Galapagos seismic gap filled

from Peter J. Smith
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ALTHOUGH all active oceanic ridges are marked by chains of shallow focus earthquakes, the density of epicentres is far from uniform throughout the ridge system. There are, for example, far fewer events along fast-spreading ridges than along slow-spreading ridges. Macdonald and Mudie (*Geophys. J.*, **36,** 245; 1974) have examined earthquakes of magnitude 5.0+ along spreading ridge sections (that is, excluding those events associated with known transform faults), as recorded during the years 1961-1969 by the World Wide Standardised Seismograph Network (WWSSN), and find that on average there were 8 shocks per 1,000 km of ridge for the northern mid-Atlantic Ridge, where the spreading rate is 12 mm yr^{-1}, but less than one shock per 1,000 km along the East Pacific Rise, where the spreading rate is 35-50 mm yr^{-1}. Moreover, fast-spreading ridges are particularly prone to apparent gaps in seismic activity of up to hundreds of kilometres in length. Along the East Pacific Rise between 36° S and 49° S, for example, there are seismic gaps (as revealed by WWSSN records) as long as 1,400 km.

Another area in which there seems to be a seismic hiatus, according to the WWSSN, is the 600-km long central Galapagos spreading centre, a ridge section spreading at a half-rate of 32.5 mm yr^{-1} between the Cocos plate to the north and the Nazca plate to the south. But is earthquake activity truly absent from this region, or is the gap in seismicity merely a reflection of the low sensitivity of land based stations? To find out, Macdonald and Mudie used sonobuoys in an attempt to detect seismicity at close range along the Galapagos spreading centre—in other words, to see if, notwithstanding the lack of large earthquakes, they could detect microearthquake (magnitude less than 4.0) or earthquake swarm activity. The attempt succeeded. During 45 h of recording time (not continuous) Macdonald and Mudie detected an average of 15 events an hour near the ridge axis and up to 80 shocks an hour at the peak of a swarm which occurred a few kilometres from the ridge. Magnitudes ranged from $m_b = -0.4$ to $m_b = +0.8$. This is the first time that the microseismicity of a fast-spreading ridge with no activity detectable by the WWSSN has been measured.

The association with an active ridge leaves little doubt that the recorded microearthquake activity is caused by seafloor spreading processes, although the specific origin is more difficult to determine. Sykes (*J. geophys. Res.*, **75,** 6598; 1970), who investigated ridge swarms elsewhere recorded by the WWSSN, attributed such swarms to volcanic, hydrothermal or magmatic processes on the ridge crest; and it seems probable that one or more of these processes are also responsible for the Galapagos events. Williams *et al.* (*Eos*, **54,** 244; 1973) suggested that hydrothermal circulation may be an important method of heat transfer at the Galapagos ridge crest, for heat flow there can be greater than 30 heat flux units and narrow, near-bottom, positive water temperature anomalies of several hundredths of a degree have been found over the crest near, as it now turns out, the source of the microearthquake activity. But what is probably the most convincing evidence comes from the Macdonald-Mudie study itself. The b value for the Galapagos events (the frequency-magnitude parameter in the relation $\log N = a - bm_b$, where N is the number of events of magnitude m_b or greater) is very high at 3.0, which is consistent with a volcanic or magmatic source but not with the generally much lower b values for fracture zone events.

Flowing superfluid films

from Peter V. E. McClintock
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THE thickness of a superfluid helium film below 1 K is reduced by an increment which varies quadratically with the velocity at which the film is flowing, according to an experiment by Williams and Packard of the University of California at Berkeley (*Phys. Rev. Lett.*, **32,** 587; 1974).

Some of the most dramatic demonstrations of superfluidity in liquid ^{4}He below its superfluid transition temperature at 2.18 K are found in the remarkable phenomena associated with helium films. Any surface dipping into the liquid rapidly becomes covered with a film whose thickness depends on the nature of the surface, and the height above the bulk liquid, but which is usually a few hundred Å.

Up to a certain critical velocity the film encounters no resistance to its motion and, being thus enabled to flow freely at several tens of cm s^{-1}, can act as a channel through which relatively large volumes of the liquid can be transferred: in fact the film can act as a syphon through which a small vessel of helium will empty itself in a matter of minutes, the helium flowing up the inner wall and then down the outside.

The film is held in position by the attractive Van der Waals force between the wall and the helium atoms, and measurements of the thickness of static films are found to be in reasonable agreement with theoretical predictions based on the assumption that the film always adjusts itself so as to minimise its total potential energy in the combined Van der Waals and gravitational potentials.

In the case of a flowing film, however, it may not be possible for the thickness to reach this equilibrium value since the velocity of flow is limited to the critical velocity, above which dissipative processes set in very rapidly. Although the situation is very complicated, Kontorovich was able to show (*Zh. eksp. teor. Fiz.*, **30,** 805; 1956) that, under these conditions, the thickness should be reduced by an amount depending on the square of the flow velocity.

Subsequent experiments above 1 K in a number of laboratories, however, demonstrated conclusively that the thickness was actually independent of the velocity. A possible explanation of this apparent conflict between theory and experiment was given by de Bruyn Ouboter (*J. low Temp. Phys.*, **12,** 3; 1973) who pointed out that Kontorovich's analysis had considered equilibrium conditions only within the film itself and had ignored the influence of the surrounding helium vapour: a flowing film in internal dynamic equilibrium would clearly be in disequilibrium with the vapour which, by condensing, would tend to bring the thickness back to its value for a static film. One obvious experiment to test this hypothesis was to repeat the measurements at temperatures below 1 K where the saturated vapour pressure is so small that condensation on the moving film would be a negligible effect. This is the experiment which has now been carried out by Williams and Packard.

Their experimental cell was cooled by means of a dilution refrigerator to temperatures well below 1 K, and was designed to measure the transfer rate of helium between two reservoirs, while at the same time monitoring the thickness of the flowing film. The latter measurement was performed by making the film flow between a pair of capacitor plates so that a change in its thickness resulted in a small change in their capacitance, which could be measured externally. By this means, changes as small as 2 Å could be detected. By using a second pair of capacitor plates to form the walls of one of the reservoirs, the volume of liquid present could be measured as a function of time, thus enabling the film flow rate to be deduced. The authors found that the film became considerably thinner when flowing, than when it was static. At 0.26 K with a