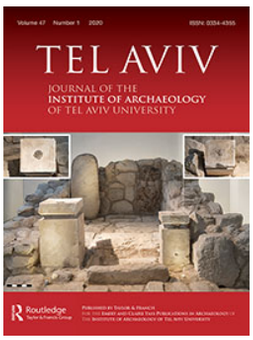

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Cannabis and Frankincense at the Judahite Shrine of Arad

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Two limestone monoliths, interpreted as altars, were found in the Judahite shrine at Tel Arad. Unidentified dark material preserved on their upper surfaces was submitted for organic residue analysis at two unrelated laboratories that used similar established extraction methods. On the smaller altar, residues of cannabinoids such as Δ^9-teterahydrocannabinol (THC), cannabidiol (CBD) and cannabinol (CBN) were detected, along with an assortment of terpenes and terpenoids, suggesting that cannabis inflorescences had been burnt on it. Organic residues attributed to animal dung were also found, suggesting that the cannabis resin had been mixed with dung to enable mild heating. The larger altar contained an assemblage of indicative triterpenes such as boswellic acid and norursatriene, which derives from frankincense. The additional presence of animal fat—in related compounds such as testosterone, androstene and cholesterol—suggests that resin was mixed with it to facilitate evaporation. These well-preserved residues shed new light on the use of 8th century Arad altars and on incense offerings in Judah during the Iron Age.

Keywords Arad, Cannabis, Frankincense, Incense offering, Altar, Iron Age, Judah, GC-MS

The 'fortress mound' of Tel Arad (Aharoni 1968; Aharoni, M. 1993; Herzog 2002) was excavated between 1962–1967 on behalf of the Institute of Archaeology of the Hebrew University of Jerusalem, by Yohanan Aharoni (Ruth Amiran served as co-director during the first season). The excavations revealed six well-preserved phases (Strata XI–VI) of two superimposed, squared fortresses, dated from the 9th to the early 6th centuries BCE (Iron IIA–IIC), which guarded the Judahite kingdom's southern border. Numerous significant Iron II finds were unearthed, among them a large number of Hebrew ostraca (Aharoni 1981) and a well-preserved shrine.[1]

[1] Former publications referred to this structure as a temple; due to its modest dimensions, we prefer to use the term 'shrine'.

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Although the Arad excavations were carried out more than 50 years ago, no final report has thus far been published (for preliminary reports, see Aharoni 1964; 1965; 1967a; 1967b; 1968; Aharoni and Amiran 1964; Herzog *et al.* 1984; Herzog 2001, 2002). Even so, due to the substantial finds from the site and their importance, many scholars dealt with the excavations' results and tried to interpret the discoveries (e.g., Yadin 1965; Mazar and Netzer 1986; Ussishkin 1988; Rainey 1994; Na'aman 1999: 405−410; Zevit 2001: 156−171). Herzog's interim report (2002) was accompanied by a preliminary report of the Iron Age pottery (Singer-Avitz 2002). These publications raised a new discussion regarding the stratigraphy and chronology of the fortress mound (Na'aman 2002: 586−592; Münnich 2004; Finkelstein and Silberman 2006: 270−271; Herzog 2010). The description below is based mostly on Herzog's views (2002; 2010), which are more comprehensive and seem to be grounded on tangible finds (especially the pottery–Singer-Avitz 2002) and the excavators' diaries, notes and plans.

The Arad shrine was first detected during the second season of excavations in 1963, when Aharoni (1967a: 247−249) revealed a cella—a small room containing cult objects. The rest of the shrine was fully unearthed during the third and fourth seasons in 1964−1965 (Aharoni and Amiran 1964: 282−283; Aharoni 1965: 250−251). The shrine was located in the northwestern corner of the fortress, on an east−west axis, with its entrance located in the east and the cella in the west. The shrine dimensions are ca. 13 × 20 m (including the cella), and is comprised of four architectural components: (1) a fenced, open courtyard (*haṣer*); (2) a storage area to the north of the courtyard; (3) a main hall (*hekal*) to the west of the courtyard and storerooms; (4) a small niche or cella (*debir*) west of the centre of the main hall.

Aharoni recognized five phases of construction of the shrine (from Stratum XI to VII), which he believed spanned ca. 350 years, from the 10th to the 7th centuries BCE (Aharoni 1968: 19−21). However, Herzog showed that the shrine was used only during two strata; he argued that it was first erected in Stratum X and went out of use in Stratum IX (Herzog 2002: Figs. 12, 15). Herzog and Singer-Avitz dated these two strata to the 8th century BCE, from ca. 760/750 to ca. 715 BCE (Herzog 2002: 98; 2010: 175; Singer-Avitz 2002: 162−180), restricting the time of the shrine to less than half a century. During these two phases of construction several architectonic changes were made in the shrine (Herzog 2002: 52−65).

A large sacrificial altar constructed of mud-plastered fieldstones (2.20 × 2.40 m) was situated in the northern part of the courtyard. It might originally have had a metal head that did not survive (Herzog 2010: 174−175). A large stone-lined installation was built in front of the altar to the south during Stratum IX; it was interpreted as a purification basin (Herzog 2002: 60−61). The southwestern part of the courtyard collapsed in antiquity into a hewn water reservoir that was located beneath the shrine.

The main hall of the shrine (10.50 × 2.70/3.10 m) was a broad room that was surrounded in its initial phase (Stratum X) on the west and south with benches. Three stairs led from the main hall to the cella; the size of the latter was ca. 1.50 × 1.50 m. Based on the finds unearthed here and in comparison with other Near Eastern temples it was concluded that the cella was the heart of the shrine; it was therefore termed 'Holy of Holies' or *debir*. The Arad shrine was compared to the First Temple in Jerusalem (e.g., Aharoni 1968: 21−26; Herzog 2002: 67−68), and it seems that the two indeed share similar

architectural characteristics (e.g., the east–west axis and the division of the architectural spaces). This may allude to similarity in cultic rituals performed in these structures.

Two superimposed stone pavements were found in the *debir*, probably representing the phases of the shrine's existence. The lower pavement (Stratum X) covered the entire area of the cella. A shallow rectangular basin was embedded into the inner (western) part. The upper floor, 30 cm higher, was detected only in the northwestern part of the *debir*. To its south, the excavators found a smooth limestone slab fallen flat on the ground, bearing remains of red color, believed to be a *maṣṣebah* (stela; biblical standing stone), that may have represented the deity's presence in the shrine.

Two limestone altars were found lying on the second stair between the main hall and the cella (Fig. 1). They were positioned in a pit cut from the upper floor, reaching the lower floor. The altars were deliberately and carefully laid down, as reflected by their orientation facing north and their location on each end of the same stair. The southern altar

Figure 1 The Holy of Holies during excavation. The two lying altars are in their original position on the second stair (at the cemter of the photograph) facing north (The Israel Museum, Jerusalem, S.J. Schweig Collection, B96.0143 [p1666]).

was smaller (IAA 1967–980; 40 cm high; 20 × 21 cm on its top) than the northern altar (IAA 1967–981; 52 cm high; 29.7 × 29.7 cm on its top). Though they differed in size, the two altars shared similar characteristics: their raw material, production technique, form, proportions, and a groove that separated their top part from their base.

The upper surfaces of both altars had a shallow depression (Fig. 2). In the centre of both of these depressions, round heaps of black solidified organic material was preserved, tightly adhering to the altars' upper surfaces. In his preliminary report of the second season of excavations Aharoni mentioned that the dark material was submitted for analysis to the Department of Biochemistry of the Hebrew University (Aharoni 1967a: n. 29). The results of the examination were inconclusive regarding the exact nature of the substance, though by process of elimination Gad Avigad, who examined the material, suggested that it contained animal fat. No final report was published, and only a small number of scholars ever referred to this result (e.g., Nielsen 1986: 50; Zwickel 1990: 167). Most scholars termed the objects 'incense altars' (e.g., Fowler 1984: 184; Gitin 1989: Table 1: 1–2; Aharoni, M. 1993: 83; Herzog 2002: 64–65; Finkelstein and Silberman 2006: 270), though no positive evidence for burning incense was found.

It is worth noting that the black organic material on both altars is clearly visible in some of the excavations' original photos (Aharoni 1967a: Pl. 47; 1968: 13; Herzog 1997: Figs. 47–48). Yet, today only the organic heap on the big altar is still well-preserved (Fig. 2; its diameter was approximately 9 cm, and its height 0.5 cm). Therefore, we assume that

Figure 2 Frontal view of the cella of the shrine at Arad, as rebuilt in the Israel Museum from the original archaeological finds. The inserts show a top–down view of the altars: on the left, the larger altar; on the right, the smaller altar. Note the visible black residue (Collection of the Israel Antiquities Authority, Photo © The Israel Museum, by Laura Lachman. Scale bar stands for 20 cm [1:7])

Avigad may have examined only the organic material present on the small altar, as very little currently remains (Fig. 2; the diameter of the burnt imprint on the altars is ca. 6.5 cm).

As mentioned above, the Arad shrine was excavated from 1963−1965. During this period, the Israel Museum was under construction in Jerusalem. It seems that the sensational discovery of a Judahite shrine led to the transferring of the original stairs, floor (of Stratum X) and furniture[2] of the *debir* (without its enclosing walls) to the permanent exhibition in the archaeology wing of the museum. The Holy of Holies from Arad has been one of the main attractions of the museum ever since its opening in May 1965. Reference to the results of the previous sampling of the small altar by Avigad might be found in the provisional guide of the new archaeological museum, where the altars are reported to contain the remains of sacrifices and not incense (Israel Museum 1965: 33, #141).

During the renewal of the archaeology wing of the museum, between 2007−2010, the Arad shrine was relocated to a new gallery. It was decided to reconstruct walls (with stones brought from Tel Arad) in order to ensure comprehension of this significant discovery (Fig. 2). These changes encouraged new analyses of the organic material found on the altars with the hope that improved techniques might shed new light on the materials used—and, perhaps, the rituals performed—in this unique shrine.

Material and methods

Materials

To protect the research potential and curatorial importance of the black materials on top of the small and big altars, a very small sample (≤5mg) was taken with a sterile scalpel from the lower parts of each dark heap and was preserved in aluminum foil. To reassure the obtained results and minimize the possible cross-contamination during sampling, extraction and lab processing of the samples, sampling was independently repeated in two different incidents and analyzed using GC-MS instruments (see below) in two laboratories—one at the Technion, Israel Institute of Technology, Haifa and the second at the Hebrew University of Jerusalem, Givat Ram.

Methods

Total organic composition extraction

All glassware was rinsed with acetone, followed by dichloromethane, and dried in a fume hood. The samples were manually ground to powder in a porcelain mortar and pestle.

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[2] The original furniture of the *debir* that was transferred to Jerusalem included the standing stone and the two altars. A stone slab made of flint was also displayed in the gallery; Aharoni interpreted it as a second standing stone positioned in the *debir*. However, in the new presentation of the *debir* the museum's curators accepted Herzog's (2002: 63) interpretation, and today the flint slab is incorporated into the back wall of the reconstructed *debir*. It might have been an old stele that was no longer used as a *maṣṣebah* in the later phase (Stratum IX) of the shrine.

The whole homogenized powder was used for each extraction. With each sample batch a routine blank was analyzed, to monitor any laboratory contamination.

The extraction and analysis procedures of the total lipids followed organic residue analysis (ORA) routinely applied (e.g., Namdar, Amrani and Kletter 2015). Eight millilitres of a high grade purity dichloromethane methanol mixture (2:1, v:v) was added to each sample, followed by sonication for 15 minutes. The tubes were then centrifuged for 10 min at 3500 rpm. The supernatant was transferred to a clean glass vialand and evaporated under a gentle stream of nitrogen. Prior to analysis, 100 µl of N,O−bis(trimethylsilyl) trifluoroacetamide (BSTFA) containing 1% trimethylchlorosilane (TMCS) was added to the dry extracts followed by heating at 65 °C for 20 min. Two main methods are used today for cannabinoids identification—liquid chromatography (HPLC) and gas chromatography (GC), both with different detectors, mostly mass spectrometers (MS). For the identification of terpenoids only GC-MS is suitable. As we worked on very small samples, of unknown compositions, we chose to analyze the extracts using GC-MS for its wide variability and high sensitivity. One microliter of each sample was injected into the gas chromatograph (GC) with mass selective detector (MS) as detailed in the following section. Every extraction was repeated twice, in separate extraction batches, to evaluate reproducibility and monitor laboratory contamination.

Gas chromatography with mass spectrometry (GC−MS)

GC−MS analyses carried out at the Hebrew University of Jerusalem used a HP7890 gas chromatograph coupled with a HP5973 mass spectrometer (electron multiplier potential 2 KV, filament current 0.35 mA, electron energy 70 eV, and the spectra were recorded over the range m/z 40 to 800) using a splitless injection mode. An Agilent 7683 autosampler was used for sample introduction. Helium was used as a carrier gas at a constant flow of 1.1 ml s^{-1}. An isothermal hold at 50 °C was kept for 2 min, followed by a heating gradient of 10 °C min^{-1} to 325 °C, with the final temperature held for 10 min. A 30 m, 0.25 mm ID 5% cross-linked phenylmethyl siloxane capillary column (HP-5MS) with a 0.25 µm film thickness was used for separation. The injection port temperature was set at 220 °C. The MS interface temperature was 300 °C. Results are shown in Fig. 3.

GC−MS/MS analyses carried out at the Technion used a Thermo Scientific TRACE 1310 GC coupled with TSQ 8000 Evo triple quadrupole mass spectrometer, in full scan acquisition mode. Injections performed using a Thermo Scientific AI/AS 1310 autosampler for automated liquid injection. Chromatographic separation was achieved on a TraceGOLD TG5SilMS GC, 30 m × 0.25 mm × 0.25 µm capillary column with 5 m integrated guard (P/N 26096-1425). Data was acquired using full-scan and timed selective reaction monitoring (t-SRM) and processed with Thermo Scientific TraceFinder software. The injection port temperature was set at 220 °C. The MS interface temperature was 300 °C. Results are shown in Fig. 4.

Peak assignments were carried out with the aid of library spectra (NIST 1.6) and compared with published data and MS data obtained from the injection of standards of high purity terpenoids and cannabinoids purchased from Restek (Restek Corporation, PA, U.S.A).

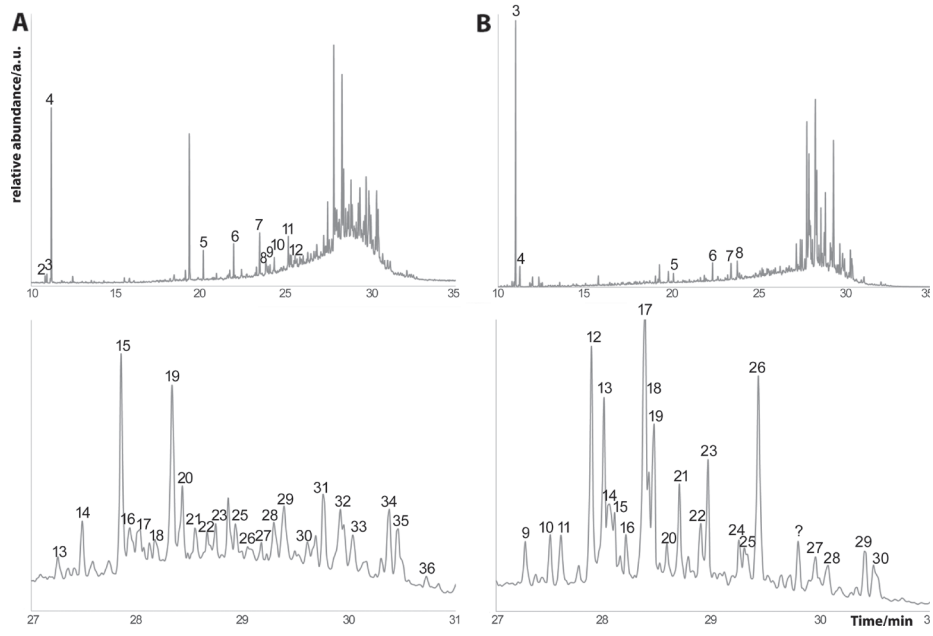

FIGURE 3 Chromatograms of the silylated samples (see 'Methods'), taken from the dark residues adhering the altar surfaces, analyzed using the Hebrew University instruments. (A) small altar (with A' for elution time of 32–38 mins); (B) big altar (with B' for elution time of 32–38 mins). For full peak annotations, see Table S1. Non-marked peaks—phthalates (for external contamination).

Results

The complete list of organic compounds present in the extracts of the sampled altars and their relative abundances are listed in Table 1.

The Small Altar contained cannabidiol (CBD), Δ^9-tetrahydrocannabinol (THC) and its degradation by-product cannabinol (CBN) were detected (Fig. 4A and Table 1A). Along the cannabinoids, mono- and sesqui-terpenes such as borneol, α-farnesene, β-caryophyllene, α-bulnesene, guaiadiene, and longipinocarvone complimented this unique find. This assemblage may point to very well-preserved residues of *Cannabis Sativa* L., inflorescence, leaves or oil. Other terpenes were also detected, in different relative amounts (see Table 1A).

Fatty acids present in the extract are palmitic and stearic acids in relative abundance showing predominance of stearic over palmitic acid ($C_{18:0}$>$C_{16:0}$) (Table 1A). Such given fatty acid ratio of $C_{16:0}$<$C_{18:0}$ is usually attributed to animal fat (Evershed 2008, Baeten *et al.* 2013). This assemblage—accompanied by cholesterol isocaproate, epi-tostesterone derivatives, together with several amines such as α-L-arginine, leucine and valine—may point to a mammalian origin fat. Moreover, urea and coprostanol degradation derivative may suggest that mammalian feces was in contact with the upper surface of the altar, either during use or after the altar was buried under a footstep.

The Big Altar contained an assemblage of sesqui-, di-, and triterpenes alongside some fatty acids, sterols and stanols (Fig. 4B). The terpenoids included cembrene A, elemonic acid, norursatriene and norursadiene, noroleanadiene, epi-β- amyrin and α-amyrin, and (keto-/) β-boswellic acid (Table 1B), all indicating frankincense resin.

TABLE 1

Compounds detected in the BSTFA (1%TMCS) treated samples, taken from the dark heaps adhering to the altars' surface*

	Compound ID	Compound class	Suggested origin	Relative amount (%)
A. Small altar				
1	borneol	monoterpene	cannabis?	0.7
2	carbitol	glycol ether		0.6
3	urea	amide	animal	0. 7
4	morphinan−2,4−dioi−6−one			5.4
5	palmitic acid	fatty acid	C18:0>C16:0 animal fat	0.4
6	stearic acid	fatty acid		0.9
7	dis−p−tolylacetatylene			1.8
8	α−farnesene	sesquiterpene	cannabis?	1.2
9	morpholinor−dioxo−dihydrofurazan			0.6
10	α−L−arginine	amine	animal	0.9
11	leucine	amine	animal	1. 6
12	valine	amine	animal	0.6
13	artemisinin	sesquiterpene	plant	0.7
14	aziridin	amine	animal?	0.8
15	β−caryophyllene	sesquiterpene	cannabis?	2
16	β−carotene	carotenoid		7.4
17	α−bulnesene	sesquiterpene	cannabis?	4
18	lanosterol	triterpenoid	animal/fungal	2.5
19	guaiadiene	sesquiterpene	cannabis?	9. 6
20	glycerol monomyristate	fatty acid		5.3
21	hexobarbital	barbiturate		3.4
22	cannabidiol (CBD)	cannabinoid	cannabis	3.4
23	propanone mercaptodiphenyl			2.8
24	7−epi−trans−sesquisabinen hydrate	sesquiterpene	cannabis? also in micromeria	8.6
25	glycerol monoolein	fatty acid		2.1
26	thunbergol	diterpenoid		0.6
27	monoacyl behenate	fatty acid		1.2
28	cholesterol isocaproate	sterol derivative	animal	3.6
29	epi−testosterone		animal fungal	5.2
30	ergostadienol	sterol	plant	2.2
31	coprostanone	sterol	animal, fecal?	4.3

*Analyzed in the Technion laboratory. Compounds detected as laboratory contamination were excluded from identification and relative amounts calculations.

	Compound ID	Compound class	Suggested origin	Relative amount (%)
32	trans−Δ9−tetrahydrocannabinol (THC)	cannabinoid	cannabis	9.3
33	androsterone hexanoate	sesquiterpene	steroidal hormone	1.4
34	stigmastadienol acetate	sesquiterpenes, phytosterol derivative	cannabis?	1.2
35	longipinocarvone	sesquiterpene	cannabis?	2.1
36	cannabinol (CBN)	cannabinoid	cannabis	3.5
B. Big altar				
1	methyl ester			0.7
2	benzyl alcohol			0.8
3	cembrene A	diterpenoid	frankincense	8.5
4	morphinadiolone			1
5	palmitic acid	fatty acid	C18:0>C16:0 animal fat	0.2
6	stearic acid	fatty acid		0.4
7	cis−calamenene	sesquiteprene		0.3
8	totarol	diteprenoid		1.1
9	tryptoline	alkaloid		2
10	stigmasterol tosylate	sterol		1.8
11	stigmastadienol	phytosterol		2.3
12	elemonic acid	triterpenoid	frankincense	7.4
13	norursatriene	triterpenoid	frankincense	11.5
14	thujopsene	sesquiterpene		1.2
15	noroleanadiene	triterpenoid	frankincense	2.3
16	α−spirostane	aglycone		2.6
17	norusadiene	triterpenoid	frankincense	13.4
18	testosterone derivative	steroid	animal	6.1
19	dihydroquinoline	quinoline derivative		2.3
20	ergostenol	stenol	plant	4
21	serratol	diterpenoid	frankincense?	2.7
22	androstenone	steroidal pheromone	animal fat	4.7
23	epi−β−amyrin	triterpenol	frankincense	2.8
24	cholesterol	sterol	animal? also in plants	2.6
25	solavetivone	sesquiterpene	plant	3.9
26	keto−β−boswellic acid	triterpenoid	frankincense	2
27	β−boswellic acid	triterpenoid	frankincense	2.8
28	valerinadiene			1.7
29	α−amyrine	triterpenol	frankincense	1.8
30	ergostadienol acetate	sterol derivative	plant/fungal	2

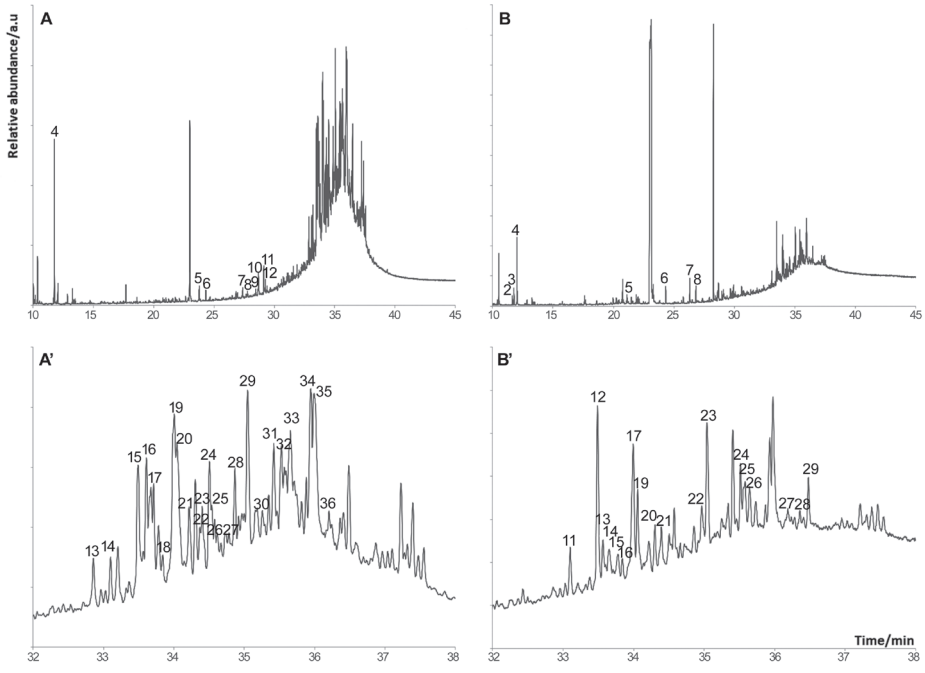

FIGURE 4 Chromatograms of the BSTFA (1%TMCS) treated samples, taken from the dark heaps adhering to the altars' surfaces, analyzed using the Technion instruments. (A) cannabis—contained on the small altar; (B) frankincense—contained on the big altar. Non-marked peaks—phthalates (for external contamination). For compound identification see assignments of correlated numbers in Table 1

Similar to the results from the small altar, fatty acids present in the extract of the organic remains from the big altar are palmitic and stearic acids with a predominance of stearic over palmitic acid (C18:0>C16:0) (Table 1B and Fig. 4B). This assemblage—accompanied by cholesterol, androstenol and tostesterone derivatives—may point to a mammalian fat (but not feces)

Laboratory blanks were run with the samples in each batch of extraction contained nothing but $C_{16:0}$ and $C_{18:0}$ in $C_{16:0}$>$C_{18:0}$ ratio, opposite to what was found in both altars' extracts. The fact that there was no cross-contamination between the two altars and the different molecular assemblages extracted from them exclude the possibility that the extracts represent a cross-contamination introduced by sample processing.

Discussion

The small altar with cannabis residues

Cannabidiol (CBD), trans-Δ^9-tetrahydrocannabinol (THC) and its degradation by-product cannabinol (CBN) were detected in the black heap of organic remains accumulated on the upper surface of the small altar. Cannabinoids are naturally formed only in *Cannabis* plants. Finding the activated cannabinoids THC and CBD on top of an altar may intimate that cannabis inflorescences were burnt there, conceivably as part of a ritual that took place in the shrine.

Cannabis sativa produces hundreds of secondary metabolites that affect the human body (Mechoulam and Gaoni 1965; Aizpurua−Olaizola *et al.* 2016). It contains more than 500 different phytochemicals, among them 151 phytocannabinoids (Hanuš *et al*. 2016). However, the two main phytocannabinoids produced in *C. sativa* trichomes and accumulated mostly in its inflorescences are cannabidiolic acid (CBDA) and Δ^9-tetrahydrocannabinolic acid (THCA) (Mechoulam and Gaoni 1965; Hanuš *et al*. 2016). Either of these cannabinoids, and mostly both of them in different ratios, are found in any cannabis strain/variety existing today.

Upon heating, CBDA and THCA decarboxylate into CBD and THC, respectively (Fig. 5; Pennacchio, Jefferson and Havens 2010: 63−64). Only decarboxylated THC is potent and can cause psychoactive effect in humans as the decarboxylated phytocannabinoids can interact with the CB1\CB2 endocannabinoid receptors to activate a physical reaction (Hanuš *et al*. 2016). Therefore, heat is required for releasing the active compounds, so they can be inhaled. With time, Δ9-THC further oxidize non-enzymatically into cannabinol (CBN) (Fig. 5; ElSohly and Slade 2005, Brenneisen 2007, Namdar *et al*. 2019a). Further degradation pathways are less known (Hanuš *et al*. 2016).

Alongside the three activated phytocannabinoids detected, an assortment of different terpenoids with 2, 3 or 4 pairs of isoprene units (i.e., mono−, sesqui−, di−, and triterpenes) were also found in the extract. In general, monoterpenes govern the scents of flowers, fruits and grasses. *C. sativa* produces hundreds of terpenes and terpenoids, which vary in relative abundance within the different strains/varieties of the species (Aizpurua−Olaizola *et al*. 2016, Namdar *et al*. 2019b, Shapira *et al*. 2019). Each terpene detected in the extract is not unique to cannabis and may be found in various different plants. However, most of the given terpenoids identified in the dark heap from the small altar are known to be produced by cannabis inflorescences, in significant amounts. Moreover, β-Caryophyllene that was detected in the extract of the material found on the small altar, is the most abundant terpene in all cannabis chemovars (Aizpurua-Olaizola *et al*. 2016, Namdar *et al*. 2018). Thus, it may be suggested that together with the cannabinoids identified, which are unique to cannabis, at least part of the given terpenes and terpenoids also derive from the cannabis used. As terpenoids are a common component in the plant domain it would be difficult to infer that any other plants may also have been burnt on the same altar.

Similar phytocannabinoidic assemblages were detected in two finds from different areas in China. The first is a magnificently well preserved find of ancient seeds and leaves of *Cannabis sativa*, retrieved from a burial cave in Yanghai tombs located in the Gobi Desert near Turpan, Xinjiang-Uighur Autonomous Region. The find, dating to 700 BP, was botanically (Jiang *et al.* 2006), morphologically, chemically and genetically (Russo *et al*. 2008) identified as *Cannabis sativa* L. In the extract of the seeds, obtained in similar extraction and analytical methods to those applied here, assemblages of phytocannabinoids and their degraded by-products were identified. A similar assemblage of decarboxylated phytocannabinoids, containing CBD and its degradation by-product CBL, along with CBN, the THC degradation by-product, was recently reported from the Jirzankal Cemetery (ca. 500 BCE) in the eastern Pamirs region (Ren *et al*. 2019). These similar cannabinoid assemblages reinforce the suggestion of cannabis presence on the Arad altars. Both finds show that in adequate conditions cannabinoids can be well preserved over many centuries.

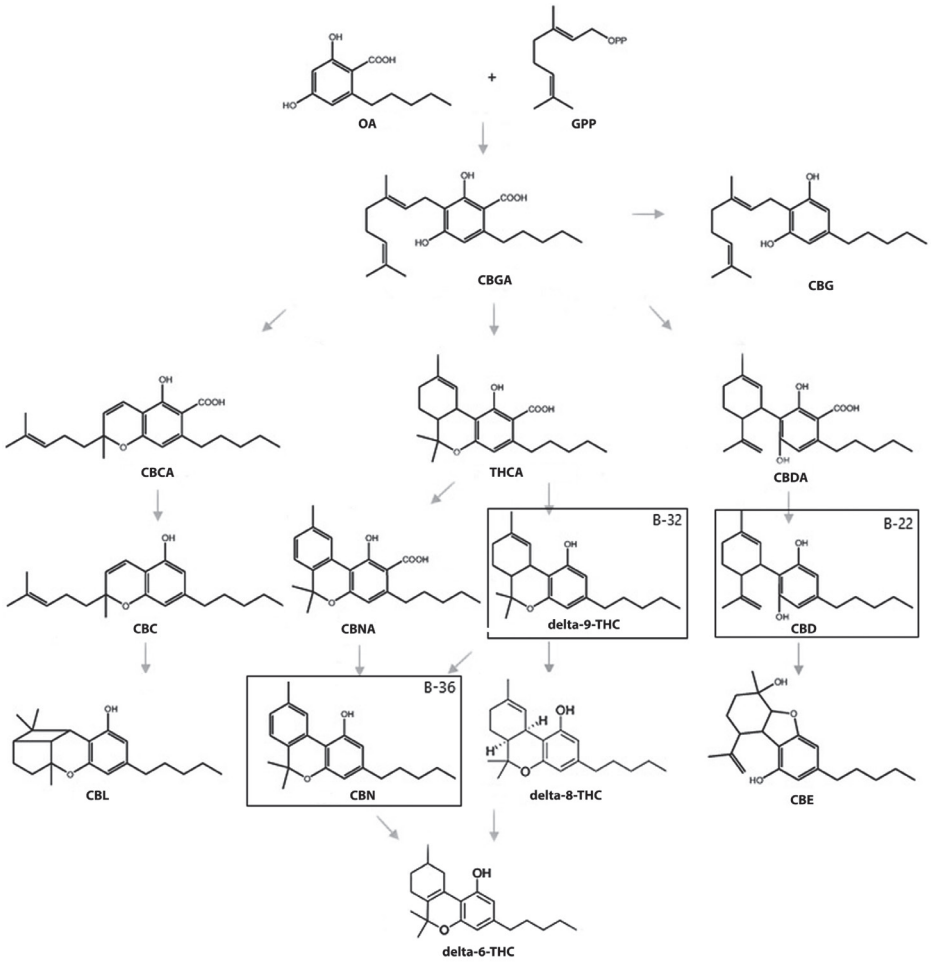

Figure 5 The main cannabinoids creation–decarboxylation–degradation by-products.

As the terpenoids detected are not unique to cannabis and may be found abundantly in many other local plants, it is likely that the cannabis burnt on the altar was not imported for its smell or therapeutic virtues but for its mind-altering abilities, expressed only by heating. *Cannabis sativa* L., popularly known as marijuana, has long been appreciated for its ability to produce psychoactive effects on humans (Russo 2014). Anthropological observations demonstrate *C. sativa* uses for recreational purposes. Members of the Gaddi tribe of India's western Himalayas, for example, smoked the resin of female cannabis plants for the hallucinations it induced (Singh and Kumar 2000). In the Buganda kingdom of Africa, as well as in Kanabad village in Pakistan tribe members smoked cannabis leaves and flowers to induce a state of euphoria (Hamill 2001; Gorsi and Miraj 2002). The Tenetehara of Brazil also smoked the flowers and the leaves for their psychoactive effects (Wagley and Galvão 1949).

The species also has a number of medicinal properties, from which the best known is its pain relieving ability, especially pain associated with childbirth. In Africa, the Sotho smoked the leaves and other parts of the plant for this reason (Watt and Breyer-Brandwijk

1962). In Morocco, midwives used the smoke of cannabis to induce abortion in pregnant women wishing to terminate their pregnancy (Merzouki, Ed-derfoufi and Molero Mesa 2000). In the archaeological record, in a cave dated to the 4th century CE in Jerusalem, remains of a 14-year-old girl who died during labour were found, with the skeleton of a 40-week fetus trapped in her pelvis. A juglet with black material in it was retrieved near the skeletons. The analysis of the dark material revealed the presence of Δ^6-THC, an acid catalytic by-product of Δ^1-THC and cannabidiol (CBD). Zias *et al.* (1993) concluded that the purpose of feeding the cannabis to the girl (by inhalation) was to increase the force of uterine contractions and to reduce birth pain.

All cannabis types are currently categorized as one species named *C. sativa* L. (Clarke and Merlin 2013, Sawler *et al.* 2015). Attempts to build a more developed taxonomy for this plant are still debated despite significant morphological and chemotaxonomic differences (Lynch *et al*. 2016). Claiming the opposite, Hillig (2005) showed that cannabis derived from two major gene pools, *C. sativa* and *C. indica*, one originated in China and moved to India, Nepal and Africa, while the other was cultivated in the region between Turkey and Russia. How and when cannabis arrived in the southern Levant is not known (more below), although *C. sativa* can be grown in Israel and Sinai (Hillig 2005). Studies of the origin and trans-location of the different wild types of this plant growing in China are abundant (Stevens *et al*. 2016; Lynch *et al*. 2016). However, several other centres of origin were considered (Merlin 2003). For example, McPartland and Hegman (2018) deduced that one centre of origin of *C. sativa* must have been in Europe, where it was cultivated around 7000 years ago. Later, the plant spread to other regions and was introduced to the New World only after 1492 CE (Merlin 2003). Thus, the question of the origin of cannabis is not yet resolved.

One cannabis strain, or variety, called *Sinai Ruderalis* is an Egyptian landrace strain cultivated in the Sinai Peninsula by the local Bedouins (Clarke and Merlin 2013). However, Ruderalis contains very low amounts of cannabinoids. Furthermore, pollen analysis carried out on samples taken from both altars by Dafna Langutt (Tel Aviv University) concluded that no plant material was preserved on the Arad altars. In fact, no cannabis seeds or pollen remains are known from archaeological contexts in the Ancient Near East, as opposed to northeast China or southeast Russia, where all parts of the cannabis plant and seed were found at different archaeological sites and contexts and were dated as early as 2000 BCE (Jiang *et al.* 2016; Russo *et al*. 2008; Russo 2014). Therefore, we suggest that cannabis female inflorescences may have been imported from distant origins and were transported as dried resin (commonly known as hashish).

It seems feasible to suggest that the use of cannabis on the Arad altar had a deliberate psychoactive role. Cannabis odors are not appealing, and do not justify bringing the inflorescences from afar. The frequent use of hallucinogenic materials for cultic purposes in the Ancient Near East and beyond is well known and goes back as early as prehistoric periods (e.g., Rudgley 1995; Merlin 2003; Guerra-Doce 2015). In the Levant and its surroundings one should mention Minoan ecstatic cult (Warren 1981), opium from Cyprus (Merrillees 1989; Smith *et al.* 2018), cave experiences in Greece (Ustinova 2009: 267−275) and Philistine cult objects from the southern Coastal Plain of Israel (Namdar, Neumann and Weiner 2010; Gadot *et al.* 2014; Namdar, Amrani and Kletter 2015). These psychoactive

ingredients were destined to stimulate ecstasy as part of cultic ceremonies. As shown in this study, 8th century Judah may now be added to the places where these rituals took place.

The big altar with frankincense residues

We interpret the chemical composition of the sample scraped from the surface of the big altar, containing indicative di- and tri-terpenoids, to originate from frankincense (*Boswellia*) resin. A similar molecular assemblage of terpenoids was studied using analytical methods and instruments comparable to those applied in this study, and showed direct association with archaeological absorbed frankincense (Baeten *et al.* 2014). The degradation breakdown compounds proposed to be driven from ancient frankincense (Fig. 6) were detected in the extract of the material found on the big altar of Arad.

Frankincense resin, also known as olibanum oil, is a yellowish to red oleogum-resin produced by several types of *Boswellia* trees (Burseraceae family), which is characterized by resin bearing ducts. There are some 15 members of this much revised genus (Al-Harrasi and Al-Saidi 2008). *Boswellia* trees grow naturally in relatively arid zones, mostly in Africa and southern Arabia (Langenheim 2003). To obtain frankincense, the bark of the tree is repeatedly injured (cut multiple times) causing a white, milky gum-resin to seep from the wounds. The gum-resin is left on the tree to dry in the sun for a few days, after which it is scraped off. The colour of the dried resin varies from light yellow to dark brown (Mertens, Buettner and Kirchhoff 2009). Despite its estimated high value and avowed widespread use, frankincense has to date rarely been recovered in archaeological contexts. It has been identified mostly in Egypt (Mathe *et al.* 2004, Evershed *et al*. 1997, van Bergen *et al*. 1997), Yemen (Regert *et al*. 2008, Hamm *et al*. 2005, Mathe *et al*. 2007) and lately also in Britain (Brettell *et al*. 2015). Baeten *et al*. (2014) were the first to demonstrate the preservation of absorbed organic residues attributed to frankincense, as they identified frankincense residue in extracts of late medieval (11th and 15th century CE) funerary pots from different sites in southern Belgium. As the chemical composition of secreted oleogum-resin differs by its botanical species, Baeten *et al*. (2014) analyzed commercial resins from four different *Boswellia* species, setting a reasonable basis for the identification of the compounds detected by us as deriving from *Boswellia* resin named frankincense.

The use of frankincense as incense for burning and its transportation from its regions of origin were thoroughly studied (e.g., Bowen 1958; van Beek 1958, 1960; Ogino 1967; Hepper 1969; Bulliet 1975: 57–86; Müller 1976; Groom 1981; Zohary 1982: 197; Nielsen 1986; Amar 2002: 87–95; Peacock and Williams 2006; Ben-Yehoshua, Borowitz and Hanuš 2012; Musselman 2012: 59–61). The earliest archaeological evidence of frankincense probably comes from the wall reliefs of the mortuary temple at Deir el-Bahri (Lucas 1930; Phillips 1997), where Queen Hatshepsut of the 18th Dynasty recorded, at the beginning of the 15th century BCE, a trading expedition to the land of Punt (the exact location of Punt is still debated; probably northern Somalia; Kitchen 1993). Five ships loaded with treasures and exotic animals were depicted on the walls; one of them has 31 fragrant young incense trees, believed to be frankincense or myrrh (see Hepper 1969 vs. Dixon 1969). The attempt to transplant living incense trees from Punt to Egypt (that probably failed) reflects the immense importance of these trees for the Egyptians.

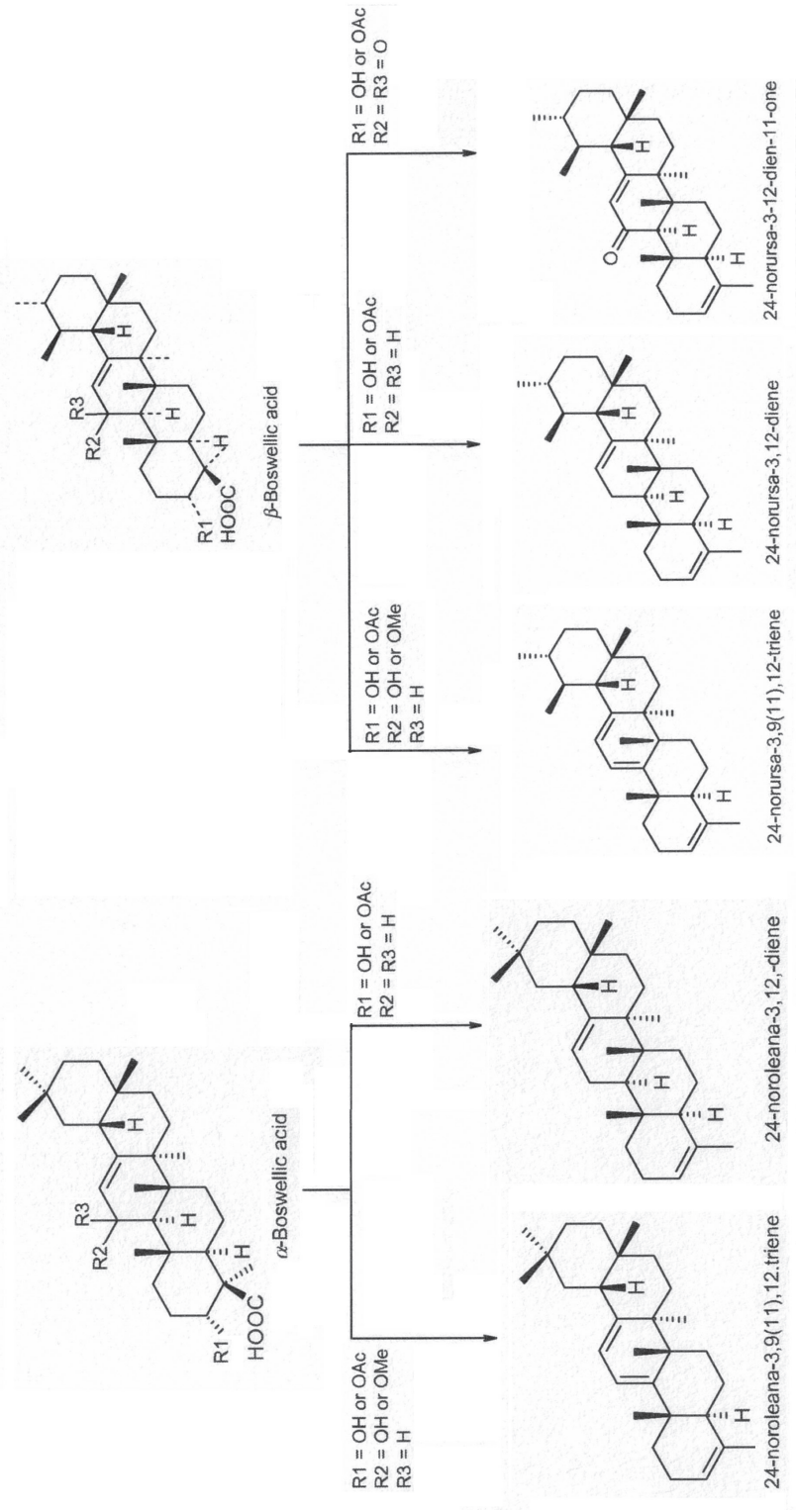

FIGURE 6 Degradation breakdown compounds of the main molecules typical of frankincense.

The high value of frankincense is further reflected in the Bible, where its price is compared several times with that of gold and precious stones, and it is often described as a royal treasure (Haran 1993: 240). Frankincense was also highly esteemed throughout Assyria, Babylonia, Persia, Greece and the demand reached its peak when Romans burned it in temples, at funerals and in domestic contexts for appeasing the gods (Kasher 1982: 70; Singer 2006). Obviously, the high price of frankincense was due to the efforts required for its import from the remote production areas over long distances, to regions where it was in demand.

Frankincense trade routes can be tracked back to the southern Arabian Peninsula both in historical sources (i.e., Assyrian inscriptions and Greco-Roman literature; van Beek 1958: 142−143; Groom 1981: 55−95; Singer-Avitz 1999: 4−6) and from archaeological evidence (see below). The early frankincense trade routes originated in Dhofar (today's Oman), passed through Yemen and followed the eastern coast of the Red Sea northward into the Levant and Egypt (van Beek 1960: 91−95; Groom 1981: 165−188; Miller and Morris 1988; Singer-Avitz 1999: 46−50), with traders utilizing camel caravans as attested by the growing numbers of camel bones found in excavations in the northern Negev (Sapir-Hen and Ben-Yosef 2013: Table 2).

This commercial activity can be observed in the region of Tel Arad (the Beer-sheba Valley), which flourished during the last third of the 8th century BCE.[3] Although this area was taken-over by Assyria only in the days of Sennacherib in 701 BCE, it lived under effective Assyrian hegemony earlier. This imperial supremacy laid grounds for the rise of South Arabian commerce in this region (Singer-Avitz 1999: 54−60). At Tel Beer-sheba, for example, several artefacts hinting at this trade system were found, such as a limestone seal bearing a South Arabian inscription, several South Arabian stoppers made of stone and a set of cubic altars, one of which is incised with a figure of a camel (*ibid*.: Figs. 11 and 15).

This trade expanded greatly during the 7th century BCE. The Assyrians established several forts and commercial centres along the trade routes in Edom, Philistia and Judah (Finkelstein and Silberman 2002: 267−270). Even though much attention was drawn to frankincense trade (also later, under the Babylonian and Persian empires), due to its perishable nature only scarce evidence of it remained. Until the present research, the only archaeological evidence of frankincense in the southern Levant was a small Persian period limestone altar found at Tel Lachish. It bears an inscription that reads: "The frankincense (altar) of Iyosh son of Maḥalya from Lachish" (Aharoni 1975: 6−7).

It has often been suggested that frankincense is incense burnt during cultic activities (Nielsen 1986: 68−88; Heger 1997: 19−22; Ben-Yehoshua, Borowitz and Hanuš 2012: 31−33). Together with myrrh (*Commiphora* family) the two have often simply been termed 'incense', and although their resins have different chemical compositions (Langenheim 2003: 586) in religious literature they were frequently related to each other (van Beek 1960: 82−86). Frankincense was not only used for cultic purposes, either official or private; it also served in mortuary rites, medical treatments, cosmetics and mundane household uses (e.g., Nielsen 1986: 89−100).

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[3] Trade with South Arabia and even further probably began earlier, with evidence for this still accumulating (Gilboa and Namdar 2015).

Why two? The burning fuel used on the altars

The two Arad altars differ in size and use, as indicated by the organic substances associated with them. They also differ in the fuel applied to burn them. Wood material is scarcely found in the dry environment of Arad so other fuel sources had to be sought (Shahack-Gross 2011). In both cases mammalian-origin material was used, however of two different types. Organic compounds detected on the big altar indicate the use of animal fat (for biomarkers matching animal fat, see Evershed 2008, Baeten *et al.* 2013). The molecular assemblage extracted from the small altar matches that of animal dung (Langgut *et al*. 2016). This difference may have to do with the plant material associated with the two altars—frankincense on the big altar, cannabis on the smaller one. The temperature required for decarboxylation of the cannabis phytocannabinoids into their neutral and active form is mild, not exceeding 150 °C. This could be achieved by burning of animal dung-cake (Kenoyer 1994, Shahack-Gross 2011). Determining the animal species that donated the dung is impossible in the current case (Lancelotti and Madella 2012; Linseele *et al*. 2013). Frankincense resin, on the other hand, requires a higher temperature to release its fragrance—around 260 °C (Hamm *et al*. 2003). Animal fat can reach and maintain this temperature.

Incense and altars: some new thoughts

The two altars from the Arad shrine are part of a larger group of about 50 similar items that have been found in the southern Levant. This group consists mainly of medium-sized, four-horned altars, approximately 20 to 70 cm in height. These rather rare objects, which were unearthed in the territories of the Kingdoms of Israel, Judah and Moab and in the Philistine city-states, have undergone scrupulous study in recent years (Gitin 1989, 1992, 2002, 2009; Zevit 2001: 306–314; Daviau 2007; Gibson, Kennedy and Kramer 2013; Maeir, Hitchcock and Kolska-Horwitz 2013: 20–21). Although most scholars identified them as incense altars, others proposed they might have been used for the sacrifice of small animals (Fowler 1984: 184) or the offering of animal parts (Zevit 2001: 310) or grains (Haran 1985: 230–245; 1993; 1995). We believe that each case should be investigated in its own context, and that similar altars may have been utilized for a variety of purposes over their period of use. The suggestion that some of these altars were employed for the sacrifice of small animals cannot be ruled out for the moment, though no evidence for this has ever been found. Haran's proposal that these objects were used for grain-offerings is based on biblical considerations only (Gitin 2002: 108–113). He rejected the possibility that the Arad altars were used for burning incense, because according to him this activity was only sanctioned at the Temple in Jerusalem (Haran 1995: 34–35). Haran specifically referred to the residue on the Arad altars, saying: "I would be surprised … if any of these remains provides evidence of incense burning" (*ibid*.: 33). Our results justify naming this group of objects incense altars.

The excavator of Arad assumed that the two altars (and the entire shrine) were deliberately buried for ritual reasons (Aharoni, M. 1993: 83). The motivation for this cultic interment is debated. Many scholars followed the excavator and assume that it was part of a cultic reform in Judah under King Hezekiah (e.g., Münnich 2004: 342–343; Finkelstein and Silberman 2006: 279–280; Herzog 2010: 196–197). Other scholars suggest that the

abolishment of the shrine came out of a desire to protect it from the danger of damage prior to the Assyrian occupation (Fried 2002: 447; Uehlinger 2005: 290–292); according to Na'aman (1999: 408; 2002: 592) it was only after the Assyrian destruction that the altars were interred by the Judahites to preserve their sanctity. Our results cannot side with any of these theories, but the very good preservation of the organic material on the altars does indeed reinforce the assumption that they were intentionally interred.

In the past when it was assumed that two standing-stones stood in the Holy of Holies of the Arad shrine (see above n. 1), scholars suggested that each altar stood in front of each of the standing-stones. This reconstruction brought about the conclusion that two deities were worshipped at the shrine, possibly a divine couple (e.g., Zevit 2001: 310). Moreover, in other cultic rooms, where two incense altars were found together (e.g., Megiddo, Building 2081; Loud 1948: 45–46; Fig. 102), the same conclusion of multiple deities worshipped was drawn (Ganor and Kreimerman 2019: 228). Herzog's suggestion that only one standing-stone was erected in the cella of the Arad shrine might seem difficult to accept, as it insinuated that two altars faced one standing-stone. In light of our results it is clear that the number of altars does not echo the number of deities worshipped in the shrine, but rather it indicates the different kinds of incense used in it.

The very high price of frankincense, and presumably that of cannabis, reinforces the assumption that the fort of Arad was an official institution, owned by the Kingdom of Judah. Being part of the kingdom administration, the residents of the fort could have had the resources to obtain such precious materials.

Conclusions

Tel Arad is the first locale where incense from Iron Age Judah has been successfully examined. Two different incense components and two different fuel beds were defined on two altars from an 8th century BCE shrine. The results show that the larger altar contained frankincense that was mixed with animal fat for evaporation. On the other altar, cannabis substance was mixed with animal dung to enable its mild heating.

Although frankincense is well-known as one of the key components of biblical incense, it has not yet been scientifically identified in a Levantine archaeological context. The presence of frankincense at Arad indicates the existence of South Arabian trade that took place under the patronage of the Assyrian empire as early as the 8th century BCE. Historical and biblical texts demonstrate that the use of frankincense was varied and that it was utilized both in the public and private spheres. Arad presents the earliest known identification of frankincense in a clear *cultic* context.

The discovery of cannabis on the smaller altar was a surprise. Arad provides the earliest evidence for the use of cannabis in the Ancient Near East. Hallucinogenic substances are known from various neighboring cultures, but this is the first known evidence of hallucinogenic substance found in the Kingdom of Judah. To explore this further, more altars, incense burners and other cult related objects from Judah and its neighbors, deriving from controlled excavations of well-preserved contexts, should be studied. For example, two contemporary stone altars from Khirbet el-Mudēyine in Jordan (Daviau 2007: 133–134, 137, Figs. 3, 8) bearing charred botanical material were not analyzed for their chemical content.

The Arad shrine was in use for merely half a century (from ca. 760/750 to ca. 715 BCE) and the stone altars may have been in use for a shorter period of a decade or two. The fact that only one substance (accompanied by a single burning material) was associated with each altar, points to either the same use for each altar over again, or, preferably, the altars' surfaces were scrubbed clean between uses.

The utilization of plant material for fragrance or psychoactive alterations is not new to the region in general, nor to ceremonial complexes in particular. Frankincense has long been used as incense during ritual ceremonies. The use of psychoactive materials is also well known in ancient Near Eastern and Aegean cultures since prehistory. It seems likely that cannabis was used at Arad as a deliberate psychoactive, to stimulate ecstasy as part of cultic ceremonies. If so, this is the first such evidence in the cult of Judah.

The Bible only relates to incense for its agreeable fragrance; frankincense is mentioned as a component of the incense that was burnt in the Temple of Jerusalem for its pleasant aroma. The presence of cannabis at Arad testifies to the use of mind-altering substances as part of cultic rituals in Judah. The plants detected in this study can serve as an extra-biblical source in identifying the incense used in cultic practices not only at Arad but also those elsewhere in Judah, including Jerusalem.

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