Middle Pleistocene bifaces from Fengshudao (Bose Basin, Guangxi, China)

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ABSTRACT

The Bose (also Baise) Basin in Guangxi, southern China is well known for the presence of Paleolithic bifacially worked implements. The Bose Basin handaxes came to the attention of the international scientific community primarily for two reasons: 1) the age at 803 ka (thousands of years), places it at the Early to Middle Pleistocene transition; and 2) the presence of bifaces tests the validity of the Movius Line and whether it was time to simply discard the model. However, questions were almost immediately raised because the age was based on the supposed association of Australasian tektites that may or may not have been redeposited, and at the time of the initial publications all of the Bose Basin handaxes were surface collected. Thus, whether the Bose bifaces can necessarily be associated with the tektites and whether the tektites themselves were redeposited are important considerations. Here, we report the findings from recent excavations from the Fengshudao site located in the Bose Basin. The primary findings are: 1) the in situ excavation of tektites, which do not appear to have been redeposited, in association with bifaces from one stratigraphic level from one site indicates that the age of these stone tools should be around 803 ka; 2) the Fengshudao hominins were utilizing locally-available quartz, quartzite, and sandstone river cobbles; and 3) in a number of aspects, the Fengshudao handaxe morphology differs from the typical western Acheulean, and are quite large and thick compared with even the bifaces from other regions of eastern Asia (e.g., Luonan Basin, China; Imjin/Hantan River Basins, Korea). Although Fengshudao may be a case of western Acheulean hominins dispersing into the Bose Basin from nearby South Asia, it is quite possible that the Fengshudao bifaces can be considered an example of convergent evolution.

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Introduction

Variation in behavioral evolution across space and time during the Quaternary has often posed very perplexing problems for prehistorians. For instance, explaining the presence/absence in bifacially worked implements east and west of the Movius Line has traditionally been one of the most debated topics in Paleolithic archaeology (e.g., Movius, 1944; Boriskovskii, 1968; Hutterer, 1977; Yi and Clark, 1983; Watanabe, 1985; Huang, 1987, 1993; Bae, 1988; Pope, 1989; Clark, 1994; Schick, 1994); a debate that is still being intensively discussed and deliberated today, with more emphasis now on evaluating the morphological variation in the handaxes (e.g., Hou et al., 2000; Leng and Shannon, 2000; Norton, 2000; Keates, 2002; Corvinus, 2004; Wang, 2005; Norton et al., 2006; Lycett, 2007; Yoo, 2007; Lycett and Gowlett, 2008; Wang et al., 2008; Norton and Bae, 2009; Petragnia and Shipston, 2009; Brumm, 2010; Lycett and Bae, 2010; Lycett and Norton, 2010; Norton and Lycett, 2010; Shipston and Petragnia, 2010; Bar-Yosef et al., 2012; Wang et al., 2012). Explanations for the archaeological patterning of the Movius Line include (as recently reviewed by Brumm, 2010; Lycett and Bae, 2010; Lycett and Norton, 2010;
some would argue (e.g., Norton et al., 2006; Norton and Bae, 2009; Lycett and Bae, 2010; Lycett and Norton, 2010) that the pattern in the archaeological record that Movius originally observed is still more or less supported by what we currently know of the record. Indeed, the Movius Line was recently reconfigured into a Movius Line sensu lato (Norton et al., 2006) that still acknowledges many of the original observations made by Movius, but better reflects the current state of the eastern Asian Paleolithic record today. The primary points of the Movius Line sensu lato (Norton et al., 2006) are: 1) the number of sites in eastern Asia that have handaxes are much fewer than west of the line; 2) the sites in eastern Asia that have bifaces occur in very low frequencies (~5%); 3) the handaxes that are found east and west of the line are generally morphologically different; and 4) there is an absence of the Levallois technique in younger, overlying layers in eastern Asian sites that do have bifaces (Norton et al., 2006; Norton and Bae, 2009; Lycett and Bae, 2010; Lycett and Norton, 2010).

Regarding Point 3, a number of recent studies have suggested that at least some of the eastern Asian materials can be classified as typical Acheulean (e.g., Hou et al., 2000; Wang, 2005; Petraglia and Shipton, 2009; Mishra et al., 2010; Shipton and Petraglia, 2010; Simanjuntak et al., 2010; Zhang et al., 2010). Indeed, in their examination of the bifaces from Indonesia, Simanjuntak et al. (2010:420) recently argued that “the Pacitan (and other Indonesian) handaxes ought to be classified as ‘normal’ handaxes.” Nevertheless, a growing number of studies suggest that the handaxes east and west of the Movius Line are noticeably different (e.g., Norton et al., 2006; Lycett, 2007; Norton and Bae, 2009; Lycett and Norton, 2010; Wang et al., 2012). We address this third point in more detail below.

Although Movius (1944, 1956) initially described some proto-handaxes from Indonesia and picks from Dingcun, China, it was not until bifacially worked implements were discovered in 1978 at Chongokni, in Korea, that archaeologists more strongly argued to discard the Movius Line (e.g., Yi and Clark, 1983). Nevertheless, as noted by Norton et al. (2006), despite the fact that Paleolithic archaeologists have been intensively searching for handaxes for more than half a century in eastern Asia, bifacially worked implements are still known from only five core sites/basins: Indonesia (Movius, 1944; Mishra et al., 2010; Simanjuntak et al., 2010); Imjin/Hantan River Basins (IHBB), Korea (Yi, 1986; Bae, 1988, 1994, 2002; Norton, 2000; Norton et al., 2006; Yoo, 2007; Norton and Bae, 2009); Dingcun, China (Movius, 1956; Pei et al., 1958); Luonan Basin, China (Wang, 2005); and Bose/Baise Basin, China (Hou et al., 2000; Xie and Bodin, 2007; Wang et al., 2008, 2012; Zhang et al., 2010).² The focus of this paper is the handaxes from this latter region.

The Bose (or Baise) Basin is located in western Guangxi Zhuang Autonomous Region, southern China, extending in a northwest-southeast direction (Fig. 1). The basin is ∼80 km in length and ∼15 km in width. Currently, 113 Paleolithic sites have been identified and 13,767 stone artifacts (7405 from excavations, 6362 from surface surveys) collected (Huang et al., 2012). More than 300 handaxes have been discovered, primarily from surface surveys, and 282 tektites derive from excavations and surface survey. Handaxes from the Bose Basin have been known since 1973 (Li and You, 1975), but it might be argued that it was not until the publication of the Hou et al. (2000) paper that the Bose bifaces really came to the attention of the broader international scientific community. Following the publication of the Hou et al. (2000) study, two criticisms were raised, primarily focused on the age of the bifaces (~803 ka [thousands of years]). First, the age of the Bose Basin bifaces were based on their supposed association with Australasian tektites that were dated to ∼803 ka. It was suggested that tektites are normally redeposited and that even if the tektites were dated, it did not mean they could necessarily be associated with the stone artifacts (Koeberl and Glass, 2000). Second, at the time of the Hou et al. (2000) publication, no handaxes from Bose had been found in situ (S.L. Lin, 2002). We present a detailed study of a set of bifaces and tektites that were excavated and surface collected from the Fengshudao site, located in the Bose Basin, that can be used to address both of these concerns (see also similar, though not as extensive, findings from the nearby Damei site; Wang et al., 2008).

Furthermore, it was suggested that there was substantial overlap in morphology between the Bose Basin and western Acheulean bifaces (e.g., Hou et al., 2000; Zhang et al., 2010). We test this latter hypothesis by placing the Fengshudao handaxes in broader comparative perspective by conducting a series of inter-regional metric comparisons with bifacial assemblages from the IHRB, Luonan Basin, and the western Old World (for a recent geometric morphometric analysis of the Bose Basin bifaces, including many from Fengshudao, see Wang et al., 2012).

**History of paleoanthropological research in the Bose Basin**

Initial Paleolithic archaeological field surveys in the Bose Basin began in 1973 (Table 1). Based on a dozen stone artifacts that were surface collected from the Shangsong site, the researchers assigned these stone tools to the traditional heavy duty pebble tool culture in South China, with an age estimated to be Late Pleistocene (Li and You, 1975). Between 1977 and 1983, several local museums conducted more intensive field surveys in the basin, which resulted in the discovery of dozens of Paleolithic open-air sites. These surveys led to the collection of more than 6000 stone artifacts, including dozens of bifacially worked handaxes (Zeng, 1983). During this time period, a test excavation was conducted at the Changsheling site in eastern Bose (Qin et al., 1983). Although numerous Paleolithic sites and a large number of stone artifacts were found during this period, the nature and age of the Bose Paleolithic was still ambiguous. Between 1988 and 2000, a long term, comprehensive multidisciplinary research program was conducted in Bose that involved more detailed geological investigations, more systematic archaeological excavations, and chronometric studies. Based on the excavations conducted at the Gaolimgpo site in 1988, 1989, 1991, 1993, and 1995, the Bogu site in 1993, and the Xiaomei site in 1996, it was determined that most of the stone artifacts derived from the laterite of the fourth fluvial terrace (Huang et al., 1990; Hou et al., 2011).

**Geological history and age of the Bose Basin**

The Bose Basin is a pull-apart basin formed at the beginning of the Paleogene (Li, 2001). During the Eocene, the basin was a northwest-southeast facing extended lake, filled by sediments of lacustrine mudstone, sandstone and deltaic sandy conglomerate, with thickness of up to 3500 m in some areas (Chen et al., 2005). At the end of the Eocene, the Paleogene strata were compressed,
folded and uplifted, leading to the disappearance of the lake and formation of a residual rift basin (Li, 2001; Liao et al., 2005). The Youjiang River appeared inside the basin sometime during the Early Pleistocene, which eroded the older sediment and deposited new sediment, leaving at least four terraces (Yuan et al., 1999).

The Bose Basin is mainly surrounded by low mountains composed of Triassic sandstone, shale and mudstone, with elevations between 500 and 1500 m above sea level (m asl). The southeastern section of the basin is enclosed by Permian limestone and dolomite, where the karstic forests, depressions and multilayered caves are widespread. The Youjiang River cuts through the Bose Basin, from ~109 m asl in the northwest down to ~81 m asl in the southeast. Ten to 15 m cutbanks are usually present on both sides of the river, with the alluvial plains poorly developed. The Youjiang River and its tributaries typically meander down through the basin rather than moving in a straight line (Yuan et al., 1999).

In general, the fluvial terraces are flat and broadly distributed on both sides of the Youjiang River. Laterized fluvioglacial deposits of Late Pliocene and Pleistocene age crop out and form five distinct river terraces (T1 through T5) of differing elevation. The formation of these terraces is associated with episodic uplift of the Qinghai-Tibetan Plateau (Hou et al., 2000). Terrace 1 (T1), which is the most extensive and stable stratum, is situated 10–15 m above the current level of the river. Terrace 1 is comprised of upper light yellow sandy clay underlain by a gravel bed. The upper part of T1 contains Neolithic artifacts, such as those found at the Gexinqiao site (Xie et al., 2003), suggesting that the age of T1 should be terminal Pleistocene and/or Early Holocene. Based on our recent field observations, the second and third terraces (T2 and T3) are also developed in the basin, but not as extensive as T1 and T4. Currently, no Paleolithic deposits of note have been identified in T2 or T3. Terrace 2 usually crops out as a small-scale platform around 10–15 m above T1 and consists of upper yellow-red sandy clay and a lower light gray gravel bed. Terrace 3 is commonly distributed, currently identified only in the middle and western part of the basin. Terrace 3 is represented as a small to large platform or slope about 20–30 m above T1 and is comprised of upper middle weathered reticular mottled red-yellowish clay and a lower gray gravel bed, about 15 m thick (Huang et al., 2012; Xu et al., 2012).

The most important terrace in the basin is Terrace 4 (T4). Besides T1, T4 is also the most extensively developed terrace in the area. Terrace 4, fragmented by faulting, forms several platforms situated 25–100 m above the present river level. Terrace 4 consists of an upper sedimentary unit, 7–10 m thick, of poorly developed latosols underlain by reticular mottled red clay typical of laterites, and of a lower unit, 5–20 m thick, of well-sorted cobble conglomerate. In general, the state of preservation of T4 varies throughout the basin. In most places, T4 is highly eroded and forms isolated platforms. However, in a few areas, T4 is well preserved on a large scale, with some of the platforms being over 5 km² wide, such as the Damei site near Bose City.

Although reports state that seven terraces are present in the Bose Basin (Yuan et al., 1999; Hou et al., 2000; Huang et al., 2012; Xu et al., 2012), our recent research suggests that only the fifth terrace (T5) may be identified in the basin. For instance, at the Fengshudao site, where the upper fine sediment has eroded over time, only the lower conglomerate cobbles, which overlie the Paleogene strata about 15 m above T4, are preserved. The sixth and seventh terraces were previously defined on the basis of small linear platforms in association with surface scattered gravels. For example, such deposits were found at the Gaocunshan site at a height of 265 m asl. However, further studies suggest that these strata are difficult to distinguish with any confidence from T5. Recent systematic archaeological investigation show that T4 Paleolithic sites vary in elevations from 152 to 298 m in the west Bose Basin (Huang et al., 2012), implying strong regional differential uplifting. The terrace sequence in the basin needs further documentation in the future. Although all of these terraces have been fragmented by faulting and weathering to varying degrees, T4 is not difficult to identify. This is largely because of the presence of large-scale platforms with eroded badlands at the edges, strongly weathered deposition, and

Figure 1. Location of Fengshudao in Bose Basin.
<table>
<thead>
<tr>
<th>Paleolithic site</th>
<th>Date of discovery</th>
<th>Artifacts</th>
<th>Summary</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shangsong</td>
<td>1973</td>
<td>11 stone artifacts, including four cores, six choppers and one scraper surface collected.</td>
<td>Paleolithic tools were first recognized by a research team from the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Guangxi Museum and Guangxi Petrogeology Research group at the Shangsong site in northwest Bose Basin.</td>
<td>Li and You, 1975</td>
</tr>
<tr>
<td>71 sites in the Bose Basin</td>
<td>1977–1978</td>
<td>5150 stone artifacts, including 60 handaxes surface collected.</td>
<td>Youjiang Ethnological Museum carried out an extensive survey in the Bose Basin, led to the identification of numerous Paleolithic sites and a large numbers of stone artifacts were surface collected.</td>
<td>Zeng, 1983</td>
</tr>
<tr>
<td>Changsheling</td>
<td>1979</td>
<td>Four stone artifacts excavated in situ, 106 stone artifacts surface collected.</td>
<td>A test excavation was conducted by the Guangxi Museum at the Changsheling site in Tiandong County. Small number of stone artifacts were excavated from laterite deposit, two handaxes (originally called pointed-chopper) were surface collected.</td>
<td>Qin et al., 1983</td>
</tr>
<tr>
<td>Numerous sites</td>
<td>1982–1983</td>
<td>~1000 stone artifacts surface collected.</td>
<td>The Guangxi Museum carried out an extensive survey in the Bose Basin, numerous Paleolithic sites were found and a large numbers of stone artifacts were surface collected.</td>
<td>Xie et al., 2003</td>
</tr>
<tr>
<td>Gaolingpo (or Tanhe)</td>
<td>1988–1991</td>
<td>100 stone artifacts excavated in situ.</td>
<td>IVPP, Guangxi Museum, and local museums carried out two test excavations at the Gaolingpo site (or Tanhe). About 100 stone artifacts were excavated from T4 laterite deposits, age was estimated to be the Middle Pleistocene and possibly penecontemporaneous with Zhoukoudian Locality 1.</td>
<td>Huang et al., 1990</td>
</tr>
<tr>
<td>Gaolingpo and Bogu</td>
<td>1993</td>
<td>503 stone artifacts and nine tektites excavated in situ.</td>
<td>A joint team, formed by IVPP, Guangxi Museum, Natural History Museum of Guangxi (NHMG), Institute of Geology and Geophysics (IGG) in China, and the National Museum of Natural History (NMNH) in USA, carried out two formal excavations in the Gaolingpo and the Bogu sites, respectively. 433 stone artifacts and three tektites were excavated in Gaolingpo, and 70 stone artifacts and six tektites were unearthed in Bogu.</td>
<td>Hou et al., 2000, 2011</td>
</tr>
<tr>
<td>Poxiling</td>
<td>1994</td>
<td>244 stone artifacts excavated in situ.</td>
<td>Guangxi Museum excavated at the Poxiling site in east Bose Basin. Hundreds stone artifacts were recovered from T4 laterite deposit, including choppers, picks, scrapers and débitage.</td>
<td>Q. Lin, 2002; S.L. Lin, 2002</td>
</tr>
<tr>
<td>Xiaomei</td>
<td>1996</td>
<td>36 stone artifacts and two tektites excavated in situ.</td>
<td>A joint IVPP, IGG, NHMG and NMNH team carried out an excavation in Xiaomei, and extensive geomorphological survey of the entire basin. The terrace system has been affirmed in the basin, T1 through T7.</td>
<td>Yuan et al., 1999; Hou et al., 2000</td>
</tr>
<tr>
<td>Shangsong</td>
<td>2002</td>
<td>185 stone artifacts and 106 tektites excavated in situ.</td>
<td>The Guangxi Museum conducted an excavation at the Shangsong site, nearly 200 lithic artifacts and plentiful tektites were recovered from T4 laterite deposit with area of 1000 m².</td>
<td>Xie et al., 2003</td>
</tr>
<tr>
<td>Baidu</td>
<td>2002</td>
<td>1500 stone artifacts excavated in situ.</td>
<td>The Guangxi Museum carried out a formal excavation at the Baidu site in Tiandong County, eastern Bose Basin.</td>
<td>Xie et al., 2010</td>
</tr>
<tr>
<td>Liuhaishan</td>
<td>2005</td>
<td>136 stone artifacts excavated in situ.</td>
<td>A field team from the IVPP carried out an excavation at the Liuhaishan site in western Bose Basin.</td>
<td>Pei et al., 2007</td>
</tr>
<tr>
<td>Fengshudao</td>
<td>2004–2005</td>
<td>88 stone artifacts, including five handaxes, and nine tektites excavated in situ.</td>
<td>A field team from the NHMG carried out a formal excavation at the Fengshudao site in northwest Bose Basin. It is the first time that handaxes were unearthed in situ in the Bose Basin. Before 2004, all of the handaxes in the basin were surface collected.</td>
<td>This paper</td>
</tr>
<tr>
<td>Hengshandao, Luci, Labakou</td>
<td>2005</td>
<td>123 stone artifacts, including 33 handaxes surface collected.</td>
<td>These sites are situated close to the Fengshudao site. The original T4 sediments were eroded, however, dense concentrations of stone artifacts were exposed on the surface, including 33 handaxes, 21 picks, 18 cores, 15 flakes, 7 scrapers, 18 choppers and 11 utilized pieces.</td>
<td>This paper</td>
</tr>
</tbody>
</table>

(continued on next page)
What exactly tektites are, including their origin, has been the focus of much debate over the past half century (Faul, 1966; O’Keefe, 1976; Koeberl, 1990). Although it was originally suggested that tektites were of lunar origin, most researchers appear to accept that they originated from terrestrial near-surface deposits, almost likely from asteroid and/or comet impacts (Koeberl, 1994). The generally accepted hypothesis is that when an asteroid or comet impacts the earth, the near-surface rocks get melted by the impact, transformed into tektites, and then are spewed out as part of the resulting vapor cloud and with a distribution range dependent on variables such as size of the extraterrestrial object and speed of the original impact. These depositional areas are usually referred to as strewn fields (Koeberl, 1994). Four primary strewn fields are known worldwide (North America, Central Europe, Ivory Coast, Australasia), with impact craters associated with at least two of them (Ivory Coast, Central Europe). It is not clear which impact craters the Australasian and North American strewn fields originated from Koeberl (1994). Irrespective of the size of a particular strewn field, all tektites associated with that specific strewn field are considered to be the result of a single impact event.

Tektites in the Bose Basin are only found distributed in the reticcular mottled red clay of the upper unit of T4 within a zone 20–100 cm thick. This is typically 5–7 m above the top of the lower unit of T4. In general, the Bose tektites are very fresh, translucent, black or olive-green color, with sharp edges and bubble/etch pits or flow bands; thus, implying an original deposit (Zhu et al., 2001). This appears to differ from the depositional (or re depositional) histories of tektites in places like Indonesia (Koeberl and Glass, 2000). Macroscopically identified tektites less than 5 cm in diameter commonly exhibit delicate forms, such as elongate, sphere, ellipse, plate, stick, dumbbell, teardrop, tile, shell and irregular shapes. The thin, angular features of these tektites would not have survived transportation and redeposition by water. However, some tektites are larger than 10 cm in diameter; the margins preserve flow-like features and bubbles that are absent only a few millimeters into the body of the tektites. These larger tektites are typically spherical, ellipsoidal to cakey and original splashform shaped, with sharp-edged pits and other features commonly present on one side and smooth, melt-like features on the opposite side (Potts et al., 2000).

The characteristics of the Bose tektites are not unlike those from other tektite fields found along the south coast of Guangxi, Leizhou Peninsula, Hainan Island in South China and Southeast Asia (Zhang et al., 1994; Huang, 1995). Thus, it is generally assumed that the Bose Basin tektites are part of the Australasian strewn field. These Australasian tektites have been dated to 732 ± 39 ka by fission track (Guo et al., 1996) and 803 ± 3 ka by 40Ar/39Ar (Hou et al., 2000).

### Background of the Fengshudao site

Fengshudao is located along the south bank of the Chengbihe River, a tributary of the Youjiang River, northwest Bose Basin (N23°57′39″, E106°40′39″) (Fig. 2). This branch originates from an underground river in the karstic mountains of the southeast Yunnan-Guizhou Plateau, and cuts through Eocene hills before joining the Youjiang River at Bose City. Fluvial terraces are developed on both sides of the Chengbihe River. However, only T4 and T5 are exposed at present. Because a reservoir was built in 1957 at Chengbihe, creating Chengbihe Lake, the lower terraces are currently under water (Fig. 1). Early to Middle Pleistocene laterite covers the higher ground, forming numerous ‘red’ islands and peninsulas in the reservoir. Fengshudao is one of these laterite islands and was chosen for excavation due to the presence of bifacially worked stone implements that were found abundantly on the surface and eroding out of the T4 sediments as well.

A 49.3 m² area was excavated at Fengshudao during a seven week field season from December 2004 to January 2005. Using standard archaeological excavation techniques, eight 2 × 2 m
squares and two 1 × 2 m squares were excavated in 5 cm arbitrary levels down to the gravel bed. A 13.3 m² geological trench was also excavated toward the south upper part of the hill (Figs. 3–4). The site lies within T4, extending 100 m east to west, and sloping from north to south roughly 10–30 m. A high density of stone artifacts was found eroding out of the sediment. A few fresh stone artifacts were exposed in the excavation squares, while several tektites and a diversity of stone artifacts were surface collected, including ~ 100 bifacial tools. The excavated artifacts were three-dimensionally piece plotted.

Stratigraphy and tektites

The Fengshudao stratigraphy is similar to other Paleolithic sites in the Bose Basin, such as Bogu, Yangwu, Xiaomei, and Damei in western Bose, Nalai and Laikui in middle Bose, and Gaolingpo in eastern Bose. The stratigraphy can be divided into four layers (from top to bottom) (Fig. 5):

1. Brown fine sandy clay (~ 40 cm);
2. Reddish fine sandy clay, poorly developed latosols, containing a few intermediate sized weathered gravels (~270 cm);
3. Red sandy clay (reticular mottled clay), containing stone artifacts, tektites, and charcoal (~750 cm) (for all intent and purposes, this is T4);
4. Light brown gravel bed, well-sorted cobble conglomerate (~100 cm)
5. Eocene sandstone

Nine tektites were excavated in situ at Fengshudao, one from the trench and the other eight in five of the squares. All of the tektites are distributed between 185.95 and 187.06 m asl, restricted to an interval in 110 cm. They are of typical shape and color, and their average length is 24.23 mm (S.D. = 12.25) and average weight is 11.96 g (S.D. 20.48), indicating a wide range of variation (Fig. 6) (Table 2). Due to the lack of evidence of rounding, sorting, or erosion, none of the tektites appear to have been transported long distances or redeposited. Although tektites are rarely discovered in

Figure 3. Plan of the Fengshudao excavation.

Figure 4. Photograph taken during the excavation of Fengshudao site.
situ in Australasian strewn fields (Koeberl and Glass, 2000), the sedimentary and stratigraphic context, composition, and morphology of the Fengshudao tektites suggest that they did not move very far after landing on the site. In other words, anything found in T4 can be confidently associated with the tektites.

**Lithic assemblage**

The excavated lithic assemblage from Fengshudao is comprised of 155 artifacts (Table 3). As stated above, all of the artifacts are restricted to T4 (here our level 3; see also Fig. 3). The artifacts include cores, whole flakes, bipolar cores, bipolar flakes, scrapers, choppers, a pick, handaxes, chipped cobbles, débitage, and manuports. The composition of the Fengshudao lithic assemblage is broadly similar to many of the other Early Paleolithic stone tool assemblages from Bose. The primary difference is that there is a relatively heavy concentration of bifacially worked implements at Fengshudao compared with the other Bose localities.

One of the interesting features of the Fengshudao materials is that five bifacially worked implements were excavated in situ (Fig. 7). Using the Leakey (1971) classification system, we classify these five heavy duty tools as handaxes. Because of the importance of finding in situ bifaces in Bose, we describe these five artifacts in more detail in Supplementary Online Material (SOM) 1 (see also Fig. 8).

**Raw materials**

The Fengshudao site is located on the south bank of the Chengbihe River, a primary tributary of the Youjiang River. All of the stone artifacts and manuports unearthed from this site are made of locally available fluvial cobbles. Therefore, we examined the continental deposits of Eocene fluvial/lacustrine and Quaternary fluvial sediments around this area to assess the raw material selectivity of these toolmakers. The Eocene sediments are comprised of two formations called Nadu and Gongkang (Tang et al., 1974). The Nadu Formation is formed by mudstone, coal and freshwater limestone, while the Gongkang Formation is formed by mudstone, sandy shale and sandstone. Quaternary sediments include five terraces (T1–T5). Terrace 5 can only be recognized by several platforms on the top of the Fengshudao hills, ~215 m asl, which preserve partial red clay and scatters of large cobbles. The T5 cobbles are rounded, formed mainly by weathered sandstone, and are 20–50 cm in maximum dimension. Terrace 4 is represented by an upper laterite layer about 10 m thick and a lower gravel bed about 2 m thick. The gravel bed contains many large cobbles, composed of sandstone, quartzite, quartz and lava. The gravel bed cobbles are 10–30 cm in maximum dimension.

Except for the cobbles from T5 and T4, no other source of similarly-sized rounded cobbles such as those used at Fengshudao is present anywhere else in the study area. Although it was
previously suggested that the Bose toolmakers used raw materials from cobble outcrops that were exposed throughout the basin after an episode of woody plant burning and widespread forest destruction initiated by the tektite event (Hou et al., 2000), our more recent geoarchaeological research suggests the utilized cobbles from the T4 gravel bed were a deliberate choice by the hominins. This opinion is reinforced by two observations made during our recent fieldwork: 1) stone artifacts are not only found in the laterite bed, but also the gravel bed of the exposed profile at Fengshudao; and 2) gravels from the present Youjiang and Chenghige rivers are seasonally exposed along the riversides and river channels except during flood periods. When these toolmakers visited these areas where the gravels were exposed, it appears that they readily utilized suitable cobbles to manufacture stone tools.

In order to further assess the raw material selectivity of these toolmakers, we randomly collected 100 cobbles from a T4 conglomerate exposed at the Fengshudao site. The selection criteria were cobbles that were greater than 50 mm in maximum dimension and of a size suitable for knapping. We then compared the raw material variability with that of the collection of 125 artifacts (excluding the débitage) excavated from the Fengshudao site. From the randomly collected sample of cobbles we found the raw material variability to be 25% quartz, 30% quartzite, 32% sandstone, 8% lava, and 5% chert. The raw material composition for the excavated artifacts was 28% quartz, 33% quartzite, 36% sandstone, 1% lava, and 2% chert. Chi-square analysis of the distributions indicates no significant difference between the collected cobbles and excavated artifacts ($\chi^2 = 8.84; df = 4; p = 0.065$; Fisher’s exact $p = 0.064$). Thus, it appears that the Fengshudao toolmakers were utilizing the raw materials in proportion to their availability. The Bose Basin chert cobbles are not homogenous and contain many internal fractures. Besides availability, this may be another reason why other raw materials were selected over chert. The Fengshudao raw material selectivity appears to be similar to other sites in the Bose Basin.

### Table 2

Descriptive data for the Fengshudao tektites.

<table>
<thead>
<tr>
<th>Number</th>
<th>L (mm)</th>
<th>W (mm)</th>
<th>T (mm)</th>
<th>Wt (g)</th>
<th>Shape</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSD-099</td>
<td>40.09</td>
<td>34.17</td>
<td>29.77</td>
<td>48.00</td>
<td>Subspheric</td>
<td>187.06</td>
</tr>
<tr>
<td>FSD-095</td>
<td>47.25</td>
<td>31.27</td>
<td>28.41</td>
<td>48.00</td>
<td>Elliptic</td>
<td>186.79</td>
</tr>
<tr>
<td>FSD-125</td>
<td>23.56</td>
<td>20.74</td>
<td>11.99</td>
<td>5.00</td>
<td>Irregular</td>
<td>186.39</td>
</tr>
<tr>
<td>FSD-173</td>
<td>26.91</td>
<td>11.88</td>
<td>11.96</td>
<td>2.00</td>
<td>Irregular</td>
<td>185.95</td>
</tr>
<tr>
<td>FSD-124</td>
<td>20.22</td>
<td>13.64</td>
<td>9.96</td>
<td>2.00</td>
<td>Irregular</td>
<td>186.37</td>
</tr>
<tr>
<td>FSD-121</td>
<td>19.92</td>
<td>14.44</td>
<td>7.32</td>
<td>1.13</td>
<td>Broken-shell</td>
<td>186.22</td>
</tr>
<tr>
<td>FSD-086</td>
<td>13.90</td>
<td>10.36</td>
<td>9.33</td>
<td>0.96</td>
<td>Subspheric</td>
<td>186.43</td>
</tr>
<tr>
<td>FSD-170</td>
<td>9.76</td>
<td>8.79</td>
<td>6.07</td>
<td>0.30</td>
<td>Broken-shell</td>
<td>185.95</td>
</tr>
<tr>
<td>FSD-172</td>
<td>16.48</td>
<td>9.05</td>
<td>4.18</td>
<td>0.29</td>
<td>Broken-shell</td>
<td>185.95</td>
</tr>
</tbody>
</table>

L, length; W, width; T, thickness; Wt, weight.

### Table 3

Fengshudao artifact categories: frequencies and descriptive data.

<table>
<thead>
<tr>
<th>Artifact</th>
<th>N = 155</th>
<th>L (mm)</th>
<th>W (mm)</th>
<th>T (mm)</th>
<th>Wt (g)</th>
<th>Shape</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>11</td>
<td>105.98</td>
<td>48.20</td>
<td>83.41</td>
<td>38.76</td>
<td>56.59</td>
<td>18.30</td>
</tr>
<tr>
<td>Flake</td>
<td>17</td>
<td>71.10</td>
<td>34.72</td>
<td>53.18</td>
<td>21.29</td>
<td>19.86</td>
<td>8.75</td>
</tr>
<tr>
<td>Bipolar core</td>
<td>4</td>
<td>43.22</td>
<td>12.17</td>
<td>27.46</td>
<td>8.72</td>
<td>23.10</td>
<td>8.69</td>
</tr>
<tr>
<td>Bipolar flake</td>
<td>13</td>
<td>29.90</td>
<td>11.12</td>
<td>22.55</td>
<td>11.17</td>
<td>10.32</td>
<td>7.39</td>
</tr>
<tr>
<td>Chopper</td>
<td>3</td>
<td>136.01</td>
<td>10.95</td>
<td>131.99</td>
<td>19.31</td>
<td>74.97</td>
<td>13.86</td>
</tr>
<tr>
<td>Scraper</td>
<td>2</td>
<td>115.90</td>
<td>10.35</td>
<td>83.32</td>
<td>6.52</td>
<td>35.38</td>
<td>4.89</td>
</tr>
<tr>
<td>Pick</td>
<td>1</td>
<td>149.14</td>
<td>10.30</td>
<td>101.26</td>
<td>73.86</td>
<td>37.07</td>
<td>28.34</td>
</tr>
<tr>
<td>Handaxe</td>
<td>5</td>
<td>166.02</td>
<td>33.60</td>
<td>109.51</td>
<td>22.78</td>
<td>73.24</td>
<td>14.37</td>
</tr>
<tr>
<td>Stone hammer</td>
<td>6</td>
<td>112.14</td>
<td>16.75</td>
<td>102.79</td>
<td>14.89</td>
<td>79.39</td>
<td>8.01</td>
</tr>
<tr>
<td>Chipped-cobble</td>
<td>36</td>
<td>115.47</td>
<td>32.05</td>
<td>92.96</td>
<td>28.59</td>
<td>66.94</td>
<td>23.94</td>
</tr>
<tr>
<td>Débitage</td>
<td>30</td>
<td>83.37</td>
<td>44.93</td>
<td>60.07</td>
<td>35.97</td>
<td>37.07</td>
<td>24.93</td>
</tr>
<tr>
<td>Manuports</td>
<td>27</td>
<td>130.21</td>
<td>40.42</td>
<td>103.85</td>
<td>34.49</td>
<td>74.92</td>
<td>31.22</td>
</tr>
</tbody>
</table>

L, length; W, width; T, thickness; Wt, weight; s.d., standard deviation.
One hypothesis we tested was to determine whether significant variation between handaxes with provenience (i.e., excavated in situ) and those without (i.e., surface collected) exists. Finding no significant variation would justify inclusion of the surface collected finds in subsequent analyses, assuming a strong argument can be made that most or all of the surface collected materials are probably penecontemporaneous with the excavated deposits. At least in the case of Fengshudao, no artifacts appear to be present in other terrace deposits in the area.

A series of inferential statistical tests (Mann–Whitney U tests) were used to analyze the Fengshudao biface collection, which was made that most or all of the surface collected materials are probably penecontemporaneous with the excavated deposits. At least in the case of Fengshudao, no artifacts appear to be present in other terrace deposits in the area.

One hypothesis we tested was to determine whether significant variation between handaxes with provenience (i.e., excavated in situ) and those without (i.e., surface collected) exists. Finding no significant variation would justify inclusion of the surface collected finds in subsequent analyses, assuming a strong argument can be made that most or all of the surface collected materials are probably penecontemporaneous with the excavated deposits. At least in the case of Fengshudao, no artifacts appear to be present in other terrace deposits in the area.

A series of inferential statistical tests (Mann–Whitney U tests) were used to analyze the Fengshudao biface collection, which was divided into excavated (N = 5) and surface-collected (N = 99) samples. Results indicate that in only one of the five tests is the variation significantly different at the p ≤ 0.05 level (Table 5). The length, width, and thickness measurements and the elongation ratio (L/W) all result in non-significant variation. Only the refinement (T/W) metric results in significant variation. This may be because the majority of the surface collected bifaces were produced on flakes (N = 63) rather than cobbles (N = 36), and flakes are generally thinner (see below). Although a small sample size (N = 5), the excavated assemblage is comprised of more cobbles (N = 3) than flakes (N = 2). It should be noted that in neither of the linear measurements (thickness or width) that are used to calculate the refinement ratio were significant variation found between the excavated and surface-collected samples. Thus, if the excavated sample was larger it is quite possible the refinement metric would also not be significantly different at the p ≤ 0.05 level. A series of scatterplots also indicate the close overlap between the surface collected and excavated samples (Fig. 9). We suggest that these findings are grounds to group all of the specimens (excavated and surface-collected) together, particularly because at least in the Fengshudao case, it is assumed that all of the materials are penecontemporaneous.

Again restricting our dataset to the Fengshudao materials, we ran a series of statistical analyses to test the hypothesis that one of the primary reasons why the eastern Asian bifaces are thicker than those found in the West is because they are produced primarily on locally available river cobbles (Norton et al., 2006). The Fengshudao handaxe assemblage is divided into cobbles (N = 39) and flakes (N = 65). Results indicate that the linear length and width measurements are not significantly different and the elongation ratio (L/W) is also not significantly different (Table 6). However, the thickness measurements between the cobble and flake samples are very significantly different. Not surprisingly, the refinement measure is also very significantly different (Table 6). Because there is almost no difference between the cobble and flake widths (t = −0.011, p = 0.991), it is clear that variation in thickness is driving the variation in refinement (t = 5.002, p < 0.0001). Although production of bifaces on cobbles may not be the only reason to explain the noted very thick trait of the eastern Asian handaxes, at least in the case of the Fengshudao bifaces, it appears to be at least one of the primary reasons.

We then evaluated the Fengshudao handaxes in a broader interregional comparison (Table 7). Using the three basic linear measurements (length, width, thickness), our results indicate that the Fengshudao bifaces more closely resemble their eastern counterparts (e.g., IHRB, Luonan) than they do the larger western Acheulean dataset. In all cases, the Fengshudao handaxes had larger mean measurements. This is not all that surprising given that one of the noted characteristics of the handaxes from Boise is the large size (Olsen and Miller-Antonio, 1992; Hou et al., 2000). Furthermore, we used the coefficient of variation (CV, defined as standard deviation divided by mean, multiplied by 100; Sokal and Rohlf, 1995), to explore the nature of variation between assemblages (see Vaughan, 2001; Lycett and Gowlett, 2008; Lycett and Bae, 2010; Shipton et al., 2013, for applications to archaeological datasets and Rightmire (2004) for application to a hominin fossil dataset). The Fengshudao CVs all are well below the western Acheulean CVs and are well within range of the CVs from the IHRB and Luonan (Table 7). The Fengshudao width is the least variable trait of the three variables in question (length, width, thickness), a pattern consistently observed in other handaxe assemblages (see Vaughan, 2001; Lycett and Gowlett, 2008). It should be noted that in this context the CV refers to variation in the size component, whereas the Wang et al. (2012) study focused on shape variation.

Because the thickness variable is one of the most characteristic traits when describing the variation between handaxes west and east of the Movius Line (Norton et al., 2006; Norton and Bae, 2009;
Petraglia and Shipton, 2009; Lycett and Bae, 2010; Shipton and Petraglia, 2010), we explore this variation further. In Table 7, we see that the Fengshudao mean thickness is 67.87 mm and the western Acheulean is 40.38 mm. Not surprisingly, the Fengshudao thickness data is highly significantly different from the western Acheulean (Table 8). Despite the fact that the mean thickness of the IHRB and Luonan Basin handaxes are not significantly different (Lycett and Bae, 2010), somewhat surprisingly, the Fengshudao handaxes are significantly thicker than even the former two data-sets. The mean thickness of the Fengshudao bifaces is 6.7 mm greater than the IHRB and Luonan handaxes (Table 8).

Discussion

The Fengshudao bifacially worked implements are important to addressing questions related to Pleistocene hominin behavioral variability, particularly east and west of the Movius Line sensu lato. Hou et al. (2000) presented a range of evidence to conclude that the Bose handaxes fall within the range of the Acheulean technocomplex or the equivalent of Mode 2 technologies. For instance, they noted that the flake scar counts were on average higher for the Bose handaxes than penecontemporaneous bifaces from Olduvai Gorge in East Africa, which led them to argue that Bose handaxes are as refined, if not more refined than the African materials. In addition, Hou et al. (2000; 1624) observed that “unifacial and bifacial LCTs [large cutting tools], which possess clearly defined tip and butt ends, make up 58% of all flaked pieces (n = 172), which is well above the minimum frequency (40%) defined by Leakey (1971) for the African Acheulean.” Interestingly, in a brief report published recently by Zhang et al. (2010: 442) that introduces Fengshudao, one of the conclusions drawn is “with the true bifacial technology present at Fengshudao (Bose, China), the lithic industry conforms to the Mode II Acheulean variability.” The primary data Zhang et al. (2010:442) use to support their conclusions are “the slight convexity of predominant removal preparation, and the recurrent unidirectional method during the procedure of knapping.” Nevertheless, our own analysis of the Fengshudao materials finds little support for many of the observations drawn by Hou et al. (2000) and Zhang et al. (2010). However, two points do lend support to the conclusions of Hou et al. (2000) and Zhang et al. (2010).

First, Hou et al. (2000) suggested that one of the reasons why the Bose handaxes fall within the range of Acheulean variation is because the flake scar counts are at the high end of the spectrum of Acheulean biface variation (Fengshudao mean = 26.95; SOM 2). The mean scar count for penecontemporaneous Olorgesailie handaxes is 20.0 (Hou et al., 2000), which is significantly lower than Fengshudao (t = 8.435; p < 0.0001). We are currently exploring the meaning of the high frequency of flake scars on the Fengshudao bifaces. These closer evaluations include designing blind tests to
ensure that all of the authors are seeing and counting the same number of flake scars within a 95% degree of confidence.

Second is the fact that Fengshudao presents a high density of bifaces from one constrained spatio-temporal point east of the Movius Line. As discussed above, one of the primary criteria of the Norton et al. (2006) Movius Line sensu lato model is the relatively low density of bifaces at any particular site (see also Norton and Bae, 2009). Thus, the Fengshudao evidence could potentially be used to weaken the Movius Line sensu lato model of Norton et al. (2006). However, it should be noted that Fengshudao is actually considered atypical of the sites even within Bose in terms of handaxe density. Currently, all of the sites in Bose, except for Fengshudao, have no or relatively few handaxes (Huang et al., 2012; Xu et al., 2012).

Those two points aside, the comparative analyses presented here suggest that the handaxes are morphologically distinct from the western Acheulean. Primarily because many of the bifaces were produced on locally-available river cobbles, the Fengshudao bifaces are extremely thick (even when compared with the IHRB handaxes, which are probably best known for their thickness). Other measurements appear to indicate that the Fengshudao handaxes are more similar to the IHRB and Luonan Basin assemblages than they are to the western Acheulean. Furthermore, a recent multivariate comparative study of the Bose handaxes and the western Acheulean also supports the argument that the bifaces east and west of the Movius Line are morphologically quite different (e.g., Wang et al., 2012).

There is no current evidence of the Levallois prepared core technology in eastern Asia until the Late Paleolithic (Gao and Norton, 2002; Norton et al., 2009). However, Zhang et al. (2010:442) state that the Fengshudao handaxes clearly “prefigure the Levallois method” and that “finding the actual Levallois technique in a Chinese site (just as ancient than [sic] Fengshudao, or even more), is a challenging issue.” As others have suggested (Movius, 1944; Schick, 1994; Lyckett, 2007; Norton and Bae, 2009; Lyckett and Bae, 2010), in regions of the Old World where a true Acheulean tradition is present, the Levallois prepared core technique is almost always found in younger deposits at the same sites or nearby regions. The absence of the Levallois until relatively recently in eastern Asia is a point that has been emphasized repeatedly (e.g., Movius, 1944; Schick, 1994; Gao and Norton, 2002; Norton et al., 2006; Lyckett, 2007; Lyckett and Bae, 2010; Lyckett and Norton, 2010). The absence of Levallois technology in overlying stratigraphic levels at Fengshudao and other sites in the Bose Basin supports the argument made previously that the appearance of bifacially worked implements east of the Movius Line sensu lato is likely an example of short term convergence (Norton and Bae, 2009; Lyckett and Bae, 2010; Lyckett and Norton, 2010; Wang et al., 2012). At least in the case of Fengshudao, no evidence currently exists to support the argument that the Levallois technology is present and is penecontemporaneous with the bifaces (contra Zhang et al., 2010).

One important observation that Hou et al. (2000:1624) make that we feel still stands is that they suggest that even if the finds from the Bose Basin can be considered part of the Acheulean tradition, then because of the intermittent “flow of population and cultural information across the line, [the tradition] may not have been extensive.” Elsewhere, it has been suggested that eastern Asia likely was a region that had relatively low population densities vis-à-vis Africa (Movius, 1944; Wolpoff et al., 1984; Schick, 1994; Lyckett, 2007; Bae, 2010; Lyckett and Bae, 2010; Lyckett and Norton, 2010; Norton et al., 2010). Thus, even if the Bose materials were considered representative of the true Acheulean, they were probably the result of a short-lived event, which may be more parsimoniously explained as a case of convergent evolution (see Wang et al., 2012).

**Conclusions**

The excavated association of tektites that date to 803 ka and bifaces from one stratigraphic level from Fengshudao indicates that the Bose Basin handaxes most likely date to the Early to Middle Pleistocene transition. Closer evaluation of the tektites suggests that they probably did not travel very far from the point of initial impact, thus effectively resolving the question of whether they were in fact redeposited. Analysis of the raw materials indicates that the Fengshudao hominins were utilizing locally-available quartz, quartzite, and sandstone river cobbles over lava and chert raw materials. Comparative inter-regional analyses of the Fengshudao handaxe morphology with bifaces from other regions of eastern Asia (e.g., Luonan, IHRB) indicate a substantial amount of overlap. However, it should be noted that the Fengshudao bifaces are quite large and thick even in comparison with the Luonan and IHRB materials. The Fengshudao handaxes also appear to differ from the typical western Acheulean bifaces based on analyses of three standard linear measurements (length, width, thickness) and ratios (elongation, refinement). This corresponds well with the recent detailed comparative multivariate morphometric analysis conducted by Wang et al. (2012) that found a number of notable differences between the Bose and western Acheulean handaxes.

Handaxes and cleavers are the representative tool types of the Acheulean Industrial Complex. Based on observations made by Movius (1944) almost three-quarters of a century ago that there was an apparent absence of bifacially worked implements in eastern Asia, the actual discovery of handaxes east of the Movius

**Table 6**

Comparisons between Fengshudao handaxes produced on cobbles and flakes.

<table>
<thead>
<tr>
<th>Locality</th>
<th>N</th>
<th>Length (mm) Mean</th>
<th>Length (mm) SD</th>
<th>Length (mm) CV</th>
<th>Width (mm) Mean</th>
<th>Width (mm) SD</th>
<th>Width (mm) CV</th>
<th>Thickness (mm) Mean</th>
<th>Thickness (mm) SD</th>
<th>Thickness (mm) CV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fengshudao</td>
<td>104</td>
<td>157.71</td>
<td>28.13</td>
<td>17.84</td>
<td>118.06</td>
<td>19.33</td>
<td>16.37</td>
<td>22.29</td>
<td>40.38</td>
<td>11.25</td>
</tr>
<tr>
<td>IHRB</td>
<td>58</td>
<td>153.86</td>
<td>30.46</td>
<td>19.8</td>
<td>94.16</td>
<td>13.92</td>
<td>14.78</td>
<td>21.47</td>
<td>60.19</td>
<td>12.92</td>
</tr>
<tr>
<td>Luonan</td>
<td>44</td>
<td>151.58</td>
<td>32.64</td>
<td>21.53</td>
<td>101.99</td>
<td>13.28</td>
<td>13.02</td>
<td>61.63</td>
<td>40.38</td>
<td>11.25</td>
</tr>
<tr>
<td>Western Acheulean</td>
<td>292</td>
<td>134.37</td>
<td>38.44</td>
<td>28.61</td>
<td>81.35</td>
<td>18.13</td>
<td>27.86</td>
<td>40.38</td>
<td>11.25</td>
<td>27.86</td>
</tr>
</tbody>
</table>

Notes: **Bold** indicates significant at \( p < 0.05 \). See SOM 2 for raw data.
Line took on greater importance in paleoanthropology (Lyckett and Bae, 2010). Since Movius’ observations, bifacially worked implements have been primarily identified in Indonesia, Korea (Imjin/Hantan Rivers Basins), and China (Dingguan, Luan, Bose/Boze Basin). Although some studies have concluded that the morphological variability of the handaxes east and west of the Movius Line overlap substantially (e.g., Hou et al., 2000; Wang, 2005; Simanjuntak et al., 2010; Zhang et al., 2010), there are a growing number of studies (including this one) that have found a fair number of differences among the bifaces assemblages between the two regions (e.g., Norton et al., 2006; Lyckett, 2007; Norton and Bae, 2008; Lyckett and Bae, 2010; Lyckett and Norton, 2010; Wang et al., 2012). It is suggested here that simply going out and trying to find more handaxes to ‘disprove’ the Movius Line will likely not resolve many of the issues currently surrounding the debate; rather, more intensive hypothesis-driven analyses using more sophisticated methodologies will likely contribute much more to strengthening, weakening, and/or resolving the various models that exist (e.g., Movius Line sensu stricto, Movius Line sensu lato, or simply discarding the Movius Line altogether) (Norton and Jin, 2009). The Fengshudao materials can contribute to resolving some of these debates in Paleolithic archaeology.

Acknowledgments

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Appendix A. Supplementary material

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.jhevol.2013.11.002.

References
