Using Optical Microscopy to Evaluate Human History
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INTRODUCTION
When most people think of archaeology, they picture Indiana Jones discovering the lost ruins of ancient cities. Archaeologists in fact spend more time in the library and the laboratory than they do in the field. Two ubiquitous and important issues that must be resolved in archaeological research are determining the source of the sediments in which artifacts are buried and evaluating any chemical changes that have occurred since deposition. In recent years, archaeologists have increasingly used micromorphology, the study of consolidated, oriented blocks of sediments, to get at these issues in great detail. Here we provide two examples of applications of this technique, the first from what may be the earliest use of fire by humans, the second from one of the earliest villages.

DESCRIPTION OF TECHNIQUE
Micromorphology identifies not only the constituents (rock fragments, quartz sand, bone, pottery, etc.) in sediments and soils, but also their physical arrangement. For this reason, samples for micromorphological analysis must be collected as intact blocks. This can usually be done by cutting out a block of sediment from an exposed trench face and then wrapping it tightly in tissue paper and tape to preserve it. In some instances, sediments may be too loose or too rocky in which case a sample can be collected by inserting a section of PVC pipe into the sediment or by isolating a block of sediments, then wrapping it in plaster-soaked bandages.

Back in the laboratory the sample is placed in a container that is then filled with polyester resin. The resin hardens after several days, essentially turning the sample into a rock. The sample is then trimmed to the desired size (either 50 x 75 mm or 70 x 140 mm) and a thin section is made. Typically, thin sections are ground to a thickness of about 30 µm.

In our experience, the best strategy for analyzing thin sections is to examine them under increasingly higher magnifications so that different aspects of the deposit are revealed at each level. Accordingly, we begin with a microscope reader and a binocular microscope (generally 10x to 20x) and progress to higher magnifications using an optical petrographic microscope (magnifications ranging from 20x to 400x). Different types of illumination are also used including reflected, plane- and cross-polarized, and ultraviolet epi-fluorescence. An additional advantage of the technique is that the cut blocks can also be polished and studied under the binocular microscope.

EXAMPLES
Zhoukoudian Cave, China
The site of Zhoukoudian, situated ca. 50 km southwest of Beijing, is one of the most well-known archaeological sites in the world and has been considered for many years as among the most secure evidence for the earliest use of fire by early hominids. In 1929 the remains of several hominid skeletons, named collectively 'Peking Man', were discovered at Locality 1 - the most important area at Zhoukoudian. The use of fire by these early hominids demonstrated the cognitive abilities of the species and would have provided them with an important new method of adapting to cold climates and improving the nutritional value of food by cooking it.

Two layers at Locality 1, layer 10, the lowest archaeological horizon possibly dating to 600,000 years ago, and layer 4 dated to 250,000 to 300,000 years ago, exhibited characteristics that the initial excavators interpreted as evidence for the use of campfires by Peking Man. In layer 10 the evidence included the presence of burned bones associated with artifacts of quartz, and a lenticular band of yellow and red clay, which resembled baked clay and was overlain by a dark, apparently charcoal-rich band at the base of the layer. In layer 4 the evidence for fire included four to six meters of pale yellow, powdery deposits, thought to be ashes derived from fires. In 1996 and 1997 samples were collected for micromorphological and mineralogical analysis, the latter conducted by S. Weiner using Fourier-transform infrared spectroscopy (FTIR)[1].

Micromorphological study of thin sections from the putative hearths in layer 10 showed that these features actually consisted of finely laminated silt and clay interbedded with reddish brown and yellow brown fragments of organic matter, limestone fragments, and dark brown, laminated silt, clay, and organic matter (Fig 1) [2]. No evidence of wood ash - essentially calcium carbonate - or fragments of charcoal were identified.

On the basis of the composition as well as the bedded to finely laminated nature of the bands, we concluded that the sediments were not due to in-situ burning, but rather to deposition of day and redeposited organic matter (although some of this may have been burnt elsewhere) in standing or slow-flowing water. In other parts of layer 10 we found no other evidence for burning or wood ash, but rather micaceous silt clay with sand- and granular-size clasts of quartz, bone, redeposited aggregates of clay, mm-sized clasts of limestone, and fragments of carnivore excrements, presum-
ably from hyenas which frequented the cave. Under the microscope, layer 4 is clearly composed of laminated silt-sized quartz, mica, and some clay (Fig 2). This composition and arrangement is totally unlike that which results from the burning of wood, which generally results in the production of rhombic or prismatic crystals of calcite [3]. The sediments in layer 4 actually resulted from the accumulation of silts that were washed into the site from the surrounding slopes where they had originally accumulated as the aeolian dust (loess) for which China is famous. Once again, the micromorphological data demonstrate that deposits in the site that were attributed to fire are, in fact, naturally accumulated mineralogenic materials.

Dhra’, Jordan

The site of Dhra’ overlooks the southern end of the Dead Sea and, at 11,000-8,000 years old, is one of the first permanent villages in the world [4,5]. Prior to this time humans had been nomadic hunter-gatherers. Houses and other structures from villages of this period are typically small circular buildings 3-4 m in diameter with a stone foundation and a mud brick superstructure [6,7]. Occasionally, as at Dhra’, walls were built of layers of mud, a technique known as terra pisé. In studying this early phase of village life, several important questions have emerged, including the source of building materials and the construction techniques used in different structures. In 2000 and 2001 samples for micromorphological analysis were collected from various walls, floors and mud-lined pits at Dhra’. Within one terra pisé structure, two walls (an earlier and a later) and a floor were found. Each was composed of a different type of adobe (Fig 3). The earlier wall was a mixture of rounded gravel, very calcitic mud, and fragments of tufa that came from a nearby wadi. The later wall was composed of a mixture of sandy silt, clay, and fragments of bone, flint, and charcoal. This sediment is very similar to that found across most of the site and it is likely that the residents were simply using the sediments immediately around them to build the wall. The earlier wall also contained burned grass that was added as a temper. The floor of the building was a mixture of sand and clay and was likely obtained from marl deposits 23 km from the site. It also contained voids which had originally been filled by barley glumes that were added to the mud used to make the floor. When these decayed, their shape was preserved.

The material used in the two walls has been found in other structures at the site, but the floor material remains unique. In later periods, the residents used lime plaster, made by burning limestone. The analysis of different types of building material has revealed that the residents were obtaining material from a wide range of deposits around the site, sometimes travelling over a kilometer. They were also using different types of vegetal temper and mixing adobe according to different recipes [8]. The analysis indicates the understanding that these villagers had of the properties of different sedimentary deposits in their region.

In a 2m deep trench excavated outside of the terra pisé structure a layer of dark gray silt was found that, in the field, appeared to be composed of wood ash. Analysis of a thin section of this deposit revealed that this layer was not composed of wood ash, but of bedded layers of burned grass and animal dung (Fig 4). Such bedded deposits are typical of animal stables and indicates at least one area at Dhra’ where goats (the first domesticated animal) were kept at the site. Goats (and later other domesticated animals such as sheep, cattle and pigs) represented...
not only food sources, but also potential sources of wealth. Understanding where these animals were kept in relation to the houses can help to indicate whether each family maintained their own flock or whether the villagers pooled their resources. At Dhra’ the central location of the only stable identified so far indicates the latter.

CONCLUSIONS
The use of optical microscopy to analyze thin sections of in-situ blocks of sediments has enabled researchers to understand sites in far greater detail than would otherwise be possible. By analyzing both the constituents of sediments and their organization, archaeologists can understand how deposits formed and separate those characteristics that were part of the original formation of the deposit from changes which occurred later. In the case of Zhoukoudian, it has allowed claims for the use of fire to be re-evaluated and rejected, refining our understanding of early hominids and their adaptive skills. At Dhra’ it has enabled the excavators to identify the range of materials that villagers used in constructing houses and other buildings, providing insight into their understanding of building technology and the local environment. It has also identified at least one area where goats, an important resource, were stabled near the center of the village. In both cases, the use of microscopic analysis refines and amplifies what archaeologists learn in the field.

REFERENCES