

Integrated tephrochronology of the West Antarctic region- Implications for a potential tephra record in the West Antarctic Ice Sheet (WAIS) Divide Ice Core

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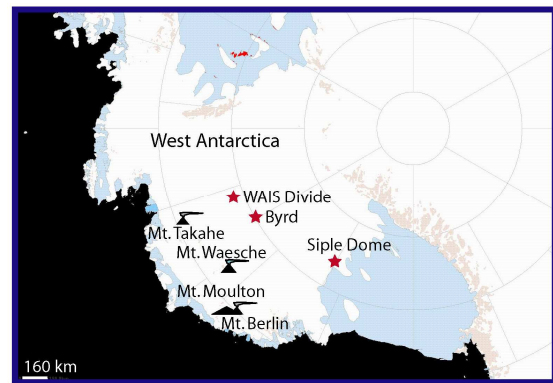
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Ice cores from polar regions, in addition to being a climate archives, also capture volcanic particles (tephra) and aerosols, produced during major explosive eruptions. Tephra layers in ice cores can provide important time-stratigraphic information if geochemically tied to a known, dated eruption, or used as cross-correlated time horizons between ice cores. Tephra examined in West Antarctica are dominated by local source volcanoes, although some record of non-Antarctic volcanism is also present.

Source Volcanoes: Mt. Berlin and Mt. Takahe

A number of volcanoes protrude through the West Antarctic Ice Sheet (LeMasurier and Thomson, 1990) (Fig. 1). Of these, Mt. Takahe and Mt. Berlin have been the most active ash-producers over the last 500,000 years. Mt. Takahe, a flat-topped stratovolcano, has produced a number of recent trachytic eruptions, including events at 8.2 ± 5.4 ka, 93.3 ± 7.8 ka and 102 ± 7.4 ka (Wilch et al., 1999). Mt. Berlin has also erupted a number of times over the last 100,000 years, including young events sampled in the crater region of Mt. Berlin at 10.3 ± 5.3 , 18.2 ± 5.8 , 25.5 ± 2.0 (Wilch et al., 1999). The explosive eruptions from these volcanoes, particularly Mt. Berlin, could have reach heights of 30 km (Wilch, 1997). A number of eruptions from Mt. Berlin have been recognized in an englacial tephra section at Mt. Moulton (discussed below). These explosive eruptions are typically of peralkaline trachytic composition, but distinct chemical differences have been observed between the two volcanoes, and as well as between different eruptions from the same volcano.



The explosivity and apparently large area covered by deposits from some of the eruption mentioned above suggest that some may be present in the WAIS Divide ice core. Deposits resulting from some of these explosive eruptions have been found in outcrop on the source volcanoes (Wilch et al., 1999). However outcrop exposures of many of the deposits are likely to be absent due to erosion or coverage by subsequent eruptions. A more complete record of the explosive eruptions is preserved as tephra layers in ice than is represented by near-source rock outcrops. Three sites in West Antarctic containing significant tephra records are known. These include the Mt. Moulton and Mt. Waesche blue ice deposits, and the Siple Dome ice core. The tephra record at these sites provides insight into the record that may be found in the WAIS Divide ice core.

Mt. Moulton, Mt. Waesche, and Siple Dome

A site on the shoulder of the ice-filled summit crater of Mt. Moulton, located at an elevation of 2800 meters in West Antarctica, exhibits a long section of exposed blue ice and intercalated tephra layers. Many of the tephra layers are thick (up to 10 cm) and coarse (pumice up to 3 cm). A total of 48 visible tephra layers are observed. Most of the Mt. Moulton tephra layers are trachytic, and are thought to be derived from Mt. Berlin, located only 30 km away from the blue ice site. Eight of the tephra layers at the Mt. Moulton site have been directly dated using $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology of potassic feldspar phenocrysts, to (in stratigraphic order from top to base of the blue ice section) 10.5 ± 2.5 ; 24.7 ± 1.5 ; 92.1 ± 0.9 ; 104.9 ± 0.6 ; 118.1 ± 1.3 ; 135.6 ± 0.9 ; 225.7 ± 11.6 ; and 495.6 ± 9.7 ka.

In contrast to Mt. Moulton, the Mt. Waesche site, located at between 1900-2000 meters elevation in a blue ice field on the south side of the volcano, displays a complex, deformed stratigraphy. The tephra layers at Mt. Waesche are dominantly either coarse and basanitic, probably of local derivation, or fine and trachytic, mainly derived from Mt. Berlin or Mt. Takahe. One of the stratigraphically highest tephra layers at Mt. Waesche is geochemically correlated to the 8.2 ± 5.4 ka from Mt. Takahe.

Three tephra layers at Mt. Waesche have been geochemically correlated with layers found at Mt. Moulton. The correlative layers have ages of between 15 and 27 ka, 27 ± 2 ka, and between 106 and 119 ka, consistent with apparent stratigraphic order. A single tephra layer at Mt. Waesche, which is chemically consistent with derivation from Mt. Berlin has been directly dated using $^{40}\text{Ar}/^{39}\text{Ar}$, and yields an apparent age of 117 ± 7 ka.

A total of 36 tephra-bearing layers have been recognized in the Siple Dome A ice core. The source volcanoes for these tephra layers are largely found within the Antarctic plate, although some South American and possibly a New Zealand volcano are also represented. Statistical geochemical correlations have been made between 12 of the tephra layers and source volcanic eruption. Ten of the tephra layers are correlated to known tephra layers found at Mt. Moulton or Mt. Berlin. One correlation is also made to an eruption from Mt. Takahe, which took place at 8.2 ± 5.4 ka. This tephra layer has also been recognized in the Byrd Core (Palais et al., 1988).

WAIS Divide

The WAIS Divide ice core is located in central West Antarctica (Fig. 1), in reasonably close proximity to the two main West Antarctic tephra-producing volcanoes, Mt. Takahe and Mt. Berlin, and is therefore likely to contain a number of known tephra layers from the two volcanoes. The youngest widespread tephra layer from a West Antarctic volcano is the 8.2 ka eruption from Mt. Takahe. This widespread tephra layer is found in the Byrd ice core (Palais et al., 1988), the Siple Dome ice core, and at Mt. Waesche. The WAIS Divide site is closer to Mt. Takahe than any of these other sites (350 km away as opposed to 430, 950 and 380 km, respectively), and therefore likely to have received a substantial deposit of tephra, given a favorable wind direction at the time of deposition. The presence of the tephra in the Byrd ice core suggests that the wind direction was at least somewhat favorable for deposition at the WAIS Divide site. The Mt. Takahe ash layer in the Siple Dome core was one of the 8 visible layers in the core, and contained abundant glass shards. At Mt. Waesche, the layer was thick enough to be visible on a blue ice surface, suggesting that this was a major eruption.

In lower part of the WAIS Divide core, Mt. Berlin is likely to dominate the tephra record. Of the numerous eruptions from Mt. Berlin that occurred between 100,000 yrs ago and present, a number are present at Mt. Waesche, Mt. Moulton and in the Siple Dome sites. At least some of these tephra layers expected to reach the WAIS Divide site. The most promising targets are those that have been identified both at either Mt. Berlin or Mt. Moulton and in the Siple Dome ice core, because the two sites are in different directions from the source volcano, suggesting that the area of deposition was relatively broad. This includes a total of 9 tephra layers, ranging in age from $<10.5 \pm 2.5$ to $>92.1 \pm 0.9$ ka. Discovery of these layers in the WAIS Divide core could provide a number of useful cross-correlated time-stratigraphic markers linking the climate records.

The age of the deepest WAIS Divide may be on the order of 100,000 years. There are a number of tephra layers that may be found in the deepest part of the core. These include the 92.1 ± 0.9 ; 104.9 ± 0.6 ; 118.1 ± 1.3 ka tephra layers erupted from Mt. Berlin and found at Mt. Moulton. Two other possibilities include the 93.3 ± 7.8 ka and 102 ± 7.4 ka eruptions from Mt. Takahe. Ideally, more than one of these tephra layers will be present in the WAIS Divide core, providing a robust chronology for the oldest ice in this important climate record.

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