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Seismic seconds: The challenges of precisely dating and timing earthquakes in New England in the past four centuries

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New England has the longest continuous earthquake record in the United States. Earthquake catalogs document the exact time that an earthquake struck. When consulting historical sources, however, it becomes clear that there is much more ambiguity concerning these documented times.

Earthquakes in New England

Earthquakes that took place during historical times are often recorded in historical documents. Where earthquakes are infrequent, they are perceived as something extraordinary and are remarked upon as such in diaries, letters, newspapers, and sermons. A list of regions in the United States that evoke associations with earthquakes include California, Alaska and Washington. New England does not necessarily spring to mind. However, despite being located on a tectonic plate, some distance away from the active continental margins, earthquakes do occur there. These seismic events are called intraplate earthquakes.

The seismic activity in this region is caused by the repercussions of the ancient collision between the African continent and the North American continent, which formed the supercontinent Pangea 450 to 250 million years ago, and the subsequent breakup of Pangea, which formed the Atlantic Ocean. Today's fault lines are echoes of these events in deep geological time (Kafka 2004). Some of these fault lines are occasionally reactivated by stress caused by the movement of the North American plate, moving away from the mid-Atlantic ridge, and by postglacial rebound, which is an uplift of a tectonic plate formerly weighed down by thick sheets of ice during an ice age; in this case, the ice sheets that started to melt around 10,000 years ago (Natural Resources Canada).

In North America, earthquakes to the east of the Rocky Mountains are felt in a much larger geographic area than those to the west. Indigenous peoples residing in North America experienced earthquakes here for a long time and passed on knowledge about them through oral history. Settlers arriving from Europe in the 17th century started recording them in written form after their arrival. In annotated almanacks, for instance, we can see that locals recorded when they felt the "small shock of an earthquake" (Fig. 1). The Massachusetts-based physician, Cotton Tufts, wrote that particular entry about an earthquake on 29 November 1783 CE that originated in northern New Jersey and was felt across New England (Kleemann 2018). Early American residents of the northeastern parts of the country, unlike modern residents, did not regard earthquakes as "such an anomaly" (Robles 2017).

Notable earthquakes felt in New England (Fig. 2) originated in New Hampshire in 1638 CE; in Newburyport, Massachusetts, in 1727 CE; off the coast of Cape Ann near Boston in 1755 CE; in Moodus, Connecticut, in 1791 CE; in New York City in 1884 CE, in New Hampshire in 1940 CE; and in Virginia in 2011 CE.

Earthquakes put early American timekeeping practices to the test

The above-mentioned earthquakes are listed in earthquake catalogs. In addition to the approximate magnitude and intensity, these listings also include information on the date and time of the earthquake. Today, this is common practice and relatively easy to reconstruct, as a network of hundreds of seismographs around the world are recording earthquakes near and far. Seismographs were only invented in the late 19th century (Coen 2012). Seismographic records for New England date back to 1900 CE (Ebel et al. 2020). Older earthquake catalogs, however, also list precise times for those earthquakes that took place before the invention of the seismograph.

One problem that can arise, when considering the timing of historical earthquakes in this period, is the apparent discrepancy between the dates documented across certain borders. This occurs because some regions at the time still used the Julian calendar, whereas other regions had already adopted the Gregorian calender, which was first introduced in 1582 CE as a modification of the Julian calendar. In historical earthquake catalogs, this has sometimes led to confusion and incorrect listings. For instance, the geologist William T. Brigham listed 26 January 1662 CE and 5 February 1663 CE as separate earthquakes in his Historical Notes on the Earthquakes of New England; however, they are one and the same event. This earthquake was felt widely and originated in La Malbaie, New France, today's Canada; a Catholic area that used the Gregorian calendar while the American colonies were still using the Julian

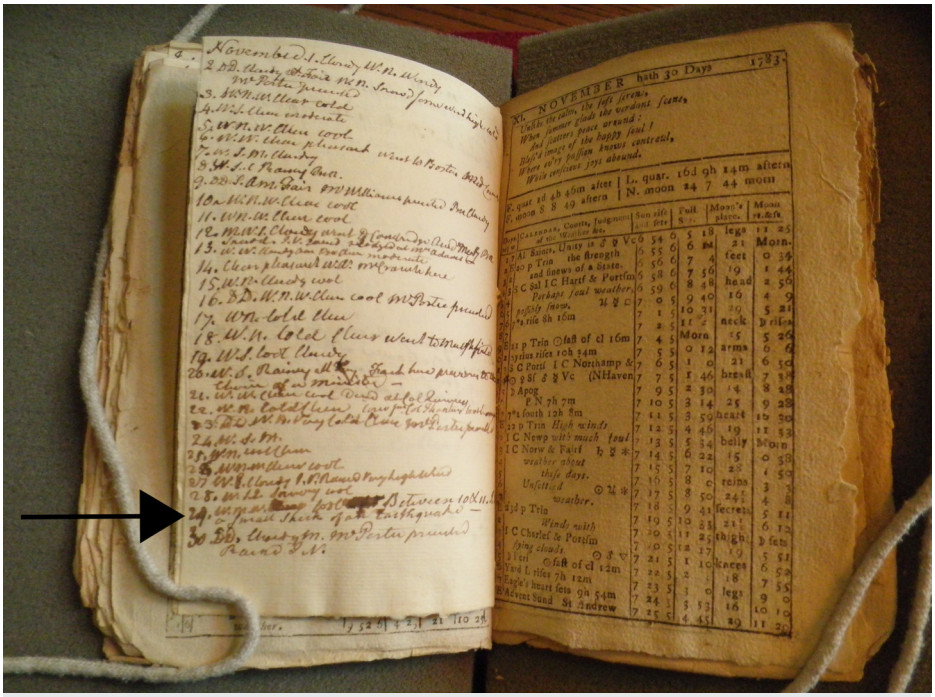

Figure 1: A page of Cotton Tufts' annotated almanack showing his entry for an earthquake on 29 November 1783 CE (see black arrow). Photography by the author. Credit: Cotton Tufts' diary, 29 November 1783 CE, Collection of the Massachusetts Historical Society.

calendar (Brigham 1871; Ebel 1996). In New France, the new year began on 1 January, whereas it only began on 25 March in New England. January was considered part of 1662 CE in New England and 1663 CE in New France; this observation explains the huge discrepancy in recorded dates and the subsequent mix-up by Brigham (1871).

The most specific time listed for an early modern earthquake in the United States Earthquake Intensity Database (United States Geological Survey 1986) catalog is for the 1755 CE Cape Ann earthquake. The time given for the event is 4:11:35 a.m. How was such a precise time recorded? In 1620 CE, the Mayflower ferried pilgrims across the Atlantic without a single timepiece on board (Hering 2009). At first, little metal was available in the New World, which made it challenging to produce clocks locally. Therefore, settlers began bringing timepieces with them from Europe, starting in 1650. Towers of churches, town hall, and other public buildings also began to install clocks around the same time (Distin and Bishop 1976). By 1700 CE, every colony had clockmakers (O'Malley 1990). The clocks available in the 17th and 18th centuries needed to be wound up regularly to run. Over time, as would be expected, the clocks in the New World improved (Distin and Bishop 1976).

Clocks were relatively expensive, only becoming more affordable and accessible toward the end of the 18th century with the beginning of mass production. Before this, it was mostly merchants, professionals, and shopkeepers who owned clocks and watches. Townspeople were more likely to have access to timepieces than those in the country (O'Malley 1990).

Coming back to the question of precise timing of the 1755 CE earthquake, John Winthrop, a professor at Harvard College, had found that one of his clocks had stopped precisely at 4:11:35 a.m (Winthrop 1755). For the purpose of another experiment, he had previously placed an item inside his clock's case, which had dislodged during the earthquake and fell against the pendulum inside the case, thereby stopping the clock. When consulting the sources, however, it becomes apparent that many other times when the 1755 CE Cape Ann earthquake allegedly struck are available, ranging from 3 to 5 a.m. While Winthrop, as a professor and person of science, likely took good care of his clocks, it should still be considered as one reading among many. It remains impossible to know precisely when the earthquake occurred.

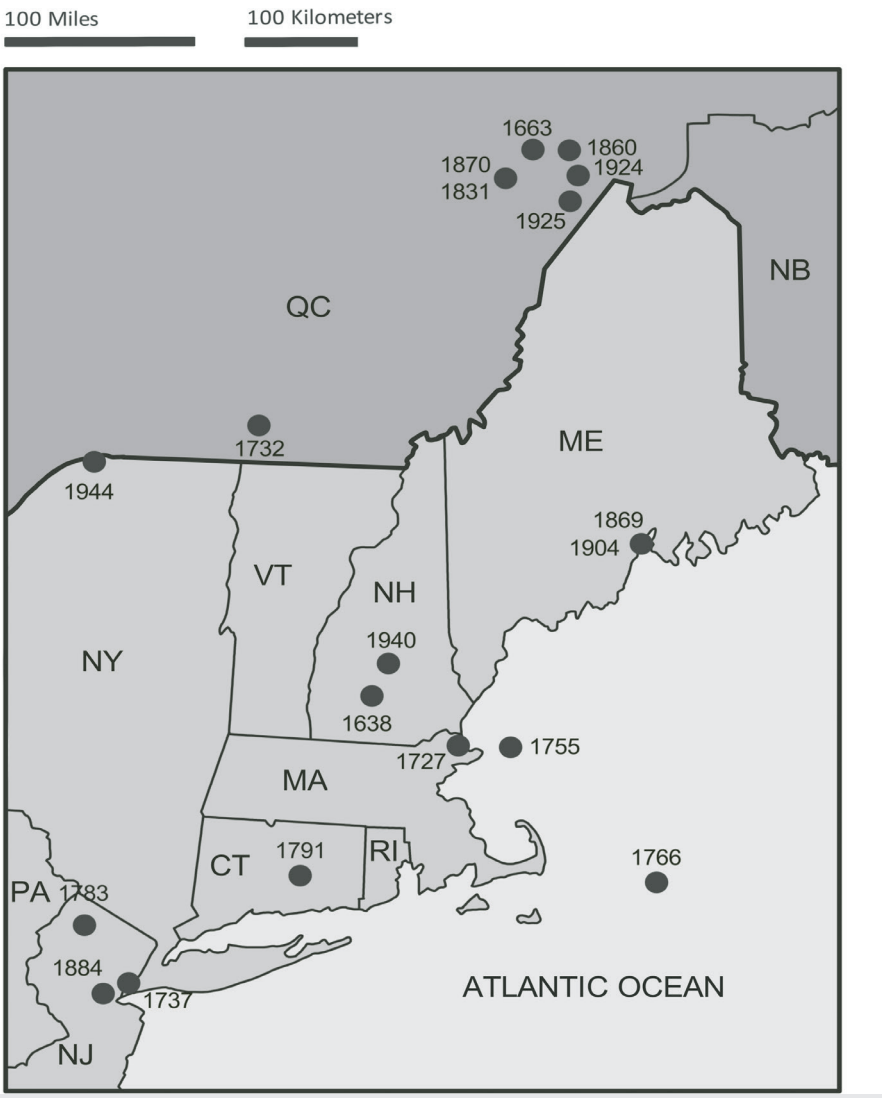

Figure 2: A map showing the assumed epicenters of selected earthquakes that affected New England over the past four centuries. The abbreviations on the map refer to the American states and Canadian provinces (NJ refers to New Jersey, QC to Quebec, etc.). Artwork credit: Jack Walsh, used with permission.

Earthquakes and timekeeping from the 19th century onward

Before the widespread use of railroads made the standardization of time zones necessary, the local time of a given town was set when the sun crossed the meridian. Every town had its own time zone, slightly different from those towns to the east and west (Bartky 2000). While travel during this time was slow, measured in days rather than hours and minutes, the almost instantaneous spread of an earthquake's waves put timekeeping practices to the test. In 1883 CE, delegates from the US railroads adopted the Standard Time System, which was officially recognized by the passing of the Standard Time Act by the US Congress in 1918 CE (Olmanson 2011). Today, towns no longer observe their own time zones based on solar time. Not only does this make communication and transportation more practical, but it also makes recording earthquakes around the globe easier.

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