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Climate, Desertification, and the Rise and Collapse of China's Historical Dynasties

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Introduction

Arid and semiarid areas of ancient China include the Mongolian Plateau, northern China, and some parts of central China. These regions have experienced multiple arid phases throughout the Quaternary, and are highly sensitive to climate change (Z. Zhu and Liu 1982). These areas were traditionally managed using fragile pastoral and agricultural systems even though most of this area is covered by gobi deserts, eolian dunes, sandy land, and steppes (Fig. 1), where both agriculture and the native vegetation have been seriously degraded by frequent desertification cycles (Z. Zhu *et al.* 1980). Over the past 5,000 years, Chinese dynasties have been founded, have flourished, and have then declined and collapsed in various regions. In particular, the rise and decline of dynasties in northern and central China, possibly due to desertification cycles, strongly influenced China's historical cultures (Rhoads 2003), which themselves played a dominant role in Asian and world history (Stavrianos 1999). The Mongolian Plateau and northern and central China, where historical dynasties were supported by traditional pastoral and agricultural systems, were highly sensitive to changes in desertification and biological productivity produced by the late-Holocene Asian Monsoon (Neff *et al.* 2001; Fleitmann *et al.* 2003). Because of the importance of a stable food supply to support the large populations required to economically and militarily sustain a dynasty, these changes would have had a direct impact on the health of dynasties in these regions.

Archaeological evidence (Bao and Zhang 1984; Feng and Jiang 1996) reveals that cycles of desertification and decreasing biological productivity occurred frequently and in almost all cases, dynasties flourished when desertification was reversing and biological productivity was increasing, and collapsed when desertification expanded in their core regions (H. Wang 1996). Similarly, Man *et al.* (2000) suggested that the climate changes during historical periods had significant effects on changes in the position of agriculture–grazing transitional zones and the fate of Chinese dynasties. However, the rise and decline of China's historical dynasties and their relationship to changes in the region's climate are poorly understood. While there is considerable evidence for the effects of cultural and other socioeconomic factors (Lv 1991), and there is some evidence of the collapse of dynasties during periods with a weak summer Asian Monsoon (Yancheva *et al.* 2007) or periods with unusually low temperatures (Zhang *et al.* 2007), the overall influence of climate remains poorly understood.

However, recent advances in climate change research using proxies allow a review of the relationship between climate and the fate of the dynasties using high-resolution data. We here present evidence from published high-

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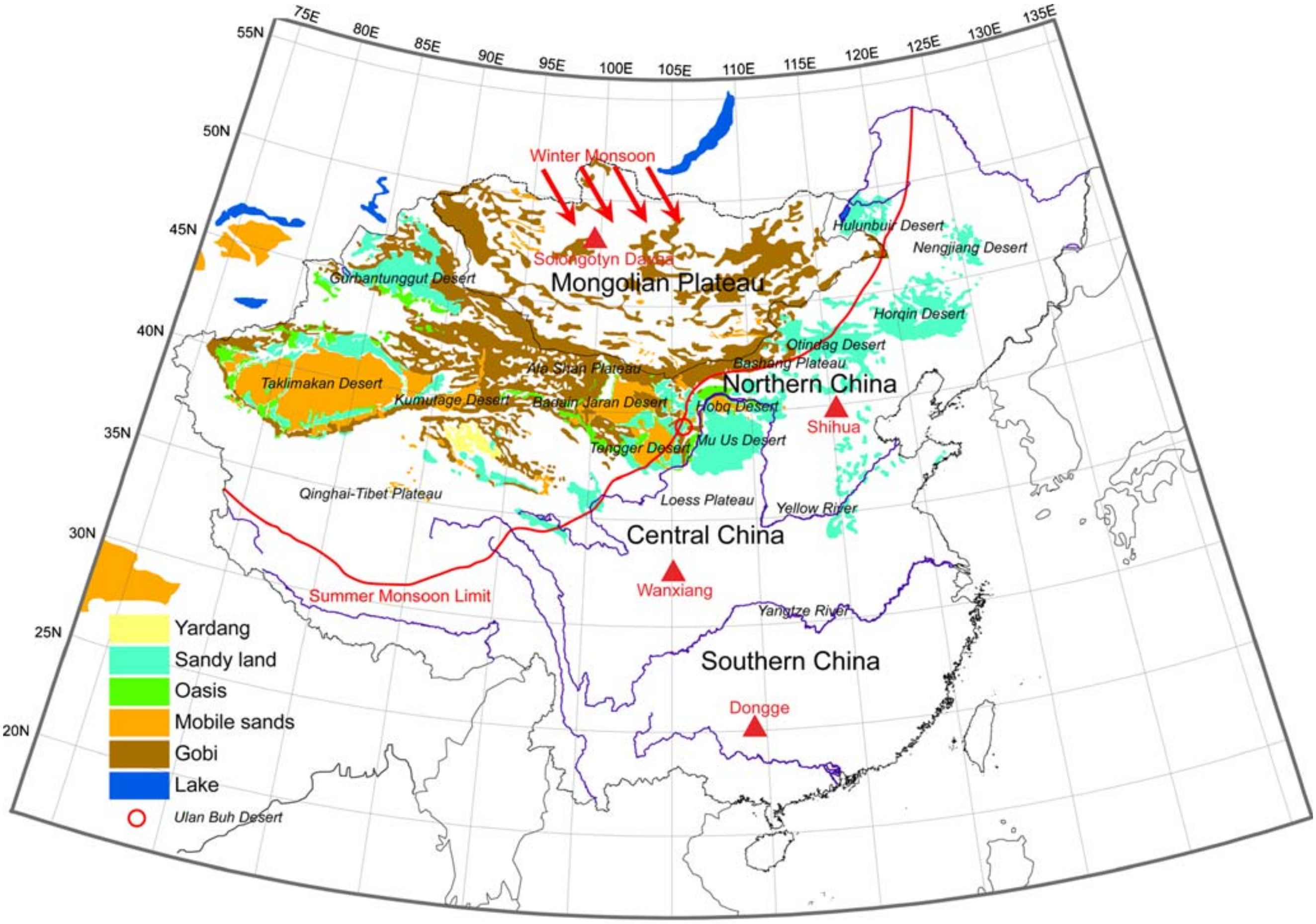


Fig. 1 Geomorphological map of the Mongolian Plateau and China. Areas of sandy desert and sandy land, oases, steppes, and gobi deserts are regions with a high risk of desertification, but were also the homes of dynasties founded in the Mongolian Plateau and northern China. The sampling locations used to obtain the climate series in this study and the limit of the modern Asian summer monsoon are also identified

resolution palaeoclimate data (records from stalagmites and tree rings) for the Mongolian Plateau and for northern, central, and southern China from 300 to 1700 A.D. that shows strong relationships between the rise and decline of dynasties and historical cycles of desertification and biological productivity.

Material and Methods

Historical Data on Desertification

In China, desertification has usually occurred in and around gobi areas, oases, steppes, sandy lands, and deserts with mobile sand (Fig. 1) in which cultivation and grazing take place; the resulting adverse changes have been defined as land degradation characterized by wind erosion, mainly as a result of a lack of coordination between human impacts and natural conditions in arid, semiarid, and some subhumid regions (Zhu 1998). However, the Convention to Combat Desertification and UNEP define the desertification process as “Land degradation in arid, semiarid and dry subhumid areas resulting from various factors, including climatic variations and human activities” (UNEP 1992). Desertification during different dynasties of ancient China has been extensively reported in the historical literature based on archaeological evidence. Over the past 2000 years, desertification occurred in sandy deserts and in areas such as the Mu Us, Ulan Buh, Hobq, Otindag, and Horqin deserts during parts of the East Jin, Northern, and Southern dynasties, during the late Tang period, during the late Liao and Jin dynasties, and during the Ming Dynasty (e.g., Zhang 1989, 1991; Zhao and Ren 1998; Niu *et al.* 1999; Wang 2000; Du 2005; Yang *et al.* 2006; He *et al.* 2008). Without exception, desertification occurred during periods of low temperature or decreased precipitation. Archaeologists have also reported extensive reversal of desertification during the Western Han Dynasty (206 B.C. to 24 A.D.) and the early Tang Dynasty (Shi 1998; Sun 2000; Xiao and Yu 2005), which were dynasties of major historical importance for China and which flourished during relatively warm periods (Zhu 1973; Guo *et al.* 2006).

These historical reports of desertification only describe relative changes in processes and relative comparisons during certain periods, because Chinese scholars have only considered the advance and reversal of desertification, and did not quantify the actual areas affected (Zhu and Chen 1994). Unfortunately, the available historical data on the extent of desert areas and on the boundaries of each dynasty is inadequate to permit a precise comparison between these areas and changes in climate proxies. As a result, we can only quantitatively examine the relationship between desertification status (whether deserts were expanding or contracting in size) and the status of a dynasty (rising, stable, or declining). In the Mongolian Plateau, northern China and some parts of central China, desertification occurred during periods when temperature or precipitation decreased compared with values in the prior period. For instance, the later years of the Tang Dynasty in northern China (600–900 A.D.) exhibited more desertification than early periods.

From the historical period to modern times, human activities such as overgrazing, over-use of land, and over-cutting of natural vegetation such as forests in arid and semiarid China have not been the primary causes of desertification, though they have undoubtedly exacerbated trends resulting from longer-term changes in climate (Wang *et al.* 2008). In northern China, the Mu Us Desert and its adjacent regions are representative areas that have been deeply affected by human activities, and some scholars believed that historical desertification in this region mainly resulted from over-use of land for agriculture (Hou 1973). However, in recent decades, firm archaeological evidence has supported the hypothesis that desertification mainly resulted from climate change (Zhao 1981; Wang 2002; Han 2003). In addition, increased desertification during modern cold periods in northern China has been revealed through desertification monitoring (Wang *et al.* 2002, 2003, 2004; Zhong and Qu 2003; Xue *et al.* 2005) and examinations of climate records. During the past five decades, desertification expanded from the 1970s to the late 1980s, which was a cold period in northern China, but after the 1990s, temperatures increased and a reversal of desertification occurred consistent with the archaeological evidence (Ding *et al.* 2006; Fig. 2). In the Mongolian Plateau, temperature variations are closely correlated with the occurrence of the winter monsoon in and near Siberia. Although we lack monitoring data for modern desertification in Mongolia, historical periods of desertification in the Mongolian Plateau have mainly resulted from low temperatures, as documented in Chinese historical records (Bai 1996; Lu *et al.* 1996; Tian 1996). In addition, livestock mortality in modern times appears to be more sensitive to dzuds (severe winter weather) than to droughts (Begzsuren *et al.* 2004), indicating that unusually cold periods could significantly reduce livestock populations.

Climate Data

To obtain climate time-series data for our study period (ca. A.D. 300 to 2000), we selected data sets with long time series and high resolutions from the summer monsoon regions of southern China (Dongge Cave; Wang *et al.* 2005), central China (Wanxiang Cave; Zhang *et al.* 2008), and northern China (Shihua Cave; Tan *et al.* 2003). We obtained another climate series from tree-ring data from the Solongotyn Davaa region of Mongolia (D'Arrigo *et al.* 2001), which lies north of the region affected by the summer monsoon. These sites represent a range of climatic conditions in eastern Asia from low to high latitudes. The stalagmite data from Shihua Cave and the tree-ring data from Solongotyn Davaa have a 1-year resolution; therefore, we used the original data in our analysis. For the stalagmite records from the Dongge and Wanxiang caves, the original data had 3- to 5-year resolutions, but were precisely dated. We therefore resampled these data series at a 1-year resolution following Paillard *et al.* (1996), which is suitable for comparing geological data of different resolutions and has been widely used with data from ice cores, marine isotopes, and other time-series. This method is based on linear interpolation between the original data points, and therefore does not change the trends and variations in the original data series. After the resampling, all selected time series could be compared using the same 1-year resolution.

We used the precipitation and temperature data (1961–2000) from three stations (Beijing, Wudu, and Hechi, which are the nearest stations to Shihua, Wanxiang, and Dongge, respectively) for correlation analyses. Our results showed that from 1960 to 2000 there were significantly different trends and amplitudes of fluctuation for precipitation at the three sites, and that these differences reflected differences between the Mongolian Plateau, northern China, central China, and southern China that have been previously described (Wang and Lin 2002; Gong and Ho 2003). Spatial correlation analyses revealed that areas that were relatively strongly correlated with precipitation at the Beijing station in northern China are found mostly in northern China; similarly, areas that were strongly correlated with precipitation data at the Wudu station, in central China, are found in central China, and areas that were strongly correlated with precipitation at the Hechi station, in southern China, are found in southern China (Fig. 3).

Temporal trends in mean annual temperature at the three stations showed that despite a general warming from 1960 to 2000, the amplitude of the fluctuations differed significantly among the stations. The 10-year adjacent averages for annual temperature also differed. In addition, our spatial correlation analyses showed that despite positive correlations in overall trends between northern and southern China, significant differences existed. In the Mongolian

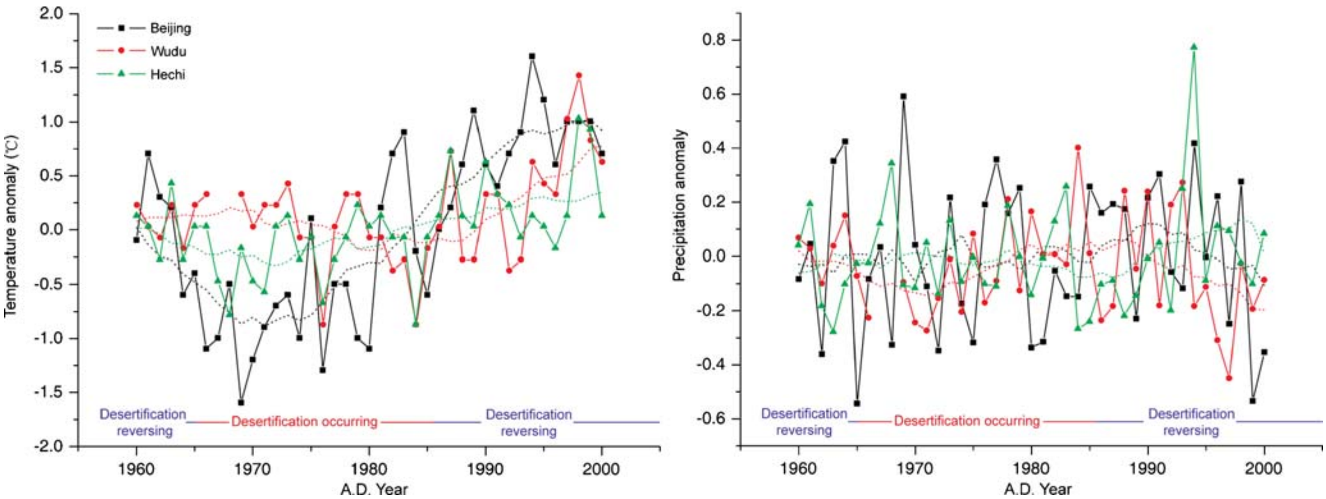


Fig. 2 Annual temperature and precipitation trends at Beijing (39°48′ N, 116°28′ E, ~40 km from Shihua), Wudu (33°24′ N, 104°55′ E, ~12 km from Wanxiang), and Hechi (24°42′ N, 108°02′ E, ~60 km from Dongge) from 1961 to 2000. Data from 1967 and 1968 are missing for Wudu. Solid lines represent actual data; dashed lines represent the smoothed (10-point running mean) data. The desertification and desertification reversal trends for northern China (on the *x-axis*) are based on data from T. Wang *et al.* (2002, 2003, 2004), Zhong and Qu (2003), and Xue *et al.* (2005)

Plateau, we lacked sufficient precipitation and temperature data for these analyses, but previous studies (e.g., Liu and Ding 2007) have shown a significant negative correlation between the winter northern hemisphere annular mode index (NAMI) and the spring temperature on decadal timescales. Thus, even though the effects of large-scale atmospheric circulation in the northern hemisphere produce broadly similar climate trends for the Mongolian Plateau, northern China, central China, and southern China, significant differences nonetheless exist among these regions.

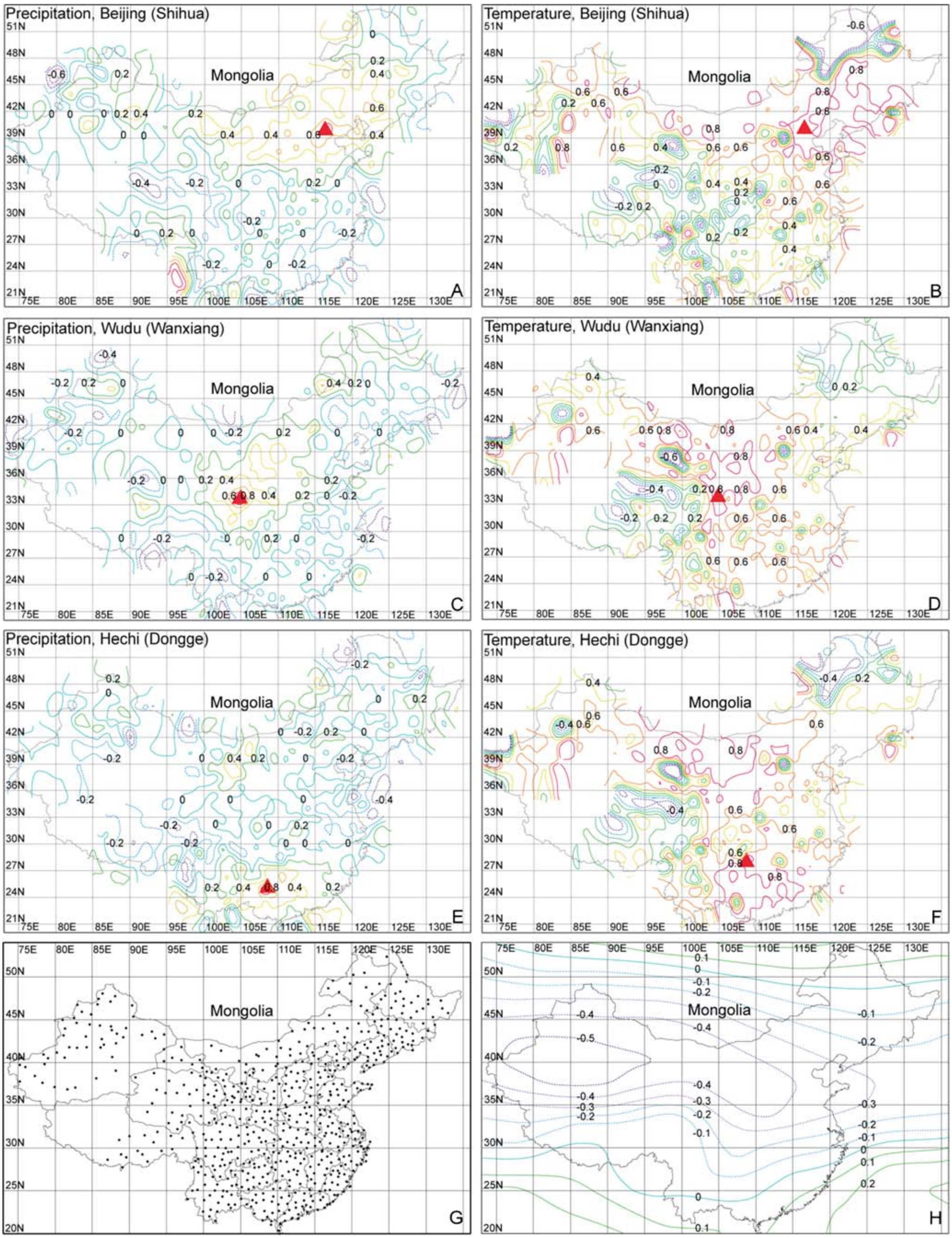
Desertification Cycle Estimation

For our discussion of desertification cycles and the rise, flourishing, decline, and collapse of the most significant ancient dynasties of China (Fig. 4) we divided the climate series into five main periods (A.D. 300 to 700, 600 to 1000, 900 to 1300, 1200 to 1700, and 1600 to 2000). First, we calculated the mean values of several climate proxies during the selected periods. Because our preliminary analysis showed that climate trends based on 10-year intervals were sufficient for discussing the desertification cycles and reducing the uncertainties of dating (for Dongge Cave, ±2 years; for Wanxiang Cave, ±1 to 5 years; for Shihua Cave, a maximum of ±5 years), we therefore smoothed these series by means of 10-year adjacent averaging. Because our analysis depended on the trends in these proxies and no reliable statistics are currently available on the area covered by deserts during each period, we cannot discuss the actual desertification intensity. Therefore, we divided any given period into sub-periods in which increasing desertification or the reversal of desertification occurred. This is sufficient resolution for us to assess the relationship between desertification cycles and the rise or collapse of ancient dynasties. We assessed the state of desertification (increasing or reversing) based on the mean values of the proxies and the 10-year running means.

Results and Discussion

During the abovementioned historical periods, ancient China and the Mongolian Plateau were sometimes governed simultaneously by several dynasties, and sometimes controlled by one united dynasty. In northern China and the Mongolian Plateau, a cold and dry climate that reduces biological productivity and causes in desertification would weaken any dynasty that depends on agricultural and livestock production. Conversely, a warm and wet climate that increases biological productivity and reverses desertification would strengthen such a dynasty. Therefore, fluctuations in the desertification cycles (and thus, in the ability of each dynasty to support its population) and changes in the political relationships among dynasties in central and southern China resulted in the rise and decline of dynasties. The three stalagmite data sets (Tan *et al.* 2003; Wang *et al.* 2005;

Fig. 3 Spatial correlation analyses for annual precipitation and temperature at the Beijing, Wudu, and Hechi stations (**a**–**f**) with the values from 637 other meteorological stations throughout China (**g**) based on data from 1961 to 2000. The contour intervals represent increments of 0.2. The correlations are between the previous winter's NAMI (1953–2002) and the spring 500 hPa temperature field (1954–2003) data in the Mongolian Plateau and China (Liu and Ding 2007)



Precipitation, Beijing (Shihua)
Mongolia
A
Temperature, Beijing (Shihua)
Mongolia
B
Precipitation, Wudu (Wanxiang)
Mongolia
C
Temperature, Wudu (Wanxiang)
Mongolia
D
Precipitation, Hechi (Dongge)
Mongolia
E
Temperature, Hechi (Dongge)
Mongolia
F
Mongolia
G
Mongolia
H

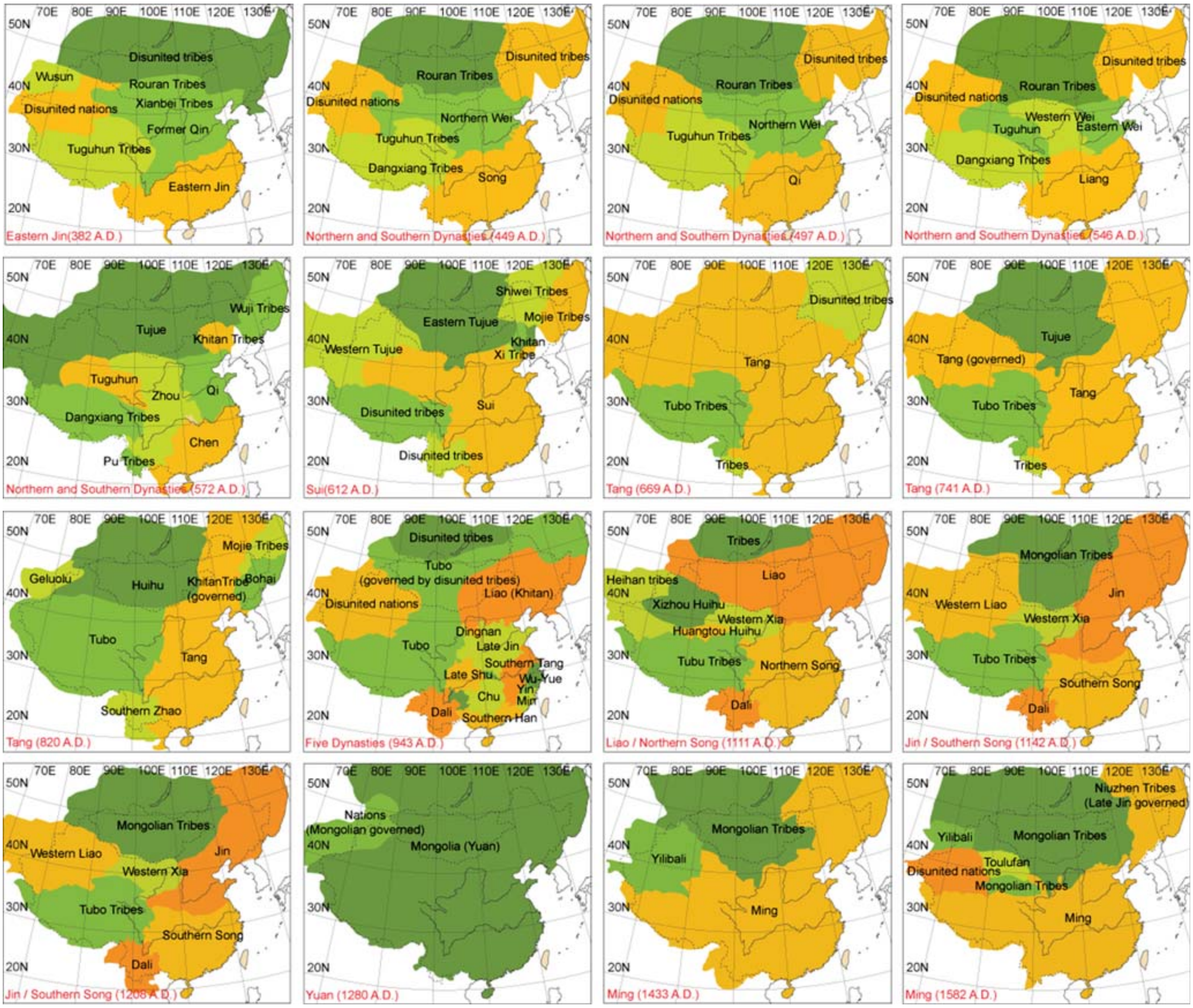


Fig. 4 Regions governed by the dynasties of ancient China during different periods. This figure was compiled mainly based on the data in Tan (1982)

Zhang *et al.* 2008) and tree-ring data (D'Arrigo *et al.* 2001) reveal differences in climate fluctuations in the various regions of China, even though all these regions had broadly similar trends to those revealed by reconstructions of northern hemisphere temperatures (Esper *et al.* 2002; Mann and Jones 2003; Moberg *et al.* 2005) between 300 and 2,000 A.D. (Fig. 5), which have been confirmed by modern records (Fig. 3). Although a previous study (Zhang *et al.* 2008) claimed that the Dongge cave record used to provide the stalagmite data contained dating uncertainties, the reconstructed records nonetheless show significant differences in climate trends among the Mongolian Plateau and northern, central, and southern China. Warm periods in the Mongolian Plateau occurred from the mid-950s to the early 1000s, around the 1150s, from the 1200s to the 1250s, from the 1360s to the 1460s, from the 1470s to the 1570s, around the 1650s and 1760s, and after the 1900s.[1] The Shihua cave records show that in northern China, warm periods occurred from the 350s to the 450s, the 540s to the 630s, around the 700s and 750s, from the 860s to the 1240s, from the 1300s to the 1440s, and after the 1700s. During the warming periods in the Mongolian Plateau and northern China, desertification reversed and the dynasties founded in those regions usually flourished or at least remained stable.

In central China, the Wanxiang cave records show periods with a strong summer Asian monsoon from the 300s to the 340s, the 360s to the 830s, the 950s to the 1030s, the 1080s to the 1320s, and after the 1850s. In southern China, cycles between strong and weak Asian

[1] We did not use the period prior to 900 A.D. due to the low sample size

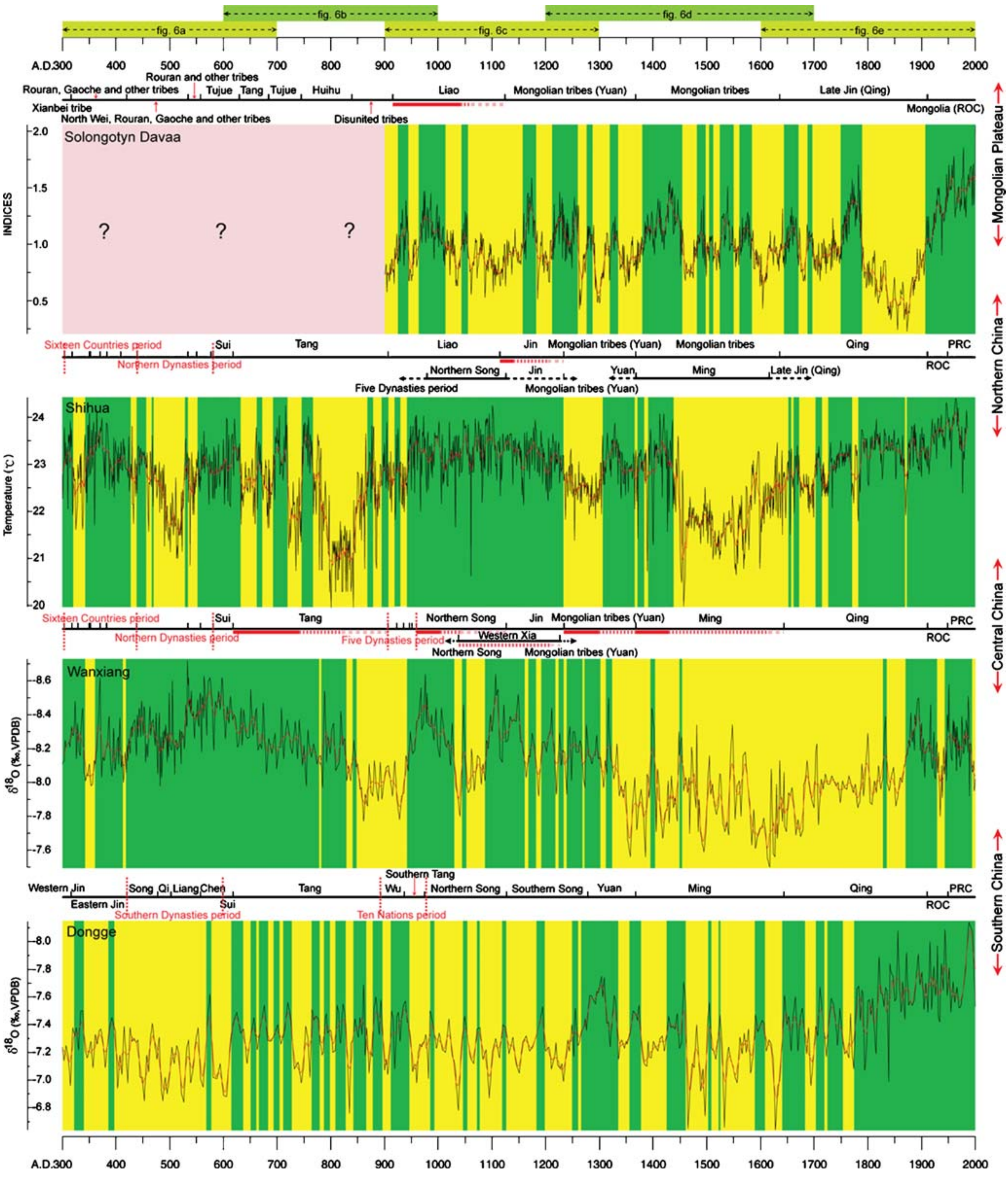


Fig. 5 Cycles of desertification and biological productivity during historical dynastic periods in the Mongolian Plateau and in northern, central, and southern China from 300 to 2000 A.D. The *red lines* show the 10-year smoothing results produced by means of adjacent averaging. Increased desertification and decreased biological productivity are shown in *yellow*, whereas the reversal of desertification and increased biological productivity are shown in *green*. These trends were estimated based on published data (D'Arrigo *et al.* 2001; Tan *et al.* 2003; Wang *et al.*, 2005; Zhang *et al.* 2008). *Red lines* associated with the dynasty names below the graphs indicate periods of flourishing (*solid red*) and decline (*dashed red*) for these dynasties based on historical data (Cai 1965; Fan 1965; Bai 1996; Lu *et al.* 1996; Long 1996; Luo 1996; Yang and Mo 1996)

summer monsoons were frequent, and it is difficult to clearly identify the major periods of strong Asian summer monsoons from the Dongge cave records. Thus, we were only able to identify periods from the 620s to the 740s, the 760s to the 940s, the 1250s to the 1340s, the 1430s to the 1450s, and after the 1640s. However, at least before the 1200s, southern China played a relatively minor role in Chinese dynastic history (Cheng 1987), and it remains true that throughout China from 300 A.D. to the late 1700s, the rise and fall of individual dynasties were consistent periods of warming and cooling respectively in the core regions governed by these dynasties (Fig. 4).

Detailed analysis of the records more clearly shows strong correlations between the nature of the climate and the rise, flourishing, decline, and collapse of dynasties. From 300 to 700 A.D., the major early periods of desertification reversal in northern China were mainly from 300 to 320, 341 to 426, 438 to 453, and 551 to 631 A.D. (Fig. 6a). During the same period in central China, a politically and culturally important region, the period from 300 to 430 A.D. exhibited significant decreases in biological productivity resulting in the Jin Dynasty being limited to southern China and some parts of central China, while the fragile Eastern Jin dynasty in southern China finally collapsed. We cannot assess climate conditions in the Mongolian Plateau for the same period due to lack of data, but historical records indicate that from 300 A.D. until after 530 A.D., the Rouran tribe may have been at the initial stages of founding a dynasty that governed or controlled neighboring tribes (Bai 1996). However, during this period, a significant reversal of desertification in northern China and a decrease in biological productivity in central China resulted in frequent competition among dynasties for control of northern China and a high frequency dynastic changes in central China.

In the period after ca. 418 A.D., desertification in northern China and decreased biological productivity in central China robbed the governing dynasties of both regions of the ability to retain power, leading to the period of the Northern and Southern Dynasties. Around 540 A.D. increased biological productivity in central China and a reversal of desertification in northern China led to the rise of the Northern Zhou and Sui dynasties. At the same time, continuing decreases in biological productivity in southern China allowed the Sui Dynasty to reunite China (although the Tujues, a Turkish people, flourished on the Mongolian Plateau) (Lu *et al.* 1996). However, the rapid collapse of the Sui Dynasty (581 to 618 A.D.) and its subsequent replacement by the Tang Dynasty cannot be explained by climate changes because during this period northern and central China both had favorable environments and stable biological productivity. Only in southern China was biological productivity decreasing, leading to unrest in the region. The best explanation of the cause of the collapse of the Sui Dynasty and the rise of the subsequent Tang Dynasty is that these political changes may have resulted from disputes among aristocratic families.[2]

From 600 to 1000 A.D., the Tang remained one of the strongest dynasties in Chinese history. Cave and tree-ring records from this period support the conclusion that this was a time of reversing desertification and increasing biological productivity (Fig. 6b). During the early Tang period (about 618 to 780 A.D.), this dynasty governed central and northern China, and both regions flourished (Fan 1965). Over time the Tang extensively expanded their domains until they finally ruled an empire that covered all of China and most of central Asia. However, in 755 A.D. they had to suppress extensive unrest in northern China, and desertification occurring after the 790s in northern China followed by decreasing biological productivity after the 820s in central China led to the decline of the Tang Dynasty, and their former domains fell under the control of warlords. Unrest recurred in central China due to extreme droughts after 840 A.D., exacerbating the decline of what remained of the Tang Dynasty. However, by the final decades of the Tang decline, northern China was experiencing a reversal of desertification.

After the collapse of the Tang Dynasty, most of China by the early 900s experienced a relatively long period of disorder, referred to as the Ten Nations period in southern China and the Five Dynasties period in central China. At the same time, the reversal of desertification in northern China led to intense competition for control of this region. The resulting conflicts lasted until around 950 A.D., when increased biological productivity in central China brought an end to the Five Dynasties period with the rise of the Zhou and Northern Song dynasties.[3]

From about 920 A.D., the Mongolian Plateau experienced a significant reversal of desertification, and tree-ring records indicate that this lasted until around 1050 A.D., despite a short resurgence of desertification from around 1020 to 1040 A.D. (Fig. 6c). However, in northern China this reversal of desertification allowed the Khatin Tribe to flourish and take control of the Mongolian Plateau and some parts of northern China, leading to the rise of the Liao Dynasty. The resulting wars between the Northern Song and the Liao for control of northern China ended in a truce in 1040 A.D. (Fan 1965), a time of growing desertification in the Mongolian Plateau and decreasing biological productivity in central China. At the same time, on the northwestern border of the declining Northern Song dynasty, the Western Xia Dynasty rose after 1010 A.D.,

[2] The first emperor of the Tang (Li Yuan) was the cousin of the Sui emperor (Yang Guang).

[3] The replacement of the Zhou Dynasty by the Northern Song Dynasty involved usurpation of the throne rather than warfare.

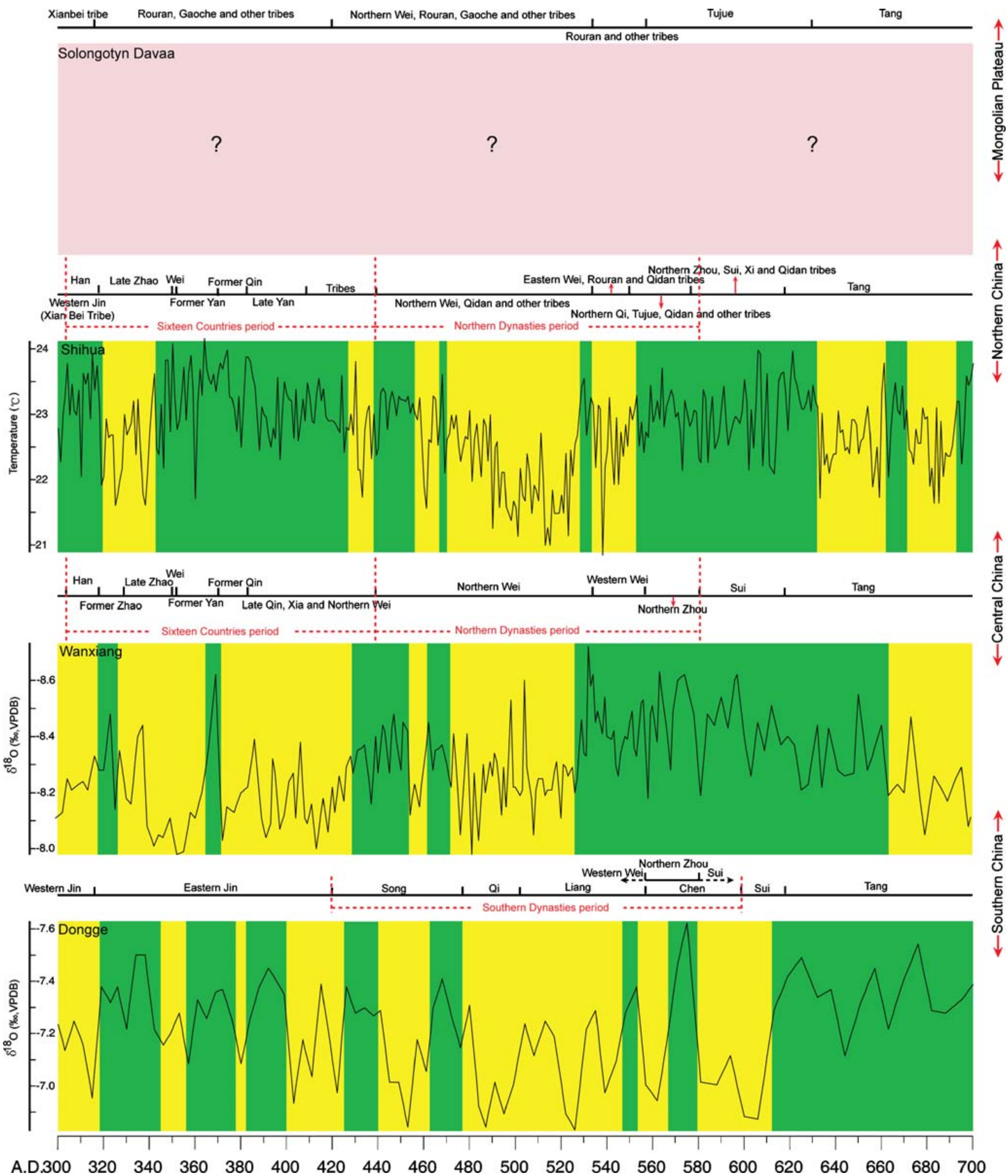


Fig. 6 Desertification and biological productivity cycles in the Mongolian Plateau and in northern, central, and southern China. Increased desertification and decreased biological productivity are shown in *yellow*, whereas the reversal of desertification and increased biological productivity are shown in *green*. *Red lines* associated with the dynasty names below the graphs indicate periods in which the dynasties flourished (*solid red*) or declined (*dashed red*) based on historical data. Figures show the periods **a** from 300 to 700 A.D., **b** from 600 to 1000 A.D., **c** from 900 to 1300 A.D., **d** from 1200 to 1700 A.D., and **e** from 1600 to 2000 A.D.

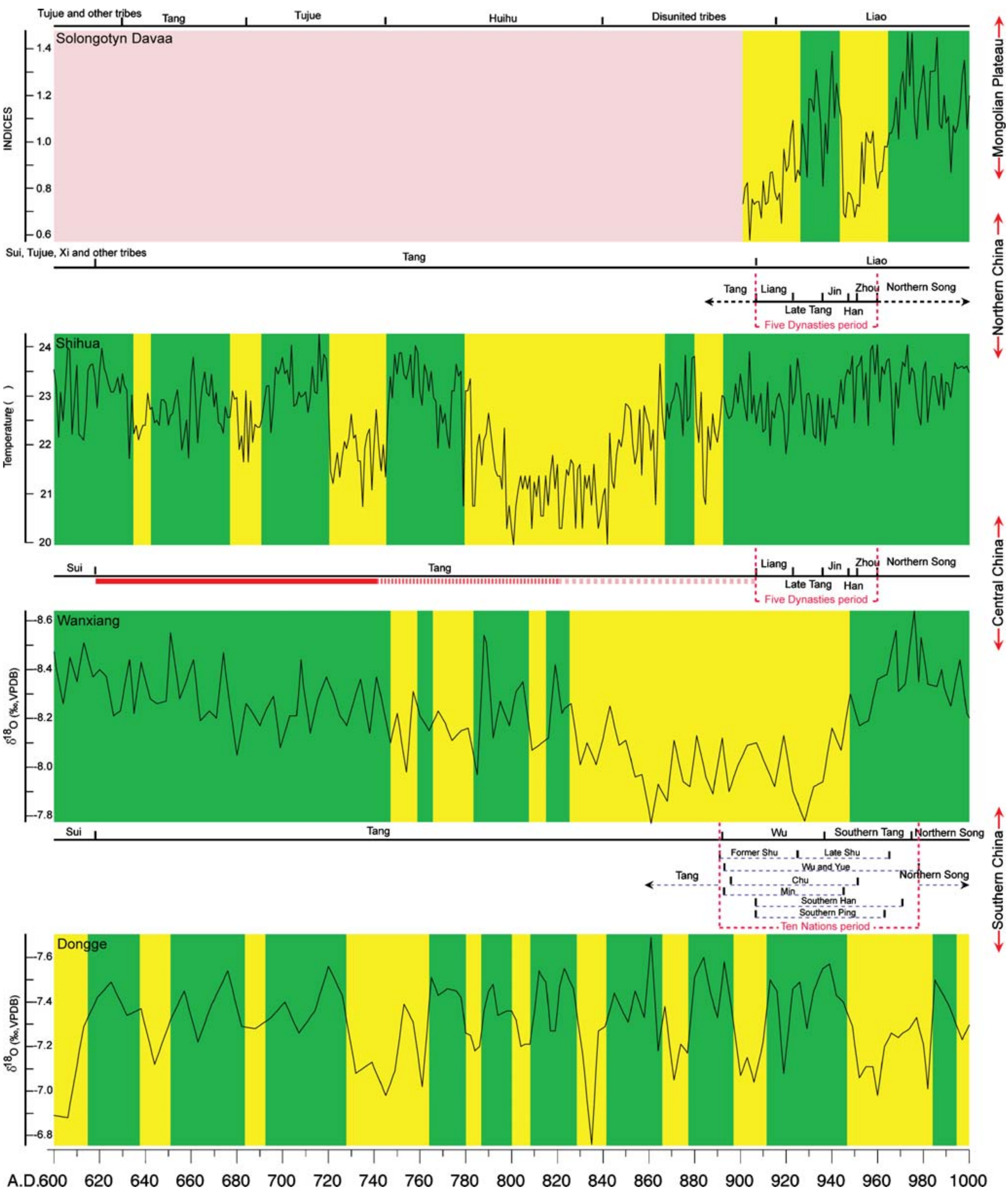
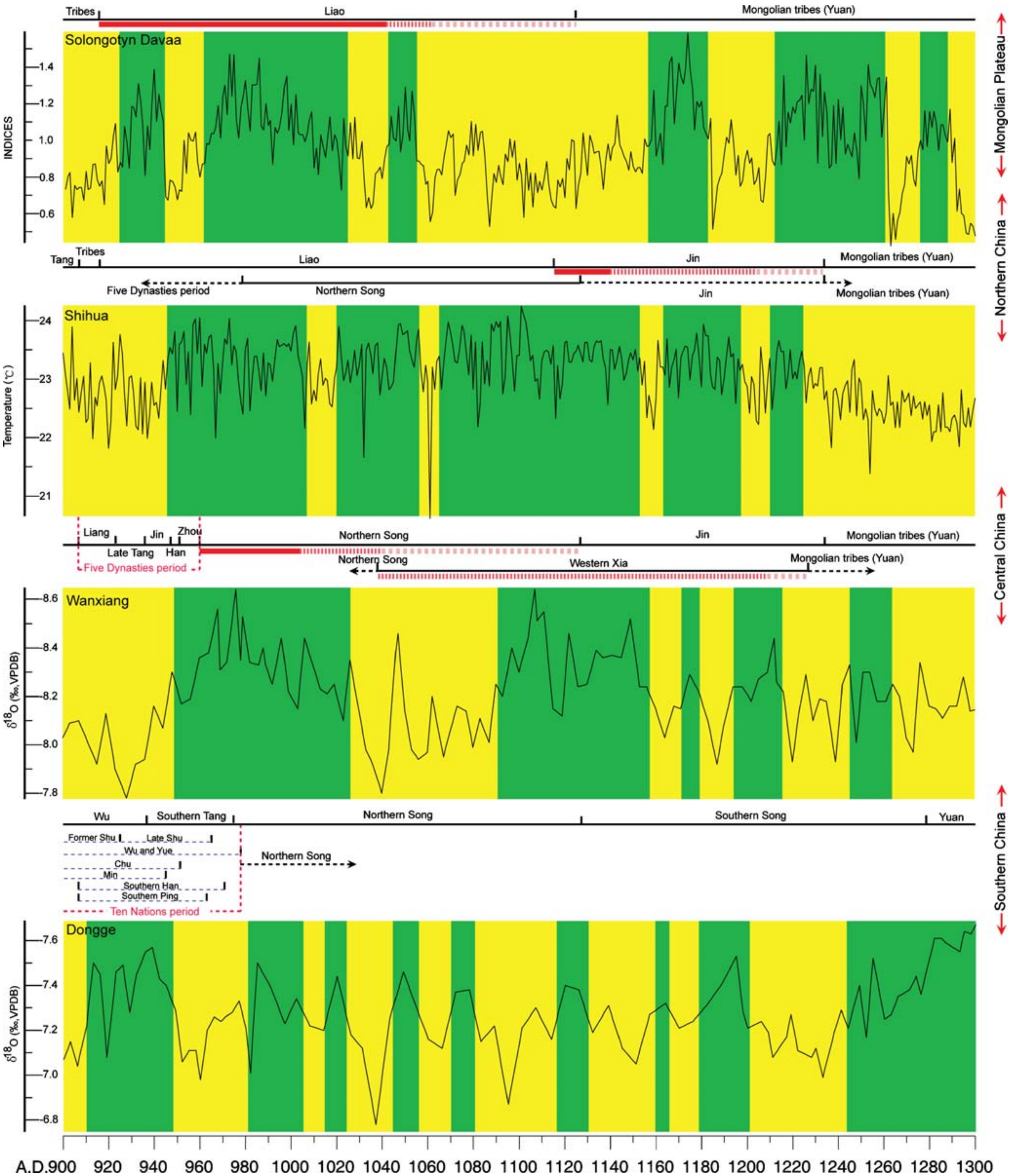


Fig. 6 (continued)

and although unstable through most of this period, they persisted because of the weakness of the Northern Song, the Liao, and the subsequent Jin dynasties until the Mongols invaded China during the early 1200s.

After 1040 A.D., increasing desertification and decreasing biological productivity in the Mongolian Plateau and central China, accompanied by the reversal of desertification in northern China, provided an opportunity for the Jin



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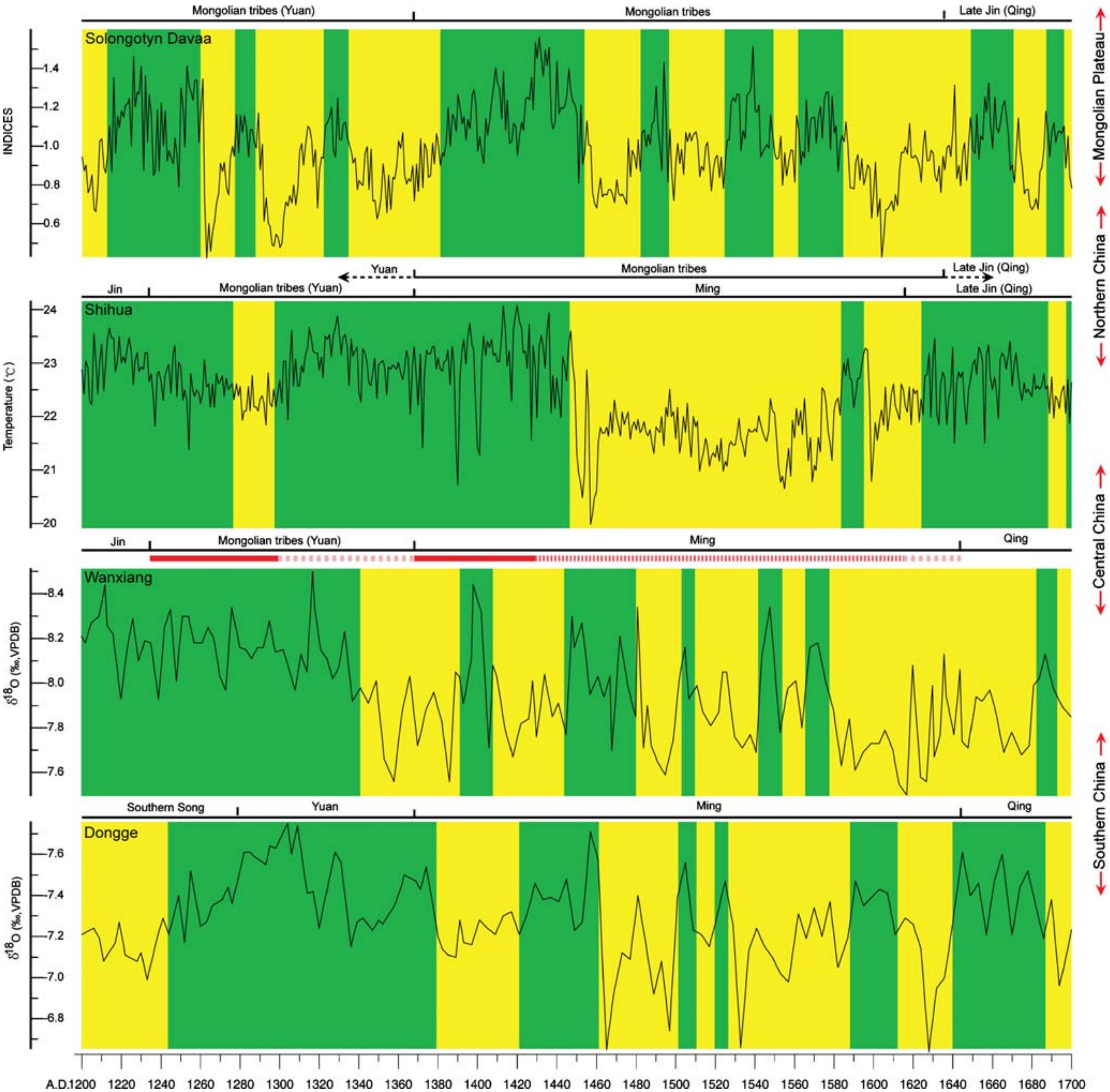
Dynasty to flourish. Within about 20 years after 1110 A.D. (Long 1996), the Jin had conquered the Liao, had occupied the Mongolian Plateau, northern China, and parts of central China, and had forced the Northern Song to retreat into southern China. (The migration of the Song to the south led to southern China playing a major role in China's development after the thirteenth century (Zheng 2003).) However, Jin possession of the Mongolian Plateau did not



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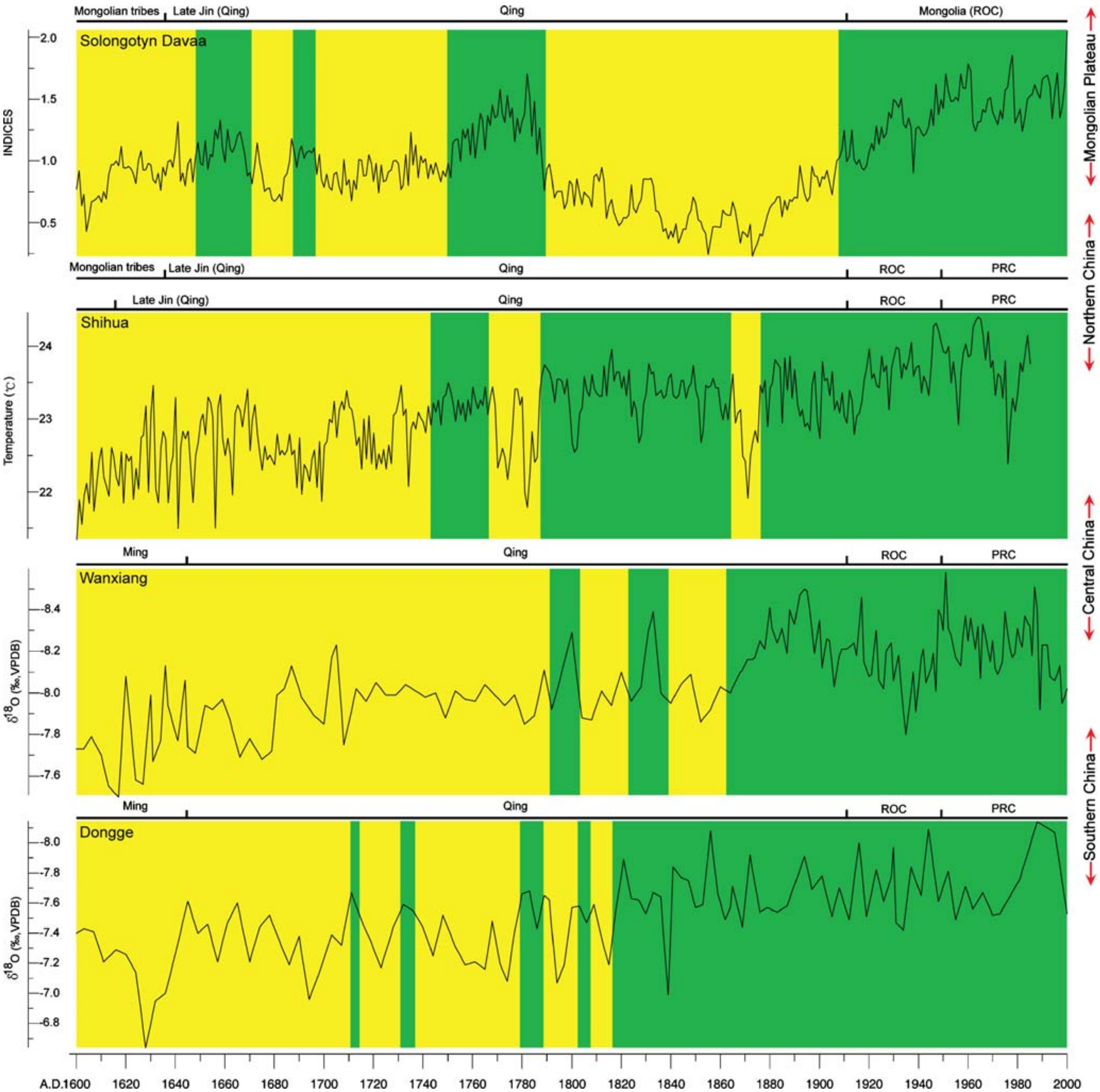
last long; after 1160 A.D., a significant reversal of desertification facilitated the Mongol invasion of the Plateau. In northern and central China, due to the desertification and decreased biological productivity that began after 1220 A.D., the Mongols finally destroyed the Jin in 1234 A.D.

The significant flourishing of biological productivity on the Mongolian Plateau between 1160 A.D. and about 1260 A.D. provided the Mongols with excellent opportunities to conquer China, most of Asia, and even some parts of Europe (Fig. 6c, d). During this period, desertification in the Plateau fluctuated between about 1180 and 1210 A.D., but in northern and central China significant desertification increases and biological productivity decreases after 1220 A.D. made it impossible for the Jin to defend their domains against the Mongolian invaders (Fig. 6c). Mongol possession of northern and most of central China ensured that they had sufficient strength to expand their conquests throughout Asia and finally create an extensive empire, the Yuan Dynasty. However, due to frequent recurrence of desertification in the Mongolian Plateau from the 1250s to the 1370s and decreased biological productivity after the



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1340s in central China, the Mongolian government was unstable, and serious unrest in central China (Fan 1965; Luo 1996) finally forced the Mongols to retreat from southern and central China to the Mongolian Plateau and some regions of northern China.

The Ming Dynasty (1368 to 1644 A.D.) based in central China, faced a high frequency of unrest and low population levels despite an early flourishing period (Cai 1965). Throughout the Ming Dynasty, central China experienced frequent periods of increased desertification and decreased biological productivity (Fig. 6d), which limited the expansion of Ming domains towards the north and its control of western China. Although the Ming occupied central China and (at one time) most of northern China, the reversal of desertification from 1380 to 1450 A.D. ensured that the Mongols continued to dominate the Mongolian Plateau and share northern China territories with the Ming (Yang and Mo 1996). However, frequent desertification after the early 1600s in the Mongolian Plateau, accompanied by the reversal of desertification in northern China in the 1620s and decreasing biological productivity in central and southern China, resulted in the flourishing of the Late Jin (who became known as the Qing) in northern China and their conquest of the Mongols, while the Ming lost their control of northern China. Finally, a high frequency of unrest, natural disasters, and famines in central China ended the Ming Dynasty there (EGCMH 2003), but in northern China it was the Late Jin (Qing), who flourished (Yang 1996) due to a significant reversal of desertification during this period, who finally ended the Ming Dynasty.

The Qing Dynasty flourished during the mid-1700s (Cai 1965) even though northern, central, and southern China were mostly still experiencing desertification and decreased biological productivity (Fig. 6e). However, after 1840 A.D., China was no longer a closed society supported exclusively by agriculture and pastoralism (Cai 1965) and the collapse of the Qing Dynasty in the early 1900s was not primarily due to desertification or decreased biological productivity. Climate conditions are still mainly responsible for modern desertification in northern China and parts of central China. This has potentially huge significance for China, as well as for the world's ecology and food supply (Reynolds *et al.* 2007), because desertification remains one the world's most urgent issues (Wang *et al.* 2008).

Conclusions

During the past several thousand years, northern China and the Mongolian Plateau have experienced multiple desertification cycles, which have been recorded in both Chinese historical documents and palaeoclimate records for this region. Here, we have provided the first strong, wide-scale, and long-term evidence to support the hypothesis that there are close relationships between expanding desertification and the collapse of Chinese dynasties. Our analysis results show that desertification and food production trends in the Mongolian Plateau and in northern, central, and southern China have paralleled the rise, decline, and collapse of China's historical dynasties. During the reversal of desertification, the dynasties founded in Mongolia and northern China flourished, and governed most of ancient China. In contrast, desertification in northern China and the Mongolian Plateau allowed southern dynasties to conquer or share dominion over these areas with the northern dynasties. During desertification, biological productivity also typically decreased, leading to periods of conflict.

Although social, cultural, and economic factors undoubtedly played a role in the fates of Chinese dynasties, the role of the environment may have been neglected. The results of the present study demonstrate that the rise and collapse of China's dynasties were closely related to (respectively) favorable and adverse climate change, and although correlation does not imply causality, we have proposed a plausible hypothesis that can be tested once better historical and biological data become available: that a dynasty cannot survive for long if adverse climate prevents its people from producing sufficient food to maintain a strong economy and a strong army capable of defending the dynasty or even expanding its borders. We believe that this information will contribute to future discussions of the relationships among climate, desertification, and social changes during historical periods.

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