Between Two Models: Exploring Exchange and Direct Procurement Strategies for Natufian Food Processing Tools of el-Wad Terrace, Israel

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Abstract

We present the results of a detailed geochemical provenance study of 54 Natufian (ca. 15,000–11,700 cal BP) basalt pestles from the site of el-Wad Terrace (EWT), Israel. It is the first time precise locations whence basalt raw materials derive are provided. The results indicate that the Natufian hunter-gatherers used multiple sources of basaltic rocks, distributed over a large area surrounding the Sea of Galilee. For EWT, this area is located at a considerable distance of ca. 60–120 km away, in a region where contemporaneous Natufian basecamps are few. We consider two possible models that suggest vehicles for the transportation of these artifacts to EWT, namely the exchange obtaining model (EOM) and the direct procurement model (DPM). We argue that these mechanisms are not mutually exclusive and may have operated together. We also suggest that at a time of increasing Natufian territoriality, a large area around the Sea of Galilee remained unclaimed. The paper concludes with a brief discussion of the implications for the two models. In particular, we note that the DPM implies that technological know-how for pestle production was maintained within the EWT community.

Introduction

The nascence of sedentism profoundly impacted human societies' mobility patterns, requiring a host of adjustments. Among its immediate implications are economic intensification and preoccupation with territoriality, both within and across communities. In the southern Levant, these developments are epitomized by the Natufian Culture (ca. 15,000–11,700 cal BP[1-8]), notable for its preference to intensively exploit the site's catchment area. The site of el-Wad Terrace (EWT) in Mount Carmel (Israel) illustrates this well. Its inhabitants drew on a broad spectrum of resources, including plants, animals [9-13], ochre[14] and flint[15, 16], all of which derive from within the site's immediate vicinity. For hunted ungulates, this pattern is manifested in the comparatively complete body-part profiles, indicating that the hunt took place close by and that one did not have to haul the catch over great distances[17]. For other resources (e.g., flint, ochre, mollusks), it is estimated that they were retrieved from locations no more than 12 km away[16, 18].

Thus, the advent of a sedentary way of life dovetailed with the emergence of an early sense of possession. As groups became more closely attached to a certain place and invested in their immediate surroundings, they probably began cultivating prefatory claims of ownership[19, 20]. In this vein, the Natufian culture is also notable for introducing a new sort of geopolitics: the emergence of socio-territorial entities, a landscape of more-or-less distinct spatial units attached to organic groups, probably separated from one another by unclaimed "buffer zones." Importantly, as one group claims an area and its resources, it also denies it to others, setting in motion a dialectic of alienation and suspicion. Under such circumstances, every unwarranted entry readily becomes a threat and an act of aggression[21]. And yet, while the Natufian culture marks a trend of increasing territoriality and decreasing mobility, the widespread distribution of basalt tools suggests a mechanism that encouraged outreach and mobility. Because these artifacts often derive from distant locations, they inevitably implicate procedures that

span considerable distances. They entailed trade/exchange across groups, as suggested by Weinstein-Evron[22, 23], purposeful and predetermined forays to distant sources, or a combination of the two.

This paper presents the results of a meticulous geochemical provenance study of 54 basalt pestles from the site of EWT (Figs. 1-2). Acknowledging the two mechanisms defined above, we seek to determine the pestles' geological origins and, by extension, gain access to how they were procured and delivered to the site. Previous studies in this vein are few and, at most, of preliminary significance. Of particular relevance for our purposes is a study by Weinstein-Evron and colleagues[22, 24] of 22 basalt tools from el-Wad and other Natufian sites in the Galilee. They sought to identify the raw materials' origins by applying K–Ar dating to the basalt items and potential geological sources. They observed that the raw materials used to manufacture these items derive from basalts dated to the Pliocene and Pleistocene. Basaltic rocks of these ages are altogether absent from Mount Carmel, but accessible in the Galilee, Golan Heights, and various other areas east of the Jordan Valley. However, determinations that were more precise were not forthcoming (Fig. 1[22]).

Picking up from where Weinstein-Evron and colleagues left off, our study draws on the geochemical and mineralogical features of basaltic rocks to (1) trace pestles back to the provenance from which their raw materials were procured, and (2) articulate the assemblage's compositional variability. We argue that the EWT pestle assemblage embodies multiple geological sources, all of which are located at a substantial distance of 60–120 km from the site, scattered around the Sea of Galilee. We discuss the mechanism of trade/exchange as a possible explanation and continue to ponder the alternative of direct procurement, considering the implication of these two models.

The Natufian site of EWT and its food processing stone tools

EWT is the northeastern part of the site of el-Wad (Fig. 2; Supplementary Fig. S1), one of the largest Natufian hamlets in the southern Levant. It is located near the Mediterranean coastal plain on the western face of Mount Carmel, Israel. Mount Carmel consists of sedimentary rocks—mainly limestone and dolomite—and intercalated Cretaceous volcanic rocks (Fig. 1). An area of ca. 70 m^2 was excavated at EWT, exposing a >1.5 m thick sequence of Natufian deposits[16, 33, 34]. A composite stratigraphy of the site[35, 36] suggests a sequence spanning the temporal range of ca. 15,000–12,000 cal. BP [9, 37, 38].

Consisting of nearly 600 items, the ground stone tools assemblage of EWT[39] is one of the largest of its kind, most of which were found in the Early Natufian layers (nearly 60% of the assemblage). Of the various food processing tool types (Supplementary Fig. S1), basalt pestles, mainly represented by small fragments (Supplementary Fig. S1), are the most abundant (22.8% of the assemblage). Most of them derive from Early Natufian contexts (ca. 70% of the total pestles), only a handful originated from Late Natufian phases, and the remainder was retrieved from indeterminate contexts. Of these, a total of 47 Early Natufian and seven Late Natufian pestle fragments were chosen for geochemical analysis.

Results

All pestles analyzed are made of compact, fine-grained, non-porous basalt, with a geochemical composition broadly defined as *hawaiite* (Supplementary Fig. S2[40]). The petrological classification recorded four types of volcanic rocks: alkali basalt (n=46), basanite (n=2), trachybasalt (n=5), and transitional alkali basalt–trachyandesite (n=1). Distribution of major and trace elements (Supplementary Fig. S3, Supplementary Table S1) suggests a distinction of several possible sources; the distribution of rare earth elements (REE, Supplementary Fig. S4) suggests a distinction between at least two groups. However, the major elements indicate greater differences in the artifacts' geochemical composition than the trace elements do (Supplementary Fig. S4). Plotting the distributions of chemical elements derived from archaeological specimens against those of geological samples[41] (Fig. 3, Supplementary Fig. S3, Supplementary Table S2), demonstrates that the EWT pestles originate in the lava flows of the Cover Basalt. Cluster analyses of these data distinguished at least 18 sources, of which 13 have been traced to specific locations around the Sea of Galilee (Fig. 3, Supplementary Table S1). These sources were defined as "virtual extraction sites" (specific, presently unidentified, extraction sites[41, 42]) where the raw material for basalt pestles was procured. Most analyzed pestles (44.4%) originate from the lava flows west (fourteen pestles) and north of the Sea of Galilee (ten pestles, the Korazim basalt block); fewer were traced to locations east (five pestles, western slopes of the Golan Heights) and south of the Sea of Galilee (three pestles, western slopes of the Jordan Valley). The provenance of the remaining twelve is yet undetermined.

Discussion

The present study is the first successful attempt to trace Natufian basalt tools to precise geological and geographical sources. Previous attempts to do so mobilized radiometric dating techniques and resulted in significant but, for the greater part, equivocal and indefinite results. They succeeded in narrowing the range of probable sources to general regional and geological whereabouts—Pliocene and Pleistocene basalts of the Galilee, Golan Heights, and various areas east of the Jordan Valley—but they were unable to go further[22, 24]. Our study, on the other hand, conducted a comparative, high-resolution analysis of geochemical data for the tools and their potential geological sources. The results suggest that the Natufians of EWT were using pestles made of basalts that originated from multiple geological sources, all of which are located at a substantial distance of 60–120 km from the site. Specific and accurate results were provided for the majority of analyzed items (59.3% of the tested basalt pestles), all of which were shown to derive from Pliocene Cover Basalt around the Sea of Galilee, mainly to the north and west, and less so to the east and south (the geographic distribution of the sources exploited span an area of at least 1200 km^2).

Weinstein-Evron *et al.*[22, 23] suggested that exchange across Natufian groups was the principal vehicle that circulated these items. Drawing on ethnographic literature, they envisaged formal networks of trade/exchange that partake in ongoing maintenance of inter-group social relations[23]. We call this hypothesis the Exchange Obtaining Model (EOM). This model gained considerable traction over the past two decades, widely echoed in syntheses of the Levantine Epipaleolithic, especially those concerned with

inter-group ties [43-45]. It is not, however, the only hypothesis on the table. Whallon[46], for instance, suggested that hunter-gatherers may move and interact across mesoscale social networks, seeking access to diverse resources and exotic items. Accordingly, we can suggest that inhabitants of EWT may have made their way as far as the Golan Heights to acquire the materials for their pestles directly from the source. We call this the Direct Procurement Model (DPM). In either case, as noted by Kaufman[47] and Weinstein *et al*.[23], it was the social networks that provided the foundations for the procurement of essential raw materials. It was through systems of alliances and the establishment of reciprocal social obligations between Natufian groups, with mutual reciprocity, that served to guarantee access to raw materials or enabled trade/exchange.

Deciding between the two models (EOM/DPM) for the basalt pestles of EWT is difficult. In fact, it is equally probable that both mechanisms were at play, constituting different, perhaps complementary, channels for the circulation of substances and goods. The small number of Early Natufian base camps in the Mediterranean climatic zone and the comparatively imprecise dates available for them pose considerable obstacles before any attempt to determine relationships among groups and territories[48]. Therefore, it is questionable whether links can be confidently established between certain Natufian sites and favorable basalt outcrops. Moreover, even if located at a reasonable distance, the lack of indications for basalt tool production at Natufian basecamps[39] renders any association of this sort unsubstantiated and circumstantial, at best. This is particularly notable for sites like Early Natufian Wadi Hammeh 27[49] and the smaller Hof Shahaf[50], and the Late Natufian Nahal Ein Gev II[51] that are located in the vicinity of “virtual extraction sites” and yet bear no signs of intensive basalt production.

While neither these observations nor our geochemical analyses disprove the EOM discussed above, it seems that they do lend some force to the DPM. First, they suggest a diffused and decentralized network that lacks specialized nodes for procurement, production, transport, or consumption. This diffused network is implied by the wide distribution of extraction sites (Fig. 3), the absence of major production sites, and the conspicuousness of the basalt ground stone tools across all Natufian occupations. Thus, contrary to the EOM expectations, it is as if the various nodes (i.e., sites, communities) fulfilled all or most functions. Second, while directing our attention to the area surrounding the Sea of Galilee, our geochemical analysis also points out that the Natufian inhabitants of EWT chose not to use high-quality basaltic rocks available only ca. 15 km away[42, 52, 53]. Insofar as this is unlikely to have been due to economic considerations or incognizance, socio-territorial constraints are probable. Under these circumstances, nearby sources may have been claimed by another group and consequently withheld from EWT foragers, forcing them to seek other locations to procure basalt for pestles’ production. In a similar vein, it is possible that large areas around the Sea of Galilee were unclaimed by any particular Natufian group and thus were accessible for basalt procurement by inhabitants of EWT.

Interestingly, while the two mechanisms are not mutually exclusive and may have operated simultaneously, perhaps in combination, they have different implications and embody different priorities. Specifically, the EOM entails less mobility but more inter-group interactions, whereas the DPM entails

greater mobility in space and less inter-group interactions. Thus, if the EWT inhabitants obtained their basalt pestles via direct procurement, they were also engaged in maintenance and preservation of their technological know-how. On the other hand, if their pestles were obtained via an exchange mechanism, the know-how of pestle production was probably held by others, constituting a more restricted and controlled body of knowledge. Admittedly, our analysis does not resolve these issues. But it does offer support for a hypothesis that is yet to receive the attention it deserves, and it does demonstrate how basalt tool provenance studies have the potential to tap into constitutive ideological and behavioral features of the Natufian culture.

Methods

Sampling. The entire basalt food-processing tool assemblage of EWT was studied in the Laboratory for Ground Stone Tools Research (LGSTR) at the Zinman Institute of Archaeology, University of Haifa, Israel. All metric and morphological traits were recorded. Fifty-four pestles were selected for analysis, 47 from the Early Natufian assemblage (over 50% of the Early Natufian pestles), and seven from the Late Natufian assemblage (100% of the Late Natufian pestles). Samples for geochemical analysis were produced by removing a small piece with an iron chisel.

Geochemical analyses. The generation of geochemical data for the artifacts and the analysis of these data against the comparative geological database were conducted at the Institute for Geosciences at the Johannes Gutenberg University, Mainz, Germany. Analyses concentrated on the specimens' geochemical composition. All samples were first tested for loss on ignition (LOI). Subsequently, glass beads were produced on an iridium strip-heater[54] and analyzed for major elements utilizing a wavelength dispersive 2002 Philips MagXPro X-ray spectrometer. On two occasions that the samples were too small for major elements analysis by XRF, the analysis was conducted with a Jeol JXA 8900 RL electron-microprobe (EMP), with an acceleration voltage of 15 kV, a beam current of 12 nA, and a beam diameter of 5 µm. Five spots were measured per sample. In order to guarantee the compatibility of the major element results across devices, the EMP results were converted into the XRF-results using the calibration presented by Gluhak and Rosenberg[52].

Trace elements were measured in an Agilent 7500 CE quadrupol ICP-MS. The samples were ablated from the glass beads by an ESI New Wave Research NWR 193 (ArF-excimer) laser ablation-system. Three spots were measured on every glass bead, with a diameter of 100 µm, a pulse rate of 10 Hz, and laser densities of ca. 6 J/cm². ^{43}Ca measures served as internal standards, taken from the XRF-measurements and the EMPA-results. As reference material NIST SRM 612, NIST SRM 610, and USGR BCR-2G were analyzed for quality control, the values were taken from the GeoReM online database[55]. Data reduction was carried out on GLITTER 4.4.2 software (Macquarie University, Sydney, Australia). The analyses' results for the artifacts and their computability with specific geological samples are given in Supplementary Table S1.

In order to articulate the geochemical variability of the EWT assemblage and to correlate it with geological field samples from Gluhak and Rosenberg[41] cluster analyses were conducted. For this

purpose, all geochemical data were log-transformed and z-standardized. They were then subjected to two cluster algorithms: Average linkage (with City Block and Euclidean distance) and Ward (with Euclidean distance). The clusters produced by each algorithm were then tested against those of the other for consistency. Only clusters consistent across algorithms were considered valid. A cluster's provenance was determined based on geological samples associated with it (Supplementary Table S2). If different geological samples were associated with the same cluster of artifacts, it would be regarded invalid unless the samples were collected from spatially proximate locations. Under circumstances of spatial proximity, the cluster is assigned general provenance. All other el-Wad artifact samples, which are not affiliated unequivocally to specific geological samples are individual samples, whose provenance could not be determined based on the present data (samples EWT 22, 25, 27, 52, 59, 67, 90, 111, 114, 116, 124, 188). The results of these cluster analyses are presented in Supplementary Table S2.

Excavations. Renewed excavations at EWT were conducted by the University of Haifa with the acquiescence of the Israel Antiquities Authority; excavation licenses G-15/2001, G-8/2002, G-13/2003, G-28/2004, G-13/2005, G-20/2006, G-3/2007, G-2/2008, G-4/2009, and G-5/2010. All stones suspected to be worked or appeared to have derived from a non-local geological milieu were kept and examined. The excavated sediments were sieved in their entirety, and all other such items were recovered (i.e., small basalt flakes). All pestles discussed in this paper derive from these excavations and constitute part of the ongoing study of the site's stone tool assemblages[34, 39].

Declarations

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Figures

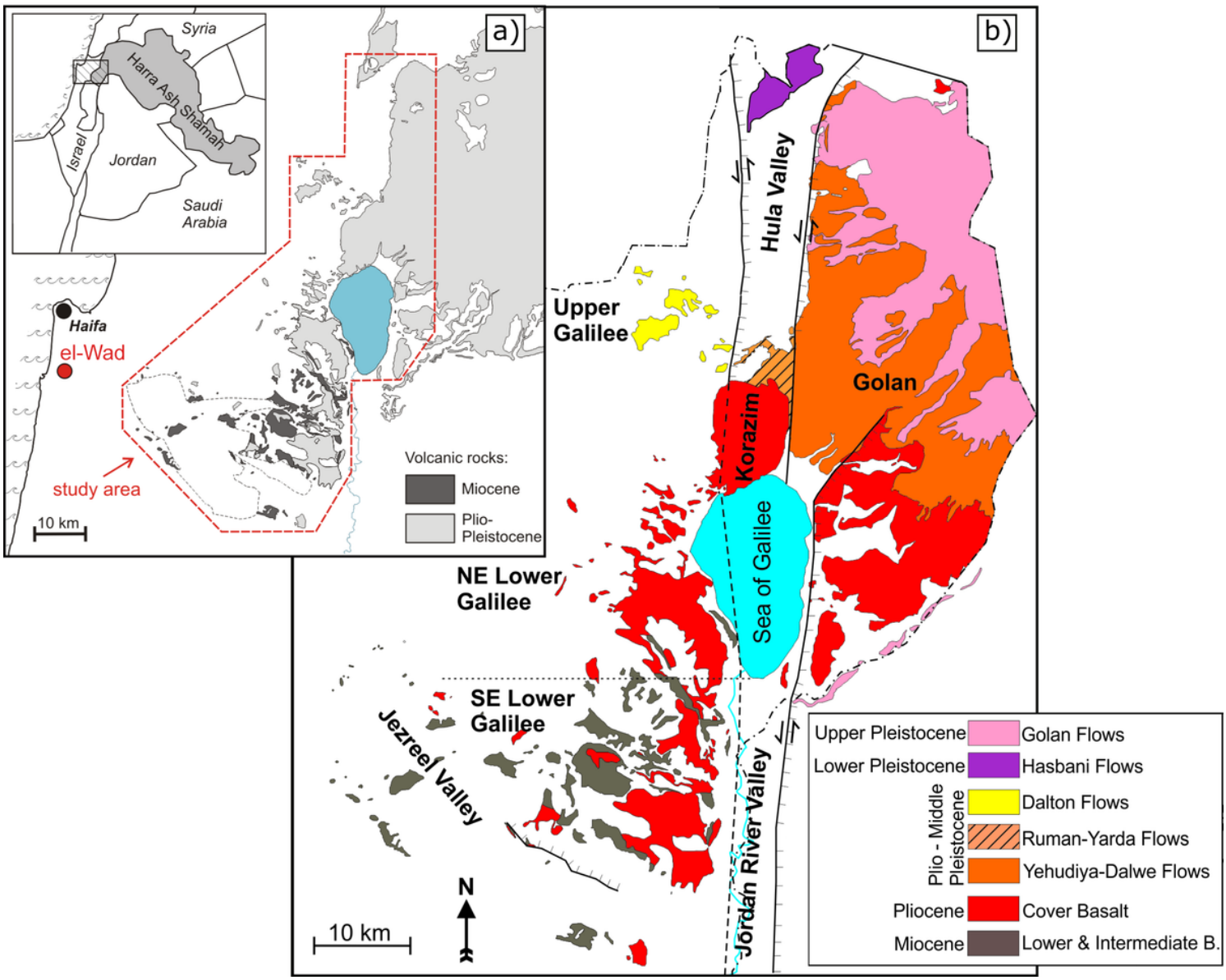
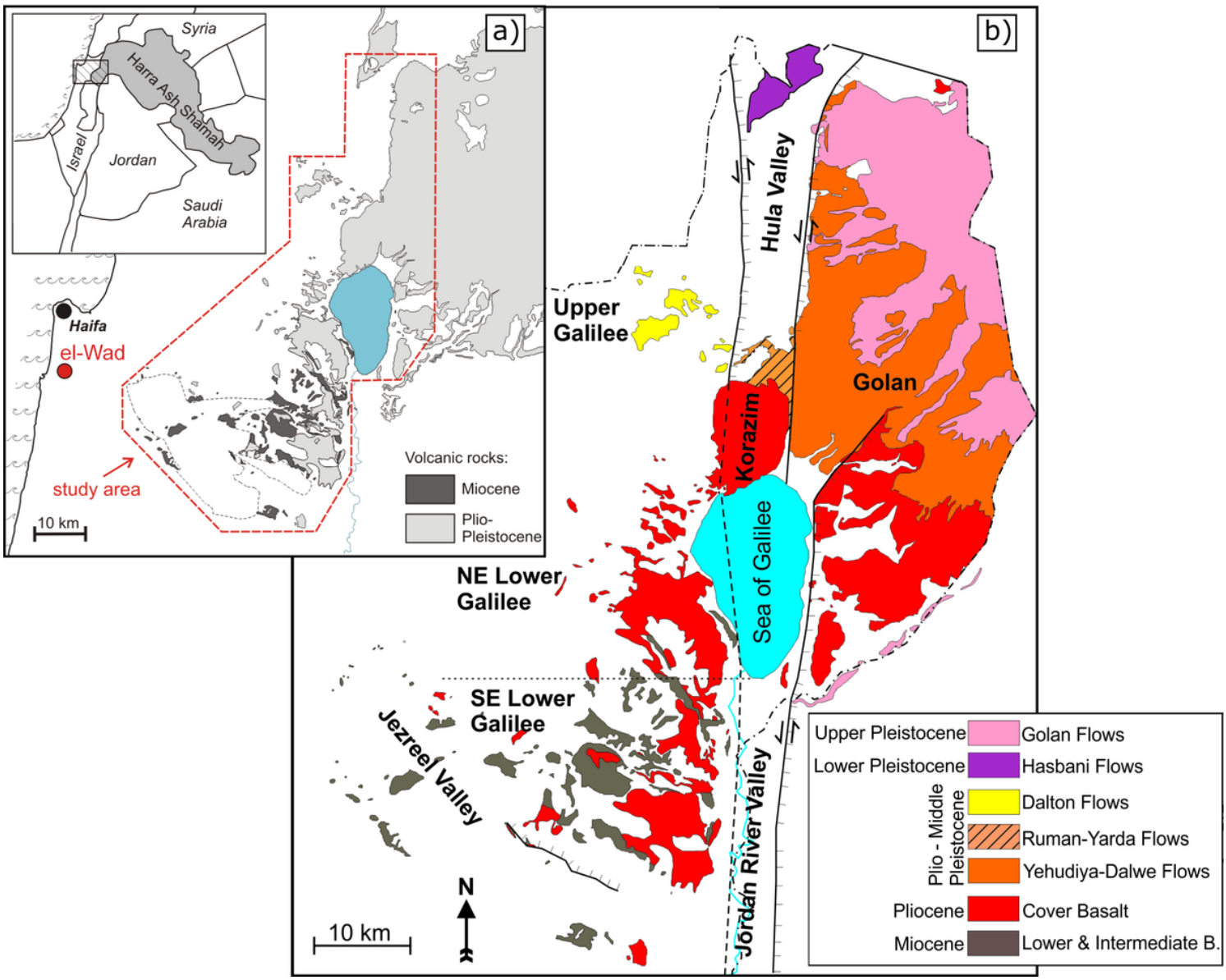


Figure 1

a. Location map of the study area, b. simplified geological map of the Neogene and Pleistocene volcanic rocks in northern Israel, based on Bogoch and Sneh25, Hatzor26, Levitte and Sneh27, Sass28, Sneh29, Sneh and Weinberger30, 31 and Sneh et al.32. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



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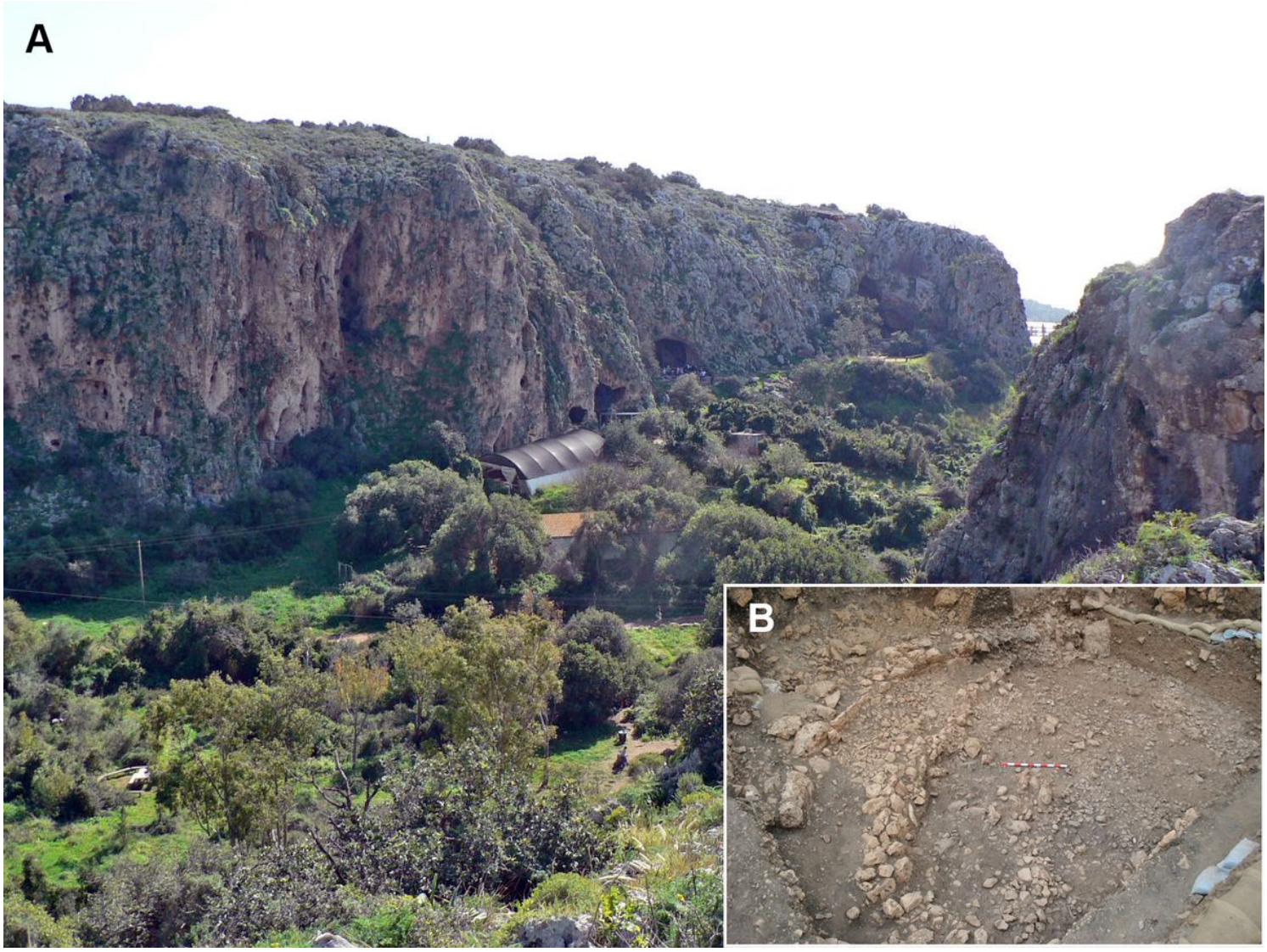
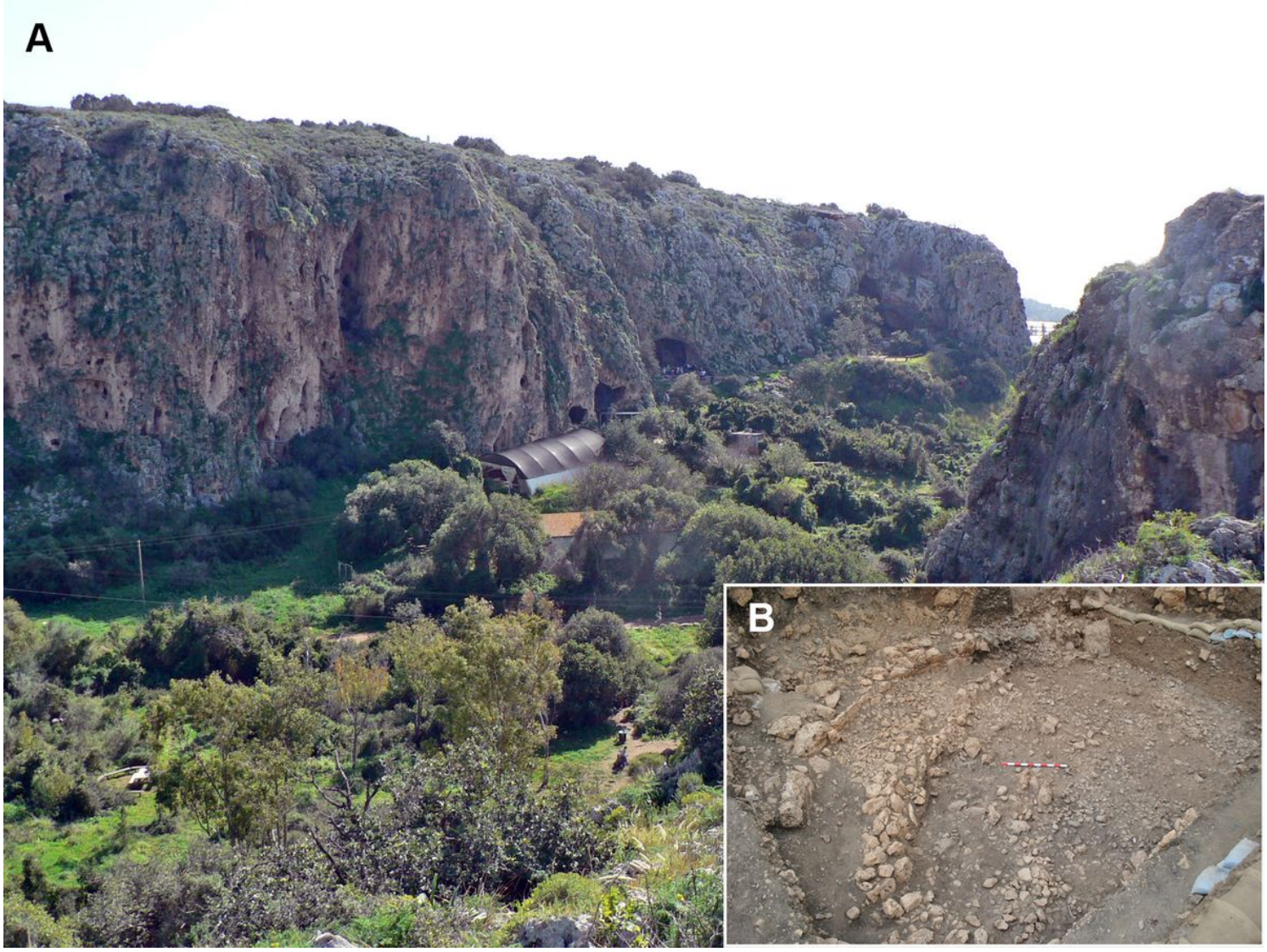


Figure 2

a. A view of Nahal Me□arot Caves. EWT is located under the greenhouse near the cliff; b. EWT during the excavations. Note the long curvilinear “terrace wall” and enclosed/incorporated structures and living surfaces (for a plan, see S fig. 1) of this Natufian sedentary hamlet.



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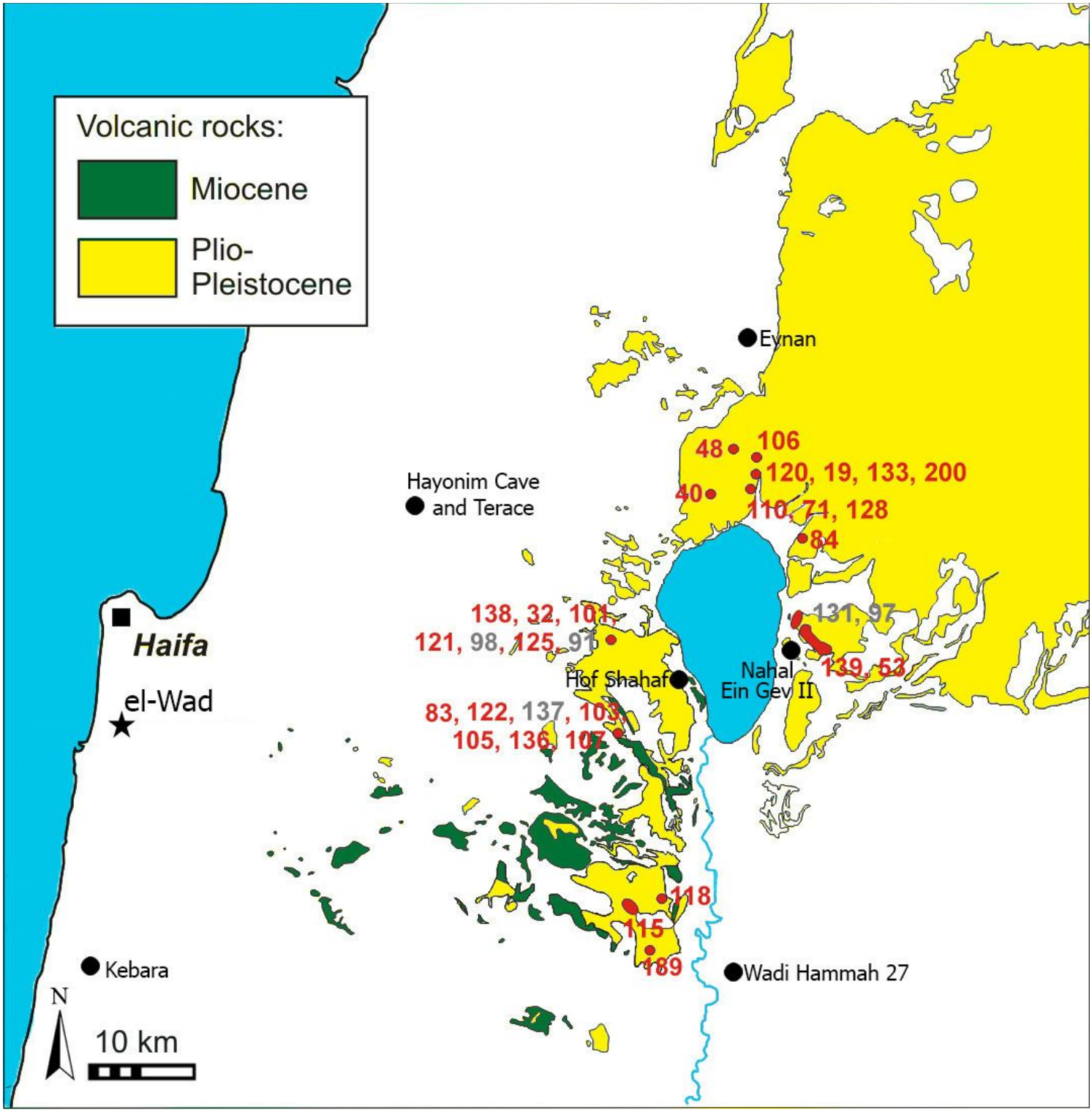

Figure 3

Provenance of the EWT pestles (see Table SI-1). Red dots indicate exact locations. The fields indicating the provenance of EWT 131 and 97, of EWT 139 and 53, and EWT 115 (marked in grey) define the area where the corresponding geological samples were collected. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its

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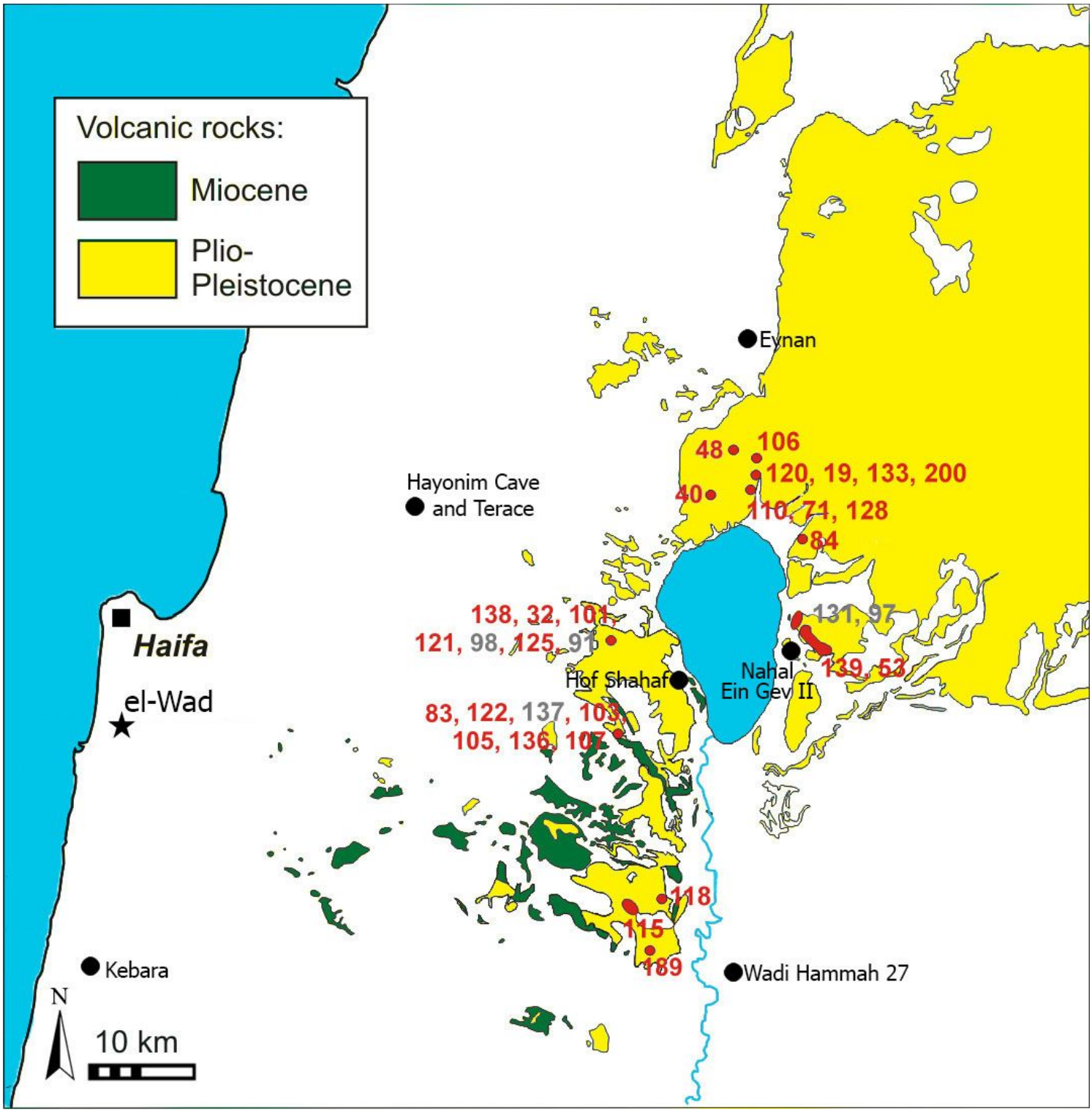

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