SEGREGATION OF OLIVINE GRAINS IN VOLCANIC SANDS IN ICELAND - IMPLICATIONS FOR MARS.

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Introduction: Dark sand is widespread on the planet Mars especially in the north polar region and in the floor of several craters. On Earth, volcanic sands are present in desertic areas like volcanic islands such as Canaria Islands, Iceland, Réunion, or Hawaii, and arid to semi-arid volcanic provinces such as Washington plateau, New Zealand, Andes plateaus [1]. Their composition displays a large variety including basaltic minerals, volcanic glasses, cinders, and lithic fragments derived from explosions. These sands have been poorly studied, mainly because of the predominance of quartz-bearing sand and the lack of large deserts dominated volcanic sands. The primary goal of this study is to better understand the composition and sorting of volcanic sands in a context where basaltic minerals are predominant. In Iceland, many sand plains are composed of volcanic glass grains formed in subglacial context [2]. Nevertheless, one plain located in the Lambahraun plain, in the southwest of the country, is composed of basaltic minerals eroded from two shield volcanoes. In this plain it is possible to analyze variations in composition from eolian sorting. This location has been used as a natural laboratory to test wind effects on volcanic grains.

Observations: The Lambahraun lava field is blanketed by a mantle of eolian sands, especially to the western part where the terrain is relatively flat. Eolian ripples are frequent, but no true eolian dunes exist. During field campaigns katabatic winds were observed coming down from the Langjökull glaciers producing a strong northern wind. Drifting of sand was visible on the ground raising up in the air a large amount of dust through saltation of sand particles. The corridor defined by the sand movement is visible on the Landsat image where the smoothest part of the lava field is elongated from north to south at the western edge of the field (Fig. 1).

Composition of sand and source rocks were achieved with fluorescence X. Most major and minor elements have a weight oxides proportion in between the two source rocks. However, an enrichment in Mg, Fe and Ni is observed for most sand samples compared to source rocks. This enrichment can be explained by a significant increase in the proportion of olivine. Indeed, this mineral is dominated by Mg and Fe. In Eldborgir lavas, the predominant metal present is Mg, as established from ion microprobe. The olivine measured are indeed forsterite (Fo64-Fo82). Ion microprobe results also indicates that the olivine grains contain strong proportion of Ni (0.16% in average), whereas other grains are devoid of Ni. Thus, Nickel corresponds to a good chemical indicator of variations of olivine proportion in the different samples. As these three elements (Mg, Fe, Ni) are enriched simultaneously in sand, they may indicate a higher proportion of olivine in sand.

Fig. 1: SPOT image of the Lambahraun plain with samples collected along the main wind direction (north to south). Bottom: Image of the Lambahraun plain.

To analyze this hypothesis more in-depth a plot displaying Ni versus Mg abundance has been derived for all sands and rocks (Fig. 2). The plot of the ELD rock composition is normalized by a mean of six samples of the Eldborgir lava flows. It is visible that the other sand source, the basalts from the Skersli volcano, has a proportion in Ni and Mg almost similar to Eldborgir lavas. All sand compositions are significantly enriched in Ni and Mg with regards to the source rocks. Moreover, they all plot on a straight line which demonstrate that the trend observed results of a conjugated enrichment in Mg and Ni. Only samples ELD4S and ELD5S are poorly enriched. They are located close to the source region. The point ELD3G indicates gravels taken on a glacial moraine in the source area with a slightly higher abundance in Mg and Ni. These moraines already contain sand size grains, probably explaining this slightly higher ratio. Thin sections were used to derive relative proportions of olivine in sand.
and rocks. It has been observed that olivine constitute typically 5 to 10% of rock mineralogy, whereas it constitute about 20% of grains in sands.

At this point it should be demonstrated that the enrichment in olivine in sands is related to eolian processes. Sand sizes for all sand samples were measured from a laser granulometer. Finest sand samples correspond to those showing a predominant grain fraction below 400 µm, thus #ELD3S, ELD8S, ELD11S and ELD12S. The sample ELD12S has been collected from saltating grains during a storm, therefore corresponding a typical eolian sand sorted by wind. It shows a peak in grain size at about 200 µm, therefore demonstrating a typical eolian sand sorted by wind. It shows a peak in grain size at about 200 µm. Coarser sands correspond to ELD4S and ELD5S that are composed largely by >400 µm grains. They are poorly sorted by wind with only minor fraction of small grains in the 200 µm range. The most sorted sands correspond to those with the highest Ni and Mg fraction, therefore demonstrating that the enrichment in olivine is related to the eolian sorting.

Volcanic plains are not predominant on Earth, therefore limiting the consequences of these results to a few regions of the world. In contrast, Mars is a planet widely covered by volcanic plains in a dry climate that creates widespread sand dunes. Infrared hyperspectral imagery taken from orbit has found that the composition of dark dunes is frequently dominated by pyroxenes, with local presence of olivine, plagioclase, volcanic or impact glass, or magnetite depending on locations [e.g. 3, 4]. This is not surprising given the predominance of basaltic plains at the surface of Mars. However, many volcanic regions are covered by sand, and the composition of sand is often taken as a mean for extracting the average composition of the underlying bedrock [5]. Global maps do not care to the detailed morphology for establishing the composition of volcanic regions despite plains can be extensively covered by sand. Yet, sorting effects in sand grains may modify the composition of sand and therefore may change the apparent composition of the underlying bedrock. Despite being small variations, these effects in Iceland occurred over 4000 years, while Martian eolian erosion over million of years enables much longer eolian sorting and related minerals segregation.

**Conclusions:**
The Lambahraun volcanic plain in Iceland displays widespread sand composed of local basaltic grains. Sands display subtle differences from the source rocks. The chemical and mineralogical analyses demonstrate that a conjugate of Mg and Ni enrichment in sands relative to rocks is due to the higher proportion of olivine grains in sand. This enrichment is correlated to a lower mean grain size of sands, therefore to a higher eolian sorting. Applications of these results to previous studies about volcanic sands on Mars suggest that the physical sorting of olivine grains should be taken into account when extracting composition from orbital data.

**References:**

![Fig. 2: Proportion of Ni and Mg ratioed over the mean source rock composition. The correlation between Mg and Ni increase in sand demonstrates the increase in olivine proportion in sands number 1, 8, 9, 10, 11, 12. The sample 6F is a fraction of fine grains taken from the sample 6.](image1)

![Fig. 3: Median diometer (d50) of each samples versus the Ni proportion, which is a direct mean for olivine proportion increase. The most sorted sands are the most enriched in olivine demonstrating that eolian sorting is responsible of the olivine increase in sand.](image2)