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Dating young tephras – a distal solution to proximal controversy

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In-situ dating of young volcanic rocks (<50ka) is fraught with difficulties, a classic example being Changbaishan Volcano NE China. During the caldera-forming 'Millennium' eruption (ca. 940-950 CE) tephra was deposited around the world and as primary fall deposits on the caldera rims. The proximal deposits have been studied using multiple dating methods (e.g. 14C, 40Ar/39Ar, U-series and TL) but controversy and contradiction surrounds the age of these tephra deposits and, as a consequence, the proximal stratigraphy of the 'Millennium' eruption. Accurate characterization of the 'Millennium' tephra is vital if the tephras are to be used to reliably link disparate palaeoclimate archives on a hemispheric-wide scale.

Our approach has been to use glass geochemistry to correlate the proximal units with a distal lake sequence from Lake Kushu Japan ca. 1100 km from Changbaishan. Investigation of a 19 m lake core revealed a crypto-tephra deposit with an approximate 'Millennium' age (i.e. 913-1395 cal. CE, 95.4% confidence), confirmed by the 14C-based Bayesian age model of the sedimentary record. Geochemical analysis of tephra shards for both proximal and distal deposits, confirmed identical major, minor and trace element chemistry. This allowed us to correlate the distal crypto-tephra with proximal pyroclastic fall units and to revise the 'Millennium' stratigraphy. Contrary to published data we propose that the 'Millennium' eruption is evident as a composite proximal sequence and that there is no evidence of any post-caldera deposits at the investigated profile (Chen et al., 2016). This is a significant step in our understanding of the nature and timing of Changbaishan eruptions and allows us to resolve an uncertain stratigraphy and eruption history.

The correlation of the Lake Kushu crypto-tephra deposit to the distal Millennium (i.e. B-Tm) tephra reported from the Greenland ice-core (Sun et al., 2014) allows the use of high resolution ice-core tephra ages to validate and improve the radiocarbon-based Bayesian age model of the lacustrine sedimentary record. Modelling reveals that the import of ice-core ages (e.g. GICC05 timescale) has placed significant constraints on our correlative tephra, narrowing down the resultant age to 933-949 cal. CE (95.4% confidence). This improves the chronological control on forthcoming proxy data and subsequent tephra layers identified in the lake core within the same timeframe.

The 'Millennium' tephra (i.e. B-Tm) is a hemispheric-wide chronological maker that is closely associated in time with the Medieval Climate Anomaly (ca. 900-1300 CE). Interestingly the timing, amplitude and duration of this Holocene anomaly may vary (Broecker, 2001; Ge and Wu, 2011) and could be evaluated by integration of chronological and environmental data. Assessment of the temporal and spatial variations of such climatic events will help us better understand the dynamics of these rapid and short-lived climatic episodes.

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