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Analysis of reflectance spectra of volcanic rocks from Deception Island (Antarctica)

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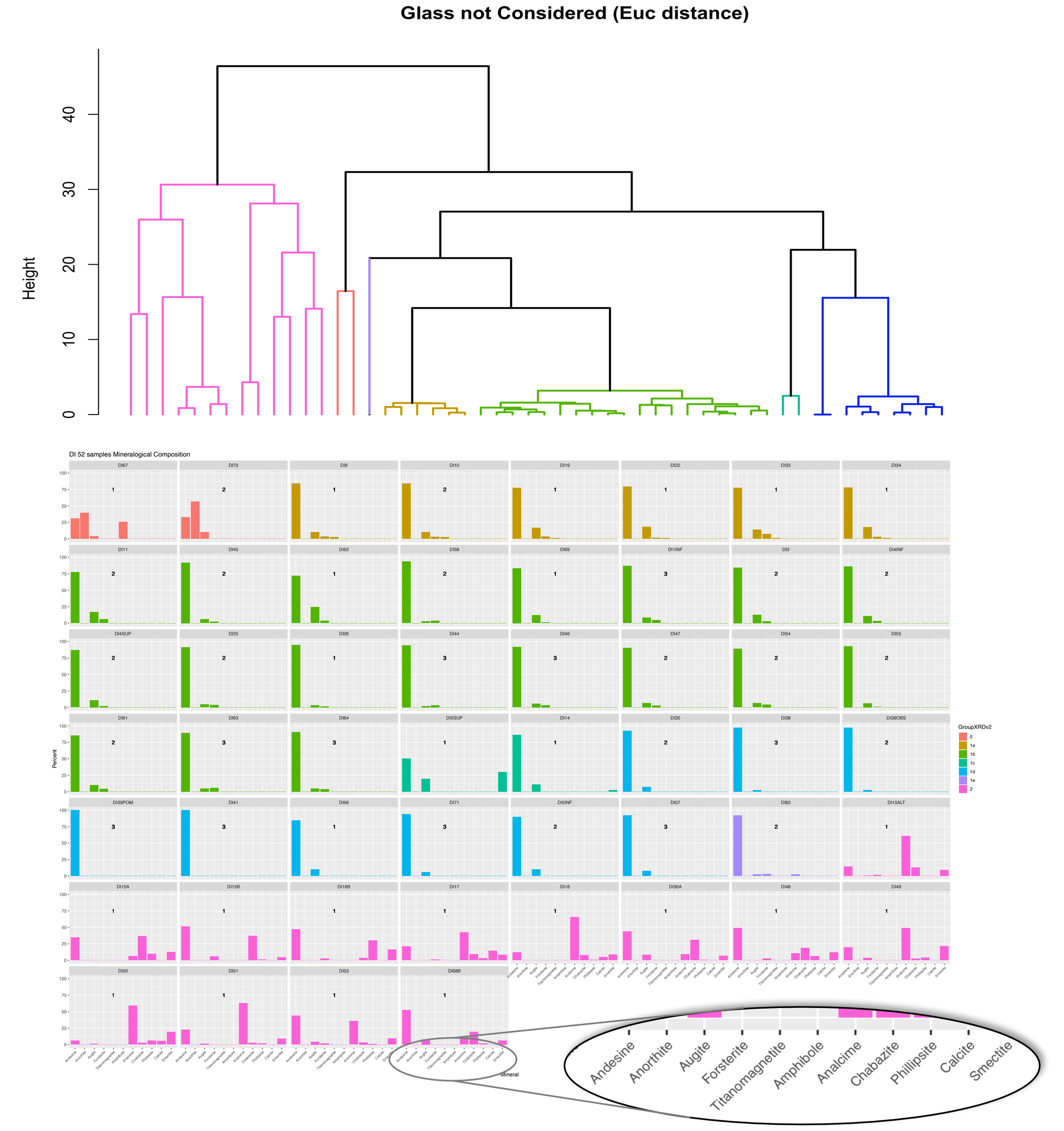
Introduction

Spectrometry can be of great help for geological mapping provided reflectance spectra can be linked to relevant geological materials. We analyse laboratory reflectance spectra (460 and 1700 nm) of volcanic rocks from Deception Island (Antarctica) in regard to mineral composition (from XRD analysis), geochemical composition and rock taxonomy (from macroscopic inspection).

Mineral Composition

Clustering based on XRD results



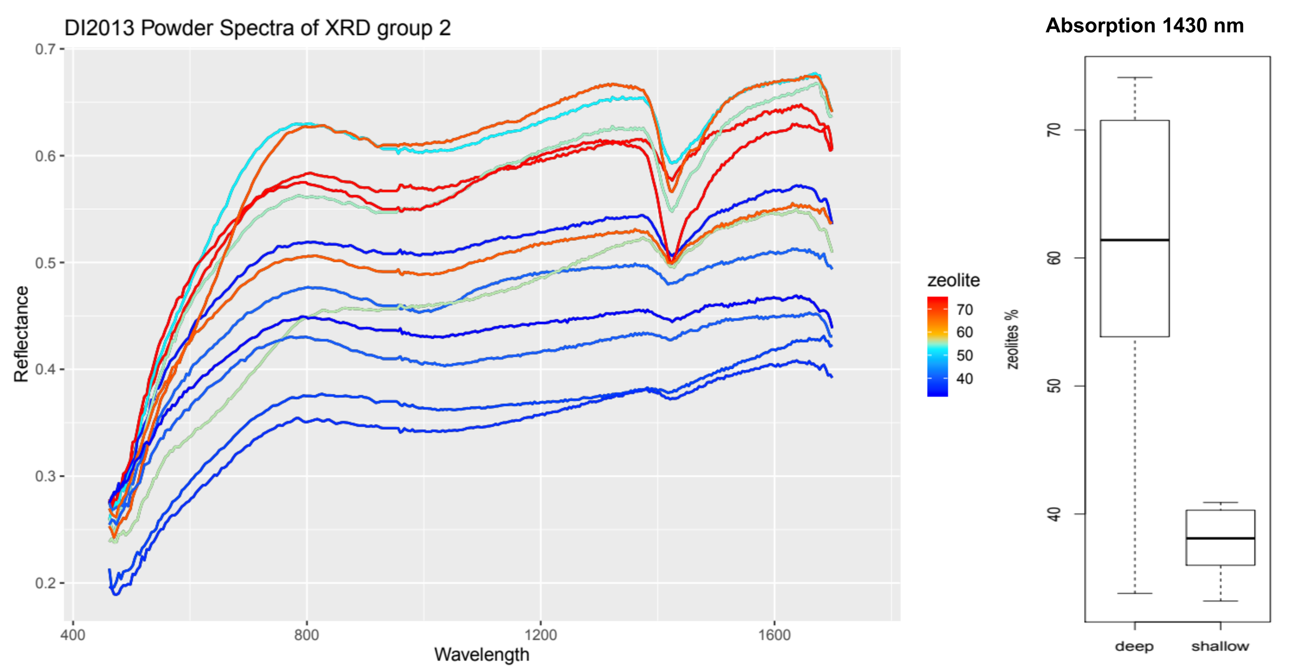
A hierarchical divisive clustering based on mineral composition derived from XRD analysis indicates that samples can be organized in two main groups: those (n=13) samples with lower glass content and with zeolites and smectite (indicating alteration), and those with higher glass content and missing the mentioned minerals. Except for two samples of plutonic rock with anorthite and lower andesine percent, the second group includes the majority of samples (n=37), with a high (> 75%) content of andesine, absence of minerals related to alteration and, in general, high glass content.The majority group can be further subdivided according to the differential contents of pyroxene (augite), forsterite and titanomagnetite

Reflectance spectra of powdered samples

Reflectance spectra of the same powder that was used for XRD analysis are able to discriminate the two main groups found by XRD (LDA classifies with 91% accuracy), but accuracy drops to 63% if the subgroups are considered. We conjecture that this is caused by the abundance of glass, which has important effects on reflectance but cannot be considered in the learning phase due to the lack of quantitative data: being glass abundant, mineral composition on its own cannot explain the shape of reflectance spectra. The presence of Fe, Mn and Ti and other transition metals in the glass of non-altered samples, as confirmed by the geochemical analysis, makes their respective reflectance spectra much darker than predicted by the spectral mixing of mineral constituents.

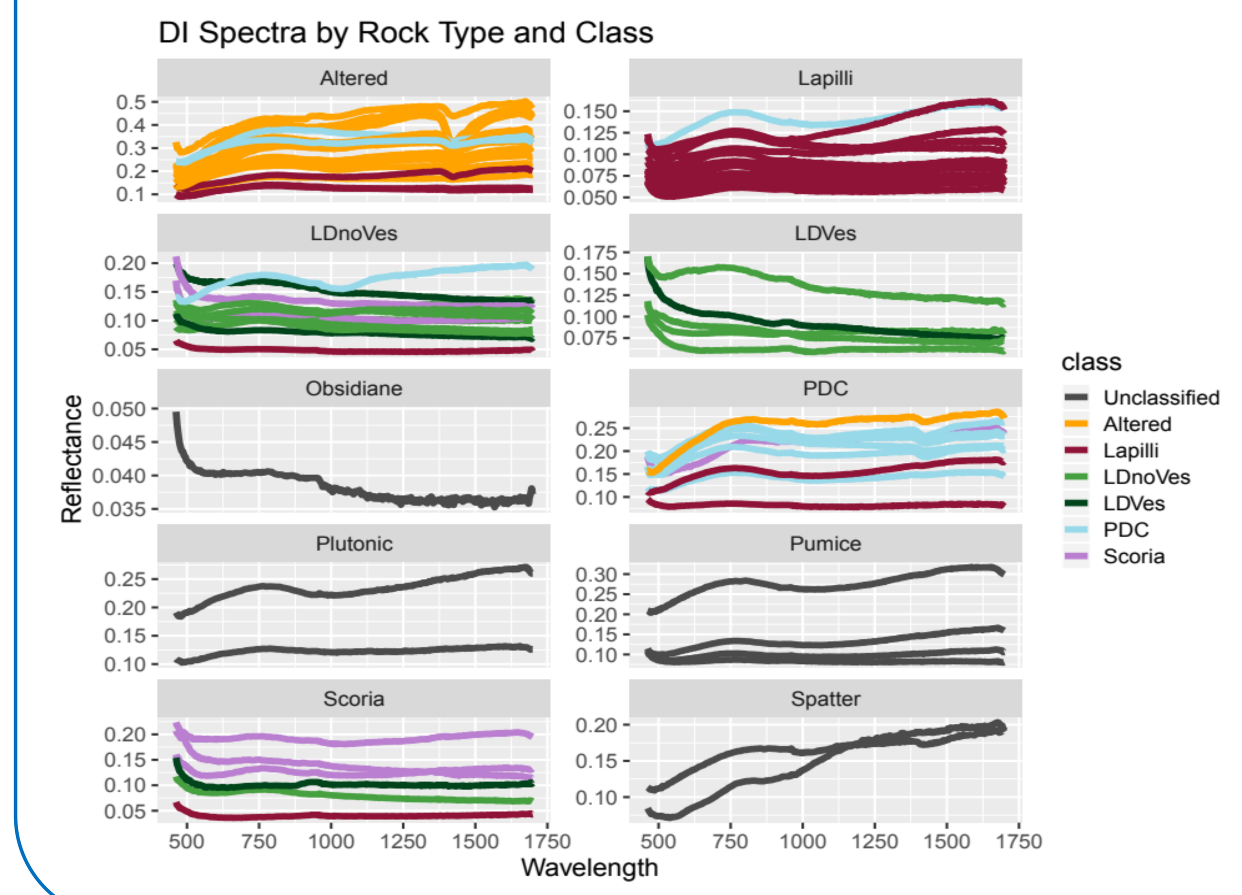
Reflectance spectra of the altered samples have a higher albedo and are flat-bell shaped in the VISNIR region with a maximum at 800 nm, and linear in the 900-1700 nm region

An absorption feature can be observed at 1430 nm, which is semi-quantitatively related to the abundance of zeolites (analcime, chabazite and phillipsite). The groups of "deep" vs. "shallow" absorption feature significantly differ in terms of zeolite abundance (t = 4.461, df = 8.173, p-value = 0.002).



Reflectance spectra of original samples (I)

Samples were classified according to a coarse rock typology by macroscopic inspection and checking for consistency with mineral composition. Reflectance spectra were acquired with a Cubert FireFly S185 (450 – 950 nm) and a Specim FX17 (950 – 1700 nm)



Observed	Predicted: Altered	Lapilli	LDNoVes	LDVes	PDC	Scoria
Altered	**15**	3	0	0	2	0
Lapilli	0	**17**	0	0	1	0
LDNoVes	0	1	**6**	2	1	2
LDVes	0	0	4	**1**	0	0
PDC	1	2	0	0	**6**	1
Scoria	0	1	1	1	0	**3**
	94%	**71%**	**55%**	**25%**	**60%**	**50%**
			LD 87%			

LDA on the spectra using Rock Type as grouping variable results on a classification with an **overall 68% accuracy.** It must be noted that most of the error of LDVes and LDNoVes is due to confusion between these two classes, thus both could be lumped together into one single class, LD, which would increase **overall accuracy to ~76%**

Reflectance spectra of original samples (II)

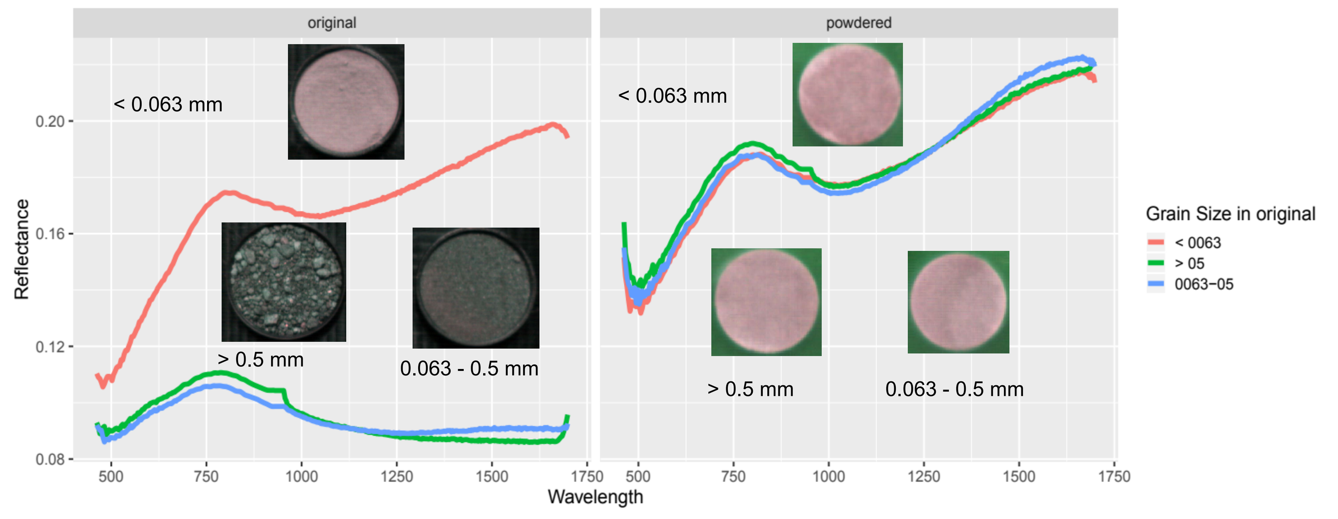
Lapilli

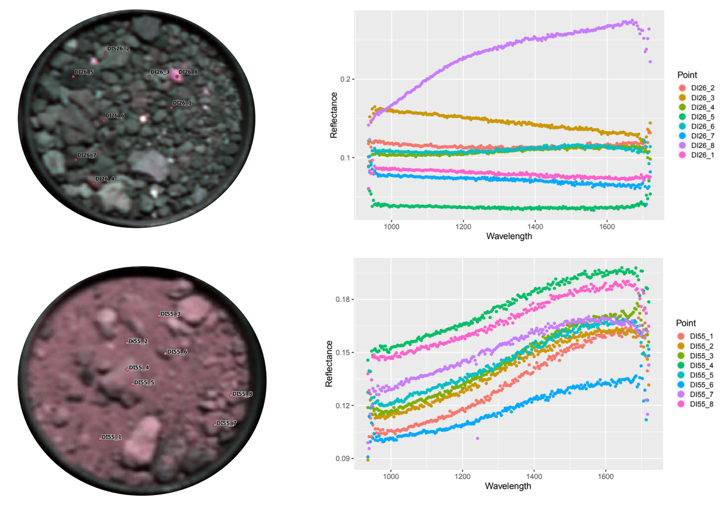
Reflectance spectra of lapilli samples are affected by grain size distribution: increasing VISNIR albedo as grain size decreases (phi increases), all other factors kept equal.

We also observe an increase of the slope between 1000 nm – 1700 nm that seems to be rather under the control of differential composition for fine (~0.063 mm) fractions. This is observable in the false color composite NIR images (1627 nm, 977 nm, 1144 nm represented as RGB). Note in the images that linearly decaying NIR spectra correspond to finer grains in some cases but not in others. This response was not observed in the rest of samples.

The VISNIR part of the lapilli spectra is also affected by the content of Fe-rich minerals such as augite, with a wide absorption at 800 nm.

Linear models to predict FeOt from either the top reflectance (reflectance at 750 nm) or the difference of reflectance values at 750 nm and 500 nm are weak, with the best models including phi50, suggesting that coarser granules might be richer in FeOt.

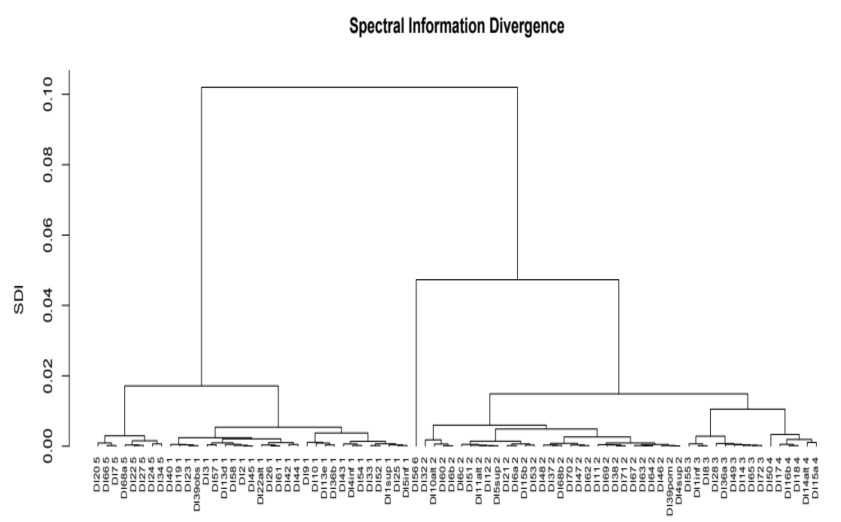


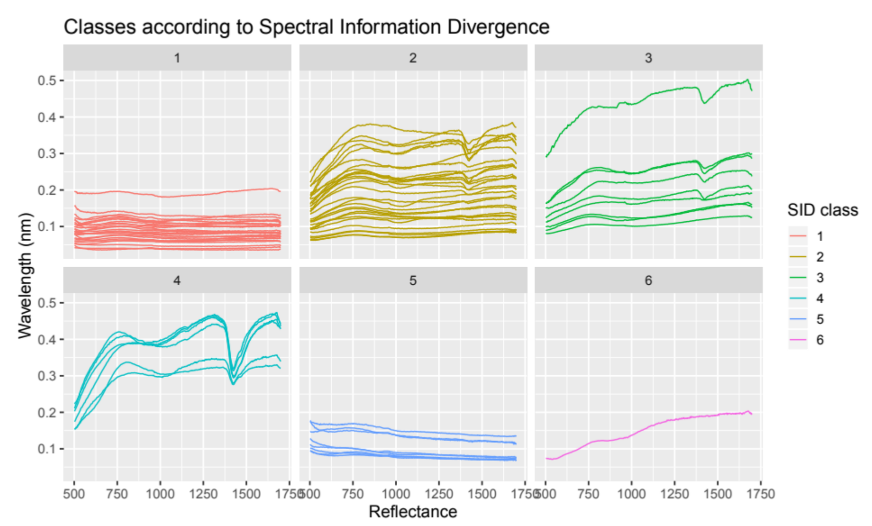


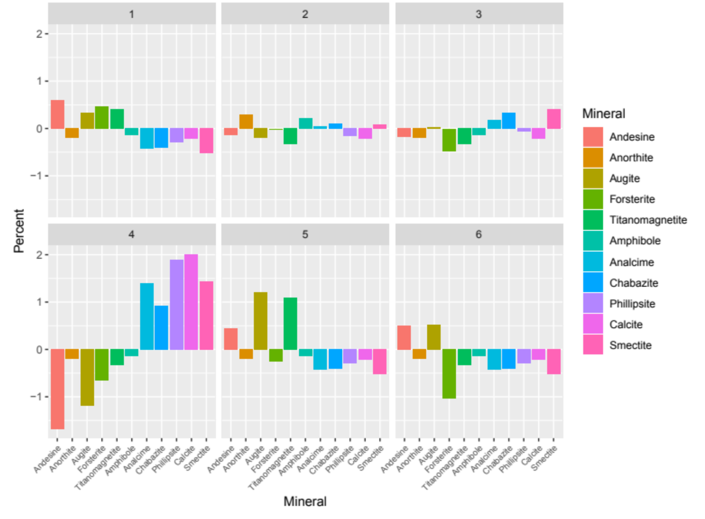
Model	R2	*p*	
FeOt ~ Reflectance@750	0.191	0.09	
FeOt ~ phi50	0.586	**0.01**	(*)
FeOt ~ Reflectance@750 + phi50	0.587	**0.04**	(*)
FeOt ~ DifRef(750, 550)	0.341	0.02	
FeOt ~ DifRef(750, 550) + phi50	0.356	0.06	
FeOt ~ phi50	0.585	**0.01**	(*)
FeOt ~ DifRef(750, 550) + phi50	0.603	**0.04**	(*)

Part of the weakness of the models is likely due to the fact that reflectance readings and geochemical analysis were acquired from different sub-samples. Also, the variability of glass is also probably disrupting both reflectance and FeOt (which cannot be exclusively linked to Fe in minerals).

Unsupervised Clustering of Reflectance Spectra







Note some spectral classes have very distinct mineral composition, but this is not always the case: part of the differences among spectral classes are probably explained by differences in volcanic glass.

Conclusions

- Reflectance spectra of volcanic rocks can be interpreted in part by mineral composition retrieved from XRD analysis (i.e., spectra of altered rocks), but information on volcanic glass is required to fully understand these spectra. This is particularly evident from the mineral composition of classes found by unsupervised clustering of spectra.
- Using spectral reflectance, we have been able to classify our samples in terms of "Altered", "Lava or Dique", "Lapilli" and "PDC" with a 76% accuracy. In particular, spectral reflectance is very efficient at detecting alteration. Considering LDA is an exploratory method, there is room for improvement using other classification techniques, which is encouraging for lithological mapping through satellite imagery. Also, we find clear differences among lapilli samples (associated to grain size distribution but also probably to mineral and glass composition), which indicates that we should be able to discriminate among different lapilli deposits.

Acknowledgements

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