Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85–1.78 Ma

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The early Pleistocene colonization of temperate Eurasia by *Homo erectus* was not only a significant biogeographic event but also a major evolutionary threshold. Dmanisi's rich collection of hominin fossils, revealing a population that was small-brained with both primitive and derived skeletal traits, has been dated to the earliest Upper Matuyama chron (*ca.* 1.77 Ma). Here we present archaeological and geologic evidence that push back Dmanisi's first occupations to shortly after 1.85 Ma and document repeated use of the site over the last half of the Olduvai subchron, 1.85–1.78 Ma. These discoveries show that the southern Caucasus was occupied repeatedly before Dmanisi's hominin fossil assemblage accumulated, strengthening the probability that this was part of a core area for the colonization of Eurasia. The secure age for Dmanisi's first occupations reveals that Eurasia was probably occupied before *Homo erectus* appears in the East African fossil record.

Lower Paleolithic | paleoanthropology

In recent years, paleoanthropologists have intensified the search for evidence for one of the most significant events in human evolution: the dispersal of early *Homo* from Africa to Eurasia. That *Homo erectus* was the first hominin to leave Africa and colonize Eurasia has been accepted by paleoanthropologists for over a century. However, models that linked the first African exodus to increases in stature, encephalization, and technological advances (1–3) have been challenged by discoveries at Dmanisi (4). Dmanisi is located in the southern Georgian Caucasus (41°20'10"N and 44°20'38"E), 55 km southwest of Tbilisi (Fig. 1). The prehistoric excavations at Dmanisi have been concentrated in the central part of a promontory that stands above the confluence of the Masavera and Pinasauri rivers. Lower Pleistocene deposits are preserved below the Medieval ruins and above the 1.85-Ma Masavera Basalt (Fig. 1). Those excavations yielded numerous exceptionally preserved hominin fossils. Stratigraphic studies revealed that that all of those hominin fossils are from sediments of stratum B, dated to *ca.* 1.77 Ma, based on $^{40}Ar/^{39}Ar$ dates, paleomagnetism, and paleontologic constraints (4, 5). In the main excavations, no artifacts or fossils have been found in the older stratum A deposits, which conformably overlie the Masavera Basalt. Dmanisi's rich collection of hominin fossils reveals a population with short stature and cranial capacities of only 600–775 cc (4–9). Artifact assemblages are all indicative of a Mode I technology, with no bifacial tools (10). Recently completed testing in the M5 sector of Dmanisi has yielded in situ artifacts and faunal remains from the older stratum A deposits, pushing back Dmanisi's occupational history into the upper Olduvai subchron. These findings indicate that African and Eurasian theaters for the evolution of early humans had been established even earlier than thought previously, with implications for the age of dispersals not only within Eurasia but also between Eurasia and Africa. This article describes the results of these investigations at Dmanisi and their implications for future research.

Results

Geology and Geochronology of the M5 Section. The M5 test unit is situated 85 m west of the block 1 excavations (Fig. 1). A narrow geologic trench and then a 2 × 2-m test unit exposed 6.2 m of deposits overlying the Masavera Basalt (Fig. 2). This thick exposure of conformably bedded deposits is divided into nine stratigraphic units, named A1 to B5 (*SI Text* and Table S1). At M5, as in the main excavation areas, stratum A deposits display normal geomagnetic polarity and are correlated with the upper Olduvai subchron. The stratum B deposits all display reverse polarity and are correlated with the earliest Upper Matuyama chron. Stratum A1, which conformably overlies the Masavera Basalt, is a massive to weakly laminated bed of silt and fine sand-sized black volcanic glass shards and tears, with rare obsidian granules. The only pedogenic features of these deposits are rare carbonate filaments. These sediments and the Masavera Basalt contain olivine, indicating rapid deposition with little weathering (*SI Text*). Here, and across the site, the A1a ashes quickly filled the lowest depressions on the irregular basalt surface. A1b deposits are glass sands and fine obsidian granules, indicative of erosional sorting of A1 sediments from a higher position.

Stratum A2 is a black, indurated fine to medium silt ash. These sediments show evidence of moderate pedogenesis, including many carbonate filaments, veins and concretions, and thin clay and carbonate pore linings (Table S2). Micromorphological analysis of stratum A2 in the main excavations record similar pedogenic features (11). The substrata of A2 lack olivine and contain clay minerals supporting the soil morphological evidence for cyclic deposition and stability; however, the clear contacts between the substrata indicate serial ash falls that promoted the stratification of artifacts in this unit. Strata A3 and A4 are firm dark reddish brown silt ashes with common carbonate filaments and pore linings.

The weak to moderate soil development in each of the stratum A deposits is illustrated by the weak structure, high porosity, and lack of argillic (clay-enriched) horizons. All of the strata A soils here have pedogenic carbonates, indicating a drier setting and probably slower rates of weathering. However, above stratum A2a, those carbonate fabrics are limited to filaments, pore linings, and rhizomorphs; these are Stage I soil carbonates (12), indicating brief periods of surface stability and weathering.

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The authors declare no conflict of interest.

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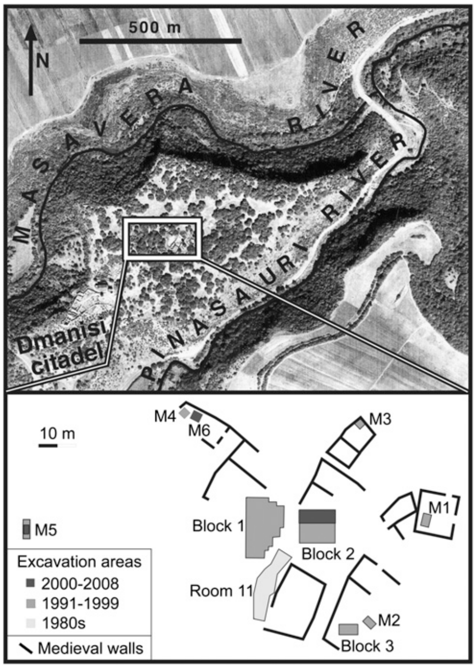

Fig. 1. Dmanisi promontory and map of excavation areas. Sediments beneath Medieval ruins in blocks 1 and 2 yielded Dmanisi's assemblage of early *Homo* fossils, dated to *ca*. 1.77 Ma. The recent discovery of stratified stone artifacts in Unit M5, push back even farther the age of Dmanisi's first occupations to the late Olduvai subchron, 1.85–1.78 Ma.

Accordingly, the entire suite of sediments in stratum A can be viewed as a cumulic sedimentary profile consisting of a series of ash fall events, alternating and overprinted by weakly developed soils stabilized by grasses, a few shrubs, and rare trees (13). Although stratum A deposits also accumulated in the areas of main excavations, they experienced more erosion, leaving thinner and sometimes incomplete sections. In those main excavations, all of the hominin fossils and thousands of mammal fossils have been recovered from reversely polarized strata B1x–B1z pipe and gully sediments (4, 10), which are notably absent at the A4/B1 contact in the M5 section (Fig. 2).

The M5 paleomagnetic data are in accord with the results of previous studies in the main excavation areas (4, 5) as well as lithostratigraphic correlation of the deposits between the two areas of the site (Fig. 2 and Fig. S1). Although a single sample from the top of stratum A exhibited normal inclination and reversed declination (i.e., south directed but downward dipping), this sample is not sufficient to indicate the Olduvai/Upper Matuyama transition. Here, the magnetostratigraphy and $^{40}Ar/^{39}Ar$ dating of the Masavera Basalt (4) constrain the age of stratum A deposits and the recently discovered artifact and faunal assemblages between 1.85 Ma and 1.78 Ma, the age of the Olduvai/Upper Matuyama reversal (14). Moreover, the lowest artifacts, in stratum A2a, are separated from the Masavera Basalt by the unweathered stratum A1 ashes, showing that these artifacts must be close in age to the basalt, i.e., just after 1.85 Ma.

Archaeological Assemblages. Excavations at M5 produced a total of 122 lithic artifacts, including 49 from stratum B (*SI Text* and Tables S2 and S3). The 73 artifacts from stratum A were recovered over a vertical range of ∼1.5 m in strata A2a–A4a (Fig. 2 and Table 1). The bones were all unidentifiable but included 32 fragments from A4 and two long bone fragments from A2a; a hyaena coprolite was recovered from A3. All of the bones were quite weathered, in contrast to the well-preserved bones from the rapidly deposited pipe and gully fills in the main excavation (5, 15). These M5 faunas and artifacts record serial living surfaces as supported by the stratigraphic separations, fine-grained sediments, and associated soil features (*SI Text* and Table S1). The location of M5 and the stratigraphic range of the recently discovered finds emphasize that the site-wide spatial and stratigraphic distribution of artifacts and faunas at Dmanisi is both extensive and dense. This finding reveals that the site was inhabited many times, implying an established, apparently quite mobile population.

The stratum A artifact assemblage is dominated by flakes but includes cores and core/choppers (Table 1 and Fig. 3). No retouched tools were found, but these are rare in the larger samples of artifacts from the Dmanisi excavations (10). Of the 73 flakes in stratum A, 48 are complete or proximal fragments with platforms. The size and raw materials of distal flake fragments indicate that breakage has not unduly inflated the sample size. The dorsal scar patterns on the flakes are predominantly unidirectional (Fig. 3 *B–E*). However, four of the larger flakes, each of a different raw material, reveal core rotation to produce thick flakes with one sharp edge (Fig. 3 *F–G*). Dorsal cortex forms indicate that the tuffs were principally acquired from Cretaceous bedrock exposed near the site, whereas the other raw materials were well-rounded alluvial cobbles from more distant channel and/or terrace sources. The one complete core, mentioned above, has unidirectional flaking from a roughly facetted platform of nearly 90°. The four core fragments are all tuff and have flake scars on two or three surfaces. Two core/choppers with bifacial platforms, one of green tuff and the other basalt, were recovered in stratum A2b.

The artifacts from stratum A differ from those in stratum B in terms of raw material selection and reduction intensity (Table 1 and Tables S3 and S4). Compared with stratum B raw materials, stratum A artifacts have a high proportion of red tuff, which is very rare in the materials from blocks 1 and 2. The stratum A sample has no andesite and only two pieces of basalt; excluding tuffs, those materials dominate artifacts from stratum B, both in M5 and the main excavation areas (10). Three flakes of rhyodacite, a black, near-glassy material, are the first reported incidences of this material recovered at Dmanisi (Fig. 3*F*). This material has been found in outcrops ∼15 km west of the site and as cobbles in the Masavera River gravels. A notable difference between the strata A and B assemblages is that only 29% of the stratum A flakes have dorsal cortex, compared with 71% in stratum B. Debitage from stratum B in the main excavations has a similarly high proportion of cortical pieces (10), suggesting that, during the earlier occupations, either cores were more intensively reduced or selected flakes were made elsewhere and carried to the site. Larger samples, with good prospects for refitting, will allow comparisons of Dmanisi's earliest assemblages with those from contemporary and earlier African sites. Progress in the study of Mode I industries (16–18) reveals knapping skills that were neither simplistic nor static and that raw material quality was a major factor in technological variation among these early assemblages.

Discussion

The stratified lithic assemblages at M5 affirm that the site was occupied repeatedly during the late Olduvai subchron, *ca*. 1.85–1.78 Ma. The stratified finds in stratum B deposits, including all of the Dmanisi hominins, extend the range of Dmanisi's occupations to *ca*. 1.77 Ma, with a minimum age of *ca*. 1.76 Ma, based on stratigraphic correlation of Dmanisi sediments to the nearby Zemo Orozmani locality (4). It is now clear that Dmanisi was occupied repeatedly over an interval of as much as 80 ka, strongly suggesting a sustained regional population. The recently discovered data show that Dmanisi was occupied at the same time as, if not before, the first appearance of *Homo erectus* in east Africa (1, 19). This scenario has important implications for understanding the origins, dispersal, and biological variability of our first cosmopolitan ancestor. The case for a possible Eurasian

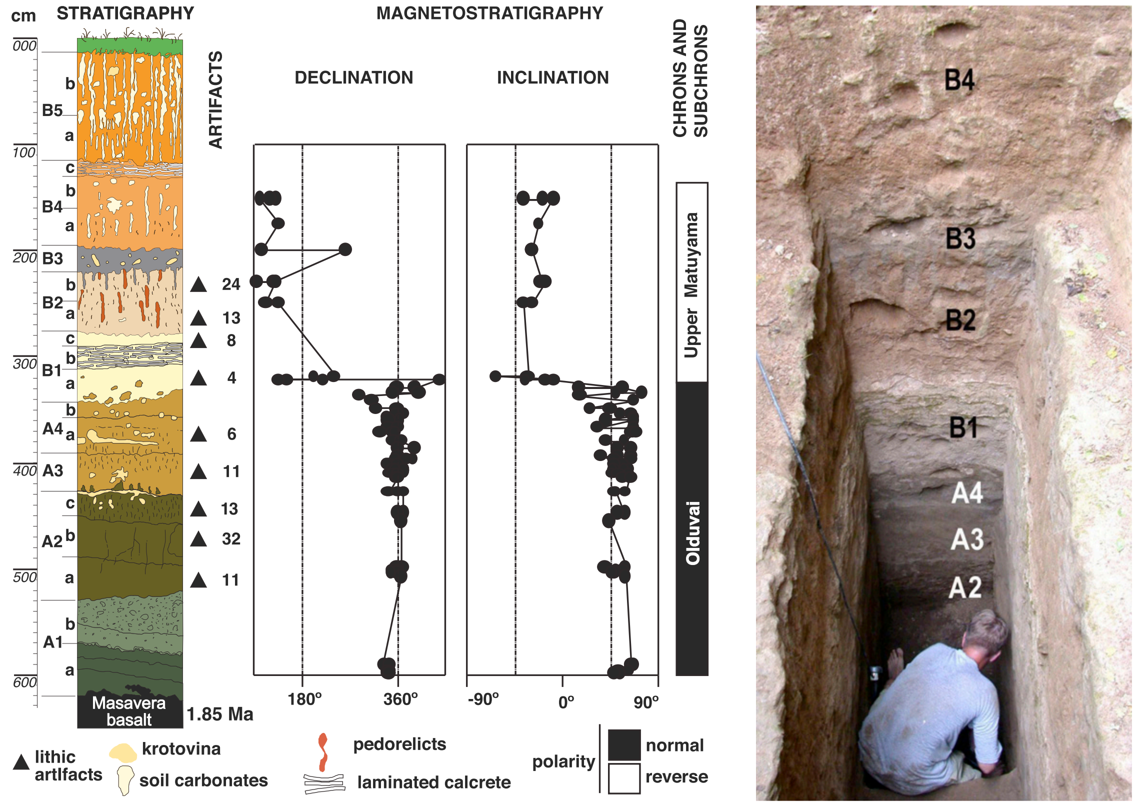

Fig. 2. Stratigraphy and archaeological discoveries in Unit M5. The 6.2-m section shows that Dmanisi's sedimentary/geomagnetic record spans the late Olduvai subchron (stratum A) through earliest Upper Matuyama chron (stratum B). Test excavations recovered 73 stone artifacts from strata A2–A4, which are firmly dated to 1.85–1.78 Ma.

origin of *Homo erectus* (1, 20) is increasingly supported by chronometric and biogeographic evidence.

The initial occupations of Dmanisi are possibly older than the first appearance of *Homo erectus* in East Africa. With the exception of the surface find of a human occipital fragment (KNM-ER 2598) at Koobi Fora, the earliest appearance of African *Homo erectus* is considered to be *ca*. 1.78 Ma (21) but probably is closer to 1.65 Ma (22). The newly dated horizons at Dmanisi also accommodate the increasingly older ages documented for hominin fossils in both eastern and western Eurasia. Human presence in China is dated to *ca*. 1.7 Ma (23, 24), and *Homo erectus* fossils in Java are dated to *ca*. 1.6 Ma (25). The earliest occupations of Flores are now dated in excess of 1 Ma (26). The record of colonization of Western Europe is also >1 Ma (27–29). The increasingly older age of Eurasian occupations by early *Homo* is important for defining patterns of dispersal and adaptations in environmental context (3, 30–32).

The possibility that *Homo erectus* evolved in Eurasia provokes two obvious corollaries. The first, that a more primitive ancestor arrived from Africa more than *ca*. 1.85 Ma (1, 19), is consistent with anatomical analyses of both the Dmanisi fossils (17) and those of *Homo floresiensis* (33). The second, that *Homo erectus*

Table 1. Lithic artifacts from M5

	Stratum A					Stratum B			Total, %	
Raw material	A2a	A2b	A2c	A3	A4	B1a	B1c	B2	A	B
Red tuff	8	6/2	6	2	2		1		35.6	2.0
Brown tuff	1	13/1	4/2	3		1			32.9	2.0
Tan tuff		4		5	1	1/1	1	8/3	13.7	28.6
Green tuff		2/1			2		3		6.8	6.1
Vitreous green tuff							1	4		10.2
Rhyolite		2	1		1		1		4.1	2.0
Andesite						–/1	2/1	1/4		18.4
Rhyodacite	2	1							4.1	
Basalt		–/1		1			–/1	9/2	2.7	24.5
Aplite								1		2.0
Diorite								1		2.0
Chert								1		2.0
Total	**11**	**28/5**	**11/2**	**11**	**6**	**2/2**	**6/2**	**28/9**	**73**	**49**

Single digits are counts of flakes; *n/n* shows counts of flakes/cores.

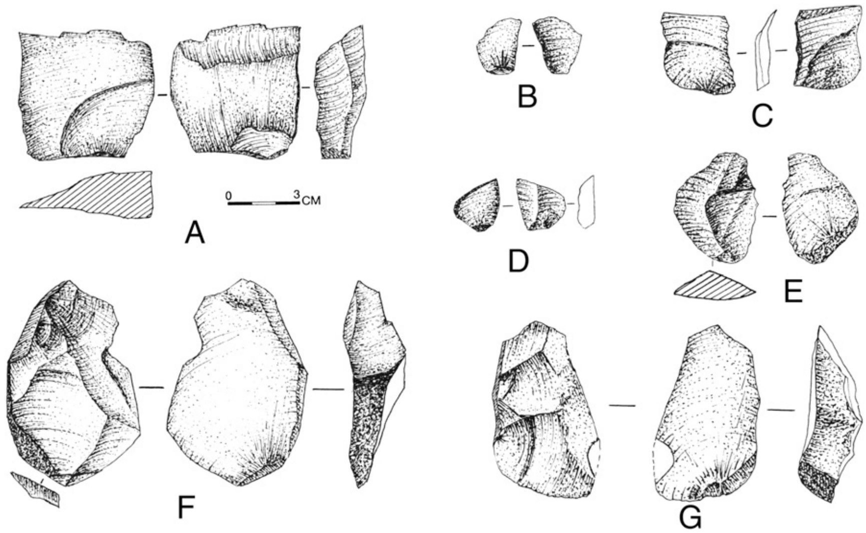

Fig. 3. Lithic artifacts from stratum A deposits at Dmanisi. These flakes (*A–G*), all from stratum A2 (Fig. 2), were recovered from two of the five occupation horizons defined thus far in the 1.85- to 1.78-Ma deposits in the M5 unit. Although simple unidirectional flaking is dominant (*B–E*), three of these pieces have scar patterns showing core rotation to permit removal of large flakes with sharp edges (*A*, *F*, and *G*). (Drawn by O. Bar-Yosef, Department of Anthropology, Harvard University, Cambridge, MA.)

may have migrated back to Africa, receives support from the conclusion that *Homo erectus* and *Homo habilis* survived as contemporaries after the appearance of the former in the East African fossil record (34).

Although the presence of hominins beyond East Africa as early as 1.9 Ma is documented at Ain Hanech in North Africa (35), claims for occupations of that age or somewhat earlier in Israel (36) and Pakistan (37, 38) are based on lithic materials collected from gravels. Although it seems ever more probable that hominins were in Eurasia before Dmanisi was first occupied, well-dated materials in unequivocal contexts are required. Both the age and evolutionary affiliations of the earliest hominins to arrive in Eurasia remain to be determined by new discoveries. This important, unresolved issue in human evolution is a call for the aggressive survey for evidence of even earlier colonists.

Methods

For magnetostratigraphic study, one to four samples were obtained from each studied horizon. All samples were collected by hand after exposure of fresh sediment that was oriented with a magnetic compass. Remanent magnetization measurements were carried out with a 2G Enterprises high-resolution cryogenic magnetometer with superconducting quantum interference device (SQUID) sensors at the Paleomagnetism Laboratory of the Scientific Technical Services of Barcelona University. After measuring the natural remanent magnetization, a stepwise demagnetization was applied at least to one specimen per horizon. Demagnetization of 99 samples was done thermally because it was observed to be an efficient method in previous studies (4, 10). Samples were demagnetized from room temperature to 600 °C, generally with an 8- to 10-step protocol. Both normal and reverse polarities are found along the section. Reverse polarity levels display a low-temperature secondary component, which was completely removed at 200 °C. For all of the studied levels, a high-temperature component (between 200° and 600 °C) was used to calculate a primary component, considered a characteristic remanent magnetization (see declination and inclination values in Fig. 2). See also *SI Methods*.

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