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Interactive Comment

Interactive comment on "Greenland ice core evidence of the 79 AD Vesuvius eruption" *by* C. Barbante et al.

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Title: Greenland Ice Core Evidence of the AD 79 Vesuvius Eruption
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General comments

I agree with the authors that this paper is presented to"... investigate the GRIP ice core between 428 to 430 m depth to determine if evidence of the 79 AD Vesuvius

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eruption is preserved in the ice strata." I have to add that over the last thirty years, the development of Greenland ice core stratigraphy has become dependent on several set points established by correlating volcanic products found in ice cores with historical or prehistorical records of global volcanism (e.g., Clausen et al, 1997; Meese et al., 1997; Vinther et al, 2006 ; Svensson et al., 2008). One such key point is the A.D. 79 Vesuvius Eruption. Originally, (Clausen et al, 1997) in Table 3 reported an acidity spike in Dye 3 (A.D. 80) and GRIP (A.D. 79) but didn't attribute it to the historical A.D. 79 Vesuvius eruption. A decade later, Vinther et al, 2006 used Vesuvius as a "historical tie point" (Table 4) based on identified tephra quoted as: "C. Barbante, personal communication, 2005" on page 6.

This paper presents results of SEM-EDS analyses of tephra found on 4 μm porosity filters from 16 samples obtained after equally dividing along the 55 cm long 3x3 section of ice and melted using a Millipore stainless steel filtration system. I have no means to confirm the developed time scales for both Dye-3 and GRIP ice cores, because high resolution data are not yet available to the general public. I agree with the short comments (SC) made by Drs. Baillie and Sigl that, based on data presented by the authors, the chronology of the eruption timing is confusing. Clarification in the paper text or figure caption is needed. If we assume that the Greenland Ice core Chronology 2005 (GICC05) time scale is valid around A.D. 79, then timing of the acidity peak in several Greenland ice cores coincides with the Vesuvius A.D. 79 eruption. At the present time one of the most accepted methods to independently confirm the origin of volcanic material is to investigate the composition of tephra particles. Overall, Icelandic volcanic sources are very well characterized in Greenland ice core records (e.g., Hammer, 1984; Davies et al., 2010; Coulter et al., 2012) mainly because the size of tephra particles allows preparation of samples for high quality analytical measurements using microprobe (Dunbar et al., 2003; Kuehn et a., 2010; Hayward, 2011) or LA-ICP-MS (see methodology in Pearce et al., 2011).

Unfortunately, when tephra particles extracted from meltwater ice core samples are

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small (smaller than 10 μm), it is hard to impossible to polish samples for quantitative analytical measurements of geochemical composition using instrumentation currently available to most ice core researchers. Of the results presented in this paper, correctly pointing from the list of "known major volcanic eruptions between 50-100 A.D." (see Table 2) only A.D. 79 Vesuvius Eruption belongs to K-phonolitic series. The data presented in Table 1 make it impossible to evaluate the precision and accuracy of the analyses conducted on tephra particles extracted from ice cores. In general, high silica, high alkali glass are quite unstable under the electron beam. If this is the case, several potential volcanic regions with relatively poor historical records from the Azores (e.g. Ablay et al., 1998) to Iceland or Iranian volcanoes (Davidson et al., 2004) are possible candidates based on geochemical fingerprint and measurement errors. Saying this, I would like to point that the paper provides an important contribution to further develop Greenland tephrochronology. If possible, I would like to recommend including the following additional information on measured tephra particles from the GRIP ice core:

- SEM images
- total number of particles and grain size analyses using SEM images
- Philips XL30 and EDAX DX4 settings, including geometry of EDS detector(s).
- results of EDS measurements of Vesuvius white pumice of the same size on the same instrument under the same operating conditions and with the same tools and supplies.
- Monte Carlo simulation of grain size dependance on tephra particle analysis that could predict possible changes in measured composition.

The information will not probably convince skeptics but will be very useful for future investigations, considering the constantly evolving field of cryptotephra research (Lowe, 2011).

My last major point is related to the comment made by Dr. Baillie about potential "circularity" in loading for the A.D. 79 Vesuvius Eruption, estimated from ice core records (see page 5438, Line 25). The majority of ice core researchers are well aware that the atmospheric loading calculation for this eruption is based on magnitudes of sulfate spikes in Dye 3, GRIP and GISP2 ice cores. It is also known that in the GISP2 annual counted chronology the only available acidity peak was about ten years off from the A.D. 79 date (see Zielinski, 1995, page 20,940), thus providing a possibility for "another volcanic event". I agree with Dr. Baillie's concern that large sulfate spike attribution to A.D. 79 eruption could mislead the estimation of the total sulfate eruption burden if no other independent methods for the estimate of sulfate emissions from this eruption are used. The authors probably could clarify their position in the next revision.

In my opinion, by providing the original ice core data the authors demonstrate that they are trying to resolve whether the Vesuvius A.D. 79 eruption is a source of volcanic material in the Greenland ice sheet. The paper one more time confirms that there is tephra in ice core records and it should play a role in resolving the ambiguity in interpretations of source volcanic eruptions in the future. I think this paper moves tephrochronology in GRIP ice core in the right direction. Ice cores are unique media because not only climate signal is preserved in the ice, but also composition of the atmospheric impurities that could help us to interpret past climate forcing mechanism once we learn better to extract the information preserved in these paleoclimate archives. I do not see major conflict in the developed time scale (see Dr. Baillie comments) because no observation is absolutely accurate. Additional modifications of GICC05 time scale probably can be avoided by reevaluation of uncertainty in developed time scale as more (and better resolution) ice core data will become available. The presented paper is not dealing directly with time scale development. Probably the authors should adjust the text to clearly stay focused on the major goal that they stated in the Introduction section: **To publish tephra record from GRIP ice core**. I would not recommend any major

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revisions because the authors clearly separated the interpretation part from data. It is clear that new emerging methods would help future geochemical fingerprinting of cryptotephra from ice cores.

Specific comments

Page 5430, line 25. Why do the authors reference Kelly et al., 1996 and ignore early work on this topic? Maybe add some specific details why his paper was important for understanding how "low-latitude explosive volcanoes ... are capable of cooling the global climate for several years " .

Page 5431, line 10. Maybe replace the reference to Langway et al., 1988 with the paper by Rampino and Self (1982). Reword lines 10-13 so it is clear to the reader that SO_2 injected into the stratosphere by large volcanic eruptions is more likely to be transported to polar regions once it is converted into H_2SO_4 based aerosols.

Page 5433, line 25. Need more explanation about why mass of material suggest that tephra reached Greenland.

Page 5435, line 7. "are generally considered to signify volcanic eruptions in Greenland ice cores ". I agree with Dr. Baillie that new data from a number of ice cores show complex relationships between acidity peaks, tephra layers and confirmed historical volcanic eruptions. (see more in Davies et al., 2010; Coulter et al., 2012). The authors also say this on Page 5432, Line 12. Maybe remove the reference to Clausen et al., 1997 and just mention that there is an ECM peak at 429.1 m depth in the GRIP ice core?

Page 5441, line 6. "We demonstrate that the high acidity signal and SO_2 spike found at 429.1 m depth and the microparticle peak at 429.3 m in the GRIP ice core are caused by a major volcanic eruption." Maybe remove this line or reword? This sentence is not really related to the goal of the paper.

Page 5441, line 14. "The low number of glass fragments in the ice is likely due to the

15 relatively low height of the eruption column (26âĂŽÄì32 km), and the SSE trajectory of the plinean phase of the eruption (Carey and Sigurdsson, 1987; Sigurdsson et al., 1990). This low number of volcanic glass fragments is consistent with quantities of volcanic ejecta in ice cores (Palais et al., 1992)." Transport of volcanic material to polar regions is still relatively poorly understood. References provided by the authors do not provide any quantitative information on how the number of volcanic particles in the Greenland ice core should be related to the magnitude of the volcanic events.

Fig. 4. Plot individual tephra particles (only six data points are available anyway) from ice core instead of showing all measurements data combined together.

Technical corrections

Page 5431, line 13. Change spelling of "scavanged" to "scavenged".

Page 5433, line 4. Change spelling of "plinean" to "Plinian".

Page 5434, line 3. It is an important paragraph but it feels a little bit out of place here... Maybe move the information about time scale and ice core locations to the next section?

Use A.D. instead of "AD" in the text.

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