Solid Earth Discuss., 3, C635–C639, 2012
www.solid-earth-discuss.net/3/C635/2012/

Solid Earth
Discussions

Interactive comment on "Floating sandstones off El Hierro (Canary Islands, Spain): the peculiar case of the October 2011 eruption" *by* V. R. Troll et al.

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Received and published: 26 January 2012

In response to Reviewer R. Paris's comments we would like to give the following replies:

1) The origin of the gas that causes vesiculation of the 'restingolites' is most probably a mixture of volatiles released from: (i) Breakdown of OH-bearing sheet silicates as suggested by XRD data where evidence for thermal decomposition of clays is provided; (ii) Traces of gypsum and carbonate and their thermal alteration phases (e.g. wollastonite) point to potential mobilisation of SO2 and CO2, respectively. (iii) Although not well constrained, some pore water may be present even at depth, which could then contribute to the volatile budget of the restingolites. The higher vesicularity compared to the results

of Berg (2011) may be due to higher temperatures and higher sheet silicate contents of the restingolites than what has been used in the experimental approach of Berg (2011).

2) Other hypotheses: This point has several aspects. Firstly, the whole rock composition of the restingolites shows SiO2 in excess of 70 wt. %. The point that we make is that no such composition is recorded on El Hierro. There, only rare occurrences of trachyte with 65 wt. % SiO2 that have been reported. Magmatic compositions from the other Canary Islands barely attain 70 wt. % in silica, and any that do are from the late stages of volcanism during island growth (e.g. post-shield). Thus, the occurrence of high silica magmatic 'rhyolite' is very unlikely on El Hierro. Secondly, concerning mineralogy, we point out that wind-blown quartz is very fine-grained and that island flank sediment would, in addition, be full of igneous/volcanic detritus. Indeed, dredge samples of ocean bottom sediments from near the eruption site and from many other places in the Canaries show an abundance of igneous detritus. The occurrence of large, macroscopic, and clearly non-igneous quartz crystals, in turn, points to a turbiditic mode of transport of the original sediment from the nearest continent (Africa). At the same time, the complete absence of igneous minerals supports the hypothesis that the sediment formed prior to the availability of igneous detritus, i.e., before the island formed. These points are all made already in the manuscript but we will aim to clarify our argumentation in the revised version

3) Comparison to other xenoliths: We appreciate that the referee would like more detail here, but we feel that giving reference to the previous work has to suffice as it is not the task of this manuscript to review the topic extensively. The description of the La Palma pumice xenoliths by Araña and Ibarrola (1973) fits exactly to most of the restingolites. The absence of these xenoliths in lava flows is probably due to their low survival potential in slowly cooling lava, where they would tend to become progressively assimilated rather than freezing to a glassy foam. Ejection and quenching of these xenoliths can occur during eruption on land as well as on the seafloor, and entrapment of the xenoliths by the host basanite is independent of the subsequent eruption site. Regarding

the ranges in the vesicularity of different xenoliths, we note that vesiculation clearly depends on a range of factors that include (1) duration of magma-xenolith interaction, (2) temperature of the host magma, and (3) composition and solidus of the xenoliths.

Note for example, that the GC xenoliths are inhomogeneous in their vesicle distribution (Fig. 1M-O). Alternatively, differences in the amount of vesiculation (in the GC samples and in case of the experimental results by Berg (2011)) are likely a function of different initial volatile contents. Regardless of the degree and detailed style of vesiculation, the fundamental point is that the occurrence of foamy and non-vesiculated pre-island sedimentary material is known from other places in the Canaries, i.e., the phenomenon is not new and probably a rather common process that we (the society) have now witnessed in action during the recent El Hierro events.

Finally, newly obtained oxygen isotope data on three restingolite samples points to their formation by magmatic processes as being highly unlikely. The restingolites exhibit d18O values that are in excess of +9 per mil., which is significantly higher than highly evolved Canary Islands magmatic rocks, e.g. such as those reported in Hansteen & Troll (2003) showing, e.g., 6.84 per mil. for feldspar in a rhyolitic ignimbrite. We have now added this preliminary data to the paper and discuss it further. Specific comments: Title: The curiosity of the eruption was specifically that these were floating, so we believe that the title should reflect this likely search criterion of a potential reader. However, we see that the term “sandstone” might be misunderstood and is also not reflecting unambiguously the origin of the xenoliths from layer 1 of the ocean crust as opposed to ocean floor surface sediment. We therefore propose the following alternative title for title re-phrasing: - Floating stones off El Hierro, Canary Islands: xenoliths of pre-island sedimentary origin in the early products of the October 2011 eruption line 69: We have added references to Carracedo et al. (2001) and Pellicer (1979) as they report on the most silicic compositions observed on El Hierro. lines 77-78: We moved the sentence to line 60. lines 78-81: We believe that a sentence summarising our findings should occur in the introduction. line 159: We added “and

structure”. Consequently, we deleted reference to sample No. 2 and make this a more general statement. lines 176-178: We added reference to Hoernle, 1998; Hansteen and Troll, 2003; Berg, 2011. line 210: We added the following sentence: “Layer 1 of the oceanic crust is usually built of deep-sea sediments and, near continents, terrigenous, turbidity-current derived sediments (cf. Fig. 5).” Sampling of the following phases (November 2011) did not reveal any white pumice, only basanitic magma. This is an important observation to mention.: We made this point in lines 227-231: ” The large quantities of “restingolites” during the early eruption phase and their disappearance during the later stages of the eruption is a likely consequence of the establishment of a relatively stable conduit, the formation of which required clearing the way for the ascending magma through the sedimentary rocks of layer 1.” In addition, we added the following statement to the introduction: “Two distinct types of eruptive products were observed at different stages of the eruption: 1) abundant rock fragments resembling lava bombs on a decimetre scale, characterised by glassy basaltic crusts and white to cream coloured interiors, were found floating and drifting on the ocean surface during the first days of the eruption; 2) entirely basaltic “lava balloons”, frequently exceeding 1 m in size, often with hollow interiors, were sampled by ship while temporarily floating above the emission centre in the later phase of the eruption (e.g. November onward; IGN, 2011).” line 240: We changed this sentence to “Seismicity at El Hierro prior to and in the early phase of the eruption clustered primarily between 7 and 17 km depth, i.e. within the igneous ocean crust and at the base of crustal layer 1 (IGN, 2011), but above the proposed level of final crystal fractionation proposed for El Hierro by Stroncik et al. (2009).” Fig. 3E & EF: The occurrence of clay fragments indicates incomplete melting and suggests that these particular xenoliths had very short magma contact before being quenched, probably on the order of hours perhaps. Progressive vesiculation will also have slowed down the heating rate and put up the melting point(s) in some parts of the xenoliths. Minor local entrainment of clays from the present-day sea bottom cannot be ruled out completely, but is unlikely because of the mode of restingolite occurrence (i.e. associated with quartz-rich compositions completely coated by the host basalt and with an absence of igneous minerals). Fig. 4: Zirconium is used as differentiation index, because zircon is absent in even the most evolved lavas of El Hierro. Hence, Zr progressively rises in concentration with degree of differentiation and reliably traces it (Watson, 1979; Wolff, 1987; Wolff & Toney, 1993; Bryan et al., 2002). Technical corrections: Location map: We have now worked in a new figure 1 that includes satellite images of the Canary Islands and El Hierro. We have renumbered all other figures accordingly. line 27: We replaced “intriguing” with “peculiar”. line 51: We added “submarine eruption” to the key work list. line 60: We moved the sentence from lines 77-78 to line 60 so that sampling dates are mentioned here. line 173: We corrected the reference to the figure. line 227: We started a new paragraph. Table 1, Figs A2 & A3: We would like to keep the table in the main text as it summarises in a very simple manner the results of XRD analysis. As a consequence, the XRD plots only need to appear in the appendix. References: Sparks, 1998. We deleted this reference, as it was in fact identical to McLeod and Sparks. References Bryan SE, Marti J, Leosson M (2002) Petrology and Geochemistry of the Bandas del Sur Formation, Las Canadas Edifice, Tenerife (Canary Islands). J Petrol 43 (10):1815-1856 Watson EB (1979) Zircon saturation in felsic liquids: Experimental results and applications to trace element geochemistry. Contrib Mineral Petrol 70 (4):407-419 Wolff JA (1987) Crystallisation of nepheline syenite in a subvolcanic magma system: Tenerife, Canary islands. Lithos 20 (3):207-223 Wolff JA, Toney JB (1993) Trapped liquid from a nepheline syenite: a re-evaluation of Na-, Zr-, F-rich interstitial glass in a xenolith from Tenerife, Canary Islands. Lithos 29 (3-4):285-293

Interactive comment on Solid Earth Discuss., 3, 975, 2011.