Available online at www.sciencedirect.com
ScienceDirect
PALAEO
Palaeogeography, Palaeoclimatology, Palaeoecology 245 (2007) 317–331
www.elsevier.com/locate/palaeo

What triggers the transition of palaeoenvironmental patterns in China, the Tibetan Plateau uplift or the Paratethys Sea retreat?

Zhang Zhongshi [a,c,*], Huijun Wang [a], Zhengtang Guo [b,c], Dabang Jiang [a]

[a] *Nansen-Zhu International Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, 100029, China*
[b] *Institute of Earth Environment, Chinese Academy of Sciences, Xi'an, 710075, China*
[c] *Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, 100029, China*

Received 1 January 2006; received in revised form 9 August 2006; accepted 9 August 2006

Abstract

Geological research has illustrated the transition of palaeoenvironmental patterns by the earliest Miocene from a planetary-wind-dominant type to a monsoon-dominant type, indicating that the East Asian monsoon became markedly intensified and played a leading role in the East Asian climate. From a modeling point of view, the pioneering research using the reduced number of scenarios had demonstrated that both the Tibetan Plateau uplift and the Paratethys Sea retreat were important for understanding the Asian monsoon evolution. However, the sensitivity of the Paratethys retreat to the East Asian climate still needs further studies based on the more detailed scenarios. Thirty numerical experiments under the six Paratethys Sea and the five Tibetan Plateau conditions illustrate the shifts from zonal climate to the monsoon climate in East Asia. The results confirm again that both the Paratethys retreat and the Tibetan plateau uplift play important roles in the formation of the monsoon-dominant environmental pattern, and show that the Paratethys retreat can strengthen the East Asian monsoon and greatly increase humidity and aridity respectively in the monsoon areas and Northwest China, which is similar to the impact of the Tibetan Plateau uplift on the East Asian climate. Furthermore, the fact that the Paratethys Sea retreats to the Turan Plate is found to be the key criterion for the palaeoenvironmental patterns' transition in China. The shrinkage of Paratethys Sea leads to the reconstructions of the pressure system and the atmospheric circulations, which result in the variations of precipitation and the transition of palaeoenvironmental patterns.

Keywords: Paratethys Sea; Tibetan Plateau; Palaeoenvironmental patterns; Precipitation fields' pattern; Turan Plate

1. Introduction

Geological studies (Zhou, 1982; Wang, 1990; Liu and Guo, 1997; Sun and Wang, 2005; Zhang and Guo, 2005) illustrated that the Paleogene palaeoenvironmental pattern in China was dominated by a roughly zonal climate (Fig. 1a), which was considered to have resulted from the planetary wind system (e.g., Liu and Guo, 1997; Guo, 2003; Sun and Wang, 2005). Conspicuous changes occurred in the Neogene when the originally arid southwest and southeast parts of the country became much more humid and the geographic location of the arid region in North China became closer to that of the present day (Fig. 1b), indicating that the East Asian monsoon remarkably intensified and played a leading

* Corresponding author. Nansen-Zhu International Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, 100029, China.
E-mail address: zhongshizhang@mail.iggcas.ac.cn (Z. Zhongshi).

0031-0182/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2006.08.003

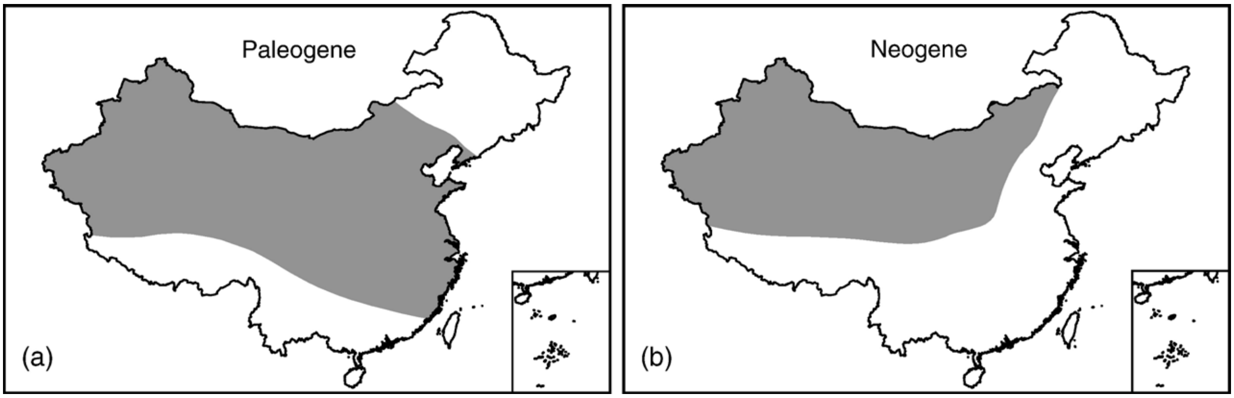

Fig. 1. Palaeoenvironmental patterns in China during the Cenozoic, (a) for the planetary-wind-dominant palaeoenvironmental pattern in the Paleogene and (b) for the monsoon-dominant palaeoenvironmental pattern in the Neogene. Arid regions are shaded. (Modified after Zhang and Guo, 2005).

role in East Asian climate. The Paleogene and Neogene palaeoenvironmental patterns were respectively called "planetary-wind-dominant type" and "monsoon-dominant type" (Guo, 2003; Zhang and Guo, 2005).

However, there were different opinions about the causes and mechanisms of the above palaeoenvironmental patterns' transition and East Asian monsoon intensification, especially about the impacts of the Tibetan Plateau uplift (e.g., Ruddiman and Kutzbach, 1989; Prell and Kutzbach, 1992; An et al., 2001; Liu and Yin, 2002) and the Paratethys (an epicontinental sea) retreat (Ramstein et al., 1997; Fluteau et al., 1999). Many numerical experiments (Manabe and Terpstra, 1974; Hahn and Manabe, 1975; Ruddiman and Kutzbach, 1989; Kutzbach et al., 1989; Prell and Kutzbach, 1992; Chen et al., 1999; An et al., 2001; Liu et al., 2001; Liu and Yin, 2002; Abe et al., 2003; Kitoh, 2004) underlined the impact of the Tibetan Plateau uplift on the Asian monsoon system, not only the direct effect on the atmospheric circulations, but also the feedback via changing sea surface temperatures (SSTs) and ocean general circulations. These experiments revealed that progressive Tibetan uplift played an important role in the formation and development of the Asian monsoon. Being a subsystem of the Asian monsoon, the East Asian monsoon was also sensitive to the Tibetan Plateau uplift (Chen et al., 1999; An et al., 2001; Liu et al., 2001; Liu and Yin, 2002; Kitoh, 2004). The uplift could strengthen monsoon circulations (An et al., 2001; Liu and Yin, 2002; Kitoh, 2004) and changed the shape of the rain band in East Asia (Liu et al., 2001). On the other hand, several studies (Ramstein et al., 1997; Fluteau et al., 1999) emphasized the impact of land–sea distribution conditions. Ramstein et al. (1997) pointed out that the Paratethys retreat intensified the South Asian monsoon and shifted the central Asian climate from temperate to continental conditions, and played a role as important as the Tibetan Plateau uplift in driving the Asian monsoon. Fluteau et al. (1999) suggested that the shrinkage of the Paratethys Sea would have played a major role in the large-scale atmospheric changes, though both the shrinkage and the uplift were the main causes of monsoon changes.

In summary, past studies have paid more attention to the impact of the Tibetan Plateau uplift on the Asian monsoon system and revealed that both the Tibetan Plateau uplift and the Paratethys retreat can affect the Asian monsoon. However, there still are two important questions, which need to be addressed. 1) How the Paratethys retreat impacts the East Asian monsoon system? 2) What triggers the transition of palaeoenvironmental patterns, the Tibetan Plateau uplift or the Paratethys retreat? Here, we use the IAP_AGCM (the atmospheric general circulation model developed at the Institute of Atmospheric Physics, Chinese Academy of Sciences) model to run 30 numerical experiments under different Paratethys Sea and Tibetan Plateau conditions, in order to figure out the impacts of the Paratethys retreat on the East Asian monsoon and the causes of the palaeoenvironmental patterns' transition during the Cenozoic.

2. Model and experimental design

2.1. Model

The IAP_AGCM used was designed and developed by the Institute of Atmospheric Physics, Chinese Academy of Sciences. It is a global grid point model with 5×4 (longitude by latitude) horizontal resolution and 9 unequal levels in the vertical with the upper model boundary at 10 hPa. As Jiang et al. (2003) has introduced, the