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The origins of wheat in China and potential pathways for its introduction: A review

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ABSTRACT

Today in China, hexaploid wheat (*Triticum aestivum* – common wheat or bread wheat) is one of the major staple food crops. The other key cereal staples – rice, foxtail millet and broomcorn millet – are widely accepted as Chinese domesticates, but the origins of wheat cultivation in China are the subject of debate. There has long been a belief among Chinese scholars that China was an independent centre of wheat domestication, but recent scholarship suggests that cultivated wheat was introduced to China from its original site of domestication in the Near East. The precise path of entry is unknown. It is argued here that it is most likely to have been introduced at some time around the late 6th to early 5th millennium BP. Two hypotheses are presented. One hypothesis, supported primarily by the paleobotanical evidence, postulates that *T. aestivum* came in from the west, through northern Xinjiang, probably from Afghanistan or the Central Asian oases rather than the Eurasian steppes. The second, supported by the available archaeological evidence, proposes that the route of entry might have been from the north-west, from Eurasia, through southern Siberia and Mongolia.

1. Introduction

Agriculture in China began around ten thousand years ago with the indigenous domestication of rice (*Oryza sativa*) and millet (*Setaria italica* [foxtail] and *Panicum miliaceum* [broomcorn]) (Chen, 1989a,b; Zhao and Piperno, 2000; Hunt et al., 2008; Lu et al., 2009). Bread wheat (*Triticum aestivum*) is also one of the major staple Chinese food crops, but how it came to be cultivated in China has been much disputed, particularly within China itself. An independent centre of domestication in China was originally postulated by Chinese scholars (see e.g., Li, 1980, 1982, 1984). More recently this viewpoint has begun to change with gradual recognition of the possibility that wheat might have been an introduced species (see e.g., Jin, 2007; Chen, 2008; Liu and Chen, 2012: 92). Western scholars (see e.g., Flad et al., 2010; Frachetti et al., 2010) also support the idea of external origins for Chinese wheat.

Outside China, wheat was first domesticated in the Near East (Western Asia). From here, cereal cultivation spread westwards into Europe and eastwards into Asia. Wheats derived from the wild progenitors einkorn (*Triticum monococcum* ssp. *boeoticum*) and emmer (*Triticum turgidum* ssp. *dicoccoides*) were cultivated in the Near East as early as the 11th millennium BP (10,200 BP: 9970 cal. BC). Recognizably domesticated wheat is known from archaeological contexts in the same region from at least the late 10th millennium BP (9250 BP: 8550 cal. BC) (Tanno and Willcox, 2006). From the Near East, these founder crops were dispersed eastwards across the Iranian plateau to Central and South Asia and northwards into the Caucasus and southern Russia (Table 1) (Harris, 2010: 76). However, how they found their way into central China is as yet unclear.

2. Wheat cultivation in China: theories and facts

The ‘independent centre’ theory was originally driven by Chinese historians who cited written documents to support their ideas. The earliest of these texts are Shang Dynasty hieroglyphic oracle inscriptions on turtle shell dated to around the 16th century BC (Yu, 1957). Two characters, *mai* and *lai*, found on oracle inscriptions are interpreted by Chinese hieroglyphic experts as signs for wheat (Ho, 1975: 74; Zhao, 2005). These two characters also appeared in the early poetry book Shī Jīng (Waley, 1996), dated in the Zhou period around the 13th–11th centuries BC, where they have again been confirmed as signs for wheat (Keng, 1974). Although the notion of a Chinese centre of domestication was firmly held, there were some Chinese scholars who offered alternative ideas. As early as 1969, Ping-Ti Ho suggested that Chinese wheat farming was adopted from the West around the late 5th or

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Table 1
Summary of archaeological evidence for dispersal of wheat from Western Asia into China (earliest dates selected from greater published ranges).

Region	Date range	Site name	Evidence for crops	Lab. no./age BP/cal. age (2σ range) BC	Reference	Basis for dating
Western Ukraine	ca. 4000 –3500 cal. BC	Linear Pottery and Volynskaya cultures	Seed impressions on pottery and clay daub. Emmer (*Triticum dicoccum*)		Pashkevich, 2003	Indirect dating based on associated material culture
Armenia	6024–5753 cal. BC	Aknashen	Carbonized wheat (*Triticum monococcum, Triticum dicoccum, Triticum* sp.)	AA-68561 7035 ± 69 6024–5753	Hovsepyan and Willcox, 2008	Charcoal
Armenia		Artashen	Carbonized wheat (*Triticum monococcum, Triticum dicoccum, Triticum* sp.)	AA-64175 6948 ± 73 5988–5713	Hovsepyan and Willcox, 2008	Antler
		Artashen		AA-64177 6913 ± 49 5905–5711		Charcoal
Southern Turkmenistan	6380–5920 cal. BC	Jeitun III/IV	Carbonized Einkorn (*Triticum monococcum*)	OxA-2914 7270 ± 100 6380–5920	Harris, 2010	*T. monococcum*
Western Pakistan	5300–4700 cal. BC	Mehrgarh	Traces of grains in mud bricks. (*Triticum monococcum, Triticum dicoccum, Triticum aestivum/durum*)		Costantini, 1984, Meadow, 1996	Charcoal
Tajikistan	3905–3775 cal. BC	Sarazm Period I	Carbonized wheat (*Triticum aestivum/durum*)	Le-2172 5050 ± 60 3905–3775	Isakov, 1996, Willcox, n.d.	Charcoal
Kashmir	3375–2871 cal. BC	Gofkral	Wheat (*Triticum sphaerococcum* Pers., *Triticum* cf. *aestivum* type)		Kajale, 1991, Bandey, 2009	Charcoal
		Gofkral IA		4420 ± 110 3375–2871		Charcoal
Kashmir	3029–2465 cal. BC	Burzahom I	Wheat (*Triticum sphaerococcum* Pers., *Triticum* cf. *aestivum* type)	4175 ± 115 3029–2465	Kajale, 1991, Bandey, 2009	Charcoal
Northern Afghanistan	2887–2030 cal. BC	Shortughai	Carbonized wheat (*Triticum aestivum/durum*)		Willcox, 1991, Possehl, 1997–8	Charcoal
Kazakhstan	2460–2150 cal. BC	Begash	Wheat (*Triticum aestivum/turgidum*)	Beta-266458 3840 ± 40 2460–2190, 2170–2150	Frachetti et al., 2010	Carbonized wheat and millet grains
Gansu	ca. 2700 –2350 cal. BC	Xishanping	Wheat phytoliths	TKa13884 <4870 ± 35 <3658–4712	Li et al., 2007	Charcoal
Gansu	2026–1959 cal. BC	Ganggangwa	Wheat	OZK658 3558 ± 47 2026–1759	Dodson et al., 2013	Wheat
Gansu	2135–1895 cal. BC	Huoshiliang	Carbonized wheat	OZK603 3636 ± 44 2135–1895	Dodson et al., 2013	Carbonized wheat
Gansu	3645–2925 cal. BC	Donghuishan	Carbonized wheat (*Triticum cf. aestivum*)	4605 ± 150	Li and Mo, 2004, Li, 2002	Wood and bulk soil/ charcoal sample
Gansu	3368–1980 cal. BC	Donghuishan	Carbonized wheat	BA92101 4110 ± 250	Gansu/Jilin, 1998, Li and Mo, 2004	Carbonized wheat
Gansu	1623–1452 cal. BC	Donghuishan	Carbonized wheat	BA06031 3265 ± 35 1623–1452	Flad et al., 2010	Carbonized wheat
Gansu	1879–1538 cal. BC	Donghuishan	Carbonized wheat	OZK654 3405 ± 50 1879–1538	Dodson et al., 2013	Wheat
Henan Shaanxi Shandong	ca. 5000 BC	Miaodigou	Wheat seed impressions on burned clay		Li, 1984	Based on ceramic typology – cannot be verified
Henan Shaanxi Shandong	ca. 2500–1900 BC	Liangchengzhen	Carbonized wheat		Crawford et al., 2005	Indirect dating based on associated material culture
Henan Shaanxi Shandong	2500–2270 cal. BC	Zhaojiazhuang	Carbonized wheat		Jin et al., 2011	Charcoal
Henan Shaanxi Shandong	2562–2208 cal. BC	Zhaojiazhuang	Carbonized wheat		Jin et al., 2011	Carbonized wheat
Henan Shaanxi Shandong	ca. 2400–2000 BC	Zhaojialai	Carbonized (?) wheat stems		Huang, 1991	Indirect dating based on associated material culture
Henan Shaanxi Shandong	ca. 2200 BC	Jiaochangpu	Carbonized wheat		Zhao, 2004	Indirect dating based on associated material culture

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Table 1 (*continued*)

Region	Date range	Site name	Evidence for crops	Lab. no./age BP/cal. age (2σ range) BC	Reference	Basis for dating
Henan Shaanxi Shandong	ca. 2000 BC	Zhouyuan	Carbonized (?) wheat		Zhouyuan Archaeological Team, 2004	Indirect dating based on associated material culture
Xinjiang	3092–1531 cal. BC	Gumugou	Common wheat (*Triticum aestivum*) and poulard wheat (*Triticum turgidum*)		Wang, 1983, Archaeological Institute XASS, 1995	Wood, wool and leather
		Gumugou		4260 ± 80 3092–2620		Wood artefact from grave
		Gumugou		3615 ± 170 2469–1536		Sheep skin
		Gumugou		3480 ± 100 2114–1531		Woollen blanket
Xinjiang	2011–1464 cal. BC	Xiaohe	Wheat (*Triticum aestivum*)		Xinjiang Kaogusuo, 2003, Li et al., 2011	Animal skin, felt, millet seed and fabric
Xinjiang	1755–1427 cal. BC	Xiaohe	Wheat (*Triticum aestivum*)		Xinjiang Kaogusuo, 2003, Li et al., 2011	Wheat grains
Xinjiang	2006–1622 cal. BC	Xintala	Wheat	OZK663 3430 ± 50 1883–1622	Dodson et al., 2013	Wheat grains
		Xintala	Wheat	OZL437 3515 ± 50 2006–1694		Wheat grains
Xinjiang	1508–1318 cal. BC	Wupaer	Wheat	OZL441 3155 ± 39 1508–1318	Dodson et al., 2013	Wheat grains
Xinjiang	1493–1132 cal. BC	Sidaoguo	Wheat	OZK665 3080 ± 60 1493–1132	Dodson et al., 2013	Wheat grains
Xinjiang	1350–900 cal. BC	Luanzagangzi	Wheat (*Triticum aestivum/durum*)	UBA-9061 3000 ± 24 1373–1130	Jia et al., 2011	Charcoal
Tibet	1439–929 cal. BC	Changguoguo	Wheat	ZK-2814 2985 ± 102 1439–929	Fu et al., 2000	Charcoal

4th millennium BP. He based his argument on the hieroglyphic symbol *lai* (wheat) for which the original meaning in Chinese is "come", implying, perhaps, that the wheat came from somewhere external to China (Ho, 1969, 1975: 74). However, to many Chinese academics, the origins of wheat farming, or at least "Chinese wheat farming", should be sought within China itself, with no influence or contact with others (Zhang, 2008). Recently this viewpoint has begun to shift. The changing perspective has been driven in part by new discoveries and in part by rigorous analysis of the existing archaeological record. As new genetic studies are undertaken (e.g., Jiang et al., 2006; Hao et al., 2011), and new paleobotanical evidence emerges (Jin, 2007; Chen, 2008; Flad et al., 2010), Chinese archaeologists are now starting to consider the likelihood that wheat farming was originally adopted from outside through early contact between China and the West.

2.1. *Dating wheat remains in China*

The arguments for a Chinese origin are complex, but they have had a significant effect on Chinese scholarship. Wheat became an established cultigen in the Lower Yellow River Valley around the middle to late 4th millennium BP (Lee et al., 2007; Liu, 2009), but there have been a number of documented cases of earlier occurrences and some have been used to support the argument for indigenous domestication. One study reflecting this viewpoint by a respected and influential Chinese botanist (Li, 1980, 1982, 1984) was based on finds from the site of Miaodigou in central China (Li, 1984: 37–48). Excavations at Miaodigou in the 1950s produced seed impressions on burnt clay. These were identified as those of wheat and dated on the basis of associated ceramic comparisons to around 7000 BP. Later, in north-west China, charcoal found at the site of Donghuishan in association with charred common wheat seeds (*T. aestivum*) produced radiocarbon dates from as early as the first half of the 6th millennium BP (3645–2925 cal. BC) (Li et al., 1989a, 1989b; Li and Mo, 2004; see also; Flad et al., 2010). Although these have been used in support of the 'Chinese origins' theory, evidence from both of these sites is problematic. There are, in fact, now several sites in China that have produced dated evidence for the local presence of wheat earlier than the 4th millennium BP (Fig. 1; Table 1). The earliest apparent occurrence, around 7000 BP at Miaodigou has now largely been dismissed (Jin, 2007). The data were first reported in the 1950s (Archaeological Institute CASS, 1958). The identifications are unreliable and cannot be checked as there are no published images either for the seed impressions themselves or the associated ceramics, said to be of Yangshao type. The Yangshao is a Neolithic culture dated broadly from 7000 to 5300 BP (Liu, 2004: 78).

Discounting Miaodigou, there is still a small cluster of sites with samples dated earlier than the 4th millennium BP, all distributed along the Yellow River in northern China. The earliest is that of Donghuishan (Li and Mo, 2004). Excavations at the site conducted from 1975 to 1987 focused mainly on an extensive cemetery. The artifacts from the graves can be linked to the Siba culture. Siba communities were village based with economies based on agriculture, herding and hunting (Li, 1993; Yang, 1998). Radiocarbon dates from charcoal found at another Siba site, Huoshaoguo, suggest that the Siba culture should be dated in the early to mid-4th millennium BP (1900–1300 cal. BC) (Flad et al., 2010; Gansu/Jilin,

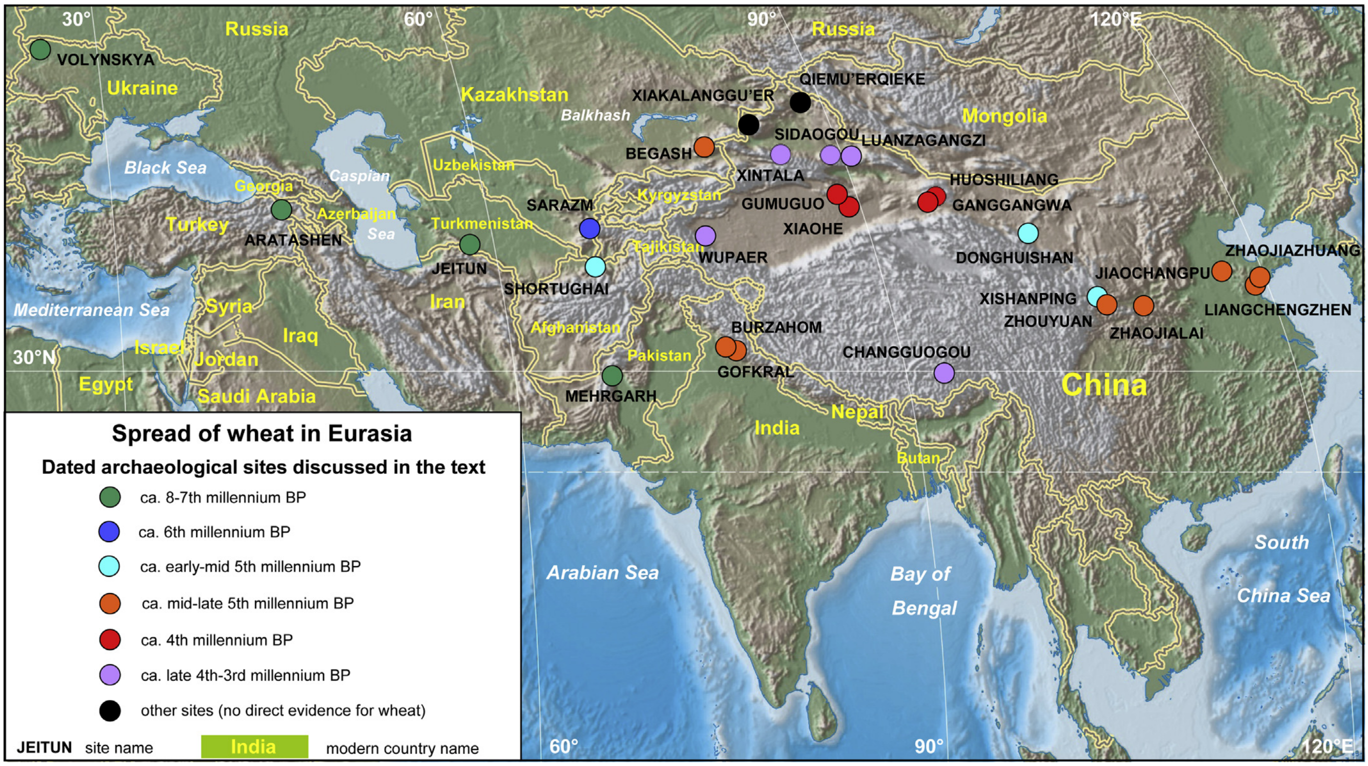

Fig. 1. Map showing the spread of wheat out of Western Asia. Sites shown in black (other sites) are sites mentioned in the text which do not have direct evidence for wheat. Modern state borders and names are shown for orientation. Age estimates are based on calibrated radiocarbon dates.

1998: 133–134). However, some of the first dates obtained from Donghuishan fall around the late 6th to early 5th millennium BP, apparently too early to be linked with the Siba cultural material from the site (Gansu/Jilin, 1998; Li and Mo, 2004). Only one of the dates is on a carbonized seed (3368–1980 cal. BC). The rest are mainly from bulk charcoal collected from layers in which carbonized grains of wheat were also recovered (Li et al., 1989a, 1989b; Li and Mo, 2004). The excavators speculated that the wheat might belong to an unknown cultural complex pre-dating the Siba complex which somehow was not preserved at Donghuishan (Li and Mo, 2004). The contexts from which these early samples were obtained are not clear (Flad et al., 2010: 957).

More recently, a new series of dates has been obtained from a soil profile cut into an erosion gulley dissecting the occupation levels of the ancient settlement at Donghuishan (Flad et al., 2010). Occupation levels could be differentiated in the section but no associated material cultural evidence was obtained. A substantial amount of carbonized plant material was recovered, including clearly identifiable wheat (*T.* cf. *aestivum*) and barley. From this, dating was conducted directly on carbonized grains of both cereals. The dates fall around the mid-4th millennium BP (1623–1388 cal. BC) and are compatible with the previous dates for the Siba culture (Flad et al., 2010: Fig. 5). This still leaves unexplained the question of the earlier dates previously obtained from the site. What it does, however, demonstrate, is that wheat cultivation was far from being a new element in the economy at Donghuishan. By the early to mid-4th millennium BP, wheat cultivation was well established and one may assume a fairly long history of less intensive wheat agriculture as the cereal slowly became established as a dominant staple crop (Flad et al., 2010: 963).

There are several ways of dating the presence of wheat beside ages obtained from wheat seed, as used by Flad et al. (2010). Many other parts of wheat plants can be amenable to radiocarbon dating. These include parts of flowers, starch grains, leaves, glumes and phytoliths. In the future it may be possible to identify a wheat-specific organic biomarker, such as a leaf wax or protein which can be dated. This technique is well known and examples of application of compound specific radiocarbon dating are given by Stott et al. (2003), Uchikawa et al. (2008) and Galy et al. (2011). Additional approaches involve identifying and dating wheat components in sound stratigraphic settings or with archaeological associations. An early date for wheat comes from the site of Xishanping in Gansu, and this is based on the occurrence of wheat phytoliths in a well-dated sediment section. Xishanping is a large archaeological site with a long but not necessarily continuous cultural history from around the 8th to the 4th millennium BP (5850–1050 cal. BC) (Archaeological Institute CASS, 1999; Li et al., 2007). Key periods are those of the Majiayao (3350–2250 cal. BC) and Qijia (2350–1950 cal. BC) cultures which are characterized by intensive agricultural production (Archaeological Institute CASS, 1999; An et al., 2005; Li et al., 2007). In 2004 a section was cut into a river terrace where cultural levels were exposed. The section has a relatively high sedimentation rate and a consistent set of radiocarbon ages which leads to a high degree of confidence in the age precision of the sequence. From 5250 cal. BP (3300 cal. BC) the Xishanping cultural sequence is first marked by the appearance (identified by seeds and phytoliths) of millets and then rice (5070 cal. BP or 3120 cal. BC) and oats. Wheat (*T. aestivum*) first appears at ca. 4650 cal. BP (2700 cal. BC); barley and buckwheat is present from 4600 cal. BP (2650 cal. BC) (Li et al., 2007). Wheat and oat seeds occurred in relatively low abundance compared to millet seeds in particular but also rice seed numbers. In the far west of Gansu, and slightly later, wheat seeds from two other Siba culture sites, Huoshiliang and Ganggangwa (Dodson et al., 2013), are dated in the early 4th millennium BP (2135–1895 cal. BC; 2026–1759 cal. BC).

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In eastern China, there is evidence from sites of the Longshan culture (ca. 4600–3800 BP) (Liu and Chen, 2012: 216), such as the charred wheat seeds found at the Jiaochangpu and Zhaojiazhuang sites (Zhao, 2004). For Jiaochangpu, dating is based only on association with material culture, but dates in the mid to late 5th millennium BP (2500–2270 cal. BC) have been obtained for Zhaojiazhuang. One date was obtained directly from a grain of wheat (2562–2208 cal. BC) (Jin et al., 2011). Liangchenzhen, a typical site of the Shangdong Longshan culture, lies near the Shandong coast. Here two seeds were identified as *T.* cf. *aestivum.* One of these was found within a Longshan pot and the other was recovered from a posthole (Crawford et al., 2005). Wheat in association with Longshan culture remains has also been reported from Baligang in Henan and at Wangjiazui, Zhouyuan and Zhaojialai in Shaanxi Province, but these too are dated only on the basis of associated artefacts (Fuller and Zhang, 2007; Huang, 1991; Zhouyuan, 2004).

To the west there is more reliable, but not quite so early, evidence from the site of Gumuguo in Xinjiang (Archaeological Institute XASS, 1995) where an abundance of wheat grains was recovered from baskets in graves. The Tarim Basin is remarkable for the organic preservation of archaeological remains. Clothing, basketry and food stuffs are frequently recovered almost wholly undecayed, naturally conserved through the unique conditions of aridity, sandy soils and high salinity. Dates obtained on wood from coffins and burial shrouds indicate that Gumuguo was in use around the 5th–mid-4th millennium BP (3092–1531 cal. BC) (Wang, 1983; Flad et al., 2010: Table 133). Broadly similar dates have been obtained for the equally well preserved site of Xiaohe (2011–1464 cal. BC), again with an abundance of cereal remains including wheat (*T. aestivum*) and millet (Xinjiang Kaogusuo, 2003; Li et al., 2011), although dates directly obtained from wheat grains so far fall around the mid-4th millennium BP (1755–1427 cal. BC). Recent dates for wheat grains from three other sites in Xinjiang also fall around the same range. Dodson et al. (2013) report dates from Xintala (2006–1622 cal. BC), Sidaoguo (1493–1129 cal. BC) and Wupaer (1189–418 cal. BC).

The earliest dates are now concentrated in north-western China. There are slightly later dates for wheat in eastern China (Jin, 2007) which have continued to support the idea of an indigenous centre of domestication in the east, but the weight of evidence is now pointing more strongly to the west. As the idea of external origins grows, and while the archeological evidence is still somewhat tenuous, there is an increasing acceptance that north-west China, Gansu and Xinjiang are the pathways for wheat farming dispersal into China, although other ideas are still debated (see e.g., Zhao, 2007, 2008; Zhang, 2008). Some believe it was via the south route through South and Southeast Asia; others lean to the northern route through Xinjiang and east Central Asia, or across the steppe through the Mongolian grassland. Multiple routes are also proposed (Zhao, 2008). Sites with evidence for wheat cultivation around the early second millennium BC (Table 1) are mainly located in the Mid and Lower Yellow River area. More systematic dating is needed to test these hypotheses. There may have then been a somewhat uneven spread outwards from north-west and central China as wheat cultivation was selectively adopted by individual communities depending on their cultural, social, economic or environmental needs (Chen, 2008).

2.2. Botanical considerations

From a botanical perspective, the evidence for indigenous domestication is weak. Domestication will normally only take place within the natural range of distribution of the wild progenitor (Zohary and Hopf, 2000: 10–11). *Triticum* is a genus of about 20 species of annual and biennial grasses native to the Europe – West Asia region (Willis, 1966). Wild species were exploited originally and are known from archaeological sites in Syria, Turkey and Iran. None are native to China (Flora of China, 22: 442). The wild progenitors of einkorn and emmer wheat are found in the Near East (Zohary and Hopf, 2000: 53). Wild einkorn has never been recorded east of the Caspian Sea (Harris, 2010: 77). It is believed that domestication of einkorn and emmer was limited largely to the Near East, including Anatolia (Diamond, 1997; Heun et al., 1997; Bar-Yosef, 1998; Lev-Yadun et al., 2000; Ozkan et al., 2002; Zohary and Hopf, 2000), although within these areas there may have been more than one centre of domestication (Jones and Brown, 2000).

In addition, studies have suggested that hexaploid wheat (*T. aestivum*), common or bread wheat, is unlikely to have a wild counterpart. Common wheat is a hybrid from two progenitors, cultivated tetraploid *T. turgidum* (emmer) wheat and a diploid wild grass *Aegilops squarrosa* (Zohary and Hopf, 2000, 51). *Aegilops squarrosa* is the eastern-most diploid species in the wheat group which includes both *Triticum* and *Aegilops*. It is common in Iran, Afghanistan, Central Asia, the Caucasus and the Caspian region. Wild *T. turgidum* is found only in the arc of the Fertile Crescent in the Near East. Since the two ancestral species occupied geographically differing habitats, it can only have been after *T. turgidum* began to spread as a domestic crop that the process of hybridization took place. Since *Aegilops squarrosa* is a successful colonizer of disturbed habitats such as fields, it is easy to see how this process may have occurred. It seems likely that the area of origin was the south-western Caspian region, in and around modern Armenia and Georgia (Zohary and Hopf, 2000: 54), at some time after the expansion of *T. turgidum* to northern Iran and Transcaucasia around 8000–7000 BP (Van Zeist, 1976).

However, some Chinese plant biologists believe that they have found the wild progenitor of common wheat in China (Li, 1984, 1982, 1980). Plants put forward to support this argument include *T. aestivum* ssp. *xizangense* F. Li, *nov.* (Li, 1984: 43) found on the Tibetan Plateau (Liang, 2006; Chen, 1989a,b; Li, 1984: 43; Li, 1982; Li, 1981) and the weeds *Aegilops* L. and *Aegilops squarrosa* occurring in central China. These species are distributed over very limited areas, usually in modern wheat fields, but with no natural wild distributions in those areas (Li et al., 1980). This rather fragile archaeological and botanical evidence has been broadly quoted by many historians in China, often in combination with mythological accounts, to support the argument for the Chinese origins of wheat farming (see e.g., Cao, 1983; Zhang, 1998; Li, 2007), although some scholars in China have criticized this Sino-centric approach (see for example You, 1988).

From a botanical perspective, other evidence used to support the ‘Chinese origins’ theory is based on the three types of modern common wheat cultivated only in China. They are Tibetan weed-race (*T. aestivum* ssp. *Tibetanum* Shao), Yunnan hulled wheat (*T. aestivum* ssp. *Yunnanense* King) and Xinjiang rice wheat (*Triticum petropavlovskyi* Udacz. et Migusch). They are all found in western China, either in the south-west (Tibet and Yunnan) or the north-west (Xinjiang). It has been suggested that the existence of these three types of common wheat strongly supports the argument for the ‘Chinese origins’ theory (Li, 1984: 47–48; Li, 1982, 1980), or at least that those three types of wheat originated in China (Yang et al., 1992). Current molecular biological studies, however, suggest that both Tibetan weed-race and Yunnan hulled wheat probably originated from the same progenitor, the normal hexaploid common wheat, through a long period of selective cultivation. Unlike the Tibetan weed-race and Yunnan hulled wheat, the Xinjiang rice wheat may have some genetic connections with Polish wheat (Chen et al., 1998; Chen, 1999; Jiang et al., 2006; Wang, 2007) which could indicate some past contact between Xinjiang, eastern Central Asia and eastern Europe. This suggests that Xinjiang rice wheat may also be ruled out as support for the “Chinese origins” theory.

3. The spread of early wheat cultivation outside China

There are a number of paths by which wheat cultivation may have reached China and it is possible that more than one was actually involved in the role of transmission (Fig. 1). From the centre of domestication in the Near East, there is evidence that the practice of wheat farming spread quite rapidly in a number of different directions. To the north, agricultural economies appear in the western Ukraine by the 7th millennium BP (Zvelebil and Lillie, 2000: 75). By the mid-6th millennium BP, cereal cultivation was well established. Seed impressions were found on fragments of pottery and clay daub from a number of Neolithic settlements of the Linear Pottery and Volynskaya cultures. The main food crops appear to have been emmer (*Triticum dicoccum*) and naked barley (*Hordeum vulgare* var. *coeleste*) (Yanushevich, 1989; Pashkevich, 2003; Monah, 2007). This generally marked the eastern boundary of the Eurasian early agricultural zone. Sites of the Dnieper-Donets culture in the Dnieper basin seem to have been predominantly hunter–gatherers until the mid-5th millennium BP, when there is evidence that they began to adopt a pastoral-based economy (Zvelebil and Lillie, 2000: 77). Beyond this, on the Eurasian steppes, agriculture was known but rarely practiced in the Neolithic. Hunting and gathering persisted until relatively late, also gradually giving way to forms of nomadic pastoralism. Thus the late 6th to early 5th millennia BP in the steppe saw the transition from Neolithic cultures with economies based predominantly on hunting and fishing with some stock breeding and pockets of agriculture to an increasing focus on mobile herding practices in the grasslands by the start of the Bronze Age (Frachetti, 2008: 39). There is limited evidence for cereal cultivation throughout the 4th millennium BP across the eastern steppe (Kuz’mina, 2003; Kohl, 2007: 156; Frachetti and Mar’yashev, 2007: 221–2).

Cereal agriculture appeared in the Caucasus by the 8th millennium BP (5900–5400 cal. BC) where wheat (*Triticum monococum*, *T. dicoccum*, *Triticum* sp.) has been identified at the Armenian Neolithic sites of Aratashen and Aknashen (Hovsepyan and Willcox, 2008). Further to the north-east of the heartland of cereal domestication in western Asia, agriculture based on wheat and barley spread through northern Iran (Harris, 2010: 60) and was established in southern Turkmenistan by the 8th millennium BP (Harris, 1996: 563) where radiocarbon dates (6380–5770 cal. BC) have been obtained on grains of einkorn (*T. monococcum*) from the site of Jeitun (Harris, 2010: 120). This new subsistence strategy also seems to have spread rapidly eastwards across the Iranian plateau and Afghanistan. Barley, with a limited amount of wheat, was cultivated in western Pakistan by around the 8th to 7th millennia BP, as evidenced by finds from Mehrgarh where traces of domestic cereal grains were found in mud bricks. Dates for the earliest period, IA, are problematic but those for Period IB (5300–4700 cal. BC) are more reliable. The hulled wheats *T. monococcum* and *T. dicoccum* are present in very low proportions in Period IA, with even smaller proportions of *Triticum aestivo/durum*, but by the late 6th millennium BP (Period V) hexaploid forms dominate (Meadow, 1996: 393; Costantini, 1984).

Further north there are hints that sites in northern Afghanistan and southern Tajikistan may have been occupied as early as the 8th millennium BP by agro-pastoralists, but the evidence is not robust (Dupree, 1972; Harris, 1996: 563; Harris, 2010, 59). The earliest reliable evidence for wheat in northern Afghanistan comes from Shortughai Period I (*T. aestivo/durum*) (Willcox, 1991), dated in the 5th millennium BP (2887–2030 cal. BC) (Possehl, 1997–8). The earliest evidence for wheat in India comes from the sites of Burzahom and Gofkral in Kashmir (*Triticum sphaerococcum* Pers.; *T.* cf. *aestivum* type) dated by associated charcoals to the early 5th millennium BP (Burzahom: 2780–2650 cal. BC; Gofkral: 3060–2990 cal. BC) (Kajale, 1991: 160, 171; Bandey, 2009: 80, 180). The dates for wheat tend to grow gradually later across the Indian subcontinent as represented, for example, by the site of Damdama (Fuller, 2006) near the Nepalese border where there is evidence for wheat by 4000 BP, on the route from India to the south-east regions of China.

After the establishment of early farming villages in southern Turkmenistan, agriculture later spread out eastwards across Central Asia as new settlements appeared successively in the oases formed by rivers draining from the mountains that mark the southern limits of Central Asia. One of the most easterly sites with early agriculture is that of Sarazm in Tajikistan where there is evidence for wheat cultivation (*T. aestivum/durum*) from the early 6th millennium BP (3905–3645 cal. BC) (Isakov et al., 1987; Isakov, 1996; Willcox, n.d.). The site has close cultural links to the expanding Eneolithic out of Turkmenistan.

4. Possible routes of transmission of wheat cultivation into China

There are geographical limitations to the routes by which wheat cultivation may have spread into China (Fig. 2). It is possible, but unlikely, that the practice may have entered China from the south, through India and perhaps south-east Asia. The earliest date for wheat in Tibet at Changguogou falls in the late 4th to early 3rd millennium BP (1439–804 cal. BC) (Fu et al., 2000). Dating was based on charcoal and bone found in association with wheat grains. In Yunnan in south-west China the earliest is the site of Haimenkou with wheat dated to around 3300 BP (Yunnan Museum, 1958). In Tibet, at the site of Karuo, millet farming is documented more than 3000 years earlier than wheat (Tibetan Relics and Sichuan University, 1985). This implies a long period of established agriculture before wheat was introduced to the region. Climate may have been a significant obstacle to the introduction of wheat through southern China. The assumed south route is located at low latitudes, with sub-tropical climates and a high altitude landscape, combined with a high level of rainfall, normally of more than 1000 mm per annum (Atlas of China, 1998: 40). These warm, wet conditions are not favorable for wheat cultivation.

A route through northern Afghanistan and Tajikistan into the south-western corner of the Tarim Basin in Xinjiang is a possibility. Access into Xinjiang from Central Asia and the Eurasian steppe is only possible over mountain passes. Natural routes follow rivers, several of which flow in an east-west direction. The suggestion of 8th millennium BP agro-pastoralists in northern Afghanistan and Tajikistan cannot be verified (Dupree, 1972; Harris, 1996: 563; Harris, 2010: 59), but the small number of known sites in these regions hints at quite early establishment of wheat cultivation. The site of Shortughai (Francfort, 1989; Willcox, 1989; Willcox, 1991) lies on the south bank of the Amu Darya near the ancient city of Ai Khanoum in northern Afghanistan. The earliest levels at the site, dating from the 5th millennium BP, indicate its apparent establishment as a Harrapan outlier, with later levels indicating influences from the Central Asian Bactrian/Margianan Bronze Age. Given the evidence from Mehrgarh (Meadow, 1996), this might indicate that wheat was introduced from the south, but the archaeobotanical evidence indicates that agriculture in the Ai Khanoum plain was already adapted to the local environment from the establishment of the site and showed few affinities with that of the Indus Valley (Willcox, 1991: 151). Similarly, the agricultural sites that arise in Kashmir in the early 5th millennium BP appear

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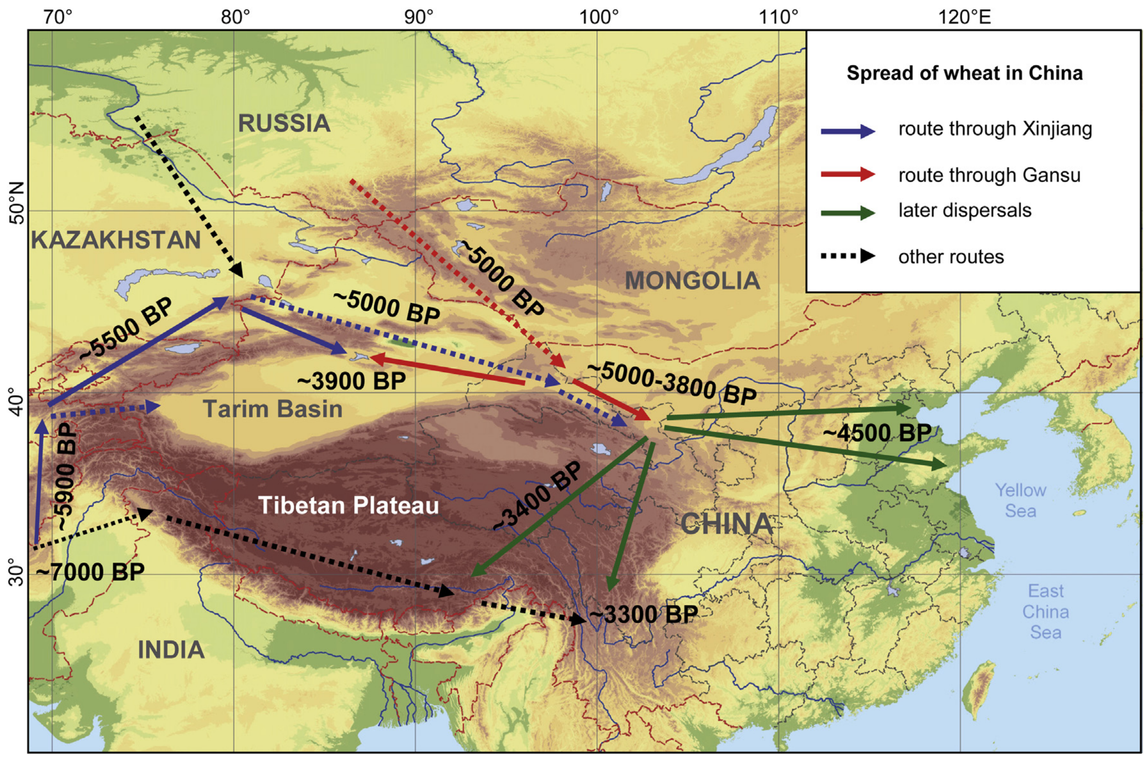

Fig. 2. Map showing possible routes for the introduction of wheat into China. Age estimates are based on calibrated radiocarbon dates.

with apparently already well developed agricultural economies, implying the possible existence of earlier cereal cultivating settlements within the wider region (Bandey, 2009: 180).

On the north bank of the Amu Darya in southern Tajikistan late 4th millennium BP settlements of the Sapilli culture with links to the Bactria/Margiana complex have been found in the Hissar, Tairsu and Vaksh valleys. Earlier Bronze Age sites have not yet been found here but they may exist as cultures derived from the Neolithic Hissar culture (P'yankova, 1994: 368). Good (2007) suggests the presence of an early agro-pastoral Bronze Age, based on complex patterns of transhumance in the varied web of environmental zones around the Pamirs and the Wakan Corridor. Tributaries of the Vaksh run up to the Kyzylsu, the headwaters of which lie on the opposite side of a watershed feeding the headwaters of the River Kashgar. This is a principal source of water for the Kashgar oasis in the western Tarim where there are several sites known from regional survey which have the potential to yield information on early wheat farming in this area, particularly Aketala (Kashgar) (Xinjiang Museum, 1977), which lies on the south-western edge of the Taklamakan Desert. Surface collections at Aketala indicate that the ceramics from the site may be dated to around 4000 BP. The Xinjiang chronology is only very loosely established and on the basis of comparison with excavations in nearby regions the site may well be earlier. The lithics from the site indicate that this might be the case (Jia et al., 2009; Shao, 2007: 44). Some well-made stone sickles collected from Aketala suggest intensive harvesting activities, perhaps related to wheat farming (Shao, 2007: 44).

Moving northwards along the western flanks of the Pamirs and the Alai mountains, the site of Sarazm, with evidence for wheat cultivation from the mid-6th millennium BP, lies on the Zarafshan, upstream from the oasis of Samarkand. The headwaters of the Zarafshan are only a watershed away from the Kyzylsu valley so that a route might also have led into the Kashgar oasis. North of the Zarafshan, the rich, fertile Ferghana valley stretches far eastwards into the south-western Tianshan. Isolated finds from the Ferghana valley indicate the appearance of peoples from the south-western oases around the late 5th to early 4th millennium BP (Masson, 1992: 244). The Syr Darya follows the valley and provides a route up to the modern town of Naryn from where routes cross the mountains south into the Tarim Basin, connecting again with Kashgar, and north into the Chu valley from where there are further routes north into the Ili valley and east-south-east along the Tianshan down to Korla on the northern rim of the Tarim Basin. There is evidence for the use of this latter route linking the northern Tarim with the steppe in the later Bronze Age by at least the late 4th millennium BP. Finds from the site of Xintala in Heshuo county, in the southern foothills of the Tianshan bordering the Tarim Basin, included grey-black pottery and a socketed axe that find parallels in the Andronovo culture that broadly dominated the Eurasian steppe at that time (Mei and Shell, 1999; Kuz'mina, 1998).

The Ili River rises in the western Tianshan and runs out into Lake Balkhash in Kazakhstan. The site of Jilintai in the Ili valley in Xinjiang contained a basal level with microlithic cores underlying cultural levels associated with the Andronovo (Ruan, 2004). The Ili valley is accessible by passes from Kyrghyzstan or directly from the Kazakh steppe. Passes lead from its headwaters over the Tianshan north into the Zhunge'er (Junggar) Basin and south into the upper rim of the Tarim Basin. Just to the north of the Ili valley, in Kazakhstan, wheat broadly identified as *T. aestivum/turgidum* and dated to the late 5th millennium BP (2460–2150 cal. BC) has been identified from the site of Begash on an upper tributary of the Koksu River (Frachetti et al., 2010). The carbonized grains were found together with millet in a burial context on a site apparently associated predominantly with pastoral activity. Frachetti suggests that the grains resemble Indian dwarf wheat, *T. aestivum* spp. *sphaerococcum*, found in India and Pakistan and common on Harappan sites in the northern Indus Valley in the 5th–4th millennia BP (Weber, 1999: 821–2; Kajale, 1991: 160, 171). If this was the case then, as suggested by Frachetti et al. (2010: 1002), the wheat may have arrived from the south through the Pamirs, the Alai and the western Tianshan rather than being carried across the Kazakh steppe.

Continuing northwards, other possible routes lead through the Tacheng lowlands and the E'erqisi valley along the upper reaches of the Irtysh River into the Zhunge'er Basin. This latter route might also have led on into the Mongolian steppe as suggested by Zhao (Zhao, 2008). The site of Xiakalanggu'er in the Tacheng district on the western rim of the Zhunge'er Basin (Yu, 1998) is one of a number of settlement sites along the banks of the Kalanggu'er River. The pottery is distinct and does not find clear parallels in other regional assemblages, but the chipped stone suggests a fairly early Bronze Age or late Chalcolithic date (ca. 5500–4000 BP) for these sites (Jia et al., 2009). On the sandy banks of the E'erqisi River are numerous palimpsest spreads of microlithic tools probably indicative of a pre-Bronze Age culture based extensively on fishing.

While as yet evidence for very early agriculture is absent, within the Zhunge'er basin there are Bronze Age sites that show links with the Eurasian steppe. The earliest of these are the Qiemu'erqieke sites in northern Zhunge'er and southern Mongolia (Xinjiang Kaogusuo, 1981; Jia and Betts, 2010). Related finds are reported from Xikanerzi in Qitai (Qitai Wenhuaguan, 1982; Jia et al., 2009). The date of the Qiemu'erqieke cultural complex has been the subject of some discussion but there are indications that the earliest stage may date in the late 5th to early 4th millennium BP, possibly contemporary with the later Afanasievo but more likely with the Okunevo tradition of the Upper Yenisei in southern Siberia (Jia and Betts, 2010). The Qiemu'erqieke cultural complex is known only from cemeteries and thus nothing is yet known of the economy. Further to the east the site of Kaersang in Yiwu (Wu, 1964) links the Zhunge'er Basin and the southern rim of the Mongolian Plateau, leading on to the Upper Yellow River area.

5. Discussion

What then can be made of this somewhat thin web of evidence? The hypothesis of indigenous domestication of wheat within China itself should probably be excluded, since the botanical evidence militates against it. Based on practical considerations and the admittedly sparse evidence, the case for the route into southern China via India is not strong, at least as an initial point of entry. The archaeological data suggest two other more convincing external routes but each has questions associated with it. A good case can be made for either one as a testable hypothesis but multiple points of entry at different times also cannot be excluded (Fig. 2).

One such route is from the far west of China, through Xinjiang. Although the dates for Xinjiang are slightly later than the earliest dates clustered around Gansu, overall, early dates are concentrated in north-west China while early dates in Central Asia are from sites fairly close in relative terms to north-west China. The absence of earlier dates in Xinjiang to match those in Gansu may quite simply be a matter of the very limited paleobotanical research yet conducted in Xinjiang.

Based on evidence to date, the earliest transmission of wheat cultivation into China probably occurred at some time between the mid-6th to early 5th millennia BP. If wheat did enter through Xinjiang then the external routes must be sought first in the hill country and then beyond to the steppes and oases to the west. The fact is that we know little in detail about the populations of eastern Eurasia and the mountain regions of Central Asia in the 6th and 5th millennia BP (Kuz'mina, 2007, 211). In the south, the Central Asian oases were home to settled, agriculturally based peoples at sites such as Namazga, Altyn-depe and Anau. Migrants from the Geoksyur Oasis appeared at Sarazm in the Zerafshan valley, presumably to exploit the rich mineral resources of the region. In doing so, by the mid-6th millennium BP they established cereal farming yet closer to the borders of Xinjiang. There are hints (Willcox, 1991; Dupree, 1972; Harris, 1996: 563; Harris, 2010: 59) that agriculture was established in the mountain regions of Afghanistan and Tajikistan earlier than the mid-5th millennium BP. In the north, in southern Siberia, the western Altai and eastern Kazakhstan, the Eneolithic Afanasievo culture has been documented through graves and associated material culture (Vadetskaya, 1986: 15–26). Broadly dated from the early 5th millennium BP (Svyatko et al., 2009), it is believed to be derived from migrating populations from the west (Kuz'mina, 2007: 214). The economy seems to have been based largely on herding. Cereal agriculture was known, but seems to have been rarely practiced (Frachetti et al., 2010: 994; Ryabogina and Ivanov, 2011). Recent stable isotope analysis of the diet of prehistoric populations along the Upper Yenisei in southern Siberia (Svyatko et al., 2013) suggests that agriculture only appears there from the Late Bronze to Early Iron Age, and was based on the cultivation of millet. However, although there is little evidence for wheat cultivation in the steppe, the still limited archaeological evidence from eastern Eurasia means that this route of transmission should not be ruled out.

The distribution of wheat types is also important. Recent DNA studies on naturally preserved wheat grains from Xiaohe have shown that bread wheat, *T. aestivum*, was grown in Bronze Age Xinjiang (Li et al., 2011). In the Eurasian steppe hulled wheats and barley were the dominant cereal crops throughout the Bronze Age with *T. dicoccum* one of the most widespread (Pashkevich, 2003: 294–6). A dwarf form of naked bread wheat, *T. aestivo-compactum*, appears first in the Bronze Age north of the Black Sea, but does not come to dominate until early medieval times (Yanushevich, 1989). Bread wheat, *T. aestivum*, as discussed above, is a hybrid, born of ancestral species that do not share the same habitat. Zohary and Hopf (2000: 54) suggest that its most likely area of origin was the south-western Caspian region, in and around modern Armenia and Georgia, at some time after 8000–7000 BP. This idea is supported by the fact that the bread wheats *T. aestivum* and *T. aestivo-compactum* were the two most widespread cereal crops in the Crimea and east of the Black Sea from as early as the 8th millennium BP (Yanushevich, 1989: 618; Yanushevich and Rusishvili, 1984). In the Kopet Dagh Neolithic, wheat from the site of Jeitun was predominantly glume wheat, *T. monococcum*, with a small amount of *T. dicoccum*. A few samples were tentatively identified as *T. aestivum.* The same cereal crop was found in larger amounts from the lowest levels at Anau (IA) (Miller, 2003) dating from the late 7th millennium BP (4447–3808 cal. BC) (Hiebert, 2003: 55). In northern Afghanistan, *T. aestivum* was found from the lowest levels at Shortughai, with indications that it may have been established in the region earlier than the 5th millennium BP (Willcox, 1991). *T. aestivum* was also found at mid-6th millennium BP Sarazm in Tajikistan (Willcox, n.d.). With the steppe dominated by hulled wheats while bread wheat saw an early spread across the Central Asian oases, this pattern lends weight to the likelihood that if wheat arrived into China through Xinjiang, then it arrived at the borders from the south-west rather than across the steppe.

Under this hypothesis, the vector for the transmission of wheat cultivation should be sought in the hill country of the Pamirs and the western Tianshan. Here the land was originally populated, albeit perhaps rather sparsely, by an earlier prehistoric population about which little is known (Jia et al., 2009: 175). Neolithic sites are represented mainly by scatters of chipped stone (An, 1992: 163; Matyushin, 1986), and the limited evidence for subsistence economies suggests that they were based on hunting, collecting and fishing. There is little clear evidence to suggest that there was long range migration of Bronze Age populations into Xinjiang, either from the steppe or from the oases. It seems at present more likely that the practice of cereal cultivation would have arrived in Xinjiang via cultural diffusion and short-range movements of peoples across the western mountains.

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Transhumant agro-pastoralism is a particular response to the conditions pertaining in the mountain regions from the Pamirs through the Tianshan to the Altai. Studies of modern communities in these mountain regions (Kerven et al., 2011) show that individual groups generally base themselves on a valley or valley system with low-lying cultivable land and permanent winter housing, together with upland grazing areas accessed in summer while the herders live in tents (Wagner et al., 2011). The growth of fodder crops is essential for the survival of their animals in winter, which obliges them to practice some form of cultivation. Agro-pastoralists engage in different kinds of cultivation, including gardens, hay meadows and fields producing food, usually cereals. Sometimes the level of cultivation can be quite minimal, as in the high Altai where areas of small streams are fenced off and irrigated to produce a crop of hay or, as in many areas in the western Tianshan, the lower reaches of the river valleys can be quite intensively cultivated.

In spring the animals are driven up into the high alpine pastures close to the mountain peaks. This practice brings herders from either side of the great mountain ranges into relatively close proximity, increasing the likelihood of contact and exchange of ideas (Frachetti, 2004: 414; 2008). Bronze Age burials have been found along the routes followed by modern transhumant pastoralists (P'yankova, 1994: 369), while evidence for high altitude transhumance in the mid-4th millennium BP comes from the identification of cashmere in cloth from oasis sites along the southern rim of the Tarim Basin (Good, 1998; Debaine-Francfort and Abduressul, 2001). Cashmere comes from goats specifically adapted to high altitude. Agro-pastoral groups have now been documented on the western side of the Zhunge'er range in Semirech'ye by the late 5th millennium BP (Frachetti et al., 2010) and in Xinjiang by the late 5th to early 4th millennium BP (Xinjiang Kaogusuo, 2003; Flad et al., 2010). The former is based on mountain transhumance, the latter represents an adaptation to oasis living. Abundance of wheat at sites such as Xiaohe and Gumuguo indicates not simply supplementary wheat cultivation but the intensification of wheat agriculture (Flad et al., 2010).

The obvious problem with this hypothesis is that the earliest dates for wheat in China are not in Xinjiang, but in Gansu. This could simply be due to the limitations of archaeological research in Xinjiang. Earlier sites may not yet have been found. At sites such as Xiaohe wheat cultivation is clearly well developed, implying an earlier, as yet unknown, history of more limited cultivation. However, it is also necessary to consider that Gansu might have truly been the first point of entry. This second hypothesis has already been put forward by Dodson et al. (2013). The authors suggest that wheat based agriculture arrived in established millet growing areas of Gansu via Russia or Mongolia, and its use as a crop expanded regionally and then east and west over around 300–400 years. Based on the evidence from China alone, this is, in fact, the most robust model. It has problems, however, in that it postulates the introduction of wheat from the north-west, from southern Siberia through Mongolia in areas which, although admittedly also under-researched, show little signs of early agriculture (Ryabogina and Ivanov, 2011; Svyatko et al., 2013). Svyatko et al. (2013) in fact argue that the route of transmission was in the other direction; that millet agriculture was introduced to southern Siberia from China. In addition, the line of transmission would reach back into Eurasia, presumably via the Afanasievo culture, where although there was probably some knowledge of agriculture, as argued above, the wheat cultivated is most likely to have been *T. dicoccum* rather than *T. aestivum*.

6. Conclusions

The evidence is still sparse but sufficient to suggest some conclusions. Wheat is likely to have come into China around the mid-6th to early 5th millennia BP. Indigenous domestication of wheat within China can probably be ruled out. Introduction of wheat into China from the south via India seems unlikely, at least as the main route for its first appearance, although its role as a secondary route cannot be ruled out altogether. Two more likely models can be suggested, but each has some problems. The earliest wheat found in China so far is in the region of Gansu, suggesting the possibility of entry from the north-west from southern Siberia through Mongolia, arriving into pre-existing millet cultivating agricultural economies. However, the archaeological data for the prehistoric economies in the potential source regions outside China show little evidence for agriculture in the relevant period, and any wheat that may have been cultivated there around the 6th to 5th millennia was most likely to have been not bread wheat but hulled wheat. The second model, the route through Xinjiang, is supported by the presence of cultivated bread wheat on the western fringes of the mountains bordering Xinjiang by the 6th millennium BP, but lacks clear evidence thus far for 5th millennium BP wheat cultivation within Xinjiang itself. However, with time both models can be tested and a clearer picture may emerge.

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