Geomorphology of the Sumatra Subduction Zone: Expressions of Tectonic and Seismic Activity

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Abstract

Bathymetric data were collected in 2015 off the west coast of Sumatra by Earth Observatory of Singapore scientists on the R/V *Falkor* using a Kongsberg EM302 and EM710. The Java Trench subduction zone between the Indo-Australian and the Eurasian Plates has high potential to cause catastrophic earthquakes and tsunamis, as evidenced in 2004. High resolution bathymetric surfaces were prepared using CARIS HIPS 9.0 to study the trench at four different study sites, covering depths ranging from 2500 to 6500 m. This area shows characteristics of a filled-in trench with little to no surface expression, along with parallel submarine faulted ridges on the overriding Eurasian Plate west of the subduction zone. Scarps from slumping were found along the ridges, likely triggered by seismic activity. The two northwestern-most sites contain several distinct scarps along the submarine ridges at depths of 4000 to 5000 m, whereas fewer scarps are evident in the southwestern sites, possibly indicating less seismic activity. This study will add to our understanding of tectonically and seismically active zones that may cause tsunami activity.

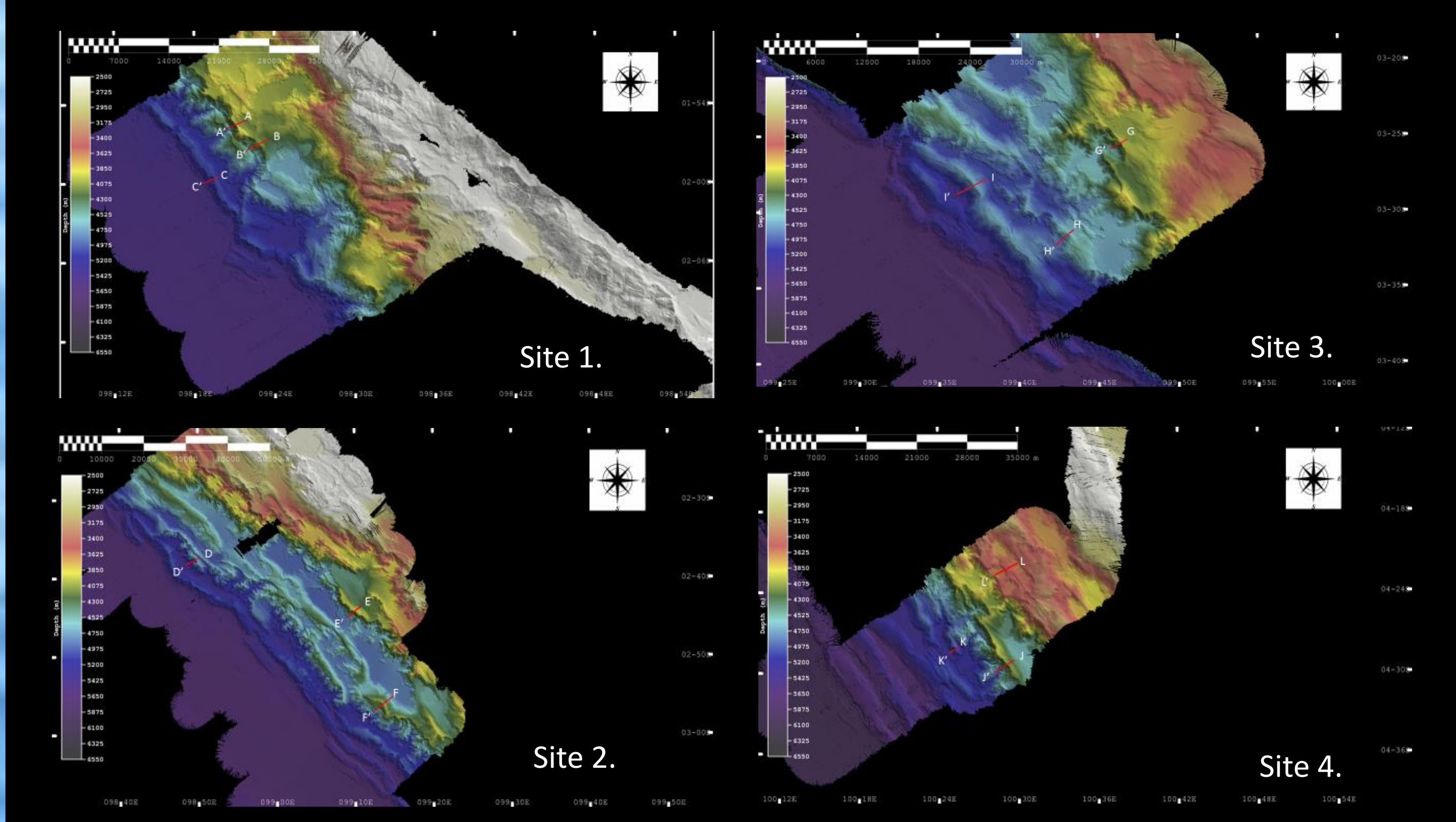


Figure 2. 2D view of study site 2 using the aspect layer. Submarine ridges are represented in red, indicating they all have similar aspect.

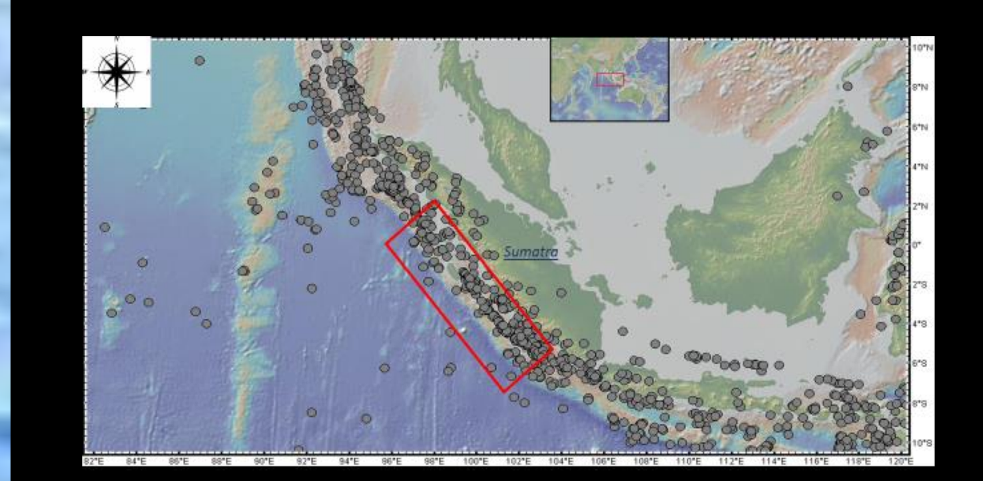


Figure 3. Earthquake locations along study site, shown by the red box. (Image from GeoMapp App)

Background

The area of study is the Java Trench and accretionary wedge located of the southwest coast of Sumatra where the Indonesian Plate and the Eurasia Plate converge (Figs. 1 and 2). On December 26th 2004, a massive earthquake occurred at the trench's subduction zone, generating a devastating tsunami that struck Sumatra and several other countries. The quake and tsunami together caused approximately 230,000 casualties and billions of dollars in property damage. The earthquake resulted from the sudden release of tremendous pressure along the plate boundary, causing a 9.2 megathrust earthquake (Bilek et al., 2016) (Fig. 3). The purpose of the study is to understand the Sumatra subduction zone and the potential for a tsunami geohazard. The geomorphology reveals possible clues that can reveal the seismic and structural past of the trench and adjacent seafloor. Scarp features (Figs. 4 and 5) located east of the sediment-filled Java Trench were analyzed to understand the geomorphology of the accretionary wedge, or prism. Observations of scarps located on the prism support observations by Henstock et al. (2016) that co-seismic surface rupture may occur at the prism toe.

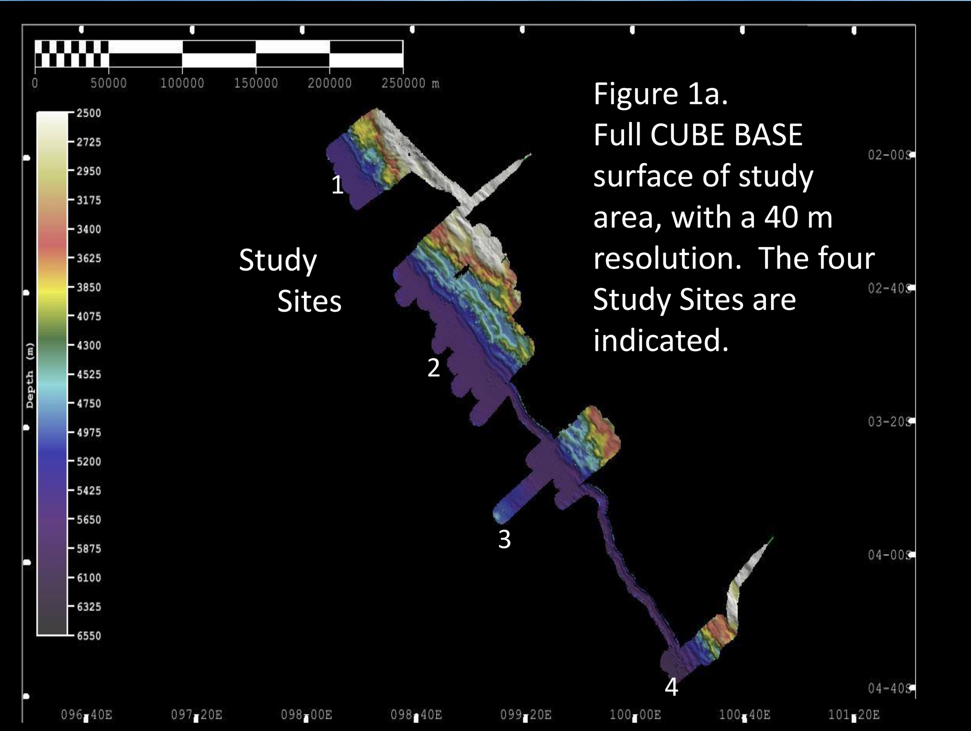


Figure 1a. Full CUBE BASE surface of study area, with a 40 m resolution. The four Study Sites are indicated.

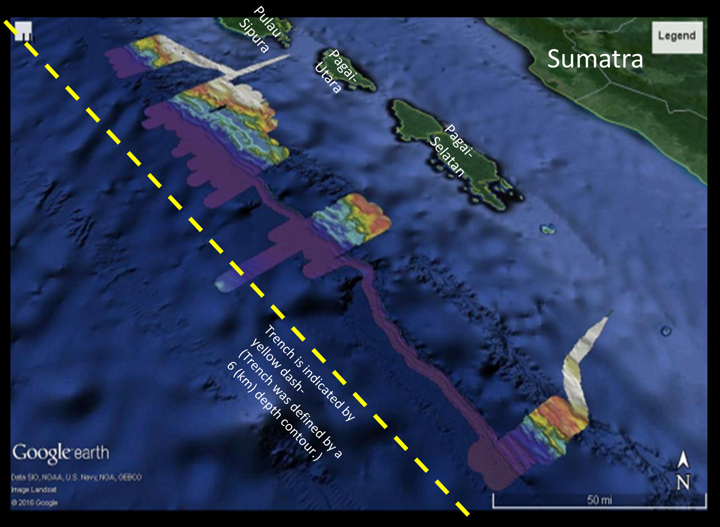


Figure 1b. The study site is located off the western coast of Sumatra, along the Java Trench. (image from Google Earth.)

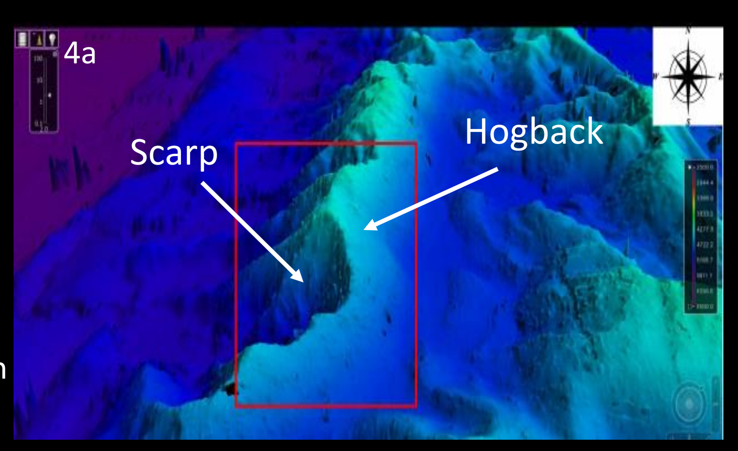


Figure 4a. 3D view example of scarp and hogback

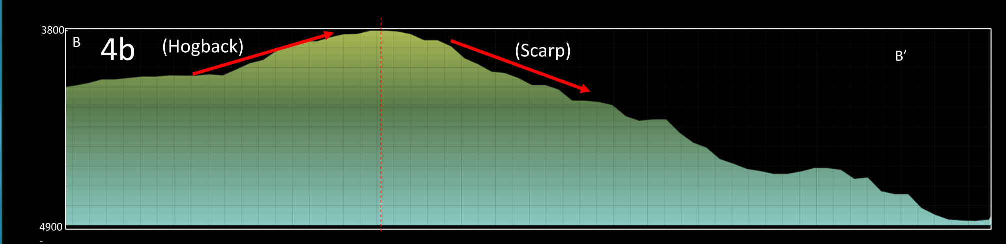
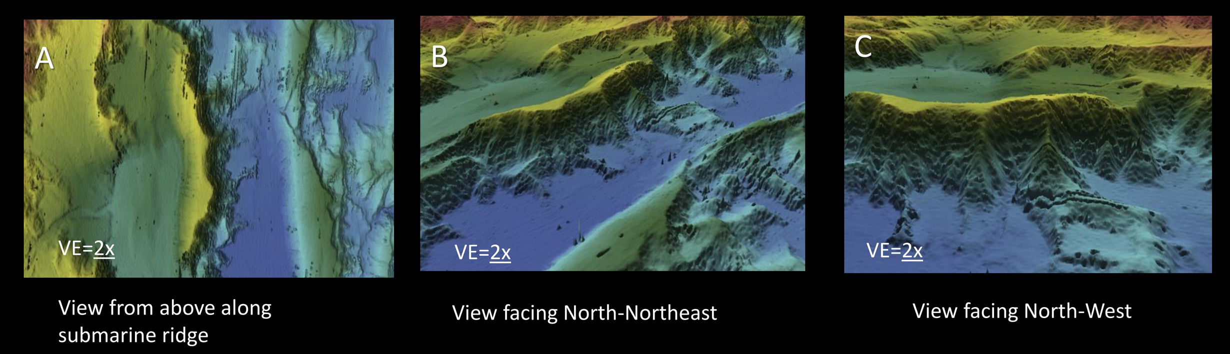


Figure 4b. Cross-Section of scarp B with Hogback and Scarp

Methods

- Multibeam sonar data were collected onboard the Schmidt Ocean Institute R/V *Falkor* with a Kongsberg EM302 and EM710 by Chief Scientist Sieh, Kerry from Earth Observatory of Singapore, NTU.
- Data were processed using CARIS HIPS 9.0 Software
- High resolution bathymetry was used to analyze the Sumatra subduction zone and accretionary prism.
- Height, length and slopes for each tilted block were measured and compared using the profile tool (Table 1, Figs. 4 and 6).
- 2D and 3D depth and aspect layers were created at 40 (m) resolution (Fig. 8).

Figure 5. 3D views of scarp E



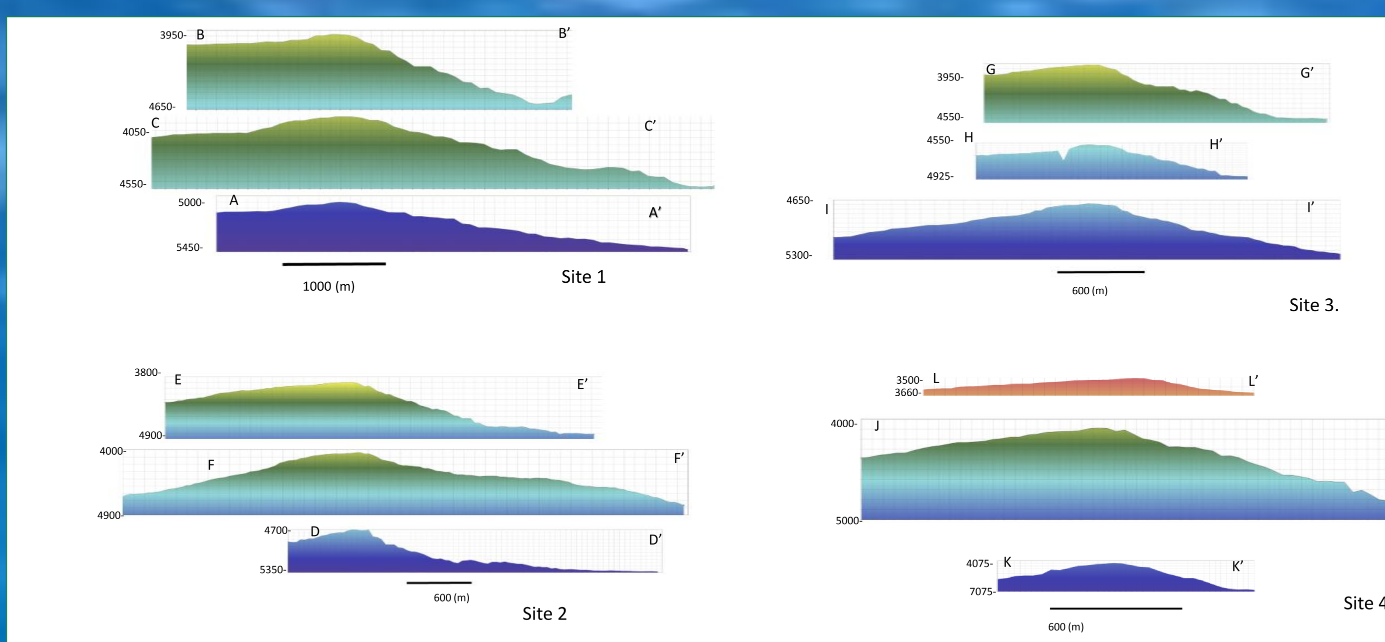


Figure 6. Profile views of scarps A-K along Sites. Cross sections were organized in increasing depth (m)

Results

- Distances from the trench to the scarps ranged from 1,330 to 84,600 m (Table 1)
- Slopes of the hogbacks studied ranged from 0.07 to 0.27, whereas slopes of the scarps ranged from 0.19 to 0.66 (Table 1, Fig. 7a).
- A weak positive correlation exists between distance from the trench and a slope of the scarps – the seismic expression areas (Fig. 7b).

Figure 7a. Variation of both hogback and scarp slopes at sites 1-4.

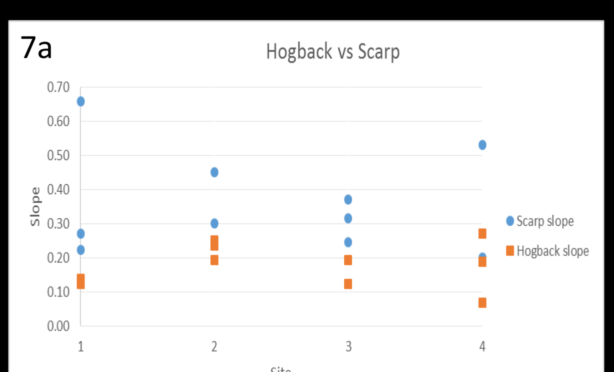
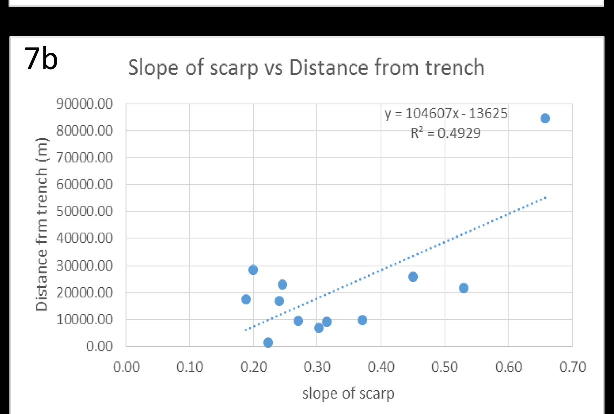


Figure 7b. Relationship of Slope of Scarps A-L and their distance from the trench.



Study area	Scarp	Slope of Scarp	Slope of Hogback	Distance from Trench (m)
1	A	0.66	0.14	84600.00
	B	0.53	0.14	9433.80
	C	0.45	0.13	1330.90
2	D	0.37	0.25	7025.67
	E	0.32	0.19	25802.96
	F	0.30	0.24	16733.36
3	G	0.27	0.13	22981.46
	H	0.25	0.13	9718.21
	I	0.24	0.19	9050.48
4	J	0.22	0.27	21720.24
	K	0.20	0.19	17371.10
	L	0.19	0.07	28401.89

Table 1. Data collected for scarps A through L, in the four study sites.

Discussion

This study focused on fault surface expressions known as scarps. The study took place off the western coast of Sumatra, an area known for being ravished by the 2004 tsunami. Multibeam sonar data were collected summer of 2009 by Chief Scientist Kerry Sieh onboard the R/V *Falkor*. One of the main ways tsunamis are caused is by seismic activity. This study assumed the presence of scarps as a proxy for seismic activity. Multiple scarps were identified along submarine ridges running parallel to the subduction zone on the overriding Eurasian Plate. The subduction of the oceanic Indonesian Plate creates an accretionary wedge as sedimentary rocks are scraped off the subducting plate. Thrust faulting is prevalent and causes rotation of faulted blocks, resulting in the occurrence of high submarine ridges. The converging plates and accretionary wedge results in trench infilling, and there is little to no surface expression of the trench feature. Subducting oceanic plate fabric exerts a first-order control on the morphology of the lower slope of the accretionary prism (Kopp, 2008). While there was weak but some positive correlation between the distance from the trench and the slope of the scarp. The slopes of the hogbacks remained consistent throughout the different study sites.

Figure 8a (right). Slope Aspect of full BASE surface. Arrows indicate ridge orientation/direction.

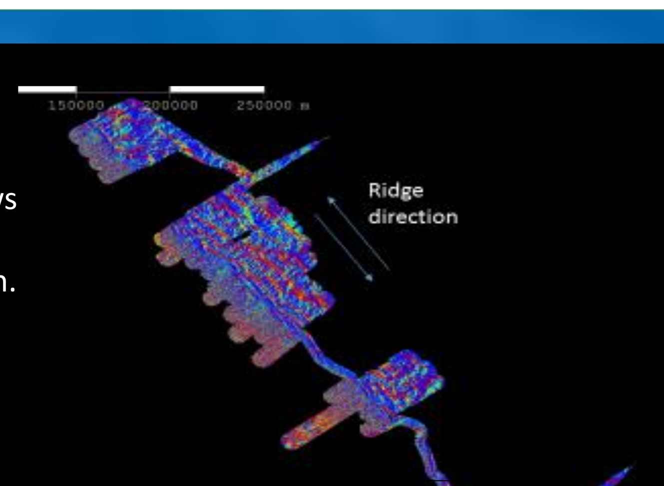
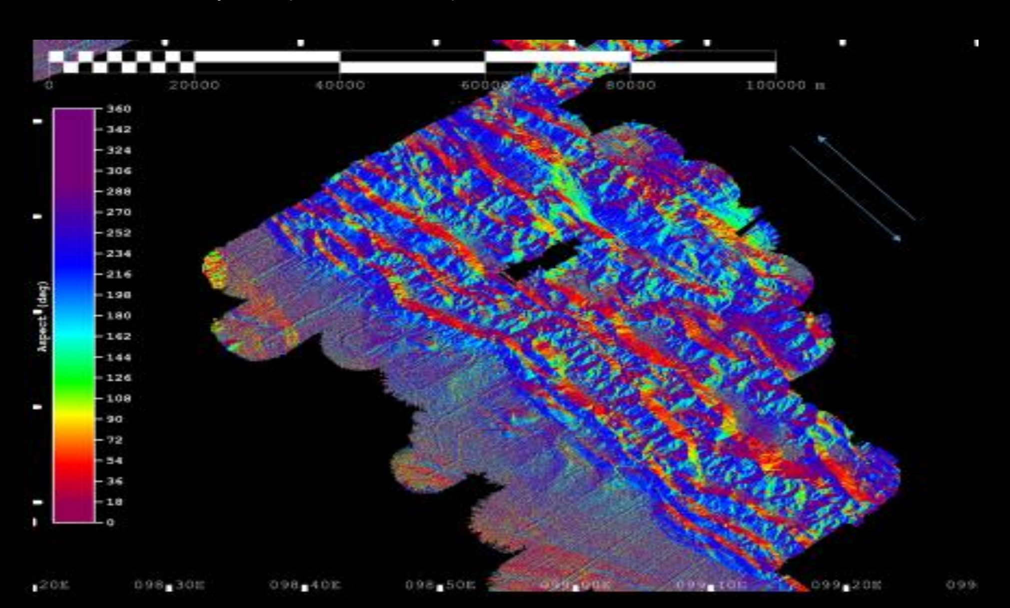


Figure 8b (below). 2D view of study site 2 using the slope aspect layer. Submarine ridges are represented in red, indicating they all have similar aspect (orientation).



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Acknowledgements

We would like to thank CARIS for their Academic Partnership, Dept. of Geology and Environmental Geosciences School of Math and Science, the College of Charleston BEAMS program, and the crew of the R/V *Falkor* for there bathymetric data collected using a Kongsberg EM302.

(Scan for 3d flythrough)

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