Ken,

Thanks again for these follow up discussions/postings on the recent Endeavour event response. If I may, I'd like to briefly interject a few points.

First, it definitely is true that from seismicity alone we can't be sure if a dike reached the seafloor. But another key point to remember too is that whether a dike breaks the surface or not, just the physical process of injecting magma may cause faulting/fissuring that results in the release of an "event" plume. This is an important question and one we were hoping to gather more information about with the response cruise.

Second, you make several important points about the interpretation of the seismicity data. During the overwhelming effort to locate the earthquakes as quickly as possible and provide a rapid evaluation of the earthquake swarm to our sea-going colleagues, we were probably not as thorough in our presentation of the data on our website as we would like to have been. I will take this opportunity now to clarify a couple of misconceptions:

1) We did not interpret the apparent migration of the earthquakes during the Endeavour swarm as tracking the motion or movement of magma at depth. The migration distance is small (<20 km) and much of it is within the location error of the earthquakes and therefore was not used as a defining criteria in deciding on a response cruise.

2) At the onset of all of the JdFR-Gorda Ridge earthquake swarms detected on SOSUS that we have responded to (a total of five), there has been continuous, broad-band energy (3-30 Hz) that accompanied the seismicity. We have interpreted this energy as "intrusion" tremor, similar to tremor observed at Krafla Volcano in Iceland (Brandsdottir and Einarsson, 1992). Intrusion tremor accompanies the injection of small magma dikes and stops once the magma reaches the surface or the dike stops propagating. Alternatively, “harmonic” tremor, as defined by Chouet (1992, 1996) is a sustained, low-frequency ground vibration that exhibits evenly spaced spectral peaks. Harmonic tremor has been observed on active subaerial volcanoes throughout the world and has been attributed to resonance of a volcanic conduit or fluid-filled cavity. To my knowledge, there are no examples of harmonic tremor being detected from a mid-ocean ridge at regional distances (>100 km) by a seismo-acoustic network, either on SOSUS or by the French Polynesian T-phase network that has been monitoring the EPR for the last 25+ years (Talandier and Okal, 1987). On the other hand, we have several examples of harmonic tremor from submarine island-arc volcanoes in the western Pacific recorded on SOSUS (Dziak and Fox, 2002) and it is very easy to distinguishing between island-arc harmonic tremor and mid-ocean ridge intrusion tremor.

I think your idea of developing formal response criteria is a good one; it has been something we on the TCS committee have been working toward for sometime now. But for the reasons I point out, some care has to be given even to the seemingly straightforward criteria you laid out (i.e. time-magnitude anomalies, harmonic tremor and presence of a magma chamber). The highest priority over the next several months for myself and the TCS group will be to write a paper summarizing all of the seismicity,

seafloor, and water-column observations we have made during our response efforts to try to distill characteristics unique to a plume-producing, dike-injection event along mid-ocean ridges.

Best regards,

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References

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