* (1982); Barth (1998) describes some of the scientific difficulties that led to it. Press *et. al* (1959) summarizes the Berkner report. Oliver and Murphy (1971) tell the story of the WWSSN; other instrumental developments resulting (in large part) from VELA-UNIFORM are described by Carpenter (1965), Melton (1981) and Farrell (1985).

21. The history of continental drift and plate tectonics has been told by Le Grand (1988), Hallam (1989), Oldroyd (1996) and Oreskes (1999). Two personal accounts which include the seismological component are Oliver (1996) and Menard (1986). Minster (1985) gives an overview of the resolution of the earthquake-mechanism debate, and describes many more recent developments in source mechanism studies. Eaton (1996) and Lee and Stewart (1981) describe some of the history of local-network seismology, while Wallace (1996) gives a US view of the turn to seismic hazard reduction. Lomnitz (1994) has an idiosyncratic history of earthquake prediction efforts.

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