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Late Glacial-Holocene tephra from southern Patagonia and Tierra del Fuego (Argentina, Chile): A complete textural and geochemical fingerprinting for distal correlations in the Southern Hemisphere

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ABSTRACT

Explosive volcanoes from the southern Andes are able to disperse ash over wide areas of the Southern Hemisphere, potentially as far as Antarctica. With the aim of improving correlations between sources and tephra in southernmost South America and, possibly, Antarctica, this work presents new field, textural and geochemical data on tephra layers from southern Patagonia and Tierra del Fuego (Argentina and Chile). Major- and trace-element data, obtained on single glass shards allowed to identify tephra sources in Late Glacial-Holocene eruptions from Hudson, Reclus and Mt Burney volcanoes, located in the Southern and Austral Volcanic Zone of the Andean Cordillera. Twelve new radiocarbon age determinations of charcoals, peats and soils have further constrained the correlations between the studied tephra layers and known eruptions from Hudson, Mt Burney and Reclus volcanoes. Therefore, this study contributes to expand the geochemical dataset on volcanic glasses valuable for tephra correlations in South America, and improves the current tephrostratigraphic framework of this region. Furthermore, we revised literature data by compiling a database including Neogene-Quaternary volcanic tephra found in Antarctic ice cores, marine sediments, blue ice and continental outcrops as well as tephra produced by volcanic sources located in Antarctica and circum-Antarctic areas. This revision shows that Antarctic tephra can be correlated with confidence to Antarctic and circum-Antarctic (South Shetlands and South Sandwich Islands) volcanic sources, whereas correlations with South American sources are arguable, and a complete geochemical fingerprinting is needed for validation.

1. Introduction

Tephra layers preserved in geological records represent a valuable tool for reconstructing the past volcanic activity of a given area. Moreover, they are isochronous marker horizons providing time-stratigraphic information whenever they are geochemically fingerprinted and tied to a known, dated eruption (Lowe, 2011; Lowe and Alloway, 2015). Volcanoes of southernmost South America have been proposed as possible extra-Antarctic sources of some tephra recovered in Antarctic glacial archives (Kurbatov et al., 2006; Narcisi et al., 2010, 2012), along with those from the South Sandwich Islands and New Zealand (Dunbar et al., 2017; Narcisi et al., 2005, 2012). Thus, in this perspective, tephra recovered from southern Patagonia and Tierra del Fuego (hereafter SPTF) have additional value as a tool for the correlation of geological, paleoclimatic and paleoenvironmental archives at intercontinental scale.

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Late Glacial to Holocene tephra layers in SPTF (Argentina and Chile) have been recovered in different sedimentary archives including terrestrial outcrops, marine and lacustrine cores (Fontijn et al., 2014). They have been produced by several volcanoes during tens of eruptions some of which are characterized by intensities up to a Volcanic Explosive Index (VEI) of 6 (Naranjo and Stern, 1998). Some of these eruptions emplaced volumes of tephra larger than 20 km^3 (e.g., Hudson Ho eruption; Weller et al., 2014), with a dispersal area covering almost the whole SPTF and extending over the surrounding oceans.

Despite their significance, and with the exception of few cases (Haberle and Lumley, 1998; Kilian et al., 2003; Kratzmann et al., 2010; Stern, 2008; Weller et al., 2014), most of the eruptions occurred in the SPTF have been solely characterized by the chemical composition of the bulk tephra deposit or the bulk rock analysis of the juvenile component. Conversely, textural and mineralogical characterization, as well as major- and, even most, trace-element analyses of glasses are scarce. This issue represents a significant limitation when correlating tephra at both proximal to distal scale (i.e., SPTF) and distal to ultra-distal, Southern Hemisphere-wide scale (e.g., with the Antarctic ice records). In fact, the major- and trace-element compositions of the bulk deposit may significantly differ from that of individual glass shards, commonly recovered and analyzed in ultra-distal locations, since the former may be variably affected by sample heterogeneity, and inter-shard variations (Pearce et al., 2004). Moreover, the bulk rock composition will correspond to that of glass fraction only if the first one is aphyric and formed only by juvenile material with no accidental lithics. Finally, many explosive eruptions are rhyolitic or dacitic in composition and almost indistinguishable using the major-element chemistry alone. In such cases, the study of textural and mineralogical features of tephra (e.g., nature and abundance of the components, particles morphology, vesicle size and distribution and crystal content) associated with single-glass-shard trace-element data is an invaluable help for the identification of their eruptive sources and for the correlation of different tephra layers (Pearce et al., 2004). This approach, typical of modern tephrostratigraphy, has never been fully applied to Patagonian tephra and only few papers report on the textural and physical features of studied deposits as well as on the mineralogical assemblage of distal tephra.

In this work, we present and discuss new data on texture, mineralogy, major- and trace-element geochemical composition performed on single glass shards of several tephra layers occurring in different, mostly unreported, stratigraphic sections in SPTF (Argentina and Chile). In addition, we provide new radiocarbon ages of charcoals, peats, and soils that further constrain the correlation between tephra layers and known volcanic eruptions. Findings of this investigation implement the existing tephrostratigraphic framework for the SPTF by also increasing the inventory of known outcrops. In the light of these results, we discuss the provenance of some tephra layers found in the Antarctic ice-records and previously attributed to the volcanoes of Southern and Austral Volcanic Zone of the Andean Cordillera.

2. Volcanological framework

In South America, most of the explosive Holocene volcanism is produced by the Andean Arc, a segmented volcanic arc along the Andean Cordillera (Stern, 2004). Volcanism formed as a result of the subduction of the Nazca and Antarctic plates underneath the South American Plate (Fig. 1), and is subdivided into four main volcanic zones separated from each other by volcanic gaps (Stern et al., 1984): the Northern (NVZ), the Central (CVZ), the Southern (SVZ), and the Austral Volcanic Zone (AVZ). The SVZ and AVZ are the closest to the area under study.

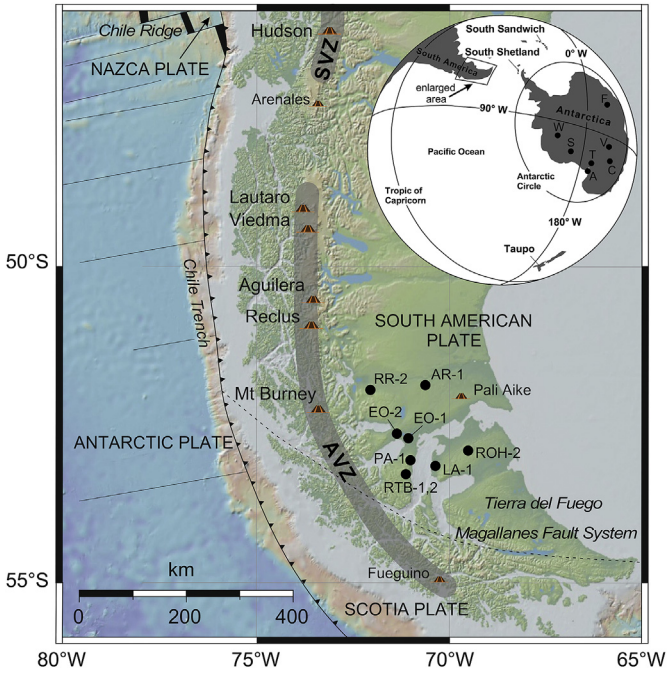

Fig. 1. Map of southernmost South America showing the locations of the Holocene volcanoes, the extent of the Austral Volcanic Zone of the Andes, and the tephra outcrops studied in this work. Abbreviations: AR, Arroyo Robles; RR, Río Rubens; EO, Estancia Otway; ROH, Río O'Higgins; PA, Punta Arenas; LA, Laguna de los Cisnes; RTB, Río Tres Brazos. The inset shows the Southern Hemisphere with the localities mentioned in the text: F, Dome Fuji; V, Vostok Station; C, Dome C; T, Taylor Dome; A, Andrill; S, Siple Dome; W, WAIS Divide.

The SVZ comprises 60 volcanic centers aligned along a 1400 km-long, continuous volcanic arc active since the Late Quaternary. Similarly, the AVZ volcanic arc comprises six volcanic complexes active since the Late Quaternary: Lautaro, Viedma, Aguilera, Reclus, Mt Burney and Fueguino, also known as Cook (Corbella and Lara, 2008; Stern and Kilian, 1996).

Tephrostratigraphic and tephrochronological studies conducted in the Patagonia-Tierra del Fuego region have shown that explosive volcanism has been extremely active during the Holocene and Late Glacial period, often with high magnitude eruptions (Fontjin et al., 2014). In geological records, tephra layers have been correlated to large eruptions from four principal sources: Hudson, Mt Burney, Reclus and Aguilera volcanoes (Stern, 2008, Fig. 1).

The Hudson volcanic complex is the most active in the southern SVZ. Tephrostratigraphic records count at least a dozen of large-scale explosive eruptions since the Late Glacial period (Fontijn et al., 2014). The major explosive events of Hudson volcano occurred at ca.17,400 cal yrs BP (Ho) (Weller et al., 2014), at 7750 cal yrs BP (H_1) (Fontijn et al., 2014; Prieto et al., 2013), at 3920 cal yrs BP (H_2) (Naranjo and Stern, 1998), and in AD 1991 (H_3) (Scasso et al., 1994). All these eruptions produced a considerable volume of pyroclastic material, possibly ranging between >20 km^3 (Ho) to ca. 4.3 km^3 (H_3).

Mt Burney is a volcanic complex formed by a somma and an inner stratocone. The study of tephra over the Patagonia and Tierra del Fuego has yielded evidence for several eruptions from Mt Burney volcano, including two large Plinian eruptions named MB_1 and MB_2 (Stern, 2008). Radiocarbon dating indicates an age for MB_1 eruption comprised between 8851 and 9949 cal yrs BP (Kilian et al., 2003; Stern, 2008). The age of MB_2 tephra has also been determined at several sites between 3818 and 4711 cal years BP (Kilian et al., 2003; McCulloch and Bentley, 1998; McCulloch and Davies,