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cates that a lot of heat was produced (*8*), which would have been sufficient to generate melt if the width of the slipping zone was narrow (less than 30 cm). In addition, the source process was highly dissipative, indicating that little of the available energy was radiated seismically and suggesting that much of the energy may have been used in melting material near the fault.

The details of the melting model are speculative, in that the width of the slip region cannot be determined from seismic analysis and is thus unconstrained. In addition, no specific mechanical model by which the melt promotes crack growth has been proposed. Models that have been proposed to explain melting in shallow faults that are observed geologically (pseudotachylytes) offer a possible analog. In one such model (see figure), a zone of frictional melt production moves with the rupture front along the fault (*9*). Melt covers the fault within the slip region, thus providing lubrication that facilitates slip. Melt injection under high pressure may also occur ahead of the melt zone, facilitating crack propagation through the medium. Melt production tends to reduce friction along the fault, but this action will then reduce the production of melt. In this way, an equilibrium between friction, melt production, and melt lubrication may be reached, allowing the fault to propagate smoothly.

Another major question is what initiates the crack propagation that grows into the large earthquake rupture. Melt can only lubricate the fault after it is produced by friction along an already slipping interface, so the melting model makes no statement about what type of instability creates the initial slip. One possibility is that transformational faulting initiates the rupture, which then propagates through the melting mechanism proposed by Kanamori *et al.* If true, the melting mechanism may explain why the fault widths of the largest deep earthquakes are incompatible with the transformational faulting mechanism and also suggests why other large deep earthquakes can propagate outside of the Wadati-Benioff zone formed by smaller earthquakes (*10*).

A melting model for deep-earthquake fault propagation may also help to explain growing evidence that the deep-earthquake rupture process is fundamentally temperature sensitive in a way that shallow earthquakes are not. For example, deep earthquakes show much different magnitude-frequency relations and aftershock production in different subduction zones, with warmer slabs showing much lower occurrence rates for small earthquakes and very few aftershocks (*11*). In addition, there is some evidence that the rupture parameters of the largest deep earthquakes are also correlated with slab temperatures (*12*). Melt-assisted faulting would presumably be sensitive to the temperature of the slab material and may operate well only in warmer slabs such as South America.

It is not clear whether this proposal can explain all deep earthquakes. The very characteristics that suggest melting for the Bolivia earthquake—the high stress drop, low rupture velocity, and low seismic efficiency—are actually the characteristics that make it seem most anomalous. For example, both of the other recent large deep earthquakes (1994 Tonga and 1996 Flores Sea) show lower stress drop, higher rupture velocity, and higher seismic efficiency (*10, 12, 13*).

Therefore, the melting model of Kanamori *et al.* may only be applicable to the largest deep earthquakes, a group that includes the 1954 Spanish deep earthquake and the 1970 Colombia event, in addition to the 1994 Bolivia earthquake. These earthquakes seem to occur only in regions without smaller earthquakes, suggesting that temperatures there may be too hot for the nucleation of typical earthquakes, and that a melting "runaway" effect may result in great earthquakes once shear failure is initiated. Ideally, we would like to observe a larger number of these events to clarify the true nature of these unusual earthquakes. Unfortunately, these isolated, exceptionally large earthquakes are very rare, and seismologists will probably be kept waiting for years, if not decades, for another event like the 1994 Bolivia earthquake.

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Edited by David Voss

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