

## d3 Seismology < remote sensing >

Conquests will come and go, but this work will endure.

—Napoleon Bonaparte’s uninformed praise of Jean Baptiste Joseph Delambre and Pierre Francois Andre Mechain’s triangulation survey of points between Dunkirk and Barcelona that lyingly established the meter defined as “exactly” one ten-millionth of the distance from the North Pole to the Equator and so the distance that separates marks scratched in 1799 on the platinum International Meter Bar, in Paris.<sup>1</sup>

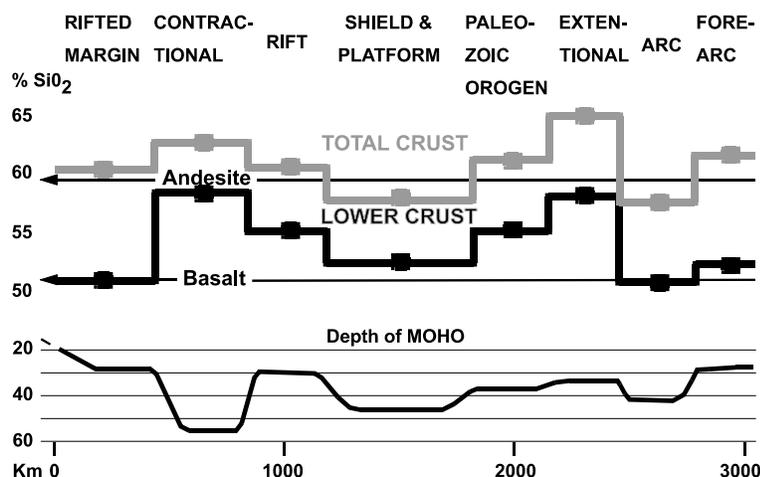
Because of variations in the density and distribution of its matter, Earth has the sphericity of a potato. To remotely sense its interior, a most often used tool is the *seismograph*.<sup>2</sup> This instrument records earthquakes: the motion is sensed by that part of the instrument called a *seismometer* and what is sensed is output as an image called a *seismogram* (**Figure d3.1**). A seismogram is constructed using the principle that a pendulum will remain stationary if its natural oscillation period is longer than that of an occurring earthquake. *Seismology* is the name Robert Mallet (1810-1881) coined for the scientific study of earthquakes that he began in 1857. The first (recording) seismographs were made, beginning 1880, by Alfred Ewing, Thomas Gray and John Milne while at the Imperial College in Tokyo, Japan.<sup>3</sup> Improvements in detection, measurement and analysis of seismic events, continue.

In 1909, Andrija Mohorovičić (pronounced *moho-ro-vu-chick*) (1857-1936) discovered that familiar rocks do not extend to great depth. He had just finished equipping a seismic observatory in Zagreb when at some remove an earthquake occurred that his station and others could record.<sup>4</sup> *Note*: seismic wave velocity increases with rock rigidity (which is a proxy for rock density). The arrival of this earthquake disturbance at stations distant from the epicenter was early *unless* below the relatively shallow depth of 43 km rocks are abruptly more rigid (denser) than surface rocks.<sup>5</sup> That seismic boundary is there and, now called the *Mohorovicic Discontinuity* (or Moho for short), has been found worldwide at similarly shallow depths (**Figure d3.2**). The rocks above the Moho are those that comprise Earth’s *crust*. The denser rocks below the Moho, are the rocks of the *mantle*. However, if mantle rocks continue to the center, their density (even though increased by pressure) is insufficient to account for Earth’s mass. A very heavy *core* must occur within. Using seismology, geologist Richard Dixon Oldham (1858-1936) (**Footnote d3.1**) in 1906 discovered the core<sup>6</sup> that does not transmit S-waves and which he inferred to be liquid, and Beno Gutenberg in 1913 found the mantle-core boundary<sup>7</sup> to be sharp and at a uniform depth of 2905 (revised) km. The core (radius 3473 km) is a liquid of molten iron in its outer part and this surrounds a solid inner (central) spherical ball (radius 1,221 km) of crystalline iron. Earth’s center is at a depth of 6,378 km (equatorial radius).



Figure d3.1<sup>8</sup>  
A seismogram

Figure d3.2<sup>9</sup>  
Characteristic average % SiO<sub>2</sub> in several continental tectonic settings (arrangement and widths schematically shown) in the total crust, and in the lower crust, above the MOHO.



**Footnote d3.1**  
[R. D. Oldham] was the only man I have ever known that did first-rate work in a subject that did not interest him. —H. Jeffreys.<sup>10</sup>