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Stratigraphy and palaeoenvironmental implications of Pleistocene and Holocene aeolian sediments in the Lhasa area, southern Tibet (China)

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ABSTRACT

Along the middle and lower reaches of the Kyichu River and its tributaries (Lhasa area, southern Tibet), a multidisciplinary study was carried out in order to investigate the areal distribution, sedimentological properties, ages and palaeoenvironmental implications of aeolian deposits including intercalated palaeosols. This research was initiated to investigate to what extent southern Tibet is influenced by past human activity, as even recent evaluations perceive the present treeless desertic environment as natural. Fifteen profiles were recorded at an altitude of 3540–4580 m a.s.l. with subsequent sedimentological, geochronological (OSL, AMS ^{14}C) and palaeobotanical (charcoal) analyses. Sediment properties of both loesses and aeolian sands reveal an origin from aeolian sorting of nearby fluvial deposits. The calculated ages are the oldest obtained thus far on aeolian sediments from southern and interior Tibet, revealing natural aeolian sedimentation before and around the Last Glacial Maximum (c. 20 ka). However, a distinct portion of Late Holocene sandy aeolian sediments also occurs. Both the evidence for the aeolian dynamics (widespread Pleistocene loess and aeolian sand deposition, local Late Holocene aeolian sand deposition, modern reactivation of widespread Pleistocene aeolian sands) and the palaeobotanical findings (Late Holocene vegetation change from a tree-bearing to a widely treeless landscape) provide evidence that the Lhasa area was strongly influenced by human activity since at least the Late Neolithic (c. 4200 cal yrs BP). Thus the present-day desertic environment might not primarily be a result of the semiarid climate or the high-altitude conditions, but rather of activities of the humans and their collateral effects. However, once established, this semi-natural ecosystem persisted, controlled by strong grazing, firewood extraction, erosion and harsh edaphic conditions, preventing the recovery of trees.

1. Introduction

Aeolian dynamics are a characteristic of Central Asian landscapes and originate from the mainly arid climate conditions and specific atmospheric and geomorphic settings. During the cold stages of the Quaternary, the territory affected by aeolian processes was considerably enlarged due to the areal expansion of a cold and dry climate (Yang et al., 2004; Ding et al., 2005). However, human activity, mostly in the form of deforestation and agriculture, has intensified aeolian processes in vast areas with semiarid climate conditions in both the present and the recent past (Li et al., 2005; Huang et al., 2006; Sun et al., 2006). In China, for instance, desert expansion has accelerated with each successive decade since 1950. From 1994 to 1999 alone, the Gobi Desert expanded by 52,400 km^2 now reaching an area only 250 km north of Beijing (Brown, 2003). Thus, in general, tracing present day and predicting future aeolian dynamics is a vitally important environmental issue in Central Asia. However, both understanding the long-term scale (thousands of years) and identifying the causes (climate, geomorphic setting, humans) necessarily require past aeolian processes to be considered as an aspect of the landscape history.

The southern part of Central Asia is formed by the Tibetan Plateau, the largest alpine plateau in the world (c. 2.2×10^6 km^2). However, in comparison to the adjacent Chinese Loess Plateau, where research on both past and present-day geomorphic dynamics has been well-established for a long time (e.g. An et al., 1991; He et al., 2006), knowledge of the distribution pattern, sedimentological properties and dating of aeolian deposits on the Tibetan Plateau is still in an early stage.

Vast areas on the Plateau are covered by relatively thin aeolian mantles consisting of silty and sandy loesses and loess-like sediments (e.g. Clarke, 1995; Péwé et al., 1995; Lehmkuhl, 1997). The thickness of these deposits is often below 1 m, covering nearly all areas up to c.

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5000 m a.s.l. (Kaiser, 2007; Kaiser et al., 2008). However, at the north-eastern margin of the Plateau and at altitudes proximately below the rim thick loess covers exist, which attain more than 20 m in the Aba Basin (c. 3500 m a.s.l.; Lehmkuhl, 1995) and c. 260 m around Xining (c. 2300 m a.s.l.; Kemp et al., 1996; Lu et al., 2004). Furthermore, coversands and sand dunes (= aeolian sands) of a few metres to decametres in thickness occur locally, mostly along the major rivers, in the foreland of glaciers and in intramontane basins (e.g. Liu and Zhao, 2001; Li et al., 2006; Porter and Zhou, 2006).

The few stratigraphical investigations on the Tibetan Plateau performed so far have been mainly focussed on dating aspects using luminescence ages of loesses and aeolian sands as well as radiocarbon ages of intercalated palaeosols. Most of the studies took place in northeast, east and central Tibet (e.g. Lehmkuhl et al., 2000; Fang et al., 2003; Stokes et al., 2003; Lu et al., 2004; Küster et al., 2006). Remarkably, despite the fact that only a few sequences with unquestionable dating control are available and comparably few sedimentological data exist, far-reaching models on the age of aeolian deposits and the sedimentary process have already been proposed (Lehmkuhl and Haselein, 2000; Porter and Zhou, 2006; Sun et al., 2007). Conversely, the possible role of humans in triggering Holocene aeolian processes has been considered only rudimentarily (Jäkel, 2002; Klinge and Lehmkuhl, 2003, 2005).

This paper presents results on the stratigraphy and sedimentology of aeolian deposits in southern Tibet. Our study area is the Kyichu ('Lhasa River') Valley and its tributaries, where the research project 'Holocene geomorphic genesis of the Kyichu catchment' was launched to clarify the more recent geomorphic and palaeoenvironmental history, continuing previous research on past human–environment relationships in that area (Miehe et al., 2003, 2006; Kaiser et al., 2006; Miehe et al., 2008a; Kaiser et al., in press; Fig. 1). As even recent evaluations perceive the present treeless desertic environment as natural, seemingly originating from the high altitude and / or semi arid climate conditions (Yu et al., 2001; Song et al., 2004; Luo et al., 2005), this research was initiated to access the extent that southern Tibet is influenced by past human activity. In the course of the project, and for the first time in southern and interior Tibet, Last Interglacial and Last Glacial aeolian sequences and corresponding palaeosols are detected, therefore the temporal focus comprises the last c. 100,000 years.

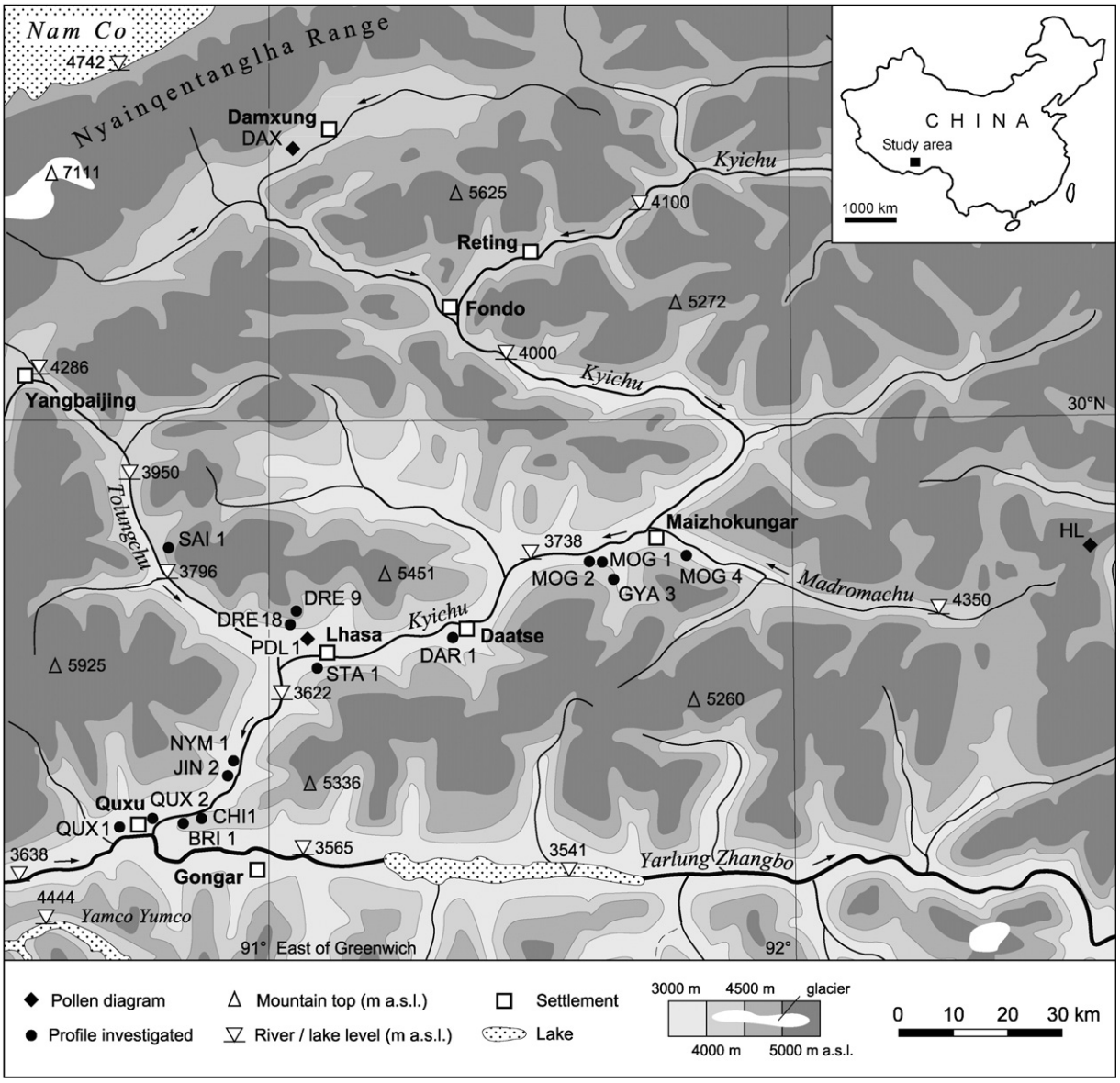

Fig. 1. Study area with the profiles recorded (map adapted from Atlas of Tibet Plateau, 1990). Abbreviations of pollen diagrams: PDL 1 = Lhasa 1, HL = 'Hidden Lake' / Co Qongjiamong, DAX = Damxung.