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Dating of the Buddha Statues – AMS ^{14}C Dating of Organic Materials

Introduction

Plant materials can be dated with radiocarbon dating. This method has improved greatly by the use of AMS (Accelerator Mass Spectrometry) regarding the sensitivity of the measurements and the amount of required sampling material. On the Buddha statues plant materials have been used in connection with the clay layers: the coarse clay layer contains straw and plant residues. The substructure of the fold ridges of the Western Buddha was made of wooden pegs and ropes. As many of these ropes have been found still imbedded in the clay, they provide short-lived plant material the date of which reflects the age of the Buddha. For larger protruding parts wooden beams have been used as anchoring elements. Most of the ones retrieved from the rubble come from the Western Buddha, but single ones could also be found on the Eastern Buddha.

As the attempts to date the statues until 2004 were based only on stylistic criteria, the hope was that the use of AMS ^{14}C would give exact dates und thus help to understand the origin and history of the statues.

It cannot be excluded that the clay layers are altogether younger than the sculpted stone and were applied in a phase of repair. There is no evidence for this assumption, but also no information definitely contradicting it. As the definite design was reached with the clay modelling, the stylistic criteria were also based on the clay rather than on the stone itself.

Dating based on historical and stylistic criteria

The beginning of Buddhist life in Bāmiyān and the building of a monastery are still unknown. Historical sources only tell that the first Buddhist period of Bāmiyān was interrupted in 770 AD by a hundred years of Muslim domination. In 870 AD, the region became Buddhist again until 977 AD when Islam irrevocably took over. The time span for the creation of Buddhist works of art can thus be restricted to the periods before 770 AD and between 870 AD and 977 AD. Furthermore, Xuanzang passed through the area around 630 AD and described Bamiyan as a flourishing Buddhist centre.[58]

Table 1 Overview of dating of the Buddha statues based on stylistic criteria

author	Eastern Buddha	Western Buddha	reason
Hackin 1922[3]	2nd to 3rd century	3th to 4th century	monastery linked to Kushan king Kanishka. It was built firstly around Eastern Buddha; Buddha shows Gandharan influence Western Buddha influenced by Gupta period or Mathura style Dating of caves (murals): executed East to West, dating from 3rd to 6th to 7th century
Yoshikawa 1939[4]			murals of niches around Western Buddha: 5th century
Rowland 1979, p. 87[5]	2nd to 3rd century or 4th to 8th century	5th to 7th century	Eastern Buddha: classical style of '*toga*'-like *sangati* or 'Neo-Gandhara' style between 4th and 8th century Western Buddha: influenced by Gupta period style of Mathura
Tarzi 1977[6]	580 to 630	6th century	
Kuwayama 1987[7]	middle of 6th century	middle of 6th century	change in trade routes between India and China; since middle of 6th century the Western route through the Hindukush passes through Bāmiyān
Klimburg-Salter 1989[8]	6th to 8th century, slightly older than Western Buddha	6th to 8th century	stylistic dating of murals in the niches and caves
Tanabe 2004[9]	635 to 645 or later		dating of murals around the Eastern Buddha; Xuanzang was either wrong or did not tell that the Buddha statues were not finished yet

Attempts to date the sculptures based on stylistic observations and historical sources have been made since the 1920s. A connection to the art of Gandhara is recognisable, but the estimation how fast or long-lasting this influence was on Bāmiyān varies considerably. For the Eastern Buddha dates between the 2nd and the 6th century were proposed, for the Western Buddha between the 3rd and the 8th century. The Eastern Buddha is mostly assumed to be slightly older than the Western Buddha.[59] More recent stylistic studies tend to date them to the 6th to 8th century and thus later than the authors of the first half of the 20th century. The most important attempts of dating are listed in table 1.

The National Research Institute of Cultural Properties, Japan and the Nagoya University used AMS ^{14}C dating on organic materials taken from the murals of the caves at the Buddha cliff in Bāmiyān and other cave sites.[67] The samples were not taken from the caves connected to the Buddha niches themselves. The investigation revealed that the clay plasters of the murals were made between 438 AD and 980 AD.[68] This means that work on the cliff of Bāmiyān continued until the very end of the Buddhist time.

Aim of the investigation with AMS ^{14}C dating

The aim of the analyses was to obtain a dating of the organic materials used on the Buddha statues to understand if they date back to the same age or to different ages. The latter would mean that at least parts could be attributed to repair phases.

As clay layers and ropes were found still connected to each other, it was obvious that they must stem from the same time. For the pegs, however, it was only clear that they belonged to the system of substructure using ropes, but they could have been replaced. For the larger wooden elements, consisting of beams or poles of 20 to 80 cm length, the assumption was that they were positioned in the larger square holes discernible at both statues, but had never been seen in situ. Thus they could have been originals as well as replacements or even not have belonged to the statues at all.

In some areas on both statues, three clay layers instead of the usual two layers were found, all of them below the paint layer. This raised the question if the top layer(s) – and consequently also the paint layers – had to be interpreted as later repairs. 22 fragments were selected for AMS ^{14}C dating (see examples in figure 1). The sample material comprised:

- 12 samples of straw and chaff from the clay plaster of both statues;
- 2 samples of wooden pegs and ropes of the Western Buddha;
- 2 samples of ropes;
- 4 samples of larger wooden beams of both statues;
- 1 sample of a wedge to adjust the larger wooden beam.

11 samples came from the Eastern Buddha and 10 from the Western Buddha. One additional sample was taken from niche I behind the Western Buddha to investigate if the niches were decorated at the same time as the clay modelling of the statues. The samples are listed in table 2.

The samples were analysed in three measuring phases, in May 2004, December 2004 and February 2009 and they were done at two institutions:

Dr. Georges Bonani, ETH (Eidgenössische Technische Hochschule) Zurich, Institute for Particle Physics	2 samples	May 2004
	7 samples	January 2009
Prof. Dr. Pieter Grootes, Dr. Matthias Hüls and Dr. Marie-Josée Nadeau, Leibnitz Laboratory for Radiometric Dating and Isotope Research, Christian-Albrechts-Universität zu Kiel	13 samples	December 2004

Fig. 1. Three of the samples selected for ^{14}C-AMS dating

Table 2 List of samples for ^{14}C-AMS dating

sample code	lab no.	statue	material/description	institution/ year
Kleiner Buddha – 1	ETH-28498	Eastern Buddha	plant metrial from clay	ETH 2004
Kleine Buddha – 2	ETH-28499	Eastern Buddha	plant material from clay	ETH 2004
KBL 026	KIA 25567	Eastern Buddha	chaff from undercoat	Kiel 2004
KBL 037	KIA 25568	Eastern Buddha	chaff from undercoat	Kiel 2004
KBL 052	KIA 25569	Eastern Buddha	chaff from undercoat	Kiel 2004
KBL 085	KIA 25570	Eastern Buddha	chaff from undercoat	Kiel 2004
KBL 095	KIA 25571	Eastern Buddha	chaff from undercoat	Kiel 2004
KBL 172	KIA 25794	Eastern Buddha	chaff from undercoat	Kiel 2004
327-901 (KBL 525a)	ETH-36793	Eastern Buddha	chaff and straw from the two top layers of three-layered clay plaster	ETH 2009
328-901 (KBL 252b)	ETH-36794	Eastern Buddha	chaff and straw from the two top layers of three-layered clay plaster	ETH 2009
331-901 (KBL 498)	ETH-36788	Eastern Buddha	probably from a wedge for locking a larger wooden beam (from substructure)	ETH 2009
334-901 (KBL 530)	ETH-36789	Eastern Buddha	from 27 cm long round log, without bark (from substructure)	ETH 2009
GBL 106	KIA 25564	Western Buddha	chaff from undercoat	Kiel 2004
GBL 192	KIA 25565	Western Buddha	chaff from undercoat, relation to Great Buddha or cave wall not clear	Kiel 2004
GBL 016	KIA 25560	Western Buddha	rope	Kiel 2004
GBL 028	KIA 25561	Western Buddha	rope	Kiel 2004
GBL 033	KIA 25562	Western Buddha	wooden peg	Kiel 2004
GBL 091	KIA 25563	Western Buddha	wooden peg	Kiel 2004
298-901 (GBL 247)	ETH-36790	Western Buddha	from 51 cm long square beam, traces of saw, one side axed	ETH 2009
291-901 (GBL 248)	ETH-36791	Western Buddha	from 64 cm long beam, partly with bark, sawn and axed, covered with red slurry	ETH 2009
296-901 (GBL 254)	ETH-36792	Western Buddha	from 81 cm long square beam, one of the largest beams found so far, sawn and axed	ETH 2009
GBH 1	KIA 25566	Cave I, behind Western Buddha, back of niche, centre	wooden anchoring element	Kiel 2004

Procedure of AMS ^{14}C dating in Kiel

The excellent preservation of the sample material suggests little to no contamination and also allowed rigorous cleaning. The selected material was checked, mechanically cleaned under the microscope. It was then extracted with acid (HCl), base (NaOH) and again acid (HCl) to remove carbonates as well as acid and alkali soluble organic contaminants. The combustion to CO_2 was performed in closed quartz tubes together with CuO and silver wool at 900°C. The sample CO_2 was reduced with H_2 over Fe powder as catalyst, and the resulting carbon/iron mixture was pressed into a pellet in the larger holder. The sample material selected contained between 2.8 and 4.2 mg C.

The samples were measured at the Leibniz Laboratory in Kiel using the 3.0 MV HVEE tandetron-based AMS system equipped with a separator-recombinator. The final results are the averages of six-minute interval measurements. The number of interval measurements varied from 10 to 20, depending on the impact of the uncertainty on the calibrated 2 sigma ranges. The raw isotope ratios were compared to Oxalic Aced II (134.06 pMC) and background samples (coal) of similar sizes for process blank correction.

The final uncertainty of each measurement is the larger of either the counting statistics or the error on the mean (Standard Deviation / $\sqrt{n}$). Although this practice is sometimes contested, it has been adopted in Kiel because some samples vary more than others during measurement. The idea is that this instability (up to ~ 1.5 x counting statistics) should be included in the overall uncertainty of the final result. This instability is believed to be due to the impurities in the sample gas, producing graphite of a lesser quality. The uncertainty of our background correction is also included in the uncertainty of the final result.

The product of the probability distributions vs. calendar age of the 11 samples from the Eastern Buddha and eight samples from the Western Buddha were calculated using OxCal 4.0 (function combine), and the 1 σ and 2 σ probability ranges calculated from it by the program.

Interpretation of results

The results of the single samples are listed in table 3. All of the samples can be dated to the 5th to 7th century, except for one sample of a wooden beam which probably has to be dated after 1950. It can be interpreted as a replacement or support beam inserted by the Indian restorers.

Table 3 Results of ^{14}C-AMS dating

sample code/lab no.	material	^{14}C age	ages (probability)		institution/ year
		Eastern Buddha			
Kleiner Buddha-1, ETH-28498	chaff	1440 ± 40 BP	1 σ range: 585AD-650AD (68,2%)	2 σ range: 550AD-660AD (95,4%)	ETH 2004
Kleiner Buddha-2, ETH-28499	chaff	1460 ± 40 BP	1 σ range: 570AD-640AD (68,2%)	2 σ range: 530AD-660AD (95,4%)	ETH 2004
KBL 026, KIA 25567	chaff	1499 ± 19 BP	1 σ range: 550AD-600AD (68,3%)	2 σ range: 535AD-635AD (95,4%)	Kiel 2004
KBL 037, KIA 25568	chaff	1540 ± 23 BP	1 σ range: 430AD-490AD (35,6%) 530AD-570AD (32,6%)	2 σ range: 4300AD-580AD (95,4%)	Kiel 2004
KBL 052, KIA 25569	chaff	1499 ± 19 BP	1 σ range: 550AD-595AD (68,2%)	2 σ range: 535AD-615AD (95,4%)	Kiel 2004
KBL 085, KIA 25570	chaff	1503 ± 25 BP	1 σ range: 545AD-595AD (68,2%)	2 σ range: 440AD-490AD (4,0%) 530AD-640AD (91,4%)	Kiel 2004
KBL 095, KIA 25571	chaff	1532 ± 22 BP	1 σ range: 440AD-490AD (22,0%) 530AD-580AD (46,2%)	2 σ range: 430AD-600AD (95,4%)	Kiel 2004
KBL 172, KIA 25794	chaff	1510 ± 22 BP	1 σ range: 540AD-590AD (68,2%)	2 σ range: 440AD-490AD (6,9%) 530AD-610AD (88,5%)	Kiel 2004
327-901, ETH-36793 (KBL 525a)	chaff	1510 ± 30 BP	1 σ range: 535AD-600AD (68,2%)	2 σ range: 430AD-490AD (14,9%) 500AD-630AD (80,5%)	ETH 2009
328-901, ETH-36794 (KBL 252b)	chaff	1475 ± 30 BP	1 σ range: 560AD-620AD (68,2%)	2 σ range: 540AD-645AD (95,4%)	ETH 2009
331-901, ETH-36788	wooden beam	> 1954 AD			ETH 2009
334-901, ETH-36789	wooden beam	1515 ± 35 BP	1 σ range: 460AD-490AD (7,0%) 530AD-610AD (61,2%)	2 σ range: 430AD-620AD (95,4%)	ETH 2009
		Western Buddha			
GBL 106, KIA 25564	chaff	1459 ± 21 BP	1 σ range: 585AD-640AD (68,2%)	2 σ range: 560AD-645AD (95,4%)	Kiel 2004
GBL 192, KIA 25565	chaff	1503 ± 15 BP	1 σ range: 545AD-585AD (68,2%)	2 σ range: 540AD-605AD (95,4%)	Kiel 2004
GBL 016, KIA 25560	rope	1448 ± 19 BP	1 σ range: 600AD-640AD (68,2%)	2 σ range: 575AD-650AD (95,4%)	Kiel 2004
GBL 028, KIA 25561	rope	1450 ± 16 BP	1 σ range: 600AD-640AD (68,2%)	2 σ range: 575AD-645AD (95,4%)	Kiel 2004
GBL 033, KIA 25562	wooden peg	1441 ± 24 BP	1 σ range: 600AD-645AD (68,2%)	2 σ range: 575AD-655AD (95,4%)	Kiel 2004
GBL 091, KIA 25563	wooden peg	1451 ± 22 BP	1 σ range: 595AD-640AD (68,2%)	2 σ range: 565AD-650AD (95,4%)	Kiel 2004
298-901, ETH-36790	wooden beam	1460 ± 30 BP	1 σ range: 580AD-640AD (68,2%)	2 σ range: 550AD-650AD (95,4%)	ETH 2009
291-901, ETH-36791	wooden beam	1425 ± 30 BP	1 σ range: 605AD-650AD (68,2%)	2 σ range: 575AD-660AD (95,4%)	ETH 2009
296-901, ETH-36792	wooden beam	1455 ± 35 BP	1 σ range: 580AD-645AD (68,2%)	2 σ range: 550AD-660AD (95,4%)	ETH 2009
GBH 1 (cave behind Buddha), KIA 25566	wooden beam	1461 ± 21 BP	1 σ range: 580AD-635AD (68,2%)	2 σ range: 560AD-645AD (95,4%)	Kiel 2004

Results of AMS ^{14}C dating in Kiel

The calibration of the average of the results for both statues shows that the Eastern Buddha was built about 50 years before the Western Buddha. The calibration of the age of the Eastern Buddha of (1513 ± 7 BP) leads to a 2 sigma probability range of 540 to 591 AD while that one of the Western Buddha ranges from 580 to 636 AD. The sample taken from cave I behind the Western Buddha (sample GBL 192 / KIA 25566) can be dated to exactly the same time as the samples from the Buddha itself.

The very good agreement between the samples of the Western Buddha (except for one sample) also shows that the period of the manufacturing did not take too long. The larger scatter in the ages of the Eastern Buddha could indicate that the coating of the Eastern Buddha took longer to make than the one of the Western Buddha (fig. 2).

The samples analysed in Zurich showed that the chaff taken from the three-layered clay plaster could be dated to the same time as the usual double layered plasters. The three-layered structure thus could be proved to belong to the same modelling period; it is not a later repair. The larger wooden beams could be dated to the same time as the chaff and the pegs. This proved that they are part of the substructure. Table 4 provides a summary of the combined calibration for the measured samples.

Conclusion

The plant material (wood, ropes, organic additives of the clay) of both statues could be dated with AMS ^{14}C. The results of the single samples correspond to each other what means that wooden substructures and clay layers date from the same time. The time periods for the statues are:

Eastern Buddha	544 to 595 AD (2 σ)
Western Buddha	591 to 644 AD (2 σ).

Three-layered structures of clay could be prooved not to be a result of a repair, but of a correction during modelling, as they come from the same time as the usual two-layered structures.

Larger wooden elements recovered from the rubble also belonged to the statues. This seems to support the assumption that the larger damages on the right leg of the Western Buddha already happened during modelling and were reconstructed using timbers and clay or brick material. An obviously modern beam also showed that beams were replaced, probably during the Indo-Afghan restoration in 1969-78.

The results of the AMS ^{14}C-dating of the plant material can be interpreted as a dating for the creation of the statues, based on the assumption that wooden substructures and clay layers aslready originally must have been integral parts of the statues. The stone itself, however, cannot be dated. Thus there still is the possibility that the sculpting in stone started earlier or that the clay layers have been replaced at an early stage of repair. The fact that the existing clay layers survived more than 1500 years, however, and that no traces of older modelling could be detected supports the assumption that wooden support elements and clay are part of the original design.

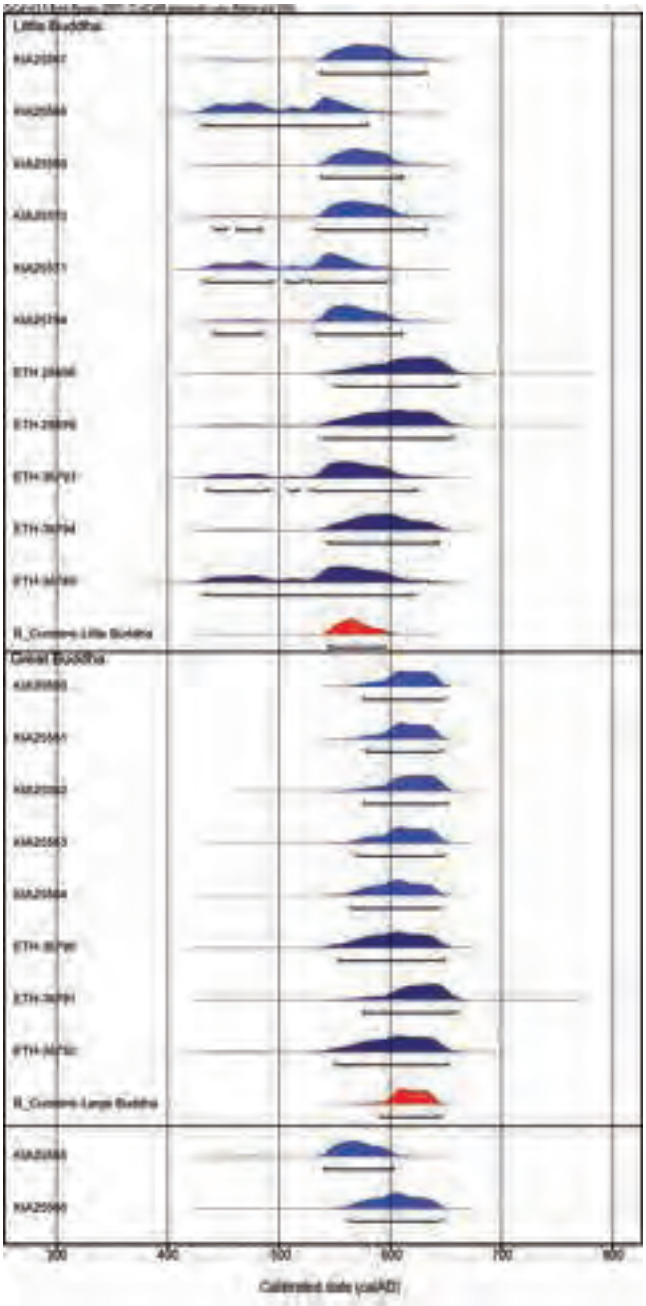

Fig. 2. Calibrated sample ages. Light blue colours refer to samples measured in the Leibniz Laboratory, Kiel, and dark blue colours to measurements done at ETH, Zürich. The red coloured field gives the product of the probability distributions vs. calendar age of the samples from the Eastern Buddha and the Western Buddha.

Table 4 Interpretation of ^{14}C-results. Overview of means

	Calendar years (probability)
Eastern Buddha	1 σ range: 549AD - 579AD (68.2%) 2 σ range: 544AD - 595AD (95.4%)
Western Buddha	1 σ range: 605AD - 633AD (68.2%) 2 σ range: 591AD - 644AD (95.4%)

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