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Reply to comment on "Anti-phase oscillation of Asian monsoons during the Younger Dryas period: Evidence from peat cellulose $\delta^{13}C$ of Hani, Northeast China" by B. Hong, Y.T. Hong, Q.H. Lin, Y. Shibata, M. Uchida, Y.X. Zhu, X.T. Leng, Y. Wang and C.C. Cai [Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 214–222]

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ABSTRACT

The intensity variation of the East Asian Summer Monsoon during the Younger Dryas (YD) cold period remains an important scientific issue requiring clarification. In our article published in Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 214–222, based on the Hani peat cellulose $\delta^{13}C$ sequence from Northeast China, we have documented the abrupt strengthening of the East Asian Summer Monsoon during that period. Our findings support the occurrence of wet conditions in the north and of dry conditions in the south of the Chinese Mainland, and they indicate behavior in anti-phase with the Indian Ocean Summer Monsoon that weakened during the same period. This result agrees with the previously revealed anti-phase variations of the two monsoons during the ice-rafted debris (IRD) cold events occurring in the North Atlantic Ocean. We have also proposed a theory for the anti-phase variations of the monsoons and for the anomalous distribution of precipitation. We have attributed these events to the occurrence of an El Niño-like phenomenon in the Equatorial Pacific Ocean during the YD. G. Schettler has argued that "this palaeo-climatic interpretation cannot be substantiated by chemical data from the nearby Lake Sihailongwan or by biomarker studies of the Hani peat. The inferred inverse correlation between the summer monsoon strength in northeast and southern China during the Younger Dryas appears questionable." However, after carefully examining Schettler's [G. Schettler, Comment on "Anti-phase oscillation of Asian monsoons during the Younger Dryas period: Evidence from peat cellulose $\delta_{13}C$ of Hani, Northeast China" by B. Hong, Y.T. Hong, Q.H. Lin, Y. Shibata, M. Uchida, Y.X. Zhu, X.T. Leng, Y. Wang and C.C. Cai [Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 214–222], Palaeogeography, Palaeoclimatology, Palaeoecology, this issue] water chemistry data from Lake Sihailongwan, we find considerable accumulation ratios of biosilica during the YD period that clearly indicates abrupt strengthening of the East Asian Summer Monsoon. We point out that Schettler referred incorrectly to Zhou's research results. Zhou et al. have clearly indicated that elevated *n*-alkane P_{aq} values and C_{23}/C_{29} ratios serve to record an especially moist local climate in YD. We also confirm that the influence of an increased relative contribution of *Sphagnum* species to Hani peat composition on peat cellulose $\delta^{13}C$ is negligible. Therefore, our conclusions that, during the YD cold period, the EASM abruptly strengthened and that, moreover, an anti-phase occurred between the two Asian monsoons during the YD period, are both, in fact, substantiated not only by biomarker studies of the Hani peat but also by chemical data from the nearby Lake Sihailongwan. We therefore consider Schettler's statement to be untenable.

1. Introduction

Considerable evidence suggests that during the Younger Dryas (YD) cold period, the global atmospheric and oceanic circulation patterns reorganized, and a series of abrupt climatic changes appeared on centennial to millennial time scales. Several studies have documented that the intensity of the Indian Ocean Summer Monsoon (IOSM) underwent an obvious abrupt weakening during that period. However, against this background of global changes, available knowledge of the East Asian Summer Monsoon (EASM) during the YD is still quite vague (Hong et al., 2010). This lack of information represents a weak link in global climatic change research on the YD interval. To better understand EASM activity during the YD, we published a high-resolution and sensitive proxy record of EASM monsoonal precipitation using Hani peat cellulose $\delta^{13}C$ from Northeast China in Palaeogeography, Palaeoclimatology, Palaeoecology 297 (2010) 214–222. By comparing this proxy record with the pollen

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record from the sediments of Lake Sihailongwan near the Hani peat mire (Stebich et al., 2009), we have revealed the abrupt strengthening of the EASM. Our results support the occurrence of wet conditions in the north and of dry conditions in the south of the Chinese mainland during that period. These results further indicate that an anti-phase between the two Asian monsoons occurred during the YD period. This result agrees with the previously revealed anti-phase variations of the two monsoons during the ice-rafted debris (IRD) cold events of the North Atlantic Ocean (Hong et al., 2003, 2005). We have also proposed a theory for the anti-phase variations of the monsoons and the anomalous precipitation distribution. We attribute these events to the occurrence of an El Niño-like phenomenon in the Equatorial Pacific Ocean during the YD period (Hong et al., 2010). G. Schettler (2011-this issue) has argued that "This palaeo-climatic interpretation cannot be substantiated by chemical data from the nearby Lake Sihailongwan or by biomarker studies of the Hani peat. The inferred inverse correlation between the summer monsoon strength in northeast and southern China during the Younger Dryas appears questionable". To date, only Schettler and his colleagues have performed detailed investigations of the water chemistry of Lake Sihailongwan (SHL). Neither Schettler nor Hong have conducted biomarker studies of the Hani peat. We therefore conducted a careful review of the Lake SHL water chemistry data and of the relevant results of studies of the Hani peat biomarkers. We welcome this research opportunity.

2. Discussion

2.1. The EASM intensity during the YD period inferred from the biomarkers of the Hani peat

Schettler cites two papers on biomarker studies of the Hani peat (Yamamoto et al., 2010; Zhou et al., 2010). He concludes that our finding that the Hani-SHL region had more monsoonal precipitation during the YD period cannot be substantiated by these biomarker studies of the Hani peat. However, we believe that Schettler's conclusion is incorrect because, in fact, the opposite is the case. After considering Yamamoto's research result (W. Zhou is also a co-author of Yamamoto's article), W. Zhou et al. further determined the molecular compositions of *n*-alkanes, *n*-alkanols, and *n*-alkanoic acids from the Hani peat. In their paper, published in Earth and Planetary Science Letters, Zhou et al. clearly indicate that elevated *n*-alkane P_{aq} values $[P_{aq} = (C_{23} + C_{25})/(C_{23} + C_{25} + C_{29} + C_{31})]$ and C_{23}/C_{29} ratios, both of which are molecular proxies for water-loving plants, record "an especially moist local climate" during the YD (12.9 to 11.5 cal. Ka BP) (Zhou et al., 2010). Obviously, the climate condition during the YD recorded by the biomarker lipid composition is the same as that recorded in the cellulose $\delta^{13}C$ of the Hani peat. It should be emphasized that these two kinds of different proxy climate indicators independently show the same results because Hong's manuscript was submitted to Palaeogeography, Palaeoclimatology, Palaeoecology on 4 March 2010, and Zhou's article was available online on 3 April 2010. In addition, we will cite an additional research result from biomarker studies of the Hani peat, namely the determination of hydrogen isotopic ratios of plant wax *n*-alkanes in the Hani peat (Seki et al., 2009). Although Seki et al. did not specifically discuss the climatic conditions during the YD period, their data clearly show that the effective precipitation of the local summer monsoon, inferred from $\Delta\delta D$, was maximized during the YD (Fig. 1b). We can therefore confirm that Schettler's conclusion that Hong's research results cannot be substantiated by these biomarker studies of the Hani peat is untenable.

2.2. The EASM intensity during the YD period inferred from the water chemistry data from Lake SHL

Based on net accumulation rates for biogenic silica (F-bSiO_2) and additional proxies, Schettler et al. (subsequently referred to simply as Schettler) have reconstructed the palaeohydrological variation of Lake SHL for the period 15,000–2000 cal. yr BP (Schettler et al., 2006). Schettler indicates that "in Lake SHL, F-bSiO_2 is positively correlated with the inflow of nutrient-rich groundwater. Since groundwater inflow is mainly fed by seepage of summer monsoon rainfall, F-bSiO_2 documents changes in summer monsoon strength." To examine the F-bSiO_2 proxy indicator, Schettler has compared the F-bSiO_2 sequence of Lake SHL with the Hani peat cellulose $\delta^{13}C$ (Hong et al., 2005) and with four other lake sediment records from northern China (Fig. 9 of Schettler et al., 2006). In the section of the paper that compares the F-bSiO_2 data with the Hani peat cellulose $\delta^{13}C$ records, Schettler suggests that both datasets show the same trend of variation in EASM strength at several time intervals. For example, he refers to an "early Holocene maximum in summer monsoon circulation shortly after 10,000 cal. yr BP," "a weakening of the EASM strength in a sedimentation interval between 9500 and 8000 ca. yr BP," "the abrupt shift to a wetter climate around 8000 cal. yr BP and a gradual weakening of the EASM until 6200 cal. Yr BP," and "re-strengthening of the EASM around 4200 cal. Yr BP (Fig. 9f), which finds strong response in the proxy data from the Hani peat." Indeed, these two records of F-bSiO_2 in Lake SHL and the Hani peat cellulose $\delta^{13}C$ show the same or similar responses to several climatic events occurring during the past ca. 12,000 years. It can be seen from our Fig. 2 that corresponding to 7 IRD North Atlantic Ocean cold events, these two proxy indicators both appear to record a strengthening trend in the EASM precipitation. For this reason, we have stated (Hong et al., 2010) that "some research results have revealed that, corresponding to the IRD events in the Holocene, including an IRD-8 event, the intensity of the EASM strengthened (Hong et al., 2005; Schettler et al., 2006)," although Schettler actually did "not report a correlation between the IRD events in the North Atlantic and a strengthening of the East-Asian Monsoon."

The problem of the climatic conditions during the YD period must now be addressed. Fig. 9 of the Schettler article does not include any F-bSiO_2 data for the YD. These data occur in the 15,000-year record of F-bSiO_2 in Lake SHL (Fig. 3b, Schettler et al., 2006), cited here as our Fig. 3. It can be seen from our Fig. 3 that, although the previous curve of biogenic silica in Lake SHL for the Holocene epoch is straightened by the change of scale, the accumulation rates of F-bSiO_2 during the YD still clearly show increasing deviations. Schettler also recognized this phenomenon. He states, "The balanced bSiO_2 flux of SHL sediments shows distinct positive deviations on a multi-decadal scale that may partially correspond to short-term negative deviations of $\delta^{13}C$ in the Hani peat profile". Unfortunately, he chooses to bypass this phenomenon and to say that "I abstain from quantifying possible changes in groundwater inflow on the basis of bSiO_2 flux rates for the YD interval". Nevertheless, based on Fig. 3, we can estimate that the groundwater inflow in the Lake SHL region should have increased rapidly during the YD. Schettler states, "In general, YD sediments document substantial flux rates of biogenic silica. Under the presumption that diatom growth in Lake SHL is controlled by groundwater inflow also during the YD, the local climate was never as dry as the climate of Central Europe during this period". This statement is obviously very vague. It is more accurate to say that, in general, YD sediments document considerable flux rates of biogenic silica. Assuming that diatom growth in Lake SHL was controlled by groundwater inflow during the YD, the local climate during YD may have been wetter than it was during most intervals of the Holocene.

2.3. Influence of possible changes in peat composition on peat cellulose $\delta^{13}C$ during the YD

Schettler criticized us for disregarding any possible changes in peat composition, particularly the contribution of *Sphagnum* species to peat composition. In fact, we had discussed this subject in our previous articles (Hong et al., 2000, 2003, 2009, 2010). The dominant plant population in the Hani peatland is the vascular sedge family of C_3 plants, including *Carex*, *Eriophorum vaginatum*, and *Kobresia*. The

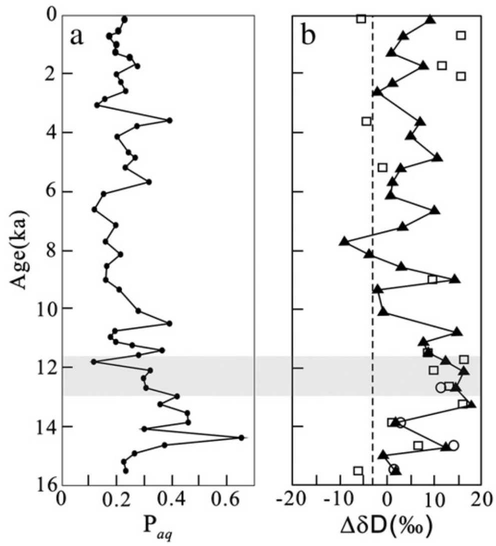

Fig. 1. Comparison of the P_{aq} water level proxy index (a) with δD between C_{31} and C_{23} *n*-alkanes (open circles), δD between C_{31} and C_{25} *n*-alkanes (open squares), and δD between C_{31} and C_{27} *n*-alkanes (solid triangles) (b) in the Hani peat core (Seki et al., 2009). The gray band traces a wetter Younger Dryas interval.

peat deposits of some thick layers on the Chinese mainland always develop in relatively stable sedimentary environments. This is the case for the Ruoergai peat at the eastern edge of the Tibetan Plateau, for the Jinchuan peat in Jilin province (formed in a crater lake), or the Hani peat in Jilin province (formed in a dammed lake). The peat profile thus reflects a relatively stable floristic composition. The importance of the relative stability of the floristic composition was particularly highlighted by the study of the Jinchuan peat. This study revealed that more than 80% of the plant residue on the profile was composed of vascular sedges (C_3 plants), whereas the *Sphagnum* residue represented an extremely small proportion of the profile (Hong et al., 2000, 2010).

Two issues need further clarification here. First, elevated *n*-alkane P_{aq} values and C_{23}/C_{29} ratios in the Hani peat during the YD period indicate an increased contribution of water-loving plants—for instance, *Sphagnum* spp.—to peat composition. As Seki has stated, "Because vegetation in a bog environment significantly depends on water level P_{aq} can also be used to assess changes in water level in the past (Seki et al., 2009)." Therefore, from the perspective of vegetation change, an increase in the relative contribution of *Sphagnum* spp. to peat composition during the YD indicates a moist local climate (Seki et al., 2009; Zhou et al., 2010). This finding agrees with the conclusion inferred from the peat cellulose $\delta^{13}C$. The second issue is the influence on peat cellulose $\delta^{13}C$ of an increase in the relative contribution of *Sphagnum* spp. to peat composition. This influence depends on the value of $\delta^{13}C$ of *Sphagnum* and on the changes in this value that take place under the conditions of a wet climate. The isotopic composition of 18 modern plants in the Hani peatland has been measured (Table 1 of Hong et al., 2005). The mean $\delta^{13}C$ value of 3 species of *Sphagnum* (*Sphagnum palustre*, *Sphagnum agellamicum*, and *Sphagnum acutifolium)* is −25.35‰. The mean $\delta^{13}C$ values of 3 species of sedge plants (*Carex schmidtii*, *Carex tenuiflora*, and *Eriophorum vaginatum*) and of all 18 plants taken together are −24.70‰ and −25.28‰, respectively. These three mean $\delta^{13}C$ values are very close. In addition, based both on the results of previous research on the relationship between *Sphagnum* $\delta^{13}C$ and environmental moisture and on practical investigations, J. Loisel et al. have suggested that ^{13}C-depleted values of *Sphagnum* are related to low water table depths or to a drier local climate, whereas ^{13}C-enriched values of *Sphagnum* correspond to a water table that is close to the peat surface or to a wetter local climate (J. Loisel et al., 2009). This finding shows that the relationship between the $\delta^{13}C$ and climate variation for Sphagnum spp. differs from that for vascular plants. The mechanism responsible for this difference has been explained in terms of the different leaf structures of these two species plants. This result seems to imply that an increase in the relative contribution of *Sphagnum* spp. to the Hani peat composition during the wetter YD period would produce an increase (a more positive value) in the $\delta^{13}C$ value of Hani peat cellulose. However, this more positive $\delta^{13}C$ shift resulting from the contribution of *Sphagnum* species was overwhelmed by the more negative $\delta^{13}C$ shifts from other dominant vascular plants in the Hani peat during the wetter climate occurring during the YD, so that the $\delta^{13}C$ values of Hani peat cellulose clearly exhibit an overall negative shift during the YD interval (Hong et al., 2010). Therefore, even if an increase in the relative contribution of *Sphagnum* spp. to peat composition occurred during the YD period, the peat

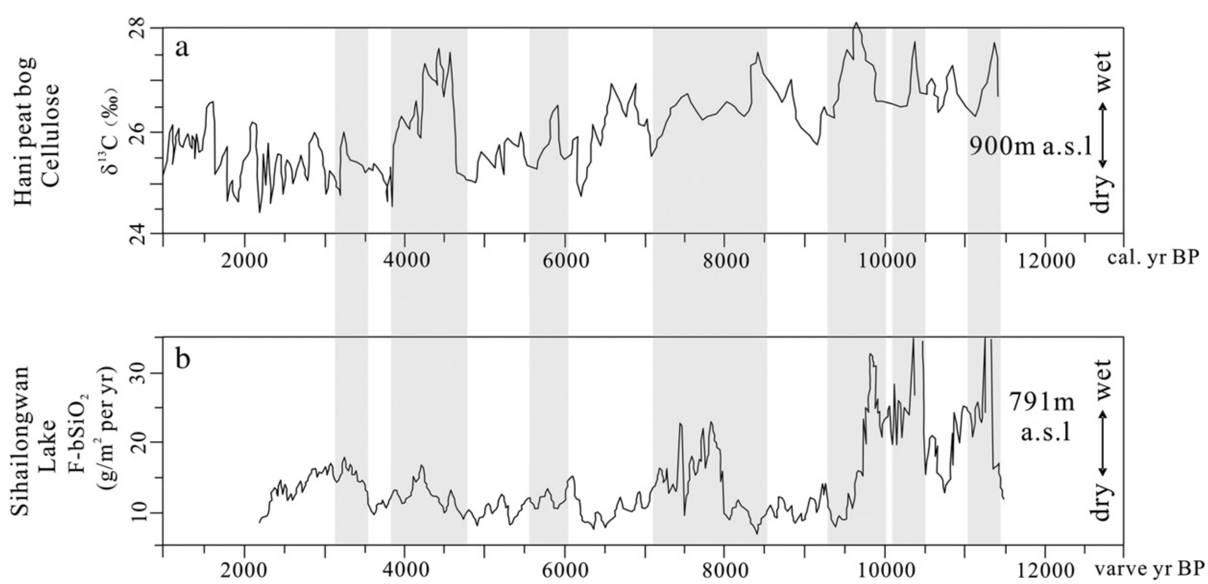

Fig. 2. Comparison between East Asian Summer Monsoon (EASM) variations inferred, respectively, from the Hani peat cellulose $\delta^{13}C$ (a) (Hong et al., 2005) and the accumulation ratio of biogenic silica in Lake Sihailongwan (b) (Schettler et al., 2006). The seven gray bands from left to right trace the variations in EASM intensity corresponding to ice-rafted debris events No. 2 through No. 8, respectively, in the North Atlantic Ocean.

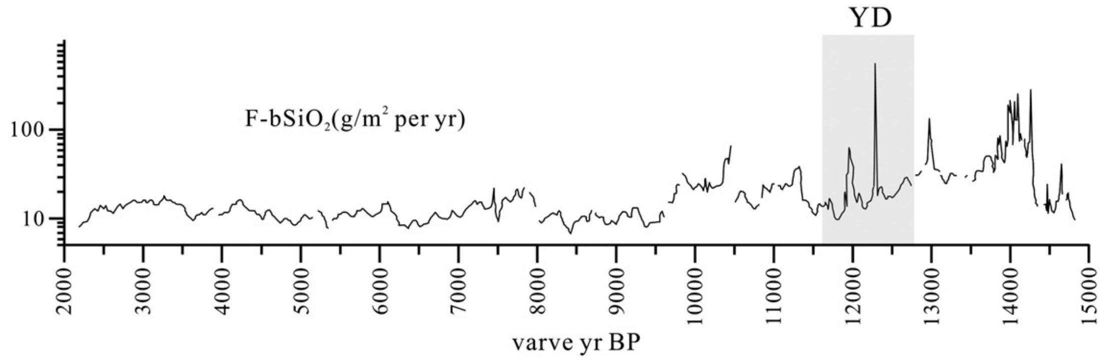

Fig. 3. The accumulation ratios of biogenic silica (F-bSiO_2) in Lake Sihailongwan during the last 15,000 years (Schettler et al., 2006). The gray band traces the considerable accumulation rates of biogenic silica during the Younger Dryas period.

cellulose $\delta^{13}C$ sequence still indicates the presence of a wet climate in that interval. These findings agree well with the results inferred from other proxy climate indicators, including the biomarkers of the Hani peat and the pollen and water chemistry data from Lake SHL.

2.4. Climatic conditions during the period approximately 14,000 to 13,000 cal. yr BP

As stated in the Introduction, the focus of our concern is the Asian monsoon activity during the YD cold period. Although we also discussed additional time intervals, for example the period from approximately 14,000 to 13,000 cal. yr BP, it is not the focus of our current research. We have noted that our primary results on the climatic conditions during this period differ from those expressing other points of view. We will carefully consider these differences in our next study.

3. Conclusion

After carefully examining Schettler's water chemistry data for Lake SHL, we have found considerable accumulation ratios of biogenic silica during the YD period. This finding clearly indicates an abrupt strengthening of EASM during that interval. We also point out that Schettler did not correctly refer to Zhou's research results. Zhou et al. have clearly indicated that that elevated *n*-alkane P_{aq} values and C_{23}/C_{29} ratios document an especially moist local climate during the YD. We also confirm that the influence on peat cellulose $\delta^{13}C$ of an increase in the relative contribution of *Sphagnum* spp. to the Hani peat composition is negligible. Therefore, our conclusions that the EASM abruptly strengthened during the YD cold period and that an anti-phase relationship occurred between the two Asian monsoons during the YD period are substantiated not only by biomarker studies of the Hani peat but also by chemical data from the nearby Lake SHL. We consider Schettler's statement to be untenable.

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