quiescence. This suggests that during quiescence, matter is supplied to the outer parts of the disk but only a very little, or no, matter flows through the disk. By studying the changes in luminosities of the dwarf, disk and spot it is possible to estimate that the amount of matter accreted onto the spot during quiescence equals the amount accreted onto the dwarf during eruption¹⁵. This suggests that matter is gradually accumulated in the outer parts during quiescent periods and accreted onto the dwarf during eruptions^{3,4,15-17}. Such a picture, supported by a theoretical model developed by Paczyński, is consistent with other observational data. In my view it gives the strongest argument for the model based on intrinsic disk instabilities.

If the mass transfer rate sharply increases during eruptions, one may expect a simultaneous increase of the luminosity of the spot. It is hard to explain in model I why such an increase is not observed. (Bath *et al.*¹⁸ argue that this is because the stream initially penetrates into the disk.)

So, why does U Geminorum erupt? Most astronomers working in the field favour the model based on intrinsic disk instabilities and I agree with them. Both models, however, have some weak points and they do not explain all the available data. For this reason it would be best, perhaps, not to try to give a categorical answer at this stage. It is likely that the controversy will stay with us for some time to come. Even when, in the future, one model is finally accepted, it should not be taken to mean that theoretical work on the other was done in vain. On the contrary: both models have already contributed greatly to our understanding of cataclysmic variables and, even more importantly, to the development of the theory of accretion disks — one of the most fundamental theories in modern astrophysics. □

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Earth science

Extensive oceanic lava flows?

from Peter J. Smith

BASALT lava flows on land can extend over huge distances. For example, some of the individual flows in the Columbia Plateau lava sequence of the western United States have spread up to 300 km from their source, and others can be traced over tens of kilometres without any noticeable change in thickness. In the oceanic ridge environment, by contrast, such impressive flows have hitherto been thought impossible. It is not that lava flows do not exist in the upper oceanic lithosphere; on the contrary, deep-sea drilling and the study of ophiolites have shown that although oceanic Layer 2A (the igneous layer immediately beneath sedimentary Layer 1) largely comprises pillow lavas, it is interbedded with sediment and sheet lava flows. Such flows are, however, often said to be of limited extent, having resulted from local eruptions whose products fail to travel very far because of rapid cooling by seawater. In the Galapagos rift, for example, the largest sheet flows appear to extend no more than 7 km from the eruptive centre.

Yet the restrictions on the underwater flow of lava may have been overestimated. Some years ago, Harrison and Rooth (in *Volcanoes and Tectonosphere*, Tokai University Press; 1976) showed theoretically that magma extruded at a modest temperature of 1,250°C on land should be able to produce a thin (< 10 m) flow extending 300 km from the source, given a slight slope (10^{-2}). They then extended their analysis to underwater flow. As far as the base of a lava flow is concerned, the thermal behaviour is largely independent of environment; heat is lost by conduction to the material below. At the upper surface, on the other hand, a subaerial flow will lose heat largely by radiation whereas an underwater flow will cool largely by convection, although Harrison and Rooth concluded that the rate of heat loss would differ by a factor of less than two. In other words, water may well be less conducive than air to the generation of extensive flows, but not so much less that extensive flows should not form on the ocean floor at all.

With this theoretical result as a starting point, Davis (*Bull. geol. Soc. Am.* 93, 1023; 1982) has looked at two oceanic regions and finds that extensive underwater flows, though perhaps rare, may indeed exist. The first area is the Juan de Fuca ridge at about 47°N (north-east Pacific). Here the ridge crest morphology is simple and symmetric; there is a central volcanic ridge, probably of pillow lava, resting on a pre-existing valley floor. The floor is for the most part flat and acoustically smooth; and the depth of the

floor is remarkably uniform, varying by less than 30 m in 30 km along the valley axis. This uniformity and smoothness, claims Davis, is precisely what would be expected in a valley floor comprising massive sheet flows stretching over at least the 30 km of the survey region, an interpretation supported by dredge samples and bottom photography.

Unfortunately, an identical effect would probably have been achieved by a series of local lava sources connected hydraulically in such a way that the eruption pressure was everywhere the same; and as there is so far no way of ruling out such a possibility, the existence of extensive flows in that part of the Juan de Fuca ridge must be considered unproven. Some 4° further north, however, in the Dellwood Knolls area of the Juan de Fuca ridge system, the evidence is less equivocal. Here there is believed to be a new (less than a million years old) spreading centre which, unlike most other spreading centres, is covered by thick turbidite sediments from a nearby continental margin (British Columbia). The evidence for extensive lava flows comes from seismic reflection profiles, which indicate the existence on and in the turbidites of numerous lava flows, some of them extending up to 60 km from their source at the Dellwood Knolls. Indeed, some of the flows are so conspicuous in reflection that it would be easy to mistake them for basement, the surface of which is actually well below.

It has to be admitted that the combination of circumstances in the Dellwood Knolls region was unusual. When spreading began, the area was already covered by almost flat-lying turbidites; and rapid sedimentation continued along with the episodic extrusion of lava. The smooth, thermally resistive and mechanically competent sedimentary surface provided ideal conditions for the formation of extensive flows; and the continued sedimentation led to a separation of individual lava flows, rendering them detectable by seismic reflection. Ridge crests are usually free of sediment and, being rugged, leave little scope for unconfined flow. Moreover, even where sediments are present, they do not always have the mechanical strength to support flows (for example, in the Gulf of California). The conditions under which extensive flows can form on the ocean floor are therefore rare but, if Davis's interpretation is correct, they are not non-existent. □

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