Shaky ground – or high tide?

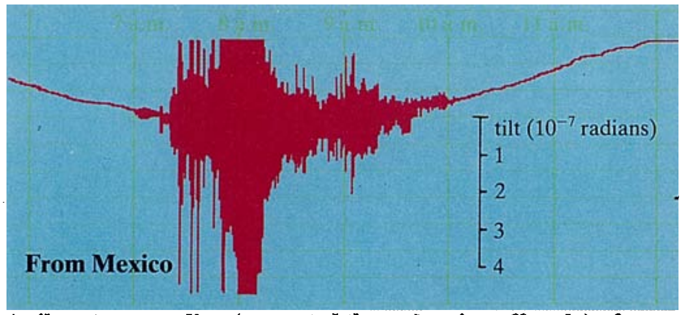
Hundreds of years ago, when Galileo rose from his knees after formally recanting the Copernican cosmology, he is reported to have muttered under his breath 'Nevertheless, it moves'. Much earlier in history, Pliny the Elder stated in his 'Historia Naturalis' that at Cadiz, near the Temple of Hercules, '... there is a closed source similar to a well, which occasionally rises and falls with the ocean, but at other times does the opposite'.

Although Galileo was referring to the movement of our planet relative to the sun, he did challenge the myth of an unshakeable earth. Today, his Inquisitor would be even more scandalized to learn not only that the earth is a spheroid hurtling through space like a badly moulded plasticine ball, but that the changes Pliny observed long ago were indeed caused by tides in the earth itself.

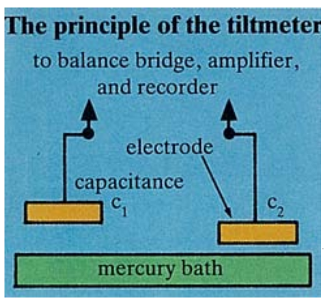
The earth is elastic, viscous, and plastic, and behaves like anything but an ideal heavenly body. Earth tides are caused by the same gravitational pull, exerted by the moon and sun, that causes sea tides. However, they are obviously much smaller than oceanic tides (because the earth and its interior are much more rigid than the surface waters).

Tidal deformations cause measurable strain in the earth's crust, slight changes in gravity, and tilting at the surface. Although the deformations extend over large areas, they may amount to strains of only 1 part in 100 million, gravity changes of about 1 part in 1 million, or tilt effects of 10^{-7} radians (about 0·000006 of a degree) — magnitudes that invite a 'matchstick to the moon' size comparison.

Mr Mumme and the Warragamba Dam tiltmeter.



A tiltmeter recording (truncated through going off-scale) of a large earthquake in Mexico, November 1978.



Any tilt in the earth's crust causes one electrode plate to move closer to the surface of the mercury while the other moves further away. The resulting difference between the two capacitances c_1 and c_2 is fed through an AC bridge, amplified, and recorded.

In a deep vault below the Warragamba Dam, 40 miles south-west of Sydney, Mr Ivan Mumme of the CSIRO Division of Mineral Physics has installed a tiltmeter that measures earth tides. The Metropolitan Water Board has made the site available to Mr Mumme for his systematic observations of earth movements, which began in August 1978.

The tiltmeter can also sense 'anomalous' strains in the earth's crust caused by changes in temperature, rainfall, wind, and atmospheric pressure, and 'cultural' strains caused by such activities as excavation. The deep, insulated Warragamba Dam vault acts as a relatively stable environment in which such extraneous seismic noise is minimized.

Two earth scientists, Dr Jack Rynn and Professor Frank Stacey, both from the University of Queensland in Brisbane, first designed, constructed, and tested the tiltmeter being used at Warragamba Dam. Obviously, because earth tides and long-term tilts are so small, measuring instruments need to be highly sensitive, and this was one of the first sufficiently sensitive short-baseline devices. It has the advantages of being portable (some earlier models had a base-line of 50 metres compared with the 1-metre base of the Warragamba Dam instrument), easy to install and calibrate, and able to generate continuous records via a chart recorder.

The instrument itself consists of two pools of mercury separated by a narrow connecting tube. The surface of each mercury pool acts as one plate of a capacitor, the other plate in each case being a fixed electrode.

If the surface on which the tiltmeter rests tilts slightly, then at one end of the instrument the plates of the capacitor move closer together while those at the other end move further apart. This causes an imbalance in an electrical circuit, producing an output voltage proportional to the tilt angle.

Apart from the 12-hourly earth tides, the tiltmeter can measure teleseismic (yes, the same sense as 'telescopic') tilting caused by distant earthquakes. During 1979, for example, in the April–December period the tiltmeter recorded more than 160 distant earthquakes, including the tremor that substantially damaged the Western Australian town of Cadoux on the evening of June 2, 1979.

More recently, Mr Mumme has recorded earthquake activity in New Zealand, the Philippines, and Mexico, and in Papua–New Guinea, where tremors have been caused by a volcano next to the Rabaul harbour entrance.

The instrument's most important current application is in testing the possibility that earthquakes in the Sydney region can be predicted by identifying any unusual tilts in the ground.

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