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The emergence of pottery in Africa during the tenth millennium cal BC: new evidence from Ounjougou (Mali)

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New excavations in ravines at Ounjougou in Mali have brought to light a lithic and ceramic assemblage that dates from before 9400 cal BC. The authors show that this first use of pottery coincides with a warm wet period in the Sahara. As in East Asia, where very early ceramics are also known, the pottery and small bifacial arrowheads were the components of a new subsistence strategy exploiting an ecology associated with abundant wild grasses. In Africa, however, the seeds were probably boiled (then as now) rather than made into bread.

Keywords: Africa, Sahara, Sub-Saharan, Sahel, Early Holocene, bifacial arrowheads, ceramics

The emergence of pottery in Asia and Africa

Prehistoric populations in Japan, Siberia and China first began to produce ceramic wares between 15 000 and 10 000 cal BC, more than 5000 years earlier than in the Near East (Yasuda 2002: 119-42; Kuzmin 2006). The emergence of pottery in East Asia is linked with the climatic amelioration at the Pleistocene–Holocene transition and coincides with the appearance of lithic industries marked by distinctive small bifacial arrowheads (Habu 2004: 26-36). This technological complex is usually regarded as an expression of the intensified

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exploitation of plant and animal resources, often including small-seeded grasses (Richerson *et al.* 2001).

In Africa, the earliest pottery has been found in the large mountain massifs of the Central Sahara, in the Eastern Sahara and the Nile Valley. About 30 ^{14}C and luminescence dates have placed the emergence of ceramics in the Sahara and the Nile Valley between the end of the tenth and the beginning of the ninth millennium cal BC (Close 1995: 24-7; Roset 2000; Jesse 2003: 40-42; Haaland 2007: 171-5). This can be related to the sudden onset of a warmer and wetter climate in the Early Holocene that enabled the re-settling of the Sahara after the hyperarid phase of the last glacial maximum, the 'Ogolien' (Nelson *et al.* 2002: 97-9). The origin of the earliest African pottery is controversial and has been much discussed, with three hypothetical scenarios proposed. The first theory places the emergence of ceramics in the Nile Valley, based principally on the early exploitation of aquatic resources and wild cereals in this region (Haaland 1992: 47). The second suggests an origin somewhere south of the Sahara (Close 1995: 23), but until recently the oldest finds of sub-Saharan ceramics were only dated to the eighth millennium cal BC, both at Lothagam in Kenya (Robbins 1974), and in the *Ravin du Hibou* at Ounjougou in Mali, for Phase 2 of its Holocene occupation sequence (Huysecom *et al.* 2004: 584). A third assumes that pottery was invented by relict populations who had survived in ecological refuge zones of the Sahara during the hyperarid Late Pleistocene (Jesse 2003: 43). Within the framework of the international research project 'Palaeoenvironment and Human Population of West Africa' (Huysecom 2002), we have discovered ceramic sherds at the site of *Ravin de la Mouche* at Ounjougou, associated with an original lithic industry and in stratified contexts dated from before the end of the tenth millennium cal BC. This discovery throws new light on the chronology of the emergence of ceramics in Africa and its environmental context.

The Early Holocene sequence at Ounjougou

The research programme at Ounjougou (14°20′ N, 3°30′ W) began in 1997 and since 2004 has developed in two parallel ravines, *Ravin du Hibou* and *Ravin de la Mouche*, where several ceramic sherds were discovered in layers that could be attributed to the initial phases of the Holocene (Figure 1). In our latest field season in September 2007, we established the definitive chronostratigraphic sequence for these two ravines and clarified the position of the pottery and the associated lithic assemblage. In general, the Holocene sedimentary sequence here is primarily composed of channel infilling due to a high-energy flow of water, strongly contrasting with the underlying Pleistocene silts and more recent Holocene silty formations (Rasse *et al.* 2006). It is now possible to divide the Early Holocene into five large chronostratigraphic units, identified from top to bottom as HA4 to HA0. The high precision chronological ranges in the titles of the next sections are based on Bayesian analysis results of ^{14}C and OSL dates (see Technical Appendix).

The HA4 formation (6700-8100 cal BC)

The most recent formation, HA4, of fine-grained particle size and particularly well-developed in the *Ravin du Hibou*, has yielded artefacts from cultural Phase 2 of the

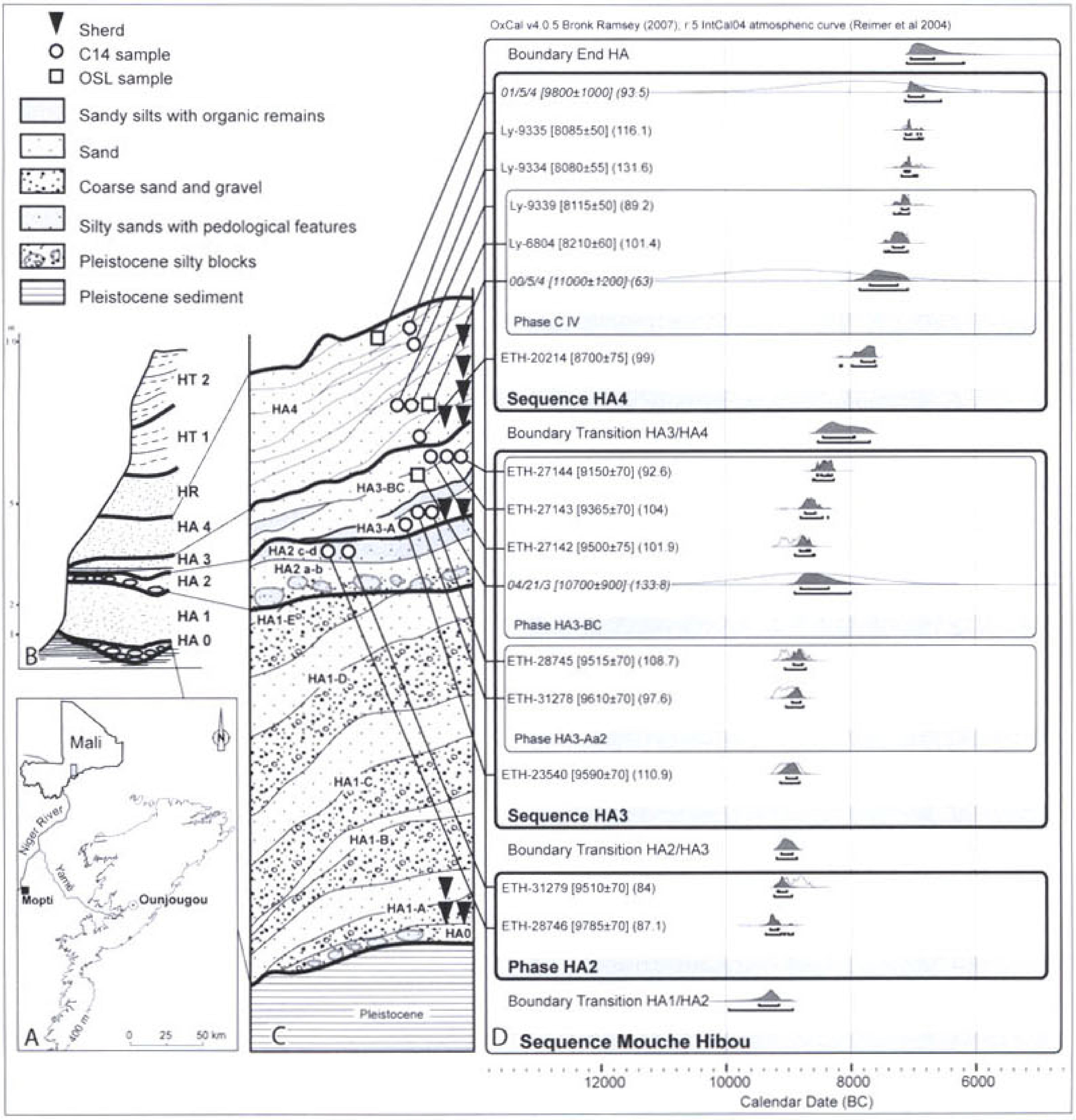

Figure 1. A) Location of the site of Ounjougou; B) general stratigraphic sequence for the Holocene of Ounjougou; C) stratigraphic sequence of the Early Holocene, with the position of the potsherds and ^{14}C and OSL samples; D) OxCal plot of the series of ^{14}C and OSL dates for the Early Holocene sequence (OxCal v. 4.0.5: Bronk Ramsey 2008. IntCal04 atmospheric curve). Figures in light grey represent the prior distributions for each sample, those in dark grey the posterior modelled distributions (hpd). Indicated on the left for each sample, are: laboratory ID, BP age or raw OSL age (in parentheses), and the individual agreement index (A) (in parentheses). The model agreement index (Amodel) for the data series is 99.6% (see Technical Appendix).

Holocene occupation at Ounjougou, dated to the eighth millennium cal BC by five ^{14}C dates on charcoal and two OSL dates (between 8080 ± 55 BP and 8700 ± 75 BP, Figure 1, Table 1). The material culture is characterised by a microlithic quartz industry, with geometric segments, associated with ceramics and grinding tools (mortar and pestles), in a Sudanian savannah context combined with *Syzygium* gallery-forests (Huysecom *et al.* 2004; Eichhorn & Neumann in press).

Table 1. Radiocarbon and OSL dates, with details of the OxCal plot results. The columns on the right of the table give the 1σ and 2σ ranges of Bayesian hpd (highest posterior density), the mean (μ), the agreement indice for each date (A) and the agreement index for the whole model (Amodel). See also Technical Appendix.

							Calibrations				Bayesian hpd (Amodel = 99.6)					
Unit/transitions	Sample	Material	^{14}C BP	±	OSL Age	±	1σ		2σ		1σ		2σ		μ	A
End HA4											7032	6654	7096	6173	6729	
	01/5_4	Quartz grains			9800	1000					7067	6829	7124	6544	6892	93.5
	Ly-9335	Wood charcoal	8085	50			7174	6867	7291	6826	7121	6868	7137	6836	7026	116
	Ly-9334	Wood charcoal	8080	55			7173	6848	7295	6820	7134	7046	7183	6923	7083	132
HA4	Ly-9339	Wood charcoal	8115	50			7172	7052	7312	6861	7182	7070	7306	7056	7160	89.2
	Ly-6804	Wood charcoal	8210	60			7317	7086	7450	7066	7322	7143	7451	7077	7243	101
	00/5/4	Quartz grains			11000	1200					7684	7234	7846	7070	7466	63
	ETH-20214	Wood charcoal	8700	75			7816	7598	8166	7582	7817	7599	8166	7582	7765	99
HA3/HA4											8439	7926	8521	7683	8132	
	ETH-27144	Wood charcoal	9150	70			8452	8286	8551	8256	8535	8293	8601	8263	8415	92.6
	ETH-27143	Wood charcoal	9365	70			8741	8556	8815	8350	8730	8559	8800	8359	8626	104
	ETH-27142	Wood charcoal	9500	75			9120	8659	9152	8629	8812	8645	8891	8572	8739	102
HA3	**04/21/3**	Quartz grains			10700	900					8800	8351	8896	7996	8501	134
	ETH-28745	Wood charcoal	9515	70			9121	8744	9155	8638	8916	8766	9054	8715	8859	109
	ETH-31278	Wood charcoal	9610	70			9184	8841	9233	8790	8939	8799	9040	8756	8886	97.6
	ETH-23540	Wood charcoal	9590	70			9148	8836	9224	8773	9036	8861	9131	8821	8966	111
HA2/HA3											9116	8935	9191	8862	9027	
HA2	ETH-31279	Wood charcoal	9510	70			9121	8734	9151	8638	9178	9024	9231	8943	9094	84
	ETH-28746	Wood charcoal	9785	70			9315	9201	9441	8925	9296	9157	9366	8927	9208	87.1
HA1/HA2											9477	9152	9959	8932	9376	

The HA3 formation (8100-9000 cal BC)

In *Ravin de la Mouche*, below HA4, unit HA3 comprises a succession of several coarse sand lenses and grey sandy silt layers with organic remains. This indicates a meandering river, with a coarse load, flowing in a floodplain with permanent ponds. Six ^{14}C dates and one OSL date allow us to place this formation of HA3 between 8100 and 9000 cal BC (between 9150 ± 70 BP and 9610 ± 70 BP, Figure 1, Table 1). Charcoal, pollen and phytoliths in this layer indicate the existence of open grassland with a few Sahelo-Sudanian tree species and a dense gallery-forest with the riverine tree *Syzygium*. Uapaca, Celtis, Palms and Marantaceae in the undergrowth were also constituents of the denser woody vegetation along the watercourses. It points to the existence of a permanent water source, which is essential for palm growth (Strömberg 2004), and for Uapaca (Arbonnier 2000). There is some evidence of fire, but only in the gallery-forest (Neumann *et al.* 2009).

With its coarser and finer laminae, HA3 represents the earliest Holocene rhythmic sediments resulting from alternating wet and dry season alluvial sedimentation. The archaeological finds of HA3 are characterised by some isolated quartz flakes and two small rounded ceramic fragments (diameter 15mm, thickness 7-8mm) which might represent a re-deposition of older material.

The HA2 formation (9000-9400 cal BC)

Under HA3, unit HA2 is composed of silty sandy alluvial sediments with grey Pleistocene silty blocks, particularly at the base of the unit (HA2/a-b), which indicates an important incision of the meandering river and river bank erosion into the Pleistocene deposits (Lespez *et al.* 2008). These alluvial sediments experienced a slight pedogenesis, particularly visible in the upper part of the unit (HA2/c-d). Two ^{14}C dates place the HA2 sequence, which is archaeologically sterile, between 9000 and 9400 cal BC (9510 ± 70 BP and 9785 ± 70 BP, Figure 1, Table 1). HA2 is a fossil soil with a massive structure and few channels with clay coating, and phytoliths originating from vegetation developed *in situ* on the ancient land surface. The spectrum of Poaceae short cell phytoliths points to a grassland similar to the modern northern Sahel, with dominating annuals (Barboni *et al.* 2007; Neumann *et al.* 2009). Among the Poaceae, short cell phytoliths identifiable to subfamily level – panicoid morphotypes – (Piperno 2006) are well represented. The grass subfamily Panicoideae comprises numerous annual species with edible grains which are commonly collected in the Sahel today (Harlan 1989) and were also used by prehistoric populations in the Sahara during the Early and Middle Holocene (Fahmy & Barakat 1999; Wasylikowa 2001). The phytolith samples also contain an allochtonous component originating from episodic flooding of the fossil soil, with morphotypes from Marantaceae and palms indicating a dense gallery-forest with a shade-tolerant undergrowth.

The HA1 formation (before 9400 cal BC)

Below HA3 and HA2, unit HA1 is 2-5m thick and consists of several sequences composed of red to ochre cross-bedded coarse sand and gravel with grey Pleistocene silt blocks, suggesting high-energy flows running through a braided river (Lespez *et al.* 2008). The phytolith samples in HA1 are very poor, due to the low amount of silt, and are therefore not interpretable in terms of the vegetation during this period. Only a few micro-charcoals were found in HA1, and gave a Pleistocene age, showing the importance of re-deposited sediments. OSL dating failed in the coarse and badly (if at all) bleached sediments. However, the ^{14}C and OSL dates of units HA2, HA3 and HA4 constitute a reliable *terminus ante quem* of 9400 cal BC for unit HA1 and the re-deposition of the archaeological material (Figure 1, Table 1). The archaeological remains of HA1 include the oldest ceramic sherds and a rich lithic industry. The artefacts, although out of archaeological context and reworked, were discovered in a well-characterised sedimentary sequence, accurately positioned in the stratigraphic sequence between the Pleistocene deposits and the first dated early Holocene sediments (HA2). They represent a former occupation on the river banks, the sites having been eroded by fluvial activity and their material re-deposited in HA1. The good preservation of two ceramic sherds and the slight wearing on the ridges of the lithic material show clearly that they had not been transported over long distances.

The HA1 assemblage

The lithic assemblage of unit HA1 numbers 479 objects, primarily knapped from quartz cobbles. It is characterised by small bifacial fusiform or oval foliate points (Figure 2), obtained by bifacial shaping, in some cases by pressure flaking, and by the absence of geometric microliths. Among the other retouched tools are drill bits, borer, burins and end-scrapers. This toolkit, although in secondary position, can be securely attributed to the Early Holocene, since these types are significantly absent in the MSA industries of the region, particularly drill bits, borers and bifacial points. The latter, based on their size, morphology and shaping technique, are quite different from those recovered in the recent phases of the MSA at Ounjougou (Robert *et al.* 2003). Moreover, retouched tools are rare or absent in MSA industries at Ounjougou, although here they represent 6.2 per cent of the entire assemblage. The other retouched tools within HA1 unit (sidescrapers, retouched flakes, scaled pieces and denticulates) could also be observed in MSA industries so they could not be securely attributed to Early Holocene.

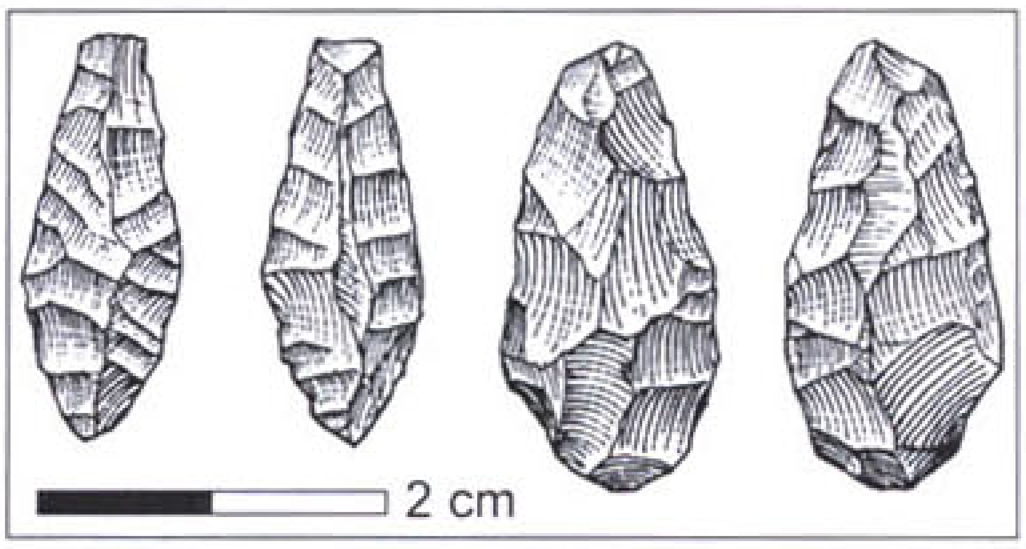

Figure 2. Bifacial arrowheads from unit HA1, directly associated with the sherds.

Three ceramic sherds from the base of the stratigraphic unit HA1A (Figure 3) are associated with this industry (their dimensions are respectively 100, 35 and 15mm). Their thickness ranges from 4.5 to 7mm. Only one form could be reconstituted as a hemispherical bowl with a simple rim and a diameter of 0.21m. One sherd shows a number of impressions which could not be precisely identified. Microscopic analysis of two samples shows a silicate matrix, free of carbonates, with 20-30 per cent of the volume being non-plastic inclusions. These are mainly well-rounded quartz monocrystals with a thin recrystallization border, very

Figure 3. Ceramic sherds from stratigraphic unit HA1, older than 9400 cal BC, including a bowl fragment (A) and a decorated sherd (B).

similar to those observed in local sandstones and clays. Therefore, a local to regional origin of the analysed samples can be inferred. Mineralogical analyses by X-ray diffraction of the clays from the closest outcrops confirm the presence of kaolinite, which is lacking in the studied material. This points to firing temperatures higher than 550°C, because kaolinite is not stable above this temperature in oxidizing firing conditions. Evidently, the studied samples are not fragments of a heat-hardened clay, but of a fired clay, i.e. of a true ceramic object.

The HA0 formation (before 9400 cal BC)

At the base of *Ravin de la Mouche*, the earliest sedimentary sequence (HA0) of the Pleistocene–Holocene transition is composed of reworked Pleistocene silts. This unit was directly cut into a channel developed within the yellow Pleistocene silts of formation U4, dated by OSL between 45 and 40ka (Rasse *et al.* 2004), and reflects a brutal hydrologic episode with significant reworking of the banks of the Yamé. It is archaeologically sterile.

Discussion: emergence of pottery south of the Sahara

At Ounjougou, new stratigraphic and chronological data for the beginning of the Holocene support a *terminus ante quem* of 9400 cal BC for an archaeological assemblage characterised by the presence of ceramics and lithics in small bifacial forms. From an archaeological viewpoint, if we consider all of the ^{14}C dates for African sites with ceramics and contemporary with the HA1, HA2 and HA3 formations at *Ravin de la Mouche* (Figures 4 and 5, Table 2), it can be observed that few of them have been dated earlier than 9000 cal BC. They are concentrated in two different regions: in the large mountain massifs of the Central Sahara (Adrar Bous 10 and Tagalagal; Roset 2000) and in the Eastern Sahara and the Nile Valley (Bir Kiseiba E-79-8, Sarurab 2 and Wadi el Akhdar; Connor 1984; Khabir 1987; Schön 1996).

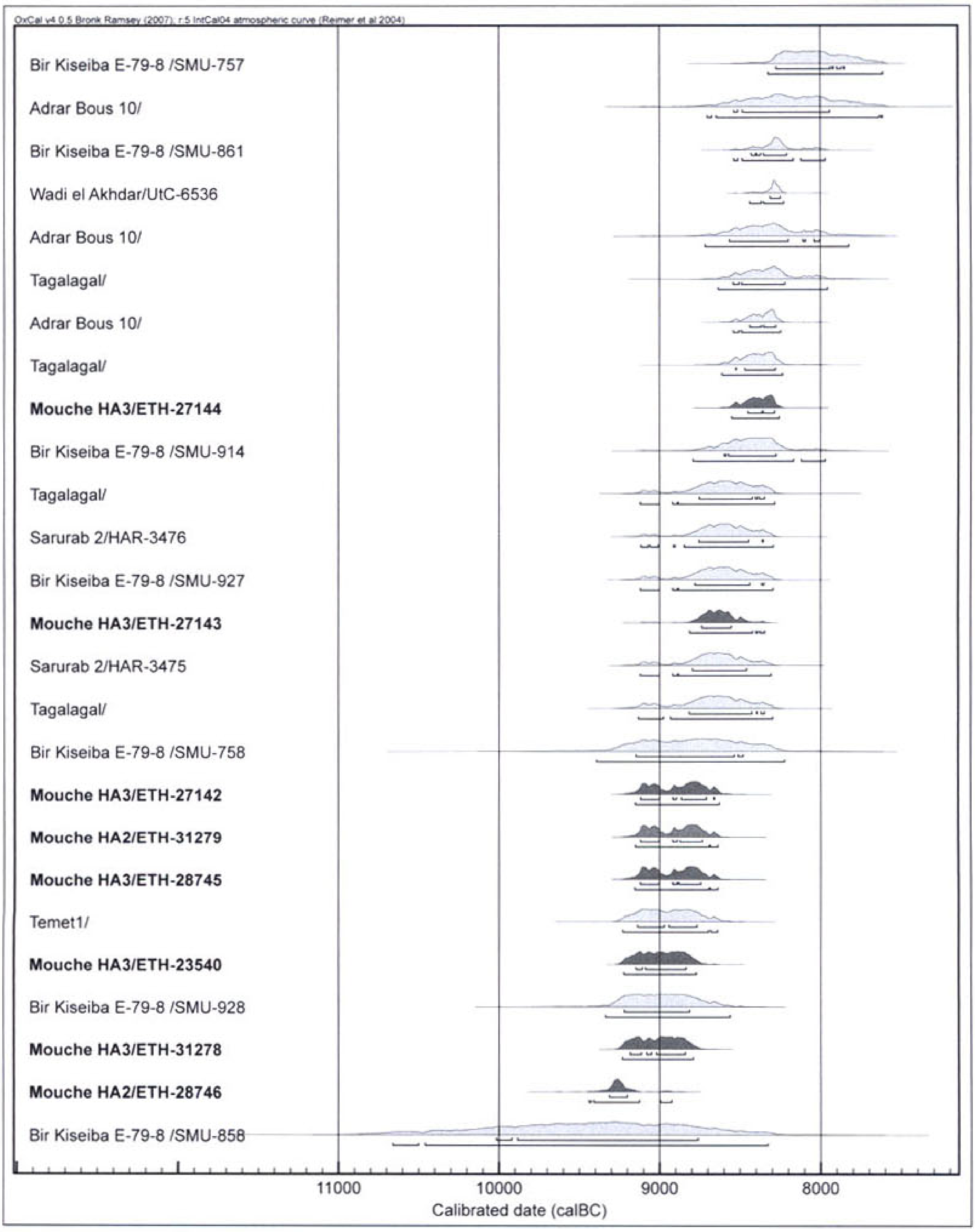

Figure 4. Summary of ^{14}C *dates from African sites with ceramics contemporaneous with the HA1, HA2 and HA3 formations at* Ravin de la Mouche *at Ounjougou, in chronological order. The* Ravin de la Mouche ^{14}C *dates are here represented as simple calibrations.*

After a review of the evidence, we have decided to exclude a series of dates lacking a clear stratigraphic context from the discussion: the earliest ^{14}C date of Uadi Ti-n-Torha in Libya 9080 ± 70 BP (R-1036, Barich 1974: 149), Tamaya Mellet in Niger 9350 ± 170 BP

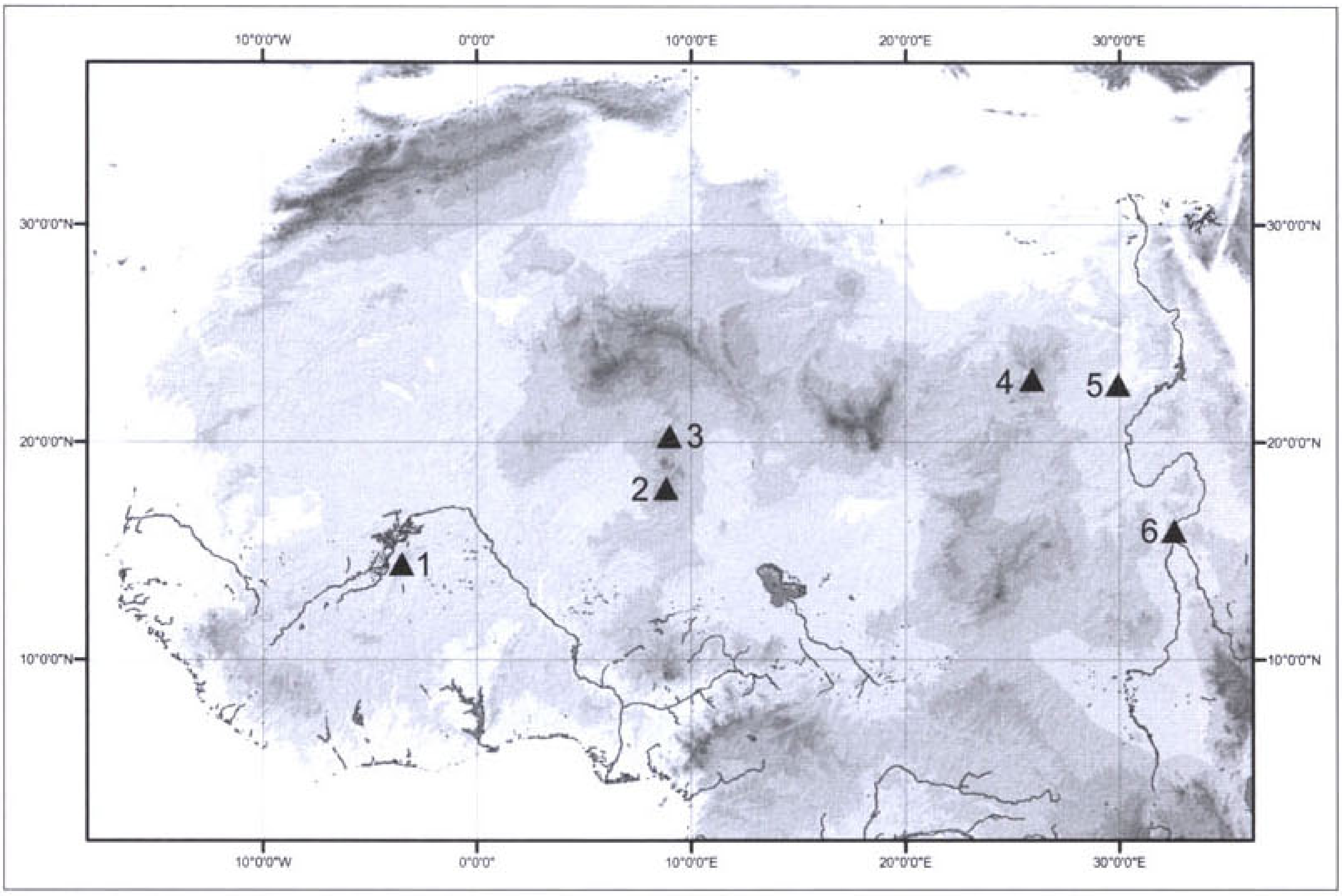

Figure 5. Map of African archaeological sites with ceramics contemporaneous with the HA1, HA2 and HA3 formations at Ounjougou: 1) Ounjougou/Ravin de la Mouche; 2) Tagalagal; 3) Adrar Bous 10; 4) Wadi el Akhdar; 5) Bir Kiseiba E-79-8; 6) Sarurab 2 (map data: SRTM and FAO).

(Gif-1728, Paris *et al.* 1993: 385), Bir Kiseiba E-80-4 in Egypt 9220 ± 120 BP (SMU-925, Close 1984: 347) and finally the Site Launey AK-AF 094-18 in Algeria 9210 ± 115 BP (UW-97, Maître 1971: 57; Maître 1974: 101). The discoveries of Temet in Niger are not included in this discussion either. The excavation of the lacustrine deposits of Temet yielded a date indicating the contemporaneity of this site with the HA2 formation at Ounjougou, at the junction of the tenth and ninth millennium cal BC (9550 ± 100 BP; Roset 1983, 1996). This is also one of the few sites that contain bifacial arrowheads comparable to those found in formation HA1 of *Ravin de la Mouche*, indicating a clear relationship between the two areas. However, Temet contains only whole or broken stone bowls made out of fibrolite. The use of pottery here is only suggested by a fragment of a short, toothed object, on a plaquette of chloritic schist. This object was interpreted as a potter's comb after the observation of impressed motifs on surface-find sherds (Roset 1983: Figure 15). The latter sherds cannot, however, be reliably correlated with the occupation of the site during the Early Holocene. In addition, this object may also be a fragment of a disc decorated with incisions, without any necessary connection to ceramic production. Until proof of the contrary, the populations of Temet appear to have opted for the use of carved and polished stone and not fired clay for the fabrication of some of their containers.

Only one comparable site can be seen as potentially contemporary with the appearance of ceramics at Ounjougou, before the HA1/HA2 transition: Bir Kiseiba, in the southern part of the Egyptian Sahara, this site having also yielded grinding equipment. The site E-79-8 at Bir Kiseiba yielded three sherds discovered during the excavation of sandy sediments

Table 2. Summary of ^{14}C dates and calibrations from African sites with ceramics contemporaneous with the HA1, HA2 and HA3 formations at Ounjougou. *Ravin de la Mouche* dates appear here as simple calibrations in chronological order.

Country	Site	N° Lab ^{14}C	BP	±	Cal BC 1σ		Cal BC 2σ	
Egypt	Bir Kiseiba E-79-8	SMU-757	8920	130	8274	7846	8323	7610
Niger	Adrar Bous 10	N	9030	190	8535	7940	8700	7612
Egypt	Bir Kiseiba E-79-8	SMU-861	9060	80	8428	8207	8536	7969
Soudan	Wadi el Akhdar	UtC-6536	9080	50	8310	8246	8437	8226
Niger	Adrar Bous 10		9100	150	8563	8004	8713	7823
Niger	Tagalagal		9100	120	8541	8221	8633	7955
Niger	Adrar Bous 10		9130	65	8437	8277	8541	8245
Niger	Tagalagal		9150	90	8525	8279	8610	8235
Mali	Mouche HA3	ETH-27144	9150	70	8450	8285	8550	8255
Egypt	Bir Kiseiba E-79-8	SMU-914	9180	140	8597	8275	8790	7971
Niger	Tagalagal		9330	130	8753	8348	9120	8284
Soudan	Sarurab 2	HAR-3476	9339	110	8755	8354	9116	8293
Egypt	Bir Kiseiba E-79-8	SMU-927	9350	120	8780	8352	9120	8295
Mali	Mouche HA3	ETH-27143	9365	70	8739	8555	8814	8348
Soudan	Sarurab 2	HAR-3475	9370	110	8796	8461	9120	8308
Niger	Tagalagal		9370	130	8817	8350	9132	8298
Egypt	Bir Kiseiba E-79-8	SMU-758	9440	230	9147	8481	9393	8224
Mali	Mouche HA3	ETH-27142	9500	75	9119	8658	9150	8628
Mali	Mouche HA2	ETH-31279	9510	70	9119	8733	9150	8636
Mali	Mouche HA3	ETH-28745	9515	70	9120	8743	9154	8637
Mali	Mouche HA3	ETH-23540	9590	70	9147	8835	9222	8772
Egypt	Bir Kiseiba E-79-8	SMU-928	9610	150	9220	8813	9336	8561
Mali	Mouche HA3	ETH-31278	9610	70	9183	8839	9231	8789
Mali	Mouche HA2	ETH-28746	9785	70	9313	9200	9440	8923
Egypt	Bir Kiseiba E-79-8	SMU-858	9820	380	10015	8759	10660	8326

(Connor 1984), found just below ground surface, as well as at depths of 0.10 and 0.60m. In the publication, the excavator indicates for the deepest sherd: *'it is possible that the sherd might have been moved to this depth by traffic over the surface of the site'* (Connor 1984: 240). Three other sherds were nearby surface finds. The seven ^{14}C dates obtained on charcoal, unfortunately, have large error margins and as a result a broad range for the calibration, which ranges from the end of the eleventh millennium to the beginning of the eighth millennium cal BC (between 9820 ± 380 BP and 8920 ± 130 BP). Without stratigraphic context to clearly correlate the three sherds and the dates, it is not possible to go further in the interpretation of this site in terms of dating the emergence of ceramics.

From a palaeoenvironmental viewpoint, geomorphological and sedimentological analyses in *Ravin de la Mouche* indicate a powerful hydrologic regime for this period that remodelled the landscape on the valley floor. This allows us to identify a relationship between the emergence of the ceramic and lithic assemblage with one of the humid phases of the Pleistocene–Holocene transition recently recognised in West Africa (DeMenocal *et al.* 2000; Duplessy *et al.* 2005; Lézine *et al.* 2005). This corresponds most probably to the abrupt resumption of the African monsoon after the Younger Dryas, between 10 050 and

9350 cal BC, the early Holocene monsoon front reaching 14°N around 9500 cal BC in West Africa (Garcin *et al.* 2007). The palaeoenvironmental data from Ounjougou and other terrestrial sites in the Sahel (Waller et al. 2007; Neumann *et al.* in press) show that the onset of the monsoon had an immediate effect on the landscape. A vast tropical grassland spread across the former desert areas, and panicoid grasses with edible grains became available in abundance. As in the Near East (Haaland 1995, 2007; Hillman 1996) and in East Asia, the massive presence of wild cereals triggered the development of new resource exploitation behaviour, linked with technological innovations for collection, storage and processing. Heat treatment of the wild cereals before consumption increases the digestibility of the starch-rich grains by amylase in the human body (Stahl 1989). While the baking of bread became the predominant form of processing in the Near East, we hypothesize that the small grains of the tropical African Panicoideae were boiled in a container, as practised today in the Sahel. As with East Asia, African ceramics were part of a new technological complex, together with the production of small bifacial arrowheads for hunting in the open tropical savannas.

Conclusion

Thus, with a solid stratigraphic and chronological context at Ounjougou, there is no doubt that ceramics appeared in sub-Saharan West Africa at least as early as in the Nile Valley, some time before 9400 cal BC. This innovation must be coupled with the re-establishment of the tropical grassland during the Early Holocene. Starting in the middle of the tenth millennium cal BC, the new technological complex may have rapidly diffused northwards, together with the advancing monsoon front, the greening of the Sahara and the massive expansion of edible Panicoid grasses.

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Technical Appendix

After calibration of the ^{14}C data (IntCal04), OSL and ^{14}C data sets have been treated together with the Bayesian statistical method. This method consists in using secure stratigraphic information to recalculate the probability density functions (pdf) for each sample (Bronk Ramsey 2000). In short, it allows the pinpointing of the most likely part of each pdf (called 'posterior' data, often referred to as 'highest posterior density' or hpd) when considering the stratigraphic relationships. The direct and interesting consequence is a reduction of the uncertainty for each individual value and thus an increase of the chronological resolution (Figure 1).

All calculations have been done with the Oxcal 4.0 software (Bronk Ramsey 2008). OSL data have been integrated to the ^{14}C ones following the recommendations of Rhodes *et al.* (2003). The A index gives an indication of the consistency of the data within the data set: when lower than 60%, the data is considered as an outsider and can be discarded. In complement to the posterior for each data, one can calculate the most likely interval for the transitions between the phases. The general chronological ranges used to describe the HA4-HA0 units are based on the intervals calculated for those transitions (68.2% confidence interval and μ). In particular, this allows concluding that the transition between HA1 and HA2 occurred between 9477 and 9152 cal BC with 68.2% confidence interval (between 9959 and 8932 with 95.4% confidence interval; $\mu = 9376$. See Table 1).

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