

***Interactive comment on* “Climate-driven desertification triggered the end of the Ancient Silk Road” by Guanghui Dong et al.**

Guanghui Dong et al.

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Reviewer #3: The general argument of the paper is that cold and dry climate prevailing during the Ming dynasty in the region of Dunhuang around 1450 CE was the chief cause for the closure of the Silk Road (meaning by it the system of communication between the Chinese capital and Central Asia) – Evidence for this hypothesis is presented in the form of climate proxies from the site of Xishawo (XSW), consisting of paleosols and sediments, dated on the basis of ^{14}C analysis of charcoal and wood samples from the same section of the site. The laboratory analysis showed an increase in desertification, attributed to especially dry and cold climate, between 1450 and 1530. – The authors also consulted historical sources and compared their results with written records. The main thesis of the study is that the closure of the trade route

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and abandonment of Dunhuang in the early 16th century was due to climatic change rather than two other causes considered here, namely, the “alternative” maritime route and warfare. In their analysis the authors argue against these two possibilities, and exclude them in favor of a climate change as the single cause for the closure of the Silk Road. In their view after 1450 transit through Dunhuang would have been impossible because of drought conditions.

General comments

1. The archaeological context of the site from where the samples were collected is not discussed. This is a critical issue since other studies have attributed the decline of the oases to Ming government policies that reduced the inhabitants. Response: Thanks for the reviewer’s constructive suggestion. The Xishanwo site is an ancient city, recently detected by Integrated RS, GIS and GPS approaches (Luo et al., 2014). While few relics have been found at the site, several cultural layers have yielded plant remains such as crop seeds and charcoal (Li et al., 2017). According to the radiocarbon dates reported in Li et al. (2017), the ancient city of Xishawo was established and developed during the Five Dynasties and Ten Kingdoms (897-979 AD), the Song Dynasty (960-1127 AD), and the Yuan Dynasty (1271-1361 AD). We cannot provide more detailed information about Xishawo because it is not currently available. Your suggestion is helpful and we have added an introduction to the site in Lines 144-149 and we have also cited the reference (Li et al., 2017). We propose that desertification related to climatic deterioration was the factor triggering the abandonment of the ancient oasis and the subsequent major migrations eastward. We do not deny that Ming government policies contributed to the reduction of the number of inhabitants in Dunhuang during ~1450-1539 AD. However, this policy was carried out during the period of desertification, with the coldest and driest climate conditions, which corresponds to the decrease in trade and frequent wars. References: Luo L, Wang X Y, Liu C S, Guo H D, Du X C. 2014. Integrated RS, GIS and GPS approaches to archaeological prospecting in the Hexi Corridor, NW China: a case study of the royal road to ancient Dunhuang.

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Journal of Archaeological Science, 50: 178-190 Li, H.M., Liu, F.W., Cui, Y.F., Ren, L.L., Storozum, M.J., Qin, Z., Wang, J., Dong, G.H., 2017. Human settlement and its influencing factors during the historical period in an oasis-desert transition zone of Dunhuang, Hexi Corridor, northwest China. *Quaternary International*, 113-122.

2. A reduction in population density is attributed uniquely to environmental factors, without considering other possibilities for the same phenomenon. Response: As mentioned above, we regard environmental factors as the trigger or the root cause rather than the only determinant of the population decline in Dunhuang during the early Ming Dynasty. We suggest that environmental factors had a “domino effect” on the social system, via the shrinkage of the habitat and farmland necessary for human survival, resulting in the four waves of human migration into the eastern part of the Hexi Corridor, and the shift of frontier from Dunhuang to Jiayuguan (Feng et al. 2019). We appreciate your comments and we have tried to clarify the discussion accordingly (Lines 442-451). References: Feng, Q., Yang, L., Deo, R. C., AghaKouchak, A., Adamowski, J. F., Stone, R., Yin, Z. L., Liu, W., Si, J. H., Wen, X. H., Zhu, M., Cao, S. X.: Domino effect of climate change over two millennia in ancient China’s Hexi Corridor, *Nat. Sustain.*, 2, 957-961, 2019.

3. Social-political analysis is uniquely based on frequency of “agri-nomadic” conflict. The category of conflict is too vague to be accepted as a proxy for political processes, and statistical means are not normally accepted in historical analysis for inferring government policies. In other words, a historical analysis should focus on specific actions by the Ming government to protect Dunhuang, increase its productivity, regulate trade and manage its population. Therefore, specific references to such policies are needed. Response: Thanks for the reviewer’s constructive suggestion. First, the frequency of warfare in the Dunhuang area in the Ming dynasty is discussed because of the previous hypotheses that frequent wars directly led to the abandonment of Dunhuang. “Agri-nomadic” conflict was distinguished from other types of conflict because it directly reflects the conflict between the central government and the nomadic peoples

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(Zhang et al., 2020). Furthermore, in this border area, it was a unique form of warfare which could have toppled the Ming regime. Second, it is not easy to quantify the social-political-economic environment because of the numerous factors involved (Chen, 2010; Fang et al., 2015). Warfare frequency was, to some extent a quantized index for social-political analysis. In addition to the complex range of factors that influenced the social-political-economic environment of the Dunhuang area under Ming rule, warfare was the final manifestation (Zhang et al., 2007; Fang et al., 2015). For example, economic turbulence, policy change, population pressure, and famine and disease were costly but gradual processes. In general, wars would not occur when the social environment was harmonious, but when a factor changed which sufficiently worsened social-political-economic conditions, then the probability of conflict would increase sharply. Finally, human social development was not sufficient to buffer the tensions caused by shrinking resources when wars became common consequences (Gleditsch, 1997; Zhang et al., 2007). Although conducting “a historical analysis about the Ming government to protect Dunhuang, increase its productivity, regulate trade and manage its population” is not our main purpose in discussing the frequency of wars, we agree that it is important to analyze the political environment in depth. Therefore, we have added several historical references to strengthen the discussion (Research Institute of History and Language of the Central Academy in Taiwan, 1962, Zhang, 1974). Please see Lines 72-73. References: Chen, G. W.: Research on the abandonment of the Dunhuang during Ming Dynasty. *J. Dunhuang Stud.*, 60, 111-118, 2011 (In Chinese). Fang, X.Q., Su, Y., Yin, J., Teng, J.C. Transmission of climate change impacts from temperature change to grain harvests, famines and peasant uprisings in the historical China. *Science China: Earth Sciences*, 2015, 58(8): 1427-1439 (In Chinese with English abstract). Gleditsch, P.N. Conflict and the environment. *Nato Asi*, 1997. Research Institute of History and Language of the Central Academy in Taiwan: *Ming Yingzong Shilu*. Taiwan, 1962. Zhang, S.D., Zhang, D.D., Li, J.B., Pei, Q. Secular temperature variations and the spatial disparities of war in historical china. *Climatic Change* (2020) 159:545-564. Zhang, T.Y.: *History of Ming dynasty*. China Publishing

House, Beijing, 1974 (in Chinese).

4. The authors assume that maritime trade could be in competition with the continental “Silk Road” trade, but in fact such trades were different and not in mutual competition. Therefore, debunking the notion that maritime trade might have led to the decline of the Silk Road in the 15th and early 16th century seems a “strawman” argument. Response: The principal aim of the study is to explore the causes of the end of the traditional Silk Road, for which there are three major explanator hypotheses. One is that the rise of Maritime Silk Road led to the end of the land route Silk Road (the traditional Silk Road) (Xie et al., 2007; Qian and Jin, 2010; Zhai, 2017). This view has been accepted by many scholars and the general public and thus it is necessary for us to examine its viability, which is why we demonstrate in detail that it is not fully supported by historical documents. This is especially the case for the timeline for the final closure of the Jiayuguan Pass and the end of the ban on maritime trade, which are landmark events for the end of the traditional Silk Road and the emergence of extensive maritime trade. We think this is a logical chain. Although arguably more evidence could be provided to demonstrate this in detail, it is not the primary research topic of the paper. References: Qian, Y., and Jin, H. L.: Study on Oasis along the Silk Road, Xinjiang people’s publishing house, 2010 (in Chinese). Xie, Y., Ward, R., Fang, C., and Qiao, B.: The urban system in West China: A case study along the midsection of the ancient Silk Road - He-Xi Corridor. *Cities*, 24, 60-73, 2007. Zhai, S.D.: The changes of the beacon flint and the land Silk Road in Dunhuang. *Gansu Social Sci.*, 05, 135-140, 2017 (In Chinese).

5. Other studies have contended that desertification was caused by a decline in population. The authors acknowledge the fragility of the oasis environment, but in fact the economy of the oasis is fragile even in relatively favorable conditions, given that maintenance of irrigation system is labor-intensive and requires substantial investments and constant attention. Therefore, a decrease in population could lead to lack of maintenance and accelerate desertification. This is a possibility that the authors do not

contemplate, and requires a more accurate investigation of both the historical and archaeological contexts. Response: This is a very helpful comment. We admit that both climate change and human activities (especially the abandonment of farmland) could induce or aggravate the process of desertification, especially in Dunhuang oasis. However, we argue that the onset of desertification in Dunhuang at ~1450 AD was induced by climatic deterioration because it was nearly synchronous with cold and dry events that are recorded in high-resolution paleoclimate archives. Moreover, we have not found any historical documentary evidence indicating that human activities caused the desertification during this period. However, the superimposed effects of climatic deterioration and human abandonment of farmland in the ancient oasis contributed to the continuation of a desert landscape in the study area until today, even though the climate became wetter after ~1540 AD (Fig. 2). The desertification between ~800 and 600 BCE only lasted for two centuries, without a major impact on human activities. Thank you very much for your constructive comments. We have revised the discussion in Lines 452-462. Farming activity in the Dunhuang area is also recorded in the archives (Research Institute of History and Language of the Central Academy in Taiwan, 1962, Zhang, 1974). References: Research Institute of History and Language of the Central Academy in Taiwan: Ming Yingzong Shilu. Taiwan, 1962. Zhang, T.Y.: History of Ming dynasty. China Publishing House, Beijing, 1974 (in Chinese).

6. The authors present as evidence of desertification the cessation of embassies and tribute missions from the kingdoms and principalities in the Western Regions (today's Xinjiang) as evidence of the collapse of the Jiayuguan transit route. While there was a decline around 1450, by no means there was a total collapse of trade missions. If we take the periods 1436-64, 1465-1509 and 1510-1539, the embassies from Turfan were respectively 5, 40, and 14, those from Hami 84, 56 and 14, and from Samarkand (further west) 14, 15, and 14. Even after this time a few embassies continued to be sent from Hami and Samarkand. Unless the authors can show that there was an alternate route, the assumption that Hexi corridor was completely impassable after 1450 is not supported by the evidence. Response: Thanks for the reviewer's comment. We agree

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with the reviewer's opinion that the Hexi Corridor was not completely impassable after ~1450 AD. The reasons for this may be first that both the desertification and oasis degradation were slow processes; and second, the Jiayuguan Pass was the primary routeway connecting the western region to the domestic territory. However, the closure of the Jiayuguan Pass in 1539 AD marked the abandonment of territory beyond the pass (including the Dunhuang area) as well as the strengthening of the restriction on the tribute trade. The twice closure of the Jiayuguan Pass contributed to a much stricter management system for the tribute trade and it also caused a pronounced reduction in trade frequency (Yang et al., 1997; Yang et al., 2014). On the other hand, trades still continued between the Ming government and several Western countries (Research Institute of History and Language of the Central Academy, 1962; Sheng, 1989; Tian, 1999). Based on our investigation of the published historical archives, the number of trades was sharply reduced after 1450 AD. References: Research Institute of History and Language of the Central Academy. Ming Shilu, Ming Xiaozong Shilu, Taiwan, 1962. Sheng, S. X., Ming Hui Dian, China Publishing House, Beijing, 1989. Tian, S. Tributary trade between Gansu town and in western regions in Ming Dynasty. China's borderland history and geographic studies, 1999 (01):15-24. Yang, F. X. The Overland Silk Road and its Trade in Ming Dynasty. China's borderland history and geographic studies, 1997(02):12-20. Yang, L. K., West wind miles of river road: Study on emissaries and business Trips on the Silk Road in the Western Regions of Ming Dynasty, Lanzhou University Press, Lanzhou. 2014.

7. The paper does not explain clearly why Dunhuang would be abandoned only seventy years after the drought event, and how the government reacted to it. In the meantime. Response: According to previous studies, human social resilience to climate change was relatively low during both the prehistoric and historical periods, and drought that persisted for many decades would have resulted in the decline of agriculture and animal husbandry, resulting in the population decrease and the collapse of ancient civilizations (e.g., the Maya, Angkor) (Buckley et al., 2010; Medina-Elizalde and Rohling, 2012). According to historical records, the government supply relief food and migrate the resident

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to Zhangye city (inside the Jiayuguan Pass) (Zhang, 1974). References: Buckley B M, Anchukaitis K J, Penny D, Fletcher R, Cook E R, Sano M, Canh Nam L, Wichienkeeo A, That Minh T, Hong T M. 2010. Climate as a contributing factor in the demise of Angkor, Cambodia. *Proc Natl Acad Sci USA*, 107: 6748–6752 Medina-Elizalde M, Rohling E J. 2012. Collapse of classic Maya civilization related to modest reduction in precipitation. *Science*, 335: 956-959 Research Institute of History and Language of the Central Academy in Taiwan: Ming Yingzong Shilu. Taiwan, 1962a. Zhang, T.Y.: History of Ming dynasty. China Publishing House, Beijing, 1974 (in Chinese).

8. The conclusions presented in other studies that are especially relevant to the questions raised here should be discussed more explicitly, in particular Zhang, et al. "A late-Holocene pollen record from the western Qilian Mountains and its implications for climate change and human activity along the Silk Road, Northwestern China." *The Holocene*, 28(7) (2018), 1141-1150 (in the reference list), and Li, Haiming, et al. "Human settlement and its influencing factors during the historical period in an oasis-desert transition zone of Dunhuang, Hexi Corridor, northwest China." *Quaternary International* 458 (2017): 113-122 (not in the reference list). Response: Thanks for your comments. Zhang et al. (2018) mainly reconstructed climate change since ~4,000 BP, based on the analysis of paleoclimate indices (especially pollen) from Tian'e Lake in the western Qilian Mountains. Although they also propose that drought may have contributed to the abandonment of Dunhuang, they only compare their paleoclimatic record with historical documents, without providing a detailed discussion of how the impact of climate deterioration was transmitted to the human living environment and social system, such as the via desertification and the shrinking of the ancient oasis. Also, Li et al. (2017) (Guanghai Dong is the corresponding author) focus on the transformation of human settlement intensity, plant exploitation strategies, and their relationship to geopolitics and climate change in the oasis-desert transition zone of Dunhuang during the historical period. The major topics of these two papers and our paper are different, although these other studies provide useful data and perspective. Therefore, we have added a citation to Li et al. (2017) in Lines 81. References: Li, H.M., Liu, F.W., Cui, Y.F., Ren,

L.L., Storozum, M.J., Qin, Z., Wang, J., Dong, G.H., 2017. Human settlement and its influencing factors during the historical period in an oasis-desert transition zone of Dunhuang, Hexi Corridor, northwest China. *Quaternary International*, 113-122. Zhang, J., Huang, X., Wang, Z., Yan, T., and Zhang, E.: A late-Holocene pollen record from the western Qilian Mountains and its implications for climate change and human activity along the Silk Road, Northwestern China. *Holocene*, 28, 1141-1150, 2018.

Detailed comments Abstract 21 Demise is not synonymous with interruption: is it a demise or an interruption? Response: Thanks for your comment. We changed “demise” to “decline” throughout the text. Please see Line 21, 64, 226, 256, 290, 319.

22 Wala: the standard term is Oirat (or other spelling, such as Oyirad) Response: Thanks for your comments. We have modified the term throughout. Please see Line 23 and 68.

24-26 Is it possible that there was more than one cause? Response: Thanks for your constructive suggestion. Although we have suggested a principal cause in this study, we have also examined two other possible causes. Although it is probable that several factors led to the interruption of the ancient Silk Road, we are concerned with the primary cause.

27-32 The dates seem to indicate a long gap between the time of the drought (1440-60) and the closure of the trade route going through Dunhuang (1539) Response: We agree with the reviewer’s opinion. As have argued throughout, the climatic factor was the primary trigger. The interactions between environmental deterioration and the government’s reactions (i.e. policy) were a slow process, like a “domino effect”, especially when the government was weak and incapable of governing the border area (Feng et al., 2019). The decline of the Silk Road is not only indicated by the official closure of the gate, but also by the steep fall in trade, which closely followed the desertification and climate change. References: Feng, Q., Yang, L., Deo, R. C., AghaKouchak, A., Adamowski, J. F., Stone, R., Yin, Z. L., Liu, W., Si, J. H., Wen, X. H., Zhu, M., Cao, S.

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X.: Domino effect of climate change over two millennia in ancient China's Hexi Corridor, *Nat. Sustain.*, 2, 957-961, 2019.

1. Introduction 43-47 Does this mean that there were no more contacts between China and central Asia, or between the Ming dynasty and the states in the Tarim Basin (today Xinjiang) after 1539? Response: Thanks for the reviewer's constructive suggestion. The Jiayuguan Pass was the only routeway connecting the western region to the domestic territory during the study period. However, the closure of the Jiayuguan Pass in 1539 AD marked the official abandonment of territory beyond the pass (including the Dunhuang area), as well as the strengthening of the restriction on the tribute trade. The twice closure of the Jiayuguan Pass contributed to a much stricter management system for tribute trades and also caused an obvious decline in trade frequency (Yang et al., 1997; Yang et al., 2014). However, a few trades still continued between the Ming government and several Western countries (Research Institute of History and Language of the Central Academy, 1962; Sheng, 1989; Tian, 1999). References: Research Institute of History and Language of the Central Academy. *Ming Shilu*, Ming Xiaozong Shilu, Taiwan, 1962. Sheng, S. X., *Ming Hui Dian*, China Publishing House, Beijing, 1989. Tian, S. Tributary trade between Gansu town and in western regions in Ming Dynasty. *China's borderland history and geographic studies*, 1999 (01):15-24. Yang, F. X. The Overland Silk Road and its Trade in Ming Dynasty. *China's borderland history and geographic studies*, 1997(02):12-20. Yang, L. K., *West wind miles of river road: Study on emissaries and business Trips on the Silk Road in the Western Regions of Ming Dynasty*, Lanzhou University Press, Lanzhou. 2014. 60-62 "The Ming : : frontier": meaning unclear. Clarify especially "transfer of the leadership to Mongolia" Response: Thanks for the reviewer's reminder. We have modified the sentence to "The Ming governor established seven garrisons in the Jiayuguan-Dunhuang area and transferred the leadership to Mongolia which governed the seven garrisons in order to consolidate the frontier territory." Please see Line 61-63.

63-87 The hypotheses presented here do not include archaeology-based hypothesis.

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Any discussion on the “closure” of the Silk Road should be documented by looking at arguments based on archaeological investigation. Response: Thanks for the reviewer’s suggestion. The archaeology evidence for the XSW site also suggests that two desertification events occurred (Li, 1990). In addition, the focus of the study is the role of desertification in causing closure, which is argued in the discussion in section 4.3. References: Li. B.C. Investigation on the Ancient Ruins in the Western Sandy land of Minqin County. Journal of Desert Research, 1990 (in Chinese with an English abstract).

66-67 vague, not relevant Response: Thanks for the reviewer’s suggestion. Lines 66-67 are intended to explain the background which led to the frequent wars in the area.

67 unclear what “expand agri-nomadic wars” means: suggest to provide references to historical events Response: Thanks for the reviewer’s reminder. We accept the reviewer’s advice and have added relevant references in this part. Please see Line 68-69. Reference: Zhang, T.Y.: History of Ming dynasty. China Publishing House, Beijing, 1974 (in Chinese). 69 Necessary to provide dates and other details and background of invasions by nomadic tribes 73-74 The reference to the rise of the maritime routes as an explanation for the decline of Silk Road in Western literature usually refer to the late 16th and especially 17th century but these are old theories that have since been criticized. The references cited here are to generic articles to which I have no access, but should be supplemented with references to a broader discussion. The ban on Dunhuang trade was irrelevant to the rise of international maritime trade, in South China which is due to Spanish and Portuguese commercial and diplomatic activities. Response: Thanks for the reviewer’s suggestion. What we have discussed in this study is based partly on previous hypotheses and discussion. The focus of the study is to test different hypotheses for the primary factors that caused end of the ancient Silk Road, as is highlighted in the Abstract. Though dates and other details and the background of invasions by nomadic tribes, and detailed documentation of these hypotheses (and other opinions), are undoubtedly helpful for understand the background to the debates,

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they are not the key content of this paper; therefore, we introduce this information by citing references. Thanks for your suggestion; however, we believe it better to discuss the issue in a future publication.

2. Study area 92-93 The statement about newly-discovered historical archives requires a reference Response: Thanks for the reviewer's suggestion. We have added a relevant reference (Cheng, 2007). Please see Line 95. References: Cheng, H.Y., 2007. The Desertification of the Hexi Area in Historical Time. Lanzhou University, Doctoral Dissertation (In Chinese with English abstract).

115-119 These lines can be deleted since they are vague and not relevant. Response: Thanks for the reviewer's suggestion. We have deleted these lines. 130 Tulufan, normally known in English as Turfan Response: Thanks for the reviewer's reminder. We have modified the term throughout. Please see Line 132. 135 Altun Mountains, normally known in English as Altyn-Tagh Response: Thanks for the reviewer's kind reminder. We have modified the term throughout. . Please see Line 137.

139-157 This is one of the most problematic, as well as critical, passages of the essay, since reference is made to a "newly-discovered site" but no information is given as to the nature of the site (settlement, village, city, palace, fortress: : :?), the conditions of the discoveries, the date of the discovery and archaeologists involved (if any). Since the evidence upon which the whole argument rests comes from this location, it is essential to provide the full picture of this site. Thanks for the reviewer's suggestion. We have added relevant content and references (Li, 1990; Cheng, 2007). Please see Line 144-149. References: Cheng, H.Y., 2007. The Desertification of the Hexi Area in Historical Time. Lanzhou University, Doctoral Dissertation (In Chinese with English abstract). Li. B.C. Investigation on the Ancient Ruins in the Western Sandy land of Minqin County. Journal of Desert Research, 1990 (in Chinese with an English abstract).

3. Methodology 203-206 Unclear where these paleoclimatic records are located. References are required for published studies. See Below 207-210 References are not to the historical sources but to secondary studies or limited collections. No reference

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is made to actual historical sources, which were not consulted (Ming shi, Ming shilu, etc.). Unclear which “sociohistorical records” relative to Dunhuang and Jiayuguan were actually used (gazetteers, memoirs, standard histories, local archives etc.) Response: Thanks for the reviewer’s comments. The “sociohistorical records” we discuss are local archives, and what the reviewer mentions are gazetteers. Although it would be much better if we were able to investigate the source of each historical event, we are seeking a statistical trend. We believe that secondary data sources are useful in this type of quantitative analysis.

4. Results and Discussion 212-223 As mentioned before, the flourishing of maritime trade in the late 16th century cannot be simply attributed to a government decision (why was then ban lifted?) Response: We agree with the reviewer’s opinion that the flourishing of maritime trade in the late 16th century was affected by various factors. In fact, coastal inhabitants occasionally ventured out to sea to support themselves, even when maritime trade was banned at the beginning of the Ming dynasty (Chen, 1962). We would be interested in discussing this topic with the reviewer; however, a full investigation is beyond the scope of the present paper. Reference: Chen, Z.L.: Ming Jing Shi Wen Bian, China Publishing House, 1962 (in Chinese). 223 Zheng He’s voyages have been amply investigated (see for instance Dreyer, Edward L. Zheng He: China and the oceans in the early Ming dynasty, 1405-1433. Pearson Longman, 2006.) Response: Thanks for the reviewer’s recommendation. We found this work very useful in our study and we cited it in Line 230. Reference: Dreyer, E.L. Zheng He: China and the oceans in the early Ming dynasty, 1405-1433. Pearson Longman, 2006. 224-239 The section of Zheng He’s voyages is immaterial, and also historically inaccurate. I would be weary of statements that attribute to “national prestige” the reason for Zheng He’s voyages. Response: Thank you for the reminder. We feel that it is important to consider the existing hypotheses and views reasonably thoroughly, even though it may be tedious for those readers who already have a detailed knowledge of the topic. 248 Few specialist historians would agree with the assumption mentioned here, especially if understood (as presented here) as a sharp break. Response: Thanks

for the comment. The aim of this study is to explore the causes of the end of the traditional Silk Road. There are three major hypotheses for this; one is that the rise of the Maritime Silk Road led to the end of the land Silk Road (the traditional Silk Road) (Xie et al., 2007; Qian and Jin, 2010; Zhai, 2017). This view has been accepted by many scholars and by the general public, and thus we consider that it is important to examine whether the assumption is tenable. Therefore, we provide detailed information on why this argument is not fully supported by available historical documents (Part 4.1). In particular, the timeline for the final closure of the Jiayuguan Pass and the end of the ban on maritime trade are landmark events for the end of the traditional Silk Road and the emergence of extensive maritime trade. We think this is a logical chain of evidence. Although more evidence is needed to support this, it is not the primary topic of this paper. Moreover, we hope that this work could promote further discussion of the issue. References: Qian, Y., and Jin, H. L.: Study on Oasis along the Silk Road, Xinjiang people's publishing house, 2010 (in Chinese). Xie, Y., Ward, R., Fang, C., and Qiao, B.: The urban system in West China: A case study along the midsection of the ancient Silk Road - He-Xi Corridor. *Cities*, 24, 60-73, 2007. Zhai, S.D.: The changes of the beacon flint and the land Silk Road in Dunhuang. *Gansu Social Sci.*, 05, 135-140, 2017 (In Chinese). 260 What is "frequent"? Response: Thank you for the reviewer's reminder. Here we mean that there were many wars (19 wars in the period of 1360-1520 AD). 261-68. Presumably this refers to wars between Ming and Mongols in the early 16th century, but it is impossible to assess the actual impact of warfare on trade without details about when, where, and between whom the conflicts occurred. Response: Thanks for the comment. Based on the timeline of occurrence of these wars and the timing of the closure, we reject the 'war hypothesis' because both of them are incompatible with the timeline. We assume that this type of time series does not require us to assess the actual impact of each war.

274 Clarify what is meant by "nomadic peoples." Not all of them were at war with the Ming. Also, statistical data about "conflict" are basically irrelevant to historical analysis unless the category of "conflict" is explained. 282-283 The category of "agri-nomadic

conflict” is not correct when discussing specific periods and cases (conflict occurs between polities, or otherwise defined groups of people, not between modes of production) Response: Thanks for the reviewer’s comments. “nomadic peoples” include the Mongols (nomadic) and the peoples who settled in the oasis area where animal husbandry and agriculture co-exist. 275 Reference to the source for data on frequency of tribute and trade is required. Response: Thanks for the reviewer’s reminder. We have added the reference. Please see Line 283-284. 303-4 Can the absence of a relationship demonstrate something? Possibly reconsider. Response: Thanks for the reviewer’s comments. We assume that absence of a relationship between the frequency of wars in the Dunhuang area and variations in the amount of tribute trade demonstrates that warfare was not the primary cause of the collapse of trade along the Ancient Silk Road trade. 354-355 This seems to be a misunderstanding. The reference in Yang et al. is to lower precipitation during the 14-century period 900 BC-500 AD. It does not indicate a specific desertification event from 900-550 BC, as is contended here. Therefore, there is no correlation with the XSW data. More generally, the significance of the “first desertification event” is difficult to place in terms of the main thrust of this article, which is about the collapse of the Silk Road from an environmental perspective. Response: Thanks for the reviewer’s comments. The evidence of a thick sand layer in the XSW section shows that desertification occurred during the period 800-600 BC., and Yang’s work on tree-rings also indicates a decrease in precipitation during 900-550 BC. The difference in timing of 50-100 years may be caused by a lagged response of desertification to the reduction in rainfall. In addition, there are possible measurement errors in the dating techniques. On the other hand, the precipitation decrease in Qilian Mountains consistent with the desertification process in 800~600 BC testified and provided more evidence for the relationship of the later ~1450 AD desertification event with tree ring records from the Qilian Mountains.

362-65 Gou et al. 2015a does not mention the period 1447-1567, but 1426–1555. Moreover, in Gou et al. 2015a and Gao et al. 2015b the climate data are based on scPSDI (self-calibrated Palmer Severity Drought Index) and SPEI (standardized precip-

itation and evapotranspiration index) values. It is unclear how these values match the data provided in this paper. Response: Thanks for the reviewer's comments. We have modified the relevant data. - please see Line 370. These references are only supporting evidence and the trend of variation and our sedimentary profile are our principal pieces of evidence. Besides, the start and finish time was fitted. 387-402 Evidence for this region from the 4th to 1st millennium BCE is based uniquely on archaeological documentation and therefore it would be better to replace "documentary" in the subtitle with either "archaeological" or "material". Response: Thanks for the reviewer's reminder. We have modified the text accordingly. Please see Line 393.

407-414 The migration of the Yugur requires context: when did it happen and how can we relate the difficulties mentioned in their oral history to the site of XSW at around 1450 CE? Response: Thanks for the reviewer's comments. We cannot provide the date of the folk song. However, the abandonment of Dunhuang led to the formation of the Yugur nationality which has been discussed in previous studies. Also, the content of the folk songs was directly related to migration from Dunhuang to Jiayuguan in the 15th century (Chen, 2011). Please see Line 414-416. References: Chen, G. W.: Research on the enclosure of the Dunhuang during Ming Dynasty. *J. Dunhuang study.*, 60, 111-118, 2011 (in Chinese).

445-466 The contention that between 1450 and 1530 the oases of Dunhuang and Guazhou were not functioning is belied by the evidence of trade-tribute missions listed in Chinese sources for this period. Therefore, more research is required on communication routes. Moreover, the evidence presented in this article does not support the notion that no ground water was available through natural wells along the caravan route. In other words, evidence of drought conditions in one place does not mean that water disappeared for the limited use of watering camels en route. Response: Thanks for the reviewer's comments. We accept the reviewer's opinion that although the desertification created major difficulties across the region, it would not have made it completely inaccessible. Even in the Qing dynasty, when the climate

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changed into wetter, foreign expeditions across the regions incurred substantial loss of people and animals. We have modified the text accordingly. Please see Lines 487-490. We conclude that the wars, land degradation, and decline in trade and other consequences of desertification led to the implementation of the government policies (the closure of Jiayuguan and the withdrawal troops from the garrisons). The reasons why we regard our hypothesis as more convincing than the others are: (i) the timing of the policies is coherent with the timing of desertification, decrease in trade, wars, migrations and climate change; and (ii) it satisfies one of the basic conditions required for the verification of causal relations, which is that 'the cause must precede the effect'.

Please also note the supplement to this comment:

<https://cp.copernicus.org/preprints/cp-2020-102/cp-2020-102-AC3-supplement.pdf>

Interactive comment on Clim. Past Discuss., <https://doi.org/10.5194/cp-2020-102>, 2020.

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