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Generating high-resolution chronological databases with varves and tephra

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The PAGES Data Stewardship Scholarship has added new tephra datasets to VARDA, an online global database of varve records, to enhance high-resolution chronology construction.

Annually laminated (varved) sediments are recovered from lakes and ocean basins in different climatic settings and provide the opportunity to examine past environmental and climatic changes at the highest possible temporal resolution, comparable to tree-ring and ice-core chronologies. The Varved Sediments Database (VARDA) was built to explore the spatial and temporal distribution of terrestrial varved archives (Ramisch et al. 2020). VARDA includes information on the location of varved sites, the duration of the varve record and available proxy datasets, and is openly accessible at varve.gfz-potsdam.de. In addition to varve counting, the database contains radiometric dating measurements (e.g. ^{14}C) that enable varve chronologies to be anchored to an absolute timescale.

An important milestone in the development of VARDA is the inclusion of tie-points that can help link spatially distant archives to understand the spatio-temporal complexity of abrupt climate change. Indeed, the combination of accurate dating, solid tie-points and annually resolved archives would be a step-change to detemine the regional environmental variability during climatic transitions, and leads or lags between forcing and responses.

The purpose of the PAGES Data Stewardship Scholarship (DSS) was, therefore, to review and incorporate volcanic-ash (tephra) layers identified in varved-lake sequences in VARDA. Tephras are airborne, near-instantaneous deposits that spread over large regions, and can be distinguished by their specific mineralogical and chemical composition. In the last two decades, there has been an increase in the use of non-visible (crypto-)tephra layers within lake-sediment sequences that greatly densified the tephra framework. Also, the correct attribution of a tephra layer to a volcanic-source area, and a specific eruption of a known age, requires measurement of the geochemical composition of individual tephra shards, generating a wealth of new data. We therefore aimed to collect and incorporate recent tephra findings in varved sediments to VARDA, including their geochemical datasets. We first focused on the last deglaciation time period, i.e. between 25–8 kyr BP.

The scholarship initially had a European focus and explored the varve-lake records with tephra horizons from both VARDA and new published datasets. This information was used to decide how the metadata would be presented and accessed within the database, and to identify the mandatory/optional datasets. From 33 lakes in Europe, 22 contained tephra layers and 19 have associated geochemical datasets updated into VARDA. In total, there are 49 discrete, known tephra layers within the time period with volcanic sources from Iceland, Eifel, Massif Central, Hellenic Arc and Italy across these sites. There are 19 tephra horizons represented at more than one site that will enable more precise synchronization and comparisons between the varve records. On the VARDA landing page, it is now possible to search with different filters for 'varves', 'tephra' and 'tephra chemistry', examining the map for those sites with tephra, and accessing the geochemistry datasets. The geochemical data also includes metadata related to the analytical procedure followed, such as the instrument and secondary standards used. Further information on the European datasets are provided in Beckett et al. (2024), who identify key outcomes from this work as: i) a single repository for tephra geochemical data within varve records, ii) better understanding of the time periods with multiple eruptions, iii) the spatial distribution of the key eruptions, and iv) the potential for new varved sites to contain specifIc tephra horizons.

This work is moving toward the final completion of the DSS by extending the tephra geochemistry information in a spatial and temporal context. Identification of an additional 32 lake records beyond Europe, and extending the time window to between 125 kyr and the present day, will expand the scope of the database and explore the potential regional and hemispheric interconnectivity of the varve records when linked using tephra horizons. The Varve Database will not only benefit the paleolimnological and lake research communities, but also aid other disciplines when trying to establish links between marine and terrestrial systems.

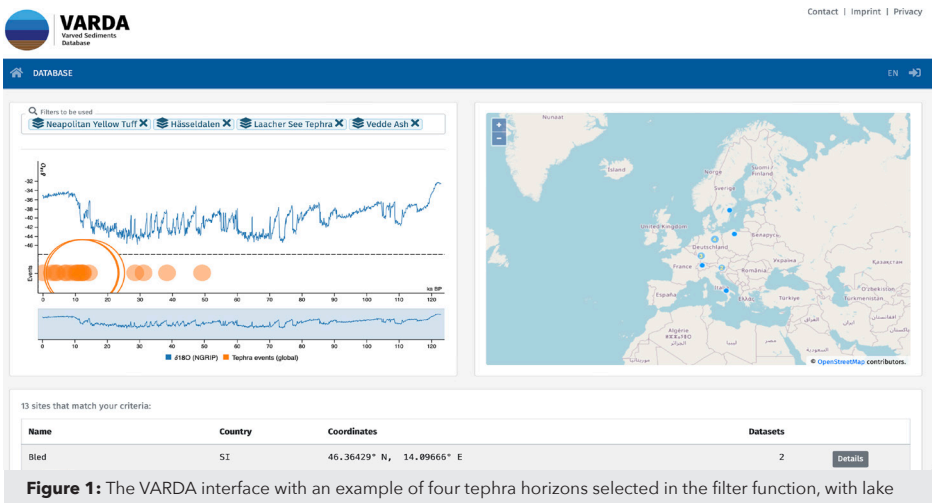

Figure 1: The VARDA interface with an example of four tephra horizons selected in the filter function, with lake sites in Western Europe that contain those records.

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