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Remote Analysis of Grain Size Characteristic in Submarine Pyroclastic Deposits from Kolumbo Volcano, Greece

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Remote Analysis of Grain Size Characteristic in Submarine Pyroclastic Deposits from Kolumbo Volcano, Greece.

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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.

Fig.1 Image of stratified pyroclastic deposits

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.

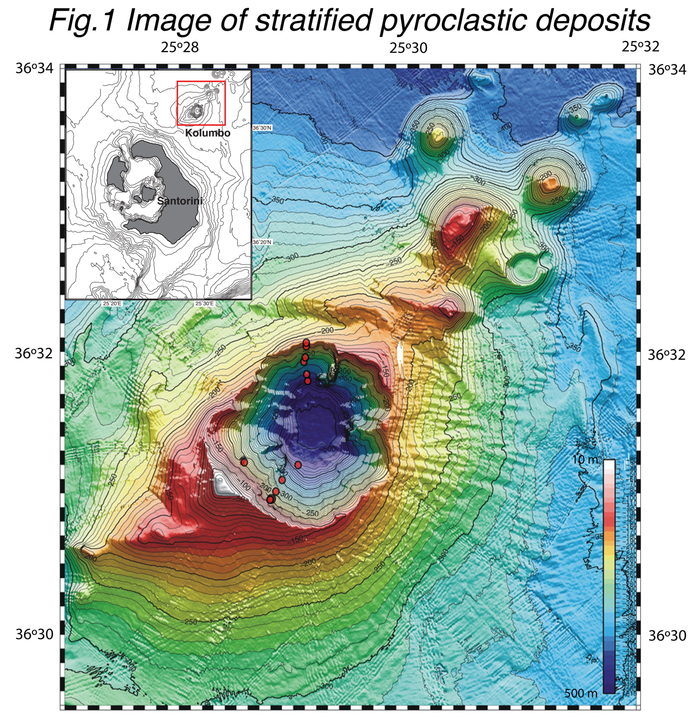

Fig. 2 Bathymetric map of the Kolumbo volcano crater, near Santorini, Greece.

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 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.

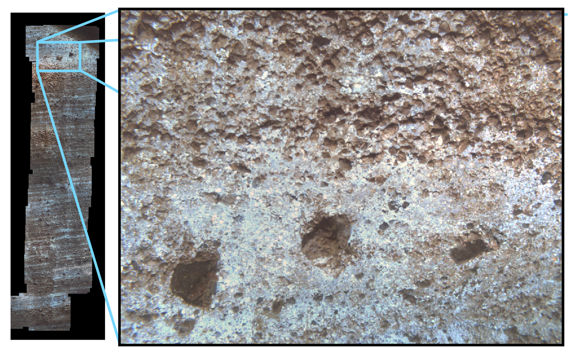

Fig.5 Original color 12 bit stereo image for this example, and its location within the photomosaic.

Clast Extraction Algorithm

Locate

Equalize

Fig.6a Adaptive histogram equalization enhances grayscale image contrast.

Threshold

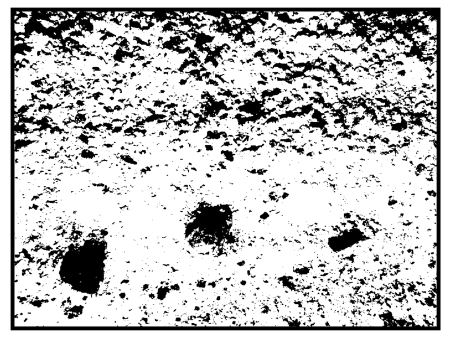

Fig.6b Aggressive thresholding separates the clasts from the background in a binary image.

Clean

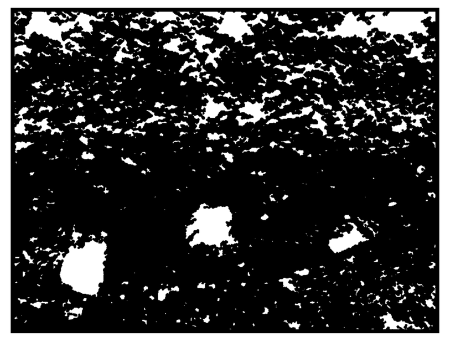

Fig.6c Distinctive clasts result from inverting the image, filling holes, and morphological cleaning operations.

Model

Centroid

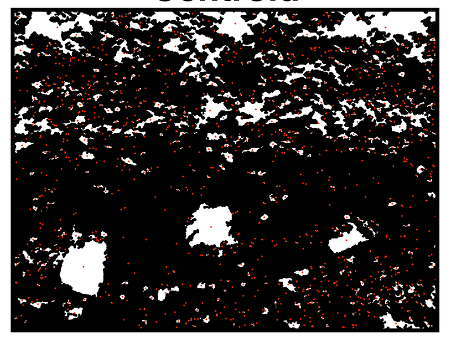

Fig.6d The location of each clast is determined by finding its centroid.

Fit Ellipse

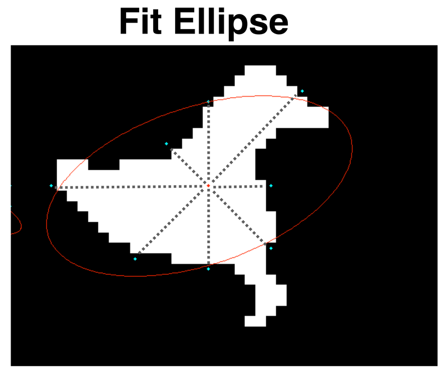

Fig.6e The ellipse estimation of each clast is completed by fitting an ellipse to eight points on the clast edge.

Represent

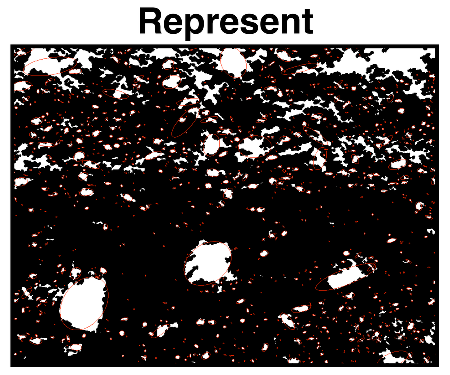

Fig.6f The resulting ellipses estimate the clasts size and location.

Photomosaic

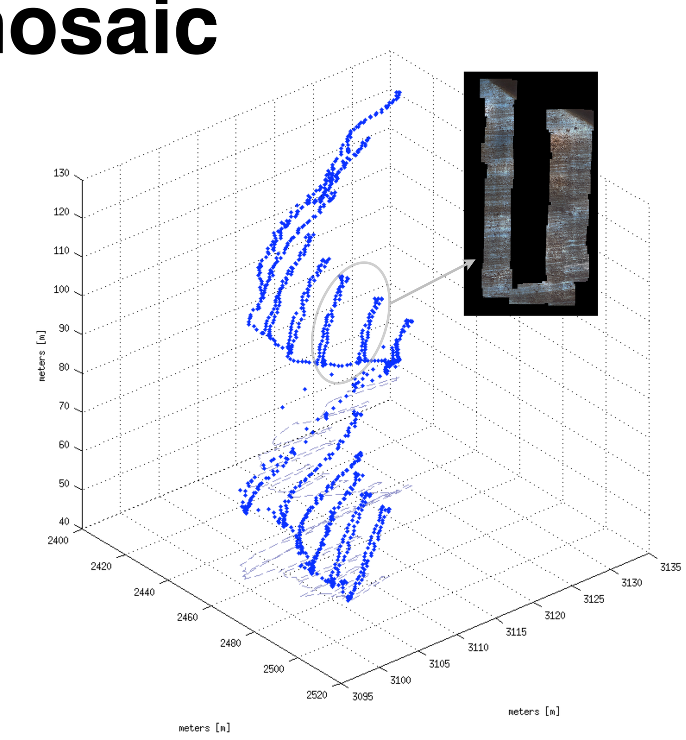

Fig.3 Isometric plot of the ROV navigation along the outcrop. Each point represents an image. Combined images form vertical photomosaic (inset).

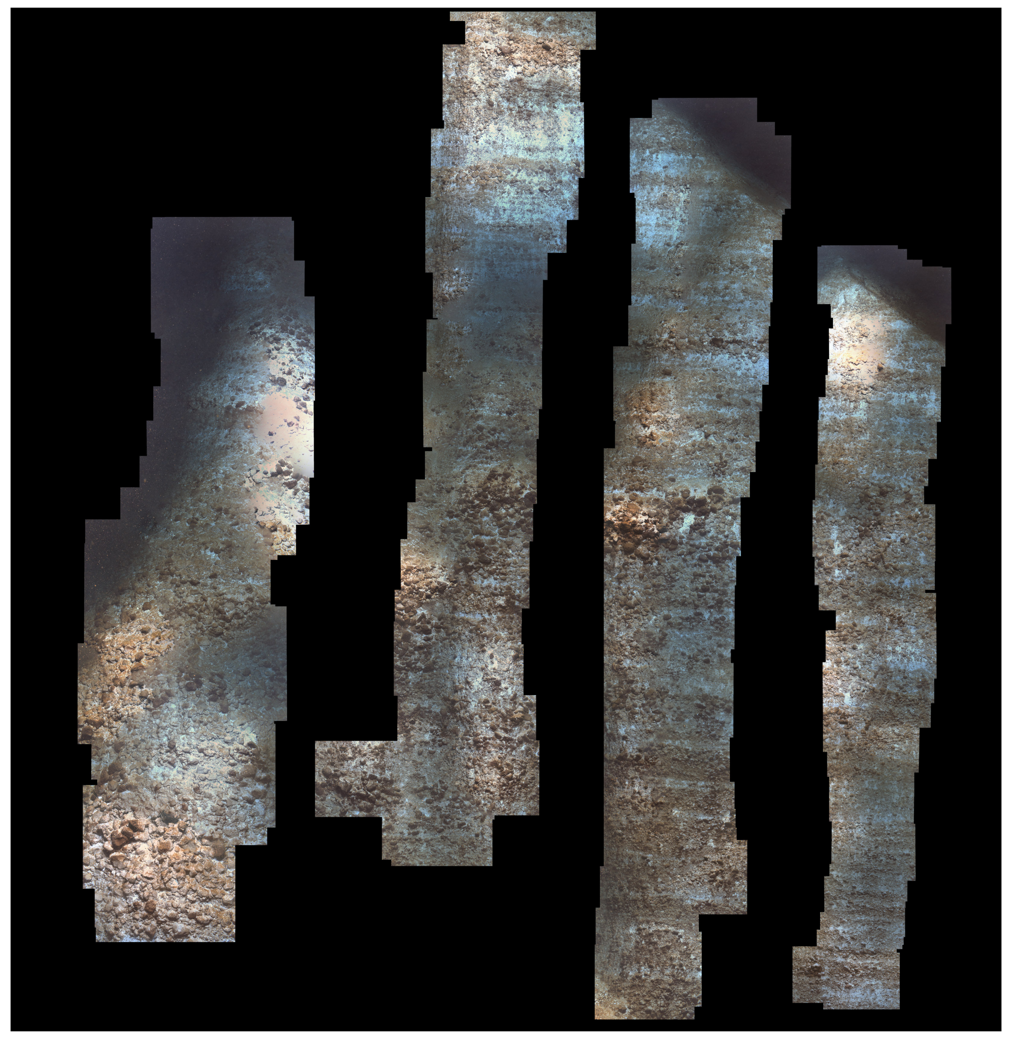

Fig.4 Sample photomosaics created from vertical transects of the outcrop. Each mosaic strip consists of approximately 60 images.

Clast Estimation Results

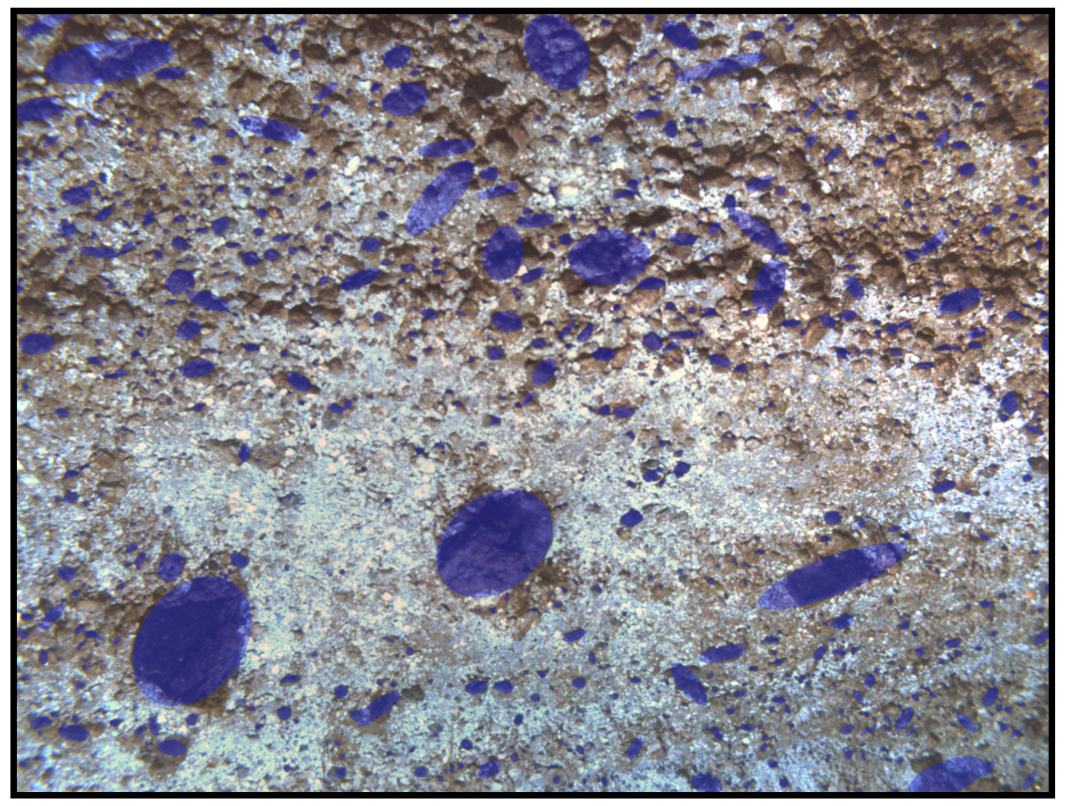

Fig.7 Resulting ellipse estimation overlay (blue) on the original image. Large clasts are well extracted, while shadows, tight packing and overlap make smaller clasts less distinct

Image Acquisition

During the summer of 2010 the ROV Hercules collected a suite of stereo images from a thick pumice sequence in the crater walls of the Kolumbo submarine volcano, near Santorini, Greece. Hercules completed transects, three meters from the wall, collecting images with forward looking stereo cameras (Fig. 3, 5). Each vertical transect was between 10 and 30 meters tall. The resulting survey images preserve the outlines and detail of the clasts.

The images captured during these vertical transects of the outcrop are combined into high resolution photomosaics. These large-scale vertical stratigraphic columns prove useful for overall documentation of the eruption sequence and intracrater correlations of distinct tephra units (Fig. 4).

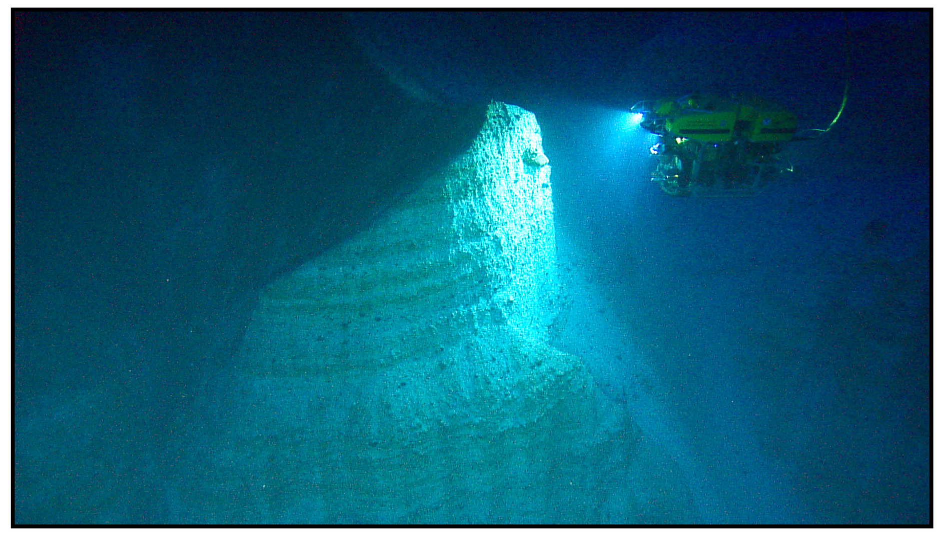

Fig. 5 The ROV Hercules completing transects of the an outcrop within the Kolumbo crater while capturing stereo images.

Clast Analysis

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.

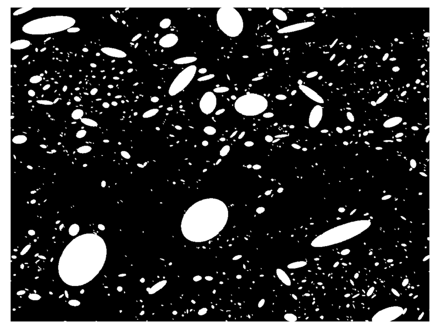

Fig.8 Ellipses of all sizes represent the clasts within the image

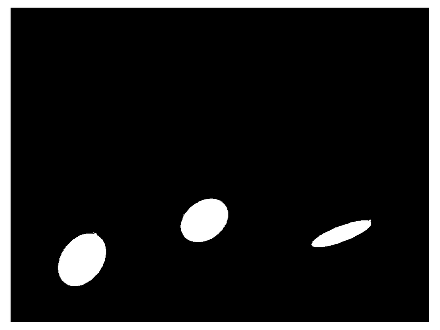

Fig.9 Only clasts with an area of more than 4500 pixels are shown, visualizing the distribution of the largest clasts within the image.

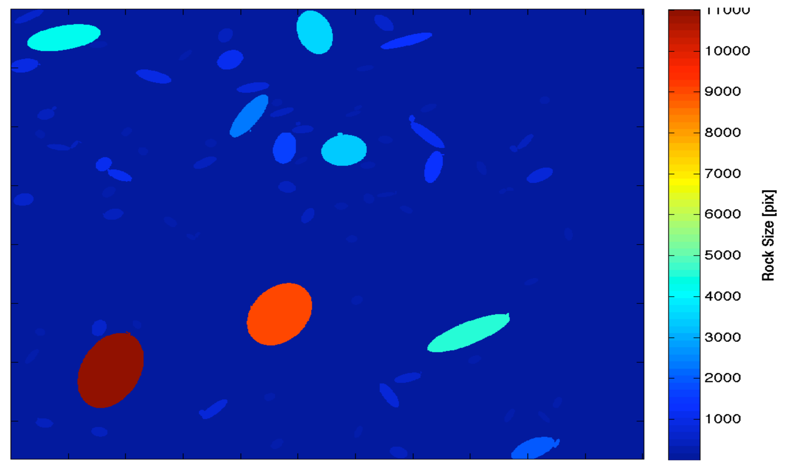

Fig.10 Clast size sorted by color, a quick visual representation of clast distribution.

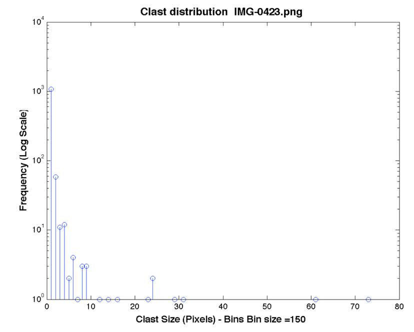

Fig.11 Histogram of the clast size distribution for the entire image.

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