Quaternary International 333 (2014) 62–68

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Macroscopic and microscopic evidence of Quaternary glacial features and ESR dating in the Daweishan Mountain area, Hunan, eastern China

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ARTICLE INFO

Article history:
Available online 15 March 2014

ABSTRACT

Whether Quaternary glaciers existed in the Daweishan Mountain area is of great significance to the reconstruction of the Quaternary environments in the Yangtze Valley. This study investigated the macroscopic and microscopic features of Quaternary glacial features in the Daweishan Mountain area, and applied Electron Spin Resonance (ESR) dating to the clay and gravel sediments to determine their age. ASTER GDEM with a resolution of 30 m, combined with field investigation, recognized the glacial landforms in the Daweishan Mountain area. Cirques and firn basins were distinguished using a flat index of $F = L/2D$ and a length–width ratio of $G = L/W$. Scanning Electron Microscopy (SEM) identified glacial traces on quartz sand grains of the clay and gravel sediments. ESR dating of 6 sections showed that the sediments were formed in 2 stages, 205–262 ka and 377–425 ka, equivalent to the late stage and middle stage of the Middle Pleistocene, respectively. There were at least 2 glaciations in the Daweishan Mountain area. In the late stage and middle stage of the Middle Pleistocene, the Yangtze Valley was influenced by a cold trough, and promoted glaciations developed in the Daweishan Mountain area.

1. Introduction

The Daweishan Mountain is situated in the Yangtze Valley, about 200 km from the Lushan Mountain, the subject of the most controversial Quaternary glaciations debate in eastern China. Whether there was Quaternary glaciation in the Yangtze Valley has been a matter of debate for over 80 years since Lee first proposed its existence (Lee, 1934), and hitherto no consensus has been reached. It was believed by the earlier researchers that 2–3 glaciations took place in the mountains of the Yangtze Valley (Yang and Xu, 1980), and that they were mostly alpine glaciers or piedmont glaciers (Sun et al., 1977). This theory was later challenged by Shi et al. (2011), whose argument that there was no Quaternary glaciation in eastern China except on a few mountains above 2500 m, and that the landforms and sediments formerly interpreted as glacial evidence were misinterpreted, caused heated debate. Shi et al. (1989, 2010, 2011) proposed that in the controversial areas of eastern China, the glacial erosional landform evidence such as cirques, U-shaped valleys and striations were insufficient, that most of the clay and gravel sediments were formed by paleo-debris flows, and the Quaternary environments in those areas were unsuitable for the development of glaciers.

Whether Quaternary glaciers existed in the Daweishan Mountain area has important implications for our understanding of the Quaternary environment in eastern China. By using a flat index, which has been widely used in the verification of glacial geomorphic genesis in the mountains of eastern China (Ma and He, 1988; Sun et al., 2005a), and length–width ratio, which has been tested in the Maritime Alps (Federici and Spagnolo, 2004) and some mountains of China (Zhang et al., 2008), the authors distinguished cirques and firn basins in the Daweishan Mountain area. The authors also applied SEM on quartz sand grains of the clay and gravel sediments to distinguish the sediments' origin (Wu et al., 1997; Chen et al., 2014).

ESR dating was applied to the clay and gravel sediments to determine their age. In recent decades, the study of the timing and extent of glaciers in the bordering mountains of Tibet has been greatly advanced (Zhang et al., 2006), while the study of controversial areas in China lagged. Quaternary glaciations were still divided into 4 glaciations (Sun et al., 1977) or 2–3 glaciations (Yang

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http://dx.doi.org/10.1016/j.quaint.2014.02.024
1040-6182/

and Xu, 1980) without specific experimental data. ESR dating has been widely used and well tested in the Quaternary geochronology of the Tianshan Mountains (Yi et al., 2002; Zhao et al., 2006, 2009a), the Qilianshan Mountains (Zhou et al., 2002), the Shaluli Mountains (Xu and Zhou, 2009) and the Altai Mountains (Zhao et al., 2013).

2. Regional setting

The Daweishan Mountain (28°20′54″–28°28′47″N; 114°01′51″–114°12′52″E) (Fig. 1) is situated in northeast Hunan Province, eastern China. It is a NE-stretching middle altitude mountain range, with its peak at Qixingling, at 1607.9 m asl. Elevation in the study area ranges from 140 m in the river valley to over 1600 m on the peak and changes abruptly in places. Above 1200 m on the mountain, numerous wetlands are preserved, and mountainside valleys are developed on both sides of the mountain.

The bedrock is dominated by the Jiuling granite (838 Ma) (Pang, 1983), which comprises biotite plagiogranite with medium-grained cordierite, and granodiorite, intruded into Mesoproterozoic metamorphic rock. Mesoproterozoic metamorphic rock is a thick flysch neritic facies clastic sandstone deposit, intercalated with tuffs and extrusive rocks (Bureau of Jiangxi Geological Survey, 1977). Dykes which suffered thermal metamorphism, mainly consisting of mica hornfels, garnet mica hornfels, and spotted slate, in the center-west peak of the study area. Surficial Quaternary sediments form ribbon-like sediments near the valleys and piedmont. In the piedmont there are mainly reddish brown clay and gravels, which are deeply weathered. On the mountain near the valleys, yellowish brown and slightly weathered sediments are exposed.

3. Materials and methods

3.1. Study of geomorphic features

Through the study of ASTER GDEM data, combined with field investigation, the authors explored the erosional and depositional landforms in the Daweishan Mountain area. ASTER GDEM is a Digital Elevation Model with a resolution of 30 m (Computer Network Information Center, 2013). Analysis of the data determined the length (L), width (W) and depth (D) of the cirques and firn basins. The flat index of $F = L/2D$ and a length–width ratio of $G = L/W$, combined with the results of studies by Derbyshire (1976) and Yao and Li (1982), were used to distinguish cirques and firn basins.

3.2. SEM of surface textures on quartz sand grains

Due to their chemical stability and surface hardness, quartz sand grains can preserve their surface textures which were formed in the process of transportation and deposition (Chen et al., 1986). The surface textures of quartz sand grains differ under different transportation media and dynamic conditions (Vos et al., 2014). Study of the quartz sand grain surface textures can distinguish aeolian sediments (LeBaron et al., 2011; Costa et al., 2013), glacial sediments (Mahaney, 1998; Strand and Immonen, 2010; Chen et al., 2014), fluvial sediments (Mahaney et al., 2001), lacustrine sediments (Sun et al., 2005b), and even tsunami deposits (Mahaney and Dohm, 2011). Five samples from the clay and gravel sediment sections were analyzed using SEM.

Quartz sand grains of 0.2–0.3 mm in diameter were picked out after the sieve separation of each sample. The samples were immersed into a concentrated solution of HCl for 5 h, washed using distilled water, and then oven dried. 25–30 quartz grains were randomly selected from each sample, and were stuck evenly on transparent tape. Each sample was coated with gold in a vacuum before viewing in a Japanese Hitachi SU8010 FESEM, and the frequency of typical features of glacial origin was counted. Sample preparation and scanning was carried out in the Scanning Electron Microscopy (SEM) Laboratory, China University of Geosciences, Wuhan.

3.3. ESR dating of clay and gravel sediments

Six samples were collected from artificial sections of clay and gravel sediments in the Daweishan Mountain area. To protect them from sunlight illumination during the sampling process, the

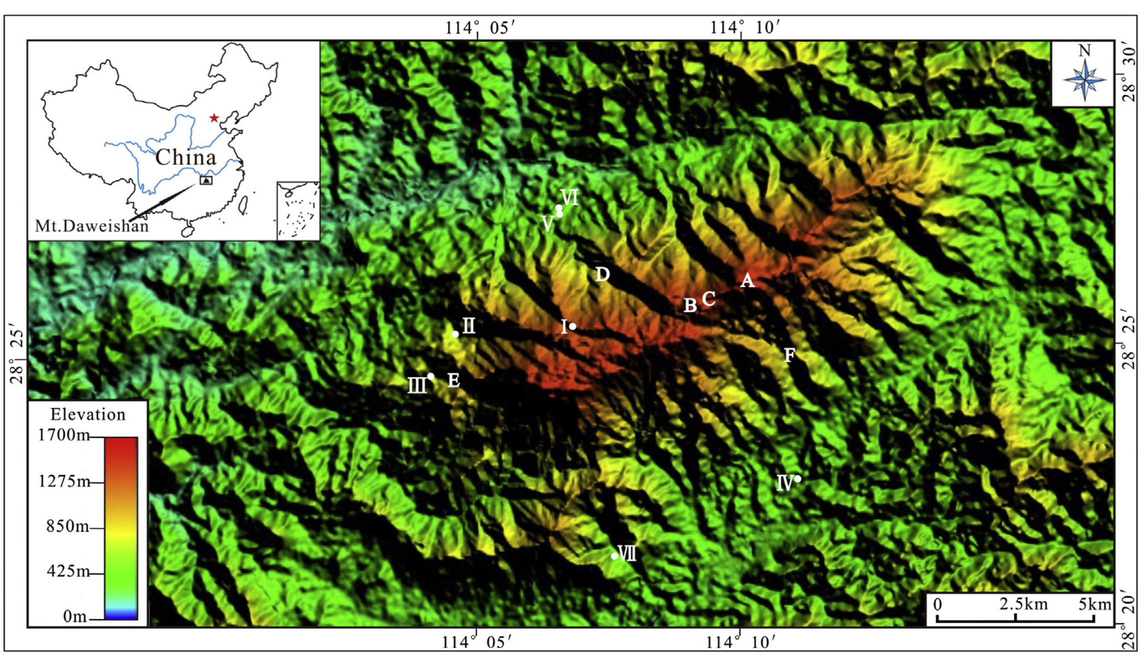

Fig. 1. The location of Daweishan Mountain and sampling sites. Locations of sampling sites are shown as white dots. I: Chunqiuao; II: Menggubao; III: Anzhou; IV: Yangmeiling; V: Jiuxiling01; VI: Jiuxiling02; VII: Wenzhu. Other places mentioned in this paper are A Qixingling; B Biandanao; C Daoquanhu; D Dawangkeng; E Hediaokeng; F Jinjiatian (The DEM data set is provided by International Scientific Data Service Platform, Computer Network Information Center, Chinese Academy of Sciences. http://datamirror.csdb.cn).