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Identifying the geographic area with best conditions for discovering lime burning: Could the lime industry have been born in the Dead Sea region?

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ABSTRACT

Archaeological studies suggest that the lime industry originated in the Near East during the Pre-Pottery Neolithic B (PPNB; 10,500–8400 cal BP). This paper describes an attempt to define a more confined area where this pivotal event could have taken place, by searching for areas where lime technology is likely to have been best known during the preceding Pre-Pottery Neolithic A (PPNA; 11,600–10,500 cal BP) period. The assessment has been undertaken by comparing the conditions for discovering lime burning in different parts of the Southern Levant during the PPNA. Lime burning is the first step in the lime production process. The assessment has been supported by two test-burning experiments by the Dead Sea. The investigations conclude that lime technology was best known in the Jordan Valley and by the Dead Sea, which is consistent with the distribution of Neolithic lime finds to date.

1. Introduction

Lime is an anthropogenic material, produced by processing limestone using heat. The oldest evidence for the utilization of lime has been found in the Geometric Kebaran (16,500–15,000 cal BP) site Lagama North VIII in the Sinai Peninsula, and consists of traces of lime on some pieces of flint (Kingery et al., 1988: 228; Rollefson, 1990: 33). The lime is believed to have acted as an adhesive to attach the flint pieces to the haft of a sickle. Remains of the oldest hearth, in which lime burning has taken place, have been found in the Natufian (15,000–11,600 cal BP) horizon of the Hayonim Cave in northern Israel (Bar-Yosef, 1998: 163; Kingery et al., 1988: 223–224). All sites mentioned in this article are located in the Near East (see Fig. 1 and Table 1).

During its infancy the use of lime appears to have been limited, since only seven examples have been reported across five sites from the Geometric Kebaran to the PPNA. This represents a time span of no less than six millennia and have all been found in the southern part of the Levant. However, during the PPNB, the lime technology developed significantly. This is clearly demonstrated by the widespread use of lime (Clarke, 2012: 11; J. Clarke pers. comm.) and the high quality of the material (Ronen et al., 1991: 151; R. Malinowski pers. comm.).

The lime material during this later period was mainly used for plastering of walls and floors, but also for producing beads, vessels, figurines and to model facial features on to sculls (Clarke, 2012: 1–2; J. Clarke pers. comm.; Rollefson, 1990: 36–52). During the PPNB, lime was utilized in many parts of the Near East, but its ubiquity was amongst sites mainly located in the Southern Levant. Considering the magnitude of the lime related activities, the PPNB could be described as the period during which the lime industry was born.

2. Objects and methods

The birth of the lime industry was a significant event, as it was the first time that a "synthetic" material was produced on a large scale, with the aid of fire. Thus, the lime industry is older than both the ceramic and the metallurgical industries in the Near East (Lambert, 1997: 30, 48, 173) and both the latter may have been influenced by it. Therefore, it would be valuable to know precisely in which part of the Near East this pivotal event could have taken place. However, Neolithic lime is rarely explicitly dated in archaeological reports (S. Weiner pers. comm.) and therefore elucidating lime manufacturing localities has required the use of other sources of data.

In the current study the aim of the research has been to locate areas where lime technology could have been best known during the PPNA, which is the period immediately preceding the earliest boom in lime production. It seems reasonable to assume that the starting point of the PPNB lime production was located not too far from that area. This study has been undertaken by searching for areas with optimal conditions for lime burning (the first step in the lime production process). The research has been supported by a series of two burning experiments, which were carried out in the Dead Sea area. The result of this analysis is that the lime technology, during the PPNA, is likely to have been best known in the southern part of the Jordan Valley and by the Dead Sea (Fig. 2). The object of this paper is to describe how that conclusion was reached.

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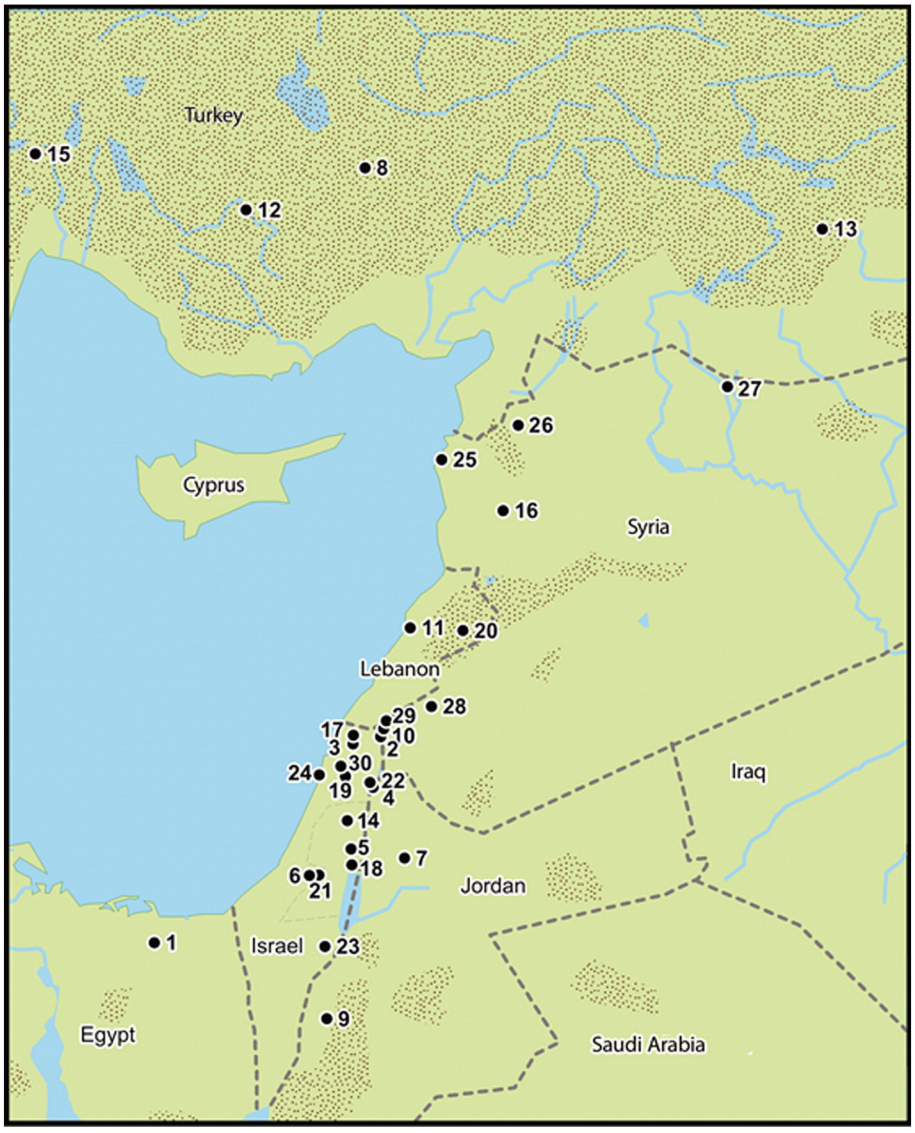

Fig. 1. Sites where lime is reported to have been found.

Both the Dead Sea and the Jordan Valley are located in the Jordan Rift Valley, a long, broad and deep depression, running from the Bay of Aqaba in the south to the Taurus Mountains in the north (Fig 3.) The Jordan Valley refers, in this paper, to the portion of the Jordan Rift Valley running from the Dead Sea to the Sea of Galilee.

3. Lime technology

Manufacturing lime starts with burning limestone in a kiln or a hearth. The purpose is to disintegrate the calcium carbonate ($CaCO_3$) in the raw materials, thereby producing quicklime (calcium oxide, CaO). The next step is the slaking of quicklime in order to produce slaked lime (calcium hydroxide, $Ca(OH)_2$), which is the binding component in lime. Finally tempers including sand, ground limestone or other inert materials, are mixed with the slaked lime. A comprehensive description of the lime burning technology is provided by (Boynton, 1980: 159–189). Adding temper has two major advantages, it reduces the amount of work required to produce lime plasters and lime mortars, and makes the material stronger and more durable (Goren and Goldberg, 1991: 137; Kingery et al., 1988: 221). The word plaster is used when lime is attached to a wall or a floor, whereas mortar is used when lime binds together two objects, for instance bricks (Lambert, 1997: 30). The bonds are created by reactions between the slaked lime and the carbon dioxide in the atmosphere, during which calcium carbonate is recreated (Lambert, 1997: 30).

The equations for the three steps are as follows:

1. Burning/calcination: $CaCO_3 + \text{heat} = CaO + CO_2$
2. Slaking: $CaO + H_2O = Ca(OH)_2 + \text{heat}$
3. Hardening: $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$.

Lime burning requires a temperature of about 800–900 °C, (Gourdin and Kingery, 1975: 134; Weiner, 2010: 186; Frierman, 1971: 213–214; Rehoff et al., 1990: 79) depending on the size and characteristics of the raw materials and the concentration of carbon dioxide in the hearth. The first equation indicates that high concentration of carbon dioxide in a hearth retards the process. Therefore, good ventilation is important, not only for boosting the temperature but also to facilitate the disintegration of the calcium carbonate (Boynton, 1980: 162). A temperature of about 750 °C is attainable in a small campfire ventilated by a moderate breeze (Frierman, 1971: 213), but attaining 900 °C requires lots of dry wood and at least a moderate breeze.

Diluting carbon dioxide, with the aid of wind is obviously more effective on the outer surface of a (limestone) rock fragment than inside of it. A temperature of about 750 °C could be sufficient to burn a thin