Overview
Grain size characteristics of pyroclastic deposits provide valuable information about source eruption energetics and depositional processes (Fig. 1). In the submarine environment the collection of such data is extremely challenging and time consuming. An image processing algorithm developed to extract grain size information from stereo images collected by a remotely operated vehicle (ROV) is likely to be valuable in the analysis of submarine explosive volcanism given the recent discoveries of extensive pumiceous deposits in many submarine calderas associated with subduction zone environments.

Kolumbo Volcano
Images gathered at Kolumbo, a submarine volcano located off the coast of Santorini, Greece (Fig. 2), exhibit distinctive stratified pyroclastic deposits. The pumice-rich deposits were likely created by the last explosive eruption of the volcano that took place in 1650 AD.

Clast Identification
Clast identification is fundamental for grain size analysis. Starting with a 12 bit color stereo image (Fig. 5) the image processing sequence includes a histogram adjustment, a thresholding operation to remove the image background, morphological operations to isolate clasts, an edge detection to find boundaries, and shape and size estimation to give a representation statistics within an image (Fig. 6). The determination of individual clast outlines proved to be challenging due to the close packing and overlapping of individual pumices, shadows and low contrast. Success was achieved in using an ellipse estimation which models clast shape and proved robust to aggressive thresholding loss (Fig. 7). Measurements were carried out on the largest clasts present at different stratigraphic levels.

Remote Analysis of Grain Size Characteristic in Submarine Pyroclastic Deposits from Kolumbo Volcano, Greece.
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Clast Estimation Results
Maximum clast size and sorting are often used to discriminate between fallout and sediment gravity flow processes during explosive eruptions. In addition, semi-quantitative analysis of the size distribution can also be determined for individual images (Figs. 8-11). Although a complete size distribution is not possible with this technique, information about the relative distribution of large and medium size clasts is likely to provide a reasonable proxy for the overall sorting of submarine deposits. Using calibrated stereo image pairs, the actual size of the clasts can be found based on the pixel area.

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