Field evidence for substrate entrainment by pyroclastic density currents and its effect on downstream dynamics at Mount St Helens, Washington (USA)

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Despite recent advances in the study of pyroclastic density current (PDC) dynamics, several fundamental aspects of the behavior of these hazardous currents remain poorly understood. Perhaps two of the more significant gaps in our knowledge are the primary control(s) on substrate erosion and the effect that substrate entrainment, i.e. bulking, has on current dynamics. Perhaps the largest limitation to a comprehensive investigation into this topic previously was the lack of sufficient exposures to confidently identify depositional evidence for substrate entrainment, the source of entrained blocks, and the effect on downstream flow dynamics. However, more than thirty years of erosion into the May 18, 1980 PDC and debris avalanche hummock deposits at Mount St Helens has revealed kilometers of new outcrops containing substantial evidence for erosion and entrainment. Here we present evidence for the entrainment of lithic blocks (>1 m in diameter in some locations) from the debris avalanche hummocks, as determined through detailed componentry and granulometry studies on the PDC deposits and debris avalanche hummocks where the lithics were derived. We find that in some locations up to 50 percent of the lithics found in lithic-rich PDC facies appear to have been locally derived from the debris avalanche deposits. We also observe numerous scours filled with block-rich lithic facies downstream from hummocks where lithic plucking has been determined. This suggests that erosion is a self-perpetuating process; when substrate entrainment occurs the increased bulk density and concentration gradient that result in the current enables further erosion and entrainment downstream from the location where bulking initially occurred. In addition, the presence of large, locally entrained lithics at various heights within a single flow unit suggests both a progressive entrainment of the substrate as well as a progressive aggradation of the deposit, depending on localized flow conditions. However, as the hummocks were progressively filled in during the eruption, the amount of entrained substrate material decreased to zero, suggesting that surface roughness is important for promoting erosion by PDCs. Taken together, these results suggest that the incorporation of substrate material by PDCs has a significant impact on PDC dynamics and deserves to be investigated further. It is possible that with the combination of field investigations, laboratory experiments, and numerical modeling a more complete understanding of how erosion and entrainment affect PDC dynamics can lead to a more accurate hazard assessment for these dangerous currents.