Anisotropy of Magnetic Susceptibility of Northern Xinjiang Loess Reveals Changes in Paleowind Direction Since the Last Glacial Period: Postprint

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Abstract

Anisotropy of magnetic susceptibility (AMS) of loess is considered one of the important proxies for reconstructing changes in paleowind direction and has been widely applied in the Chinese Loess Plateau region. However, research on loess AMS in the Xinjiang region remains relatively limited. This study investigates variations in paleowind direction and wind intensity through AMS parameters and magnetic susceptibility of the Kuerthuobie section in the Tacheng Basin, Xinjiang. The results indicate that southeasterly winds have dominated the Tacheng region since the Last Glacial Period. From bottom to top, the section can be divided into five stages: Stage 1 (12–14 m), corresponding to the MIS3c period, where magnetic fabric characteristics are significantly influenced by water flow, indicating southeasterly winds; Stage 2 (6–12 m), corresponding to the MIS3b period, where southwesterly winds appear but southeasterly winds remain dominant; Stage 3 (4–6 m), corresponding to the early to middle MIS3a period, dominated by southeasterly winds with southwesterly winds gradually disappearing and wind intensity gradually weakening; Stage 4 (0.5–4 m), corresponding to the late MIS3a and early MIS2 periods, characterized by southeasterly winds with highly variable wind intensity; and Stage 5 (0–0.5 m), where magnetic fabric characteristics are strongly influenced by pedogenesis.

Full Text

Paleowind Direction Variations Revealed by Anisotropy of Magnetic Susceptibility of Loess Deposits in North Xinjiang Since the Last Glacial Period

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Abstract: As a proxy of paleowind direction, the anisotropy of magnetic susceptibility (AMS) has been widely applied to reconstruct the paleowind history of aeolian loess deposits in the Chinese Loess Plateau (CLP). However, fewer studies have focused on AMS in Xinjiang loess. In this study, we present AMS results from an aeolian loess section near Tacherg in North Xinjiang, China. Based on magnetic susceptibility and AMS data, we discuss variations in paleowind intensity and direction. In general, southeasterly paleowinds have dominated this area since Marine Isotope Stage (MIS) 3. According to magnetic fabric characteristics, we divide the section into five stages of paleowind variations.

Stage 1 (12–14 m depth), corresponding to late MIS 3c, is characterized by reworked aeolian sediment. Stage 2 (6–12 m depth), corresponding to MIS 3b, is characterized by dominant southeasterly winds with the appearance of southwesterly winds. During MIS 3b, large-scale glaciers in the Altay Mountains may have caused stronger cold high pressure in the Junggar Basin. This pressure gradient between the Junggar Basin and Tacherg Basin would have been enlarged, producing stronger southeasterly winds in the Tacherg Basin during MIS 3b. Glaciers that developed extensively in the Tianshan during MIS 3b could also have pushed cold high pressure northward toward the Tacherg Basin, favoring the formation of stronger southwesterly winds there.

Stage 3 (4–6 m depth), corresponding to early and middle MIS 3a, is characterized by decreasing wind intensity and the disappearance of southwesterly winds. Magnetic fabric characteristics were disturbed to some extent. During this stage, temperatures increased and glaciers in the Tianshan retreated due to gradually increasing high-latitude (65°N) solar insolation. However, due to its particular location, the Altay glacier would have remained at a larger scale under the Mongolia-Siberian high-pressure system. Retreating glaciers in the Tianshan may have caused the gradual disappearance of southwesterly winds in the Tacherg Basin.

Stage 4 (0.5–4 m depth), corresponding to late MIS 3a and early MIS 2, is characterized by the complete disappearance of southeasterly winds and rapidly fluctuating wind intensity. Stage 5 (0–0.5 m depth), corresponding to the topsoil, is characterized by magnetic fabric characteristics that are totally disturbed by pedogenesis. Systematic AMS investigation of Tacherg loess will provide new insights into understanding dust sources and mechanisms of climate change in the Tacherg Basin.

Keywords: anisotropy of magnetic susceptibility; Tacherg loess; magnetic fabric characteristics; paleowind direction

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AMS Parameters and Correlation Analysis

The anisotropy of magnetic susceptibility (AMS) parameters include the degree of anisotropy (P), lineation (L), foliation (F), and the half-angle uncertainty of the maximum (Kmax) and intermediate (Kint) susceptibility axes (E12). Correlation analysis reveals that P shows a strong positive correlation with F ($R^2 = 0.7$) and a weaker correlation with L ($R^2 = 0.33$) [Figure 4: see original paper]. The relationship between P and F is more pronounced than that between P and L [Figure 5: see original paper].

When E12 $< 22.5°$, the AMS fabric is considered well-defined ($\alpha > 95\%$) [3-4, 37]. In this study, 76.15% of samples have E12 $< 22.5°$, indicating reliable AMS results [Figure 6: see original paper]. The relationship between AMS parameters and depth shows systematic variations through the section [Figure 5: see original paper].

[Figure 4: see original paper] Correlation analysis between degree of anisotropy (P) with lineation (L) and foliation (F)

[Figure 5: see original paper] Relations between parameter of AMS with depth

[Figure 6: see original paper] Relations between half angle uncertainty of Kmax and Kint (E12) with lineation (L) and foliation (F)

[Figure 7: see original paper] Anisotropy of magnetic susceptibility (AMS) results for KETB loess section

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Stage Division Based on AMS Characteristics

Based on magnetic fabric characteristics, the loess section is divided into five stages:

Stage 1 (12–14 m): Late MIS 3c, characterized by reworked aeolian sediment with AMS parameters showing Kmax $> 30°$ and Inc-Kmin $< 60°$. The magnetic fabric indicates NE-SW oriented wind transport.

Stage 2 (6-12 m): MIS 3b, dated to 44.2–56.54 ka, characterized by dominant SE winds with the appearance of SW winds. The magnetic fabric shows NE-SW orientation with some disturbance, reflecting stronger wind intensity.

Stage 3 (4-6 m): Early to middle MIS 3a, dated to 38.32–44.2 ka, characterized by decreasing wind intensity and disappearing SW winds. The magnetic fabric shows reduced anisotropy and increased disturbance.

Stage 4 (0.5-4 m): Late MIS 3a to early MIS 2, dated to 25.46–38.32 ka, characterized by completely disappeared SE winds and rapidly fluctuating wind intensity. The magnetic fabric shows complex patterns with both MIS 3a and MIS 2 characteristics.

Stage 5 (0-0.5 m): Topsoil, characterized by magnetic fabric totally disturbed by pedogenesis, with AMS parameters showing Kmax $< 30°$ and Inc-Kmin $> 60°$.

Table 1 Parameter of anisotropy of magnetic susceptibility (AMS) in each stage

Stage	Depth	Kmax	Kint	Kmin	P
Stage 1	12–14 m	1.004563	1.004838	1.009350	0.077738
Stage 2	6–12 m	1.003833	1.009068	1.012921	0.338413
Stage 3	4–6 m	1.004050	1.003117	1.007217	-0.08483
Stage 4	0.5–4 m	1.006895	1.006324	1.013343	-0.0538
Stage 5	0–0.5 m	1.004067	1.003000	1.007067	-0.1166

Paleoenvironmental Implications

The AMS results indicate that SE winds dominated the Tacherg Basin since MIS 3, with significant variations in wind direction and intensity corresponding to glacial cycles. During MIS 3b, expanded glaciers in the Altay and Tianshan Mountains created strong pressure gradients that enhanced both SE and SW winds. The gradual retreat of glaciers during MIS 3a led to weakening winds and the disappearance of SW components. The transition to MIS 2 saw further reduction in wind intensity and complete disappearance of the SE wind component.

The systematic investigation of AMS in Tacherg loess provides valuable insights into the paleowind regime and its relationship with high-latitude climate forcing, regional glaciation, and atmospheric circulation patterns in Central Asia.

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