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SEDIMENTOLOGIC AND PALEOCLIMATIC SIGNIFICANCE OF LOESS DEPOSITS IN THE MID-PERMIAN QUANZIJIE LOW-ORDER CYCLE IN BOGDA MOUNTAINS, NW CHINA

Introduction

Superbly exposed fluvial-eolian-lacustrine deposits in Turpan-Junggar Basin, NW China (Fig. 1A) provide a continuous uppermost Carboniferous-Early Triassic sedimentary and paleoclimatic record in mid-latitude NE Pangea (Fig. 2). The superbly-exposed strata offer a unique opportunity to study and understand the sedimentologic, tectonic, and climatic processes controlling basin-fill and evolution.

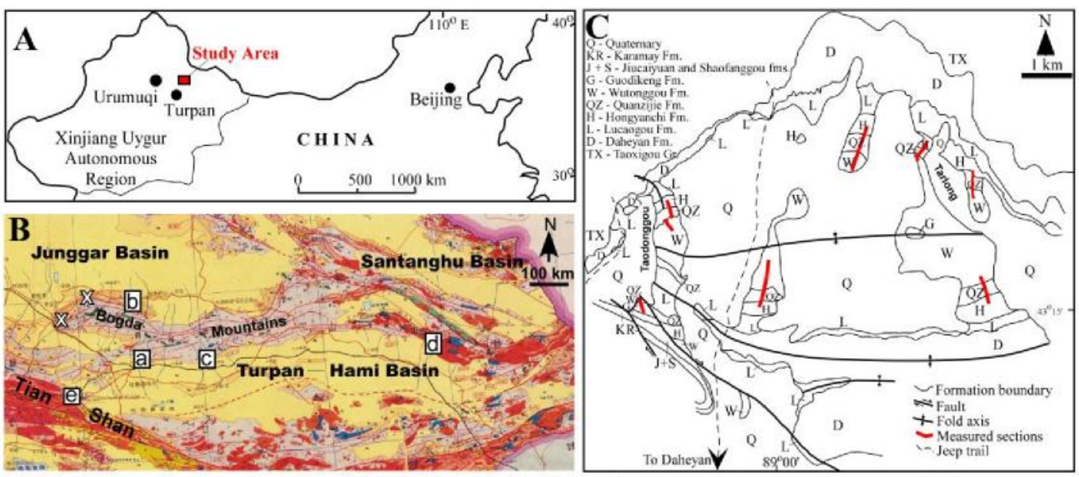


Figure 1. A) Location of study area in Xinjiang, NW China. B) Geological map of eastern Xinjiang, showing locations of: a) Tarlong-Taodonggou, b) Dalongkou, c) Zhaobishan, d) Kulai, e) Aiwergou, and two sections to be measured (white x). C) Simplified geological map of the Tarlong-Taodonggou area showing sections measured in the summers of 2010 and 2011. Modified from Yang et al. (2010). A section was also measured in the Dalongkou area in northern Bogda.

This study will focus on the mid-Permian (Wordian-Capitanian) Quanzijie Low-Order Cycle (QZJ LC). The QZL LC is one of the nine Late Carboniferous to Early Triassic Low-Order Cycles identified in the basin fill by Yang et al., (2010). The QZJ LC contains successions of thin conglomerate deposits overlain by thick, red, structureless mudrocks. The origin of the mudrocks and their relationship to channel conglomerates are enigmatic, because: 1) the width/depth channel ratio in the measured sections is 50 on average, ranging from 9 to 175, which indicates ephemeral, braided river deposits with minimal suspension load (Schumm, 1963) which should contain minimal suspension load; 2) the channels lack accretionary point bar deposits, common in well-developed meandering streams that contain abundant suspension load; 3) mudrocks show minimal pedogenic alteration, which are common in floodplain deposits (Miall, 1996); 4) the abundance of silt size material is atypical of floodplain deposits; and 5) no fossil fauna are found in the sections, atypical of floodplain deposits. The loess interpretation is proposed because: 1) the massiveness of the mudrocks; 2) the widespread occurrence of the mudrocks across the basin, with an approximate area of 60,000 km^2; and 3) the percentage of silt in the mudrocks (Fig. 3B). The QZJ LC also recorded a dramatic shift from arid to humid climate, indicated by well-developed Calcisols at the base, and well developed Fe-Mn-pisoid-bearing Gleysols at the top. From the evidence, two working hypotheses are developed: 1) the QZJ LC has a mixed fluvial-eolian origin; and 2) the climatic transition within the QZJ LC is gradual and might correlate to the mid-Permian icehouse-hothouse transition.

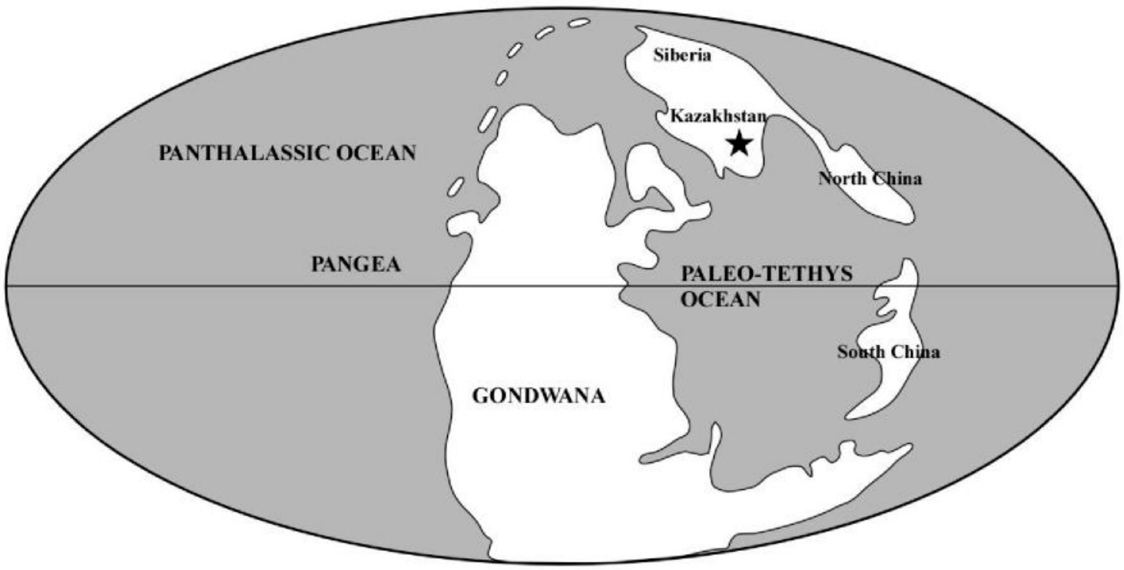


Figure 2. Global paleogeographic reconstruction for the Late Permian. Modified from Scotese (2002). The location of the study area is marked with a black star.

Geological Background

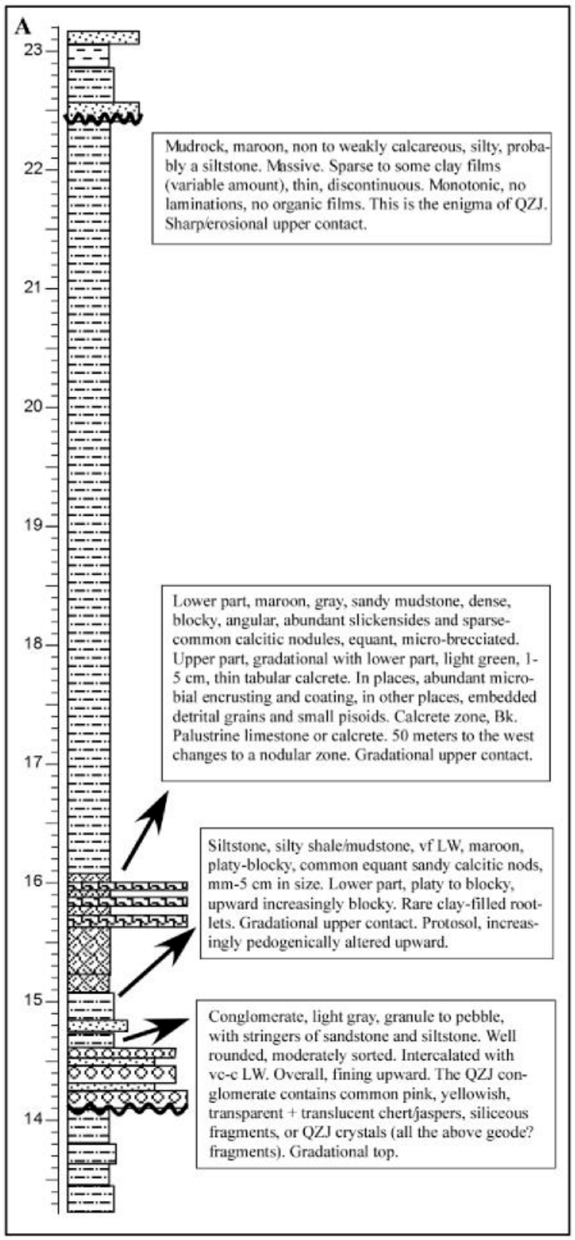
The Turpan-Junggar Basin is an intracontinental rift basin on an Upper Carboniferous volcanic-arc basement (Fig. 1A, B), initiated by extension caused by regional sinistral shearing during collision between the Junggar and Northern Tianshan plates in the latest Carboniferous (Allen et al., 1995; Heubeck, 2001; Yang et al., 2010). The fluvial-eolian-lacustrine fill in the Tarlong-Taodonggou half-graben (Fig. 1C) is ~900-1,600 m thick, showing rapid lateral facies and thickness changes (Wartes et al., 2002; Yang et al., 2010). This study will combine literature research, outcrop and laboratory data to understand the origin of the QZJ LC and its sedimentologic and paleoclimatic significance.

Research Methodology

The research methodology includes three parts to test the working hypotheses. First, extensive literature review of Quaternary loess will focus on the sedimentary, pedogenic, and magnetic characteristics and the processes involved in the formation, accumulation, and preservation of loess. The review will provide a thorough understanding on modern loess characteristics and controlling processes and factors. In addition, literature review of ancient loess will be conducted. A comparison between modern and ancient loess deposits is critical to examine what features are being preserved on ancient loess deposits and how can these be used to identify loess in the deep past. Second, eleven stratigraphic sections measured in the past three summers recorded the lithology, sedimentary texture and structure, and stratal geometry and contact. Two additional sections (Heavenly Lake Section in NW Bogda and the Lucaogou Section in W Bogda) will be measured in the upcoming summer for basin-wide correlation and to further evaluate the lateral extent of the deposits. 169 samples were systematically collected and additional samples will be collected in the new measured sections. These data will help study the sedimentary evidence and the processes controlling mixed fluvial-eolian deposits. Finally, laboratory data will be used to verify and substantiate the preliminary interpretation of a loess origin and to extract the sedimentologic, tectonic, and paleoclimatic signals in the deposits. The laboratory data includes: 1) petrographic data from point counting, SEM, particle size analysis, and XRD to document the composition, sedimentary textures, micromorphological features, and clay mineralogy of the conglomerates and mudrocks; 2) geochemical data including major and trace elemental composition, and carbonate and organic matter content; 3) paleomagnetic data to document the magnetic susceptibility of the deposits; and 4) detrital zircon chronologic data to characterize the provenance of the deposits. These data has been useful to recognize modern loess deposits and will be useful to ascertain the origin of the QZJ LC. These analyses have been previously tested (Obrist and Yang, 2012) and the results show variations of grain composition, silt content, and magnetic susceptibility (Fig. 3).

Significance

The late Paleozoic is a period when the Earth responded to global climate changes similar to the present glacial to deglacial transition (Gastaldo et al., 1996). Predicting future climatic changes relies on our ability to thoroughly comprehend past climates. One of the most complete terrestrial Quaternary paleoclimatic records is contained within loess deposits (Kukla, 1987). Loess is a widespread eolian deposit that covers about 10% of Earth’s surface (Pye, 1987). The deposits are common during glaciated periods, where accumulation of loess occurs during cold and dry glacial stages (Chlachula et al., 1997). However, loess deposits of pre-Pleistocene glacial periods are rare or absent (van Loon, 2006). These should be common during the late Paleozoic ice age because the processes responsible for generating and accumulating loess material should be similar (van Loon, 2006). Permian loess has been reported in equatorial Pangea (e.g., Soreghan et al., 2002; Sweet et al., 2013) but none has been reported elsewhere. This ongoing research reports possible loess deposits in mid-latitude NE Pangea (Fig. 2) and a potential “window” into a climatic record during the last icehouse-hothouse transition.



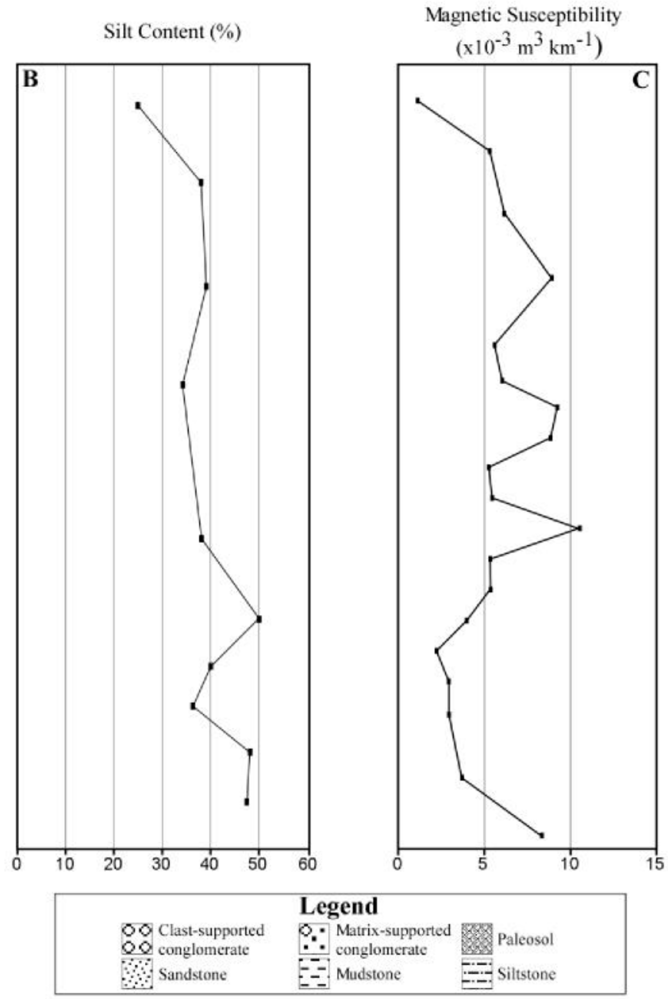


Figure 3. A) Highly-simplified segment of measured section with field descriptions from northeasternmost Tarlong section. B) graph showing the percentage of silt throughout the segment of the section. Each box correlates to a specific sample taken from the section. C) graph showing the volume-specific magnetic susceptibility reading throughout the monotonous mudrock.

Expected Research Results

The extensive literature review on modern and ancient loess deposits will be summarized and synthesized to publish in a professional journal "Earth Science Review". This publication will have an extensive summary of all the loess deposits in the world and focus mainly on the major characteristics that can be used to classify modern loess deposits and what characteristics are most useful to recognize ancient loess. The characteristics of modern loess will be compared with those of ancient loess to see what are the similarities and differences. This data will be compared with the QZJ LC and will be used to understand the depositional environment of the deposits and to support the interpretation of a loess origin.

The other paper to be submitted for publication will focus on a detailed description of the QZJ LC, outlining all the field data collected, the lateral and vertical lithological variations and the laboratory results. It will also try to present the importance of loess deposits in mid-latitude NE Pangea with respect to the climatic conditions and changes in the QZL LC. The main goal of the paper will be to provide a paleoclimatic data point in an area where little is known (cf. Metcalfe et al., 2009; Thomas et al., 2011) and will serve as ground truth for future climate modeling.

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