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Discussion

Comment on “Mudflat/distal fan and shallow lake sedimentation (upper Vallesian–Turolian) in the Tianshui Basin, Central China: Evidence against the late Miocene eolian loess” by A.M. Alonso-Zarza, Z. Zhao, C.H. Song, J.J. Li, J. Zhang, A. Martín-Pérez, R. Martín-García, X.X. Wang, Y. Zhang and M.H. Zhang [Sedimentary Geology 222 (2009) 42–51]

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ABSTRACT

Alonso-Zarza et al. (2009) argued that the Miocene sedimentary sequence near Qinan (QA-I) (Guo et al., 2002), north to Tianshui in Central China, represents mudflat/distal fan and shallow lake sediments. Here we show that they (1) did not take into account extensive observational evidence supporting an eolian origin; (2) erroneously correlated deposits of different origins and small lateral extent occurring in different geomorphic units; (3) inferred a common origin for distal fans in the Tianshui and Qinan regions despite contrasting tectonic and geomorphic conditions; and (4) in some cases misinterpreted features typical of eolian deposits. Accordingly, their study is not a sufficient basis for challenging earlier interpretations of Asian paleoclimates.

1. Introduction

Based on analysis of five sedimentary sequences, the nearest one ~12 km away, Alonso-Zarza et al. (2009) (AZ *hereafter*) argued that the Qinan sequence (QA-I; ~22–6.2 Ma) (Guo et al., 2002) represents water-laid sediments instead of eolian deposits. This conclusion challenges studies of Neogene eolian sedimentation in the western Loess Plateau (e.g. Lu et al., 2004; Garzione et al., 2005; Li et al., 2006a; An et al., 2006; Ding, 2007; Oldfield et al., 2009). It also goes against the fact that eolian and waterlain sediments commonly coexist in space due to topographic variability and erosion, such as the Quaternary lacustrine-fluvial deposits found in parts of the Loess Plateau. Here we summarize observational evidence supporting an eolian origin.

2. Extensive evidence of eolian origin

Eight Neogene eolian sequences with detailed magnetostratigraphy have been reported from the western Loess Plateau, ranging from the southern slope of the Qinling Mt. to the Qinan region, the top of the Huajialing Mt (Fig. 1A), and to the Tibetan Plateau near Xining (Lu et al., 2004). Their eolian origin, which has been supported by various lines of evidence in more than 15 publications, is summarized below:

(1) Spatially correlative stratigraphies, magnetic susceptibility and grain-size time series (Guo et al., 2002, 2008; Liu et al., 2005; Hao and Guo, 2007) provide strong evidence of eolian deposits. Water-laid sequences (as proposed by AZ) would not correlate in such detail across such a vast region and over such long time spans.
(2) The abundance of land snails and the lack of aquatic species (Li et al., 2006a, 2006b) in both soil and loess layers firmly attest to subaerial environments. Their random occurrences and well-preserved shells preclude any transportation. The dry-cold assemblages in loess and humid-warm assemblages in soils are consistent with loess-soil cycles, and do not support the interpretation that the pale (loess) layers are lake deposits representing humid periods (Alonso-Zarza et al., 2009).
(3) Several hundred reddish soils, mostly Luvisols with clay coatings (unique for soils) (Guo et al., 2002, 2008), also attest to subaerial environments, as do their calcareous horizons (nodular or calcrete) with typical pedogenic features and abundant land snails (Li et al., 2006a, 2006b), common in the Quaternary loess of China (Yin et al., 2007) and soils elsewhere

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(Retallack, 2001). The clay coatings in the soils, the lack of significant hydromorphic features, and their wavy occurrences following the palaeo-topography (Fig. 1) firmly preclude a groundwater interpretation (Alonso-Zarza et al., 2009).

(4) The fine silt textures throughout the 16-Ma (253 m) QA-I sequence (Liu et al., 2006; Qiao et al., 2006), with median grain-size varying between 6 and 13 μm and with the >63 μm fraction less than 5.3% and averaging 0.9%, also indicate dust deposits. Water-laid deposition in distal fan or shallow lake environments would not produce such continuous fine-grained sequences spanning 16 Ma, under conditions of tectonic (Molnar, 2005) and climate changes (Zachos et al., 2001).

(5) The correlative and finer grain-size at ML-V (~75 km south of QA-I), compared to the coarser sequence at QA-I, are consistent with a northern provenance of wind-blown dust (Guo et al., 2008), in contrast with AZ's statement that grain size decreases from south to north in their model of water-deposited sediments.

Other firm evidence of eolian origin includes quartz morphology (Liu et al., 2006), geochemistry (Liang et al., 2009), and magnetic properties typical of eolian loess (Hao et al., 2008). These silt sequences, similar in lithology and highly correlative in magnetic susceptibility and grain-size time series, mantling the highlands from the southern slope of the Qinling Mt., Qinan region, to the top of the Huajialing Mt. (Fig. 1B), and Tibetan Plateau (Lu et al., 2004), can only be eolian in origin, whereas AZ interpreted the Qinling Mt and Huajialing Mt as the sources for distal-fans.

3. The assumption of a common basin

AZ's study is based on the assumption that the study regions occupied a common basin thought to 'fit well with an active foreland basin'. However, no evidence suggests a Cenozoic foreland basin here because plate collision occurred in the Late Triassic and a foreland basin of Triassic–Jurassic age existed south of Qinling (Meng and Zhang, 2000).

Instead, available studies (Ma, 1989; LIS-CEA, 1993; Meng and Zhang, 2000) defined three distinct tectonic/geomorphic units in the region (Fig.1). They are (1) the Qinling Mt. with intermontane basins, belonging to the Qinling orogenic zone, (2) the northern frontal fault zone of Western Qinling (NFFWQ), and (3) highlands and inter-ridge basins around Qinan, as a marginal part of another tectonic unit, i.e. the Qilian orogenic zone.

The distribution of Neogene sediments is consistent with this tectonic/geomorphic setting (Fig.1), indicating that the basic pattern had formed by the early Miocene (Yuan et al., 2007). An erosion phase in the late Pliocene led to the formation of hilly topography in the study regions, with only thin Quaternary loess preserved (Hao and Guo, 2004; Yuan et al., 2007). These observations do not support AZ's suggestion of a common basin and a vast flat region during the late Miocene.

4. Sedimentary sequences of different origins from various geomorphic units

Rather than deposition in a common flat basin, the six sequences cited by AZ represent different sedimentary units, mostly separated by higher rocky ridges, such as the Youfu Mt. between the Tianshui basin and Qinan region (Fig.1). Their Lamashan section is from an intermontane basin in Qinling with a lacustrine–fluvial fill, while eolian deposits coexist on higher piedmonts (e.g. ML-V). The Yaodian sequence of fluvial–lacustrine origin is from a sub-basin within the NFFWQ.

Yangjiadawan and Shangnangou are located within a small inter-ridge basin with water-laid deposits surrounded by broad highlands mantled with eolian deposits, including QA-I. Because of Neogene tectonic and climate instability, some marginal parts of the highlands and the erosional topography of the loess are covered by reworked loess deposits, as in the case of the Yanwan section (Fig. 1F). However, typical loess-soil alternations appear to exist at the nearby Xiashan, as shown by the numerous paleosols identified by soil micromorphology (Pan, 2008).

AZ listed some reworked features near QA-I to support their conclusion. The *reworked calcretes* and *angular clasts* they cited may be reworked loess near the hiatus or from nearby gully deposits. Similar syn- or post-depositional features are common features of Quaternary eolian deposits (Porter and An, 2005; Yin et al., 2007), because loess is deposited on a subaerial surface. Such small-scale features are, however, avoided in loess studies through careful sampling strategies.

The different origins of these sequences are clearly demonstrated by their lithological variability (Fig.1B–H and AZ's Fig.5D). The geomorphic and sedimentary diversity was documented by Yuan et al. (2007), who were not cited by AZ. Instead, AZ assumed a common basin with 'four stratigraphic units' and correlated these independent sequences of small lateral extent to produce a model of fans, distal fans and shallow lakes.

Evidence of fan bodies critical to AZ's model is lacking. The interpretation of sediments of small lateral extent with mostly clay to sandy/fine gravel textures and uncertain ages near Ganquan (GBS, 1968) as rapidly deposited lower Neogene fans which covered a vast area is difficult to justify. They grouped these sediments in 'Unit I occupying most of the accommodation space'. They described 'Unit II' everywhere as mudflat/distal fan and shallow lake sediments, but without evidence of fans. They invoked long-term tectonic stability to explain the widespread occurrence of fine-grained sediments, even though regional tectonics was extremely unstable in the late Miocene, with intense uplift of the nearby Tibetan Plateau (Molnar, 2005).

Thus, AZ's sedimentary model lacks the necessary documentation of distribution, contacts and sedimentology. Their descriptions of 'Unit II' (AZ's Section 3) are confusing because of the lack of location information necessary to evaluate their interpretations. Of the eight pictures (AZ's Fig.5) they showed, five have no location and seven have no depth information.

5. Stratigraphic correlations

AZ were unable to assign an explicit age to their 'Unit II'. Among their five sequences, Shangnangou and Yangjiadawan have no chronology support and are probably of different ages. They did not take into account the magnetostratigraphic data for Lamashan and Yanwan (Zhang, 2008) which are unlikely to support their correlations. Yaodian was dated (Li et al., 2006c) at ~12.4–6.5 Ma, much younger than QA-I (22–6.2 Ma). Moreover, Li et al. (2006c) reported a ~240 m thickness at Yaodian over the Neogene/Paleogene boundary whereas AZ changed this to 180 m and revised Li et al. (2006c)'s lithology divisions without giving a reason. Thus, AZ correlated sedimentary sequences with insufficient support of chronological data and ignored lithological differences (Fig.1).

6. Concluding remarks

AZ erroneously correlated sediments of different origins and poorly constrained ages to create a model based on the assumption of deposition by water in a large common basin. They did not take into account comprehensive and wide-ranging evidence of an eolian origin for the Neogene deposits at QA-I and elsewhere on the Loess Plateau, widely accepted by numerous loess experts (e.g. An et al., 2006; Ding, 2007; Oldfield et al., 2009). These eolian sequences indicate a drying in northern dust source regions, along with humidification in the Loess Plateau at 22 Ma BP due to strengthened monsoons, a spatial pattern that AZ failed to appreciate.

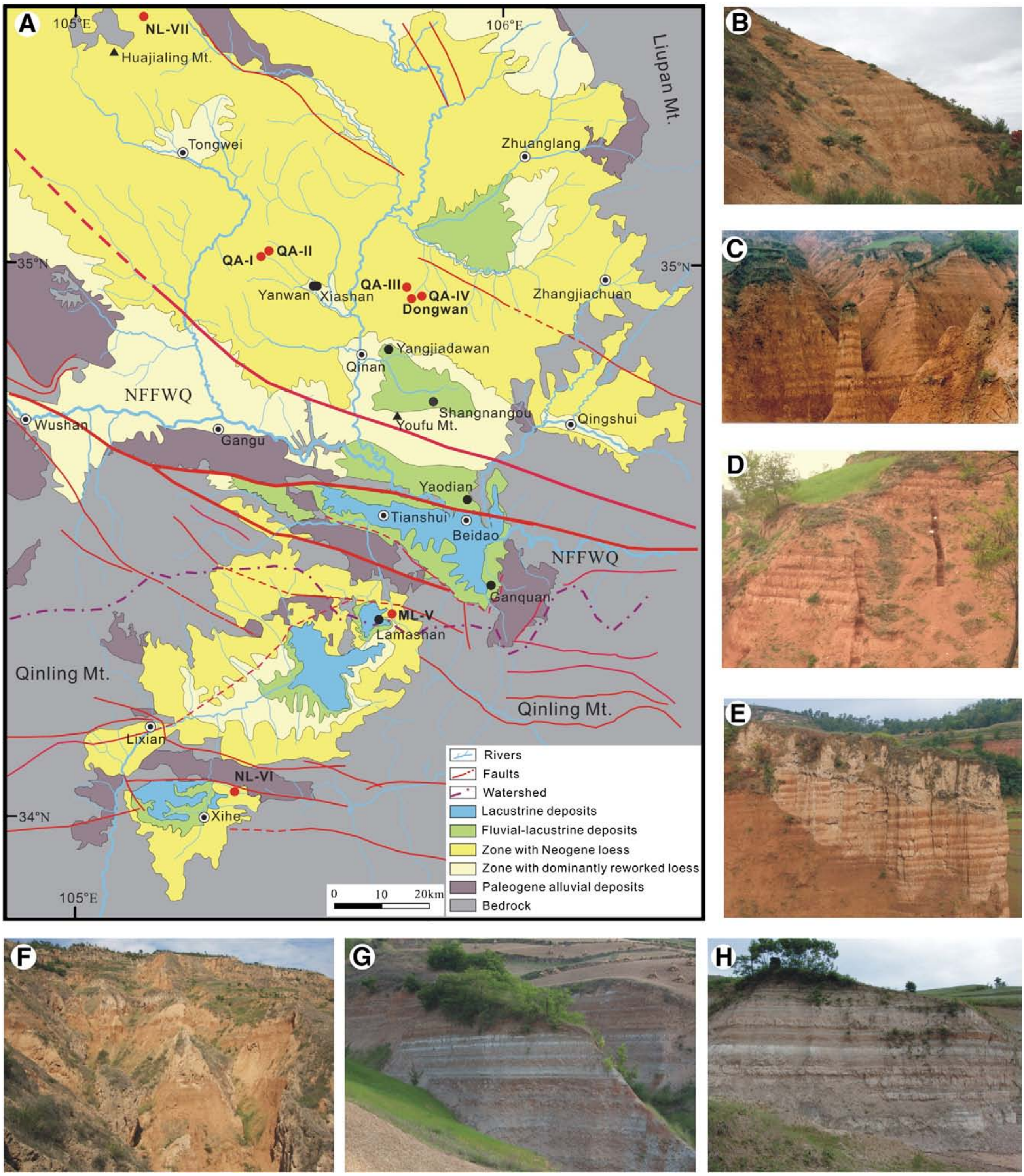

Fig. 1. A) Distribution of the Neogene sediments and relationships with the tectonic and geomorphic settings. Tectonic data are from GBS (1968), Ma (1989), Meng and Zhang (2000). NFFWQ indicates the northern frontal faulting zone of Western Qinling. Highland regions that contain Neogene loess-soil sequences are shown in darker yellow, in which erosional topography has been filled with reworked loess. Zones with dominantly reworked loess deposits are pale yellow. Distributions of fluvial–lacustrine sediments are green. Red dots show the sites of Neogene eolian sequences (NL-VII in the Huajialing Mt., QA-I and QA-II (Guo et al., 2002), Dongwan (Hao and Guo, 2004), QA-III (Hao and Guo, 2007), QA-IV (Liu et al., 2005), ML-V (Guo et al., 2008) and NL-VI in Qinling (Ge and Guo, 2008; 2010). Black dots show the sites of water-laid sequences cited by Alonso-Zarza et al. (2009) (*hereafter* AZ). B–E) Field pictures of the Neogene loess-soil sequences NL-VII, QA-I, ML-V and NL-VI, respectively. F–H) Field pictures of AZ's Yanwan, Shangnangou and Lamashan sequences, respectively. The similarity in lithology for B–E and their difference from F–H and from Yaodian (AZ's Fig. 5D) show that AZ erroneously correlated sediments of different origins.

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References

Alonso-Zarza, A.M., Zhao, Z., Song, C.H., Li, J.J., Zhang, J., Martín-Pérez, A., Martín-García, R., Wang, X.X., Zhang, Y., Zhang, M.H., 2009. Mudflat/distal fan and shallow lake sedimentation (upper Vallesian–Turolian) in the Tianshui Basin, Central China: evidence against the late Miocene eolian loess. Sedimentary Geology 222, 42–51.

An, Z.S., Zhang, P.Z., Wang, E., Wang, S.M., Qiang, X.K., Li, L., Song, Y.G., Chang, H., Liu, X.D., Zhou, W.J., Liu, W.G., Cao, J.J., Li, X.Q., Shen, J., Liu, Y., Ai, L., 2006. Changes of the monsoon arid environment in China and growth of the Tibetan Plateau since the Miocene. Quaternary Sciences 26, 678–693 (in Chinese with English abstract).

Ding, Z.L., 2007. Stepwise weakening of the East-Asian summer monsoon during the Neogene under global cooling trend. Quaternary International 167 (168), 99–100.

Garzione, C.N., Ikari, M.J., Basu, A.R., 2005. Source of Oligocene to Pliocene sedimentary rocks in the Linxia basin in northeastern Tibet from Nd isotopes: implications for tectonic forcing of climate. Geological Society of America Bulletin 117, 1156–1166.

Ge, J.Y., Guo, Z.T., 2008. A Miocene-Pliocene loess-soil sequence in the Western Qinling Mountain: implications on the tectonics and paleomonsoon. PAGE Global Monsoon Symposium, Shanghai, Program & Abstract, p. 20.

Ge, J.Y., Guo, Z.T., Basu, A.R., 2010. Neogene eolian deposits within the West Qinling Mountains:climatic and tectonic implications. Chinese Science Bulletin 55, 1483–1487.

Geological Bureau of Shaanxi (GBS), 1968. Report of Regional Geological Surveys of People's Republic of China, Tianshui (1:200, 000). Survery Team Publishing House, Wugong. (pp. 1–74).

Guo, Z.T., Ruddiman, W.F., Hao, Q.Z., Wu, H.B., Qiao, Y.S., Zhu, R.X., Peng, S.Z., Wei, J.J., Yuan, B.Y., Liu, T.S., 2002. Onset of Asian desertification by 22 Myr ago inferred from loess deposits in China. Nature 416, 159–163.

Guo, Z.T., Sun, B., Zhang, Z.S., Peng, S.Z., Xiao, G.Q., Ge, J.Y., Hao, Q.Z., Qiao, Y.S., Liang, M.Y., Liu, J.F., Yin, Q.Z., Wei, J.J., 2008. A major reorganization of Asian climate by the early Miocene. Climate of the Past 4, 153–174.

Hao, Q.Z., Guo, Z.T., 2004. Magnetostratigraphy of a late Miocene–Pliocene loess-soil sequence in the western Loess Plateau in China. Geophysical Research Letters 31, L09209. doi: 10.1029/02003GL019392.

Hao, Q.Z., Guo, Z.T., 2007. Magnetostratigraphy of an early-middle Miocene loess-soil sequence in the western Loess Plateau of China. Geophysical Research Letters 34, L18305. doi: 10.1029/12007GL031162.

Hao, Q.Z., Oldfield, F., Bloemendal, J., Guo, Z.T., 2008. The magnetic properties of loess and paleosol samples from the Chinese Loess Plateau spanning the last 22 million years. Palaeogeography, Palaeoclimatology, Palaeoecology 260, 389–404.

Lanzhou Institute of Seismology, China Earthquake Administration (LIS-CEA), 1993. Notice for Geological Map (1:50,000) of the Active Faults in the Northern Frontal Faulting Zone of Western Qinling. LIS-CEA , Lanzhou, pp.1-140.

Li, F.J., Wu, N.Q., Pei, Y.P., Hao, Q.Z., Rousseau, D.-D., 2006a. Wind-blown origin of Dongwan late Miocene-Pliocene dust sequence documented by land snail record in western Chinese Loess Plateau. Geology 34, 405–408.

Li, F.J., Wu, N.Q., Rousseau, D.-D., 2006b. Preliminary study of mollusk fossils in the Qinan Miocene loess-soil sequence in western Chinese Loess Plateau. Science in China (Series D) 49, 724–730.

Li, J.J., Jun, Z., Song, C.H., Zhao, Z.J., Zhang, Y., Wang, X.X., Zhang, J.M., Cui, Q.Y., 2006c. Miocene Bahean stratigraphy in the Longzhong Basin, northern central China and its implications in environmental change. Science in China (Series D) 49, 1270–1279.

Liang, M.Y., Guo, Z.T., Kahmann, A.J., Oldfield, F., 2009. Geochemical characteristics of the Miocene eolian deposits in China: their provenance and climate implications. Geochemistry, Geophysics, Geosystems 10, Q04004. doi: 10.1029/02008GC002331.

Liu, J.F., Guo, Z.T., Hao, Q.Z., Peng, S.Z., Qiao, Y.S., Sun, B., Ge, J.Y., 2005. Magnetostratigraphy of the Miziwan Miocene eolian deposits in Qin'an County (Gansu Province). Quaternary Sciences 25, 503–508 (in Chinese with English abstract).

Liu, J.F., Guo, Z.T., Qiao, Y.S., Hao, Q.Z., Yuan, B.Y., 2006. Eolian origin of the Miocene loess-soil sequence at Qin'an, China: evidence of quartz morphology and quartz grain-size. Chinese Science Bulletin 51, 117–120.

Lu, H.Y., Wang, X.Y., An, Z.S., Miao, X.D., Zhu, R.X., Ma, H.Z., Li, Z., Tan, H.B., Wang, X.Y., 2004. Geomorphologic evidence of phased uplift of the northeastern Qinghai–Tibet Plateau since 14 million years ago. Science in China (Series D) 47, 822–833.

Ma, X.Y., 1989. Lithosphere Dynamics Atlas of China. China Cartographic Publishing House, Beijing. (pp. 1–68).

Meng, Q.R., Zhang, G.W., 2000. Geologic framework and tectonic evolution of the Qinling orogen, central China. Tectonophysics 323, 183–196.

Molnar, P., 2005. Mio-Pliocene growth of the Tibetan Plateau and evolution of Asian climate. Palaeontologia Electronica 8, 1–23.

Oldfield, F., Hao, Q.Z., Bloemendal, J., Gibbs-Eggar, Z., Patil, S., Guo, Z.T., 2009. Links between bulk sediment particle size and magnetic grain-size: general observations and implications for Chinese loess studies. Sedimentology. doi: 10.1111/j.1365-3091.2009.01071.x.

Pan, M.H., 2008. Pedological characteristics of the Tianshui–Qin'an Miocene deposit and their paleoenvironmental signification. MS thesis. Lanzhou, Lanzhou University, pp. 1–72 (http://epub.cnki.net/grid2008/detail.aspx?filename=2008162142.nh&dbname=CMFD2008).

Porter, S.C., An, Z.S., 2005. Episodic gullying and paleomonsoon cycles on the Chinese Loess Plateau. Quaternary Research 64, 234–241.

Qiao, Y.S., Guo, Z.T., Hao, Q.Z., Yin, Q.Z., Yuan, B.Y., Liu, T.S., 2006. Grain-size features of a Miocene loess-soil sequence at Qinan: Implications on its origin. Science in China (Series D) 49, 731–738.

Retallack, G.J., 2001. Soils of the past—An Introduction to Paleopedology. Wiley-Blackwell, pp. 1–404.

Yin, Q.Z., Xiao, G.Q., Guo, Z.T., Ge, J.Y., Hao, Q.Z., Yuan, B.Y., 2007. Syn- and post-depositional modification of loess deposits and their paleoenvironmental significance. Quaternary Sciences 27, 295–302 (in Chinese with English abstract).

Yuan, B.Y., Guo, Z.T., Hao, Q.Z., Peng, S.Z., Qiao, Y.S., Wu, H.B., Xiao, G.Q., Ge, J.Y., Sun, B., Zhou, X., Yin, Q.Z., Liang, M.Y., Qin, L., Liu, L., Yao, Z.Q., Liu, T.S., 2007. Cenozoic evolution of geomorphic and sedimentary environments in the Tianshui–Qin'an regions. Quaternary Sciences 27, 161–171 (in Chinese with English abstract).

Zachos, J., Pagani, M., Sloan, L., Thomas, E., Billups, K., 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292, 686–693.

Zhang, J., 2008. Formation cause of the Neogene sediments in Tianshui–Qin'an area in Longzhong Basin and the Paleoenvironmental change. Ph. D thesis. Lanzhou, Lanzhou University, pp. 1–141 (http://epub.cnki.net/grid2008/detail.aspx?filename=2008162377.nh&dbname=CDFD2008).