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NEW EVIDENCE FOR EARLY SILK IN THE INDUS CIVILIZATION*

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Silk is an important economic fibre, and is generally considered to have been the exclusive cultural heritage of China. Silk weaving is evident from the Shang period c. *1600–1045* BC*, though the earliest evidence for silk textiles in ancient China may date to as much as a millennium earlier. Recent microscopic analysis of archaeological thread fragments found inside copper-alloy ornaments from Harappa and steatite beads from Chanhu-daro, two important Indus sites, have yielded silk fibres, dating to* c. *2450–2000* BC*. This study offers the earliest evidence in the world for any silk outside China, and is roughly contemporaneous with the earliest Chinese evidence for silk. This important new finding brings into question the traditional historical notion of sericulture as being an exclusively Chinese invention.*

KEYWORDS: SILK, INDUS CIVILIZATION, ARCHAEOLOGICAL FIBRES

BACKGROUND

The Indus Civilization, *c*. 2800–1900 BC, was one of the great urban riverine civilizations of the ancient world. Current understanding of this cultural phenomenon is that it emerged out of earlier diverse, regional cultures that interacted with each other economically and socially. Settlements of the Indus Civilization spread over a vast area, centred on the Indus and Ghaggar-Hakra river systems of Pakistan and northern India. From the Himalaya and Hindu Kush to the coastal regions of Kutch and Gujarat, westward into Baluchistan and eastward into northwestern India, sites identified with the Indus Civilization are distributed across an area larger than that of Mesopotamia or of Egypt.

Harappa, a settlement near the river Ravi in what is now Punjab Province of Pakistan, was the first of the Indus cities to be discovered (Vats 1940). For more than a century excavations have been carried out in the eponymous city (for a recent overview, see Possehl 2002; see also Kenoyer 1998). The florescence of the Indus culture (2600–1900 BC) is sometimes designated *Mature Harappan*. More than a few enigmas concerning the Indus Civilization still vex archaeologists, not least of which is the lack of substantive evidence for reciprocal exchange of commodities with Mesopotamia, where Indus-produced luxury materials such as etched and long biconical carnelian beads were found in the Early Dynastic III period royal graves at Ur (Zettler and Horne 1998).

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Recent work at Harappa (e.g., Meadow and Kenoyer 2005, 2008) has been carried out by the Harappa Archaeological Research Project (HARP), directed by Richard H. Meadow (Harvard University), Jonathan Mark Kenoyer (University of Wisconsin at Madison), and Rita P. Wright (New York University) in collaboration with the Department of Archaeology and Museums of the Government of Pakistan. A new study of artefacts recovered from the 1999 and 2000 seasons at the site has revealed the presence of silk. The silk is not degummed but contains sericin-coated twinned *brins*, or filaments, of fibroin. Micromorphological study indicates that the silk derived from wild silkmoth species rather than *Bombyx mori*. To assess the culture-historical significance of these new silk finds we take into account several wild silkmoth species known to South Asia, understanding that the real nature and extent of sericulture in antiquity is at present unknown. It has been assumed that the wild ancestor to the Chinese silkmoth, *Bombyx mandarina* (Moore) was domesticated into the well-known (and only domesticated) insect *B. mori* in China (Kuhn 1982; Chang 1986), although *B. mandarina* (Moore) is also native to South Asia. The earliest evidence to date for silk in China comes from an isolated find possibly as early as *c.* 2570 BC from the Liangzhou Neolithic site of Qianshanyang (Zhou 1980; see also Vainker 2004; Good, forthcoming). There is evidence for silk from a bead thread at Nevasa in peninsular India *c.* 1500 BC (Gulati 1961; see also Good 1995; Janaway and Coningham 1995). This new evidence of silk from both the recent excavations at the site of Harappa and from the Chanhu-daro collection curated at the Museum of Fine Arts, Boston, indicates that silk threads were being produced nearly a millennium earlier than the Nevasa finds, and were being used in more than one Indus settlement during the height of Indus urbanism. This new discovery of silk in the Indus Valley pushes back the earliest date of silk outside of China by a millennium and is roughly contemporaneous with the earliest evidence for silk from within China.

Not only has early evidence for silk been assumed to be limited to China, but the techniques of degumming and reeling have also been considered exclusive Chinese silk industry 'secrets'. The process of degumming is one in which the sericin gum is removed from the silk, by submerging the cocoons into a weak alkaline solution. Reeling silk is a process by which the long silk strands (gummed or not) are collected on to a bobbin rather than needing to be twisted as short segments into a spun thread. These two important silkworking processes have been thought to be part of a 'package' of Chinese technology known only to China until well into the early centuries AD, although the evidence presented here indicates that wild *Antheraea* silks were also known and used in the Indus area as early as the mid-third millennium BC, and that reeling was practised. The implication of evidence for silk reeling is that the silkmoth was stifled, leaving the cocoon intact in order to be unravelled. When wild silk cocoons are collected on the ground, usually after the silkmoth has eaten its way out, the remaining silk fibres must be spun rather than reeled, as they are short. Specific contributions of the present paper include discussion of new silk finds from Harappa and Chanhu-daro along with SEM imaging of modern wild specimens of *Antheraea assamensis* and *A. mylitta* silk.

METHODS

Thread samples were first investigated under a low-power binocular microscope for possible fibre identification. The samples were then examined and imaged under a high-power polarizing microscope using auxiliary fibre optics and high depth of field, allowing an optimal view of extant fibre surface structures. After this, samples were coated with a 5 Å coating of gold and examined under a LEO A FESEM scanning electron microscope at 15 and 20 kV at

Table 1 *Fibre samples from Harappa identified as silk*

HARP ID#	*Locus*	*Material*	*Context*	*Level*	*Date (cal)*	*Description*
H 99/8863-2 lab 99:4488 A	Inside copper or copper alloy bangle fragment	Silk thread fibres	Trench 11	IIIB	2200 BCE	S plied Z twist cf. *A. assamensis*
H 99/8863-2 lab 99:4488 B	Inside copper or copper alloy bangle fragment	Silk thread intact fragment	Trench 11	IIIB	2220 BCE	S plied Z twist cf. *A. assamensis*
H2000/2242-1 lab 2000–1955	Inside copper or copper alloy wire ornament	Silk thread	Trench 54	IIIC	2450 BCE	Z twist single ply cf. *A. mylitta*

Harvard University's Center for Imaging and Mesoscale Structures. Determinations were based on comparative silk specimens, viewed under SEM, collected from cocoons sampled from the Entomology Departments of the Museum of Natural History in London and the Philadelphia Academy of Natural Sciences.

RESULTS

Harappa

In the course of excavations on Mound E at Harappa in 1999, a hollow copper or copper-alloy bangle fragment (H1999/8863-2) was recovered from domestic debris that dates to Period 3C (*c*. 2200–1900 cal BC). Preserved fibre forming a thread was found inside the hollow portion of the bangle. The thread samples removed comprise two fragments: one was recovered in disintegrated condition (designated 'A') and the other still retained some thread structure ('B'). These two samples are of the same thread, and are composed uniformly of the same type of fibre. Partial mineralization and fibre disintegration hampered a simple and straightforward identification of thread sample H99/8863-2. The thread itself is a slightly 'S' twisted (at about 10°), two-plied thread with approximately 60–75 'Z'-spun strands in each ply.

Scanning electron micrographic survey at high resolution (1000× magnification and above) of various sites on both sample fragments 'A' and 'B' allowed morphological determination of fibres to be silk, and further determination of silk from the *A. assamensis* species (see Table 1 and Figs 1 and 2).

A second thread sample from Harappa (H2000/2242-1 lab 2000–1955) was recovered in the 2000 field season. It was found preserved inside a coiled wire ornament made of native copper or of a copper-alloy that was recovered from debris on the floor of a structure dating to late Period 3A or early Period 3B (*c*. 2450 cal BC). The ornament appears to be some sort of necklace made up of two strands of coiled wire strung with silk thread. This sample is also of a wild *Antheraea* silk, but appears to be from a different species, *A. mylitta*, as it has a distinctive striated fibre (Figs 3–5). The particular morphological characteristics of each type of silk are due to the unique shape of the silkworm's orifice when ejecting fibroin during cocooning. In this case, striations are characteristic of *A. mylitta* silk. These two species are indigenous to

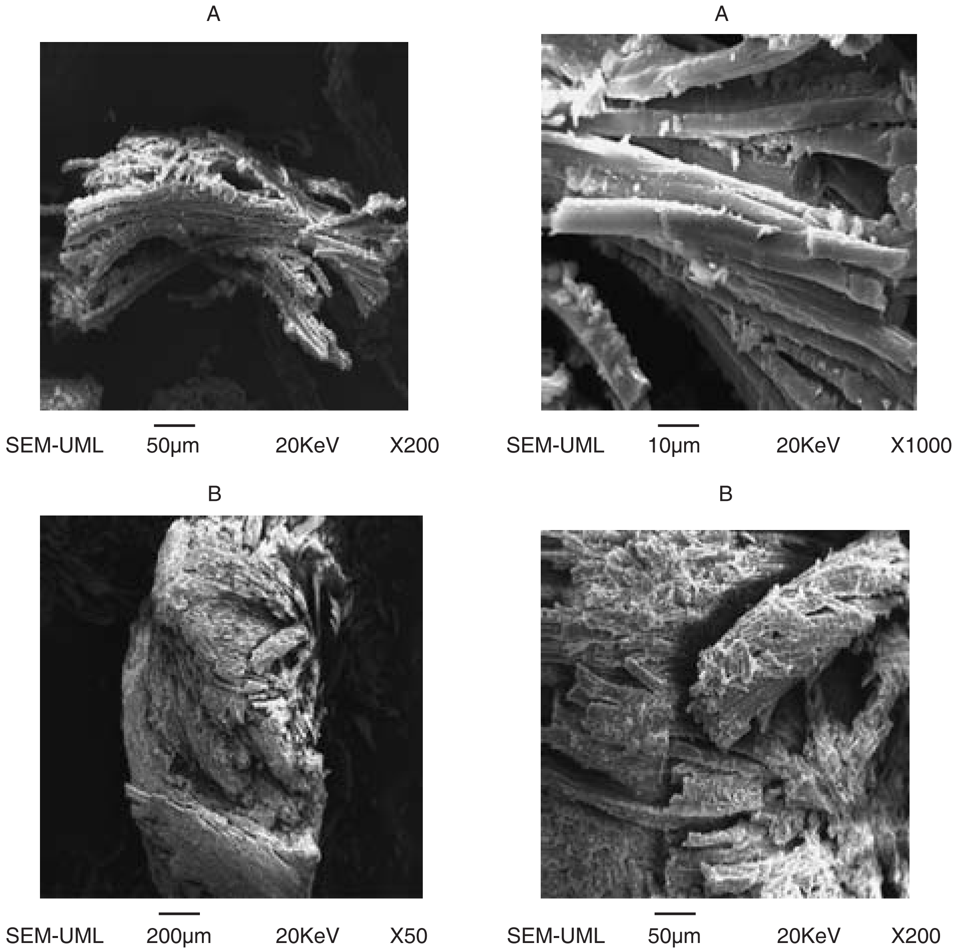

Figure 1 *Scanning electron micrographs of archaeological thread sample, views of parts 'A' and 'B' from Harappa (H 99/8863-2). Photomicrographs by I. Good and B. Chang.*

South Asia. *A. assamensis* is found in the high altitudes of the northeastern subcontinent, and *A. mylitta* is found along the tropical west coastal region. However, both regions are at a considerable distance from the Indus Valley.

Chanhu-daro

Chanhu-daro is another significant site of the Indus Civilization, located on the west bank of the river Indus in what is now Sindh province of Pakistan. Chanhu-daro was excavated in the winter of 1935–36 by the first American Archaeological Expedition to India directed by Ernest Mackay and sponsored by of the American Oriental Society and the Boston Museum of Fine Arts (Mackay 1943). A recent survey of excavated small finds (principally copper or copper-alloy artefacts such as razors and bowls) currently in the Boston MFA collections revealed

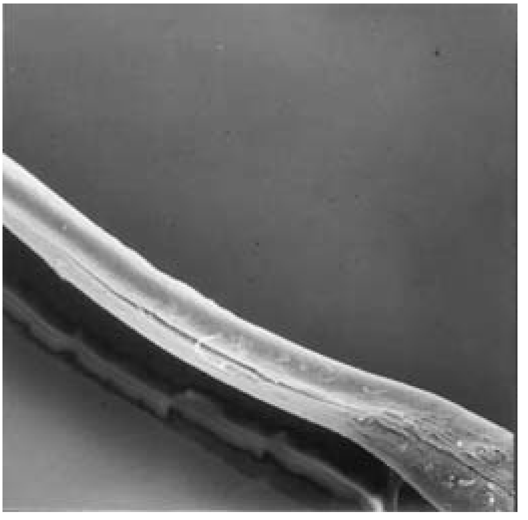

Figure 2 *Modern specimen of* Antheraea assamensis *silk. Photomicrograph by I. Good and J. Hather.*

Figure 3 *Copper or copper-alloy wire ornament from Harappa* c. *2200* BCE *revealing intact thread. Photograph by J. M. Kenoyer.*

several objects with either textile 'pseudomorph' or actual extant textile adhering to surfaces of objects. One object, a heat-fused cluster of microbeads made of enstatite (heated magnesium silicate, perhaps in the form of steatite) found inside a copper or copper-alloy bowl, had been published in Mackay's report (plate LXXIV, object 2391). The microbeads contained therein (object 2391B) were noted to include intact thread remains (see Figs 6 and 7). The object dates somewhere between 2450 and 2000 BC.

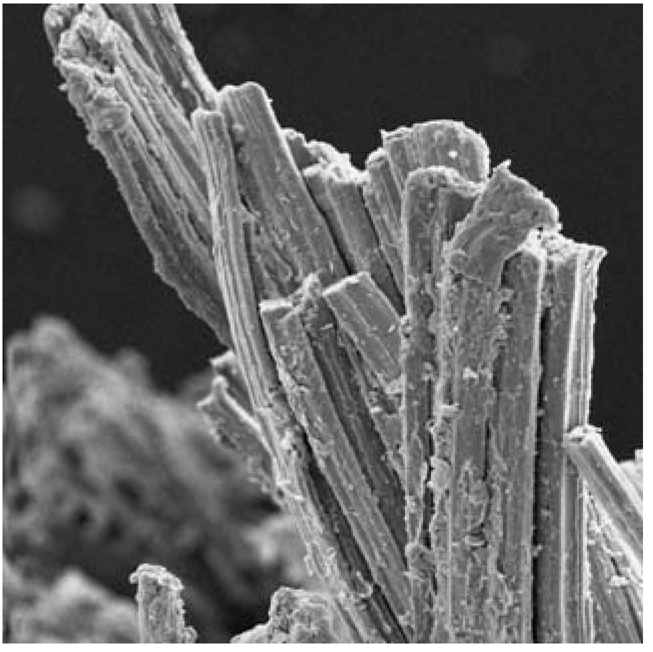

Figure 4 *Harappa 2242-1. Image showing ends and brins with longitudinal striations characteristic of* Antheraea mylitta. *Photomicrograph by J. M. Kenoyer.*

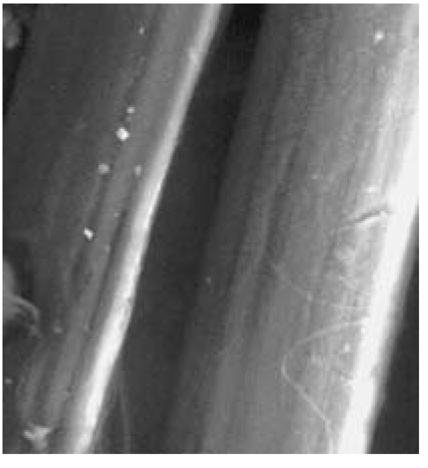

Figure 5 *Modern specimen of* Antheraea mylitta *detail showing distinctive longitudinal striations in fibroin brins. Photomicrograph by I. Good and M. Derrick.*

Microbead and thread samples from this object from Chanhu-daro were removed and analysed. The thread consists of a single ply of approximately 40–50 strands, with a slight 'S' twist (approximately 12–15°). Fibres from the thread were studied under SEM at 20 kV without sputtercoating. They appear partially gummed and partially twinned, characteristic of

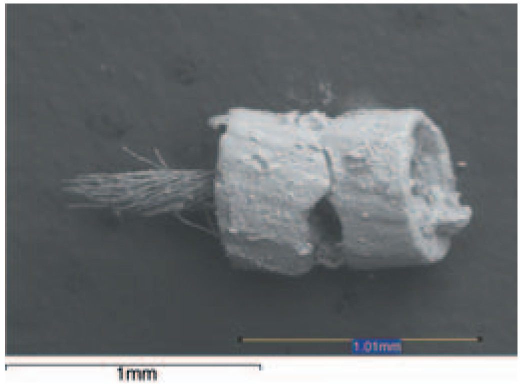

Figure 6 *Steatite (enstatite) microbead from Chanhu-daro showing slightly 'S' twisted single-ply thread. Photomicrograph by I. Good and R. Newman.*

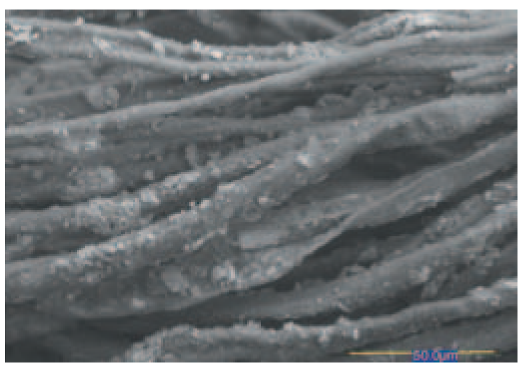

Figure 7 *Fibres from microbead. Photomicrograph by I. Good and R. Newman.*

a reeled (but not degummed) silk. It is not certain at this stage of research from which species of silkmoth these fibres derived. The fibres may be from *A. assamensis* or possibly from a species of *Philosamia* (Eri silk).

DISCUSSION

The formal exportation of silk from China took place around 119–115 BC during the reign of Han Emperor Wu-ti, who sought the fabulous blood-sweating 'celestial horses' of Ferghana (in modern day Uzbekistan). Yet archaeologists have puzzled over the early presence of silk in a late prehistoric Celtic site in Germany *c*. 700 BC, as well as silk finds from several other sites in Europe, the Mediterranean, Egypt and Central Asia (see, for example, Richter 1929; Hundt 1971; Askarov 1973; Wild 1984; Braun 1987; Lubec *et al*. 1993). For decades, archaeologists have cited these findings as evidence for early contact between China and the West (for full discussion see Good 1995; see also Good in press). What has not been adequately considered in the literature, however, is the possibility that a non-Chinese (and *de facto* wild) species of silkworm that produced workable silk was known and used in antiquity, and that the rare instances of silk that have been discovered far outside of China, and that date to before Wu-ti's trade relationship with the West began, may have, in fact, been produced indigenously or imported from regions other than China. The evidence presented here now suggests that early sericulture did in fact exist in South Asia and was roughly contemporaneous with the earliest known silk use in China.

CONCLUSIONS

This research offers new insight on the extent and antiquity of sericulture. Specifically, these finds indicate the use of wild indigenous silkmoth species in South Asia as early as the mid-third millennium BC. Careful morphological study of highly degraded fibres through images derived from scanning electron microscopy allows subtle but distinct and diagnostic features of fibre surface and fibre shaft morphology to aid in moth species identification. At least two separate types of silk were utilized in the Indus in the mid-third millennium BC. Based on SEM image analysis there are two thread forms in the samples from Harappa, which appear to be from two different species of silkmoth (*Antheraea* sp.). The silk from Chanhudaro may be from yet another South Asian moth species *Philosamia* spp. (Eri silk). Moreover, this silk appears to have been reeled.

The variety in type, technology and thread forms of these few rare examples of silk offers us a glimpse into the extent of knowledge about sericulture in the Indus Civilization during the Mature Harappan phase. This knowledge helps to explain other early instances of silk in Eurasia outside of China, specifically from the mid-second millennium BC Deccan Peninsula of India (Gulati 1961) and contemporaneously in Bactria (Askarov 1973). By careful analysis of archaeological silk fibre surface morphology, one can distinguish between the source silkworm species. Through this type of study we can also begin to better understand the origins of silk use further to the East. The discoveries described here demonstrate that silk was being used over a wide region of South Asia for more than 2000 years before the introduction of domesticated silk from China. Earlier models that attribute the origins of silk and sericulture exclusively to China need to be re-examined and revised.

NOTE

Ages employed in this article for Harappa and Indus Civilization sites are based on calibrated radiocarbon dates, of which more than 100 come from Harappa. Other dates are those current in the literature.

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Meadow and Kenoyer excavated the Harappa materials and identified samples with threads. Kenoyer conducted preliminary analyses on Harappa threads (the results of which are referred to in Kenoyer 2003, 2004). Meadow and Kenoyer provided Harappa samples to Good, who analysed and identified the threads both from Harappa and from Chanhu-daro. Good wrote the article, with contributions on Indus archaeology from Kenoyer and Meadow, and produced the images and figures, except Figures 3 and 4.

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