Characterizing Volcanic Features in Banks Peninsula, New Zealand

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I. Abstract

Mapping geologic landscapes often requires entering the field. A drawback to this fact is that often times fieldwork is expensive, dangerous, or impractical. For this reason, it would be useful to be able to identify geologic features without having to enter the field. This research identifies possible ways for identifying certain volcanic features using only a digital elevation model (DEM). It is concluded that although it is possible to form a model for such a task, there are still some obstacles such as DEM resolution and difficulty quantifying specific feature attributes using ArcGIS.

II. Introduction

Volcanic activity creates specific features such as domes, dikes, flows, and scoria cones. Just as any other landscape, volcanic regions weather and transform with time. It is important to understand the transformations that take place in these areas in order to understand how volcanic features impact transport, erosion, and deposition processes (Thouret, 1999). Additionally, it is likely that specific volcanic features result in particular erosional patterns and that volcanic landscapes will have topography that has been shaped by these erosional patterns. Using data extracted from aerial photographs and digital elevation models (DEMs), there might be a way of identifying these features without entering the field. Discovering such a methodology would be beneficial to the research community by narrowing down the locations of where certain features might be located and thus limiting the amount of time, money, and effort needed to enter the field.

III. Geologic Setting

Banks Peninsula is built from two large volcanic complexes – Akaroa Volcano and Lyttleton Volcano to the southeast and northwest respectively (Muller, 2012). There are five locations on Banks Peninsula that can represent the various types of landforms created through the volcanic processes: Panama dome, Panama dike, Goat dome, and scoria cones at Le Bons

Bay and Chorlton. Panama Rock is a trachyte dome exposed on the eastern flanks of Akaroa Volcano, at the intersection of Panama Road (Dorsey, 1988). Panama Rock is intersected by a trachyte dike 4m-thick that runs and trends approximately 240° towards the center of Akaroa volcano (Curtin, 2012). Unlike basaltic dikes, trachyte dikes tend to be larger than 4 m, therefore easier to recognize on a DEM. The readability of a feature on a DEM is important to consider when discussing ArcGIS research because a lower resolution DEM will not be able to show enough detail if a feature is too small. Goat Rock is a basaltic dome. It is located inland on the Northeastern corner of Banks Peninsula between Le Bons Bay and Okains Bay (Tramontano, 2012). The scoria cones at Le Bons Bay and Chorlton are the base models for the coastal and inland scoria cones respectively. It is important to look at coastal and inland scoria cones separately because it is likely that different geomorphology will appear.

IV. Methods

4.1 Materials and tools

These 5 volcanic features were chosen to cover the diversity of the volcanic features along the peninsula. All of the research was done using interpretations from ArcMap in the projection NZGD 2000 New Zealand Transverse Mercator. The primary materials for this research included aerial images of Banks Peninsula as well as a DEM. The aerial photograph has a 0.6 m resolution while the DEM is constrained by a 10 m resolution. The aerial photograph was used to determine the areas that would encompass each volcanic feature. Polygons were drawn around the features of interest as shown in figure 2.

4.2 Extracting slope, aspect, and elevation

By inputting the DEM of the peninsula into the slope and aspect tools, data of the slope and aspect for the entire peninsula were rendered. The model shown in figure 3 was used to facilitate the process of extracting slope, aspect, and elevation when at times the polygons needed to be redrawn or repositioned. Using the “Clip” tool, the model clips the “Input_Raster” (whether it be the slope, aspect, or elevation) according to the “zone” (the extent) created from the “Feature_Outlines” input (Esri, 2013). The “Iterate Feature Selection” tool ensures that the model repeats the process of forming a new “zone” from each individual polygon until all feature outlines have been clipped (Esri, 2011a). The output of the model is “Raster_%Value%.” The word *Raster* in “Raster_%Value%” is manually renamed to an abbreviation representing the input raster being clipped. The %Value% automatically takes the unique “Value” requested from the Feature_Outlines attribute table – for this purpose, a field called “Feature” was created for each polygon as shown in table 1. The first part of the output name would change by changing the word “input” in the output frame “Raster_%Value%” to a proper term such as slope, asp, or elev. For example, the slope, aspect, and elevation outputs of Panama Dome would be called slope_PDome, asp_PDome, and elev_PDome respectively.

4.3 Producing histograms

Upon taking a closer look at the slope, aspect, and elevation data for all features, it was determined that histograms for the slope of both domes would be useful. “Spatial Analyst” was used to create a histogram with each the slope rasters of each dome as the input (Esri, 2011b). It is important to note that the distribution produced using this method is dependent on display resolution.

V. Results

5.1 Analyzing slope, aspect, and elevation

The slope, aspect, and elevation extracted for all five features (fig 4-7). These figures were rendered using the Banks Peninsula DEM in ArcMap. It is important to note for the following figures that value ranges indicated are specific for each area. For example, the maximum slope for the Chorlton Scoria Cone is the same color as the maximum slope for Goat Dome, but not necessarily the same value. The elevation and slope ranges for Chorlton Scoria Cone are 214-365 m and 1.01-40.10˚. Le Bons Scoria Cone has an elevation range of 0-100 m and a slope range of 5.05-57.17˚. Goat Dome and Panama Dome have elevation ranges of 348-421 m and 500-608 m and slope ranges of 0-36.69˚ and 3.65-49.91˚ respectively. Panama Dike has an elevation range of 373-517 m and a slope range of 13.52-49.57˚. A summary of these values is shown in table 2.

Both Le Bons Scoria Cone and Chorlton Scoria Cone have similar aspect characteristics. Each scoria cone is divided along the center between two opposing aspects. This feature is likely due to the erosional processes that affect scoria cones. Scoria cone degradation occurs primarily through the process of mass wasting where scoria is weather to clay, and then gullied by rainfall allowing the debris to slide down slope (Wood, 1980). It is this process that likely causes a divide in aspect with the drainage path dividing the scoria cone in half. Only the aspect data was useful, as no information was extracted from slope and elevation data that would be relevant in identifying scoria cones. Both Goat Dome and Panama Dome show slope characteristics expected of domes. Both have steeps sides with very flat tops. The aspect data shows an intersection of all four directions intersecting at a single point. This characteristic is possibly the most noticeable identifying feature for the domes. Again, elevation seems to be of little use. For Panama Dike, there were no unique trends extracted from the slope, aspect, or elevation data.

5.2 Analyzing histograms

Slope histograms (fig 8) were extracted from Goat Dome and Panama Dome to demonstrate a method for finding a possible way of identifying dome type. Rock mass strength has been shown to be a major control on slope stability (Augustinus, 1995). This could mean that rock type is a control for dome slope. The trends between the two histograms are different, but whether this difference is due to a difference in composition or another factor entirely is a question that needs to be researched further.

VI. Discussion

6.1 Using ArcMap to find domes

Unfortunately, the aspect pattern for identifying scoria cones is a difficult concept to quantify using ArcMap. However, with the dome information extracted, it could be possible to find a method by which to identify domes using only a DEM. This paper recommends a two-step process. The first step is creating a filter within ArcGIS that can identify all areas on a DEM where each slope aspect meets at a single point. These areas, when identified, should be likely candidates for dome locations. The second step is encompassing an area around the identified points and looking at the slope histogram. The histogram can then be correlated to known trachytic and basaltic domes to determine composition.

This proposed model requires more research on the slope histograms of domes. More histograms of known trachytic and basaltic domes should first be identified to see if there is a correlation between slope and dome composition. It is possible there is little to no correlation between slope and composition, as domes are formed by a variety of building processes and modified over time by weathering (Thouret, 1999). Instead, looking further into slope distribution may discover a correlation between dome building and weathering processes.

6.2 Limitations

It is important to note that a major limitation of this research included the resolution of the available DEM (10 meters). This relatively poor resolution only made certain features visible and limited the information that could be extracted. Basaltic dikes tend to be smaller than trachytic dikes, so the limited DEM resolution made it impossible to analyze a basaltic dike. Additionally, little information was extracted from the trachytic dike. This is likely a result of the limited resolution.

6.3 Future work

An attribute that was not explored in this research is surface roughness. Surface roughness is defined as the variability of elevation values and is an important geomorphological variable frequently used in research to infer material properties, current and past processes, and time elapsed since formation (Grohmann et al., 2011). Microtopography is another variable important for modeling water movement, geomorphology, vegetation dynamics, and geologic features (Brubaker et al., 2013). For analyzing terrain roughness, the scale of the DEM and scale of the landscape feature being characterized are important, as roughness cannot be quantified without a high resolution (Cooley, 2014). For this reason, a higher resolution DEM would be needed.

A DEM acquired from more precise Light Detection and Ranging (LiDAR) would likely produce more detailed results (Haile and Rientjes, 2005). If at all possible, it is recommended that future research look into analyzing smaller features such as dikes at around 1 m resolution. For domes and scoria cones, it appears that the current 10 m resolution is sufficient, but higher resolution DEMs may expose more detailed topographic features that are relevant. In the case of domes, the current resolution of DEM may be more beneficial for locating the characteristic intersecting aspect pattern, as shown in this study. If other DEM resolutions are produced, it will be beneficial to see if this intersecting aspect pattern still exists or is primarily a result of low resolution. If 10 m resolution is necessary to find these dome patterns, it may be more appropriate to use this resolution of DEM in the proposed model.

VII. Conclusion

Most geological mapping requires the use of fieldwork. Unfortunately, the process of entering the field can be costly, time consuming, dangerous, or impractical. This research is part of an effort to investigate the usefulness of programs such as ArcGIS to facilitate fieldwork and possibly eliminate the need for it in certain circumstances. Creating a model for identifying volcanic features along Banks Peninsula could identify new features that have not yet been discovered.

Additionally, this research could branch out beyond the scope of Banks Peninsula into different locations. Identification methods such as this could be beneficial to the efforts of planetary geologists who have little to no access to the surface of the bodies they study. With the ability to almost certainly identify features on the surface of other planets, scientists can be more sure of where to send orbiters or landers and gain a better understanding of the landscape outside of this planet.

VIII. Acknowledgments

I would like to thank Sam Hampton for supervising this research and Kurt Joy for advising on ArcGIS. I would also like to thank the Frontiers Abroad program for providing this wonderful opportunity and allowing this research to happen.

IX. References

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Tables

Table 1. Attributes table for feature outlines.

OBJECTID	SHAPE	Feature	SHAPE_Length	SHAPE_Area
3	Polygon	Goat	1165.244	63667.8
11	Polygon	PDome	1225.249	102113.3
13	Polygon	PDike	1123.564	29327.34
18	Polygon	Chorlton	2396.1	416533.6
19	Polygon	LeBons	1913.06	153664.1

Table 2. Elevation and slope summary.

Volcanic Feature	Elevation Range (m)	Slope Range (degrees)
Chorlton Scoria Cone	214-365	1.01-40.10
Le Bons Scoria Cone	0-100	5.05-57.17

Goat Dome	348-421	0-36.69
Panama Dome	500-608	3.65-49.91
Panama Dike	373-517	13.52-49.57

Figures

Figure 1

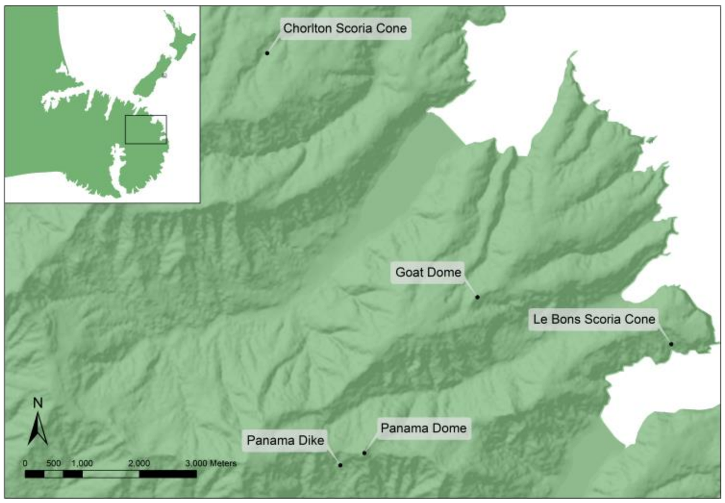


Figure 2

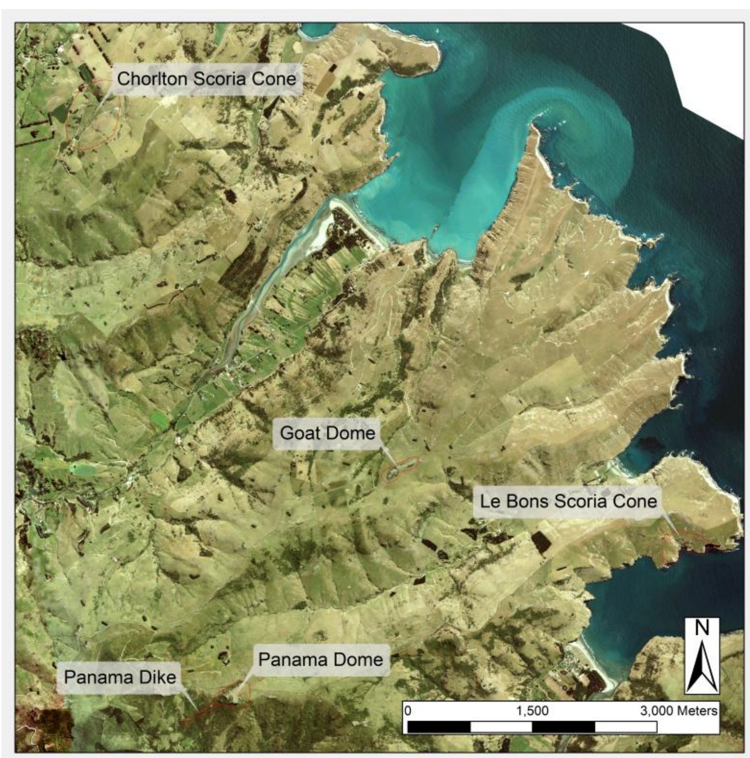


Figure 3

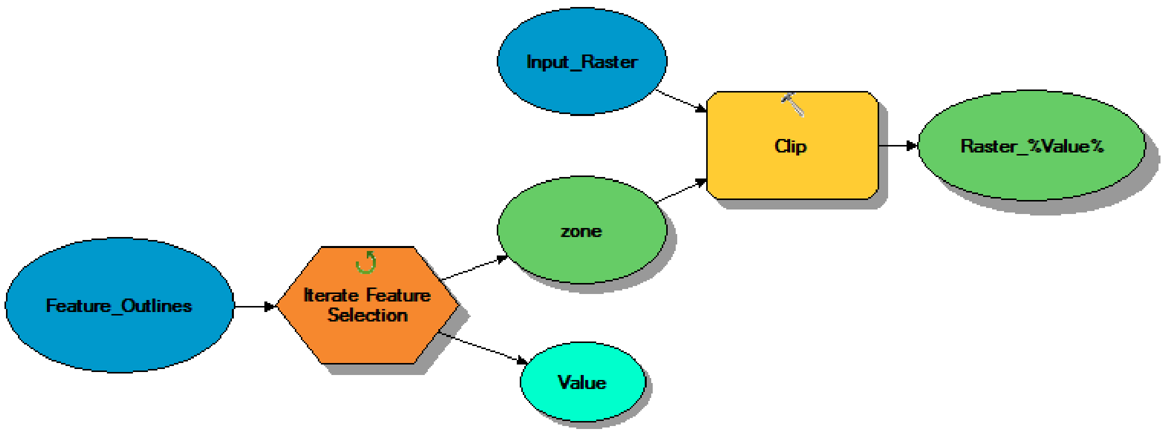


Figure 4

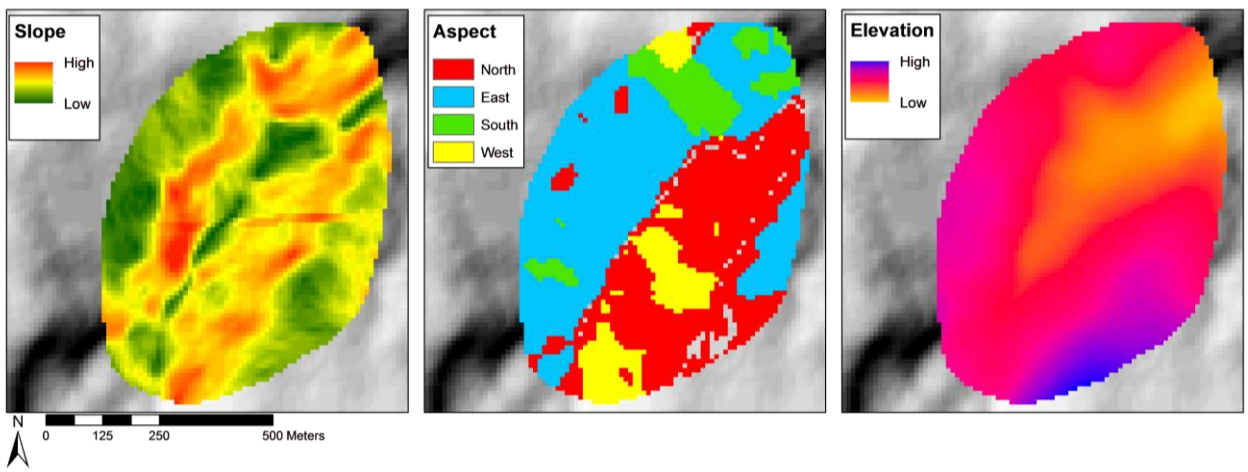


Figure 5

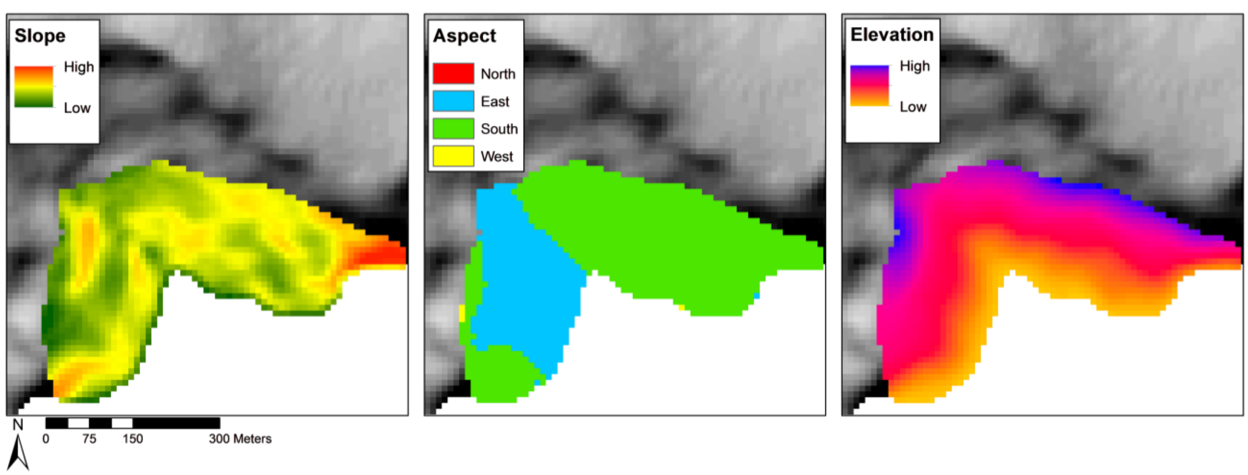


Figure 6

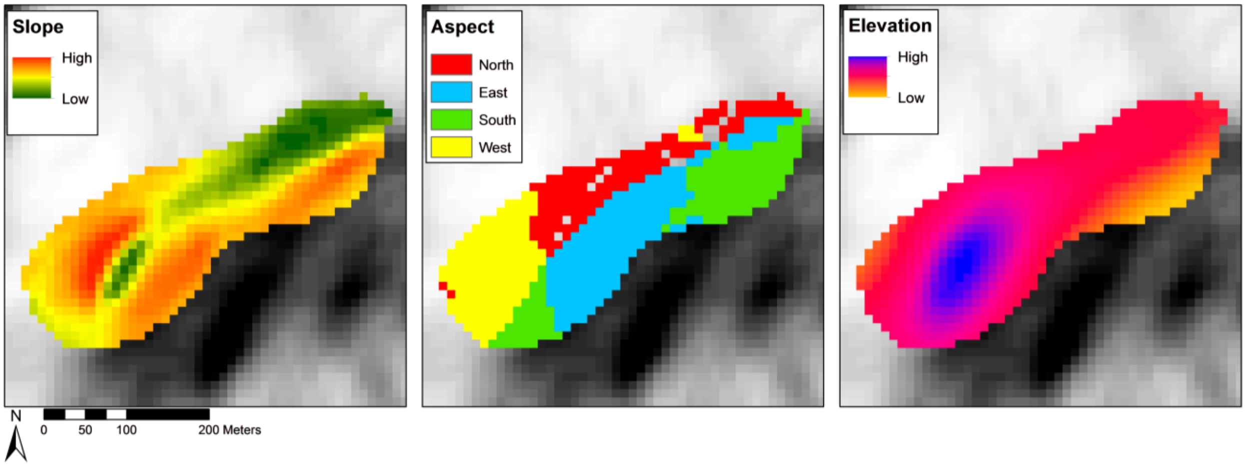


Figure 7

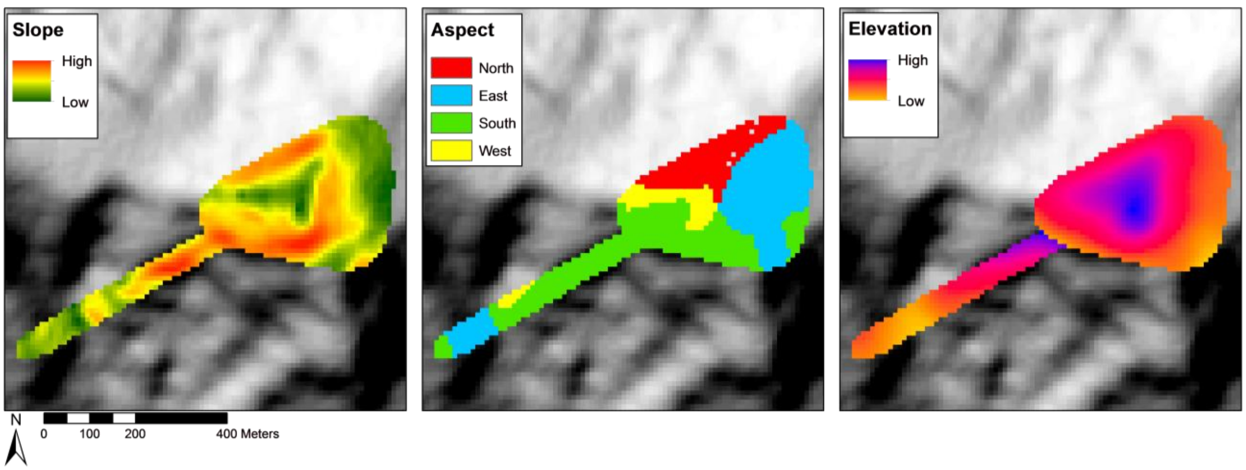
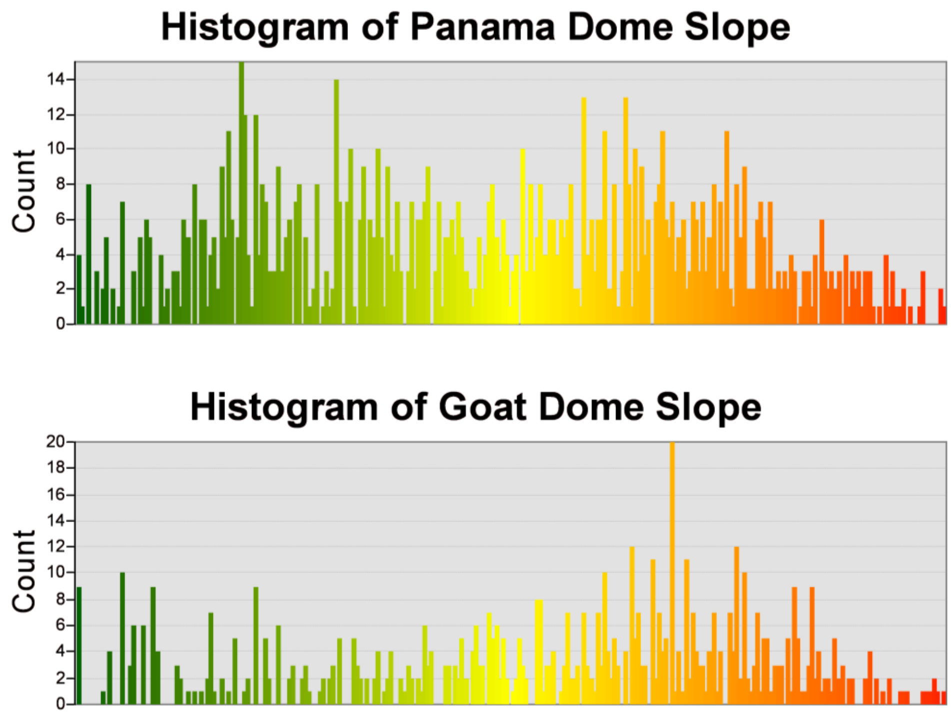


Figure 8



Captions

Figure 1 Extent of the area of interest. All five volcanic features are labeled.

Figure 2 Feature outlines. The outlines of the domes, scoria cones, and dike are drawn in red.

Figure 3 ArcGIS model.

Figure 4 Chorlton Scoria Cone. Inland scoria cone seems to have its aspect divided along a line running from its southwest corner to its northeast corner.

Figure 5 Le Bons Scoria Cone. Similarly to the inland scoria cone, the coastal scoria cone has its aspect divided along a line running from its northwest corner to its southeast corner.

Figure 6 Goat Dome. Slope values show that the basaltic dome has clearly steep sides and a flat top. Additionally, all four aspect values meet at a single point indicating the top of the dome.

Figure 7 Panama Dome and Dike. Similarly to the basaltic dome, the trachytic dome has steep sides and a flat top. All four aspect values also meet at a single point. It is difficult to see any trends relevant to the trachytic dike.

Figure 8 Histograms of Panama Dome and Goat Dome. It is unknown at this moment whether differences have to do with dome composition or other factors.