C. R. Palevol 13 (2014) 737–746

Contents lists available at ScienceDirect

Comptes Rendus Palevol

www.sciencedirect.com

Human palaeontology and prehistory

Spatial behaviours of Early Oldowan toolmakers in the Shungura Formation (Lower Omo Valley, Ethiopia): Proposal for an integrated approach

Comportements spatiaux des tailleurs de pierre de l'Oldowayen ancien dans la Formation de Shungura (basse vallée de l'Omo, Éthiopie) : proposition pour une approche spatiale intégrée

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ARTICLE INFO

Article history:
Received 10 April 2014
Accepted after revision 10 June 2014
Available online 21 August 2014

Handled by Marcel Otte

Keywords:
Early Oldowan
Spatial behaviours
Environment
Stone tools
Eastern Africa
Lower Pleistocene
Shungura Formation

Mots clés :
Oldowayen ancien
Comportements spatiaux
Environnement
Outils en pierre
Afrique de l'Est
Pléistocène inférieur
Formation de Shungura

ABSTRACT

The spatial relationships of the Early Oldowan toolmakers with their environment have been so far addressed through raw material procurement analyses and the characterization of hominid habitat. This paper proposes to integrate these two approaches into a broader spatial analysis encompassing archaeological and environmental data (palaeontological, geological and isotopic data) from Member F and lower Member G of the Shungura Formation (Lower Omo Valley, Ethiopia). Heterogeneity in data resolution induces a multiscale approach with three levels of analysis. The level of occurrence complex allows focusing on the characterization of archaeological occurrences and on their environmental settings. The level of "study area" allows working on hominid habitats and on their raw material procurement behaviours. Finally, at the Shungura Formation scale, we can address temporal issues related to the evolution of spatial behaviours between Member F and the lower part of Member G, ca. 2.3 to 2 million years (Ma).

RÉSUMÉ

Les relations spatiales des tailleurs de pierre de l'Oldowayen ancien avec leur environnement ont fait jusqu'à présent l'objet de recherches axées sur l'acquisition de la matière première et sur l'habitat des hominidés. Ce papier développe les fondements d'une approche spatiale intégrant ces deux aspects au sein d'un travail croisant les données archéologiques et environnementales (paléontologiques, géologiques et isotopiques) du Membre F et de la partie inférieure du Membre G de la Formation de Shungura (basse vallée de l'Omo, Éthiopie). Ces données se situant à différents niveaux de résolution

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http://dx.doi.org/10.1016/j.crpv.2014.06.003

spatiale, une approche multi-scalaire est proposée : l'échelle du complexe d'occurrences archéologiques pour la caractérisation des occurrences archéologiques et de leur cadre environnemental, celle de « l'aire d'étude » pour laquelle vont être apportées des précisions sur l'habitat des hominidés et leurs approvisionnements en matière premières, et enfin celle de la Formation de Shungura pour confronter entre elles les données spatiales acquises dans le Membre F et dans la partie inférieure du Membre G, entre environ 2,3 et 2 millions d'années (Ma), dans une optique temporelle.

1. Introduction

Over most of their evolutionary history, the role of hominids within the African Neogene ecosystems remains elusive, because they are documented only by rare and mostly fragmentary remains. With the appearance of the Early Oldowan stone tool record prior to 2 Ma, it becomes possible to track down hominid activities within fossil landscapes, enhancing our capacities in understanding key features of hominid adaptive success, such as behaviours, ecology, responses to environmental changes.

Questions about the taxon (or the taxa) of the Early Oldowan toolmakers are still open. Between 2.3 and 2 Ma, hominid fossils from the Omo-Turkana basin (Howell et al., 1987), whether related to the palaeo-Omo river vicinity (Shunugura Formation) or from the palaeo-Turkana vicinity (Nachukui Formation), correspond to robust *Australopithecus* and early *Homo* (Brown and Feibel, 1988; Coppens, 1970; Prat et al., 2005).

So far two types of approaches have been favoured in the analysis of the spatial relationships of the early hominids to their environment. One of them focuses on the exploitation of raw material sources, mostly in the vicinity of the archaeological occurrences in Early Oldowan contexts (Bishop et al., 2006; Braun et al., 2008; Delagnes et al., 2011; Goldman-Neuman and Hovers, 2012; Harmand, 2005; Plummer et al., 1999; Stout et al., 2005). The other approach aims at characterizing the landscapes inhabited by hominids at larger scales (Aronson et al., 2008; Bonnefille, 2010; Brugal et al., 2003; López-Sáez and Domínguez-Rodrigo, 2009; Plummer et al., 1999, 2009; Quinn et al., 2013; Reynolds et al., 2011). Although these studies deal with spatial behaviours, no spatial approach integrating all data related to resource procurement mobility (i.e. water, food and raw material) and habitat features have been developed so far for this time period. Such a holistic approach can bring significant insights into the relationships between early toolmakers and their environment, and on the evolution of these relationships.

Thanks to the rich corpus of geolocated archaeological and contextual data (palaeontological, geological and isotopic data) available for the Shungura Formation, an original integrated approach is proposed. This article defines the methodology and highlights the perspectives of this new approach. This research is developed as part of the Omo Group Research Expedition (OGRE; Boisserie et al., 2008). It also includes the data brought by earlier field works carried out by the International Omo Research Expedition (IORE) between 1967 and 1976 (Boisserie et al., 2013; Chavaillon, 1976; Coppens, 1970, 1971, 1977; Coppens et al., 1973; de Heinzelin, 1983a; Gautier, 1976; Howell and Coppens, 1985; Howell et al., 1987; Jaeger and Wesselman, 1976; Johanson et al., 1976; Merrick and Merrick, 1976).

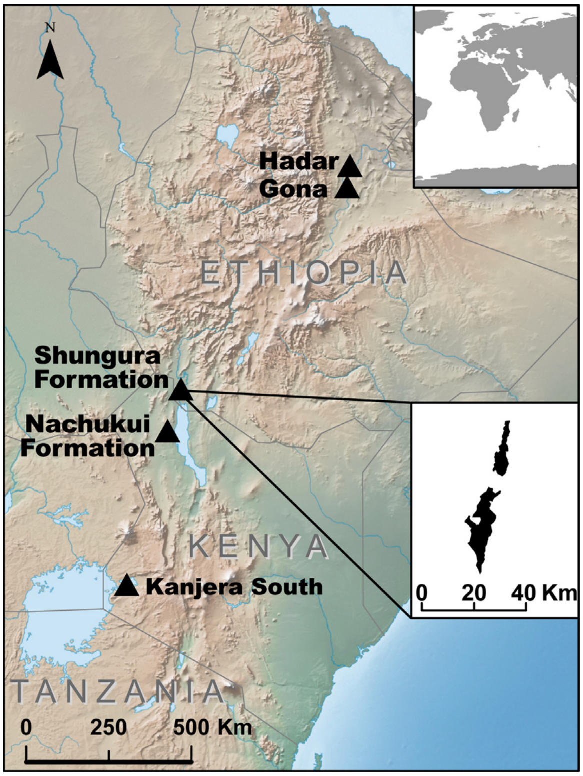

Fig. 1. (Color online.) Early Oldowan site complexes.

Fig. 1. (Couleur en ligne.) Les complexes de sites du début de l'Oldowayen.

2. Brief review of the available spatial data

Only five *in situ* Early Oldowan site complexes have been documented so far in eastern Africa: Gona, Hadar, and Shungura in Ethiopia, Lokalalei and Kanjera in Kenya (Chavaillon, 1976; Harris, 1983; Merrick and Merrick, 1976; Plummer et al., 1999; Roche et al., 2003; Semaw et al., 1997) (Fig. 1), although a large number of Early Pleistocene hominid fossils have been found in many localities from eastern to southern Africa (Reed et al., 2013). The available spatial data are limited to these archaeological complexes.

2.1. Raw material procurement and spatial data

A majority of studies has focused on the location of the closest available resources for assessing the distance of raw material transport. The general availability and diversity of raw material at a broader scale was usually not described, except at Kanjera South (Braun et al., 2008), where the distribution of two different raw materials has been mapped in the context of the local river drainage system. The distances of the raw material sources vary significantly from one site to another: within a few meters at Gona (Stout et al., 2005) and Lokalalei (Harmand, 2005), within a kilometre at Hadar (Goldman-Neuman and Hovers, 2012), over 10 kilometres at Kanjera South (Braun et al., 2008). Despite this low mobility, the selection of specific types of raw material and/or specific morphologies has been documented in all the Early Oldowan site complexes (Bishop et al., 2006; Braun et al., 2009b; Delagnes et al., 2011; Goldman-Neuman and Hovers, 2012; Harmand, 2005; Plummer et al., 1999; Stout et al., 2005). Such behaviours reflect an accurate knowledge of raw material knapping properties and availability.

2.2. Reconstructing hominid environments

Hominid environments are usually described through various proxies. These environments can be considered at a very large-scale, e.g. eastern Africa, in order to compare climatic changes with human evolution. Data from non-hominid sites with a regional representativeness, such as pollen from marine cores, and data from hominid sites with a more local representativeness, as pollen or soil carbonates, are both considered and compared mostly in a diachronic perspective (Bonnefille, 2010). At the more local scale of the hominid-bearing palaeolandscapes, the most common proxies relate to faunal assemblages (Brugal et al., 2003; Plummer et al., 2009), pollen (López-Sáez and Domínguez-Rodrigo, 2009), and soil carbonate isotopes (Aronson et al., 2008; Plummer et al., 1999; Quinn et al., 2013).

At Gona, hominids inhabited a mosaic landscape with a large proportion of wooded areas, as indicated by palynological data (López-Sáez and Domínguez-Rodrigo, 2009). In the Nachukui Formation, the palaeontological record related to the Early Oldowan occurrences also indicates a mosaic landscape (Brugal et al., 2003). Soil carbonate isotopes suggest that the archaeological occupations took place in the wooded part of this landscape (Quinn et al., 2013). Geological data are consistent with settlements in the vicinity of a lake, on the banks of lagoonal ponds (Tiercelin et al., 2010) or in the floodplain and in the vicinity of a secondary channel (Roche et al., 2003). By contrast, at Hadar (A.L. 666, Aronson et al., 2008) and at Kanjera South (Plummer et al., 1999, 2009). Isotopic and faunal analyses indicate that Early Oldowan activities took place in drier settings.

These environmental interpretations mostly come from spatially restricted records, associating few concentrations of archaeological occurrences with large-scale environmental data. They usually result in a vague "mosaic" or "grassland-dominated" assessment of the spatial structure of palaeo-ecosystems, and the distribution of hominid activities in relation to this structure remains unclear. The investigation of local variations in palaeolandscapes and hominid activities requires coeval archaeological and environmental records of significant geographical extension at a landscape scale. Currently, only the Shungura Formation displays such an Early Oldowan archaeological and spatial record, extending along a transect of at least 8 km in association with rich geological and palaeontological records.

3. The Shungura Formation, a context adapted to a spatial approach

In the Shungura Formation, our approach aims to combine archaeological locations and distributions of water, lithic, vegetal, and animal resources in the framework of micro-regional spatial analyses. The broad array of available data, including archaeological, palaeontological, geomorphological, sedimentological, isotopic, and those from dental microwear, retrieved from an extended research area has been integrated into a single GIS database. It must however be kept in mind that we cannot access the entire landscape for a given period, insofar as what we can analyse are only "observation windows" that are physically delimited by the outcrops and that represent a sampling of the palaeolandscapes. We assume that this sampling is random and that all variations in the palaeolandscape at a multi-kilometer scale are represented.

The Shungura outcrops stretch out over a length of ca. 60 km and a mean width of ca. 5 km, favouring a micro-regional spatial approach thanks to their physical configuration. Deposits are divided into members designated by letters, i.e. fluvio-lacustrine cycles interbedded between major extended tuff deposits that define the limits of each member (except for the bottom of Basal Member and the top of Member L (see de Heinzelin and Haesaerts, 1983). Members were tilted westward 10° to 20°, or sometimes more (Fig. 2), as a result of a tectonic phase dated to between 800 ka and 100 ka (Brown and de Heinzelin, 1983). Outcropping members currently form series of long and narrow strips oriented north-south. Each member also outcrops several times along an east-west axis as a result of the faulting system (de Heinzelin, 1983a). Temporal information is therefore closely related to spatial information. Previous palaeontological and archaeological studies have mostly focused on the northern part of the formation (e.g. Boisserie et al., 2010; Coppens, 1977; de Heinzelin, 1983b; Delagnes et al., 2011; Howell et al., 1987), where the fossiliferous sequence extends from the Basal Member to lower Member J, between ca. 3.6 Ma and 1.76 Ma (McDougall and Brown, 2008; McDougall et al., 2012).

The former IORE investigations suggested an archaeological occupation extending over Member E and Member F (Chavaillon, 1976; de Heinzelin, 1983a; Howell et al., 1987; Merrick and Merrick, 1976). The OGRE archaeological investigations have evidenced a quite distinct picture with an archaeological presence starting with Member F and occurring up to lower Member G

Fig. 2. (Color online.) View of OMO 1/E. The sediments of the Shungura Formation are tilted westward.
Fig. 2. (Couleur en ligne.) Vue d'OMO 1/E. Les sédiments de la formation de Shungura sont inclinés vers l'ouest.

(Delagnes et al., 2011). Member E is dated between 2.40 ± 0.05 and 2.324 ± 0.020 Ma (Feibel et al., 1989; McDougall and Brown, 2008), while Member F is dated between 2.324 ± 0.020 Ma and 2.271 ± 0.041 Ma (McDougall and Brown, 2008; McDougall et al., 2012), and lower Member G between 2.271 ± 0.041 Ma and 2.077 ± 0.012 Ma or 2.059 ± 0.013 Ma (Kidane et al., 2007; McDougall et al., 2012). The time span covered by the archaeological occurrences in the Shungura Formation would thus extend from ca. 2.3 to 2 Ma, instead of 2.4 Ma to 2.2 Ma, as previously assumed. Although all members below and above Member F and lower Member G have provided abundant collections of vertebrate remains including hominids (Boisserie et al., 2008; Coppens, 1977; Howell et al., 1987), they have not yet yielded any significant archaeological record. This absence of artefact is unlikely to result from a methodological bias, insofar as careful surveys have been performed on extensive portions of their outcrops. While discrete archaeological occurrences have been recorded outside Members F and G, it clearly appears that significant toolmaking-related activities are limited to these two members. The total surfaces of Member F and lower Member G northern outcrops are respectively about 3.28 km^2 and 8.86 km^2.

3.1. Contextual data

A geological map of the northern Shungura outcrops was drawn by IORE geologists (de Heinzelin, 1983a). We have geolocated and re-drawn this map with the help of satellite images that allow us to observe the sedimentary units within the members at a more precise chronological and environmental resolution than the geological map. In addition, sedimentological data related to a number of type sections are available (de Heinzelin, 1983a). They help us to characterize the landscape (as lacustrine, deltaic or fluviatile) during each deposition phase and to define the specific location of the archaeological occurrences within fluviatile landscapes (as channel, point-bar, levee, floodplain, fluviatile swamp [Haesaerts et al., 1983]). At a wider scale, isotopic analyses made on soil carbonates (Levin et al., 2011) and on large mammal enamel (Bibi et al., 2012; Souron et al., 2012) are also informative for reconstructing the palaeo-environments. They can be combined with palaeo-vegetation related-data such as fossil wood and pollen (Bonnefille and Deschamps, 1983).

The faunal data are particularly abundant. Some 9037 fossils have been collected from Member F and 16395 in lower Member G (combining the IORE and OGRE collections). The fossils mostly consist of isolated teeth, cranio-mandibular fragments, and post-cranial elements. They are at least taxonomically attributed at the family level, and often at the genus or species level. Each specimen collected by the OGRE since 2006 is geolocated with an individual GPS point, whereas only the GPS points related to each locality are available for the fossils collected by the IORE. There are 252 localities in Member F and 509 in lower Member G, a majority of them being positioned in a single geological unit, while others are more widespread and encompass different units (de Heinzelin, 1983b).

The collected taxa belong mostly to large mammals. Bovids predominate, followed by hippopotamids, cercopithecids, and suids. Proboscideans (elephantids and deinotheres), giraffids, perissodactyls (equids and rhinocerothids), hominids and carnivores (hyenids, felids, viverrids, mustelids) are also present. Micromammals and non-mammalian fossils such as actinopterygians, chondrichthyans, crocodilians, chelonians or molluscs are also documented.

This important corpus resulted from various sampling methods. Most of the IORE fossils were collected by two independent teams (French and American) working on two different, arbitrarily defined territories, although in practice some overlap occasionally occurred. These two teams did not use the same sampling methods (Alemseged et al., 2007; Eck, 2007), introducing biases in the corpus composition and limiting the possibilities of comparison between both collections. Conversely, the OGRE, composed of only one multidisciplinary team, collected specimens

Table 1
Inventory of *in situ* archaeological occurrence of Member F.
Tableau 1
Inventaire des occurrences archéologiques *in situ* du Membre F.

Inventory number	Occurrence name	Complex	Inventor	Expedition	Year of investigation	Texture of sediment	Fauna
OMO A16	FtJi1	FtJi1 - FtJi3 - FtJi4	H.V. Merrick	IORE	1973	Sandy silt	Present
OMO A17	FtJi3	FtJi1 - FtJi3 - FtJi4	H.V. Merrick	IORE	1972	Sandy silt	Absent
OMO A68	L204-4	FtJi1 - FtJi3 - FtJi4	A. Delagnes	OGRE	2010	Sandy silt	Present
OMO A18	FtJi4	FtJi1 - FtJi3 - FtJi4	H.V. Merrick	IORE	1973	Sandy silt	Absent
OMO A19	FtJi5	FtJi5	H.V. Merrick	IORE	1973	Tuffite	Absent
OMO A95	L182	FtJi5	A. Delagnes	OGRE	2011	Coarse sand	Present
OMO A96	L182	FtJi5	A. Delagnes	OGRE	2011	Coarse sand	Absent
OMO A97	L182	FtJi5	A. Delagnes	OGRE	2011	Coarse sand	Present
OMO A2	FtJi2	–	H.V. Merrick	IORE	1971–1973	Silty clay	Absent
OMO A40	OMO 130	–	A. Delagnes	OGRE	2008	Sand	?
OMO A7	OMO 123e	OMO 123	J. Chavaillon	IORE	1973	Sand	Present
OMO A11	OMO 123i	OMO 123	J. Chavaillon	IORE	1973	Silt	Absent
OMO A12	OMO 123j	OMO 123	J. Chavaillon	IORE	1973	Silt	Absent
OMO A13	OMO 123k	OMO 123	J. Chavaillon	IORE	1973, 1976	Silty clay	Absent
OMO A14	OMO 123l	OMO 123	J. Chavaillon	IORE	1973	Silty clay	Absent
OMO A15	OMO 123m	OMO 123	J. Chavaillon	IORE	1973, 1976	Sand	Present
OMO A130	O97	–	A. Delagnes	OGRE	2011	Tuffic sand	Absent
OMO A106	L181	–	A. Delagnes	OGRE	2011	Coarse sand	Present
OMO A31	OMO 1/E-1	OMO 1/E	A. Delagnes	OGRE	2008, 2010	Sand	Absent
OMO A32	OMO 1/E-2	OMO 1/E	A. Delagnes	OGRE	2008, 2010	Sand	Present
OMO A33	OMO 1/E-3	OMO 1/E	A. Delagnes	OGRE	2008, 2010	Clay	Absent
OMO A41	OMO 79-1	OMO 79	A. Delagnes	OGRE	2008, 2010	Coarse sand	Absent
OMO A82	OMO 79-8	OMO 79	A. Delagnes	OGRE	2010	Silt	Absent
OMO A88	OMO 79	OMO 79	A. Delagnes	OGRE	2011	Coarse sand	Present
OMO A128	OMO 79	OMO 79	A. Delagnes	OGRE	2011	Silt	Absent
OMO A167	OMO 57-5	OMO 57	J. Chavaillon	IORE	1972	Coarse sand	?

From Chavaillon, 1976; Delagnes et al., 2011; Merrick and Merrick, 1976 and recent work by the OGRE.
OGRE: Omo Group Research Expedition; IORE: International Omo Research Expedition.

with homogeneous sampling methods in all parts and in all members of the formation. This new reference corpus will be used as a standard for assessing the IORE corpus biases. This condition is a prerequisite for comparing the faunal spectra from the different areas and time periods.

3.2. Archaeological data

Many terms have been used to designate the archaeological evidence in the Shungura Formation: "sites" and "occurrences" are commonly used, but "patches" (Merrick and Merrick, 1976), "*gisements (à éclat)*", "*points*" (Chavaillon, 1974, 1980; Chavaillon and Boisaubert, 1977), and "localities" (Chavaillon, 1976; Delagnes, 2012; Delagnes et al., 2011) are also mentioned. In this article we will use the term "archaeological occurrence" as a general term that includes all the located archaeological evidence, whether or not *in situ*. Each archaeological occurrence is individually geolocated and refers to a point that is the basic archaeological spatial entity used in the GIS. To date, 99 archaeological occurrences have been found in Member F and 51 in the lower part of Member G.

The archaeological record of the Shungura Formation includes data from *in situ* excavated archaeological occurrences, *in situ* non-excavated archaeological occurrences, and surface archaeological occurrences. The *in situ* archaeological occurrences are mostly concentrated into occurrence complexes that correspond to locations grouping together several archaeological occurrences that are close enough for establishing direct stratigraphic correlations. In Member F, 22 of the 26 *in situ* recorded occurrences are found in complexes (Chavaillon, 1976; Delagnes et al., 2011; Merrick and Merrick, 1976 and recent work by the OGRE). Eight of these 21 occurrences are located in fine-grained sediments (clay or silt; see Table 1). The richest lithic assemblages (FtJi 1 and FtJi 2, OMO 57, OMO 84, OMO 123) have been first studied by Merrick and Merrick (1976) for the FtJi archaeological occurrences and by Chavaillon (1974, 1976) for the OMO archaeological occurrences. The OMO archaeological collections have been reassessed recently by De la Torre et al. (2004), and by Delagnes et al. (2011) with the addition of the material from OMO 1/E. All these studies point out that lithic artefacts are mainly flakes, made from quartz pebbles in an overwhelming majority of cases. Furthermore, the anthropic origin of the lithic tools can be rejected only for OMO 71 located in Member E (De la Torre et al., 2004; Delagnes et al., 2011).

Since 2008, the OGRE has carried out a large-scale archaeological survey together with a systematic inventory of the archaeological occurrences and raw material sources. More than 151 ha have been surveyed in Member F and more than 161 ha in lower Member G (Fig. 3). There are 97 archaeological occurrences recorded so

Fig. 3. (Color online.) OMO A82 archaeological occurrence (Member F). White circles point out artefacts.

Fig. 3. (Couleur en ligne.) Occurrence archéologique OMO A82 (Membre F). Les cercles blancs indiquent les artefacts.

far in Member F and 50 in lower Member G (Fig. 4; Table 2). An archaeological occurrence was created when at least three artefacts were found with a maximal distance of 10 m one from each other, in a primary or secondary position, excluding the lithics found in recent channels (Delagnes, 2012). The abundance of the assemblages is assessed on the field using ranges of class values.

The artefacts discovered in silts and clays give indications of the type of landscape occupied by the hominids. The related occurrences can be considered geologically *in situ* (*sensu* Sitzia et al., 2012). The assemblages discovered in coarser sediments, i.e. river sands, indicate at least that the hominids settled in the area, but it is not possible to determine their exact habitat. Finally, large spaces devoid of artefacts between occurrences located within the same geological unit reflect the lack of significant remobilisation that would have scattered artefacts over large areas. We thus assume that the spatial distribution of the artefacts can bring relevant information on the relationships between the hominids and their environment, provided that their depositional context is taken into account.

4. A multiscale approach

A three-scale approach has been developed to address a number of questions. Such a multiscale approach is required for processing data with varied levels of spatial accuracy (Pillot and Saligny, 2012) and for getting results that are consistent with variations in data resolution.

4.1. Occurrence complex level

The first level is the local scale and focuses on the occurrence complex. It gives the opportunity to better understand the hominid behaviours at a high-resolution level along both horizontal and vertical axes. The horizontal axis allows studying the spatial and environmental relationships between penecontemporaneous occurrences. On

Table 2

Artefact density per ha for surveyed parts of Member F and lower Member G (LG). The total of artefacts was calculated from the artefact number estimations for each occurrence. These estimations fall into three classes (number of surface artefacts). For class 3 to 10 artefacts, the estimation is 6.5 artefacts; for class 11 to 50, the estimation is 30.5 artefacts; for class > 50, the estimation is 165.75 artefacts. The class Indet. refers to occurrences for which the number of surface artefacts is unknown.

Tableau 2

Densité d'artefacts par hectare pour les zones prospectées du Membre F et de la partie inférieure du Membre G (LG). Le nombre total d'artefacts a été calculé à partir des estimations du nombre d'artefacts par occurrence en fonction de la classe de valeur enregistrée sur le terrain. Les estimations sont de 6,5 artefacts pour la classe 3 à 10 ; de 30,5 artefacts pour la classe 11 à 50 et de 165,75 artefacts pour la classe > 50. La classe Indet. correspond aux occurrences pour lesquelles le nombre d'artefacts de surface est inconnu.

Member	OGRE surveyed surface (ha)	Archaeological occurrences	Number of surface artefacts					Estimated number of artefacts	Artefact density
			0 (only *in situ* artefact)	3 to 10	11 to 50	> 50	Indet.		
F	151.8	97	1	48	36	10	2	3067.5	20.20750988
LG	161.35	51	0	40	10	1	0	724.25	4.488689185

OGRE: Omo Group Research Expedition; LG: lower Member G.

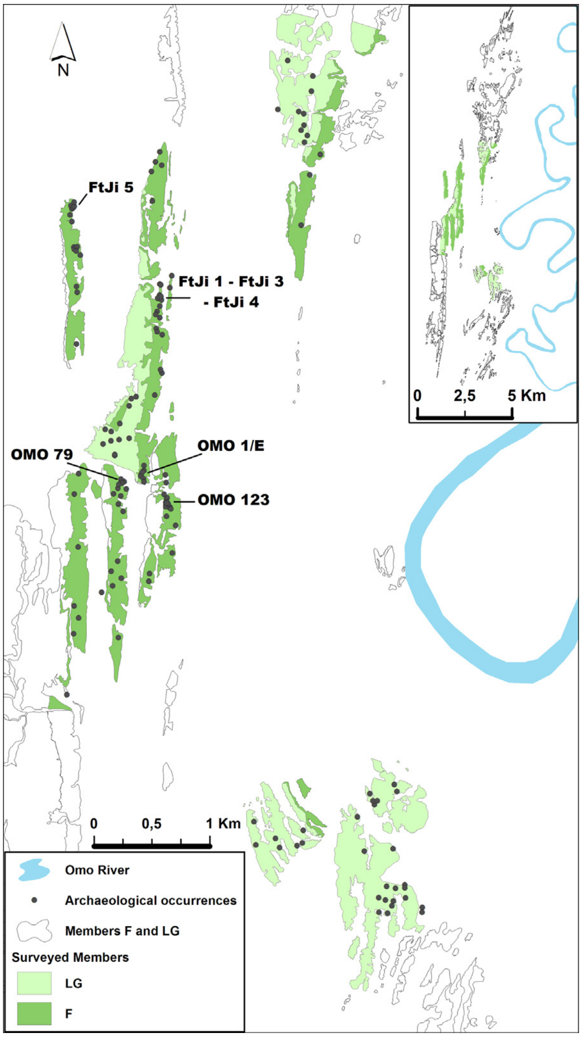

Fig. 4. (Color online.) Archaeological occurrences of the Shungura Formation. All the occurrences are located in Member F and in lower Member G (LG). The occurrence complexes are pointed out with their name. Coloured outcrops correspond to the surveyed area.

Fig. 4. (Couleur en ligne.) Occurrences archéologiques de la Formation de Shungura. Toutes les occurrences se situent dans le Membre F et dans la partie inférieure du Membre G (LG). Les complexes d'occurrence sont indiqués par leur nom. Les affleurements en couleur sur la carte correspondent aux zones prospectées.

a vertical axis, the fine chronostratigraphical placement of occurrences provides clues to settlement timing. Several occurrence complexes, e.g. OMO 123, OMO 1/E, OMO 79, show repetitive occupations of the same area at different time periods (Delagnes et al., 2011). Local-level palaeoenvironmental data (including fauna; see Table 1) help us to understand why these specific locations were preferentially occupied by hominids. In addition, the technological and raw material data can be compared between occurrences to better characterize patterns of human occupation within each complex.

4.2. "Study area" level

Understanding hominid spatial behaviours as part of a landscape archaeological approach requires focusing on a larger micro-regional scale. This scale will deal with penecontemporaneous data related to different areas that have to be precisely defined. The uncertainty of some data, such as the precise provenience of the archaeological artefacts from surface occurrences, will be offset because data are gathered by "study area" and the comparisons will be performed between the different sets of data issued from each "study area". In order to figure out the artefact density within each member, a test was made with a square mesh area of 350 meters side. The size of the mesh was chosen for fitting as much as possible with the outcrop width. An estimate of the number of artefacts for each archaeological occurrence was used to calculate this density, based on the median of the field class value for the class "3 to 10" and "11 to 50", and on the average of the available numbers of surface artefacts for the class "> 50". The resulting map shows a contrast between high and low densities of artefacts per hectare in each surveyed area (Fig. 5). The high density of occurrences in Member F seems to be associated with the presence of occurrence complexes and with a significant number of occurrences preserved in fine sediments (clay, silty clay, silt, except for FtJi5 complex for which occurrences are located in sandy tuffite).

The faunal data will provide information about the local environments, but territory sizes vary according to the mobility and the behaviour of each taxon. This scale of study aims at highlighting differences between some areas that reflect different bioenvironmental landscapes within the Shungura Formation. The location of the available resources in the landscapes is fundamental for understanding hominid interactions with their environment. A very fine mapping of the sedimentary units provides two types of information. It will first allow us to assess the representativeness of the observable landscapes in the outcrops. It should also help us to specify the position of the river system that constitutes the supplying area for water and raw materials. The raw material availability in the landscape will be studied thanks to the exhaustive survey of raw material sources. Such reconstruction of the landscape allows us to virtually correct the effects of the strata tilting.

4.3. Formation level

The third scale relates to the whole Shungura Formation. At this level, only the temporal variations will be addressed. Data should be compared between sedimentary units that refer to a particular time slice. The successive sedimentary units and members provide a time frame that allows us to characterize only major palaeoenvironmental and behavioural changes. A preliminary comparison of the artefact density from Member F and lower Member G (Table 2) shows that the density of artefacts is higher in Member F than in lower Member G for the sedimentary windows under study. This gives us a preliminary picture of the evolution of the hominid spatial behaviours over time that should be developed in our future work.

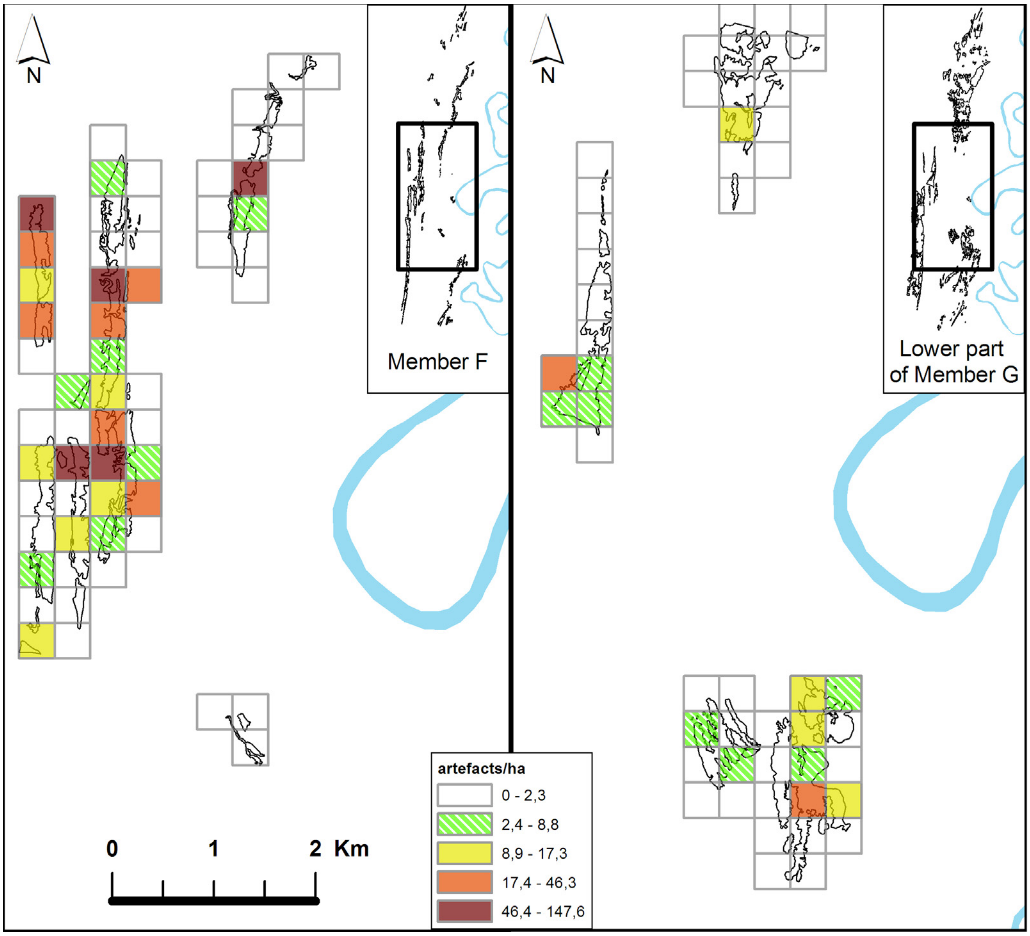

Fig. 5. (Color online.) Artefacts density per hectare in Member F (left) and in lower Member G (right). Artefact density was calculated from the sum of occurrences' estimated artefacts numbers, divided by the amount of the surveyed area within a 350 meter wide mesh.
Fig. 5. (Couleur en ligne.) Densités d'artefacts par hectare pour le Membre F (gauche) et la partie inférieure du Membre G (LG, droite). La densité d'artefact a été calculée à partir de la somme des estimations du nombre d'artefacts de chaque occurrence située dans une maille de 350 m de large, divisée par la surface prospectée dans cette même maille.

5. Conclusion

In this paper, we propose an innovative integrative spatial approach dedicated to the study of Early Oldowan hominid spatial behaviours. The wide array of available data in the Shungura Formation allows this type of study by integrating archaeological and palaeoecological data in an extended time frame and at various spatial scales. The multiscale approach aims at adapting the investigations to the potential and limits of the record. The spatial behaviours of the hominids and their changes and similarities over time at a local scale can be drawn with a very fine resolution at the site complex level using local environmental data. At a larger scale, the patterns of landscape occupation and the subsistence behaviours can be assessed thanks to the systematic survey of a wide area for both Member F and lower Member G. At the scale of the Shungura Formation, the temporal variations and continuities provide information about the landscape and the behavioural dynamics. The synthesis of the results issued from these different scales is fundamental for achieving a holistic approach of hominid behaviours. Our preliminary results related to the density of artefacts indicate that some areas were more visited by the Early Oldowan toolmakers than others. The reasons of such preferences still have to be explained using palaeoenvironmental data. Furthermore, both members do not show the same occupation patterns, with a decrease of artefact density in lower Member G. The relation between such decrease and the total lack of archaeological evidence in the Shungura Formation after 2 Ma (upper Member G and subsequent members) still has to be investigated.

The results provided by the three scales of analysis form the backbone of a holistic approach of the hominid behaviours in the specific context of a rift basin environment at various time periods. Some comparisons with other older, contemporaneous or younger contexts might be envisaged, in particular with Hadar (Reed, 2008), Nachukui (Brugal et al., 2003; Roche et al., 2003), Koobi Fora (Braun et al., 2009a) and Olduvai (Blumenschine et al., 2012).

Acknowledgments

We are very grateful to all the participants of the IORE and the OGRE, who devoted a lot of energy to collect this amount of data. We would like to thank Sabine Riffaut, Frédéric Prodéo, and Pascal Bertran for their help. This work was authorized by the Authority for Research, Conservation and Cultural Heritage. We would like to thank the ARCCH as well as the bureau of Culture of the Southern Nations, Nationalities and People Region, and of the South Omo Zone.

This work is part of Master and PhD theses (T. Maurin), which have been funded by the LABEX LaScArBx (University of Bordeaux). This research of the OGRE received funding and logistical support from the Agence nationale pour la recherche, the Ministère des Affaires Étrangères (sous-direction de l'archéologie), the Fondation Fyssen, the Centre français des études éthiopiennes, Ambassade de France en Éthiopie, CNRS, PACEA–University of Bordeaux and IPHEP–University of Poitiers (France).

We would like to thank two anonymous reviewers for their suggestions that helped us to improve the manuscript.

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