(*Reprinted from Nature, Vol.* 239, *No.* 5370, *pp.* 266–267, *September* 29, 1972)

Earth Tides and the Triggering of Eruptions from Mt Stromboli, Italy

EARTH tides with stress gradients exceeding 10^{-8} bar/m (ref. 1) and with predominant periods at approximately 12 h, 24 h and 14.7 day constitute the largest short period oscillatory stress in the Earth's crust[2]. The release of secular tectonic strain accumulation in the crust by tidal triggering has been suggested[3–5], and many attempts[2,3,5–8] have been made to correlate earthquake times with records of Earth tides. All these attempts have proved unable conclusively to relate tides to the occurrence of earthquakes, although microearthquakes may prove to be an exception[9].

For volcanic eruptions the question of whether the tides provide a triggering mechanism is still unclear, although observations of pre-eruptive strain accumulation[10,11] indicate a long-term process. Because eruptions of many of the world's volcanoes are usually described in relation to the characteristics of Mt Stromboli, Italy, that volcano was selected as a test case for these ideas. Eruptions during the past 72 yr have been relatively frequent and eruption times and descriptive details of the eruptions[12–14] were consistently better than the data from other volcanoes. Of the 33 major reported eruptions, all were known to the day and 67% to the hour. 82% of the events could be definitely classified as initial or primary eruptions following quiescent periods of varying intervals from a few months to several years. The remainder of the volcanic activity was either of secondary or tertiary nature. Geochemical analysis of the erupted products[12] indicate all to be of olivine trachybasalt character.

We have derived components of the solid Earth tide as a function of time and position using a program based on a method similar to that developed by Longman[15]. These agree with the values from other independent computations[16], and a check with published tidal observations from quartz

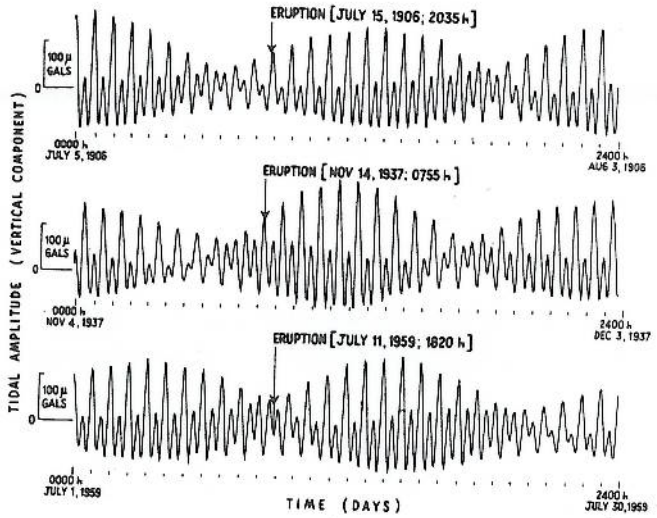
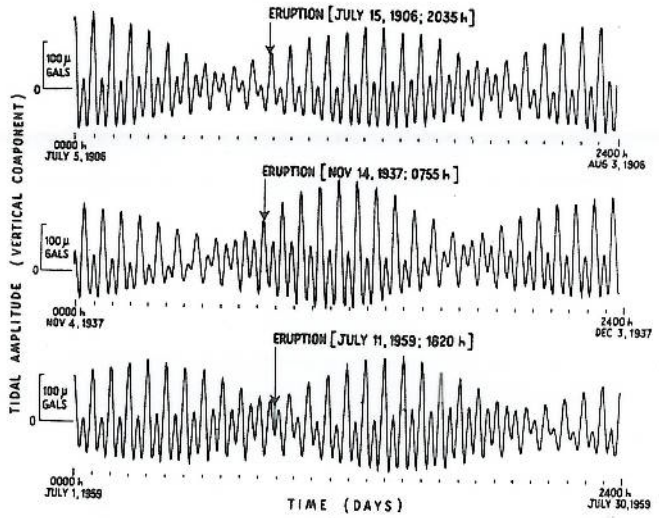


Fig. 1 Three plots of the calculated vertical tidal acceleration as a function of time before and after primary eruptions from the volcano Stromboli. Each starts 10 days before the eruption.

strain meters[9] and gravimeters[17] also gave good agreement for the tidal amplitude, phase and period.

For each of the major Strombolian eruptions (when substantial volumes of material were ejected), the Earth tide was generated for a one-month period beginning 10 day prior to the eruption. Fig. 1 illustrates three typical examples of the relation between variations of the vertical component of the tide and eruptions of Stromboli. The obvious connexion between the eruption times and the modulation envelope derived from the fortnightly tide follows quite consistently throughout the data. Taking all major eruptions from Stromboli between 1900 and 1971, we find the fraction of the total per 25° phase increment of the fortnightly component of the tide as a function of phase (Fig. 2).

Although 67% of the eruptions are known to within an hour, there is no similar clear relation between eruptions and the phase of the diurnal tide. We made a search for correlations with longer tidal periods on the possibility that repose times[18] are tidally controlled although the amplitudes of these longer period tidal components are several orders of magnitude less than the fortnightly and diurnal components. This investigation proved inconclusive.



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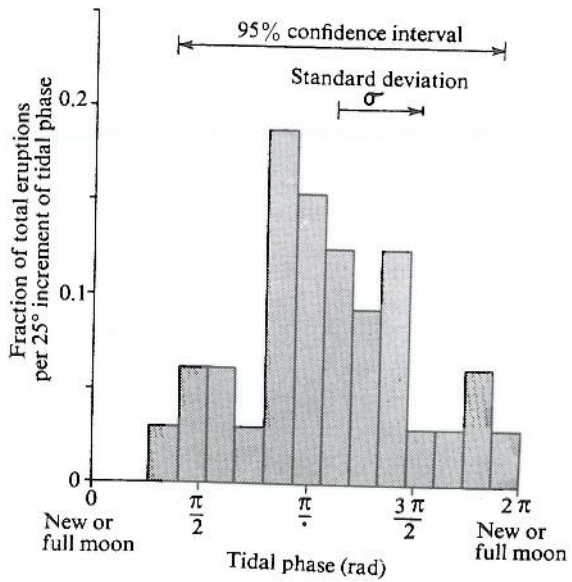

Fig. 2 Histogram of all major primary eruptions from Stromboli since 1899 as a function 25° increments of tidal phase. A 25° phase increment corresponds to approximately 1 day. The standard deviation from the mean is 2.9 day and the 95% confidence interval about the mean is 5.7 day.

We thank Dr Henry Pollack for discussions and the use of his tide-generating program.

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Received March 6, 1972.

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Printed in Great Britain by Flarepath Printers Ltd., St. Albans, Herts.