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Variability in Chinese loess single-grain provenance data and the influence of the Quaternary East Asian winter monsoon

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The Chinese Loess Plateau represents one of the world's most detailed and continuous dust and climate records, stretching back into the Miocene and, to the west of the Plateau, into the late Eocene. It has long been argued that Chinese loess deposits record variations in the East Asian monsoon system, both during the summer via pedogenetic indicators, and during winter via grain-size and sedimentation rates. However, the potential influence of non-monsoonal dust transporting winds on Chinese loess deposition has been increasingly suggested, leaving question marks over whether loess deposits record winter monsoon variability. Central to resolving this is to establish the source regions of loess material. Despite a great deal of previous work, the sources and transport mechanisms of dust on the Chinese Loess Plateau are still contested, although areas to the west and northwest of the Plateau have primarily been suggested. Recent applications of single-grain U-Pb dating of zircons in loess provenance has eliminated some of the proposed sources, although possible spatial and temporal variability across the Loess Plateau and through the Plio-Quaternary still remains contentious. Here we show detailed single-grain provenance data, including zircon U-Pb ages and heavy mineral assemblage data from multiple sites and across the Quaternary to examine the key source areas and consider their variations in space and time. These show changing source characteristics both spatially and temporally, with westerly/Yellow River influence in the west of the Plateau, and probable winter monsoon influence to the east. Furthermore, although abrupt variability within individual sediment units is commonly seen in many loess climate proxy records, a high resolution approach that would reveal this has not been applied in single-grain provenance studies. Consequently the extent to which individual samples from a unit are representative of the unit's source in general has not been demonstrated. Here we also present high sampling resolution garnet and zircon single-grain provenance results from last glacial loess from Beiguoyuan section on the NW of the Loess Plateau to test whether such shifts appear. The last glacial loess unit records significant variability in provenance on millennial timescales, potentially explaining the previously poor consensus on source changes. Overall, the results demonstrate that the Chinese Loess Plateau record cannot, in general, be used as an indicator of the winter monsoon. It shows multiple influences on sediment source that vary both spatially and through time, even when considering the same grain-sizes. However, some deposits to the northeast of the Plateau may be more influenced by winter monsoon circulation.