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Unsupervised machine learning reveals control of melting and metasomatism on water contents of the subcontinental lithospheric mantle

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Hydrogen (“water”) stored in nominally anhydrous minerals (NAMs) has profound implications for their physical and chemical properties, which induces further impact on geodynamical processes of the subcontinental lithospheric mantle (SCLM). The water content of the SCLM is theoretically influenced by both partial melting and mantle metasomatism, two processes that the lithospheric mantle experiences in its long-term evolvement. Previous works on SCLM peridotite xenoliths at different localities around the world, in contrast, have yielded contrasting relationships between the amount of water that the SCLM retains and those two processes: at some localities water followed the control of post-melting metasomatism, while at other places the relationship between melting and water contents was unaffected by metasomatism. However, sampling limitations probably played a role in those differing observations. Taking the approach of big data and machine learning, we collated a worldwide dataset of SCLM peridotite geochemistry data and water contents (in total 636 samples; only subcontinental peridotites) and divided our data into several clusters using unsupervised learning (K-means) with clinopyroxene as a proxy. The clustering results revealed, from a global perspective, that partial melting rapidly depletes water from peridotites, while mantle metasomatism can only add back very limited amounts of water. Based on these results, we constrained the water content of clinopyroxene in pristine SCLM to be ~400 ppm via kernel density estimations of related parameters, which further provided an estimation for the bulk SCLM water content to be ~130 ppm. Meanwhile, our findings indicate that, as metasomatism can hardly add water back to the pre-melting level, metasomatism does not change the low-water character of most refractory peridotites, and this could be the key to the longevity of cratons.