# Variations in magma supply ~900 $km^2$ of the Mid-Atlantic Ridge at 16.5°N

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## 1. Introduction

Small scale (10-1000 m) volcanic edifices present in bathymetric maps of mid-oceanic ridges (MORs) can be used to investigate spreading mechanisms and spatiotemporal variations in magma supply to the ridge. A morphological analysis was performed on four sets of high-resolution (~0.5 m) bathymetry maps located within ~40 km along the Mid-Atlantic Ridge (MAR) around 16.5ºN. The study has two objectives. First, to document any variation in the volcanic and tectonic budget with respect to distance from the axis. "Standard" symmetric spreading models predict that tectonic strain should increase away from the axis—but this relation may not be valid above an oceanic core complex, which is suspected to be present in the asymmetric area of study. Second, the project addresses the relative importance of volcanism between the four areas of high-resolution bathymetric coverage.

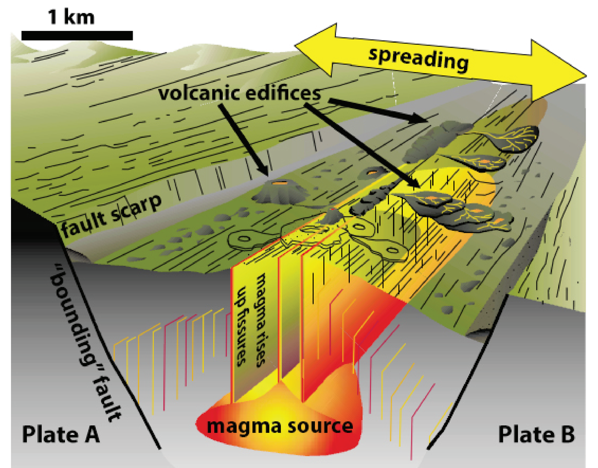


**Figure 1** Magma in the spreading zone of a mid-ocean ridge (MOR) accretes to both plates as it rises up a fissure, then extrudes from the seafloor to form volcanic edifices. (Adapted from Smith and Cann, 1999)

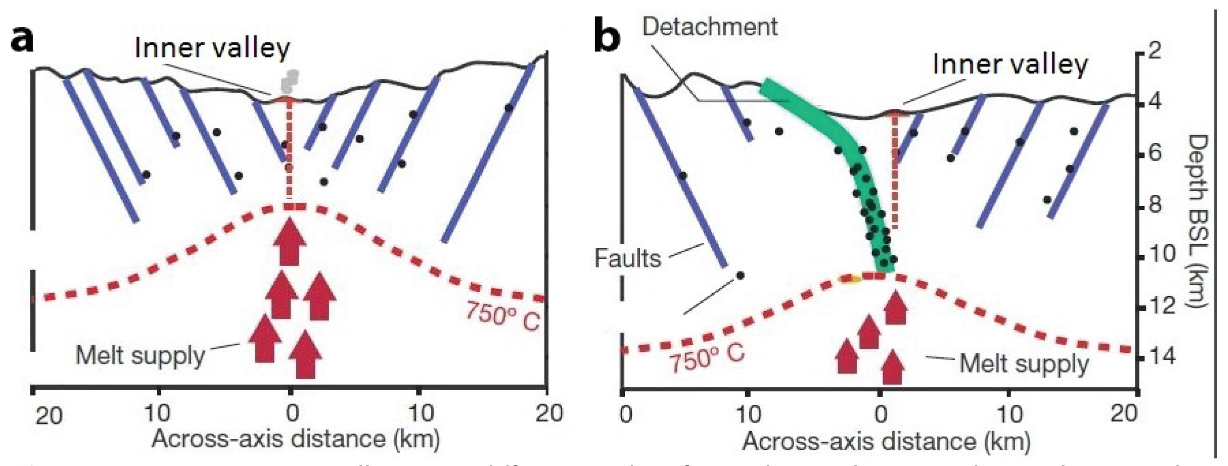


**Figure 2** Across axis sections illustrating different modes of spreading at slow-spreading mid-ocean ridges. **a)** With symmetrical spreading, less than 20% of spreading is accommodated by faults, whereas with asymmetric spreading **b)**, a single detachment fault accommodates up to half of spreading. Detachment faults can form core complexes. The black dots correspond to earthquakes. (Adapted from Escartin et al., 2008)

## 2. Hypotheses

1. Magma supply increases from north to south along axis; consequently, volcanism increases from north to south in area of study

2. In the $10^6$ yrs required to build the MOR inner valley, magma supply has remained constant along the ridge; consequently, volcanism will remain constant with with distance from ridge axis

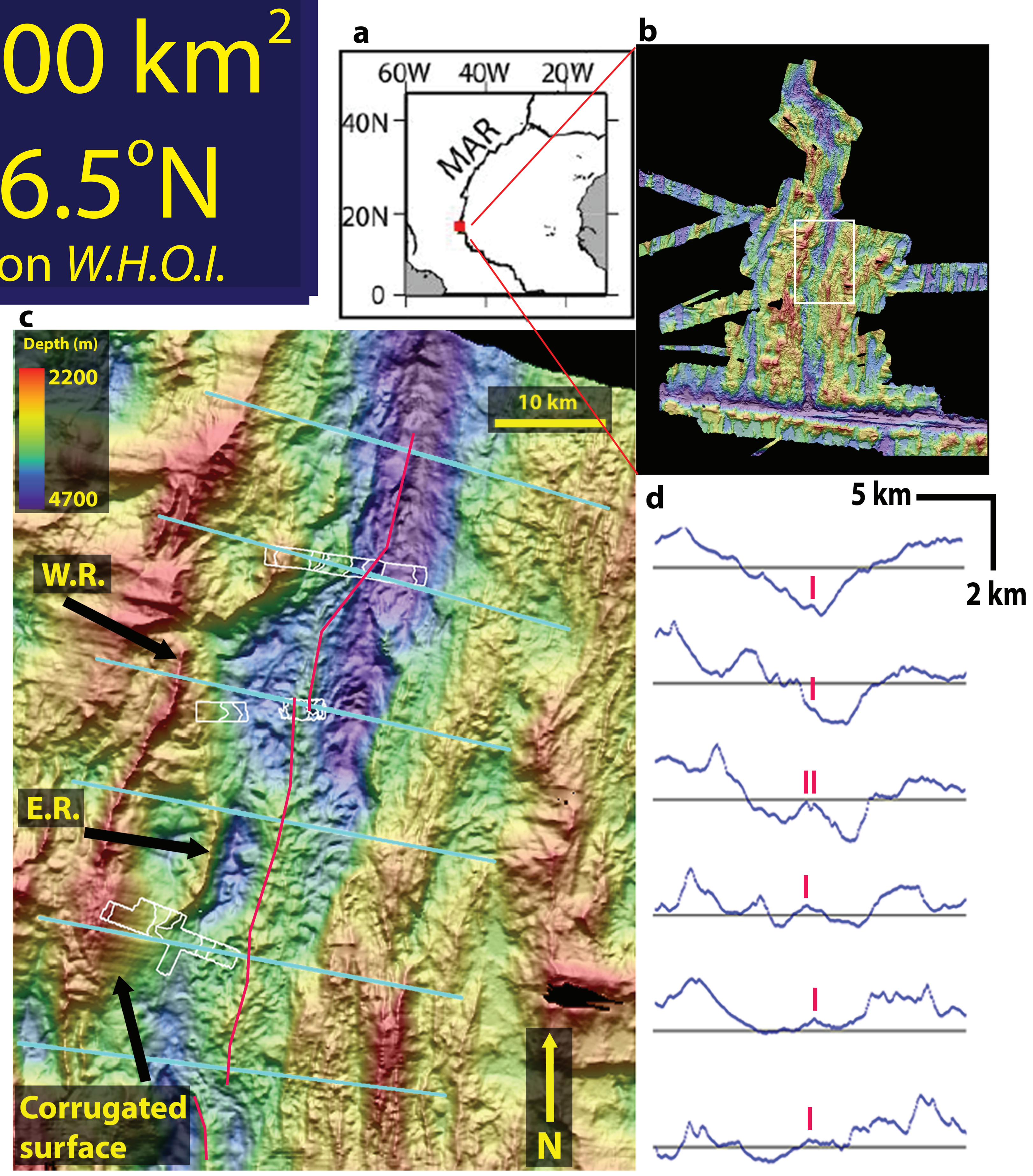


**Figure 3 a)** The red box indicates the location along the MAR of **b)** the region containing the area of study (outlined in white). **c)** The area of study contains an asymmetric ridge (approximated by central red line); white lines bound areas for which *Sentry* gathered high-resolution bathymetry data; East Ridge (E.R.) and West Ridge (W.R.) are interpreted to be the rotated tops of detachment faults, a manifestation of the tectonic activity of the region. The corrugated surface is indicative of a long-lived detachment fault forming a core complex. **d)** Profiles of the ridge and inner valley taken along the blue lines in c). The black horizontal lines are at 3500 m depth, the red lines approximate the horizontal location of ridge axis.

## 3. Experimental Method

Geographic Information Systems (GIS) integrate bathymetry data with interpretations of seafloor morphology at multiple scales, enabling a quantitative analysis of the volumes of volcanic edifices and the spatial distributions of these volumes.

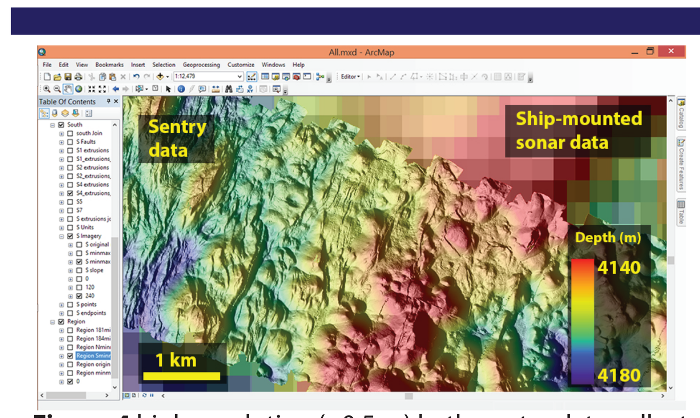


**Figure 4** high-resolution (~0.5 m) bathymetry data collected by Autonomous Underwater Vehicle (AUV) *Sentry* overlaid on low-resolution (~150 m) bathymetry data collected directly from R.V. Knorr. Data visualized in ArcGIS with partially transparent depth color ramp overlying shaded relief map.

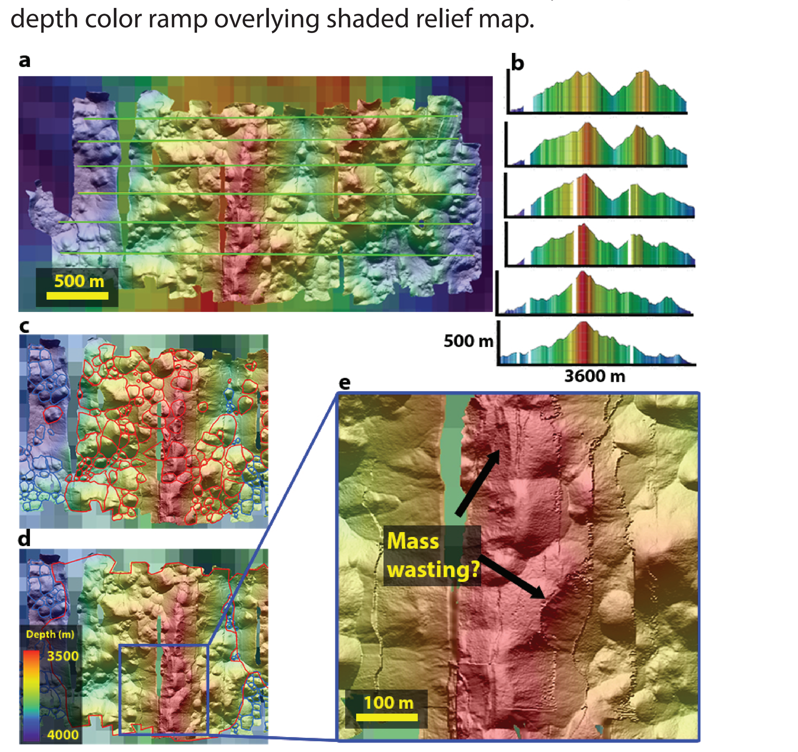


**Figure 5 a)** Units C1-C6 (not demarcated); **b)** Profiles taken along the green lines in a) reveal the strikingly triangular cross section of the ridge; **c)** Ridge defined by red polygons as individual hummocks; **d)** Ridge defined in red as one unit; **e)** Possible mass wasting on ridge

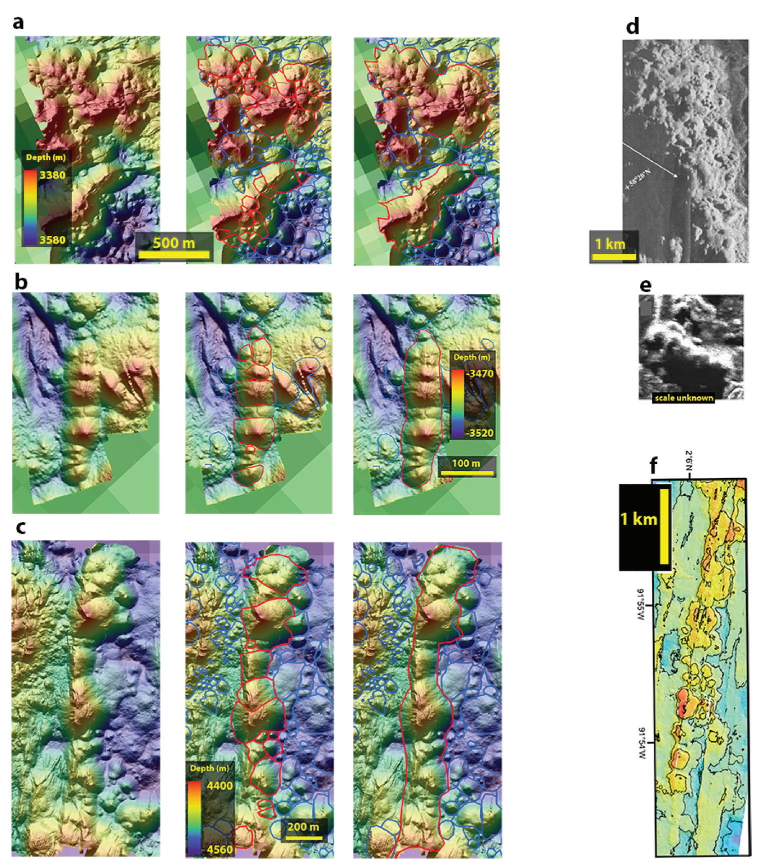


**Figure 6** ridges and hummocks from **a)** S1, **b)** S2, and **c)** N2; in each example, left image shows undefined perimeters, middle image shows individual hummocks defined, right image shows ridges and individual hummocks defined; d) from the Reykjanes Ridge (Smith, 1995); h) from the MAR at 45°N (Searle et al., 2010); l) from the Galápagos Spreading Center (Colman et al., 2012)

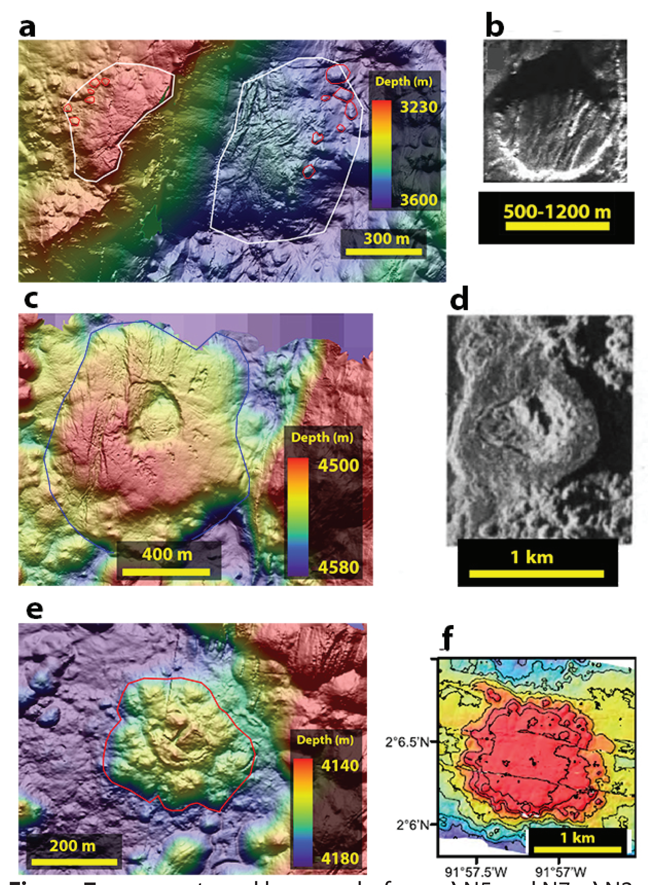


**Figure 7** seamounts and hummocks from **a)** N5 and N7, **c)** N2, and **e)** N3; seamounts from **b)** the MAR at 45ºN (Searle et al., 2010); **d)** with collapsed central crater, from the northern MAR (Smith and Cann, 1993); **f)** from the Galápagos Spreading Center (Colman et al., 2012)

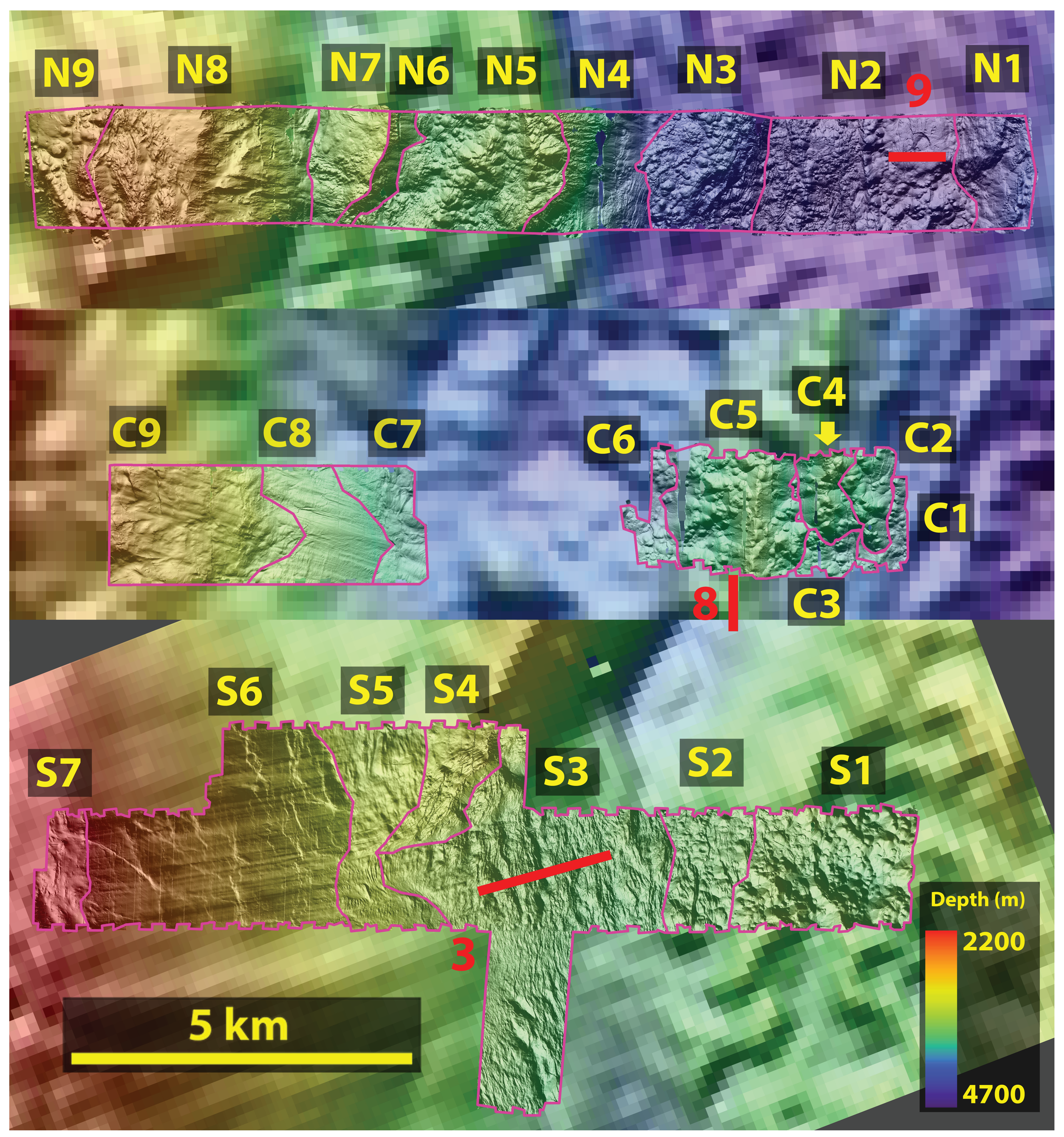


**Figure 8** High-resolution bathymetry maps analyzed in this study, with color ramp and shaded relief layers. Units are defined based on features visible at this scale, such as fault scarps, ridges, changes in seafloor morphology, and abrupt changes in slope visible in slope maps (not shown). Map areas are true to scale; orientations of maps and distances between maps have been altered (except C7-C9 and C1-C6 relative to each other). TowCam runs are approximated by red lines.

## 4. Results

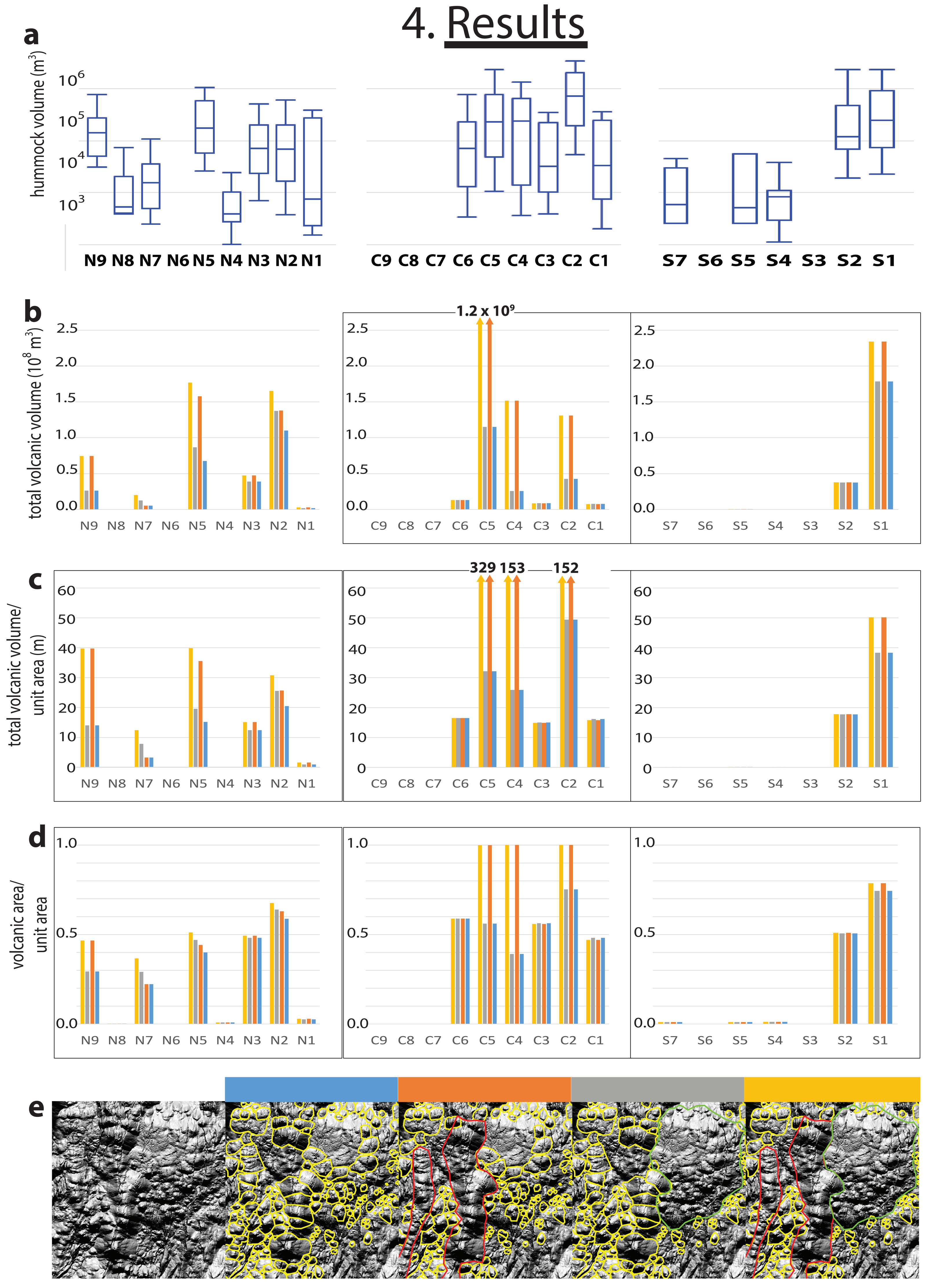


**Figure 9 a)** box and whisker plots of distribution of individual hummock volumes (hummock constructs ridges and seamounts are ignored), plotted by unit. Each horizontal bar represents, from top to bottom, the 90th, 75th, 50th, 25th, and 10th datum, respectively; **b)** total volcanic volume, plotted by unit; **c)** total volcanic volume per unit area, plotted by unit; **d)** total volcanic coverage per unit area, plotted by unit; **e)** *ArcMAP* images from unit N2 showing seafloor before interpretation (left), followed by the four different volcanic edifice classification schemes used for respective analyses (color bars correspond to bar graphs above) from left to right: individual hummocks (yellow); hummocks + ridges (red); hummocks + seamounts (green); hummocks, seamounts + ridges

1. Distributions of individual hummock volumes vary significantly off-axis (Figure 9a) in north units, and decrease abruptly from east to west in south units

2. When only hummocks are considered volcanic edifices (Figure 9a and blue bar graphs in 9b-9e), units S1 (Figure 9b) and C2 (Figure 9c) are the most volcanic units (C2 is the most volcanic when volume is normalized by unit area)

3. When hummocks and ridges are considered volcanic edifices (Figure 9 orange bar graphs), units C2, C4, and C5 are the most volcanic units

4. By all measures except individual hummock size (Figure 9a), northern area units are less volcanic than the most volcanic central and southern area units

## 5. Conclusions

Analyses in *ArcMAP* and *Fledermaus GIS* programs show that:

1. volcanic extrusion generally increases in magnitude from north to south along the ridge

2. Rates of volcanic extrusion have varied over time along the ridge