How advancements in analytical techniques are improving our understanding of the englacial tephra record in Antarctica

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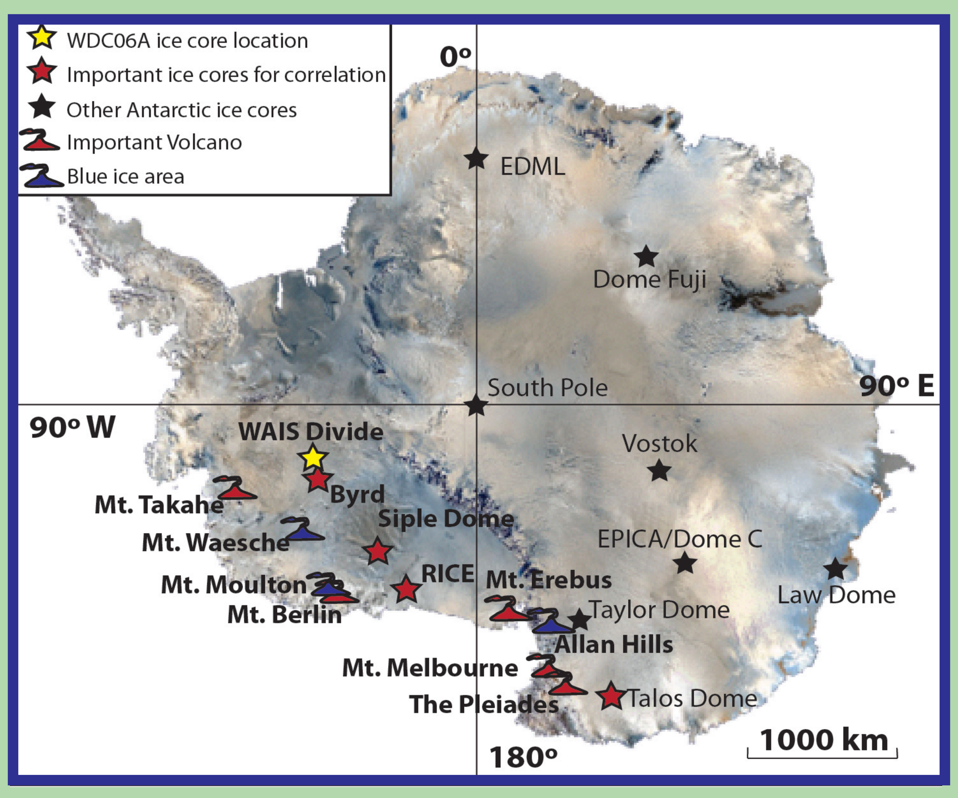
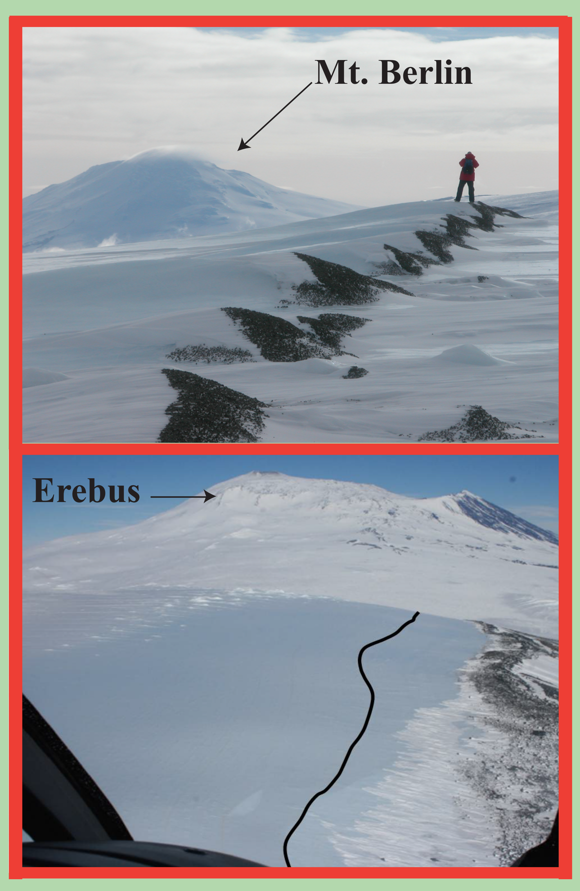
Summary

Tephra layers found in the West Antarctic ice sheet capture an excellent integrated record of Antarctic volcanism over at least the past 170ka. These layers are deposited almost instantaneously across wide areas of the Antarctic continent, creating horizons that, if found in several locations, provide "pinning points" to adjust ice core time scales that may otherwise be lacking detailed chronology. Individual tephra layers may have distinct chemical fingerprints allowing them to correlate over great distances, but the very fine grain size (typically <20 micrometers) of Antarctic tephra layers can make chemical fingerprinting challenging. An updated sample preparation method allows us to qualitatively characterize tephra morphologies and then quantitatively fingerprint the same tephra particles for major elements by electron microprobe (EMPA) and trace elements by laser ablation inductively coupled mass spectrometry (LA-ICP-MS). Combining this updated sample preparation technique with new high precision $^{40}Ar/^{39}Ar$ ages on single feldspar crystals from young (<170ka) englacial tephra are providing new insights into volcanism in Antarctica. Our study focuses on tephra layers from blue ice areas at Mt. Moulton and Mt. Waesche and includes tephra layers found in deep ice cores (WAIS Divide and Siple Dome ice cores) to better understand volcanic activity in West Antarctica.

Locations

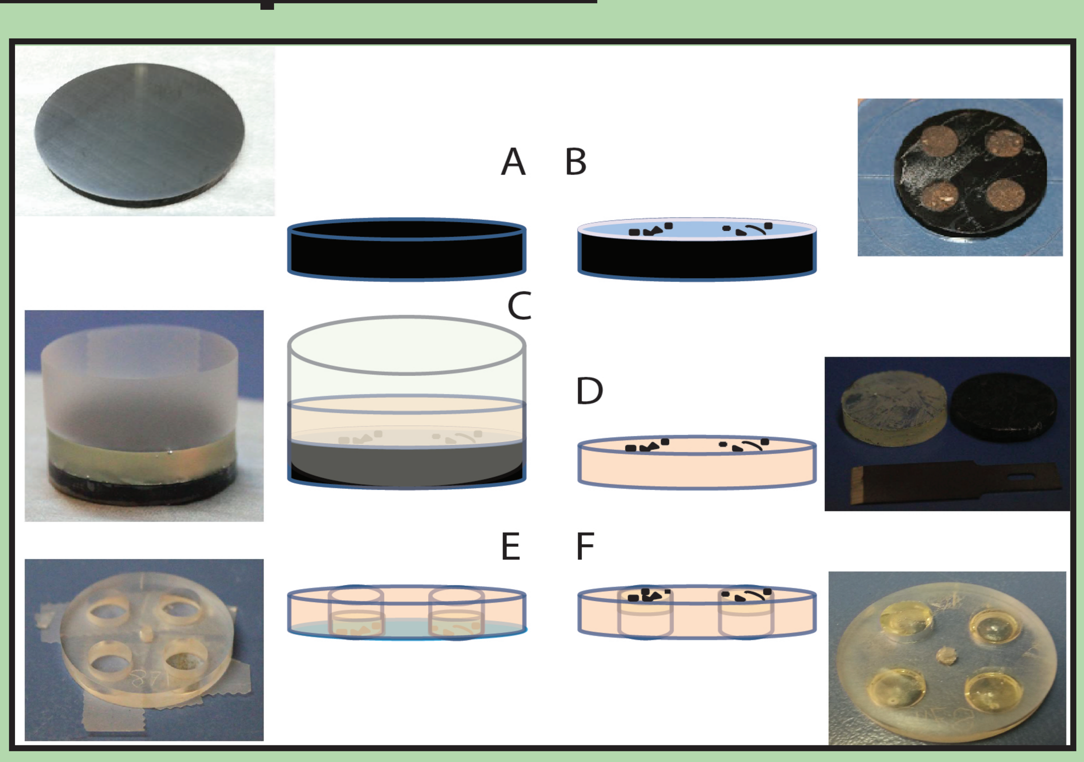


Map of Antarctica showing locations of volcanic centers, ice cores and blue ice areas. Mt. Erebus is a volcanic center and a blue ice area and includes other locations on Ross Island.



Top- Proximal fall deposit at Mt. Moulton, source is Mt. Berlin. Bottom- Distal tephra (black line) found at Mt. Terra Nova, Ross Island ~1400km away. Distal tephra appears to be correlated to Mt. Moulton (BIT-152). This layer may be another link between West and East Antarctic ice cores.

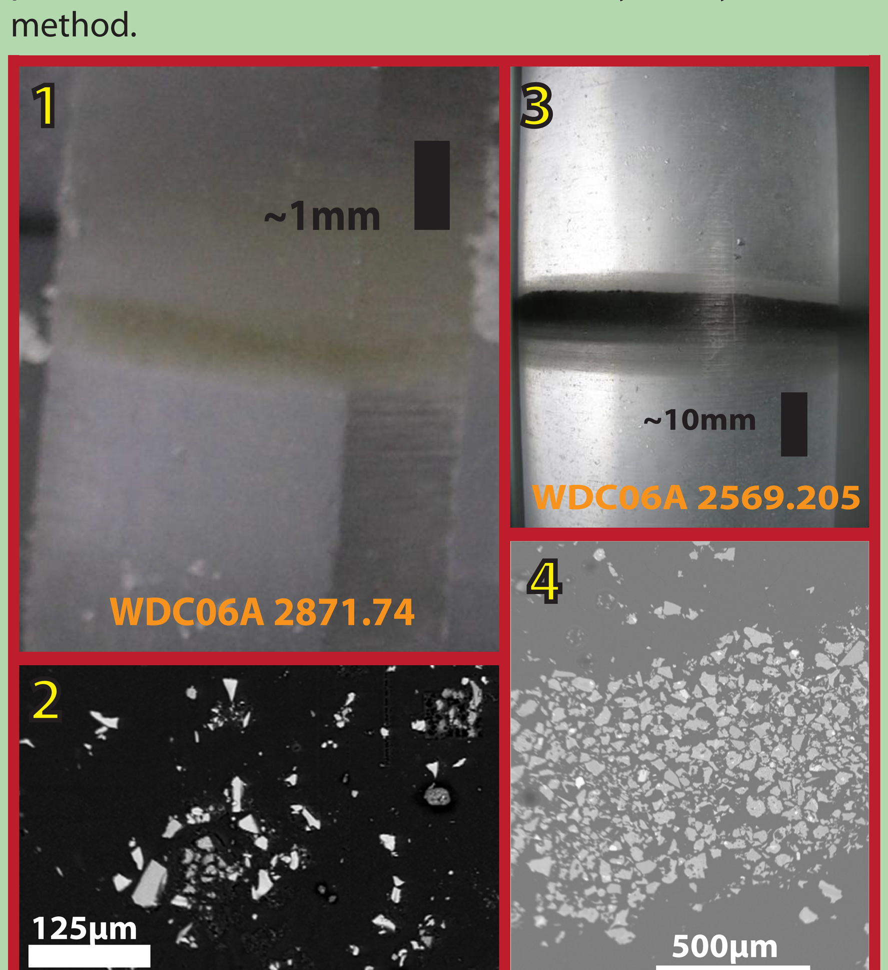
Sample Preparation

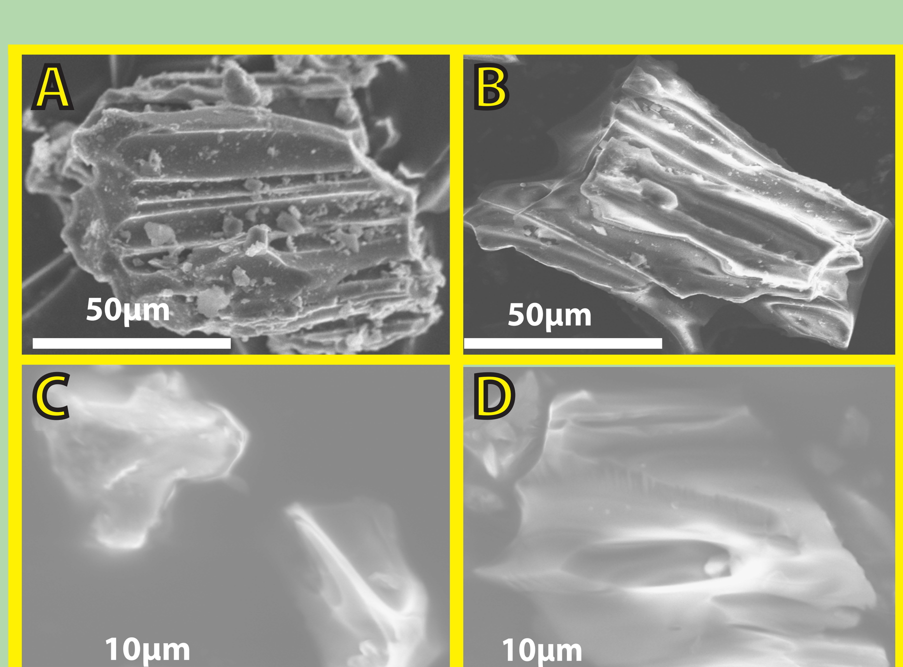


A) Diagram and photo of vitreous carbon planchet (25mm in diameter). B) Scotch tape is lightly brushed over a 0.2um polycarbonate filter to pick up tephra particles. The tape is then pressed to a planchet that has been coated with a light adhesive. Not all tephra is transferred to the planchet and will be prepared separately in step E. Planchet with tephra can then be imaged by SEM without a carbon coat. It is important to be able to image particles without carbon coat because epoxy will not adhere to particles with carbon coat.
C) A tape dam is attached around the outside of the planchet and the backfilled with EpoThin epoxy. After EpoThin is cured, the planchet and new EpoThin disk are separated with a razor blade and a hammer. D) Epothin round after being separated from the planchet. E) The tephra remaining on the scotch tape from step B is prepared by sticking tape to the bottom of a pre-drilled 4 hole round and back filled with 4-part epoxy. F) Polished 4 hole round with the same tephra layers as step D to be used as an archive.

Tephra Morphology

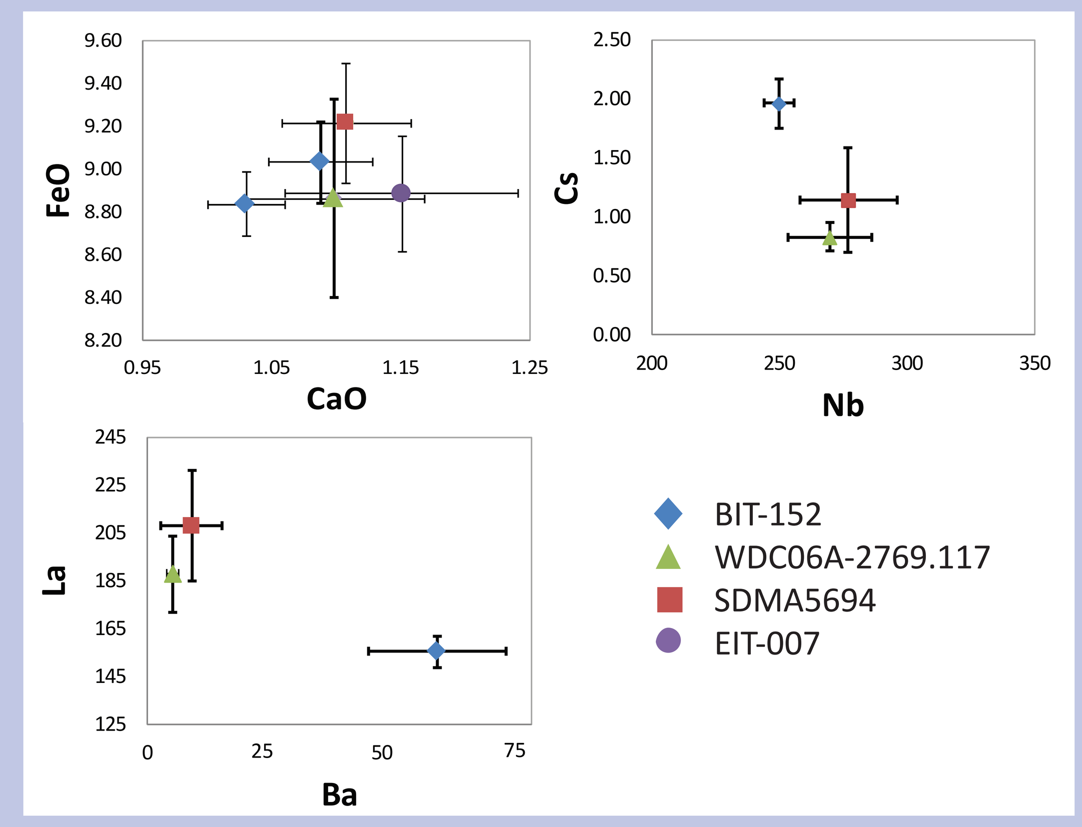
1) Example of a tephra layer found in WDC06A. 2) BSE image of the WDC06A-2871.74 tephra. Tephra was prepared using the sample preparation described above. Method is capable of obtaining qualitative imagery (A, B and C) and quantitative geochemical composition on particles ~10um in size. 3) Coarse tephra layer in WDC06A. 4) BSE images of tephra particles from WDC06A-2569.205. This layer may be abundant enough to be directly dated by the $^{40}Ar/^{39}Ar$ dating method.





Comparison of typical tephra morphologies seen in WDCO6A. A) Carbon coated sample (WDC06A-3149.138. B- D) Non-carbon coated grains from sample WDC06A-2871.74) show a small degree of charging but diagnostic morphologies are still visible. New sample preparation method can image particles greater than 50µm and as small as ~10µm with minimal charging.

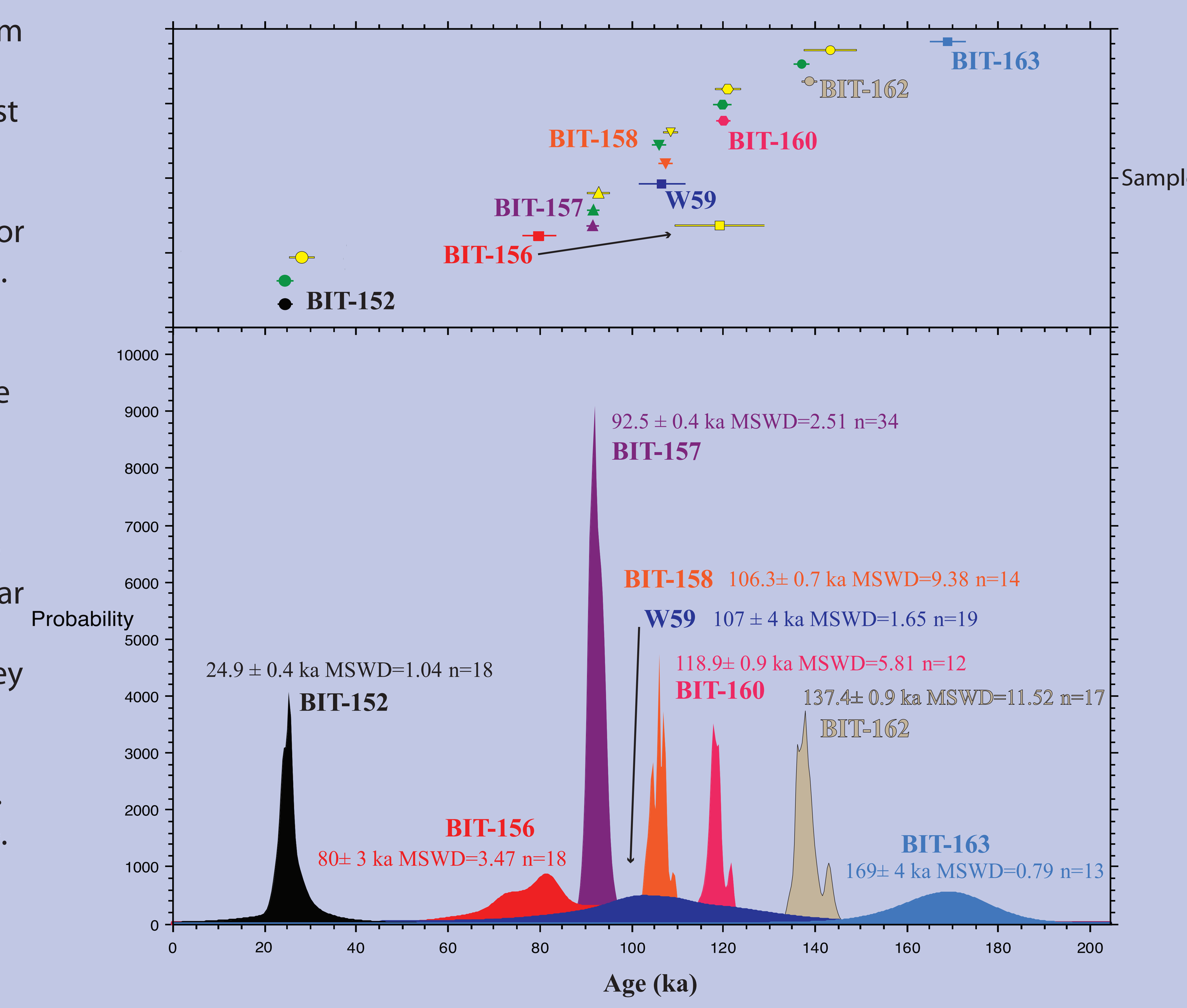
Geochemistry



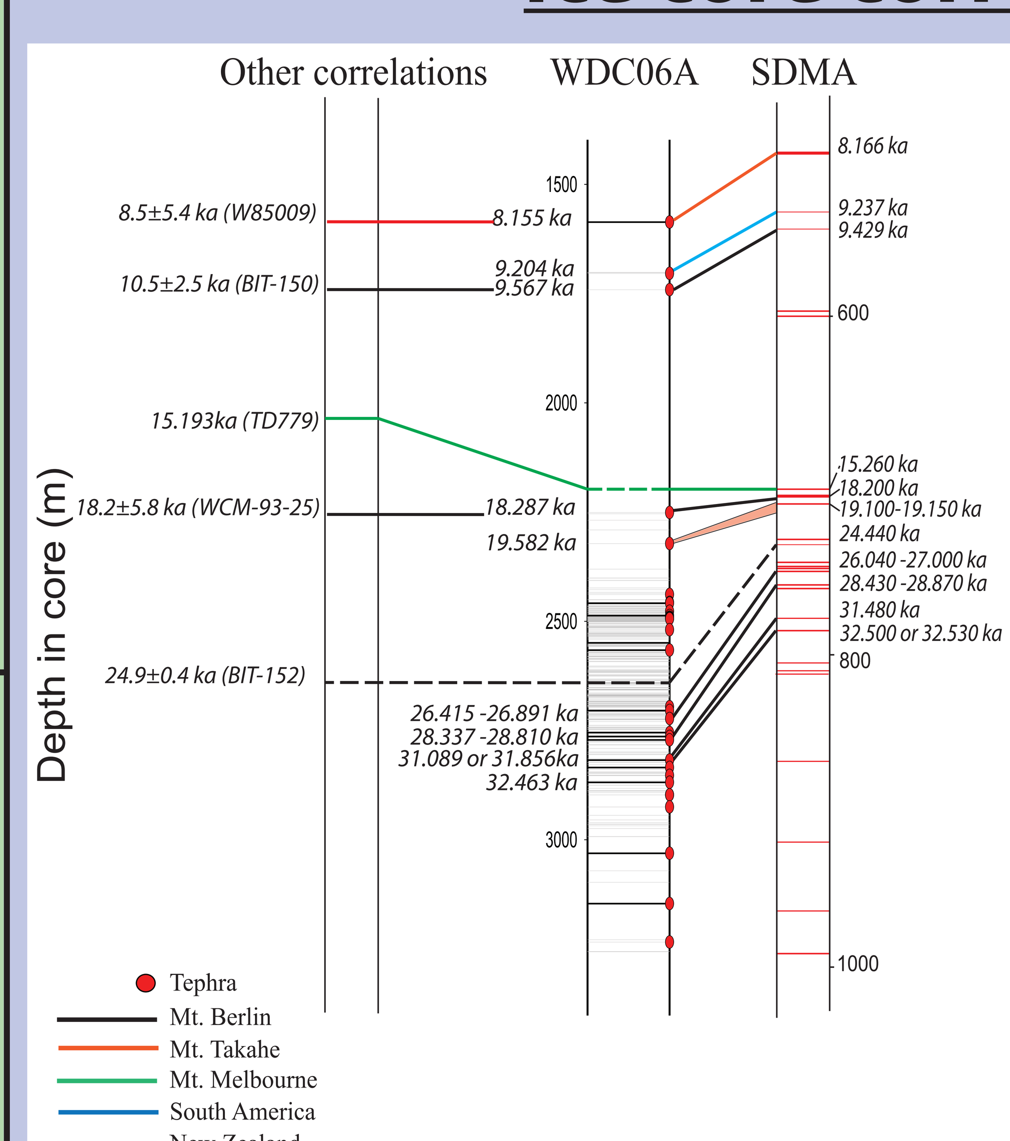
Major and trace element comparison of correlated tephra layers between distal locations at WAIS Divide (WDC06A-2769.117), Siple Dome (SDMA5694) and Ross Island (EIT-007) to proximal Mt. Moulton (BIT-152). Major element analysis was done by electron microprobe at NMT and trace element analysis was done by LA-ICP-MS at Aberystwyth University, Wales. Major element oxides are in weight percent and trace elements are in parts per million.

$^{40}Ar/^{39}Ar$ Dating

Comparison of 40Ar/39Ar ages from single crystal feldspars from selected englacial tephra from West Antarctic blue ice areas. Bottom panel are ideograms (age probability distribution diagram) for the single feldspar crystal analyses. Top panel is a comparison of three different mean ages for each sample. Symbols colored the same as the ideogram are peak probability ages as determined from multiple analyses. All yellow symbols are from Wilch et al., 1999 and green symbols are from Dunbar et al., 2008. Previous analyses of BIT-163 are not shown because they are older than 200ka. All Blue Ice Tephra (BIT) samples are sourced from Mt. Berlin and sampled at Mt. Moulton. W59 is from Mt. Waesche. New analyses were measured on the new multi-collector ARGUS VI mass spectrometers at NMGRL, Socorro, NM. Uncertainties shown at 2-sigma.



Ice core correlations



Correlations of tephra layers found in Antarctic ice. The two columns on the right are deep West Antarctica ice cores at WAIS Divide (WDC06A) and Siple Dome (SDMA). The left column shows correlations to samples from other locations seen in parenthesis. BIT-150, BIT-152 and WCM-93-25 were sampled at Mt. Takahe. TD779 is from Talos Dome (Narcisi et al., 2012). Red dots are samples that have been analyzed by EMPA and are individual tephra layers. Lines within the SDMA core schematic represent confirmed tephra layers. Lines in the WDC06A core represent "dusty" layers observed by core handlers, with darkness of the line corresponding to visual intensity of the layer. Some of these layers have been confirmed to be tephra, others are debris, and many have not been analyzed. Lines between cores are color coordinated to represent the source volcano. Dashed lines are possible correlations. Ages without errors are determined from individual ice core time scales. Ages with errors were determined by the $^{40}Ar/^{39}Ar$ dating technique.

Acknowledgements

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