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石英の ESR 信号強度を利用した砕屑物の供給源・熱履歴推定と東アジアの古気候復元

Palaeoclimatic Reconstruction of East Asia Deduced from Provenance Changes and Thermal History of Detrital Material based on ESR Signal Intensity of Quartz

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Abstract

The uplift of Himalaya and Tibetan Plateau (HTP) exerted a great impact on the establishment and intensification of East Asian monsoon (EAM). Timing of formation of deserts in inland China and temporal changes in their spatial extents provides useful information on evolution of EAM, which can be deduced from provenance and flux of eolian dusts emitted from these deserts to the North Pacific. Taklimakan (TK) and Mongolia Gobi (MG) are the two major dust sources at present. Here we examined provenance changes of the Asian dust during the last 7 Ma using the sediments at IODP site U1425, the central Japan Sea by using electron spin resonance (ESR) intensity and Crystallinity Index (CI) of quartz to the fine silt fraction (4-32 μm) of the sediments to specify the source(s) of eolian dust to the Japan Sea. Our result suggests that the contribution of dusts from TK and MG became significant after 2.8 Ma. Together with the increase in fine silt flux at 2.8 Ma, this observation strongly suggests the drastic increase of the dust flux especially from TK.

Keyword: Provenance changes of eolian dust, central Japan Sea, Electron Spin Resonance, Crystallinity Index

1. Introduction

The uplift of Himalaya and Tibetan Plateau (HTP) exerted a great impact on the establishment and intensification of East Asian monsoon (EAM). Timing of formation of deserts in inland China and temporal changes in their spatial extents provides useful information on evolution of EAM, which can be deduced from provenance and flux of eolian dusts emitted from these deserts to the North Pacific. According to Rea et al. (1998), dust flux to the North Pacific increased gradually between 25 and 3.6 Ma and then increased rapidly at 3.6 Ma. Although they estimated inland Asia as a source of dust to the North Pacific, they did not specify the source desert(s). Taklimakan (TK) and Mongolia Gobi (MG) are the two major dust sources at present and dust from TK is transported by Westerly Jet (WJ) whereas dust from MG is transported by low altitude dust storm during spring. Discrimination source areas of the Asian dust is possible by using electron spin resonance (ESR) intensity and Crystallinity Index (CI) of quartz [2]. So we examine provenance changes of the Asian dust during the last 7 Ma using the sediments at IODP site U1425, the central Japan Sea by applying this method to the fine silt fraction (4-32 μm) of the sediments to specify the source(s) of eolian dust to the Japan Sea. The fine silt fraction (4-32 μm)of one hundred sixty-eight samples from the sediments at Site U1425 covering the last 7 Ma were selected for this study.

2. Methods

The ESR signal intensity of the E_1' center in quartz, an unpaired electron in a single silicon sp3 orbit oriented along a bond direction into an oxygen vacancy [3], was used to estimate the relative number of oxygen vacancies in quartz. Oxygen vacancies in quartz have been formed by natural radiation and are known to be proportional to the age of the host rock [4] [5] [6]. Firstly, pretreated samples were irradiated with γ-radiation (total dose of 2.5 kGy) using a ^{60}Co source at the Inter-University Laboratory for the Joint Use of Japan Atomic Energy Agency Facilities. Pretreated samples were heated at 300 °C for 15 minutes to convert the oxygen vacancies to E_1' centers[4]. ESR signal intensity measurements were conducted at room temperature with an X-band ESR spectrometer JEOL JES-FA100 at the University of Tokyo under 0.01 mW of microwave power, 0.1 mT magnetic field modulation (100 kHz), 5 mT scan range, two minutes scan time, and 0.03 seconds time constant. The ESR signal intensity of the bulk sample was normalized by the weight percent of quartz in the sample to obtain the ESR signal intensity of the quartz per unit weight, whose unit is 1.3×10^{15} spins/g[5].

The CI of quartz was originally defined by Murata and Norman (1976) on the basis of the degree of resolution of the d (212) reflection of quartz at 1.3820 Å on the X-ray diffraction (XRD) profile. The CI of quartz reflects physical conditions during quartz formation and is typically the highest for quartz formed under high temperatures and/or slow crystallization rates. In this study, measurement of the CI of quartz was conducted using a PANalytical X'Pert PRO X-ray diffractometer at the University of Tokyo with a CuKα beam generated at a voltage of 45 kV and a current of 40 mA with a divergence slit 1.52mm in width and an anti-scatter slit 3 mm in width. The CI values were calculated as the degree of the quartz peak split at 67.74° 2θ, based on the definition of Murata and Norman (1976).

3. Results and Summary

Our results suggest drastic change in the dust provenance and increase in the fine silt flux at ca. 2.8 Ma. Based on the temporal variation patterns in ESR signal intensity and the CI of quartz in fine silt fraction (unpublished data), the variation patterns were divided into the four intervals that are supposed to reflect changes in provenance. Interval a (from 0 to 2.8 Ma) is characterized by highly variable ESR signal intensity and high CI. Interval b (from 2.8 to 3.6 Ma) is characterized by a relatively high and least variable ESR signal intensity and a moderate CI. Interval c (from 3.6 to 5 Ma) is characterized by relatively low and moderately variable ESR signal intensity and relatively low CI. Interval d (from 5 to 7 Ma) is characterized by slightly high and relatively variable ESR signal intensity and a moderately low CI. The figure 1a-d shows the comparison of ESR signal intensity vs CI plots of quartz from core U1425, and the plots of TK, MG (the average values as well as standard deviations of the ESR signal intensity and CI from Sun et al., 2013) and Japanese Island [6]. It is obvious that the contribution of dusts from TK and MG became significant after 2.8 Ma (Fig. 1a). Together with the increase in fine silt flux at 2.8 Ma, this observation strongly suggests the drastic increase of the dust flux especially from TK. On the other hand, larger relative contribution of detrital material from Japanese Islands (JP)

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before 2.8 Ma probably reflects lower eolian dust flux before 2.8 Ma (Fig. 1b-d).

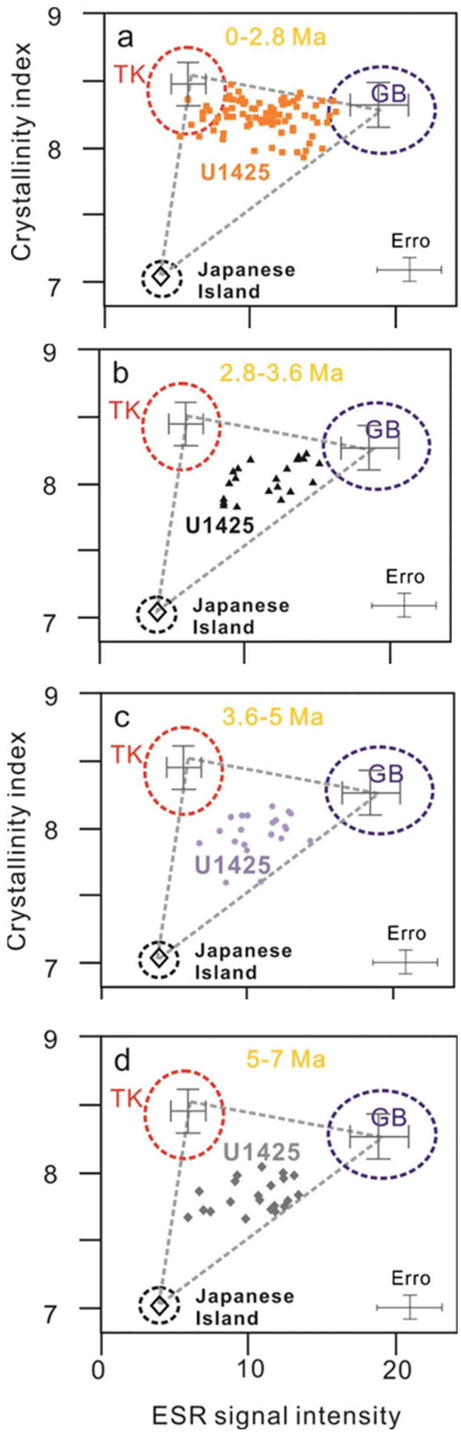

Figure 1. Comparison of ESR signal intensity and CI plots of quartz from core U1425, samples from TK, MG and Japanese Island.

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