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DETERMINATION OF USAGE AND ABSOLUTE CHRONOLOGY OF A PIT FEATURE AT THE EARLY BRONZE I ASHKELON MARINA, ISRAEL, ARCHAEOLOGICAL SITE

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OSL AND TL DATING,
BRONZE AGE,
ASHKELON
MARINA SITE

Abstract: **A study of the luminescence properties of one of several pit features removed from the Ashkelon Marina EB1 (Early Bronze I) archaeological site during a 1998 excavation unequivocally determines their function in antiquity.**

The features are shallow (Ł 50 cm) cup-shaped pits preserved in the ground. A hardened and reddened layer of earth Ł 3cm thick forms the shape of each pit, and a thin layer of white calcite is observed to lie upon the hardened earth. The pit is filled with soft buff coloured, quartz-dominated sediments, indistinguishable from the sediments which underlie it. This feature, and several others at the site, are suspected to be putative fire pit installations, over which crucibles for the melting of copper had been placed. However, the lack of any direct association of copper residues or artifacts found at the site with any of the pit features leaves this hypothesis unproven. Previous investigations, which included X-ray diffraction, differential thermal analysis, optical mineralogy studies, and FT-IR spectral measurements, have been unable to confirm the association of the pit features with fire. Calibrated radiocarbon dates place the use of the site at 5500-5300 BP.

We applied optical dating and thermoluminescence (TL) dating to the hardened red layer and the overlying fill sediments, in order to determine the last time of firing and/or exposure to sunlight of the two components of the feature. The premise driving our investigations is the fact that heated sediments will give the correct TL age. In contrast, unheated sediments will give an incorrect TL age far in excess of the depositional age, but will give a correct optical dating age. The TL analyses yielded ages of 5160 ±380 years for the hardened rim and 24,600 ±1600 years for the fill. Optical dating of the fill yielded an age of 5260 ±380 years, which is in excellent agreement with the TL age on the rim. These results fulfil the hypothesized results precisely. On this basis, we conclude that the pit features at the Ashkelon Marina archaeological site were fire pits used in early copper smelting technology.

1. SITE DESCRIPTION

Between 1996 and 1998 a rescue excavation uncovered an Early Bronze Age I (EB I) site at 18.5 m.a.s.l., above the Marina Beach in Ashkelon, Israel (**Fig. 1**). The remains of human activity included pottery shreds, animal bones, metal objects, amorphous small metal lumps and copper droplets, copper slag, and crucible fragments. The scattered archaeological material represents an intensive copper melting and refining activity and is the first metal workshop discovered in the Levant. The material remains clearly belong to the Early Bronze Age I cultural phase.

The major and almost the only architectural features unearthed were several small and empty shallow conical holes or pits ("installations") of hardened sediment in the ground.

No metals or any residues of metal activity, as well as no other archaeological remains nor any archaeological debris were found within or in connection with the installations in the ground. The slag and crucible fragments were found at a distance of at least 3 m from any of these installations. Thus, there is no archaeological proof that these totally clean and partially preserved installations were a part of the copper melting process. They are, however, the only man made features that could have served in this process.

Two AMS radiocarbon dates measured at the Instute of Physics, University of Aarhus, Denmark place the use

Fig. 1. *Location of Ashkelon, Israel.*

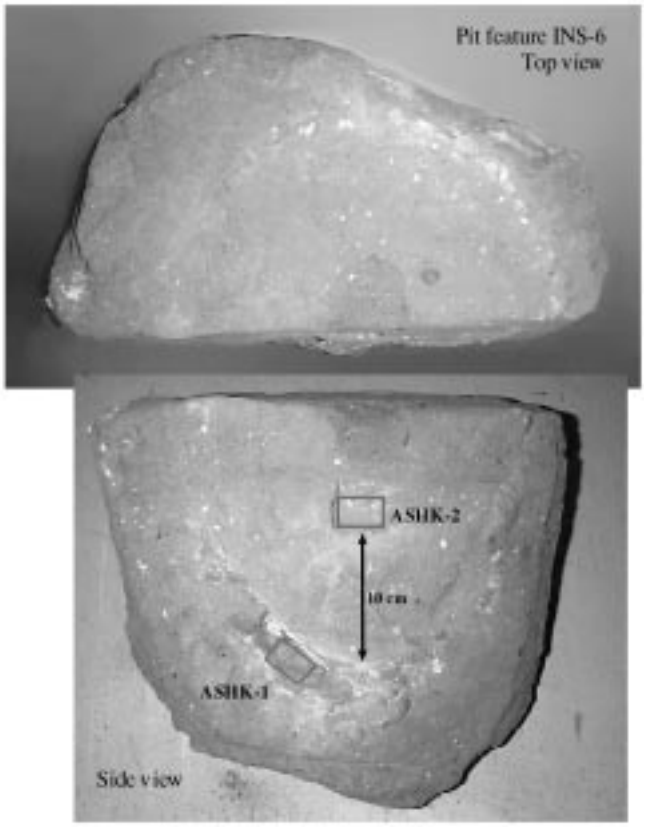

Fig. 2. *The top and side outlines of pit feature INS-6, showing the locations of the samples collected for luminescence analyses.*

of the site at 5580-5330 cal BP and 5450-5300 cal BP; both are 1 standard deviation ranges.

2. PIT FEATURES

The features are shallow (<50 cm) cup-shaped pits preserved in the ground (**Fig. 2**). A hardened and reddened layer of earth 3 cm thick forms the shape of each pit, and a thin layer of white calcite is observed to lie upon the hardened earth. The pit is filled with soft, buff coloured, quartz-dominated sediments that are indistinguishable from the sediments which underlie it. The installations appear in clusters; for example, three were found in a single excavation unit during the 1999 field season. All appear to be similar in composition. This suggests that all may have been deliberately constructed in the same manner, and/or that all served the same function.

The feature illustrated, and several others at the site, are suspected to be fire pit installations, over which crucibles for the melting of copper would have been placed. However, the lack of any direct association of copper residues or artifacts found at the site with any of the pit features leaves this hypothesis unproven. Previous investigations on seven installations which had been removed intact from the site included X-ray diffraction, optical mineralogy studies, differential thermal analysis, FT-IR spectral measurements, and phytolith analysis. These methods, however, have been unable to confirm the association of the pit features with fire (Palatnik, 1999).

3. MOTIVATION FOR THE ANALYSES

We undertook this study in an attempt to conclusively determine the origin of the pit features at this site. The premise driving our investigations is the fact that a heated sediment should give the correct TL age (Aitken, 1985). However, since the TL signal is not completely erased by exposure to light, an unheated sediment will always give a TL age well in excess of the depositional age. In contrast, the same unheated sediment should give a correct optical dating age, provided that the rate of sedimentation was sufficiently slow to allow complete zeroing of the optical signal (Godfrey-Smith, 1994).

We therefore applied optical dating (OSL) and thermoluminescence dating (TL) to quartz grains extracted from the hardened red layer and the overlying fill sediment, in order to determine the last time of firing and/or exposure to sunlight of the two components of the feature.

In addition to the principles generalized above, we also predicted that, if the rim sample had indeed been exposed to a high temperature, and if the infilling was reasonably rapid following the abandonment of the pits, as may be expected on the highly exposed coastal plain of the eastern Mediterranean Sea, then the optical age of the fill should closely match the TL age of the rim.

TL measurements

For each sample, six aliquots were prepared, each composed of ~5 mg quartz on a 1cm Al disk. Half of these were irradiated with a calibrated gamma dose of 10 Gy. After a few days of rest in complete darkness, the TL of all aliquots was measured at 3°/s to 450°C.

The TL glow curves were mass normalized. Thermally-shifted glow curves were aligned to the rest of the data set. For each 5° TL integral, a two-point De was computed using the least-squares linear fit, with the data points weighed inversely with respect to intensity. A plateau test was constructed for each sample using the TL and De data between the 200-375°C range.

Optical dating measurements

Single aliquot analysis on 15 aliquots of ~5mg was performed, using restricted green light stimulation, and detection in the near-UV region, a preheat of 230°C, held for 60 seconds, a shine of 0.5 s at 120°C, and cumulative radiation doses of 5,10, 20, 30, 40, 55, and 70 Gy. A post-additive preheat correction was applied.

The past dose De was deduced on the basis of the linear least squares fit to preheat-corrected data. The resulting De's were plotted against each aliquot's mass-normalized natural luminescence intensity.

4. DOSIMETRY

Bulk material was crushed to a fine powder using a tungsten carbide ball mill, and allowed to rest for 1 month prior to analyses. Th and U activities were measured on loose powders using thick source alpha counting. The values quoted are the averages of sealed and unsealed counts. K_2O concentrations were obtained by atomic absorption at a commercial laboratory (Bondar-Clegg of Vancouver, BC). Water contents were assumed based on known information on the site's location and typical moisture regimes in coastal Israel today.

Table 1. *Values used to compute dose rates.*

Sample	Depth [m b.s.]	K_2O [%]	Total α [ks^{-1} cm^{-1}]	Th α [ks^{-1} cm^{-1}]
ASHK-1 Rim	0.70	0.51	0.537 ± 0.011	0.220 ± 0.033
AASHK-2 Fill	0.58	0.27	0.585 ± 0.011	0.241 ± 0.035

Water content = 0.06±0.05.
Average grain size 120 mm, etched with concentrated HF.
b-value = 0.

5. RESULTS

Thermoluminescence

There is a clear distinction in the natural intensities and the glow curve shapes of the two samples, shown in **Fig. 3** and **4**. ASHK-1 has a peak TL intensity approximately one sixth as high as ASHK-2. ASHK-1 shows a maximum TL peak which falls at the nominal 325°C TL peak, and has a very low 375° C nominal TL peak, while ASHK-2 has its TL maximum at the nominal 375° C TL peak. Note that these peaks are shifted to 307°C and 345°C in our data due to a lower heating rate than that used to create reference TL curves for quartz, typically 10°/s. These shapes are typical of fired quartz (ex. from pottery) and unheated quartz (ex. from sediment), respectively.

The plateau tests, also shown in **Figs 3** and **4**, yield mean De's which differ by a factor 4.5 for the two samples. The mean De for ASHK-1 = 8.0±0.4 Gy (280-330°C plateau), while for ASHK-2 the mean De = 36.2±1.2 Gy (280-335°C plateau).

Single Aliquot Optical Dating

The data shown in **Figure 5** demonstrates that some aliquots represent grains which were more completely bleached by exposure to sunlight than others. The best De quoted below is based on the aliquots that were most completely bleached to light. Here, it is an average of the lowest four points on the graph, or 7.6±0.4 Gy.

Table 2*. Age results.*

Sample	Dose De [Gy]	Dose rate R [Gy/ka]	Apparent age [ka]
ASHK 1 Rim TL	8.0 ± 0.4	1.55 ± 0.08	5.18 ± 0.38
ASHK 2 Fill TL	36.2 ± 1.2	1.45 ± 0.08	24.9 ± 1.58
ASHK 1 Rim OSL minimum	7.2 ± 0.5	1.45 ± 0.08	4.93 ± 0.43
ASHK 2 Fill OSL best	7.6 ± 0.4	1.45 ± 0.08	5.26 ± 0.38

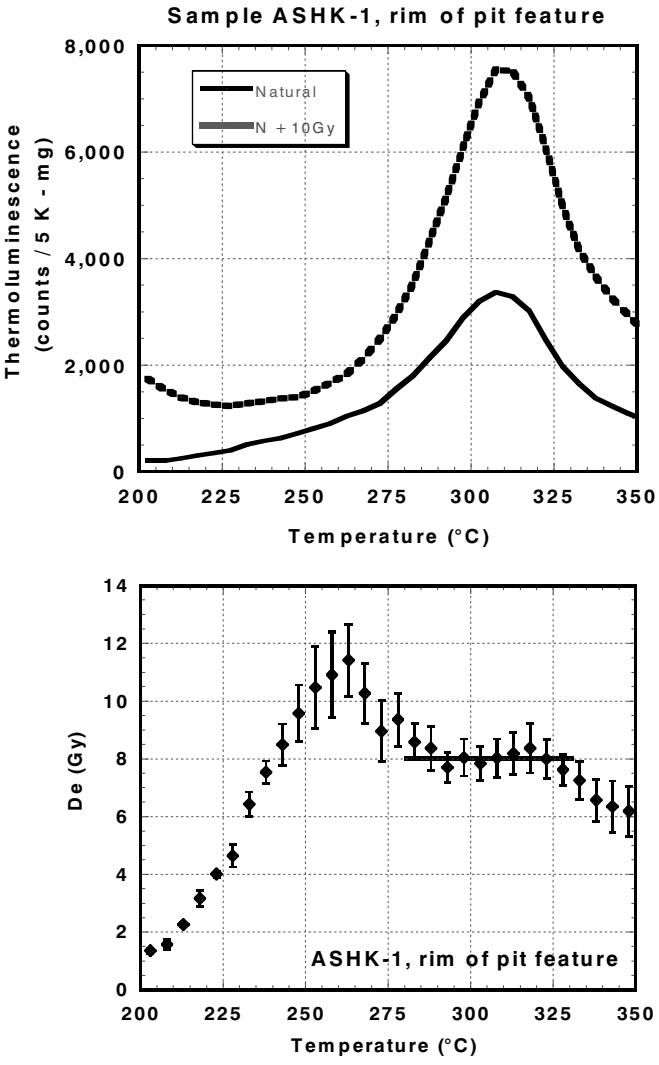

Fig. 3*. Thermoluminescence glow curves and plateau test for ASHK-1.*

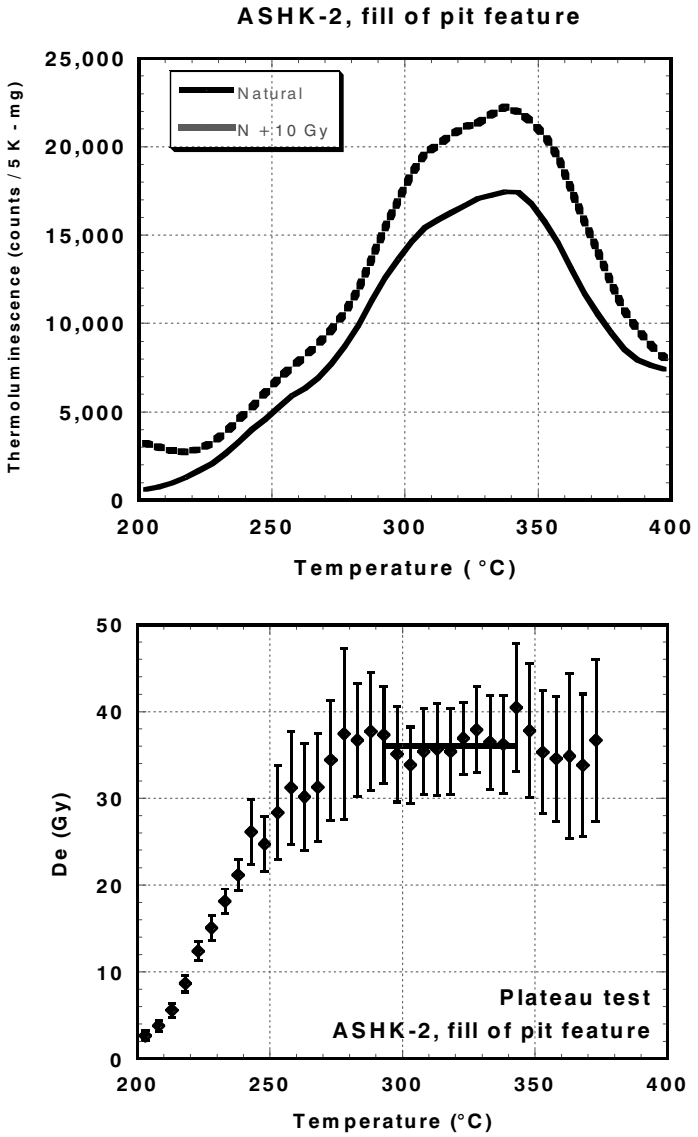

Fig. 4. *Thermoluminescence glow curves and plateau test for ASHK-2.*

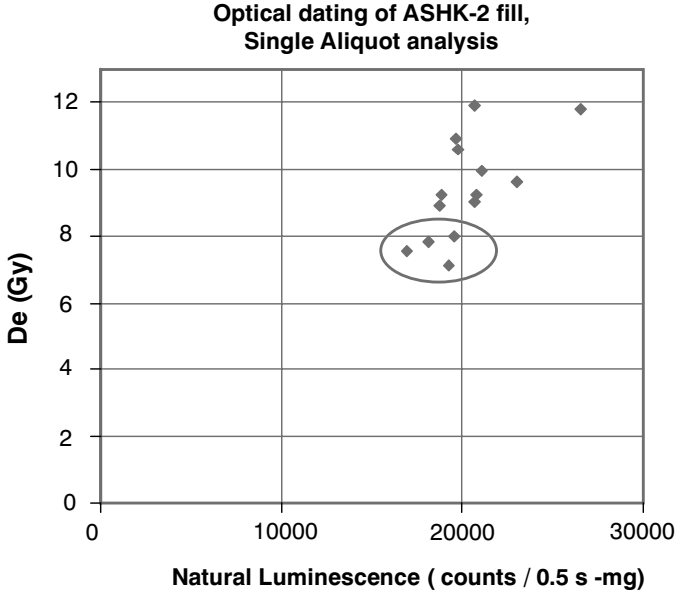

Fig. 5. *Single aliquot optical dating results for ASHK-2.*

6. SUMMARY

The apparent TL age of the fill is 4.5 times older than that of the underlying rim, even though their dose rates are nearly identical. Based on the simple natural laws of stratigraphic succession, such a result is clearly not a reasonable one if the two samples had identical thermal and depositional histories. Thus, we must conclude that sample ASHK-1 experienced a different thermal history than ASHK-2. While ASHK-1 has only the radiation dose De accrued since it was heated, sample ASHK-2, which has not been exposed to heat also carries a large residual dose of 28 Gy due to the unbleachable TL signal typical of unheated sediments. Optical dating of the fill yielded an age of 5260±380 years and is in excellent agreement with the 5180±380 years TL age of the rim, indicating that the infilling of the pit feature rapidly followed its creation and abandonment. These ages are also in an agreement with the radiocarbon chronology.

These results precisely fulfill our hypotheses. We conclude that the pit features at the Ashkelon Marina EB1 archaeological site originated as fire pits used in early copper smelting technology.

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