Reconstructing Volcanic Eruptions on Tenerife Using WorldView-2 Imagery

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Summary: This project uses multispectral data from DigitalGlobe's WorldView-2 satellite, combined with DEM and field evidence to analyse the geomorphology of a sequence of events along a 3km stretch of the Northeast Ridge of Tenerife. This includes delineation of each site, characterisation of ejected materials and a determination of relative chronology. Understanding of past volcanic behaviour on the island is particularly important due to its prominence as a tourist destination and because the main volcanic complex has long since been designated as a "Decade Volcano" by the *International Association for Volcanology and Chemistry of the Earth's Interior* and a UNESCO World Heritage Site.

KEYWORDS: WorldView-2, Tenerife, Remote sensing, Volcanic Geomorphology,

1. Introduction

Tenerife is a hugely popular tourist destination as well as a volcanically active island, with the most recent eruption on Tenerife occurring as recently as 1909. It is part of Canary Islands chain that has a number of examples of sub-aerial volcanism (Doniz *et al*, 2008). Historically, a series of eruptions have occurred up slope of the town of Fasnia resulting in the effusion of lava from a series of vents along the northeast-southwest orientated Dorsal Ridge stemming from the Pico Teide- Pico Viejo complex (Ablay & Marti, 2000). Even though they are a prominent feature on the landscape (see Figure 1) these sites have been subject to very little research into their sequencing and formation. Their position on the hillside above the popular tourist locations of southern Tenerife mean any future eruptions could cause serious consequences to the population and the economy.

In particular, the Fasnia eruption sites consist of two large surface features of effused material that are in excess of 20m in height, with each distinctly separated where the underlying topography and vegetation is evident. All sites show a covering of black lapilli, although the portions of the site covered in lapilli vary, giving an initial indication with regard to a relative time sequence.

This study aims to understand how remote sensing can be used to identify and map volcanic geomorphology. The first objective was to derive a map of the two Fasnia effusions and the single Siete Fuentes feature through photointerpretation, then assess its validity using field observations and compare to high resolution, multispectral DigitalGlobe WorldView-2 imagery. The final objective will be to reconstruct the 1704/5 Fasnia eruptions using the WorldView-2 imagery.

Figure 1. Aerial imagery of sites, showing the quality of freely available aerial imagery (Google Earth imagery).

2. Methods

Screen shots of images taken from Google Maps were analysed to provide a baseline to trace key geomorphological features. Freely available data sources provide an excellent means of initial investigation to inform future ground assessments, encompassing the ethos of remote sensing. Field observations during 2010 and 2011 confirm that the flow surfaces at each location, and within each lava effusion appear to differ both in terms of colour and composition (see Figure 2). This would suggest the characteristics of the eruption changed through time, which has been previously suggested (Costa & Marti, 2009), although the use of remotely sensed data has largely been ignored.

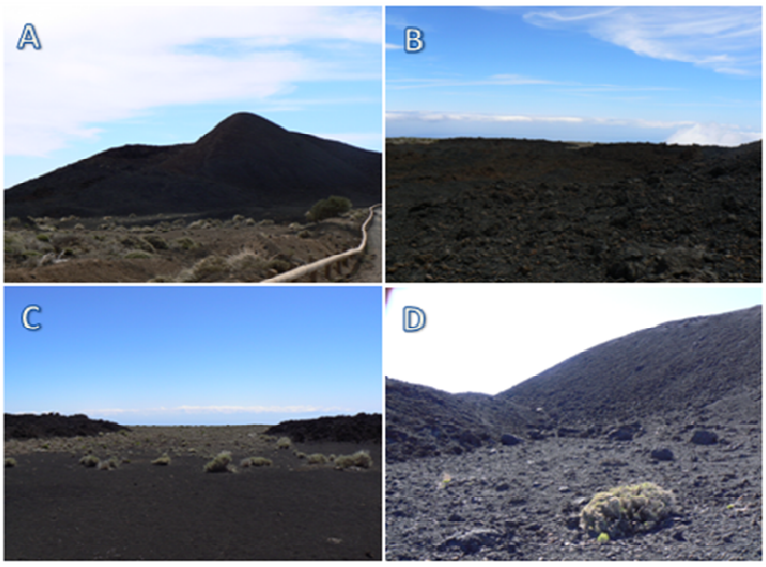

Figure 2. Photographs of Fasnia South taken in April 2011; A) View of northeast vent and flank collapse (SSW view); B) View from ridge between two vents over both tongues of flow (ESE view); C) Lapilli field and separation of flows near to divergence point (SE view); D) View of southwest flow from area shielded from

flows, some lava bombs in foreground (WNW view).

The chemical composition of rocks can change their appearance on multispectral images because of the way they their reflectance characteristics reflect sunlight and are therefore ideal for analysis using the multispectral imaging capabilities of the WorldView-2 imagery (Spatz 1997). Launched in October 2009, Digital Globe's WorldView-2 multispectral imaging is provided at a 1.85m resolution (Digital Globe, 2010). Initially, a single band view (Band 5 red band 630-690nm) was used as this is reported to be useful for identifying different geological features that highlighted variations in the lava coverage. Following from this, the 'yellow' and 'red' visible wave bands and the 'near-infrared' band are at the optimum wavelengths to sense and detect changes in the iron concentration of the varying rocks across the lava fields, and identifying areas of lapilli coverage (Costa and Marti 2009).

An additional criterion needed to assess geomorphology is elevation, which for the purposes of this study has been derived from a Digital Elevation Model of the entire Tenerife Island at a 10m resolution. A 3D ArcScene view of the Fasnia sites is shown in Figure 3.

Figure 3. 3D ArcScene DEM View with exaggerated vertical scale (View to North-North-East)

As part of the field observations, and to provide a level of ground truthing to the remotely sensed information, the outlines of the Fasnia South eruptive material were traced on foot using a hand held GPS receiver device. Readings of the trace path were taken at appropriate intervals to mark the outlines of each flow and delineation between obvious visual variations. The average horizontal accuracy of the device in the field was recorded as +/-4m.

Material samples have been taken from a number of sites across the different lava sequences, and laboratory-based spectral radiometric testing was undertaken to confirm the spectral profiles of various different materials.

3. Results

Photointerpretation and mapping of the geomorphology could be undertaken at an adequate spatial scale to identify the main body of the lava flow and extent of lapilli coverage. However, interpretation of photographs alone provides insufficient contextual information to allow a distinction between tephra fallout from one Fasnia vent covering areas associated with another vent. To complement this, the very fine spatial resolution of the WorldView-2 data allows the extraction of further detail from a range of spectral bands to provide more detailed information on the morphology of the flow and the composition of the extruded material itself (Figure 4).

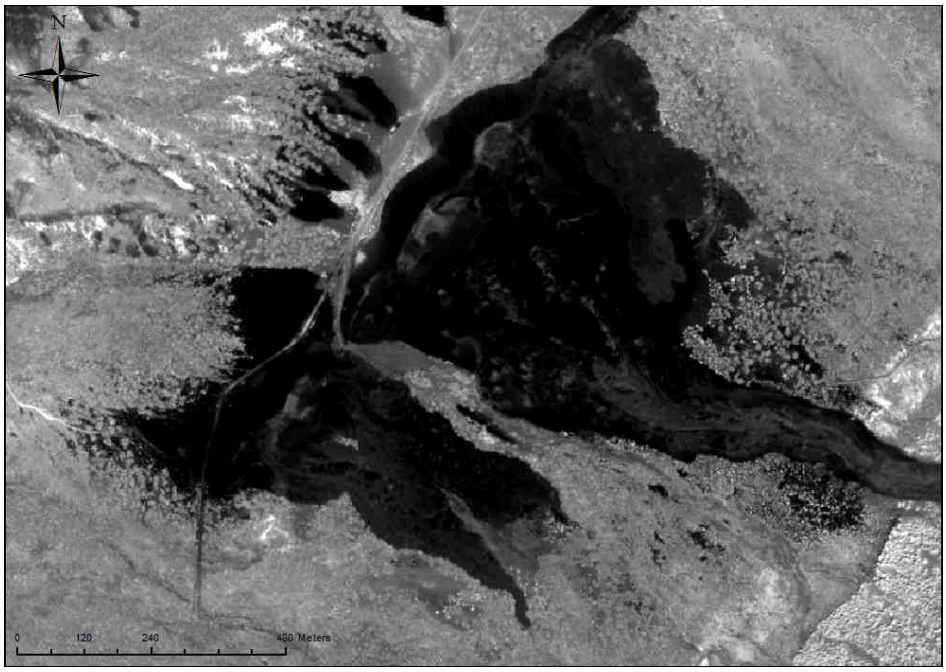

Figure 4. WorldView-2 Band 8 view demonstrating extensive lapilli coverage on distal lava deposits, consistent with the predominant coverage of the Fasnia North site.

Initial analysis of the spectral data suggests that on the Fasnia South eruption site, there are two separate vents within the structure that effused lava at different temporal scales, leading to one lava flow being overlaid by the other. Significant differences in the iron concentrations of the different eruption events are explicitly displayed when utilising the multispectral capabilities of the WorldView-2 data. A false colour composite (Figure 5) shows varying shades of blue within the lava fields highlighting the diverse chemical composition of the products. The areas shown to be black comprise significant lapilli deposits, with red hues depicting vegetation.

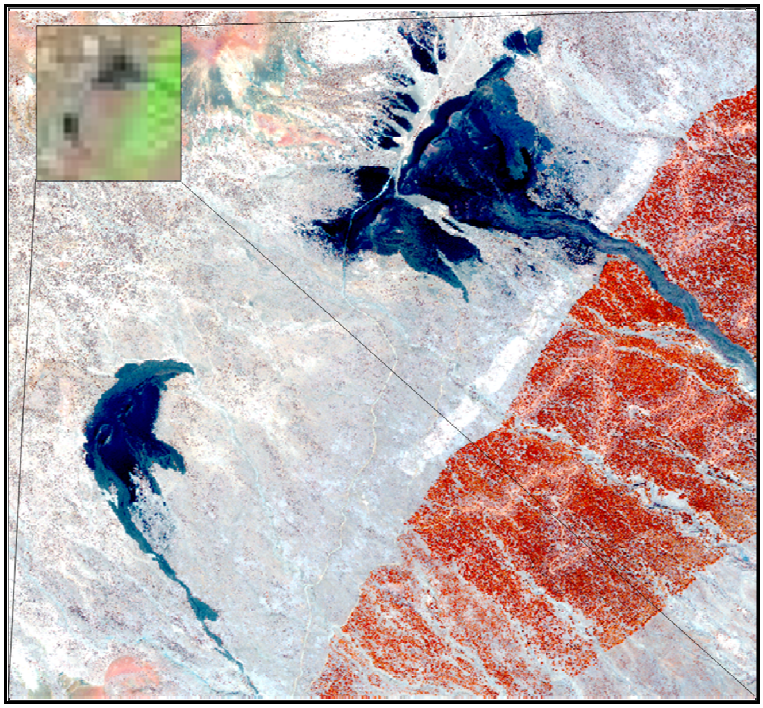

Figure 5. False Colour Composite with comparable 30m Landsat Image (Insert)

Initial results of the laboratory spectroscopy have identified a noticeable trough in the Band 5 red band (630-690nm) in the samples of noticeably red materials as would be expected. Similar profiles from the World-View2 data that exhibit this trough can therefore be considered to be similar in nature to those samples. Vegetated samples and those with different superficial structure exhibit different spectral profiles that can be utilised in a similar way (Spinetti *et al* 2009).

Reconstruction of the relative timescale of the eruptions is currently under way with validation of the findings from site assessments, including additional GPS tracking. Field samples have been taken to support field spectrometer analyses to determine the precise reflectance spectra of the varying materials. Figure 6 demonstrates an initial assessment of the relative sequence of events based on the findings of chemical composition, lapilli coverage and changes in the topography of the lava deposits.

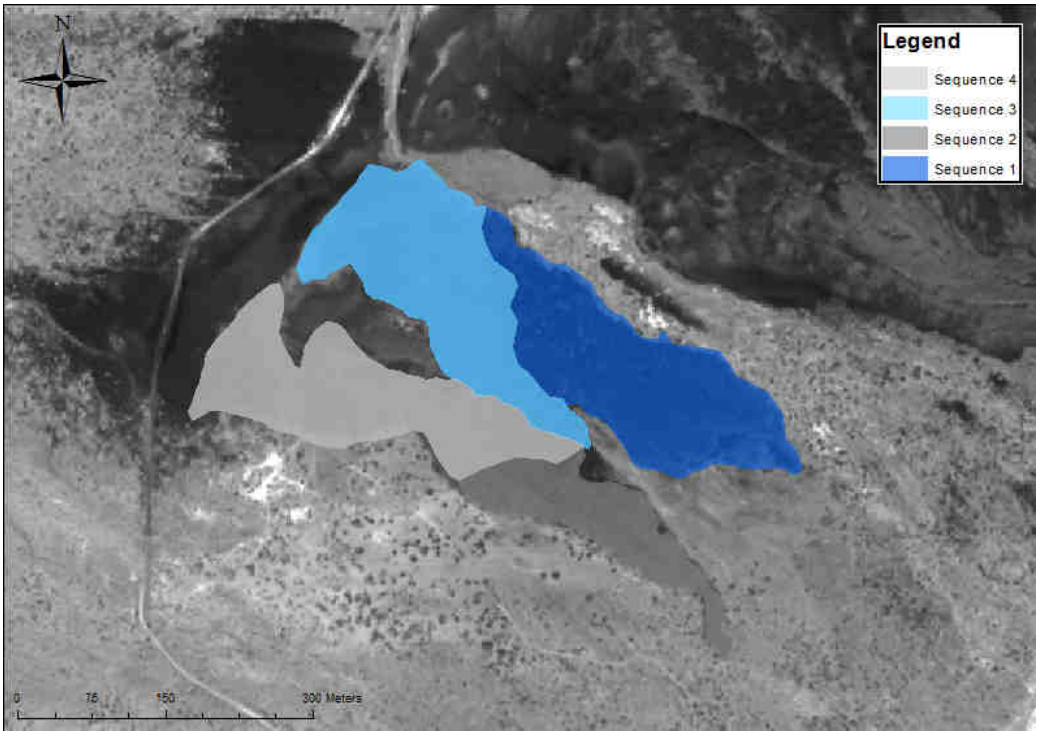

Figure 6. Initial Presentation of Event Sequence

4. Conclusions

Historic volcanic eruptions on the island of Tenerife near to the town of Fasnia are a prominent, yet relatively understudied feature. A series of eruptive events along the Dorsal Ridge fault stemming from the Pico Teide – Pico Viejo complex show differing characteristics that appear to be dependent upon existing topography and chemical composition of the effused material. Photointerpretation and ground based field analysis have been used to identify differences in eruptive material and trace the extents of a number of features but fail to give any context to the events. High resolution, multispectral images from DigitalGlobe's WorldView-2 imagery provides additional information with regard to the chemical composition of the material. Differences in the iron concentrations allows a reconstruction of the relative time series of the events that is currently being undertaken following additional field observations and data collection.

The outlined methodology has been generated specifically for the relative reconstruction of the sequence of events along a fault line. There is potential for the process to be exploited elsewhere, although the results are unlikely to provide detailed information regarding dating and effects of post-deposition processes such as weathering at other sites, or across a large spatial scale such as the entire

Canary Islands, or Tenerife as a whole. However, the relative sequencing could provide useful in terms of background information informing hazard assessments of similar eruptions in the locality in terms of their possible eruption type and the progression of multiple ejections.

5. References

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6. Acknowledgements

7. Biography

Daniel Allum is currently reading the MSc Environmental Hazards and GIS program at Coventry University whilst working at a private Engineering and Environmental Consultancy in the field of Flood Risk Management. His career aspirations and research interests include using GIS and remote sensing in the mapping, monitoring and mitigation of environmental hazards.

Matthew Blackett is a senior lecturer in Geography at Coventry University. After obtaining his PhD from King's College London, he has pursued his main research interests which focus on using satellite remote sensing, largely for the monitoring of natural hazard events.

Dr Nigel Trodd co-directs the Environment, Hazards and Risk Applied Research Group at Coventry University. His research interests lie in environmental geoinformatics and the analysis of Earth observation data to extract land cover information. He is currently working on environmental studies in Botswana, The Gambia, Saudi Arabia and Tenerife.