Possible source of Qumran gypsum: The Lisan Formation north of Qumran
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Abstract
The unique find in 2004 of an intact and sealed storage jar on the plateau south of the Qumran settlement made possible an analysis of its undisturbed interior deposit in 2011. The 2011 study concluded that the main constituent was pure gypsum, which was not a known resource near Qumran. Here we report the find and analysis of a geological outcrop of pure gypsum at Deir Hajla ca. 8 km north-east of Qumran. The consequences of the finds of the sealed jar and the outcrop at Deir Hajla are explored.

Introduction
On the 2nd of August 2004, Randall Price and Oren Gutfeld unearthed a completely intact ovoid jar with two loop handles on the Southern plateau of Qumran (Figure 1). The intact jar, named Jar-35, was sealed with an overturned bowl. The lid was removed and a camera lowered into the interior revealed a deposit up to ca. 3 cm thick lining the bottom. Upon retrieval the deposit appeared to be lined with ceramic flakes from the interior surface of the jar (Figure 2). The find of an intact and sealed storage jar is a rare event, which makes it possible to analyse its last content and in this way possibly procure insight about the use of the jar.

In 2006, Buti et al. reported that a study of the deposit using the techniques of capillary electrophoresis (CE) and high-pressure liquid chromatography (HPLC) showed that it contained a small but unquantified amount of tartaric acid, and they therefore reported that the jar had contained either wine or vinegar. In 2011 Rasmussen et al. re-analyzed a sample of the content of Jar-35 and found that there were no traces of tartrates or any other organic compounds, and that the deposit of the jar consisted of pure crystalline gypsum. The question arose how the people working at Qumran could have acquired pure gypsum, as none has been located in the immediate vicinity today, and for what purpose they were storing pure gypsum in a sealed storage jar placed on the Southern plateau. Rasmussen et al. (2011) pointed out the possibility of an as-yet unidentified industrial process. The jar was dated both by radiocarbon and TL-dating (Rasmussen et al. 2010; 2011) yielding an estimated age of 100 BCE – 15 CE (2 standard deviation interval).

In the present study we report the find and analysis of an outcrop of pure gypsum which could have been accessible to the workers at Qumran.
Sampling sites, regional geology, and the occurrence of gypsum

The Qumran site was built on the Lisan Formation, which crops out across most of the Dead Sea basin. The formation was deposited by Lake Lisan (the precursor of the Dead Sea) which covered the region including Qumran and Deir Hajla during the last glacial period, c. 70,000 to 14,000 years BP (Stein M et al. 1997; Haase-Schramm et al. 2004; Lisker et al. 2009). The Lisan Formation is up to 35 m thick, typically containing autogenic aragonite and several gypsum layers deposited by evaporating lake water, as well as allogenic alluvium containing calcite and quartz silt, sandstone and pebbles, brought by freshwater streams into the lake. The formation displays facies change from north to east and from the lake shore to its centreline, near the present Jordan River. Allogenic calcite and quartz are more common in the shallow-water facies, located near the lake shore, where wadies bring fresh water and detritus into the lake. Autogenic minerals (mostly aragonite and gypsum) are more common at the central Jordan valley facies away from fresh water input. We sampled both facies types of the Lisan Formation: the shallow facies at Qumran close to Cave 4Q, and at the central Jordan valley facies near Deir Hajla, in order to locate a possible source of gypsum used at Qumran (Figure 3). Both sites have been above the Dead Sea level during the Historic periods (Frumkin and Elitzur 2002) and must have been easily accessible 2000 years ago. The gypsum-containing outcrop of the central Jordan Valley facies was studied near Deir Hajla monastery ca. 8 km NE of Qumran and ca. 7 km SE of the present day centre of Jericho. It was sampled at the white cliff member near the upper part of the Lisan Formation (Begin et al. 1974). This sampling point represents a wide distribution of the same layer in the central Jordan valley region.

X-ray diffraction of the Deir Hajla outcrop

We undertook a structural analysis by X-ray diffraction in order to identify the degree to which the crystalline components of the outcrop at Deir Hajla are identical to the deposit inside Jar-35. Ca. 100 mg of the sample was crushed with an agate pestle and mortar, and the powder X-ray diffraction pattern was measured at room temperature using a Siemens D5000 instrument, equipped with monochromated CuKα₁ radiation (wavelength 1.5406 Å). The resulting profiles for the two samples are shown in Figure 4. The intensities of the peaks can vary to some degree because of preferred orientation (i.e. a non-random distribution of crystallites in the powder). However, peak positions must match for structurally identical samples. The deposit from the Jar-35 sample (bottom pattern in Figure 4) is essentially identical to the database entry for gypsum, CaSO₄•2(H₂O). Based on this analysis, it is evident that the only significant crystalline phase in the deposit is gypsum. The sample from the outcrop at Deir Hajla (top) is also a perfect match to gypsum, except for one diffraction line at ca. 25 degrees 2 theta. This corresponds to the most intense diffraction line in the database entry for anhydrite, CaSO₄. When exposed to water, anhydrite readily transforms to gypsum, CaSO₄•2(H₂O), by the absorption of water. Thus, the analysis shows that the outcrop material near Deir Hajla, ca. 8 km north-east of the Qumran settlement, provides a source of pure gypsum which could be identical to the deposit in Jar-35. It should be stressed that the PXRD technique identifies only crystalline phases, and has an effective detection limit in the region of 2–3 volume %. Amorphous materials, and trace organic compounds, if present, would not be detected. Thus, we have not necessarily proven that this outcrop is identical to the deposit of Jar-35. Any further strengthening of the possible connection between the deposit in Jar-35 and the Deir Hajla outcrop will await further chemical analysis.
X-ray diffraction of six samples from the vicinity of Khirbet Qumran
The Jar-35 results raised the question whether pure gypsum is found in the immediate vicinity of Khirbet Qumran. With the kind permission from the Israel Nature and Parks Authority, we collected six samples at six sites in the immediate vicinity of the settlement and within the upper cliff member of the Lisan Formation (positions shown in Figure 1). Based on the PXRD model data (Figure 5) the samples can be divided into two groups. The first group consists of the four samples KLR-8595, -8597, -8598 and -8599, all of which are almost completely devoid of gypsum, with their main crystalline components being quartz, calcite and aragonite (Figure 6). The other group consists of two samples, KLR-8596 and KLR-8600 (Figure 7), which comprise a combination of gypsum, aragonite, calcite and quartz. Although gypsum is present in these samples, they are clearly very far from pure gypsum. There is no heating or hydration/dehydration event that could convert any of the samples to pure gypsum. It is therefore evident that out of the 7 sites investigated in this study, only Deir Hajla can be a candidate for the content of Jar-35.

<table>
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<th>Lab No.</th>
<th>Field No.</th>
<th>S</th>
<th>Composition</th>
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<tbody>
<tr>
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<td></td>
<td>gypsum (m), anhydrite (t)</td>
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<tr>
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<td>Qu-6</td>
<td>Q</td>
<td>calcite (m), aragonite (m), gypsum (m), quartz (t)</td>
</tr>
</tbody>
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Table 1. Summary of the composition of the crystalline components of the 7 samples investigated. First column: sample number; second column: field number; third column: site (DH = Deir Hajla, Q=Qumran); fourth column: the main constituents as measured by PXRD (m: major component; t: trace component).

Discussion
Gypsum is not uncommon in the mineral assemblage of the Lisan formation, but seen from the perspective of the deposit in Jar-35 the interesting point is if there can be found outcrops of pure gypsum, i.e. without aragonite, calcite, quartz or any other mineral normally occurring in the facies of the Lisan formation, which was accessible to the inhabitants of Qumran. The Deir Hajla outcrop is the only such outcrop identified so far, but there may be others. The purity of the gypsum in Jar-35 could be coincidental, but it seems more likely that the purity of the gypsum was intentional, and therefore would need to be obtained from an existing source of pure gypsum, whether at Deir Hajla or somewhere else.

Gypsum has been exploited by humans since early times (Levey 1958: 337-8; Aston, Harrell and Shaw 2000: 22; Gill 1976: 165). Its most important use was for plaster and mortar. Because of its permeability, which allowed colorants to be absorbed below the surface, gypsum plaster was sometimes used for wall frescos. Gypsum stucco ‘being quick setting and excellent for making sharp impressions (therefore better for moulding and casting) was common in the oriental world’ (Rozenberg 2006: 340, with references to classical authors on gypsum. See also Ling 1972). As ‘plaster of Paris’ it was also used for modelling or making moulds. Occasionally it was ‘ground and
mixed with soap and used as the equivalent of pumice’ or was included in medical prescriptions (Levey 1958).

Theoretically gypsum could have been used for any or all of these applications in Qumran with the caveat that, as there is no evidence of fresco or stucco work at the site, it must be assumed that, if that was its purpose, it was being prepared for use elsewhere. Chemical analyses of plaster work have been made at only a few sites, predominantly Masada, Jericho and Herodium. At Masada it is said that some of the fresco plaster ‘was made from gypsum or calcite’ (Porat 1995: 224). However in more recent studies at Jericho and Herodium the use of gypsum has not been detected in either fresco or stucco work and it is unclear if it was used for stucco work at Masada (Rozenberg pers. com.).

Due to the limited supply of fuel at Qumran it is possible that the gypsum would have been heated at its source in Deir Hajla where dried reeds and drift wood would have been more easily available. Deir Hajla is close to the River Jordan downstream from Jericho. The sandstone used for dressed ashlars, column drums and capitals at e.g. Qumran, Masada and Hyrcania originated in quarries at Khirbet es-Samra (Conder and Kitchener 1883: 182, 212-3; Hirshfeld 2004: 65) about ten kilometres north of Jericho in the same general area from which much of the potter’s clay used at Qumran seemingly derived (Michniewicz 2009: 137-140). The easiest way to transport these raw materials would have been in coracles or shallow-bottomed boats floated down the River Jordan and into the Dead Sea where they would have taken advantage of its anti-clockwise current to progress down its western shore. Jars of gypsum prepared at Deir Hajla could easily have been added to the cargo as it journeyed down the Jordan.

The gypsum in Jar-35 could have been for use at Qumran itself or destined for onward transport elsewhere. The context in which the jar was found might elucidate this issue. Clearly if the jar had been sunk into a working surface it could be assumed that its contents were being utilised in the immediate vicinity. Unfortunately, although the jar was found in 2004, no final, or even preliminary, report has been published giving its precise context. The limited photographic evidence (Figures 8a and 8b) might suggest that the jar was not sunk into a surface, but this is not certain. A preliminary report of the 2002 excavation season in what is presumably a nearby location (Price 2005) reveals evidence for what one would expect; an uneven surface from the Hasmonean period outside the built up area that seems to have had no specific purpose. This area with uneven surface was probably used, as were most of the areas to the north, south and east of the buildings, as a general garbage dump (Magen and Peleg 2007: Fig. 4) and, as such, is an unlikely place to store a jar awaiting transport elsewhere. Like the ‘southern garbage dump’ north of the area in which Jar-35 was found was probably ‘in use during the Hasmonean period and abandoned already in the first century BCE’ (ibid p. 7) when fill was brought in to level off the plateau for use as a garden in the Herodian period when the ‘main’ water system was constructed and, with it, the large pools L71 and L91 from at least one of which (L91) an overflow channel ran to irrigate this area (Stacey 2007: 232-235; Stacey forthcoming). This levelling required the construction of the long retaining wall that runs east of L71 and along the eastern side of the plateau [note particularly the coin, no. 1536, of Herod the Great from within the ‘simple fill’ which was part of the construction of L71 (Humbert and Chambon 2003: L71 9/3/54) which helps date both L71 and the long retaining wall to its east]. Jar-35 could have been sunk into the ground after this fill and levelling had been accomplished ca. the time of Herod the Great.

Jar-35 is an example of ‘the typical storage jar of the last two decades of Herod’s reign’ (Bar-Nathan 2002: 34, type SJ7B, and see Bar-Nathan 2006: 55, dated to between 28/26 BCE – 73 CE, cf. de Vaux 1953: Fig. 2,1 and 3). What is not known is whether the contents of the jar were being actively used in the immediate vicinity of where the jar was found, or were for use elsewhere. On
the one hand, that the jar was found in an area used, at least in part, as a garbage dump might suggest that the jar itself was garbage. On the other hand, this seems outweighed by the find of the jar intact, with a bowl placed over the top of its mouth. A freestanding jar tossed or placed as garbage would hardly be expected to have survived unbroken and intact, loose bowl still on top, two thousand years later. Therefore although we are puzzled as to the choice of location, it appears to us that the jar and the gypsum or then-liquid plaster within it must have been intentionally sunk into the ground for some use in the location in which it was found, however this is to be interpreted. Although the use of moulds in making ceramics was not widespread in this period they were employed for the production of ‘Judean Radial Lamps’, dated from c. 85–4 BCE (Bar-Nathan 2002: 109). Two such lamps are published from Qumran (de Vaux 1954: Fig. 2,15; Fig. 6,3). A mould for these lamps was found in Jericho (the material from which it was made was not recorded) indicating that some were made there but this does not preclude their manufacture in Qumran.

Perhaps the jar held ‘plaster of Paris’ which had been mixed with water for use in forming moulds (or in plastering), and the plaster had dried out and hardened, the jar buried in the ground abandoned and surviving intact until discovered in modern times with only the dried residue left after the moisture had long since evaporated.

Conclusions
The extraordinary find of pure gypsum in Jar-35 excavated on the southern plateau in Khirbet Qumran prompted us to search for a source of pure gypsum in the vicinity of Qumran and elsewhere in the region. The best geological candidates in the immediate vicinity of Qumran have been shown not to hold pure gypsum. However, a sample from the Lisan formation outcrop at the site Deir Hajla 8 km NE of Qumran and 7 km S of present day Jericho has proved to hold sufficiently pure gypsum to be a viable candidate for the raw material in Jar-35.

An implication, if this is correct, is that the inhabitants of Qumran would have had tighter bonds to the central River Jordan valley and therefore possibly to Jericho than hitherto believed.

References


Figure 1. Situation plan of the Qumran settlement. The position of the find of Jar-35 is indicated with a star. The positions of the six geological samples analyzed are indicated by points.

Figure 2a: Jar-35 during the excavation in 2004 – here still in situ looking down into the bowl top removed;

Figure 2b: Samples of the deposit found inside Jar-35.
Figure 3. Situation plan of Deir Hajla.
Figure 4. Powder X-ray diffraction pattern of a sample of the outcrop at Deir Hajla (top, KLR-8496) and the deposit inside Jar-35 (bottom, KLR-6625). The arrow indicates the only other crystalline phases present besides gypsum (CaSO$_4$•2(H$_2$O)), namely anhydrite (CaSO$_4$).
Figure 5. Model PXRD patterns for gypsum, calcite, aragonite and quartz.
Figure 6. Measured PXRD patterns (top), for the four samples from Qumran devoid of gypsum. Below each pattern is shown a linear combination of model patterns in Figure 5 (bottom) constituting a rough approximation to the pattern in the sample.
Figure 7. Measured PXRD patterns (top) for the two samples from Qumran which contain gypsum. Below each pattern is shown a linear combination of model patterns in Figure 5 (bottom) constituting a rough approximation to the pattern in the sample.

Figure 8: 8a and 8b: Jar-35 still in situ.

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