# Nuts, nut cracking, and pitted stones at Gesher Benot Ya'aqov, Israel

**Naama Goren-Inbar*†, Gonen Sharon*†, Yoel Melamed‡, and Mordechai Kislev‡**

*Institute of Archaeology, Hebrew University of Jerusalem, Mt. Scopus, Jerusalem 91905, Israel; and ‡Faculty of Life Sciences, Bar-Ilan University, Ramat-Gan 52900, Israel

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**The Acheulian site of Gesher Benot Ya'aqov (Israel) has revealed a unique association of edible nuts with pitted hammers and anvils. Located in the Dead Sea rift, on the boundary between the Arabian and African plates, the site dates to the Early-Middle Pleistocene, oxygen isotope stage 19. In a series of strata, seven species of nuts, most of which can be cracked open only by a hard hammer, were uncovered. Five of the species are extant terrestrial nuts, and two are aquatic nuts now extinct in the Levant. In addition, the site yielded an assemblage of pitted hammers and anvils similar in pit morphology to those used by chimpanzees and contemporary hunter–gatherers. This is the first time, to our knowledge, that a site has offered both paleobotanical and lithic evidence of plant foods eaten by early hominins and technologies used for processing these foods. The evidence also sheds light on the structure of the community: ethnographic analogies suggest that mixed-gender groups may have been active on the shores of paleo-Lake Hula.**

Among many ancient and contemporary peoples dispersed over immense geographic regions, stones have been found with small depressions that undoubtedly resulted from a repetitive activity. The character of this artificially produced damage on such stones, which are referred to as "pitted anvils," "pitted stones," and "nutting stones," depends on the type of rock and the object used to inflict the damage.

Because of the simple process involved in the formation of pitted stones, archaeologists have rarely described them or attempted a uniform classification (1, 2). M. D. Leakey conducted the first major study of pitted anvils on material from Olduvai Gorge (3) Later (4), Leakey suggested that pitted anvils are in fact only one component of a pair. The pair consists of an immobile element (an anvil) and a mobile one (a hammer). In this paper, we shall use "pitted stone" as a general term to refer to either component of such a pair.

An assemblage of pitted stones was recently excavated from Gesher Benot Ya'aqov (GBY), a site located in the Dead Sea rift on the boundary between the Arabian and African plates, and is attributed to the Early-Middle Pleistocene, oxygen isotope stage 19 (5). Renewed excavations south of the Hula Valley, on the left bank of the Jordan River, exposed a sedimentological sequence deposited by paleo-Lake Hula. The sequence also revealed a series of Acheulian archaeological horizons, each containing rich lithic, faunal, and floral assemblages. In addition to the pitted stones, these horizons have yielded unique paleobotanical evidence, including edible seeds, nuts, and other fruits of diverse species.

This study examines new evidence in light of two hypotheses concerning the origin of pits on African Early Stone Age anvils. One hypothesis states that a bipolar knapping technique was involved in the formation of the pits (3, 6) but does not deal with the role played by the artifacts, and the other views the pits as the by-product of a particular task—the cracking of nuts (1). In an attempt to determine whether the pitted stones at GBY support one of these hypotheses, we examine data on nut-cracking behavior in chimpanzees and present-day hunter–gatherers, offer archaeological evidence of pitted stones from several prehistoric sites, and describe the artifacts from GBY, the site's paleobotanical and taphonomic evidence, and related experimental data.

## Chimpanzees and Pitted Stones

Growing emphasis on research into the common traits of apes and early hominins and recent advances in the study of chimpanzees have yielded extensive data on pitted stones produced by the latter. Chimpanzee communities, both wild and released (ref. 7 and refs. therein), have been observed to engage in tasks whose by-products are pitted stones. In the evergreen forests of western Africa (7–9), chimpanzees were seen using hammers and anvils to crack open six species of nuts (ref. 7 and refs. therein). As those nuts vary in size, shape, and hardness, different approaches were needed to crack them open. The physical characteristics of the nuts, coupled with the type of bedrock and soil cover, were reflected in the choice of raw material—rock, wood, or root—and the size of the hammer and anvil used. Furthermore, the great variability in the shape and size of the pits on both hammers and anvils appears to be due to the hardness of the nuts, the choice of raw material, the size of the hammer, and the force inflicted (9).

In their observations of chimpanzees consuming two types of nuts (*Panda* and *Coula*), Boesch and Boesch report that to open the harder type, the chimpanzees brought heavy stone hammers from great distances (8, 10). Moreover, the researchers found that to crack open the particularly hard *Sacoglottis gabonensis* nuts, the chimpanzees always used an anvil made of stone along with a stone hammer. In addition, Kortlandt and Holzhaus (11) found that up to 54% of the pitted stones at various cracking sites have pits on two faces.

## The Ethnographic Evidence

Cracking nuts is a subsistence activity of contemporary hunter–gatherer societies worldwide, as substantiated by extensive data on the taxonomy, seasonality, gathering, cracking, consumption, and nutritional value of nuts and the gender of participants in nut-related activities. The use of stone hammers and anvils to extract edible kernels has been widely documented (2). Examples have been reported from the Kalahari Desert and involve such nut species as *Ricinodendron rautanenii* (mongongo), *Sclerocarya birrea* subsp. *caffra* (=*S. caffra*) (morula), *Bauhinia esculenta*, and *Parinari capensis* (dwarf mobola) (12–17). However, few detailed descriptions of the cracking stones are available.

According to North American ethnographic studies, Native Americans were known to consume many kinds of nuts, including chestnuts, chinquapins, pecans, hickory nuts, walnuts, and

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Abbreviation: GBY, Gesher Benot Ya'aqov.

†To whom reprint requests may be addressed. E-mail: goren@cc.huji.ac.il or gonens@pob.huji.ac.il.

various species of acorns (18). Driver mentions 27 species of edible acorns in the Native American diet; with their high content of starches and fats, the acorns of some species constitute a particularly valuable nutritional source (19). Cracking and a variety of processing strategies preceded the consumption of these nuts (see, for example, ref. 20).

McCarthy and Setzler describe in detail a variety of hard nuts, associated cracking stones, packing material, and the particulars of nut consumption in Oceania (21). Their meticulous classification of stones and ethnographic observations show that the cracking stones vary in many ways and were used for diverse activities (22).

## The Earliest Archaeological Evidence

Whereas chimpanzee behavior has been observed directly, and a growing body of data is now available, the archaeological evidence of pitted stones remains primarily interpretative, related to the assumed tasks that led to the formation of the pits (2). Conditions of preservation rarely permit an archaeological association between such tools and nuts, particularly at sites attributed to the earlier stages of the Pleistocene. In 1975, M. D. Leakey (23) mentioned an explanation of pitted stones stated by Clark—that the pits are the product of a bipolar flaking technique. Later, Leakey explicitly proposed this interpretation (4). An experimental study by Jones tested the hypothesis, which Jones has clearly adopted (6): "... the three tool types, *outils écaillés*, punches and pitted anvils, are all most probably... by-products of a single, brief activity" (for an explanation of *outils écaillés* and punches, see ref. 4). It is this particular conclusion, which associates three lithic types, that our evidence challenges. Although there may be sites whose finds support Jones' hypothesis (ref. 24, figure 5), no other Acheulian sites have revealed an association between the three tool types (ref. 2, and J. D. Clark, personal communication, in reference to the Late Acheulian).

The prehistoric sites of Olduvai Gorge, in Tanzania, have yielded the largest and most extensively described assemblage of pitted stones. Although almost completely absent from Bed I and Lower Bed II and very scarce in the middle and upper parts of Bed II, such tools occur abundantly in Bed IV and the Masek Beds (6). According to M. D. Leakey, pitted stones constitute 14.29% of the tools in the Developed Oldowan (23). The dimensions and weights of the Upper Bed IV specimens (4) demonstrate considerable variability, which reflects the inclusion of pitted hammers and anvils in the same category. Although smaller than the chimpanzees' tools, the Olduvai tools also exhibit multiple pits on a single object.

Melka Kunture, in Ethiopia, includes a long Plio-Pleistocene depositional sequence in which Oldowan, Developed Oldowan, and Acheulian sites are bedded. Pitted stones appear throughout the Melka Kunture cultural sequence. For example, the Oldowan site of Gomboré IB has yielded pitted basalt stones ($n$ = 12), which exhibit a bimodal weight distribution and greatly varying pit dimensions (25). The phenomenon of multiple pits also occurs at Melka Kunture, as illustrated by a heavy anvil with two pits that was excavated from an Early Acheulian site (1).

In Israel, pitted stones have been discovered at two Acheulian sites in the Dead Sea rift, a sector of the Great African rift system—'Ubeidiya and GBY. The lithic assemblages from 'Ubeidiya, the earlier site, include stone hammers and anvils and a single pitted stone (26). Analysis of thousands of artifacts resulted in the identification of only four *outils écaillés* (0.043% of the items in all of the analyzed assemblages). Clearly, no systematic activity at the site generated by-products of a bipolar technique; thus we can conclude that these four items were produced unintentionally during another type of activity. The absence of punches, the scarcity of *outils écaillés*, and the presence of pitted stones render Jones' interpretation (6) invalid for the 'Ubeidiya material.

**Table 1. Stratigraphic distribution of nuts and pitted stones at GBY**

| Layer | *E. ferox* | *P. atlantica* | *Quercus* sp. | *T. natans* | Pitted stones |
|---|---|---|---|---|---|
| "Unconformity"* | | | | | 3 |
| VI-2 | | | | 4 | |
| V-5† | | | | | 1 |
| V-5/6† | | | | 1 | 2 |
| V-6† | | | | | 1 |
| VI-3 | | | | 1 | |
| VI-4 | | | | 9 | |
| VI-5 | | | | 2 | |
| VI-6 | | | | 2 | |
| I-4 | 1 | | | 10 | |
| VI-7 | | | | 3 | |
| VI-8 | | | | 1 | |
| VI-9 | | | | 1 | |
| VI-10 | 3 | | | 2 | |
| II-2 | 9 | | | 4 | |
| II-2/3† | 15 | | | 20 | |
| II-3 | 2 | | 2 | 2 | |
| VI-12† | 1 | | | 1 | |
| II-5 | 17 | | 1 | 16 | |
| II-5/6† | 13 | | 5 | 36 | 1 |
| II-6† | 221 | | 28 | 111 | 46 |
| II-7† | | | 2 | 16 | |
| IV-7 | | 1 | 5 | 3 | |
| II-8 | | | 1 | 2 | |
| II-9 | 1 | | 11 | 29 | |
| II-10 | | | | 1 | |
| II-11 | 3 | | 3 | 6 | |
| III-4 | | | | 1 | |
| III-5 | 5 | | | 1 | |
| III-6 | | | | 1 | |
| III-7 | 19 | | | 26 | |
| III-9 | | | | 2 | |
| III-11 | | | 1 | | |
| Total | 310 | 1 | 59 | 321 | 54 |

Nut frequencies refer to minimum number of nuts.
*The contact zone between the Middle Pleistocene and the Holocene.
†Archaeological horizon.

## Archaeological Evidence from GBY

The Acheulian site of GBY has yielded 54 artifacts with pits: 46 pitted cores, blocks, and slabs, and 8 pitted flakes and flake tools (Table 2, which is published as supporting information on the PNAS web site, www.pnas.org). Our detailed attribute analysis of the artifacts incorporates descriptive morphometric attributes of the blanks and the pits. Stratigraphically, the pitted items are restricted to the archaeological horizons located above the Matuyama/Brunhes chron boundary and thus within the Middle Pleistocene sequence of the site (5). The frequencies of the pitted stones and their stratigraphic assignment are presented in Table 1. Despite the extreme differences in the nature of the archaeological horizons, pitted stones are an integral part of most of their inventories. Note that layer II-6 is a stack of eight thin, archaeologically rich levels. Although sedimentologically similar, they differ in tool, bone, and wood frequencies. As the main focus of the excavations, layer II-6 yielded the greatest quantities of finds, including the highest numbers of nuts and pitted stones.

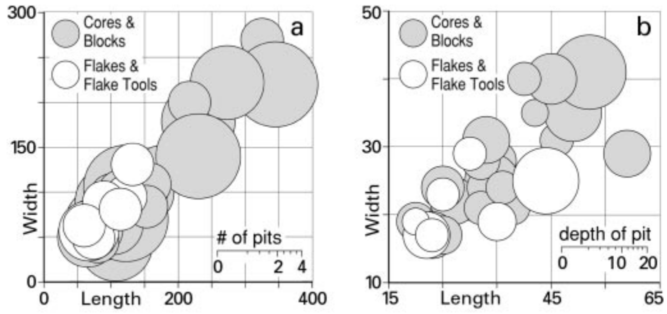


**Fig. 1.** Pitted stones at GBY. (*a*) Size of stones in millimeters (x and y axes) and number of pits per stone (diameter of bubble). (*b*) Size of pits (x and y axes) and their depth (diameter of bubble) in millimeters.

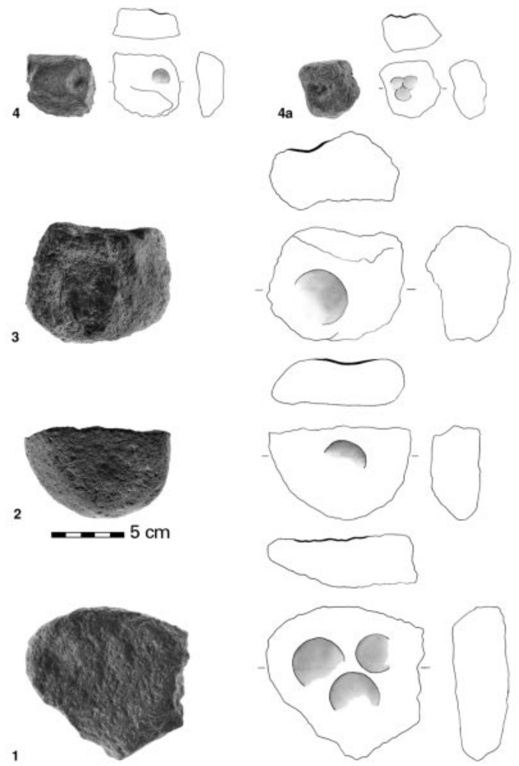


**Fig. 2.** Typology of pitted stones at GBY. (1) Incipient pits on flat basalt cobble (layer II-6 L 6). (2) Shallow pit on round broken basalt cobble (layer ''Unconformity''). (3) Large deep pit on broken basalt hammer (layer II-6 L 4b). (4) Small deep pit on basalt flake (layer II-6 L 4b). (4a) Cluster of small deep pits on angular basalt fragment (layer II-6 L 4b).

The pitted stones at GBY are made of basalt ($n$ = 49, or 90.7%) and limestone ($n$ = 5, or 9.3%) rocks that were transported to the site, the latter mostly in the form of fist-sized cobbles. Alkali olivine basalt is the dominant raw material of all of the artifacts at the site and their by-products. The nonvesicular basalt that was meticulously selected, transported, and introduced into the site for stone knapping (5) thus provided the raw material for the pitted stones.

Many of the items underwent *in situ* chemical weathering caused by the waterlogged nature of the deposits and thus have a worn appearance; on the basalt artifacts, cracks and the effects of exfoliation can be observed. Because of the stones' physical state, identifying them as actual artifacts proved difficult. To this end, we considered how conspicuous the pits are, how well defined they are, and to what extent they differ in shape and size from concavities observed on GBY's knapped and natural lithics. On this basis, we classified 24.1% of the items ($n$ = 13) as ''certain'' artifacts, 40.7% ($n$ = 22) as ''probable,'' and the rest (35.2%) as ''uncertain.''

The most frequent type of pitted object is the hammer, accounting for over half the artifacts. The paucity of blanks classified as anvils is probably due to the availability of flat surfaces on many of the stones, a morphology related to the shape of the raw material. With their blocky shape, such artifacts could easily have been placed on one of their flat sides to serve as anvils.

Large basalt slabs weighing up to 30 kg (27, 28) are present and apparently served as giant cores for the production of large flakes that were then modified into bifaces. Some of the slabs show signs of battering, and three also exhibit pits of different types. Large stone blocks classified as anvils, manuports, and cores have been described at many other Acheulian sites.

Data on the pitted artifacts' dimensions (Fig. 1) indicate that items classified as cobbles, hammers, and slabs are significantly larger and heavier than flakes. Despite their bulk, most of the former are easy to handle. The larger items also exhibit greater quantities of pits. Finally, the considerable variability in the size of the artifacts suggests that size was not a selective factor, whereas the preponderance of flat surfaces on the artifacts does seem to reflect trait-specific selection.

On the basis of our analysis of various attributes, we have defined five types of pits (Fig. 2). *Incipient* pits (18.5%, $n$ = 10) are often large and of minimal depth (Fig. 2, 1). They are typically located on a flat face that underwent massive battering. *Shallow* pits are large and well defined (Fig. 2, 2). Many of this type are found on rounded fist-size cobbles that split in two. *Large deep* pits (13.0%, $n$ = 7) generally exhibit well-defined margins (Fig. 2, 3). *Small deep* pits (9.3%, $n$ = 5) are also well defined and are often found on small artifacts (Fig. 2, 4). A subset of this group is a cluster of two or three pits (Fig. 2, 4a) [seen also at Olduvai (29)]. The fifth group consists of *other* pits (29.6%, $n$ = 16), those that could not be assigned to any of these categories.

The pitted stones at GBY show a high degree of variability in the size and shape of the pits and in their position on each surface of the artifact. Of the various pit morphologies we observed, the most common is rounded (≈37%), followed by a configuration of several pits inside a single pit (31.5%). Although the pits are most often located in the center of the object (48.1%), pits on one ''side'' are frequent as well (20.4%). In terms of size, the pits are quite similar; those found on flakes are smaller than others but of approximately the same depth (Fig. 3, which is published as supporting information on the PNAS web site).

The lithic analysis of the GBY assemblages is in progress, and of the tens of thousands of items already examined, no *outils écaillés* have been found.

**Paleobotanical Data.** Seven fruit-bearing species with edible seeds that are covered by a hard shell were found in the sedimentary sequence at GBY (Table 1). *Euryale ferox*, *Pistacia atlantica*, *Quercus* sp., and *Trapa natans* are part of the fruit assemblage, and *Amygdalus communis* (ssp. *microphylla*?), *Pistacia vera*, *Quercus calliprinos*, and *Quercus ithaburensis* were identified in the wood assemblage (30).

The seven species yield fruits from midsummer to early winter (Table 3, which is published as supporting information on the PNAS web site). They grow mostly in two kinds of habitats: in ponds or lakes, close to shore (*Euryale* and *Trapa*), and in forests. The latter habitat includes maquis (*Q. calliprinos*) and open forests (*A. communis*, *P. atlantica, P. vera*, and *Q. ithaburensis*). As many species of flora living near the site today were also found in the excavated remains from GBY, we can conclude that these habitats existed in the vicinity of the site during the Early and Middle Pleistocene.

*Overview of the plant material.* All seven species discussed here contain an edible kernel whose hard shell cannot be readily opened without a tool. In five of the species, this kernel is a nut; in the other two species, it is a nutlet and a seed, respectively. For simplicity's sake, we will henceforth refer to the edible kernels as "nuts" in generalizations about the seven species.

*A. communis* ssp. *microphylla* (=*A. korshinskii*) (wild almond) is a tree or shrub commonly found in the western Levant. The fruit consists of a compressed ovoid to ellipsoidal dry drupe with a leathery mesocarp. When ripe, the fruit dehisces. Its flattened, keeled, and irregularly pitted stone is very hard (31).

*E. ferox* (prickly water lily) is a prickly aquatic perennial with a short thick rootstock. It has floating orbicular leaves measuring up to 1.5 m in diameter. Its flowers are usually submerged after self-pollination. The fruit is a spongy berry crowned with persistent sepals and covered with stout prickles. Each fruit contains 8–40 seeds, which measure up to 13 mm long and have a pulpy aril and hard thick testa (outer shell).

Pleistocene *Euryale* fossils have been found in sediments in Poland (32) and Essex, U.K. (33). The plant's distribution area now includes tropical, subtropical, and temperate regions of eastern and southeastern Asia. It is found growing wild, for example, in India, Manchuria, and Hainan, China. The edible seeds are traded and exported in both raw and roasted form (34, 35).

*P. atlantica* (Atlantic pistachio) is a deciduous tree whose fruit is a small obovoid to globular dry drupe with a bony endocarp. *P. atlantica*'s area of distribution includes the Canaries, the eastern Mediterranean, and western Asia (31, 36).

*P. vera* (pistachio) is a deciduous tree. Its fruit is an ovate-oblong dry drupe. *P. vera* grows wild today in central Asia and is cultivated everywhere in the Levant (36, 37).

*Q. calliprinos* is an evergreen tree or shrub found in the eastern Mediterranean. Its fruit is an acorn, which can be ovoid, ellipsoidal, or oblong in shape. Although its acorns vary greatly in shape and size from tree to tree, they are uniform within each tree.

*Q. ithaburensis* (Mt. Tabor oak) is a deciduous eastern Mediterranean tree whose fruit, an acorn, matures in the second year. The acute, obtuse, or barrel-shaped acorn is 20–50 mm long and ripens in October or November (38). A sample of 22 contemporary acorns from Mt. Carmel and the northern Sharon plain measure 28–51 × 12–23 mm. Such acorns were consumed in Israel as late as the first half of the 20th century (39).

*T. natans* (water chestnut) is an aquatic annual that grows in stagnant or sluggish fresh water. Its long stems bear pectinate leaves under water and rhomboid rosulate leaves with swollen petioles on the water's surface. The leaf rosettes cover large areas of their water habitat (40). *Trapa*'s fruit is a seeded nut, the water chestnut, which contains a starchy edible cotyledon (35) and is covered with a smooth, thin, fleshy pericarp that undergoes maceration under water. This "nut" has woody projections ("horns"), and the sepals take the form of barbed spines.

People consume *Trapa* seeds both raw and cooked; in India, those who have access to water chestnuts eat them about 5 months of the year. The plant's area of distribution is Asia, Africa, and central and southeastern Europe (41).

*Economic aspects of gathering and consumption.* Rich in fat and protein, many nut kernels, such as those of *Amygdalus* and *Pistacia*, provide significant nutritional value. In addition to their high proportion of vegetal fats, nuts supply large quantities of the essential fatty acids linoleic acid and linolenic acid, which mammals' bodies cannot produce by themselves (42).

Some terrestrial Mediterranean nuts contain toxic substances that function as a defense mechanism, such as amygdalin, which is present in *Amygdalus* in the form of cyanic acid and in *Quercus* as bitter tannins. Roasting these nuts reduces the concentration of the toxic substances or eliminates them altogether.

Because large mammals such as pigs eat acorns and water chestnuts (43), hominins may have had to compete for these foods. Such competition would probably have forced the hominins to keep track of each species' ripening season (Table 3) so that they could pick the fruit before it fell or collect it from the ground immediately afterward—and all before their animal competitors.

**Taphonomic Data.** Given the paleobotanical evidence, we can postulate three explanations for the deposition of the terrestrial nut assemblage at GBY: taphonomic processes (a drift deposit), anthropogenic activity (gathering), or a combination of the two.

Botanical identification of the wood fragments, fruits, and seeds at GBY suggests that the present-day habitats of the nut species are similar to their ancient habitats. Because the aquatic plants were growing in the immediate vicinity of GBY, they are abundantly present in the remains, having been transported by either hominins or water. More problematic taphonomically are the terrestrial species. The only taphonomic agent that could have transported those nuts to the site is a fluvial one. In this scenario, the fruit-bearing trees would have been growing near a river; the nuts would have germinated at the water's edge and then been carried via the paleodrainage system into the final depositional location of paleo-Lake Hula. We suggest that the open forest habitat of *Q. ithaburensis*, *P. vera*, *P. atlantica*, and *A. communis* was situated on the hills near GBY, and the maquis inhabited by *Q. calliprinos* (and *P. palaestina*) occupied shadier areas, such as on the more northern slopes of the same hills.

The archaeological horizons yielded relatively large samples of fragmented nut shells, a quantity that we can attribute to the extensive volume of excavated deposit as compared with the volume generated by a standard geological sampling of sections. The amount of paleobotanical material in the sifted remains, which originate in numerous archaeological units (a typical unit is 50 × 50 × 5 cm), varies from unit to unit.

In contrast to wood fragments, which appear in every archaeological horizon, nuts are scarce in anthropogenic layers V-5 and V-6 and their contact zone, V-5/6. Taphonomically, a rich nut assemblage would be expected in these layers, particularly in the contact zone (44). Nut remains do exist in sedimentary contact zones at the site and sometimes in great abundance; an example is layer II-2/3, an archaeological horizon that is extremely thin but very rich in nuts and anthropogenic finds (Table 1). The lack of pitted stones in this layer may be due to the limited extent to which it was excavated.

The terrestrial fruit-bearing species, all components of today's Mediterranean vegetation, grow near the site at present; *Q. ithaburensis*, *Q. calliprinos*, and *A. communis* can be observed at a radius of 2–8 km from GBY. The sedimentary sequence of the site reflects a lake and shore environment (5), clearly forming an autochthonous habitat for the two water-dwelling species. Their remains are, indeed, much more abundant than those of the terrestrial species.

Regarding the taphonomic–anthropogenic debate, we may conclude that the data from GBY do not exhibit a typically repetitive taphonomic pattern, although a taphonomic agent cannot be ruled out. Moreover, the recovery of isolated flint microflakes in nonarchaeological strata supports the notion of an anthropogenic agent for the nuts. These microflakes suggest that there are additional archaeological horizons in the area of study that the excavations did not expose. If this is the case, the presence of terrestrial nuts could be related to anthropogenic activity. Given the available evidence, we can assume that natural processes were involved, but we cannot conclude that the nut assemblage resulted entirely from such processes.

**Experimental Data.** In an attempt to reproduce the bifacial tools of GBY, we conducted several experiments in which we knapped stones with basalt cobbles (hammers). Pits formed quite rapidly; the pits are shallow, and their interior surfaces look rough and battered (see ref. 45). On some of the GBY artifacts, the interior surfaces of the pits and marks along the edges of the artifacts resemble those produced in the experiments and hence may be the product of stone-knapping activity (see ref. 46). However, many of the GBY pits are deeper and more rounded, with smooth interior surfaces. In light of the experimental work, we may conclude that the larger pits on the GBY basalt hammers are not likely to have resulted from stone knapping. Other experimental studies also support this conclusion (e.g., ref. 47), although those investigations did not take basalt as the raw material. The presence of both battered and smooth interior pit surfaces and various pit shapes on the archaeological items from GBY suggests that two distinct activities, probably stone knapping and nut cracking, took place at GBY.

In general, few experiments have been conducted to clarify the phenomenon of pitted stones in the archaeological record. We may note Spears' attempt to shed light on the relationship between pitted stones that were found at a North American Archaic site with artifacts displaying a bipolar technique (45). His experiments covered two tasks, nut cracking and bipolar knapping, each of which yielded a distinct pattern. The archaeological artifacts, however, displayed these patterns and more; thus, we may conclude that diverse tasks were present at that site. Despite the scope of the Spears study and its interesting insights, we cannot apply its results to the Levantine artifacts because of differences in raw materials.

## Discussion

Unique paleobotanical data from GBY have revealed seven nut species and pitted stones in the same archaeological horizons. In light of these finds and evidence from chimpanzee behavior, ethnography, and prehistoric as well as more recent archaeological sites, we will examine the hypothesis that associates the GBY nuts and pitted stones as components of the same function, nut cracking.

The only indisputable evidence of stones used for cracking nuts comes from chimpanzee behavior and ethnography. Studies of chimpanzees' nut-cracking activity in Western Africa (9) and the stone tools involved highlight the importance of nut cracking as a skilled technological behavior and a dietary factor. Similarly, observations of contemporary hunter–gatherers in both the Old and New Worlds attest to the role of stones in the processing of nuts.

Archaeologically, only residue analysis can actually prove that artifacts served a particular function. As such evidence is unavailable, we have no choice but to draw conclusions from the archaeological data at hand, despite the multitude of taphonomic and other problems associated with these data.

As a result of the poor preservation of organic material, most Old World archaeological sites lack evidence of the use of stone hammers and anvils for the extraction of edible kernels. Although plant remains are almost completely absent from sites in the Mediterranean region, other geographic and cultural entities do provide some botanical evidence. Comparisons with more recent sites enable us to bolster our interpretation. For example, many associations of nuts and cracking stones have been discovered in the archaeological context of the New World, such as in Eastern Archaic sites of North America (48, 49). Archaeological finds in the form of pitted stones have also been reported from Polynesia (50), and an association between archaeological nuts and cracking stones has been observed in South Africa (46) as well as in Oceania (42, 51), to mention but a few examples.

Clearly, stone hammers (including all items defined as manuports) were used at Acheulian sites for a variety of functions (1, 2, 6), including the modification of stone tools, the breaking of bones for marrow extraction, the grinding of minerals, and more. But only repetitive actions of some duration could have led to a distinct wear pattern in the form of pits.

Pitted stones are a scarce component of Acheulian assemblages in general. Besides the evidence described earlier, isolated examples are known from Gadeb (site 8E) (52), and specimens are probably present in small quantities at many other sites. The paucity of pitted stones may well be related to the absence of hard nuts, which could be due to the transitory character of the sites or the distance between the nut trees and the sites (see also refs. 17 and 46).

Because of the waterlogged nature of the sediments at GBY, the organic material is in an excellent state of preservation (5) and can be readily identified. The hominins at GBY most likely consumed the edible kernels of the seven fruit-yielding tree species found at the site. Nuts provide high nutritional value, and wherever nuts are available, modern humans and chimpanzees consume them. We can infer that hominins behaved similarly, and that the hominins at GBY, who displayed impressive technological abilities, indeed exploited this resource. Of the species at GBY, at least the hardest kernels (almonds, some species of acorns, and *Euryale* seeds) had to be cracked open with stones. The presence of hard nuts along with pitted stones constitutes a reasonable indication of nut-cracking activity at this site, regardless of the nuts' origin—taphonomic or anthropogenic—and thus supports the hypothesis that the pitted stones served as nut-cracking tools.

Additional support comes from several other types of evidence:

- The damage patterns on many of the GBY artifacts differ from those resulting from our experimental basalt knapping. On the former, the surfaces of the pitted stones exhibit minimal damage (as seen in the shallowness of the pits) and most of the pits are centrally located.
- No punches or other evidence of a bipolar technique and associated products have been found at any Lower Paleolithic site in the Levant.
- The high frequency of edible terrestrial and aquatic nuts found in association with pitted stones in several archaeological horizons strongly suggests that the processing and consumption of the nuts occurred in the same location.
- Some archaeologically sterile layers yielded nuts but no pitted stones. Small isolated artifacts found in the sifted sediments suggest that these layers may, in fact, contain Acheulian assemblages.

With these data in mind, we may look at the Olduvai pitted stones in a new light. Perhaps the change from a limnic environment to a terrestrial one (53) led to the presence of terrestrial nuts—and hence the significant numbers of pitted stones (see ref. 2). Again, we may infer from the dietary role of nuts in present-day Africa (54, 55) that if nuts were available in ancient Olduvai, hominins probably gathered and consumed them.

## Conclusion

We have demonstrated that a diversity of edible nut species occurs within the Acheulian archaeological horizons at GBY. These species represent various ancient habitats, including a freshwater environment that supported submerged vegetation; the sloping flanks of the Rift Valley, where trees grew; and a terrestrial environment at much higher elevations than the valley floor. Through a fluvial transport mechanism, 27 tree, shrub, and climber species that grew at the lake level and at higher elevations were deposited at the site.

As many ethnographic studies have shown (56), nuts are a significant component in the diet of hunter–gatherer societies, and thus we may assume that the high nutritional value of nuts was desirable in antiquity as well. The hominins' profound environmental and ecological knowledge, demonstrated through their exploitation of fauna, flora, landscape, seasonality, and other environmental factors, and their sophisticated technological skills and craftsmanship, join to support the nut-cracking hypothesis discussed here.

Archaeological finds suggest that two major complex activities took place at GBY: the production of lithic artifacts and the processing of meat (27). Given the presence of nuts and probably nut cracking, the range of activities at the site was most likely even greater and provides additional insights into not only the functional behavior but perhaps also the composition of the social group that was active there. Ethnographic studies (e.g., ref. 17) show that women and children are usually the nut gatherers; thus, the active groups on the shores of ancient Lake Hula may well have been of mixed gender.

In the vicinity of this lake, only a short distance from the site, a rich variety of ecological resources provided great biodiversity, a trait that might have been particularly attractive to the hominins of the Dead Sea rift during Pleistocene times. In light of the evidence and interpretations discussed here and elsewhere, we may conclude that this locality served as a base for various hominin tasks during the Lower Paleolithic. With its wealth of data indicating patterns of complex human behavior, GBY appears to support the central-place foraging theory postulated by Isaac (57) for the Plio-Pleistocene era.

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