g11 Direct measurement of plate movement < cm/yr >

> ... it can be proved by accurate astronomical determinations. If continental displacements were active throughout such long periods of geologic time, it must be assumed that they are continuing even at the present day.
>
> —Alfred Wegener *The Origin of Continents and Oceans*, 1924 [Although his survey measurements failed to find this between Europe and Greenland, he continued in his hope.][1]

> This must be left to the geodesists. I have no doubt that in the not too distant future we will be successful in making a precise measurement of the drift of North America relative to Europe.
>
> —Alfred Wegener, 1929 [This has been achieved, see below.][2]

> ... when different plates are compared, it seems that the velocities at which they travel are related to the length of trench-edge that they possess: the longer the subducting margin, the faster the plate moves.
>
> —Richard Fortey, in *Earth*, 2004.[3]

The Geodynamics Branch of NASA in 1986 reported the satellite laser ranging (SLR) round-trip times that light takes from ground-based lasers, at widely separated points on Earth, to return from mirrors on satellites. The accuracy of measurement achieved is of the order of 1 cm over a lineal distance of 1000 km. In the same year, the Institut Géographique National (IGN) began to monitor the relative movement of rigid centers of 8 plates (Africa, Antarctica, Australia, Eurasia, North America, Nazca, Pacific, and South America) using DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite), a radio-electrical system for high-accuracy orbit determination and station positioning. In this, a ground localization station, of unknown initial position, sends a radio transmission (at two frequencies to allow for atmospheric distortions of travel-times to be eliminated) to two or more receiving satellite in the system. Signal arrival-times are downloaded to a data-processing control center and, as the orbital details of the satellite system are very accurately monitored, the precise positions of the ground station can be back-calculated. So, the absolute motions of the plates are disclosed.[4] An excellent correlation was found to exist over several years between such direct measurements of seafloor spreading and geologic rates earlier determined from dated magnetic-anomaly stripes in the ocean floor.

By 1989, and ongoing since, Very Long Baseline Interferometry (VLBI, which uses the difference in time at widely separated places of received quasar-emitted radio signals), and the Global Positioning System (GPS, see ***Footnote g11.1***), are used to directly monitor the details of plate movements.[5] ❑

Footnote g11.1 The Global Positioning System

From a place on the ground, the distance to a GPS NAVSTAR satellite is knowable as this space vehicle (SV) sends its moment-to-moment orbital position (its ephemeris) along with the precise atomic-clock time that it had at each point.[6] The split second difference in time on a ground receiver's clock is a direct time-distance measure to the SV's point position. Three SVs above the horizon would be sufficient to know the latitude, longitude, and elevation (or, in Cartesian coordinates, the xyz-position) of a ground receiver. (The other possible position yielded by the calculation, from three time-distances ties to the three SVs, is in deep space and so it can be logically ignored). However, the quartz clock (running fast or slow) of the ground receiver will not be precisely correct and so the calculation, inevitably, yields an imprecise xyz-ground-position. So for greater accuracy, the xyz-ground-position is calculated from simultaneously received time-distance measures to four SVs. In the calculation, time is eliminated from the solution of four simultaneous equations to obtain a precise xyz-ground-position.