NEO-LITHICS 1/09

The Newsletter of Southwest Asian Neolithic Research

Special Issue on

Rubble Slides and Rapid Climate Change

Contents

Editorial

Rubble layers, Yarmoukian landslide, the 8.2 ka cal. B.P. RCC – these and other catchwords have been used since 1984 for an intriguing phenomenon known from many 7th millennium BC sites in the Levant and Turkey: substantial accumulations of stone rubble that covers architectural remains and sometimes even suggest that they might be the reason for deserting a location. Discussed since the mid-1980s, rubble layers became the subject of various explanations, including the understanding that aquatic slope erosion must have played an important role in their deposition. But it has taken until the middle of the current decade that it became understood that rapid climatic change was responsible for such rubble deposits. It took another five years to understand that the rubble events may have quite polygenetic and multicausal origins (albeit climate and water still appears to be a major factor of their deposition), and that there were more such depositional periods than hitherto anticipated. Like no one else, Bernie Weninger has promoted the topic over the past several years with regard to radiocarbon chronology and climate, starting discussions with one of us (G.O.R.) for ʻAin Ghazal. Thus we are happy to have enlisted his help for this (delayed) special issue of Neo-Lithics as guest editor. It aims to expand the deeply needed discussion of rubble deposits representing testimonies for discontinuities in the Levant's 7th millennium BC settlement history and subsistence modes.

Rubble layer awareness is required in all respects.

Hans Georg K. Gebel and Gary O. Rollefson

Introduction

Bernhard Weninger University of Cologne, Institute of Prehistoric Archaeology b.weninger@uni-koeln.de

The Eastern Mediterranean has long been one of the world's major areas for archaeological research on early sedentary societies. Due to exciting new results from palaeoclimatology (see below), we are now expecting this region to become a key scene for some unusually close and intensive interdisciplinary research between prehistorians and palaeoclimatologists, as well as involving scientists from the neighbouring fields of geomorphology, geoarchaeology, archaeoseismology and bioarchaeology. Be this as it may, the purpose of this special issue of *Neo-Lithics* is to further encourage all such interdisciplinary research. The particular topic, to which the following issue of *Neo-Lithics* is dedicated, has been named: Rubble Slides and Rapid Climate Change.

What are Rubble Slides? Field Observations

In Jordan, as well as in other regions in the eastern Mediterranean, a large number of archaeological sites are covered to some extreme depth (often several metres) by massive rubble and gravel slides. The Jordanian list of Neolithic sites with rubble slides includes: 'Ain Ghazal, Abu Suwwan, es-Sifiya, Ba'ja, Basta, Wadi Shu'eib and 'Ain Jammam. From Turkey we also know of pebble slides and soil flows (Kuruçay Höyük, Burdur province), as well as riverine flooding of archaeological sites (*e.g.* Çayönü). The majority of these slides appear to have had natural causes, such as high energy flash floods or earthquakes.

Whereas in some cases preliminary observations indicate that the slides are associated with collapsed and abandoned Neolithic buildings, in others the rubble flows appear stratified and probably represent independent events distinguishable on the basis of variations in stone size and orientation. Further, while secondary levelling of room fill, sometimes with human or animal burials, is also observed, other rubble deposits might represent intentional backfilling, aimed at garbage management or resulting from stone-robbing. Moreover, there exist some sensational cases of material movements on Neolithic sites where recent research has identified the deliberate burial of entire buildings, presumably marking the end of an architectural or socio-religious life-cycle. Finally, in addition to these intra-site observations, where the underlying causes can be studied by archaeological means, we observe major debris and soil movements in the wider landscape linked to such events as river flooding, slope slides, or heavy rainfalls.

All in all, there is an impressive spectrum of environmental, climatic, and cultural conditions leading to rubble slides, as observed on a large number of archaeological sites in Jordan.

Rubble Slides: Environmental and Climatic Background

Quite remarkably – and the following statements are already part of our call for independent confirmation – it appears that a highly significant number of the Neolithic rubble slides (at least those presently known from Jordan) occurred during the time interval 8.6-8.0 ka calBP (6.6-6.0 ka calBC). In archaeological terms, these Jordanian rubble slides are dated to the Yarmoukian period, or, expressed more generally, to the transition from to the early PN. Accepting for the moment that at least some of these rubble slides occurred simultaneously, they may even have identical causes, such as one large earthquake. On the other hand, there are plausible alternative explanations, including widespread environmental degradation due to over-grazing by large herds of goats/sheep, and deforestation due to such factors as housing requirements, fuel consumption for domestic purposes, as well as lime-plaster production.

However, perhaps the most remarkable possibility is that there might exist a direct causal connection between at least some of the rubble slides and what we simplify in calling Rapid Climate Change (RCC). In brief, the time-interval at stake for the end of the PPNB/C is entirely simultaneous with one of the four major periods [(i) 10.2-10.0 ka, (ii) 8.6-8.0 ka, (iii) 6.2-6.0 ka and (iv) 4.3-4.0 ka calBP] that were recently identified by a major working group (16 international authors) as one of the four key global time-windows for Rapid Climate Change (RCC) during the Holocene (Mayewski *et al.* 2004).

In short, during each of these four time-windows for RCC (and in this respect quite similar to the more recent "Little Ice Age") there appears to have been an anomalously strong inflow of intensively cold polar and continental air masses into the eastern Mediterranean basin, ultimately deriving from the coldest air mass to be found anywhere on the globe, *i.e.*, from Siberia (Meeker and Mayewski, 2002). Since the underlying atmospheric patterns are inferred from Greenland ice-core records (particularly GISP2 K+- and Na+-ions), the Holocene RCC event sequences are established with highest possible (quasi-annual) temporal precision.

However, at the present state-of-research it is equally possible that the observed rubble slides were caused by other agents *e.g.* human impact on the landscape, earthquakes, or flashfloods, or a combination of such agents. To begin, in this *Neo-Lithics* issue we describe and discuss some of the many of the sites with rubble layers. In perspective, we now have hope that many more sites with rubble layers may be recorded, in maybe even new regions.

This Special Issue of *Neo-Lithics* 1/09

The present special issue of *Neo-Lithics* 1/09, clearly, cannot provide a complete description, let alone any universal (or monocausal) explanation for the large number of observed "rubble slides". What we can do is to provide a general review of the climatological issues at stake, along with some papers that focus on some of the (surely multicausal) associated archaeological, geomorphological and environmental issues. The main corpus of the newsletter covers on a site-by-site basis some of the presently known rubble layers in the southern Levant. As such, however, the reader should remain aware of the fact that other regions remain largely unexplored: we know next to nothing about the potential occurrence of such phenomena in the wider eastern Mediterranean. Notwithstanding such prevailing limitations in available data, for this wider perspective the interested reader may consider the recently published study by Weninger *et al.* 2009 on the effects of Rapid Climate Change in the eastern Mediterranean (*sensu* Mayewski *et al.* 2004) to be a useful starting point for further research.

Altogether, under "Rubble Slides" we subsumed the following archaeological and geomorphological topics:

Sites with Natural Rubble/ Soil Movements

- Sites buried partially, or entirely, by large or small rubble/ gravel/ pebble slides
- Sites covered partially, or entirely, by flood sediments from rivers

Sites with Human-Induced Rubble/ Soil Movements

- Individual rooms (or entire buildings) with intentional rubble or soil backfilling
- In-filled rooms (or entire buildings) with intentional burial.

Sites with Rubble/ Soil Movements but Unclear Agents

- Any kind of on-site stone or soil coverage, clearly catastrophic, but unclear agents

Acknowledgements: I would like to thank Gary O. Rollefson for a long cooperation in rubble slide research, and for helping to prepare this special issue of *Neo-Lithics*. I thank Hans Georg K. Gebel and Gary Rollefson for inviting me as *Neo-Lithics* guest editor on this topic.

References

Mayewski P.A., Rohling E.E., Stager J.C., Karlen W., Maascha K.A., Meeker L.D., Meyerson E.A., Gasse F., van Kreveld S., Holmgrend K., Lee-Thorph J., Rosqvist G., Racki F., Staubwasser M., Schneider R.R., and Steig E.J.
2004 Holocene Climate Variability. *Quaternary Research* 62: 243-255.

Meeker L.D. and Mayewski P.A.
2002 A 1400 Year Long Record of Atmospheric Circulation Over the North Atlantic and Asia. *The Holocene* 12(3): 257-266.

Weninger B., Alram-Stern E., Bauer E., Clare L., Danzeglocke U., Jöris O., Kubatzki C., Rollefson G., Todorova H.
2005 Neolithisierung von Südosteuropa als Folge des abrupten Klimawandels um 8200 cal BP. In D. Gronenborn (ed.), *Klimaveränderung und Kulturwandel in neolithischen Gesellschaften Mitteleuropas, 6700-22200 v. Chr. RGZM Tagungen* 1: 75-117.

Weninger B., Alram-Stern E., Bauer E., Clare L., Danzeglocke U., Jöris O., Kubatzki C., Rollefson G., Todorova H., van Andel T.
2007 Abrupt Climate Forcing Observed at Early Neolithic sites in South-East Europe and the Near East. In H. Todorova, M. Stefanovich, G. Ivaniv (eds.), *In the Steps of James Harvey Gaul, 2. The Struma/Strymon River Valley in Prehistory*. Proceedings of the International Symposium ‚Strymon Praehistoricus', Kjustendil-Blagoevgrad (Bulgaria) and Seres-Amphipolis (Greece), 27.09-01.10.2004, Sofia: 7-28.

Weninger B., Clare L., Rohling E.J., Bar-Yosef O., Böhner U., Budjar M., Bundschuh M., Feurdean A., Gebel H.G.K., Jöris O., Linstädter J., Mayewski P., Mühlenbruch T., Reingruber A., Rollefson G., Schyle D., Thissen L., Todorova H., and Zielhofer C.
2009 The Impact of Rapid Climate Change on Prehistoric Societies During the Holocene in the Eastern Mediterranean. *Documenta Praehistorica* 26: 1-53.

Yarmoukian Rubble Slides. Evidence for Early Holocene Rapid Climate Change in Southern Jordan

Bernhard Weninger University of Cologne, Institute of Prehistoric Archaeology b.weninger@uni-koeln.de

Introduction

In Jordan, a large number of archaeological sites are covered by massive rubble slides and gravel flows, often to some extreme depth (several metres). Thanks to the recent review by Rollefson, which is circulated here together with the present paper as a contribution to the 'Rubble Slide' issue (2009) of *Neo-Lithics*, we now have a first description of the Jordanian rubble slides. The list of Neolithic sites that are known to have rubble slides is indeed impressive, and includes (in alphabetical order): 'Ain Ghazal, 'Ain Jammam, 'Ain Rahub, Abu Suwwan, Ba'ja, Basta, es-Sifiya, Jebel Abu Thawwab, Umm Meshrat I and II, and Wadi Shu'eib.

The majority of these slides are dated by incorporated pottery to the Yarmoukian period or, expressed in more general terms, the slides are dated to the transition from late-PPNB/C to early PN. Accepting for the moment that many of these slides occurred 'simultaneously', in principle they could all have been caused by one large earthquake. This is not even unlikely, since all listed sites are situated in close vicinity (*e.g.* 'Ain Ghazal: 40 km) to the active Dead Sea Fault, which is the seismic boundary between the African and Arabian plates. Geological observations show slip rates between these plates in the Jordan Valley in the range of 1 to 20 mm per year (Klinger *et al.* 2000). Modern instrumental observations supply mean recurrence intervals for major destructive earthquakes in this region between 400 years (Richter Scale Magnitude MR > 6) and 3,000 years (MR > 7) (Begin 2005). Such earthquake magnitudes and recurrence rates appear quite sufficient to trigger the observed slope failures, perhaps not everywhere, but surely on those sites for which Rollefson (this issue) has documented slope declinations beyond 12°.

However, beyond earthquakes, there exist other plausible explanations for the rubble slides, none of which we would like to exclude *a priori*. Acceptable explanations (and combinations of such) include regional environmental degradation due to over-grazing by large herds of goats/sheep, and deforestation due to Neolithic housing requirements, fuel consumption for domestic purposes, and less importantly, lime-plaster manufacture. Finally, we make no secret of our present favourite explanation, even if proof for this is yet lacking, that the majority of slides were caused by slope failure due to torrential rainfall and corresponding large-scale water-lifting of the slope material. As Rollefson (2009) puts it, in this case the cause of the rubble slides would be "slippery slopes." Whether this proposal is correct or not remains to be established. However, what makes this specific hypothesis (we think) more interesting than many others is the possibility that the Yarmoukian rubble slides represent the local manifestation of a broader climate signal. Ultimately, it may be difficult to differentiate between these alternative explanations (climate or earthquake), as will be argued below. However, we focus on the climatic explanation, first.

Table 1 shows all available 14C-ages for the Yarmoukian period (Böhner and Schyle 2009). Excepting a few outliers (AA- 25424, AA-5204; GrN-15192), the remaining samples supply us with a small but consistent set of tree ring calibrated 14C ages for the Yarmoukian period, and by inference for the Yarmoukian Rubble Slides. Surely, not all sites with Yarmoukian settlement have a rubble slide (*e.g.* Sha'ar Hagolan). Nevertheless, the other way around, it is encouraging to observe that all Yarmoukian sites have 14C readings within the same time interval 6300-5900 cal. B.C. (8300-7800 cal. B.P). To facilitate comparison with climate records, in the following all calibrated 14C ages are given on both time scales (cal. B.C., cal. B.P.).

To achieve a deeper understanding of this dating, in the following we add step by step a series of climate records. These records lead us first to the Dead Sea, where we gain insight on rainfall history during the Early Holocene in the Jordan Valley. We then hop over to the Aegean, to look at an interesting marine record called LC21, with information pertaining to contemporaneous surface water temperatures. At LC21 we learn of the

Lab code	14C Age BP	Material	Site	cal. B.C.	cal. B.P.
Ly-4927	7330 ± 70	charcoal	Munhata	6200 ± 100	8150 ± 100
M-1792	7370 ± 400	charcoal	Munhata	6310 ± 420	8260 ± 420
RT-1544	7050 ± 78	charcoal	Qanah	5920 ± 80	7870 ± 80
RT-861D	6980 ± 180	charcoal	Qanah	5870 ± 160	7820 ± 160
OxA-7884	6980 ± 100	charcoal	Sha'ar Hagolan	5870 ± 100	7820 ± 100
OxA-7885	7270 ± 80	charcoal	Sha'ar Hagolan	6140 ± 80	8090 ± 80
OxA-7917	7410 ± 50	charcoal	Sha'ar Hagolan	6300 ± 60	8250 ± 60
OxA-7918	7465 ± 50	charcoal	Sha'ar Hagolan	6340 ± 60	8290 ± 60
OxA-7919	7495 ± 50	charcoal	Sha'ar Hagolan	6350 ± 70	8300 ± 70
OxA-7920	7245 ± 50	charcoal	Sha'ar Hagolan	6130 ± 70	8080 ± 70
OxA-9417	7285 ± 45	seed	Sha'ar Hagolan	6150 ± 53	8100 ± 53
AA-25424	8030 ± 65	charcoal	'Ain Ghazal	6940 ± 110	8890 ± 110
AA-5204	2880 ± 95	charcoal	'Ain Ghazal	1090 ± 130	3040 ± 130
GrN-14539	7480 ± 90	charcoal	'Ain Rahub	6340 ± 80	8290 ± 80
GrN-15192	5540 ± 110	charcoal	Abu Thawwab	4390 ± 110	6340 ± 110

Table 1 Radiocarbon Ages for the Yarmoukian Period. Tree-Ring Calibrated 14C Ages [cal. B.C.] [cal. B.P., 0=AD 1950]

existence of some strong cooling winds that blow in from Siberia, not all the time, but significantly during special periods that climate scientists call ‚RCC events' (Rapid Climate Change events). We will not argue with anybody about the difference between *events* and *periods*. Interdisciplinary discussions are difficult enough, on other scales. Each of these RCC events/ periods is associated with climatic conditions similar to recent 'Little Ice Age'. We learn this, in the next step, by turning to Greenland ice cores from Siberia. Each of these stations supplies information that adds to our understanding, hopefully, of the underlying penultimate 'global' causes for the observed Yarmoukian rubble slides.

Dead Sea Lake Levels

The Holocene Dead Sea lake level record (Fig.1) recently published by Migowski *et al.* (2006) provides a rain gauge (Enzel *et al*. 2003) with tremendous forecasting capabilities for Near Eastern archaeology, and especially for the Jordan Valley with its rich cultural heritage. In combination with other lower latitude climate proxies, the Dead Sea record takes on a central position in the present studies. Prior to using this record for 'rubble slide research', there are several aspects to acknowledge. First, the Dead Sea level responds primarily to precipitation changes in the northern Jordan Valley, which are channeled down the valley from the Lake Kinneret basin. Due to its high salinity, the Dead Sea itself does not provide the fresh water necessary to support farming communities. But the level of water in the Dead Sea does provide a sensitive supra-regional record of past precipitation changes in this region. This is due to its location at a terminal position in an extended basin (Glacial Lake Lisan), with its large, closed drainage area (Enzel *et al*. 2003).

Secondly, it is important to acknowledge the existence of a major non-linearity in the relation between (hypothetical) Levantine precipitation and (measured) Dead Sea lake level. This non-linearity is because the Dead Sea consists of two closely connected sub-basins that are separated by a sill at ~402-403 m mbsl [meters below sea level] (Migowski *et al.* 2006: 422). The deep northern basin is fed mainly by the Jordan River and to some extent by local runoff (Enzel *et al.* 2003). When the northern basin waters rise to levels above the sill, the overflowing waters flood the shallower southern basin. In this case the combined lake area is significantly enlarged, and the total evaporation then also rises significantly. Very high precipitation is necessary to simultaneously raise the water level of the northern basin above the sill and to maintain this high level against the enhanced evaporation.

Conversely, when the northern basin drops significantly below the sill during extreme arid periods, salt is deposited in the centre of the lake. This process is not evident in the level graph (Fig.1). To support interpretation of the Dead Sea record vis-à-vis this non-linearity, we have drawn a dashed horizontal line in Fig.1 at the sill height of ~402.5 m. Allowing for such scaling complications due to the existence of the sill at ~402.5 mbsl, the Dead Sea level represents a wonderful document for all climate-related archaeological research in the Levant. It remains to be mentioned that the Dead Sea record is derived from multiple cores and is supported by a large set of highly precise of AMS ^{14}C dates by the Kiel laboratory (Migowski *et al.* 2006).

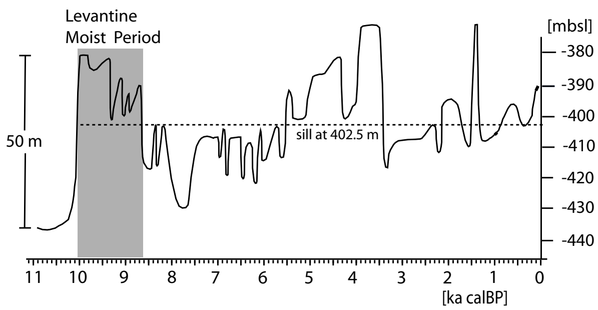

Fig. 1 Holocene Dead Sea Lake Levels (here: schematic), according to Migowski et al. (2006)

Marine Core LC21 (35.66°N, 26.48°W, -1522 m water depth)

Of further interest to our studies, due to its central position in the Southeast Aegean Sea and situation to the east of Crete, is core LC21 (35.66°N, 26.48°W, -1522 m water depth). At this location, with selected marine fauna used as sea-surface temperature (SST) proxies, it is possible to observe sensitive expansions and contractions of the cooler Aegean waters in relation to the warmer Levantine waters (Rohling *et al.* 2002). In particular, it has been established that the ratio of warm/cold surface-living foraminifera can be used to describe a series of rapid SST variations during the Holocene. The LC21 record reveals a pattern of (presently) three major temperature drops in the southeastern Aegean, dating to 8.6-8.0 ka cal. B.P., 6.5-5.8 ka cal. B.P. and 3.5-2.8 ka cal. B.P. (Rohling *et al.* 2002). Modern calibration of fauna-derived SST variations shows that these temperature drops occur, with a strong seasonal component, in winter and early spring (Rohling *et al.* 2002).

Greenland Ice-Core GISP2 (72.6°N, 38.4°W, +3200 m height)

One of the most remarkable results of LC21 core studies was the demonstration that these rapid SST variations are caused by extremely cold air masses, moving rapidly over the Aegean ocean surface with corresponding energy transfer via evaporation from the warmer ocean surface to the colder moving air. This ocean cooling mechanism was identified in an unusually high correlation between LC21 SST variations and non-sea-salt (nss) [K^+] and sea-salt-derived [Na^+] chemical ion concentrations measured in the Greenland GISP2 ice-core (72.6°N, 38.4°W, +3200 m height). High nss [K^+] is coincident with an intensification of the semi-permanent Siberian high pressure zone, whereas high [Na^+] values coincide with an intensification of the highly dynamic North Atlantic low pressure zones (Mayewski *et al.* 1997).

Correlation of Aegean Sea Surface Temperature and Siberian High Pressure

The correlation between the Aegean SST and the Greenland GISP2 nss [K^+] is of major importance for our understanding of the Holocene RCCs. As mentioned above, core LC21 is located close to Crete in a position reactive to expansions and contractions of the cooler Aegean waters. The LC21 position is highly sensitive towards such wind-induced SST variations, and especially towards the cooling effects of winds sweeping down from the Balkans. Before reaching the LC21 core location, the northeasterly winds must have traversed the open ocean surface over a distance of some 700 km. Since these winds are predominantly winter/early spring phenomena, and typically only occur for a few days at one time, the energy transfer between surface water and wind must proceed quite rapidly. When reaching the location of core LC21, the fact that such rapid SST variations are observed for such a large water column (~ 300 meter depth) – the habitat of the faunal species under study – means that during RCC times a huge amount of cold air must dissipate its energy into the water column in a very short time.

Comparison of Climate Records

Let us now take a closer look at all these records in combination (Fig.2). Of principal interest for our studies – since this record is closest to the Jordanian rubble slides – is the Dead Sea record. As can be seen in Fig.2, there was an abrupt rise in Dead Sea lake level around 10.1 ka cal. B.P. from below ~ 430 mbsl to heights ~ 380 mbsl in essentially only one big step. The high stand at ~ 380 mbsl is maintained for *ca.* 500 yrs, before it drops by *ca.* 10 m to a second high stand at ~ 370 mbsl around *ca.* 9.5 ka cal. B.P. Although Migowski *et al.* (2006) attach a number of question marks to many of the height measurements (for simplicity we have left these out of Fig.2), even the questionable levels are all higher than the sill. Then, around *ca.* 8.6 ka cal. B.P., the lake level drops significantly for the first time some 10 m below the sill. In a second step, around 8.1 ka cal. B.P., the level plunges another 15 m to values ~428 mbsl, the lowest level to have been reached at any time in the Holocene. After rising again around 7.5 ka cal. B.P. to ~405 mbsl, the relatively low level conditions continue until 5.6 ka cal. B.P. From then on, several rises and drops are observed until a second conspicuous maximum at 370 mbsl is reached. This maximum is maintained for perhaps 300 yrs between 4.0 ka and 3.6 ka cal. B.P.. Then, once again, a significant drop by 60 m is observed, down to a lake level well below the sill, at around 3.2 ka cal. B.P. (Fig.2; *cf.* Migowski *et al.* 2006).

Comparisons with other climate records, also shown in Fig. 2, indicate that the abrupt rise in Dead Sea level at 10.2 ka cal. B.P. corresponds well (within error limits of ± 100 yrs) with the onset of Sapropel S1. This is itself of major interest to archaeological research in the Levant, since the formation of sapropels in the Eastern Mediterranean during the Early Holocene is related to a strong increase in summer rainfall (*e.g.*, De Rijk *et al.* 1999; Ariztegui *et al.* 2000). Since any change from dry to humid conditions can be expected to have strong influence on the development of vegetation, and thereby impact practically all kinds of human food resources, in archaeological studies we may use (marine) sapropels as important general indicators for (terrestrial) rainfall variations. As such, we now have independent and consistent evidence from two different sources (Dead

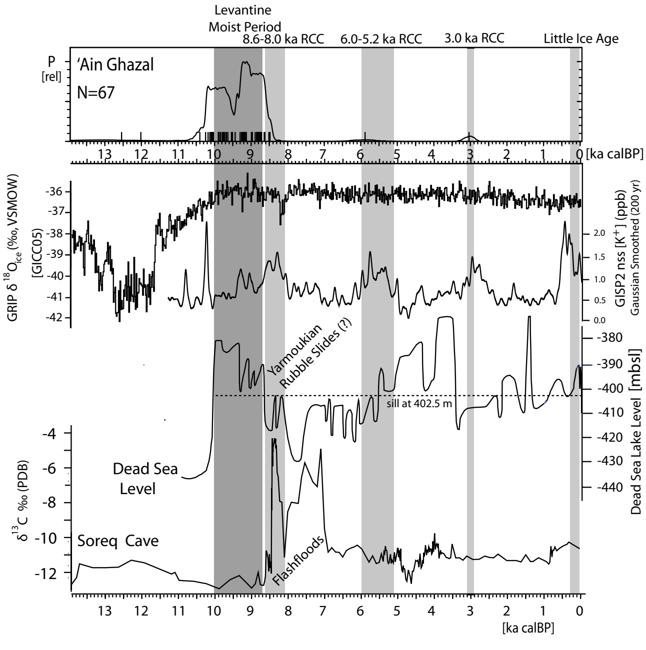

Fig. 2 Top: ^{14}C sequence from 'Ain Ghazal (MPPNB-LPPNB/C: youngest ^{14}C age is Yarmoukian).
Bottom: Dead Sea (Jordan) Lake Levels as proxy for Holocene precipitation in the southern Levant (Migowski *et al.* 2006), in comparison to Greenland GISP2 ice-core stable oxygen isotopes $\delta^{18}O$ (Grootes *et al.* 1993), Greenland GISP2 ice-core non sea-salt [K^+] chemical ions as proxy for Rapid Climate Change (Mayewski *et al.*, 1997; 2004), and Soreq Cave (Israel) $\delta^{13}C$ record (Bar-Matthews *et al.* 2003) as proxy for southern Levantine Holocene precipitation levels and flash flood intensity. Also shown (shaded intervals) is the extent of Sapropel S1 (9.8-6.8 ka cal. B.P.; dates: *cf.* Casford *et al.* 2007) with estimated interruption S1ab (8.6-8.0 ka cal. B.P.) during the corresponding RCC major global cold interval.
Note: In the Levant, simultaneously, extreme drought (cold-RCC) and flashfloods can be expected during are time-interval 8.6-8.0 ka cal. B.P. (see text).

Sea lake levels and Sapropel formation) for the onset at around 10 ka cal. B.P. of a major and extended period with enhanced rainfall in the Levant.

Perhaps not directly expected, but surely in good agreement with general biological expectations, the beginning of this moist period shows high temporal correlation to the very first use of selected domesticated cereals, essentially *simultaneously* (see below) *everywhere* (see below) in the Near East. This is demonstrated in Fig. 3, where we show calibrated ^{14}C dates for the table in which Nesbitt (2002: Tab.1) differentiates between archaeological sites with archaeobotanical evidence for the earliest appearance of domesticated (genetically changed) cereals in comparison to wild cereals (but which remain in use for a long time). In our unchanged adoption of Nesbitt's data (Fig. 3) these sites are shown here in context with the

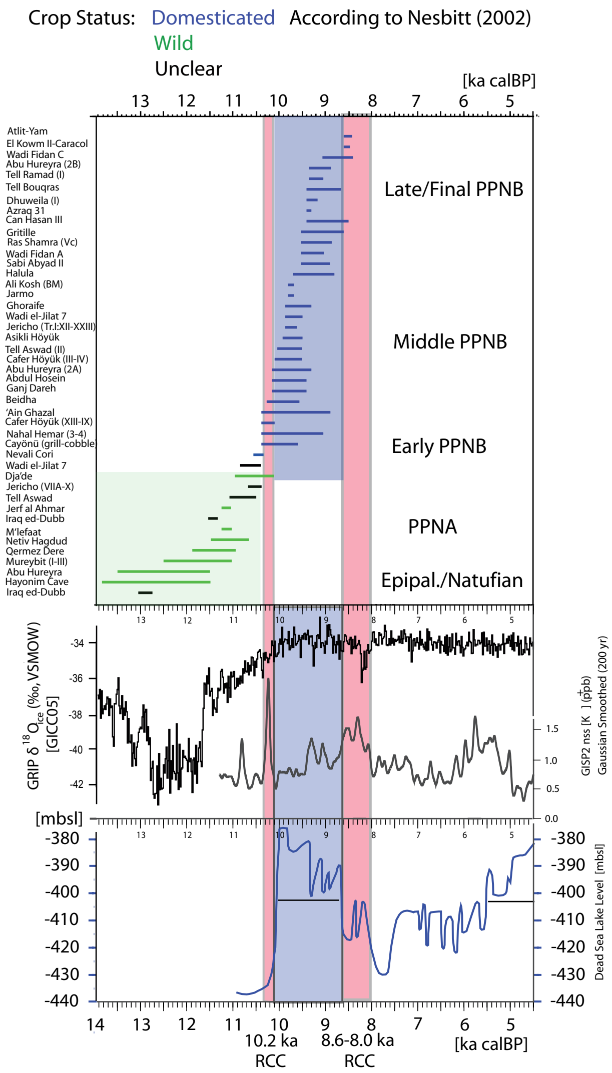

Fig. 3 Archaeobotanical records for cereals (crop status: wild, domesticated, or unclear), arranged according to site age and cultural periods according to Nesbitt (2002) in comparison to Greenland GRIP stable oxygen isotopes (Grootes *et al.* 1997), Greenland GISP2 nss [K$^+$] values (Mayewski *et al.*, 1997, 2004) and Dead Sea Lake Levels (Migowski *et al.*, 2006). Note: The archaeobotanical data shown here are taken unchanged from Nesbitt (2002: Tab.1), but with replacement of conventional ^{14}C age values by tree-ring calibrated ^{14}C dates.

Dead-Sea lake level record of Migowski *et al.* (2006). Within dating errors, the onset of genetically changed cereals coincides *everywhere* in the Near East (*i.e.*, southeastern Anatolia, northern Syria, Jordan) *exactly* (within *ca.* ± 100 yrs, 68%) with the abrupt increase in precipitation, as documented in the Dead Sea. Other correlations follow, such as the simultaneous onset of large villages that mark the beginning of the MPPNB, as shown in Fig.3**.**

Let us now turn from the highest to the lowest water level that is registered in the Dead Sea record. This low level (at ~ 428 mbsl) is first reached at 8.6 ka cal. B.P., and is clearly synchronous with the well known interruption in the Sapropel S1 formation that is indicative of low rainfall in the eastern Mediterranean, simultaneously with low levels of Nile waters (*e.g.*, De Rijk *et al.* 1999; Ariztegui *et al.* 2002), as well as to the dry spell known from the Soreq Cave stalagmite (further indicative for extended flash floods; *cf.* Bar-Matthews *et al.*, 2003). Together these records give strong support for the existence of a major arid period in the Jordan Valley, which is synchronous with the 8.2 ka cal. B.P. RCC period (Mayewski *et al.* 1997; Rohling *et al.* 2002).

In combination, these records provide tantalizing evidence for an extended period (10.1-8.6 ka cal. B.P.) with enhanced rainfall in southern Jordan and, by inference, in the entire Levant. This wet period starts abruptly, shortly following the 10.2 ka cal. B.P. cold event, and finishes abruptly, with the onset of the next cold RCC at 8.6 ka cal. B.P..

Discussion

Let us recapitulate our present understanding of the climate system in the Near East and the Aegean. By comparative study of climate records from the Jordan Valley (Dead Sea Lake Levels), the Aegean ocean (marine core LC21), the Red Sea (core GeoB 5844-2), and Greenland GISP2 ice-core nss [K$^+$] records (Fig.2), we have learnt that:

The Jordan Valley was very moist from *ca.* 10.0 - 8.6 ka cal. B.P.. We use the term *'Levantine Moist Period'* (LMP) to characterize the high levels of precipitation in this time-interval. The LMP is presently best-documented by local records in high Dead Sea levels (Migowski *et al.* 2006) and low Red Sea salinity (Arz *et al.* 2003). In the Dead Sea record, the LMP is recognisable as a *ca.* 1400 yr long period with high lake levels that remain, continuously, above the sill between the northern and southern basin. During the LMP, it appears, both basins were filled.

The LMP starts abruptly, immediately following a short (maximum ~ 200 yr) but extremely cold and dry period (10.2-10.0 ka cal. B.P.) of Rapid Climate Change (RCC).

The LMP ends abruptly, immediately before the onset of the next RCC (8.6-8.0 ka cal. B.P.). During both RCC periods (which we abbreviate as "10.2 ka GISP2 RCC" and "8.2 ka GISP2 RCC') the eastern

Mediterranean was regularly punctuated by winter/spring outbreaks of extremely cold polar air masses. During these RCC periods, for days on end and maybe even weeks in winter and early spring, the eastern Mediterranean would have been regularly 'bathed' with air masses coming directly from Siberia.

Quite consistent with this modelling expectation, and independently confirmed by the major drop observed in Dead Sea Lake Levels (Migowski *et al.* 2006), during the entire 8.2 ka GISP2 RCC event (8.6-8.0 ka cal. B.P.) the Jordan Valley experienced an extended drought.

Not unexpectedly, therefore, and independently confirmed by the absence of archaeological ^{14}C data, it appears that immediately with the onset of the 8.6-8.0 ka cal. B.P. RCC the majority of sites in the southern Jordan Valley were abandoned. An important exception is the large settlement at Sha'ar Hagolan, in the northern Jordan Valley, which was founded at this time. Interestingly, Sha'ar Hagolan was equipped with a well (Garfinkel *et al.* 2006). Although Sha'ar Hagolan is a large settlement with well-constructed houses and a major communal building (Garfinkel and Miller 2001), the site actually does not show much rebuilding. Pointing in the same direction, the quite thin stratigraphy also shows little evidence for an extended occupation, nor do the available radiocarbon dates (Table 1) support a long time span (although these derive mainly from the well). To conclude, the settlement at Sha'ar Hagolan was itself soon abandoned. Apparently, in the long run, the drought became too severe for human occupation, even in the northern Jordan Valley.

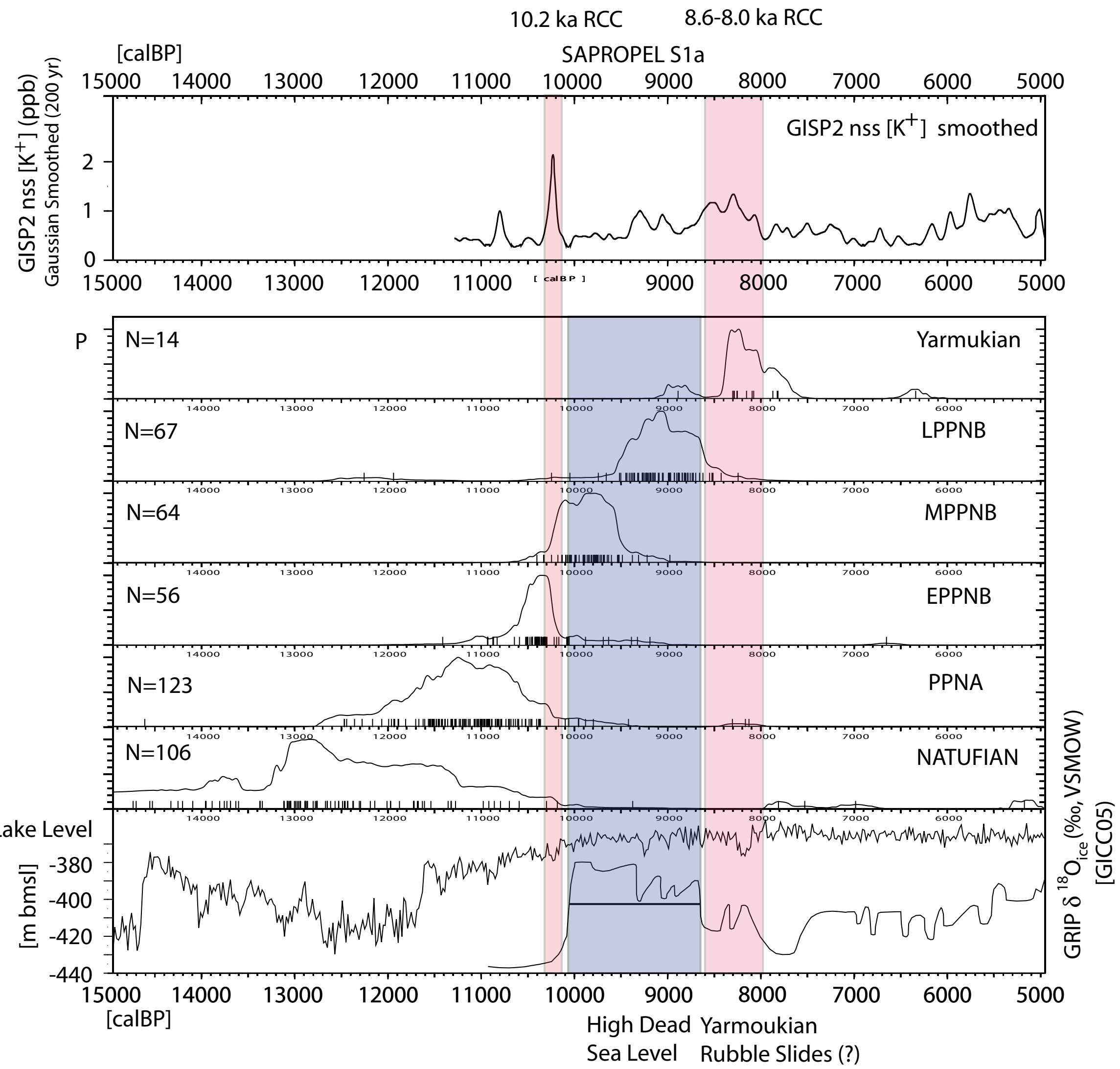

Fig. 4 Early Holocene Cultural Chronology in the Levant, based on a substantial archaeological ^{14}C database and cultural designation of ^{14}C dates supplied by Böhner and Schyle (2009) in comparison to precipitation proxies in the southern Levant (Dead Sea Lake Levels: Migowski *et al.*, 2006). Grey bands indicate periods of Rapid Climate Change (RCC) as defined by Mayewski *et al.*, 2004, with best meteorological analogy in the recent Little Ice Ages (Rohling *et al.* 2002). The Greenland ice core stable oxygen δ18Orecord (Grootes *et al.* 1997; with GICC05 age model: Anderson *et al.* 2005) is only shown for purposes of chronological orientation. Note: (i) the onset of the MPPNB (*ca.*10 ka cal. B.P.) is synchronous with an abrupt major (50 m) rise in Dead Sea Lake Levels, (ii) the end of the LPPNB/C (*ca.* 8.6 ka cal. B.P.) is synchronous with an abrupt drop in Dead Sea Levels, and (iii) the Yarmoukian Rubble Slides (8.6-8.0 ka cal. B.P.) occur during the equivalent (8.6-8.0 ka cal. B.P.) RCC global cold period, during which extreme drought is registered in the southern Levant, as indicated by Dead Sea level low stands (see text).

Conclusions

As a result of these studies, the following scenario for Jordanian Rubble Slides is proposed. During RCC times, and especially for times dwith exceptionally high GISP2 nss [K^+] values, we expect circum-polar air pressure anomalies similar to the Little Ice Age. These atmospheric pressure anomalies (record: GISP2 nss [K^+]) rapidly transmit large amounts of cold and dry air from Asia into the Balkans and adjacent regions on the northern edge of the Aegean, from where they are channelled southwards across the Aegean ocean. The cold air masses are registered as rapid sea surface temperature (SST) variations in a marine core to the east of Crete (record: LC21). Consequently, during this RCC interval (8.6-8.0 ka cal. B.P.), we may expect extremely cold and arid conditions in the eastern Mediterranean, along with strong winds in the Aegean. This is confirmed by the extreme drought for this period, as documented in the Dead Sea Lake Level record. However, due to the still relatively far north position of the moisture-bringing Intertropical Convergence Zone, at least at stochastic intervals, the cold Siberian winds will have interacted strongly with the moist Mediterranean air masses to produce some extremely flashy and intensive precipitation.

This can be recognised, perhaps most clearly, from what we call the *flash flood r*ecord, that is the Soreq cave stalagmite $\delta^{13}C$ record (Fig.2). Since the correct interpretation of isotopic stalagmite data is no easy matter, it is perhaps best, in this case, to cite the authors directly (Bar-Matthews *et al*. 2003): '*... an alternative explanation for the extremely high δ13C values, consistent with the interpretation of enhanced rainfall during sapropel intervals, is that the stripping of the soil cover was caused by deluge events, which resulted in water reaching the cave after little interaction with soil CO2'* (Bar-Matthews *et al.* 2003: 3193).

Thanks to the highly precise (U/Th) dating for the Soreq $\delta^{13}C$ record, in comparison with the archaeological observations (Rollefson 2009) and finally also the ^{14}C data for the Yarmoukian period (Table 1), such an intriguing '*deluge*' explanation would readily support our hypothesis that the Yarmoukian rubble slides were caused by torrential episodic rainfall during the otherwise arid 8.6-8.0 ka cal. B.P. RCC period. We therefore confidently conclude that the Yarmoukian rubble slides in the southern Jordan valley, although *maybe* in combination with *widespread* human-induced environmental degradation, had essentially *natural* causes.

Acknowledgements: I thankfully acknowledge support from many friends and collegues, above all Lee Clare (Köln), Hans Georg Gebel (Berlin), Jörg Linstädter (Köln), Paul Mayewski (Maine), Eelco Rohling (Southampton), Gary Rollefson (Walla Walla), and Daniel Schyle (Köln).

References

Andersen K.K., Svensson A., Johnsen S.J., Rasmussen S.O., Bigler M., Röthlisberger R., Ruth U., Siggaard-Andersen M.-L., Steffensen J.P., Dahl-Jensen D., Vinther B.M., and Clausen H.B.
2006 The Greenland Ice Core Chronology 2005, 15-42 ka. Part 1: Constructing the time scale, *Quaternary Science Reviews* 25. (Shackleton Special Issue 24, 2006)

Ariztegui D., Asioli A., Lowe J.J., Trincardi F., Vigliotti L., Tamburini F., Chondrogianni C., Accorsi C.A., Bandini Mazzanti M., Mercuri A.M., Van der Kaars S., McKenzie J.A., and Oldfield F.
2000 Palaeoclimate and the formation of Sapropel S1: inferences from Late Quaternary lacustrine and marine sequences in the central Mediterranean region. *Palaeogeography, Palaeoclimatology, Palaeoecoogy* 158: 215-240.

Arz H.W., Lamy F., Pätzold J., Müller P.J., and Prins M.
2003 Mediterranean Moisture Source for an Early-Holocene Humid Period in the Northern Red Sea. *Science* 300: 118-121.

Bar-Matthews M., Ayalon A., Kaufman A., and Wasserburg G.J.
1999 The Eastern Mediterranean paleoclimate as a reflection of regional events: Soreq Cave, Israel. *Earth and Planetary Science Letters* 166: 85-95.

Bar-Matthews M., Ayalon A., Gilmour M., Matthews A., and Hawkesworth C.J.
2003 Sea-land oxygen isotopic relationships from planktonic foraminifera and speleothems in the Eastern Mediterranean region and their implication for paleorainfall during interglacial intervals. *Geochimica et Cosmochimica Acta* 67 (17): 3181-3199.

Bar-Yosef O.
1989 The PPNA in the Levant - An Overview. *Paléorient* 15/1: 57-63.

Begin Z.B.
2005 Destructive Earthquakes in the Jordan Valley and the Dead Sea - their Recurrence Intervals and the Probability of their Occurrence. *Geological Survey of Israel*, Report GSI/12/05, Jerusalem June 2005.

Böhner U. and Schyle D.
2009 Online Radiocarbon Database (http://context-database.uni-koeln.de), registered as doi:10.1594/GFZ.CONTEXT.Ed)

Casford J.S.L., Abu-Zied R., Rohling E.J., Cooke S., Fontanier C., Leng M., Millard A., and Thomson J.
2007 A stratigraphically controlled multiproxy chronostratigraphy for the eastern Mediterranean. *Paleoceanography* 22, PA4215, doi: 10.1029/2007PA001422, 2007.

De Rijk S., Hayes A., and Rohling E.J.
1999 Eastern Mediterranean sapropel S1 interruption: an expression of the onset of climatic deterioratiotn around ka BP. *Marine Geology* 153: 337-343.

Enzel Y., Bookman (Ken Tor) R., Sharon D., Gvirtzman H., Dayan U., Ziv B., and Stein M.
2003 Late Holocene climates of the Near East deduced from Dead Sea level variations and modern regional winter rainfall. *Quaternary Research* 60: 263-273.

Garfinkel Y. and Miller M.
2001 Sha'ar Hagolan I: Neolithic Art in Context. Oxbow Books, London: 272.

Garfinkel Y.
2004 *The Goddess of Sha'ar Hagolan. Excavations at a Neolithic Site in Israel*. Jerusalem, Israel Exploration Society.

Garfinkel Y., Vered A., and Bar-Yosef O.
2006 The Domestication of Water: The Neolithic Well of Sha'ar Hagolan, Jordan Valley, Israel. *Antiquity* 80: 686–696.

Grootes P.M., Stuiver M., White J.W.C., Johnsen S., and Jouzel J.
1993 Comparison of Oxygen Isotope Records from the GISP2 and GRIP Greenland Ice Core. *Nature* 366: 552-554.

Kenyon K.M. and Holland T.A. (*eds*.)
1981 *Excavations at Jericho. Vol. III*. London, The British School of Archaeology in Jerusalem.

Klinger Y., Avouac J.P., Abou Karaki N., Dorbath L., Bourles D., and Reyss J.L.
2000 Slip rate on the Dead Sea transform fault in northern Araba valley (Jordan). *Geophysical Journal International*: 755-768.

Mayewski P., Meeker L.D., Twickler M.S., Whitlow S., Yang Q. and Prentice M.
1997 Major features and forcing of high latitude northern hemisphere circulation using a 110000-year-long glaciochemical series. *Journal of Geophysics Research* 102: 26345-26366.

Mayewski P.A., Rohling E.E., Stager J.C., Karlen W., Maascha K.A., Meeker L.D., Meyerson E.A., Gasse F., van Kreveld S., Holmgrend K., Lee-Thorph J., Rosqvist G., Racki F., Staubwasser M., Schneider R.R., and Steig E.J.
2004 Holocene climate variability. *Quaternary Research* 62: 243-255.

Meeker L.D. and Mayewski P.A.
2002 A 1400 year long record of atmospheric circulation over the North Atlantic and Asia. *The Holocene* 12(3): 257-266.

Migowski C., Stein M., Prasad S., Negendank J.F.W., and Agnon A.
2006 Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. *Quaternary Research* 66: 421-431.

Nesbitt M.
2002 When and where did domesticated cereals first occur in southwest Asia? In R.T.J. Cappers and S. Bottema (eds.). *The Dawn of Farming in the Near East*. Studies in Early Near Eastern Production, Subsistence, and Environment 6: 113-132 Berlin, *ex oriente*.

Rohling E. and Pälike H.
2005 Centennial-scale climate cooling with a sudden cold event around 8,200 years ago. *Nature* 434: 975-979.

Rohling E.J., Mayewski P.A., Abu-Zied R.H., Casford J.S.L., and Hayes A.
2002 Holocene atmosphere-ocean interactions: records from Greenland and the Aegean Sea. *Climate Dynamics* 18: 587-593.

Rollefson G.O.
2009 Slippery Slope: The Late Neolithic Rubble Layer in the Southern Levant. *Neo-Lithics* 1/09 (this volume).

Slippery Slope: The Late Neolithic Rubble Layer in the Southern Levant

Gary O. Rollefson Whitman College, Walla Walla rollefgo@whitman.edu

Introduction

In the first two seasons of excavation at 'Ain Ghazal, our efforts focused principally on a rescue archaeology approach to recover burials and architectural information exposed on a bulldozer terrace associated with the construction of a major highway that cut through the lower slope of the site. When the emergency nature of the field work subsided, we were able to expand our goals to sample other areas of the immense expanse of 'Ain Ghazal, which involved placing excavation trenches in other areas of the settlement, and contrary to what surface artifacts indicated, we encountered a substantial layer of *in situ* occupational material from the Yarmoukian Pottery Neolithic. One element in these ceramic Neolithic layers was the presence of very dense concentrations of angular limestone rubble mixed in with most of the Yarmoukian sediments. The quantity of rubble was stunningly dense and abundant, and since it was clearly characteristic of the Yarmoukian period, we named it "the Yarmoukian Rubble Layer" (Rollefson and Kafafi 1994: 11).

What follows is a sample of Late Neolithic settlements that manifest the rubble layer as well as other contemporaneous sites where the rubble layer is not present. Since the debris flow has been recognized at apparently contemporaneous sites with Jericho IX or other PN cultural material, we will hereafter refer to the phenomenon as the "Late Neolithic Rubble Layer."

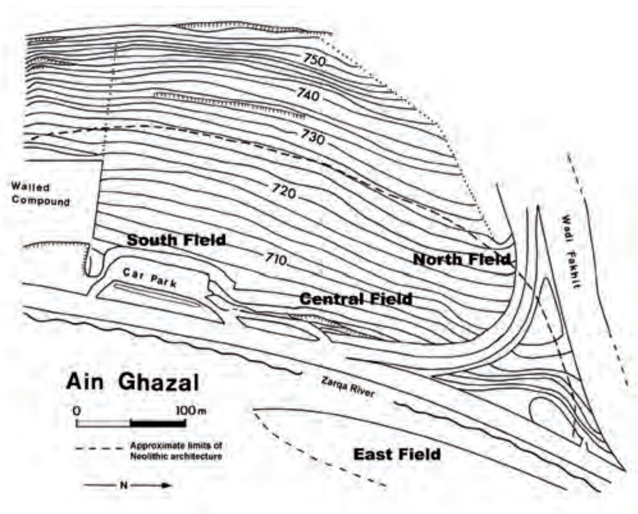

Fig. 1 Topographic map of 'Ain Ghazal, showing the location of the several fields of excavation (Drawing: Ali Omari and G. Rollefson)

The Late Neolithic Rubble Layer at 'Ain Ghazal

Our first encounter with the Late Neolithic Rubble Layer was in the South Field in the 1984 season (Fig. 1), where the thickness of the deposit was more than a meter in many places, reaching more than a meter and a half in some gullies. An example of the general sequence of events is provided in Fig. 2, a section drawing (south balk) of the excavation in Square 4655 in the South Field. All of the strata below loci 000-002 are Yarmoukian until, in the left side, PPNC layers were reached at Loci 041 and 045. The wall in the left center of the section (Locus 019) was a Yarmoukian domestic dwelling that became abandoned, and subsequently filled to much of its height with "normal" slope wash (Locus 042). Some time later, a huge pit was excavated by the Yarmoukian residents, which later became inundated with debris (Locus 011) characterized by angular limestone rubble of extraordinary density. A later rubble slide is represented by Locus 010 (the rubble of which was larger in size than in Locus 011). The physical character of the rubble events is shown in Figs. 3-4.

A "platform" or wall foundation, Yarmoukian in age, is represented by Locus 006 and Floor 029, a younger structure built atop the second rubble deposit. Locus 009, just to the left of Wall 019, is wall fall and might be associated with the eventual abandonment of the structure represented by Loci 006 and Floor 029, and Locus 009 is possibly contemporaneous with Locus 005, a wall collapse from the younger building. Locus 003 is principally an "*in situ*" slope wash with abundant angular debris, although the upper 10 cm also contains post-Neolithic pottery. Locus 002 is a post-abandonment mix of Yarmoukian materials but with relatively common Byzantine sherds as well, probably reworked sediments from higher up the slope near a Byzantine structure.

As our excavations grew in area, the same rubble layer phenomenon was noted in the Central Field, where Yarmoukian architecture was usually filled with angular debris washed from above. Near the undefined boundary between the Central and North Fields, Yarmoukian pottery disappeared, probably as a consequence of 20th century agricultural disturbance of the upper layers of soil, and no ceramics were found in the North Field either, possibly for the same reason. The rubble nature of the Yarmoukian deposits in the western Central Field was not noted in the eastern part of the Central Field; There was substantial angular debris in the upper reaches of the stratigraphic sequence in the North Field, but this appears to be related to anthropogenic causes associated with industrial uses

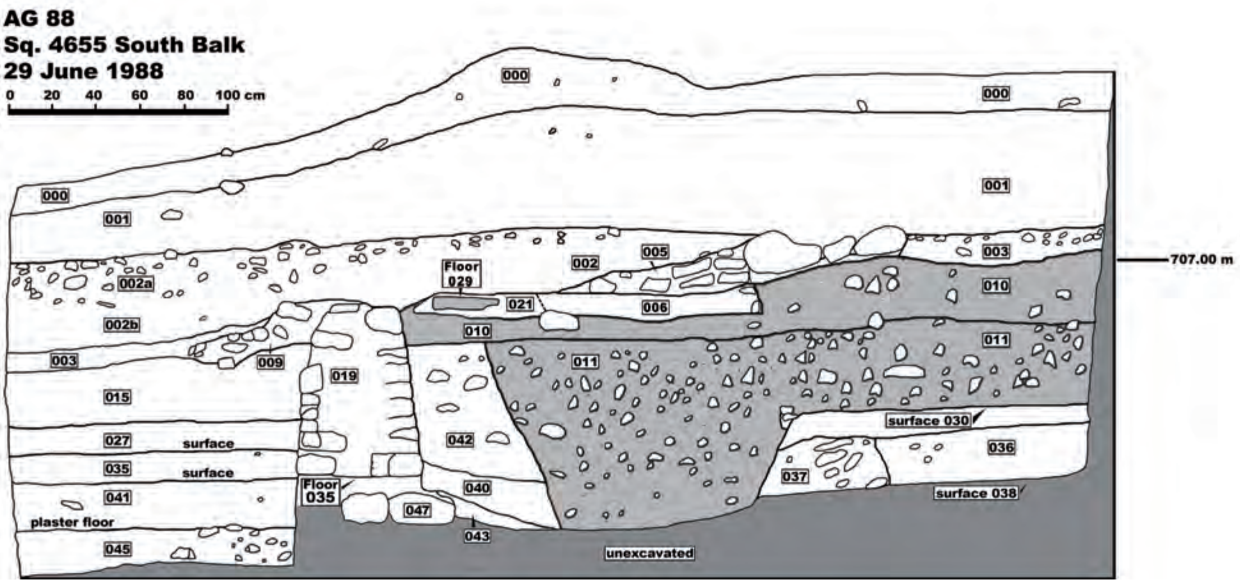

Fig. 2 Drawing of the South Balk of Square 4655 in the South Field. Loci 010 and 011 are rubble layers associated with the 8.2 k.y.a. event. (Drawing: G. Rollefson).

of chalk and soft limestone in the area (*cf.* Kafafi and Rollefson 1995: 20-21).

The Late Neolithic Rubble Layer was a curious feature of the Yarmoukian layers at ‘Ain Ghazal, but the presence of such angular debris was not novel at the site. In the MPPNB layers, especially, there were widespread dense deposits of sharply fractured stones, almost all of them poor quality flint. They were associated with fire, and these fire-cracked rocks were probably associated with outdoor processing of plant or animal resources and not related to any particular climatic events. This MPPNB rocky debris contrasted sharply with the Yarmoukian Rubble, since the latter was principally limestone fragments that seemed to have eroded downslope from exposures of bedrock higher uphill.

Across the Wadi Zarqa, which was a permanent river during the early Neolithic, there are no indications of any Yarmoukian dwellings. In fact, the only indication of the use of the eastern side of the Wadi Zarqa during the PN is a pottery production area high on the eastern escarpment, just above the higher LPPNB large cult building (*cf.* Rollefson 1998; Rollefson and Kafafi 1997: 36). The East Field is much steeper than the area to the west of the Wadi Zarqa: a greater than 30% slope is the current declination, and the modern slope is probably not much different than in the Neolithic period. Because of this steepness, there is little to catch downslope erosion before sloughing into the Wadi Zarqa itself, so it is not surprising, perhaps, that a Late Neolithic Rubble Layer has not been preserved.

One aspect of the Yarmoukian layers at ‘Ain Ghazal that might be correlated with the process responsible for the Rubble Layer is the coating of artifacts (flint, pottery, and bone) with a thick and resistant calcareous coating; only treatment with hydrochloric acid made it possible to determine the status of tool/debitage or ceramic type or animal species. One suspects that the concretion is related to free chemical radicals in the soil that were not present during the MPPNB, LPPNB, and PPNC soil regimes.

The Late Neolithic Rubble Layer Elsewhere in the Southern Levant

Wadi Shu‘eib

For some time, we were not aware that the Late Neolithic Rubble Layer was a feature that occurred in other sites, and it was not until we began working at our sister site at Wadi Shu‘eib that it became clear that the Rubble Layer was a more widespread event, occurring at another Yarmoukian site some 25 km to the west of ‘Ain Ghazal. At Wadi Shu‘eib, all along the road cut of a highway linking al-Salt with the Jordan Valley at South Shuna, “a massive sorted layer of cobbles … that roughly separates portions of the Pre-Pottery and Pottery Neolithic layers” was observable (Simmons *et al.* 2001: 7). The photograph in Fig. 5 shows two clear rubble events.

Jebel Abu Thawwab

Not far from both Wadi Shu‘eib and ‘Ain Ghazal, the site at Jebel Abu Thawwab also produced a substantial Late Neolithic Rubble Layer. Kafafi noted that the Early Bronze and Yarmoukian layers “were separated by a fill containing large quantities of small stone debris” (Kafafi 1988: 453; *cf.* Kafafi 2001 17, 32 and Plate 8B).

‘Ain Rahub

East of Irbid at ‘Ain Rahub, a thick (1.0-1.5 m) layer of limestone rubble contained Yarmoukian pottery, and it is possible that the Yarmoukian occupation continued below the rubble layer (Muheisen *et al.* 1988: 493).

al-Shalaf
The preliminary report on excavations at al-Shalaf, near ‘Ain Rahub, did not provide details of the nature of the strata at the site, but it was noted that all of the Yarmoukian pottery sherds were “covered by a layer of sinter that was in some cases thick” and which could only be studied once that layer was removed using hydrochloric acid (Bienert and Vieweger 1999: 57), an observation that echoed the situation at ‘Ain Ghazal and Wadi Shu‘eib.

Tell Abu Suwwan
Excavations at Tell Abu Suwwan, on the southern outskirts of Jerash, have recently revealed a massive layer of rubble, approaching a meter in thickness, containing Yarmoukian pottery (an-Nahar, pers. comm., 2007) overlying extensive PPN architecture.

Umm Meshrat I & II
Farther south, the survey connected with the Wadi al-Thamad project south of Madaba located an broad distribution of Yarmoukian pottery and typical stone tools; two concentrations were named Umm Meshrat I and II, and test excavations were carried out at the beginning of the current millennium. The terrace on which the sites were situated includes deposits of “fieldstones and grayish sediment, suggestive of the Yarmoukian ‘debris fields’ that may be associated with the 8th millennium BP climate shift … identified by Rossignol-Strick” (Cropper *et al.* 2001: 18).

WHS 524
In the surveys conducted by MacDonald in the late 1970s and early 1980s (*cf.* MacDonald 1988), one Neolithic site (WHS 524) ascribable to the PNA/Jericho IX cultural tradition was identified. A later intensive examination of the site’s surface and of the bulldozer cut along the highway revealed that “the archaeological layer is thick … and at its top [there is] more than a meter of coarse colluvium” (Bossut *et al.* 1988: 131).

Basta
At Basta, a sediment unit up to 2m thick in places is comprised of “tremendous amounts of detritus and mud flows” that “passed through and above the LPPNB layers” (Gebel 2004: 100; *cf.* Table 1 and Plates 2B and 2C), dated to the early or middle 7th millennium cal. B.C. Ironically, it was the sudden transport that was responsible for the excellent architectural preservation at the site, at least in some areas (Gebel 2004: 104). The pottery associated with this rubble event has not been ascribed to either the Yarmoukian or Jericho IX cultural spheres.

Ba‘ja
The situation at Ba‘ja presents different facets of the rubble slide phenomenon. Wall stone rubble layers at the site probably represent earthquake-caused debris, possibly twice near the end of the occupation. Later, the site experienced a thick flow (as much as 1.5 m in thickness) of coarse rubble and gravel with interdigitated fine gravels, all transported by water. However, the water-borne sediments came not from slope collapse but from flash flooding down the narrow gorge whose floor was much higher than at present (Gebel and Kinzel 2007: 32). There is evidently no material included in the fine gravels that is suitable for dating the events.

Abu Gosh
The settlement at Abu Gosh, at the northwestern edge of Jerusalem, produced evidence for both Pre-Pottery and Pottery Neolithic occupations. Three decades ago Ronen suggested that the post-PPN “stony layer” indicated increased precipitation during the (uncalibrated) 6-4th millennia (Ronen 1971). Farrand, who was the geologist working with Lechevallier, disagreed, claiming that the climate was instead drier during these times. More recent analysis of the geomorphological situation suggests that the stony layer is confined to the habitation area itself and is not present in the nearby areas, suggesting an anthropogenic origin for the material (Barzilay 2003: 7).

Topography and the Rubble Slide Event(s)

The sheer mass of stone in the Late Neolithic Rubble Layer at ‘Ain Ghazal and Wadi Shu‘eib impressed us greatly during our excavations there. But the high energy necessary to move such enormous quantities of rubble was understandable in view of the slopes down which the rubble was moved by water. At ‘Ain Ghazal the average slope in the South Field (where the rubble was most clearly visible) was between 25-26°, measured from the top of the hill to the edge of the Wadi al-Zarqa. The conditions at Wadi Shu‘eib were not as steep, with the slope angle averaging about 12-14° on the uphill side of sampled Areas I, II, and III (Simmons *et al.* 2001: Fig. 2).

Ain Jammam has a markedly steep slope, not less than 20° (*cf.* Gebel 2008: Fig. 3). There is a decidedly strong Pottery Neolithic occupation here (*cf.* Fino

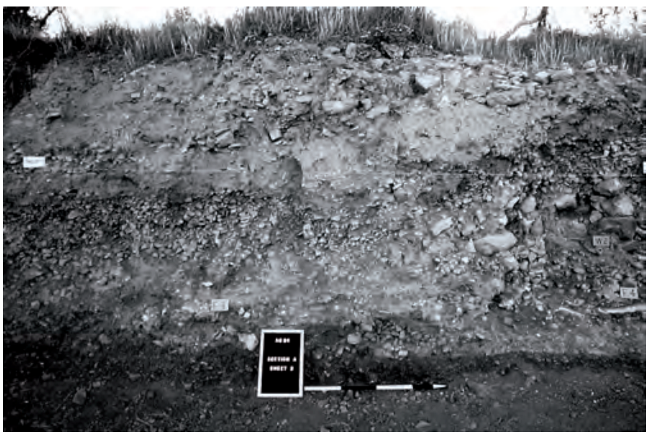

Fig. 3 Photo of a bulldozer section in the South Field *ca.* 50 m south of Fig. 2. (Photo by Curt Blair).

Fig. 4 Photo of the rubble layer in Square 4452, 15 m south of Fig. 2. (Photo by Curt Blair).

1996; Gebel 2008: 21). Fino noted three PN occupation layers (Occupations Five, Six and Seven), the last two of which, according to Kafafi, are Late Pottery Neolithic, similar to Jericho PNB for Occupation 6 and Wadi Rabah and Qatifian for Occupation Seven (Fino 1996). The older Occupation Five, on the other hand, contains dark brown friable potsherds with sand and straw temper, a sort not noted at other archaeology sites (Fino 1996).

Unfortunately, there is no published information concerning the possible presence of a rubble slide here by any of the people associated with research at the site for any of the strata (*e.g.* Waheeb 1996; Waheeb and Fino 1997; Gebel n.d.; 2008). It might be possible that debris layers of the nature of the Late Neolithic evidence at ‘Ain Ghazal, Wadi Shu‘eib, and Basta did not form at ‘Ain Jammam because of the sandstone bedrock in this area as opposed to limestone.

The slope angles at Basta were much shallower, averaging about 7-8° (Kamp 2004: Fig. 14), so “most of the drainages appear too restricted for the amount of transported flow” (Gebel 2006: 20). With debris layers as thick as they were at Basta, the energy to transport the rubble down such shallow slopes must have been tremendous and indicates that rainfall occasionally amounted to very strong cloudbursts and consequent flash flooding, as also appears to have been the case at Ba‘ja. Though there is no available published information, the slopes at Umm Meshrat I & II are as shallow as at Basta, possibly even shallower (personal observation).

Fig. 5 The bulldozer section associated with road construction at Wadi Shu‘eib. One can see at least two and perhaps three rubble layers beginning just above the head of Deborah Olszewski. (Photo: Alan Simmons).

Clearly the terrain contributed to the ferocity of the slope wash, and in the absence of steep gradients it is not surprising that prehistorians have not mentioned the presence of the rubble layer in the earliest part of the Pottery Neolithic. At Munhata, for example, Layer 3 is regarded as a period of abandonment of unknown duration (Garfinkel 1992: 16; Perrot 1964: 345). Since there was no discussion of the nature of the sediments in Layer 3 and Yarmoukian Layer 2 (*cf.* Perrot 1966), presumably there was nothing remarkable about the presence of any appreciable amount of rubble. The same topographic situation seems to pertain at sites with early PN layers, such as Tell Teo (Eisenberg *et al.* 2001) in the Hula Valley, at Yiftahel in the Lower Galilee (Braun 1997), and Sha’ar Hagolan in the Jordan Valley (*e.g.* Garfinkel and Miller 2002).

Anthropogenic Contributions to the Late Neolithic Rubble Layer

It can’t be determined on the basis of the present evidence if climate change alone could have produced the devastating avalanches of rubble around Late Neolithic settlements in the hilly countryside. Nor is it yet clear if there was only one such event, or if there were two and perhaps even more; Fig. 5, for example, indicates there were at least two and perhaps three episodes at Wadi Shu‘eib. There are, however, good grounds to assert that some and perhaps even much of the rubble slide damage was due to human overexploitation of the vicinities immediate around settlements such as ‘Ain Ghazal and Wadi Shu‘eib.

Years ago I promoted an argument for severe environmental degradation around villages during the LPPNB that may have caused the tumultuous population decrease in Jordan (and by extension, for MPPNB settlements in the Jordan Valley and Palestine) at around 8,900 cal. B.C. This argument centered on calculations of the amount of lime plaster that existed in the floors of domestic buildings throughout the southern Levant, citing data from earlier published accounts (*e.g.*, Kingery *et al.* 1988). Since then, independent assays of plaster samples from ‘Ain Ghazal house floors have shown that the original estimates of the amount of lime used in the floors was highly inflated, and that the amount of lime necessary for the floors was negligible (Affonso 1997; Telfah and Kafafi 2003). This, in turn, threw considerable doubt on the deforestation claims that were made for the production of lime and the effects this deforestation had on environmental

Fig. 6 A rubble terrace near the top of a hill in the vicinity of Mughara Wishad, not far from Kufrinja, northwestern Jordan (Photo: G. Rollefson).

degradation and settlement instability (*e.g.* Rollefson and Köhler-Rollefson 1989).

But while the effects on forest resources for lime production was insignificant, a new consideration of human impacts on stands of brush and trees has demonstrated that simple daily needs for domestic fuel (cooking, food processing, pottery production in the PN, *etc.*) had a much more devastating demand on forests than had been assumed (Rollefson and Pine n.d.). Clearance of trees and brush for fuel denuded the hillsides, and the intensive browsing by goats in the same areas prevented regrowth to protect the fragile sedimentary structures around the settlements (Köhler-Rollefson and Rollefson 1990).

When the 8.2 k.y.a. event occurred, evidently some time after the beginning of the PN period in the southern Levant, the hilly areas in highland Jordan were vulnerable to cataclysmic debris flows after a rare but destructive downpour, moving soils and rocky debris downhill with enough force to destroy buildings in some cases. This appears to be the case at ‘Ain Ghazal, although here the Yarmoukian residents rebuilt their houses and maintained their presence at the village for a considerable amount of time.

There are other examples of the potentially destructive power of heavy rains falling on a denuded landscape that includes appreciable slopes. In the hills of the Kufrinja region of northwestern Jordan, today there are high natural terraces of angular limestone rubble with very little soil or vegetation cover (Figs. 6-7). The terraces are inclined very little, not exceeding 5-6°, but this appears to have been sufficient not to move the rubble, but to remove the soil cover over it. Throughout highland Jordan, devegetation by goats (and sheep, but less affecting woody brush and trees) has been underway since the PPN period, and this could explain the presence of such rubble fields after the occasional downpour(s) during the 8.2 k.y.a. event.

Fig. 7 A rubble terrace in the same area near a suddenly steeper drop-off (Photo: G. Rollefson).

Concluding Remarks

The widespread and apparently contemporaneous occurrence of rubble layers at most known early PN settlements in the hilly areas of the southern Levant argue forcefully for a powerful phenomenon that was related to a regional agent acting on fragile landscapes. The most likely agent is the sudden and severe climatic deterioration in the last half of the 9th millennium cal. B.P.

While there may be a consensus on this aspect of the issue, much more remains to be determined. The rubble slides likely were not absolutely simultaneous, in the sense that local vagaries of weather patterns may have triggered the avalanches at different times, perhaps many years apart in various sectors of the region. It is also not clear if there was only a single rubble slide event at the sites that were affected, nor is there any reason to assume that it was a one-time affair. Instead, it is probable that denuded slopes suffered from heavy rainfall any number of times, again perhaps years apart. There is also the question of how damaging the rubble slides were in disparate localities: clearly ‘Ain Ghazal recovered from the catastrophe that assailed it, but this can’t be said with confidence about the situation at Wadi Shu‘eib, for example.

The destruction of highland settlements and farmlands immediately around them may have ushered in another massive population relocation, echoing the post-Late PPNB turbulence of the southern Levant at the beginning of the 9th millennium cal. B.P. Although there were probably several deleterious effects of the 8.2 k.y.a. event throughout the Levant, settlements in low-lying areas evidently did not have to cope with the colossal transport of rubble that affected the houses and fields of the highland populations. Is it possible, for example, that one of the reasons for the immense size of the Sha’ar Hagolan settlement could be due to the migration of residents from some of the Yarmoukian farming villages in northern and central highland Jordan?

There are several vital areas that demand more intensive investigation in the effects of the 8.2 k.a. event, and we hope to begin a two-season project at ‘Ain Ghazal to conduct microstratigraphic analysis of the Yarmoukian layers, looking for proxy evidence that will provide the means of estimating the power of the climatic-induced consequences, as well as a detailed absolute chronology of the rubble layer phenomenon at the site.

References

Affonso M.T.
1997 *Mineralogische und geochemische Untersuchungen von Kleinplastik und Baumaterialien aus dem akeramischen Neolithikum des Nahen Ostens*. Doctoral dissertation, Naturwissenschaften-Mathematischen Gesamtfakultät, Ruprecht-Karls-Universität, Heidelberg.

Barzilay E.
2003 The Geological Setting. In H. Khalaily and O. Marder, *The Neolithic Site of Abu Ghosh. The 1995 Excavations*: 3-11. Israel Antiquities Authority Reports, No. 19. Jerusalem, Israel Antiquities Authority.

Bienert H-D. and Vieweger D.
1999 Archaeological Excavations at the Late Neolithic Site of Ash-Shalaf: A Preliminary Report on the 1998 Season. *Annual of the Department of Antiquities of Jordan* 43: 49-67.

Bossut P., Kafafi Z., and Dollfus G.
1988 Khirbet ed-Darieh (Survey Site 49/WHS 524), un Nouveau Gisement Néolithique avec Céramic du Sud-Jordanie. *Paléorient* 14/1: 127-131.

Braun E.
1997 *Yiftah'el. Salvage and Rescue Excavations at a Prehistoric Village in Lower Galilee, Israel*. Israel Antiquities Authority No. 2. Jerusalem, Israel Antiquities Authority.

Cropper D., Foley C.M. and Rollefson G.O.
2003 Umm Meshrat I and II: Two Late Neolithic Sites along the Wadi ath-Thamad, Jordan. In F. Ninow (ed.), *Wort und Stein. Studien zur Theologie und Archäologie. Festschrift für Udo Worschech*: 15-32. Frankfurt am Main, Peter Lang.

Davis J., Simmons A., Mandel R., Rollefson G.O., and Kafafi Z.
n.d. A Postulated Early Holocene Summer Precipitation Episode in the Levant: Effects on Neolithic Adaptations. *Paper presented at the 55th annual meeting of the Society for American Archaeology*, Las Vegas, 1990.

Eisenberg E., Gopher A., and Greenberg R.
2001 *Tel Te'o. A Neolithic, Chalcolithic and Early Bronze Age Site in the Hula Valley*. Israel Antiquities Authority Reports 13. Jerusalem, Israel Antiquities Authority.

Farrand W.
1978 Sedimentalogical Observations at Abou Gosh. In M. Lechevallier, *Abou Gosh et Beisamoun. Deux Gisements du VII^e Millénaire avant l'Ère Chrétienne en Israel*: 91-94. Paris, Association Paléorient.

Fino N.
1996 *'Ain Jammam. An Archaeological Study*. Unpublished M.A. thesis, University of Jordan, Amman. (In Arabic)

Garfinkel Y.
1992 *The Pottery Assemblages of the Sha'ar Golan and Rabah Stages of Munhata (Israel)*. Les Cahiers du Centre de Recherche Français de Jérusalem 6. Paris, Association Paléorient.

Garfinkel Y. and Miller M.
2002 *Sha'ar Hagolan 1. Neolithic Art in Context*. Oxford, Oxbow Books.

Gebel H.G.K.
2003 Site Preservation and Site Formation Processes. In H.J. Nissen, M. Muheisen, and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 95-116. Berlin, ex oriente.
2006 The Stratigraphy and Locus Data. In H.G.K. Gebel, H.J. Nissen, and Z. Zaid (eds.), *Basta II. The Architecture and Stratigraphy*: 11-131. Berlin, ex oriente.
2008 Neolithic 'Ain Jamam near Ras an-Naqb: The Pre-1993 Field Research History. *Neo-Lithics* 1/08: 16-25.
n.d. Neolithic 'Ain Jamam near Ras an-Naqb. Observations on Site Preservation since 1986 and field operation in September 1992. Unpublished report to the Department of Antiquities of Jordan.

Gebel K.G.K. and Kinzel M.
2007 Ba'ja 2007: Crawl Spaces, Rich Room Dumps, and High Energy Events. Results of the 7th Season of Excavations. *Neo-Lithics* 1/07: 24-33.

Kafafi Z.
1988 Jebel Abu Thawwab: A Pottery Neolithic Village in North Jordan. In A. Garrard and H.G. Gebel (eds.), *The Prehistory of Jordan. The State of Research in 1986*: 451-471. BAR International Series 396. Oxford: B.A.R.
2001 *Jebel Abu Thawwab (Er-Rumman), Central Jordan. The Late Neolithic and Early Bronze Age I Occupations*. Berlin, ex oriente.

Kafafi Z. and Rollefson G.
1995 The 1994 Excavations at 'Ayn Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 39: 13-29.

Kamp U.
2004 Geomorphological Site Setting and Geochemical Results. In H. Nissen, M. Muheisen and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 53-94. Berlin, ex oriente.

Kingery W., Vandiver P., and Prickett M.
1988 The Beginnings of Pyrotechnology, Part II: Production and Use of Lime Plaster in the Pre-Pottery Neolithic of the Near East. *Journal of Field Archaeology* 15: 219-244.

Köhler-Rollefson I. and Rollefson G.
1990 The Impact of Neolithic Subsistence Strategies on the Environment: The Case of 'Ain Ghazal, Jordan. In S. Bottema *et al.* (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape*: 3-14. Rotterdam: A. Balkema.

MacDonald B.
1988 *The Wadi el Hasa Archaeological Survey 1979-1983, West-Central Jordan*. Waterloo (Ontario, Canada): Wilfred Laurier University Press.

Muheisen M., Gebel H.G., Hannss C., and Neef R.
1988 Excavations at ‚Ain Rahub, a Final Natufian and Yarmoukian Site near Irbid (1985). In A.N. Garrard and H.G. Gebel (eds.), *The Prehistory of Jordan. The State of Research in 1986*: 473-502. BAR International Series 396. Oxford: B.A.R.

Perrot J.
1964 Les deux premières campagnes de fouilles à Munhatta (1962-1963). Premières résultats. *Syria* 41: 323-345.
1966 La troisième campagne de fouilles à Munhatta (1964). *Syria* 43: 49-63.

Rollefson G.
1997 Changes in Architecture and Social Organization at ‘Ain Ghazal. In H.G.K. Gebel, Z. Kafafi and G.O. Rollefson (eds.), *Prehistory of Jordan II. Perspectives from 1997*: 287- 318. Berlin, ex oriente.
1998 ‘Ain Ghazal (Jordan): Ritual and Ceremony III. *Paléorient* 24/1: 43-58.

Rollefson G. and Kafafi Z.
1994 The 1993 Season at ‘Ain Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 38: 11-32.
1997 The 1996 Season at ‘Ayn Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 40: 27-48.

Rollefson G. and Köhler-Rollefson I.
1989 The Collapse of Early Neolithic Settlements in the Southern Levant. In I. Hershkovitz (ed.), *People and Culture in Change*: 73-90. British Archaeological Reports - International Series 508. Oxford: B.A.R.

Rollefson G. and Pine K.
n.d. *Ahlan wa Sahlan*: Measuring the Impact of LPPNB Immigration into Highland Jordan. *Studies in the History and Archaeology of Jordan 10* (in press).

Ronen A.
1971 Post-Pleistocene Stony Layers in East Mediterranean Sites. *Quartär* 22: 73-93.

Simmons A.H. , Rollefson G.O., Kafafi Z., Mandel R.D., an-Nahar M., Cooper J., Köhler-Rollefson I., and Roler Durand K.
2001 Wadi Shu‘eib, a Large Neolithic Community in Central Jordan: Final Report of Test Excavations. *Bulletin of the American Schools of Oriental Research* 321: 1-39.

Telfah J.A. and Kafafi Z.
2003 Plaster Floor Production at the Neolithic Site of Ain Ghazal, Jordan. *Mediterranean Archaeology and Archaeometry* 3(2): 53-63.

Waheeb M.
1996 Archaeological Excavations at Ras an-Naqb - ‘Aqaba Road Alignment: Preliminary Report. *Annual of the Department of Antiquities* 40: 339-348.

Waheeb M. and Fino N.
1997 ‘Ayn el-Jammam: A Neolithic Site near Ras en-Naqb, Southern Jordan. In H.G.K. Gebel, Z. Kafafi and G.O. Rollefson (eds.), *The Prehistory of Jordan II. Perspectives from 1997*: 215-219. Berlin, ex oriente.

Natural or Anthropogenic Agents? Some Examples For the Variety of Stone Surfaces in Late Prehistoric Sites in Cisjordan

Omry Barzilai Israel Antiquities Authority, Jerusalem omryster@gmail.com

Agglomerations of angular stones/cobbles mixed with archaeological finds are encountered in many late prehistoric sites within the Mediterranean woodland area in the southern Levant. In many cases these occurrences form stratigraphically defined layers that may look the same but apparently were formed by different agents (natural or human) for various reasons. In this short note we will present some examples of such occurrences from Cisjordan with respect to chronology, formation processes and functions.

Terminology

Several terms are employed in the literature for describing occurrences of stone concentrations in late prehistoric sites (*e.g.* Ronen 1971; Barzilay 2003; Goring-Morris and Horwitz 2007; Rollefson, this volume). All embrace interpretive implications since they are used for describing a specific phenomenon/activity.

For example the term "stony layers" was coined to describe post-Pleistocene rock fall layers in cave sites in the Eastern Mediterranean region (Ronen 1971). Another term, "midden", is employed for describing a layer that was formed due to repetitive waste disposals at PPNB Kfar HaHoresh (Goring-Morris *et al.* 1998:3; Goring-Morris and Horowitz 2007). "Gravel layers" is used for stone layers representing construction activities at PPNB Abu Gosh (Barzilay 2003:10). Finally, the most recent term, "rubble layers", is used for describing layers formed by natural agents noted at Yarmukian sites in the Transjordan (Rollefson, this volume).

In order to avoid confusion or any associated connotations we will employ in the paper the term 'stone surface' in a neutral sense when referring to this general phenomenon.

Chronology

Chronologically speaking, stone surfaces in Cisjordan are known from as early as the Late Epipalaeolithic (Natufian) until the end of the Chalcolithic (Ghassulian) period.

During the Natufian and PPNA stone surfaces are less common and appear only in very few sites. Natufian Eynan is one example where stone surfaces were documented throughout the site (Valla *et al.* 2001: Figs. 1-3). The stone surfaces at Eynan were divided into two types; open area surfaces representing accumulations of cooking debris and other pyrotechnological activities, and indoor surfaces that functioned as floors (Samuelian *et al.* 2006). PPNA stone surfaces (pebble pavements and fills) were reported to dominate the Khiamian layer at Hatoula (Winter and Ronen 1994:13-15). These surfaces were composed of broken cobbles displaying 'jig-saw' breakage pattern (*ibid*. Fig. 6). Although the breakage pattern of these stones suggests they derive from landslides in the vicinity of the Hatoula, their presence at the site was explained as manuports. The major argument for this explanation was the absence of such a component within the Natufian layer at the site (ibid).

Stone surfaces become a wide known phenomenon during the PPNB and PN periods, as discussed in this volume. Such were reported for many sites located in the Mediterranean woodland zone in Cisjordan (*e.g.* Rosenberg and Getzov 2006: Figs. 2-3; Barzilay 2003; Birkenfeld 2008; Getzov 2008; Barzilai *et al.,* in press). Several interpretations were proposed for these surfaces (see below) whereas their formation processes could be attributed to either natural or anthropogenic agents.

Although less reported, stone surfaces are also characteristic of the Late Pottery Neolithic (Wadi Rabah) and Chalcolithic periods in Cisjordan. Examples are the Wadi Rabah (strata VI) and middle Chalcolithic (stratum VB-C) stone surfaces at Ein Asawir and late Chalcolithic Peqi'in (Getzov 2007: Fig. 2; Yanai 2006: Figs. 2.2; 2.5; 2.6).

Formation processes and possible functions of stone surfaces

As previously mentioned there are two major causes for the formation of stone surfaces; natural and anthropogenic agents. These could be further divided into sub-types representing possible cause (natural agent) or possible functions (anthropogenic agent).

Natural Agents

Formations of stone surfaces due to natural agents include at least three types triggered by different processes. The first are surfaces which were formed as a result of "cave rock falls" (Ronen 1971:89).

Fig. 1 Natural accumulation of stones in the Jordan valley

According to Ronen their formation was accelerated in the early Holocene due to humid conditions which in turn disintegrated angular stones from cave walls, thus forming stony layers. Such stone surfaces are indeed evident at many cave sites in the Mediterranean woodland zone, but do not necessarily correspond with post-Pleistocene occupations. For example, early Epipalaeolithic occupations at Meged Rockshelter in the Upper Galilee were embedded within cave rock falls consequently forming a *ca.* 0.75-1.00 m thick layer (Kuhn *et al.* 2004:6-8).

Another type of natural agent is flash floods forming geomorphologic 'high level gravels' (Poona 1971). An example for such an accumulation can be observed where a backhoe trench dug east of the Jericho – Bet Shean road exposed a thick stony layer comprised of several horizons (Fig. 1). This differs from the cave rock falls since it is comprised of rounded cobbles and pebbles rather than angular stones. It should be noted that such natural stone surfaces could be easily confused with intentionally paved surfaces, in particular at sites located in a fluvial setting. For example, PPNA Gilgal I located in a setting of high level gravels (above Wadi Saalbiya). Still, it is quite clear that the base of the floor of house II is anthropogenic despite being made of locally available gravel and pebbles (Noy 1989:13).

The third type of natural accumulation is the 'rubble slide' which was proposed to reflect land slides in Yarmukian sites with inclined topography in Transjordan (Rollefson, this volume). These landslides were considered to be associated with rapid climatic change at 8.2 ka (Weninger, this volume). In several cases when no stone surfaces were noted (*e.g.* Shaar Hagolan), their absence was explained by the location of the site in an area with a flat topography (the Central Jordan Valley). Still, if the Yarmukian stone surfaces were indeed the outcome of land slides we should expect no surfaces at other sites located in a flat topography. However, this is not the case at Yarmukian Ard el Samra in the Akko Plain (Barzilai *et al.* in press; Getzov *et al.* in press) where an extremely thick stone surfaces were recorded (Fig. 2).

Anthropogenic agents

At least four classes of anthropogenic agents could have formed the Neolithic stone surfaces: construction, waste disposals, cooking and intentional covering.

Construction activities including ground leveling and floor making were proposed to form the stone surfaces at PPNB Abu Gosh (Barzilay 2003:10). These surfaces were found to be restricted to the settlement while none were evident in other areas around the site, thus verifying that these were indeed anthropogenic (ibid). A similar explanation was also suggested for the PPNC stone surfaces at Hagoshrim VI in the Hula Basin (Getzov 2008).

Another type of anthropogenic behavior that is

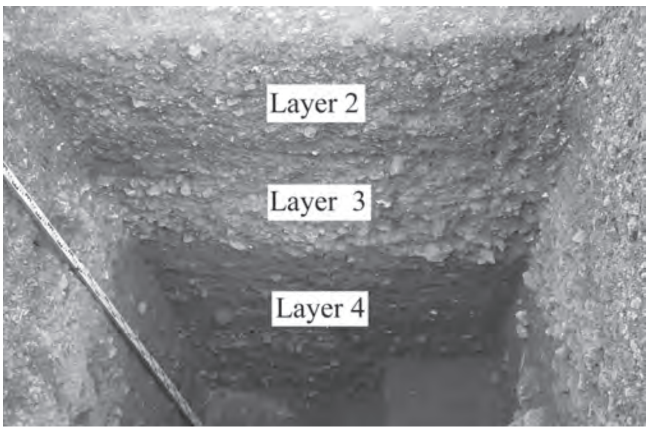

Fig. 2 Yarmukian stone surface at Ard el Samra

Fig. 3 Cooking pit filled with stones at Yarmukian Mishmar Ha'emeq

responsible for formation of stony surfaces is waste disposal. Such was noted at PPNB Kfar Hahoresh where a thick layer at the southern and western parts of the site was recorded (Goring-Morris and Horwitz 2007: Fig. 2). This dump layer consisted of accumulations of burnt stones, flint artifacts and animal bones that were proposed to represent waste disposals of feasting activities at the site (*ibid*., Fig.5).

The third type of stone surfaces made by human agents is cooking installations that make use of hot rocks (Thoms 2009). The archaeological remains of such technique usually comprise a pit filled with stones (*ibid.,* Fig. 5). A possible example for such an installation was recorded recently at the Yarmukian occupation at Mishmar Haemeq (Barzilai and Getzov 2008). Here a pit was hewed into the volcanic rock was filled with angular stones (Fig. 3). Although this feature does not exactly fit the definition of a stone surface, we should be aware that such pit installations could be the sources of dump layers.

Another cooking facility is the open oven hearths that result in many fire-cracked stones (Thoms 2008). It is noted that a repetitive use of such hearths in the same location could result in an accumulation of stones which consequently creates such a stone surface (Fig. 4).

The last proposed type is intentional coverage of architecture, in particular unique Neolithic structures which were reported to have been intentionally buried (Verhoeven 2002). One example is the „Schlangenpfeilergebäude" structure from Göbekli Tepe, dated to the EPPNB (Schmidt 2000:4). From aerial photographs one can recognize a fill of angular stones that could fit the definition of stony layer in the bottom right corner of the square (*ibid*., Fig. 2). In the southern Levant, such a phenomenon was observed in the flagstone structure at Mishmar Haemeq (Barzilai and Getzov 2008). This structure was covered by a thin layer, *ca.* 20-40 cm thick, characterized by angular stones mixed with flint items, bones and other fragmented finds (Fig. 5). Notably the stone surface was set directly on the structure while the perimeters of the building were not covered at all.

Fig. 4 Remains of a hearth with fire cracked stones at chalcolithic Nahal Secher XXIV in the Negev

Concluding remarks

The examples presented above show a wide variety of stone surfaces that could result from natural or human agents caused by various factors or intended for

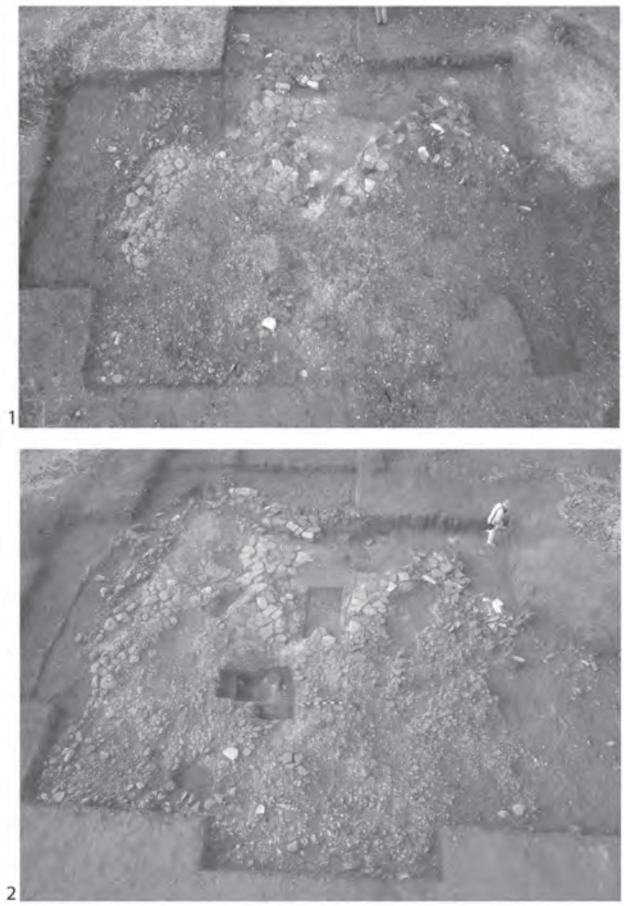

Fig. 5 The PPNB flagstone structure at Mishmar Haemeq, a view to south-west. 1: early stage in exposing the structure. Note a stone surface covering the northern and eastern parts of the structure. 2: a later stage in the excavation. Note that the sediments beyond the western and southern perimeters are free of angular stones

different functions. As for us, the archaeologists in the field, we are expected to record such occurrences and attempt to seek the origins of these stones.

In order to identify surfaces caused by natural agents we need to observe the surroundings of the site and conduct a geomorphology study. As previously noted we should expect to find such surfaces associated with climatic events as proposed by Bernard (this volume) and Ronen (1971). However we should bear in mind that not all rock fall layers in caves were formed before the Holocene (*e.g.* Kuhn *et al.* 2004) or that some stone surfaces at the Yarmukian sites (*e.g.* Ard el Samra) could not be a result of rubble slides since they are located on an alluvial plain.

The anthropogenic agents are diversified and may result from construction, waste disposal, cooking and intentional covering activities. Within the anthropogenic surfaces we should look for direct evidence. For example, accumulation of cooking stones should bear burning signs such as fire cracks, or architectural elements should show clear delimitations such as walls or plaster remains. What is striking is that it appears that anthropogenic surfaces are much more common in the PPNB and early PN periods. To my mind they are associated with early sedentism, and it should be regarded as one of the parameters that we should consider in order to comprehend the duration of occupations in archaeological sites. Still one must explain why these surfaces are not as common in later urban settlements. It is possible that they reflect changes in cooking technologies, construction, and ritual believes but such issues still await further investigation.

Acknowledgements: Thanks to Ariel Malinski Buller and Samuel Wolff for their editorial comments.

References

Barzilai O., Le Dosseur G., Eirikh-Rose A., Katlav I., Marom N. and Milevski I.
in press Ainʽ Hamifratz (Ard el Samra): A Neolithic-Chalcolithic Site Complex in the Acre Plain, Israel. *Hadashot Arkeologiot* 122.

Barzilai O. and Getzov N.
2008 Mishmar Haʽemeq: A Neolithic Site in the Jezreel Valley. *Neo-Lithics* 2/08:12-17.

Barzilay E.
2003 The Geological Setting. In H. Khalaily and O. Marder (eds.) *The Neolithic Site of Abu Ghosh: The 1995 Excavations. IAA Reports* 19:3-11. Jerusalem: Israel Antiquities Authority.

Birkenfeld M.
2008 *Aspects of Time and Space at the Early Neolithic Site of Kfar HaHoresh-A GIS based Stratigraphical and Spatial Analysis*, M.A. thesis, The Hebrew University. Jerusalem.

Getzov N.
2007 A Late Chalcolithic and Early Bronze Age Settlement at Peqi'in, in Upper Galilee. *'Atiqot* 56:1-12. (in Hebrew).
2008 Ha-Goshrim. In E. Stern (ed.) *The New Encyclopedia of Archaeological Excavations in the Holy Land* 5: 1759-1761. Jerusalem and Washington, D.C.: Israel Exploration Society and Biblical Archaeology Society.

Getzov N., Barzilai O., Le Dosseur G., Eirikh-Rose A., Katlav I., Marder O., Marom N. and Milevski I.
in press Nahal Bezet II and Ard el Samra: Two Late Prehistoric Sites and Settlement Patterns in the Akko Plain. *Mitekufat Haeven* 39.

Goring-Morris A. N., Burns R., Davidzon A., Eshed V., Goren Y., Hershkovitz I., Kangas S. and Kelecevic J.
1998 The 1997 Season of Excavations at the Mortuary Site of Kfar HaHoresh, Galilee, Israel. *Neo-Lithics* 1998/3: 1-4.

Goring-Morris A. N. and Horwitz L. K.
2007 Funerals and Feasts during the Pre-Pottery Neolithic B of the Near East. *Antiquity* 81: 1-17.

Kuhn S.L., Belfer-Cohen A., Barzilai O., Stiner M.C., Kerry K., Munro N. and Mayer Bar-Yosef D.
2004 The Last Glacial Maximum at Meged Rockshelter, Upper Galilee, Israel. *Journal of the Israel Prehistory Society* 34:5-47.

Noy T.
1989 Gilgal I : A Pre-Pottery Neolithic Site, Israel. The 1985-1987 seasons. *Paléorient* 15/1: 11-18.

Poona K. P.
1971 High Level Gravels and Related Palaeolithic Sites of Shorapur Doab, Peninsula India. *Quartär* 22: 95-110.

Ronen A.
1971 Post-Pleistocene Stony Layers in East Mediterranean Sites. *Quartär* 22:73-93.

Rosenberg D. and Getzov N.
2006 A Basalt Chipping Floor from Level VI (PPNC) at Hagoshrim. Mitekufat Haeven. *Journal of The Israel Prehistoric Society* 36:117-128.

Samuelian N., Khalaily H. and Valla F.
2006 Final Natufian architecture at 'Eynan ('Ain Mallaha). Approaching the diversity behind the uniformity. In E. B. Banning and M. Chazan (eds.), *Domesticating Space. Construction, Community, and Cosmology in the Late Prehistoric Near East*: 35-42, Berlin: exoriente.

Schmidt K.
2000 Göbekli Tepe, Southeastern Turkey. A preliminary report on the 1995–1999 excavations. *Paléorient* 26/1: 45-54.

Thoms A.V.
2008 The fire stones carry: ethnographic records and archaeological expectations for hot-rock cookery in western North America. *Journal of Anthropological Archaeology* 27: 443-460.
2009 Rocks of ages: propagation of hot-rock cookery in western North America. *Journal of Archaeological Science* 36: 573-591.

Valla F.R., Khalaily H., Samuelian N., March R., Bocquentin F., Valentin B., Marder O., Rabinovich R., Le Dosseur G., Dubreuil L. and Belfer-Cohen A.
2001 Le Natoufien final de Mallaha (Eynan), deuxième rapport préliminaire: les fouilles de 1998 et 1999. *Mitekufat Haeven* 31:43-184.

Winter Y. E. and Ronen A.
1994 The Geomorphological and Geological Setting. In M. Lechevallier and A. Ronen (eds.) *Le gisement de Hatoula en Judée Occidentale, Israël*: 5-16. Mémoires et Travaux du Centre de Recherche Français de Jerusalem 8. Paris: Association Paléorient.

Verhoeven M.
2002 Ritual and Ideology in the Pre-Pottery Neolithic B of the Levant and southeast Anatolia. *Cambridge Archaeological Journal* 12/2: 233-258.

Yannai E.
2006 *'En Esur ('Ein Asawir) I Excavations at a Protohistoric Site in the Coastal Plain of Israel*. IAA Reports 31. Jerusalem: Israel Antiquities Authority.

Environment and Architectural Change at the Neolithic Site of ‘Ain Ghazal

Zeidan Kafafi Yarmouk University, Irbid zeidank@yahoo.com
Bernhard Lucke Brandenburg University of Technology, Cottbus lucke@tu-cottbus.de
Rupert Bäumler Friedrich-Alexander University, Erlangen-Nürnberg baeumler@geographie.uni-erlangen.de

Introduction

‘Ain Ghazal is a large permanent farming Neolithic settlement on the main highway leading from the capital Amman to the city of al-Zarqa to the east. The material culture uncovered at the site greatly increased our understanding of how human society affected and interacted with the environment in the southern Levant (Rollefson and Kafafi 2007).

The site can be singled out of the other Neolithic settlements in the area because it was continuously occupied for over 2,500 years (from *ca.* 9,250-6,500 uncal. B.P.). This provides the first opportunity to examine a permanent farming settlement during this period of time. Also, the site yielded one of the richest arrays of Neolithic data - particularly the human statue and bust collections and different types of domestic and ritual buildings. This includes material from the transition from the Pre-Pottery Neolithic B to the Pre-Pottery Neolithic C and another *in situ* transition from the aceramic to the early Pottery Neolithic. Last but not least, the site occupied a very large area (*ca.* 14 ha) when it reached its climax by the end of the seventh and the beginning of the sixth millennia uncal. B.C. (Rollefson *et al.* 1992).

The site of ‘Ain Ghazal was initially discovered during bulldozing operations of opening the Amman-Zarqa highway in 1974. Unfortunately, systematic archaeological investigations started only eight years after the discovery. The project started as a rescue excavation in 1982, and the team headed by Gary Rollefson and funded by the Department of Antiquities of Jordan gave priority towards rescuing the most endangered areas located just directly to the west of the highway.

The archaeological excavations conducted in the seasons of 1992-1998 concentrated on other areas of ‘Ain Ghazal, including its fringes (Rollefson *et al.* 1990; Rollefson and Kafafi 1993; Kafafi and Rollefson 1995). Test probes at the edges of ‘Ain Ghazal demonstrated its enormous size, but more importantly, we also learned much more of its “dual” nature. Traces of Neolithic occupation were excavated at the eastern part of the site, which included stone alignments that suggested very long walls that had not been seen in the main site to the west. The excavators announced that the material from the earliest occupation of this Eastern Field (*ca.* 9,500 years ago) does not provide much information of daily life. 9,300 years ago this part of ‘Ain Ghazal appears to have been a sector that was involved in communal ritual observances (Rollefson and Kafafi 2007).

Stratigraphy and Chronology

Archaeologists researching archaeological sites follow two ways in understanding the stratigraphy of the archaeological sites. The first one is the vertical stratigraphy, which is represented by the successive accumulation of deposits over earlier strata. And second, the horizontal stratigraphy that shows the real expansion of deposits through time. The backbone of this study is interpreting and understanding the distribution of the architectural remains through time and the effect of environmental change as reflected by the appearance of a gravelly layer which spread all over the site.

It is important to mention that the horizontal stratigraphy of ‘Ain Ghazal is strongly affected by post-depositional disturbances, ancient and modern (agricultural ploughing and terracing, railway, sewage station, the highway, bulldozing a park area for cars, and the modern buildings). Despite the large bulldozed portions of most of the northern area of the site and parts of the stream banks of the Zarqa River, the excavated archaeological remains and the radiometric data indicate that the site started as a small village *ca.* 10,250 years ago. It reached a size of 4 - 5 hectares by about 9,500 cal. B.P.. The latter date marks the emergence of the Late Pre-Pottery Neolithic B (LPPNB) cultural phase, but also with a remarkable and evidently sudden expansion of the site, which nearly doubled within a century or two, including the founding of the eastern enclave across the Zarqa River (Rollefson *et al.* 1992).

The site continued to grow during the Late PPNB phase, reaching perhaps 10 hectares by the end of the 8th millennium uncal. B.C. However, the archaeological excavations conducted at the site during the 90ties proved that the East Field was not occupied during the Pre-Pottery Neolithic C. This claim may indicate that the size of the site collapsed greatly during this period. Thus it must be mentioned that this interpretation may contradict what was published earlier (Rollefson *et al.* 1992: 446). But the spaces between houses also appear to have increased, suggesting that a population plateau was reached, and perhaps not exceeding the LPPNB maximum of about 2,500 inhabitants.

Archaeological remains belonging to the Pottery Neolithic were excavated at several parts of the site, particularly the Central Field and the South Field. Architectural remains belonging to this culture were built directly over the PPNC ones or even reused those from earlier periods. No structures or pottery sherds were encountered at both the North and the East Fields, but in a sounding trench excavated in 1988/1989 at the westernmost limits of the settlement (Square 7876) Yarmoukian pottery sherds were excavated.

It is clear that the MPPNB deposits at the site spanned a depth to *ca.* 3 m in some parts of the settlement. The situation of the LPPNB was clarified by the excavations in the Northern and Eastern Fields of the site. They were mostly built either over the bedrock (the case of the East Field) or overlie a *terra rossa* (virgin-soil) (in the North Field). However, it appears at some places that there are 2 m of deposits of this period.

In the process of building structures during the PPNC, at least some excavation activities into underlying LPPNB or even MPPNB deposits took place (particularly in the South Field). Furthermore, it appears that the PPNC inhabitants at least occasionally incorporated still standing earlier structures into their own housing designs. The PPNC deposits accumulate at some places to over 1.5 m.

The inhabitants of the following period, the Yarmoukians (Pottery Neolithic), built houses with courtyards including all facilities needed for daily life as documented in the Central Field and South Field. They partially constructed new houses and partially reused the PPNC and even the PPNB structures. In average, the Yarmoukian deposits exceed 1.5 m in the South Field.

After the site had been abandoned around 5,500 cal. B.C., people returned during the Early Bronze Age I to the most southern edge of the region of the site (Petocz 1987). The inspections of the caves located on the most higher part of the East Field produced archaeological remains dated to the Early Bronze Age IV (Rollefson and Kafafi 2000). Moreover, Byzantine and Islamic pottery sherds were collected from the top and higher part of the western side of the site (Simmons and Kafafi 1988).

With regard to the absolute chronology, a number of radiocarbon dates were obtained from the Pre-Pottery Neolithic levels. But unfortunately none was collected from the Pottery due to a lack of samples sufficient for normal assaying. A rejected one obtained from the South Field, Square 4655 Locus 015 ranged from 930 ± 95 uncal. B.C. “uncalibrated” (Rollefson *et al.* 1992).

Environment and Architecture at ‘Ain Ghazal

Middle PPNB Structures (ca. 8,250 – 7,500 cal. B.C.)

The earliest houses excavated at the site of ‘Ain Ghazal are dated to the Middle Pre-Pottery Neolithic B and were excavated in the Central Field and South Field (later to be re-used during the PPNC period) in an area located close to the running water of the Wadi al-Zarqa. The houses were individual rectangular structures covering areas of 40 - 50 m^2, constructed directly on top of a virgin *terra rossa*.

They have mostly red painted plastered floors and very large central post-holes (*ca.* 60 cm in diameter) dug into the floors, so it seems that the roofs were supported by huge posts. This type of house is attributed to the beginning of the MPPNB period. Through time, the single-room type was replaced with two to three-roomed houses and the wooden posts were increasingly replaced by stone pillars or “piers”.

By the end of the MPPNB at ‘Ain Ghazal, the diameter of the exposed post-holes rarely exceeded 15 cm, and they were dug or arranged along the wall lines. In some cases there were post-holes of less than 10 cm diameters at the corners of the multi-roomed houses. These locations may have served as loom areas or for storage facilities. The walls were constructed of stone boulders. Their plastered floors were decorated with the application of pigment, some had finger-painted designs. The presence of a circular hearth in the centre of the house was evident.

Late PPNB Structures (ca. 7,500-7,000 cal. B.C.)

The Late PPNB is known as the mega-site phenomenon, an era in which several large sites with complex social forms arose. Most of all excavated sites belonging to this phase cover at least 10 hectares and are found in central and south Jordan. Late Pre-Pottery Neolithic B architecture represents the cellular type known from many sites in Jordan (*ca.* 7,500-7,000 cal. B.C.). Typical is the use of sub-floor structures, channel-like features which were found at several LPPNB sites in Jordan (especially in the south such as Basta and as-Sifiya).

Most if not all the excavated LPPNB sites in the south of Jordan used the same building techniques: naturally occurring rectangular slabs were picked up and built into walls using clay mortar and wedge stones.

Remarkably, the inhabitants found themselves obliged to build their structures at places located far away from the rivers and wadis. At ‘Ain Ghazal, it

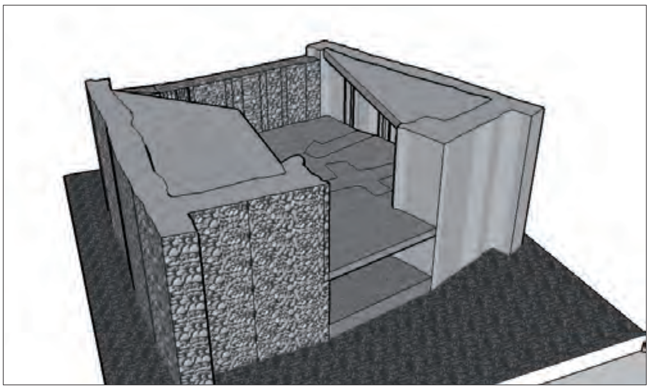

Fig. 1 A reconstruction of the LPPNB major building excavated in the North Field (drawn by Ali Omari)

must be mentioned that most if not all of the excavated LPPNB buildings (Fig. V) were constructed at some elevations on the slopes (the North Field and East Field), far from water courses. It should be noted that the LPPNB settlers of ‘Ain Ghazal never re-used the MPPNB architectural remains. In contrast, those were re-used by the PPNC and Pottery Neolithic (PN) inhabitants of the site.

PPNC structures (ca. 7,000 – 6,500 cal. B.C.)

Most of the sites excavated in Palestine and the south of Jordan were abandoned around 500 years after the end of the LPPNB (*ca.* 7,000-6,500 cal. B.C.). This was different at the sites of ‘Ain Ghazal and Wadi Shu‘eib where excavators noticed a continuation of occupation (referred to as the Pre-Pottery Neolithic C), but the archaeological material and the economic background were completely different from the LPPNB.

During the first half of the seventh millennium cal. B.C., the occupants of ‘Ain Ghazal had either reused the Pre-Pottery Neolithic B structures or built new buildings, which later became completely covered with a gravel layer of small stones. The LPPNB two-level building style was abandoned and replaced by single room houses or by a type of corridor building that consisted of very small rooms carrying another storey (perhaps consisting of a cottage, tent, or a large room).

Continuity from the Pre-Pottery Neolithic C (*ca.* 7,000-6,500 cal. B.C.) to the Pottery Neolithic (*ca.* 6,500 – 5,500 BC) is very obvious in the Central Field at ‘Ain Ghazal. A rectangular building consisting of one rectangular room measuring 4 x 3 m was excavated, which was constructed with small and medium stones and had a floor composed of dirt. This structure was built during the PPNC and continuously used into the Pottery Neolithic (Yarmoukian), which is demonstrated by several Yarmoukian pottery sherds found directly on the floor of the house.

Remains of the corridor-building style were excavated at ‘Ain Ghazal (Fig. 2) and Beidha. The room size changed little compared to the LPPNB; they were very small and separated by a central corridor leading from the front entrance to the back wall. The only completely exposed PPNC structure excavated at ‘Ain Ghazal measures 3.5 x 3.5 m and is semi-subterranean with very small cells separated by thick walls that perhaps supported an upper storey of unknown character.

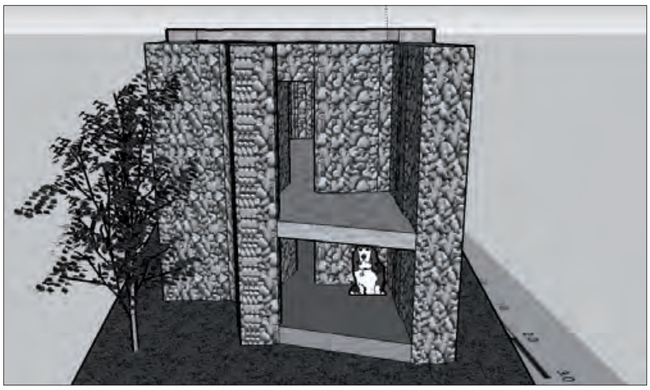

Fig. 2 A reconstruction of a PPNC building excavated in the South Field of ‘Ain Ghazal (Drawn by Ali Omari)

The environment and architecture during the PPNC can be summarized as follows:

During the first half of the seventh millennium BC people continued to build upon sub-floor channels for corridor buildings.

Houses moved back to the close vicinity of running-water, located in the same areas as during the MPPNB. This indicates that the inhabitants did not fear flash floods.

Two level-houses (corridor-buildings of diminutive size) continued to be built, but single-storey structures were also encountered.

Finely painted plastered floors similar to the MPPNB and LPPNB were no longer made, but very crude and thick plaster appeared.

Some of the MPPNB structures were re-used.

Pottery Neolithic Structures (ca. 6,500 - 5,500 cal. B.C.)

Unfortunately, representative architectural remains belonging to the Pottery Neolithic are only available from the Yarmoukian layers (*ca.* 6,500 – 5,500 BC), as the evidence from (other Pottery Neolithic sub-phases) consists either of a small exposures of houses or dwelling pits.

The excavated houses at the sites of ‘Ain Ghazal and Abu Thawwab in central Jordan were built of stones that stood above ground level and had either hard beaten earth floors or very crude and badly made *huwwar* plasters. The various architectural styles recognized in Jordan are rectangular, apsidal and curvilinear in plan (Kafafi 1993).

Several sites belonging to the second half of the seventh millennium and to the first half of the sixth millennium were excavated all over Jordan. Structural remains have also been found in the *badia*, the mountains, and the Jordan Valley regions. They were constructed either very close to perennial water sources or in the valley bottoms. At ‘Ain Ghazal the inhabitants continued to live in the areas where their predecessors had lived.

Did the “Yarmoukian Landslides” or a LPPNB Natural Catastrophe Determine the Settlement History at ‘Ain Ghazal?

While analyzing the excavated pottery sherds excavated at several Yarmoukian sites in Jordan such as ‘Ain Rahub and ‘Ain Ghazal, Z. Kafafi (1989; 1990) noticed that the pieces were covered with a thick and hard layer of calcreted soil. He added that this cement-like layer covering the surfaces of the clay pots may have resulted from a natural cause. However, Kafafi (2001; 2004) proposed that a natural catastrophe may have been the reason behind the destruction of the LPPNB culture.

Weninger *et al.* (2005) noted that most sites in the

Eastern Mediterranean belonging to the Yarmoukian culture were covered by huge rubble deposits. Although some uncertainties related to the calibration remain, it seems possible that these rubbles were laid down nearly simultaneously, which coined the term “Yarmoukian Landslides”. According to Migowski *et al.* (2004), the period 8,000-5,500 BC was seismically quiet, although some bias in the accuracy of the evaluated Dead Sea core’s bottom levels might influence this picture. If no earthquake took place, an alternative explanation for the deposition of rubble slides could be extremely heavy rainfall events. Such events could have been triggered by an extraterrestrial impact: Elias Salameh and his team recently discovered a meteorite crater in the area of Waqf es-Suwwan in the Jordanian desert. They think that the meteorite impact affected the whole Eastern Mediterranean, and might have taken place during the Early Holocene (Salameh *et al.* 2008; Elias Salameh, pers. comm., January 2009). However, Salameh and his team did not give the exact dates of this meteorite yet.

If heavy rains affected the LPPBN settlement at ‘Ain Ghazal, this might explain why:

LPPNB structures were built in places that will never be reached by a flood or high water.

LPPNB houses were built on very steep slopes.

A net of sub-floor channels and cells was built beneath the buildings, draining excess water and reducing humidity. Some of the MPPNB buildings were re-used during the PPNC (South Field) after adding very thick walls in the inside of this house consisting small cells, which may were used as a first level. It should be made clear that there is no evidence of using subfloor channels at ‘Ain Ghazal during the LPPNB.

LPPNB sites were not found in the Jordan Valley and the *badia*, which would be more strongly affected by such a disaster.

Soils and Sediments at ‘Ain Ghazal as Markers for Environmental Change [1]

In order to check the hypothesis that environmental change affected the settlement history of ‘Ain Ghazal, a small number of soil samples was collected in the South Field and Central Field from the virgin soil under the earliest MPPNB structures and a few soil and sediment layers of later settlement periods, until the “Yarmoukian Landslides”. In the South Field, the profile showed how a red soil or soil sediment (*terra rossa*) had been covered by grayish calcareous sediments of *ca.* 50 cm depth. The profile seems to turn gradually red within the covering 100 cm until the upper part exhibits clay cutans and a prismatic structure, but no secondary carbonates. Bands of flint debris and cultural material are present as well. It should be mentioned that both the cultural material and the grey sediments seem oriented along the course of the wadi as if fluvial processes led to their deposition (Fig. 3). However, gravels as

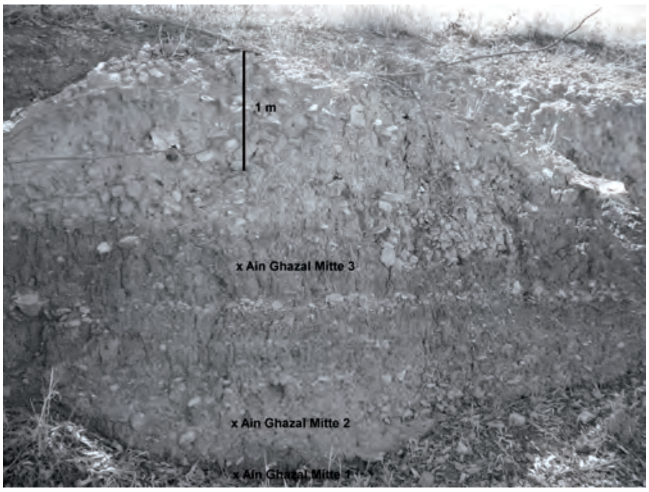

Fig. 3 The sampled profile in the South Field. Note that the lower *terra rossa* is covered by slope collapse and barely visible

indicators of floods are missing, and old occupation levels might look like fluvial layers, especially if they consist of thin bands of cultural debris as in the case of ‘Ain Ghazal. For now it can be said that all examined elongated rectangular stones were oriented along the course of the wadi, which points to fluvial action, but the number of samples was very small.

In this profile, the upper red soil of unknown age is capped by a grey top layer of *ca.* 150 cm rubble, which consists of undressed stones of more or less similar appearance and size (diameter ~10 cm). In contrast to the lower sediments, there is no orientation visible. It gives the impression of a major destructive event, *e.g.* a slope collapse or earthquake. *We think that* the very similar size of the rubble stones points towards the remains of man-made structures[2]. In the South Field, samples were taken from upper 10 cm of the lower *terra rossa* (sample ‘Ain Ghazal Mitte 1), the centre of the grey sediments covering it (‘Ain Ghazal Mitte 2), and the top 10 cm of the upper *terra rossa* (‘Ain Ghazal Mitte 3), in order to check whether the colour change is related to soil-formation processes, cultural material, or sedimentation, and to understand possible connected

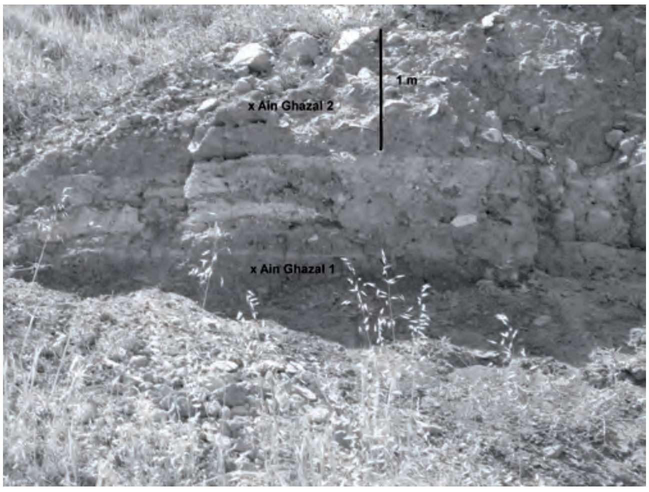

Fig. 4 The sampled profile in the Central Field

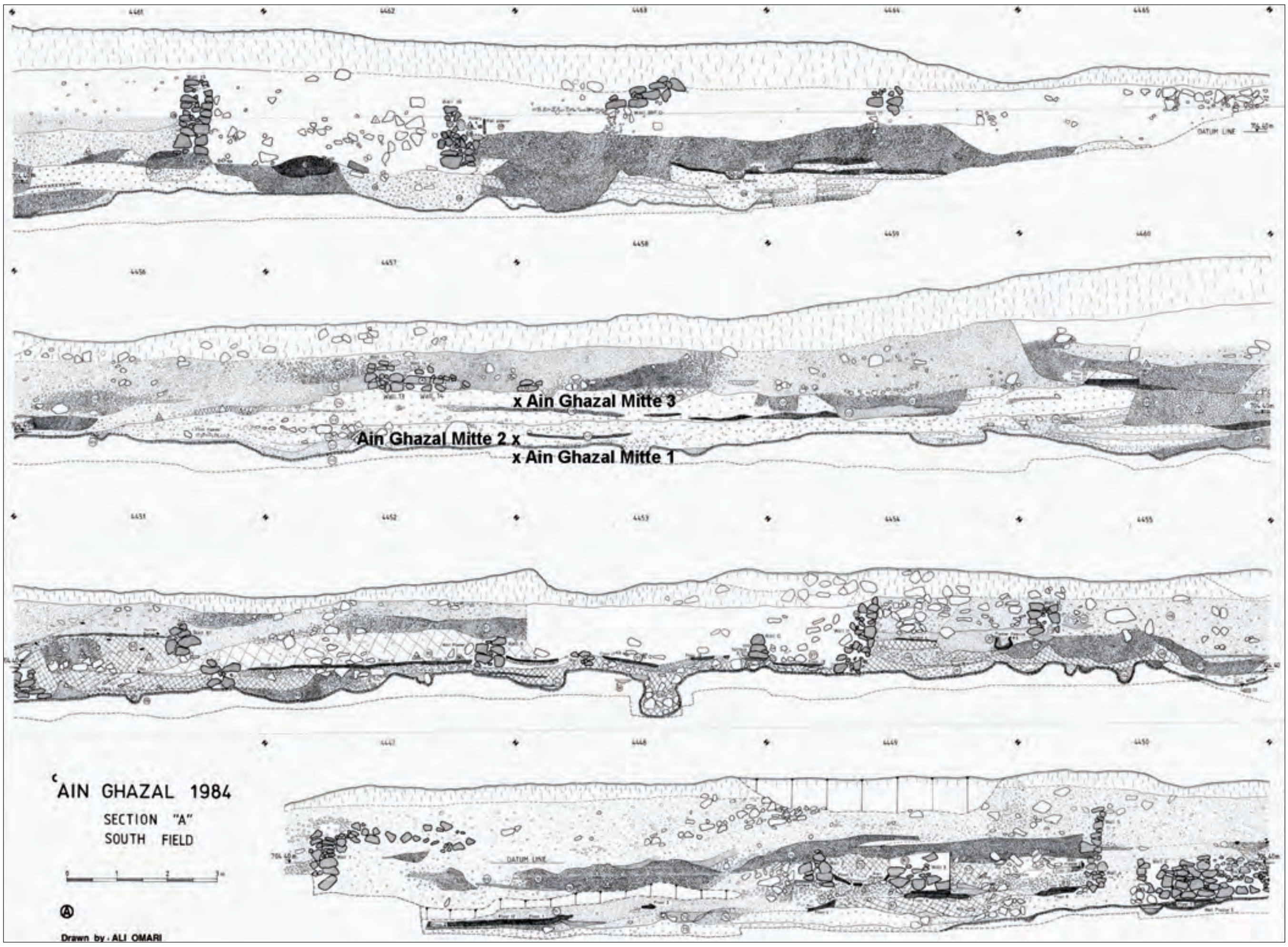

Fig. 5 Approximate location of the sampled profile in the South Field on the profile plan drawn in 1984

environmental changes and their processes at the site.

In the Central Field, the floor of a MPPNB house was built over a *terra rossa*, and covered by the “Yarmoukian Landslide” rubble (Fig. 4). This place is close to the area where the famous plaster figures were found. According to the excavators, the floor of the MPPNB house belongs to the oldest settlement at ‘Ain Ghazal. Samples were taken from the *terra rossa* (sample ‘Ain Ghazal 1) and the debris on top (‘Ain Ghazal 2).

We marked the sampled layers in the profile sheets drawn in 1984 (Figs. 5 and 6), but some probability of error remains since parts of the profiles have collapsed. Everywhere, the lower part of the profiles was obscured by debris and it is not possible to say whether other debris layers and soils can be found at deeper levels since bedrock was not reached during the excavations. Although the stratigraphic context is not yet completely clear we conducted the sampling in order to achieve a basic understanding of soils and sediments at ‘Ain Ghazal and to approach two questions:

1. The gradual increase of redness of the upper Terra rossa in the South Field could be due to an increasing share of red soil sediments, or because of *in situ* rubefaction. If the latter proves true, it would be the youngest and only example of *in situ terra rossa* formation at an archaeological site. The *terra rossas* in Jordan are usually considered as Pleistocene soil formations (Nowell *et al.* 2003, Lucke 2008), and all other occurrences of red soil at archaeological sites in Jordan have so far proven to be mudbrick or sediment (Lucke *et al.* 2005, 2008).
2. Soil properties might allow grouping of the examined layers, and provide clues about the origin of their parent material and sedimentation processes.

Results of Soil Analysis

The results of soil analysis are summarized in Table 1. The first parameter catching attention is the very high conductivity values. Such high numbers in a *terra rossa* are usually only reached in remains of mudbrick, when soil was mixed with dung for the construction of bricks (Lucke 2008). However, there is no indication that the *terra rossa* found at ‘Ain Ghazal is from the remains of mudbrick. There is also no indication for remains of garbage with elevated organic matter contents. If the red soil is the remains of mudbrick, the buildings were large to create such an amount of soil. It also underwent substantial soil genesis after disintegration

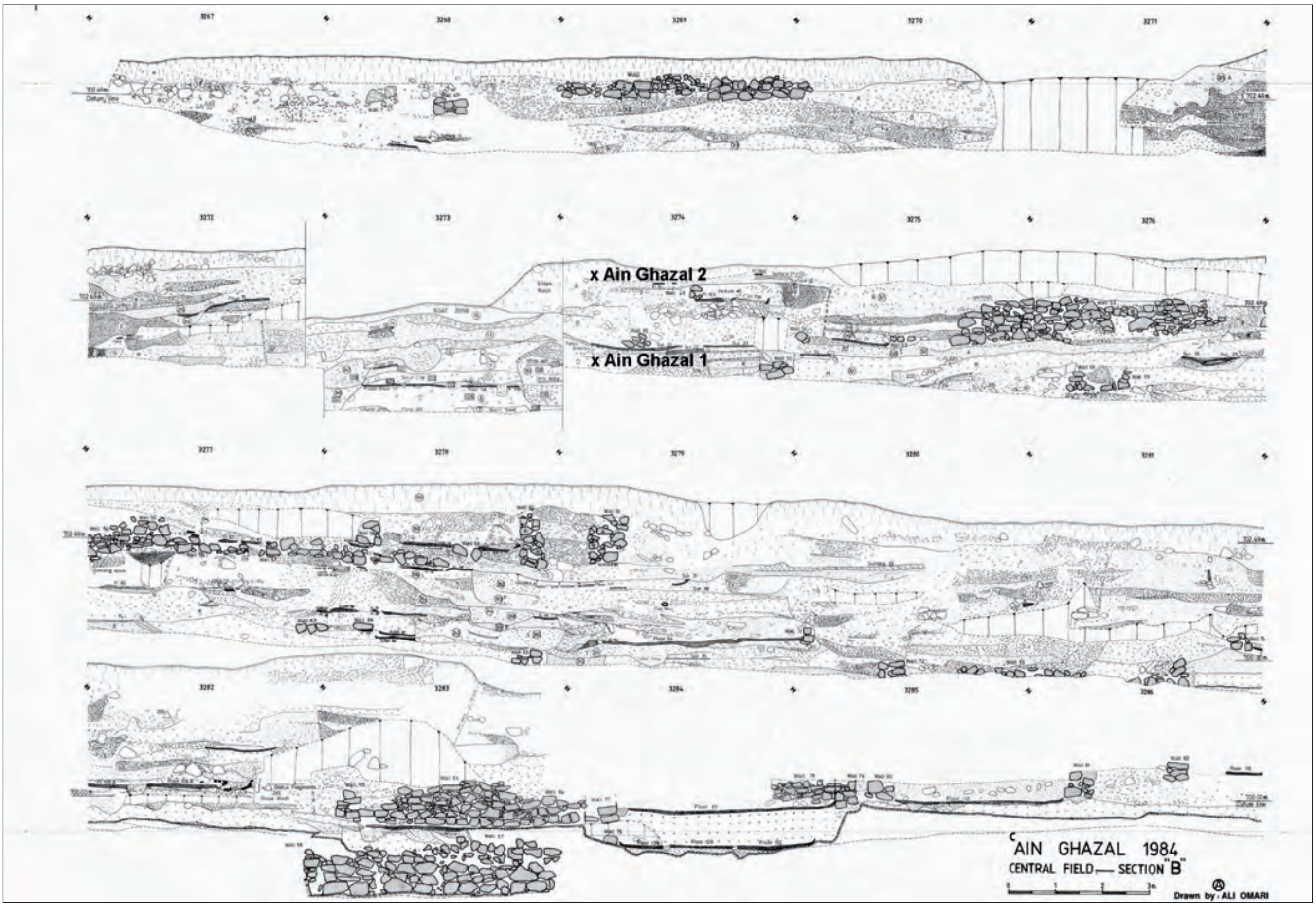

Fig. 6 Approximate location of the sampled profile in the Central Field on the profile plan drawn in 1984

of the bricks which led to the formation of clay cutans and a prismatic structure. This would finally imply that the mudbrick buildings pre-dated the MPPNB floors, which is not supported by the excavations.

Therefore another explanation is sought, which can only be irrigation – or some kind of ponding in a natural environment. As planned irrigation is unlikely for the MPPNB, we assume that the valley was subject to periodic waterlogging, possibly connected with a muddy creek and valley fill as can today be found *e.g.* in Wadi Queilbeh in the north of Jordan. A high groundwater table and winter rains might have created a marshy, pond-rich floodplain in winter which dried out during summer. It is important to note that the area where ‘Ain Ghazal was located must have been out of reach of winter floods, which would otherwise have washed out the salts. In this context, other soil analyses from northern Jordan indicate that high salt content in *terra rossa* soils are not quickly washed out, even if relict mudbrick is exposed for some decades to the present semi-arid conditions (Lucke 2008).

In this context, the silt contents of the examined red soils are remarkably high. Silt values of 35% and more after removal of $CaCO_3$ were reached in other *terra rossa*s only under a loess cover or the influence of debris (the high clay values of the debris layers can be explained by the residue of the calcareous material after treatment with HCl). However, debris is usually associated with calcium carbonate contents of 30% and more. Compared to the texture, the soil development indices of the *terra rossa*s at ‘Ain Ghazal are remarkably high, which is in agreement with the prismatic structure and clay cutans. But even the sand contents are comparably high. Putting these parameters together, they indicate that silt and sand were deposited during pedogenesis. This could have taken place from the air, especially as ‘Ain Ghazal is located near the steppe areas which are covered by loess (Cordova 2007). However, in the light of the ponding theory described above, the silt could be the result from fluvial deposition. In the light of this, and in combination with the relatively low $CaCO_3$-values, it seems that the theory of *in situ* soil formation on the debris flow (‘Ain Ghazal Mitte 2) is correct – but which might have taken place during periodic ponding with sediment deposition. However, this does not necessarily mean that the occurrence of red colour is due to soil development. Up to now, *terrae rossae* in Jordan could not be related to the Holocene (Lucke 2008), but were dated to the Middle Pleistocene (Novell *et al.* 2003). Only additional analyses, including thin sections, can clarify whether the red colour is due to *in situ* formation of hematite or an increasing share of red soil sediments, possibly due to a reduced flow of the river and prolonged ponding, which allowed an increasing share of clay-sized sediments to settle. The reduced hydrological and sedimentation activity could also explain the development of clay cutans and

Sample No.	RR (dry)	C_{org} %	$CaCO_3$ %	Fe_o [mg/g]	Fe_d [mg/g]	Fe_d/ (Fe_t/$CaCO_3$)	Mn(d/t)	Ald	pH	Conductivity (µS/cm)	Clay %	Silt %	Sand %	Skeleton %	Ti/Zr
‘Ain Ghazal Mitte 3	13	0.1	1	1.08	9.5	3	0.59	0.87	8.1	301	44	46	10	4	21
‘Ain Ghazal Mitte 2	47	0.5	17	1.14	14.9	65	0.53	0.56	7.9	980	67	21	12	46	26
‘Ain Ghazal Mitte 1	30	0.2	0.5	1.32	14.2	1	0.63	0.88	7.8	1235	46	47	7	4	23
‘Ain Ghazal 2	47	1.3	30	0.43	5.8	63	0.49	0.35	8.2	207	56	24	20	49	34
‘Ain Ghazal 1	25	0.2	7	0.76	10.3	15	0.55	0.56	8.6	1112	59	36	5	8	23

Table 1 Results of soil analyses

a prismatic structure during soil-forming processes.

The Ti/Zr ratio indicates that the parent materials remained fairly uniform until larger amounts of foreign material were deposited during the Yarmoukian Landslides.

Discussion and Conclusions

An important feature of Eastern Mediterranean environments is the appearance and disappearance of valley fills (Vita-Finzi 1969). Up to now, neither the chronology nor the processes behind the deposition and incision of valley fills has been clarified satisfactorily. Determining the chronology suffers from the fact that the extent of valley fills depends strongly on various local factors, *e.g.*, relief and slope, so that it can even be difficult to clarify the chronology within one valley (see the numerous and sometimes contradictory works on fills in Wadi Hasa, *e.g.*, Schuldenrein 2007). Furthermore, it is still unknown to what degree human activity, variations of the precipitation distribution, and vegetation cover interact. But it is known that vast valley fills were present at some times. For example, a fill near Khirbet Iskander was incised at the end of the Early Bronze Age, stripping the inhabitants of their most important agricultural area (Cordova *et al.* 2005; Rosen 2007). Many valleys in northern Jordan filled with sediments after the Byzantine period and started to incise only recently (field observations 2008), which illustrates the power and time-frames of hydrological variability and the resulting landscape changes. A paleosol near Ba’ja indicated that the PPBN site was located on an old wadi terrace or in the basin of an intramontane lake (Lucke and Bäumler 2007).

Although the number of examined samples is limited and their stratigraphy still insecure, it seems possible that the settlement at ‘Ain Ghazal was connected with a valley fill. During the MPPNB, the area might have enjoyed a high groundwater table and periodic ponding, which would have provided good hunting and farming conditions and water. A strong flood might have led to the deposition of the calcareous debris that was sampled in the South Field. However, the absence of gravels suggests that the upper part of the valley was covered with soil sediments. Debris deposition seems to vary locally, as the above mentioned debris is much less pronounced in the Central Field. This could be due to the MPPNB building connected with the floor, but a secure statement is only possible if the stratigraphy is clarified and larger areas examined. The bands of cultural material and lower conductivity of the debris in the South Field could be taken as signs for a period of more frequent floods in a basically unchanged floodplain environment, which seems to coincide with the re-location of the settlement to the higher slopes. The following *in situ soil formation* points to a return of more stable conditions with subsequent resettlement of the lower areas.

After deposition of the “Yarmoukian Landslides”, the environment at ‘Ain Ghazal seems to have changed irreversibly. Soil formation ceased, and the low conductivity values point to an end of ponding. It seems likely that the valley fill was incised and removed due to a different hydrological pattern, probably connected with a shift to more pronounced winter rains. This would have had severe impact on the subsistence economy of the village. Köhler-Rollefson and Rollefson (1990) concluded that the increasing population and domestication of goats led to overgrazing and soil erosion. However, in the light of the valley fills, the negative role of humans seems far overestimated. While early human activity may account for local environmental stress, it cannot explain a different runoff pattern. If the extent of the sites can be explained by “shifting settlements” (Karin Bartl, pers. comm., October 2008), also the number of people might have been lower than previously thought.

Up to now it is not clear whether the “Yarmoukian Landslides” were indeed landslides or whether they were connected with heavy rains or earthquakes. The corresponding layers might just represent cultural debris, as no comparable deposits were yet described from natural sediment traps. However, if we assume that their deposition was related to climate, it must have been a truly biblical flood which led to slope collapses that even masked or obliterated fluvial layers.

To conclude, the inhabitants of ‘Ain Ghazal were able to build several types of constructions using different materials that were adapted to the environment. They always lived adjacent to water sources, but when they were threatened by flooding, they moved their houses to higher areas and used different building techniques. After they felt that nature was no longer threatening, they returned back and built on the river and wadi banks.

Acknowledgements: The soil analyses were made possible by a grant from German Research Foundation in the framework of a project on the environmental history of Jordan (SCHM 2107/2-1 & BA 1637/4-1).

We thank the Department of Antiquities of Jordan for the permission to take soil samples at ‘Ain Ghazal and are grateful to Gary Rollefson for his support. Thanks are also due to the followings persons, of the Faculty of Archaeology and Anthropology/Yarmouk University, for providing the illustrations: Ali Omari, Yousef Zu’bi and Muwaffaq Batayneh.

Notes

[1] The methods of soil analysis were the following:
The soils were analyzed regarding Redness Rating (RR), pH, electrical conductivity, organic matter, $CaCO_3$-content, total element contents, and texture. These allow comparison of soil development from a genetic point of view.

Colour is a prominent parameter for soil description and sample selection. In order to make it statistically comparable, colours have to be translated into numbers, which is achieved with the Redness Rating. The pH delivers information about the chemical “milieu” of the soil, for example, the leaching processes and base accumulation. The electrical conductivity allows an assessment of the degree of base accumulation, *i.e.*, soil salinity. Organic matter provides information about the humus content and may indicate buried land surfaces. $CaCO_3$ is a weathering indicator since it is leached from soils with increasing age or moisture. The content of pedogenic oxides and hydroxides of iron and manganese usually rises with increasing weathering intensity and age of soils. In combination with other parameters, it is suited for a characterization of development stage and relative age of soils. The texture is a criterion that on the one hand delivers relative age estimation, since soils should become finer when older, and provides on the other hand information about the soil’s behaviour and suitability.

For collection of soil samples, freezer bags were filled from a *ca.* 5 cm thick strip in the middle of the identified layers/horizons. The samples were air-dried for 72 hours at 40° C and then sieved by 2 mm. The fraction > 2 mm (skeleton content) was determined and archived, and all further analyses conducted with the fraction < 2 mm. Colour was determined in the laboratory under standardized light, using the Munsell Soil Colour Chart. The Redness Rating (RR) was computed with the dry samples according to Hurst (1977). It is calculated according to the formula: RR=H*Brightness/Chroma, where H is: 5R = 5, 7.5 R = 7.5, 10 R = 10, 2.5 YR = 12.5, 5 YR = 15, 7.5 YR = 17.5, 10 YR = 20 (the index becomes the smaller the redder the soil). For example, 10 YR 8/1 = 160, and 2.5 YR 4/8 = 6,3.

The pH was determined with a glass electrode (pH-meter 530 by WTW, with electrode InLab 423 by Mettler-Toledo) in distilled water, with a soil:water solution of 1:2.5. Electrical conductivity was measured with a GMH 3410 conductivity meter in a soil:water solution of 1:5 (according to Schlichting *et al.* 1995). Contents of $CaCO_3$ and Corg were determined using a Leco TrueSpec C/N-analyser. Samples were finely ground and examined in doubles in the C/N-analyser, which delivered the total C- and N-contents. Additionally, ignition loss was determined according to Schlichting *et al.* (1995): the samples were heated for two hours to 430 °C, which is supposed to eliminate organic matter, but not to expel CO_2 from calcium carbonate. These samples were then analyzed in the C/N-analyser, too, so that Corg could be calculated from the difference after correcting the second C-content by the weight loss caused by ignition. This also allows us to calculate the $CaCO_3$-content under the assumption that the remaining inorganic carbonates are fixed in form of $CaCO_3$.

Pedogenic oxides were extracted with sodium dithionite at room temperature according to Holmgren (Schlichting *et al.*, 1995), and the iron and manganese contents measured with an atomic absorption spectrometer (AAS, M-series by Unicam, thermo-flame-spectrometer). Poorly crystallized pedogenic oxides were extracted in the dark using buffered (pH 3.25) oxalate-solution according to Schwertmann (Schlichting *et al.*, 1995), and their iron and manganese contents determined with the AAS. Total element contents were examined with X-ray fluorescence analysis (XRF), using a wavelength-dispersive sequency spectrometer type PW 2400 after preparing samples according to DIN 51001 (2003). From the total element contents, the Ti/Zr ratio was calculated as geochemical fingerprint for the origin of the material.

Particle sizes were analyzed after removing $CaCO_3$ with 10% hydrochloric acid (until no visible reaction occurred any more). Hydrochloric acid (HCl) was washed out again and samples dispersed with sodium hexametaphosphate ($Na_4P_2O_4$). Wet sieving determined the sand fraction (according to DIN 19683, 1973), while the smaller particles were analyzed with a Sedigraph 5100 (Micromeritics) (Gerzabek 1991).

[2] Perhaps walls or floors: numerous floors made of homogeneous fist-sized stones were constructed at Tell Abu Suwwan, which is the material of the Yarmoukian “landslide” layer covering the site (pers. comm. by Maysoon al-Nahar, July 2008).

References

Cordova C.
2007 *Millennial Landscape Change in Jordan.* Tucson: University of Arizona Press.

Cordova C., Foley C., Nowell A., and Bisson M.
2005 Landforms, sediments, soil development and prehistoric site settings in the Madaba-Dhiban Plateau, Jordan. *Geoarchaeology* 20.1: 29-56.

Gerzabek M.H.
1991 *Die Bestimmung der Bodentextur mittels Sedigraph 5100.* Österreichisches Forschungszentrum Seibersdorf, OEFZS Bericht Nr. 4592.

Hurst V.J.
1977 Visual estimation of iron in saprolite. *Geological Society of America Bulletin* 88: 174-176.

Kafafi Z.
1989 Late Neolithic 1 Pottery from `Ain Rahub, Jordan. *Zeitschrift des Deutschen Palaestina-Vereins* 105: 1-17.
1990 Early Pottery Context from ‘Ain Ghazal, Jordan. *Bulletin of the American Schools of Oriental Research* 280: 15-30.
1993 The Yarmoukians in Jordan. *Paléorient* 19.1: 101-115.
2001 Jordan during the Late Seventh/Early Sixth Millennia BC. *Mediterranean Archaeology and Archaeometry* 1.1: 31-42. Rhodes: University of the Aegean.
2004 The ‘Collapse’ of the LPPNB Settlement Organization: The Case of ‘Ain Ghazal. In: H.-D. Bienert, H.G.K. Gebel, and R. Neef (eds.), *Central Settlements in Neolithic Jordan*. Studies in Early Near Eastern Production, Subsistence, and Environment 5: 113-119. Berlin: ex oriente.

Kafafi Z. and Rollefson G.
1995 The 1994 Excavations at `Ain Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 39: 13-31

Köhler-Rollefson I. and Rollefson G.
1990 The impact of Neolithic subsistence on the environment: the case of ‘Ain Ghazal, Jordan. In: Bottema S., Entjes-Nieborg G., and van Zeist W. (eds.), *Man's Role in the Shaping of the Eastern Mediterranean Landscape* 3-14. Rotterdam: Balkema.

Lucke B.
2008 *Demise of the Decapolis. Past and Present Desertification in the Context of Soil Development, Land Use, and Climate*. Saarbrücken: Verlag Dr. Müller.

Lucke B., Schmidt M., al-Saad Z., Bens O., and Hüttl R.
2005 The Abandonment of the Decapolis Region in Northern Jordan - Forced by Environmental Change? *Quaternary International* 135: 65-81.

Lucke B. and Bäumler R.
2007 Soils and Paleosols at Ba‘ja. *Neo-Lithics* 02/07: 43-50.

Migowski C., Agnon A., Bookman R., Negendank J., and Stein M.
2004 Recurrence pattern of Holocene earthquakes along the Dead Sea transform revealed by varve-counting and radiocarbon dating of lacustrine sediments. *Earth and Planetary Science Letters* 222: 301-14.

Nowell A., Bisson M., and Cordova C.
2003 Wadi al-Koum survey. *American Journal of Archaeology* 107: 453-455.

Petocz D.
1987 An Early Bronze Age Site at ‘Ain Ghazal, Amman. *Levant* 19: 27-32.

Rollefson G. and Kafafi Z.
1993 The 1993 Season at `Ain Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 38: 11-33.
2000 The 1998 Excavations at ‘Ayn Ghazal: A Preliminary Report. *Annual of the Department of Antiquities of Jordan* 44: 91-98.
2007 The Rediscovery of the Neolithic Period in Jordan. In: T.E. Levy *et al.* (eds*.), Crossing Jordan. North American Contributions to the Archaeology of Jordan*: 211-219. London: Equinox.

Rollefson G. *et al.*
1990 The 1989 Season at ‘Ain Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan*.

Rosen A.
2007 *Civilizing Climate. Social Responses to Climate Change in the Ancient Near East.* New York: Altamira Press.

Salameh E. *et al.*
2008 The First Large Meteorite Impact Structure Discovered in the Middle East: Jebel Waqf es-Suwwan, Jordan. Mete*oritic and Planetary Science* 43.10: 1681-1690.

Schlichting E., Blume H.P., and Stahr K.
1995 *Bodenkundliches Praktikum,* 2nd ed. Berlin: Blackwell Wissenschafts-Verlag.

Schuldenrein J.
2007 A Reassessment of the Holocene Stratigraphy of the Wadi Hasa Terrace and Hasa Formation, Jordan. *Geoarchaeology* 22/6: 559-588.

Simmons A. and Kafafi Z.
1988 Preliminary Report on the `Ain Ghazal Archaeological Survey, 1987. *Annual of the Department of Antiquities of Jordan* 32: 127- 141.
1992 The `Ain Ghazal Survey: Pattern of Settlement in the Greater Wadi Az- Zarqa Areas Central Jordan. *Studies in the History and Archaeology of Jordan* IV: 77-82.

Vita-Finzi C.
1969 *The Mediterranean Valleys. Geological Changes in Historical Times.* Cambridge: Cambridge University Press.

The Intricacy of Neolithic Rubble Layers. The Ba‘ja, Basta, and ‘Ain Rahub Evidence

Hans Georg K. Gebel Institute of Near Eastern Archaeology, Free University of Berlin hggebel@zedat.fu-berlin.de

General Discussion

Rubble layers are a common feature at many seventh millennium BC sites located on slopes in the Jordanian Highlands. Three of these sites are discussed here: At ‘Ain Rahub, rubble layers were observed in 1985 in a deep trench transecting a slope; in Basta, they became subject of discussions in 1987, where they form substantial feature of the Post-LPPNB slope stratigraphy; and in Ba‘ja, they were discovered quite unexpectedly during the fifth season of excavations (2003) in the flattest area of the site which, and remarkably, here have no catchment for such huge accumulations. At all three sites, the origin of these accumulations of angular, fist-sized stones were an enigmatic issue, and indeed partly still are.

Significantly, rubble layers have the unique potential to serve as an empirical source for furthering our comprehension of abandonment processes, subsistence shifts, and climatic change in the Eastern Mediterranean during the seventh millennium BC. Therefore, these rubble layers might even provide evidence for the role of natural causes in the decline of LPPNB traditions and lifeways (at around 6900 BC), the adoption of pastoralism during the FPPNB/ PPNC (first half of the seventh millennium BC), and the potential impacts on agro-habitats in the PNA (Yarmoukian/ second half of the seventh millennium)[1]. Although many local parameters are responsible for the accumulation of an individual rubble layer/slide (*cf.* below), the intense and wide spread appearance of rubble deposits by the end of the LPPNB and in the Pottery Neolithic must be related to the influence of a common agent which actuated and coordinated various local parameters and ingredients: Periods of heavier rainfalls and/or topography-related flash floods and aquatic slope erosion would appear to be the main factor of these accumulations or slides. In the light of evidence for climate change in the late seventh millennium BC (8200 calBP “Hudson Bay” event), in earlier contributions rubble layers/slides have been discussed solely in relation to the contemporaneous Yarmoukian (Weninger *et al.* 2005, 2007). Recent considerations, however, seem to acknowledge that rubble layers and slides are a much wider Neolithic phenomenon (Rollefson, this issue; Weninger, this issue). Indeed, Basta and Ba‘ja have long attested to at least three rubble layer episodes during the LPPNB to PN which only partly and locally appear in the shape of slides.

The stratigraphic, structural, and chronological intricacy of the Jordanian Neolithic rubble layers and slides warns against a mono-causal explanation. Not one of the rubble deposits found in the Neolithic contexts discussed here is similar in terms of archaeological morpho-phenomenology and chrono-stratigraphy; rather, they represent locally restricted and quite dominant depositions of fist-sized angular stone rubble, the origins of which appear quite puzzling at first glance. As yet, the appearance of such accumulations in non-archaeological, *i.e.* natural Early Holocene stratigraphies has remained uninvestigated. Although representing events highly influenced by indirect or direct anthropogenic influence, rubble layers and slides could be an excellent chance to identify impacts of Rapid Climatic Change (RCC; Weninger, this issue; Weninger *et al.* 2009) or other environmental impacts which triggered the physical displacement of rubble. However, undertaking rubble layer/slide research is a very slippery terrain if it lacks consistent interdisciplinary approaches, and if

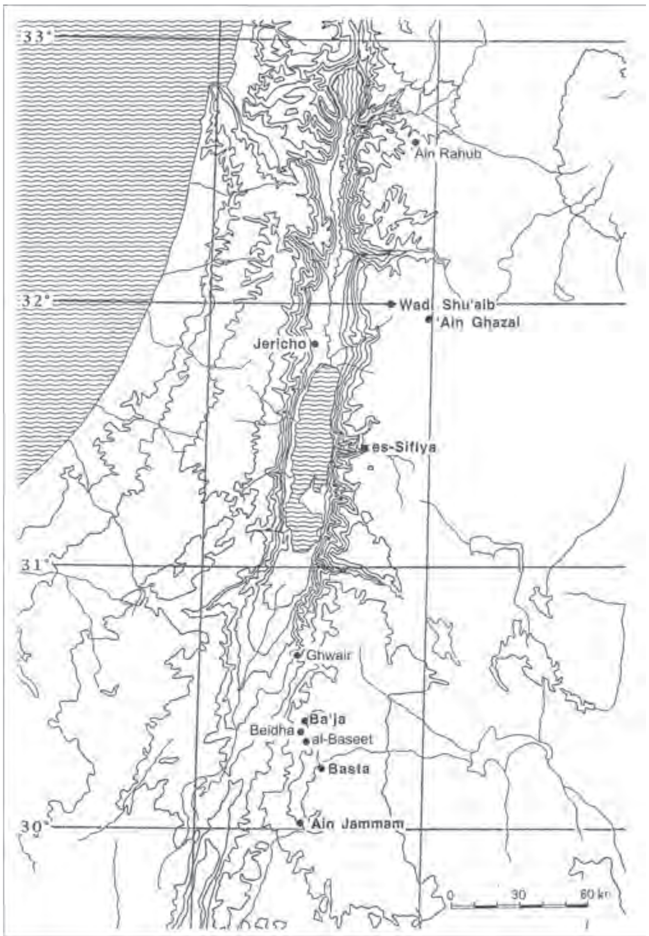

Fig. 1 Locations of LPPNB and PN sites mentioned in the text

explanations are dominated by absolute chronological, pheno-stratigrapical, pedological (*cf.* Lucke in Kafafi and Lucke, this issue) or geomorphological arguments. Especially the mere focus on supra-regional climatic change may lead us in wrong directions, as monogenetic explanations may do in general. For example, a drainage regime might have sorted and accumulated rubble without a major moist phase in the climate, and just benefited from local copious slope hydrology.

This paper summarises the archaeological features of the rubble layers; in depth geomorphological studies must follow, thus paving the way for interdisciplinary research designed to approach one of the most spectacular features of the Near Eastern Neolithic: the discontinuities in settlement history and subsistence modes during the seventh millennium BC in the Southern Levant, and their relation to rubble deposits and potential climatic/seismic impacts.

The identification of the various interacting local parameters, causes, and forces that might have contributed to the formation of any given rubble deposit is a prerequisite for any discussion of the role played by RCC, or any other factor, in rubble layer accumulation. Indeed, we have to accept that such complex phenomena will not just provide evidence for one singular cause: imagine, for example, the earthquake which triggers the flow of colluvial rubble, heavily soaked by regional RCC rains, taking up field stone clearing piles and cultural deposits on its way, before reaching its final place of deposition. The demand is that prior to an analysis of its conditions and characteristics, a rubble layer per se should not be taken as a signal for anything; in this respect, the following factors require careful consideration before an explanation is offered:

1. prevailing palaeo-drainage regimes and palaeo-topography
2. anthropogenic barriers and impacts (*e.g.* intra-site architectural barriers such as building terraces, agricultural barriers like valley terraces, size-sorting and stone extraction by man *etc.*)
3. evidence of seismic impacts
4. origin of rubble components (*e.g.* natural *vs.* anthropogenic, *e.g.* wall stone dressing, floor and wall components, *etc.*)
5. intra-site diversity of rubble within flow/deposit and its sorting (in terms of its sedimentology and deposit morphology)
6. identification, chronology, and morphology of rubble layers/slides in the Early Holocene landscapes surrounding the sites

Additionally, it should be stressed that the same factors (*e.g.* fluvial) that may have led to the deposition of rubble layers may also have caused their negative evidence, *i.e.* their removal from the stratigraphic sequence. A rubble slide deposit is only a snapshot of a site's sedimentary environment, and increased fluvial surface energy can also manifest itself in the complete or partial erosion of layers, including rubble slides.

Be this as it may, the rubble layers/slides preserved in settlements dating to the seventh millennium BC demand explanation, especially since their occurrence often appears related to disruptions in the history (intra-site and regionally) of occupation. Indeed, they represent a wider phenomenon in the Eastern Mediterranean in the seventh millennium BC (and in other, younger, time frames, too) at all places with an extant gravity regime (slope setting of sites). Indeed, many of our sites do have this landslide potential. In a further step, systematic surveys need to investigate potential rubble layers on pre-LPPNB and Late Pleistocene sites as well as below and above Post-Yarmoukian habitations. Additionally, geomorphological surveys need to clarify whether rubble layers only occur in archaeological contexts or have corresponding formations in the landscape.

It is very much a common feature of the debris and mud deposits/flows – or rubble layers/slides – that they appear far too extensive for the size of the catchment from the material is thought to stem. From the Basta and Ba'ja sites it is clear that the angular stones of the rubble layers must derive in a large part from flaking of the (dressed) wall stones, the fills of the double-faced walls, and (in Basta) the floor constructions. This means that the architectural debris from these sites produced most of the rubble found in the rubble layers. For Yarmoukian 'Ain Rahub such sources have to remain under discussion since the test trench only revealed in general (by the mudbrick fragments) an architectural context of the rubble layers, while *in situ* architecture wasn't caught.

In our previous publications (*e.g.* Gebel 2004b, 2006) we carefully spoke of rubble layers or rubble deposits; the term rubble slide was promoted by Weninger *et al.* (2007) in their discussion of the Yarmoukian landslides. However, recent (spring 2010) on-site discussions in Ba'ja and Basta with Christoph Zielhofer (Leipzig University, geomorphology) and Bernhard Weninger (Cologne University) regarding the diversity of rubble layers led to the conclusion that we should rather use the more neutral term rubble event instead of rubble slide, since only some of the rubble layers show moraine-like features.

Preliminary Definitions of Neolithic Rubble Layers and Rubble Slides

The following definitions are based on observations of Neolithic rubble layers at our sites ('Ain Rahub, Basta, and Ba'ja), and are bound to the occurrence of +/- fist-sized angular stones:

A rubble layer consists of +/- fist-size angular stones, generally – but not necessarily – embedded in a finer matrix; this matrix may contain material from re-deposited cultural layers (charcoal, ash, small flint artefacts and plaster fragments, *etc.*); occasionally rolled/rounded +/- fist-sized stones occur among the angular stones. These stone accumulations can be thin or they form thick and extensive horizontal layers following the inclination of an old surface or representing restricted lenses or piles. Components of rubble layers may not share a general orientation (although they often do), and the material can even be of purely anthropogenic origin, *e.g.*, from the typical LPPNB double-faced walls of which the dressed wall stones were sorted out and the angular fist-sized of the interior wall fill remained. On the other hand, rubble can also stem from purely natural sources, *e.g.* weathered bedrock from the slope above a settlement. On the upper parts of slopes, rubble layers have the tendency to be more shallow and linear, increasing in thickness and taking on fan-like in-sediment morphologies in lower lying parts. They also evened out surfaces by *e.g.* filling small surface runnels. In their migration onto the surface of a site they are often guided by wall remains still exposed on the slope surface. It should be noted that fist-sized rubble scatters on old surfaces are not deemed rubble layers.

Rubble slides are fluvially deposited rubble layers, or a sequence of fluvially deposited rubble layers, which may contain *in situ* occupational traces, ephemeral or solid installations (walls, burials, chipping floors, surfaces *etc.*; *cf.* Gebel *et al.* 1992). Sequences of fluvially deposited rubble slides may also contain or be interrupted by lenses and layers of other water-laid material (*e.g.* fine gravels) and/or aeolian sediments. Intra-site rubble slides potentially occur in all locations where a drainage or drainage regime forces the formation, movement, and deposition of fist-sized rubble.

Although the fist-sized stone rubble can contain natural colluvial material at some sites, it normally comprises (re-deposited) cultural layers and architectural rubble; in-site rubble contexts are rarely found sterile of artefacts. Rubble slides normally assemble in their sedimentary environment materials from any sources located higher up the slope, *i.e.* from settlement and field/garden contexts that were inhabited or influenced by humans during their deposition. Our definition of rubble slides includes that such deposits not only are attested on slope surfaces, but also filled drainages where they can appear – in case of later incisions – in the sections.

Seventh Millennium BC Rubble Slide Evidence East of the Rift Valley

The preliminary list of Neolithic sites with rubble layers east of the Jordan/Wadi Araba Rift Valley is (in alphabetical order, *cf.* also Fig. 1): ‘Ain Ghazal, ‘Ain Rahub, Abu Suwwan, Abu Thuwwab, Ba‘ja, al-Baseet, Basta, Ghwair, and Wadi Shu‘aib. Potential candidates for the rubble layer discussion are ‘Ain Jammam, Beidha (Fig. 5), Khirbet Hammam, al-Shalaf, es-Sifiya, and Umm Meshrat I and II (references for most of these

Fig. 2 es-Sifiya: Section of square with possible rubble layer (photo courtesy of H. Mahasneh)

Fig. 3 Ghwair: Section of an upper slope excavation area with rubble layers consisting of rock detritus and fine-grained (aeolian) material. View from W (photo by author with permission of M. Najjar)

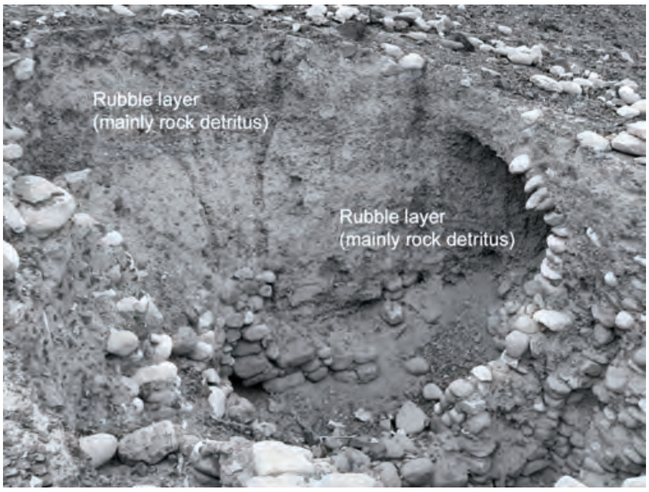

Fig. 4 Ghwair: Section of an uppermost slope excavation area with a rubble layers consisting exclusively of rock detritus in its lower parts, joined by fine-grained (aeolian?) material in its upper parts. View from W (photo by author with permission of M. Najjar)

Fig. 5 Beidha: Section with horizontally embedded gravel/ rubble layers of unknown date, located between Beidha's MPPNB architecture and the sandstone formations bordering the site in the N. View from SE

sites are given by Rollefson, this issue). Omry Barzilai, this issue, provided a general report on rubble layers from many areas west of the Rift Valley, also for the Natufian - PPNA and Chalcolithic periods; he also mentions additional anthropogenic sources of angular stone material which we do not have in the three sites discussed here.

As mentioned, we should be aware that the morphologies and phenomenologies of rubble layers and slides, featuring angular fist-sized stones and found more or less compacted in lenses or layers above and in Neolithic ruins, are not all the same. The nature of rubble layers depends on the catchment area from which materials are taken up and re-deposited. For example, the purely natural "rubble layers" on the upper slope at the site of Ghwair (Figs. 3-4) have a very limited source and catchment: Here a desert-varnish bearing outcrop weathered its "thermal" detritus into the LPPNB architecture in the shape of a rubble layer, fully covered it, and is still accumulating today. The proximity of this source of "rubble" to the architecture against which it has accumulated has made it almost impossible for other types of rubble (*e.g.* re-depositing cultural debris) to contribute to the "rubble layers" observed in this section. This situation may be different further downslope where rubble layers are also expected to contain the fist-sized angular stones from the settlement (*e.g.* Fig. 3). In Ghwair's uppermost slope, however, "rubble layers" are rather the result of aeolian/dune accumulations and a high share of bedrock weathering products (Fig. 4) from the extreme differences between the daily temperatures' maxima and minima.

'Ain Jammam is an example for rubble layers not necessarily aggregating in the upper parts of the slope: Due to the steepness of the slope, erosion transported all material downwards, including rock falls, cultural debris and fist-sized stones, until a stable surface developed in which the ruined L/FPPNB and PNA wall tops rest. Here, rubble layers with their share of anthropogenic material have to be expected in the more shallow middle parts of the slope, and are attested quite clearly at the lower fringes of the site.

The date (or dates) and stratigraphic position of the horizontal gravel/ rubble layers resting between Beidha's MPPNB architecture and the sandstone formation to the north (Fig. 5) need to become subject of future investigations; they can represent at least partly seventh millennium BC fills, but it is unlikely that the catchments reaching the area by the small gorges in the northern sandstone formation have not constantly delivered material onto the spot by the millennia. Nearby Siq al-Barid at least shows considerable deposits since Nabatean times.

For the (Post-) LPPNB es-Sifiya and al-Baseet slopes depositional conditions similar to Basta are expected with respect to their rubble layers: While such were observed in a section in the year 2000 at al-Baseet, such observations for es-Sifiya need to be verified.

One further issue should be addressed here: Recent considerations by Zeidan Kafafi (*cf.* also the contribution in this issue) tentatively claim that a meteorite impact in the Eastern Jordanian desert may have caused regional climatic change and mud/ rubble flows affecting seventh millennium BC settlements in Jordan. This notion, however, has so far not been substantiated by any solid data, and should be excluded for the time being from the rubble layer discussion.

In the following, the rubble layer data from the three sites discussed here are summarised.

The Basta Evidence

When the first evidence of rubble layers at Basta were discussed with Hans Joachim Pachur, Ulrich Kamp, and Markus Nüsser by the section exposures in 1987 there was much conjecture. However, even at this time, many of the ideas expressed already hinted towards very complex processes, including the temporal existence of agricultural fields and field clearing piles on the Post-LPPNB Basta slopes. In addition, the rubble layers were discussed with an even more intriguing feature of Basta's sedimentary environment in mind, the silt

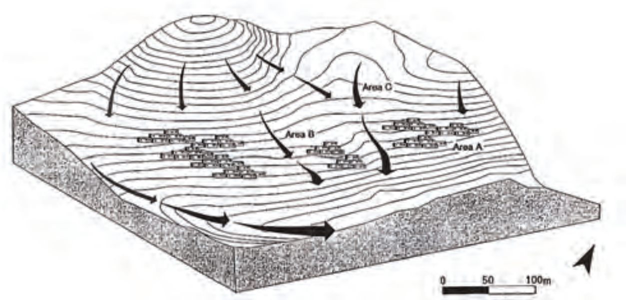

Fig. 6 Basta: Reconstructed LPPNB drainage pattern on Basta's present-day slopes. View from SSE (graph by U. Kamp, published in Gebel 2004: Fig. 1)

Fig. 7 Basta, Square B70, Loci 2-4: Surface of Upper Rubble Layers (URL). Note sub-topsoil Fine-Grained Deposits (FGD) in the sections. View from S

Fig. 8 Basta, Square B68, Central Room/ Courtyard 1 of Building 1 with rooms adjacent to the NE: Section with Upper Rubble Layers (URL) covering the top of the LPPNB ruin.
View from SW

Fig. 9 Basta, Square B85, Room/ Space 3 (foreground) of Building VII: Note the rubble flow of the Lower Rubble Layers (LRL) in front of walls (Locus 7, 16, and 8) and passing through the wall opening. View from E

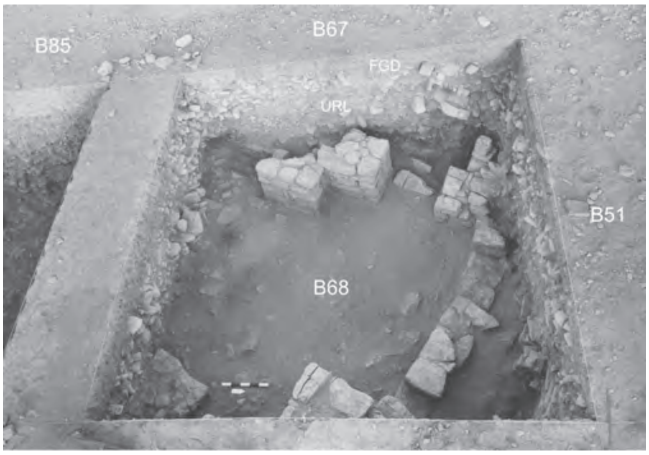

Fig. 10 Basta, Square B68: Partly removed Upper Rubble Layers (URL; *cf.* sections with URL) at the junction with the room fills. Uppermost tops of LPPNB wall ruins. View from E

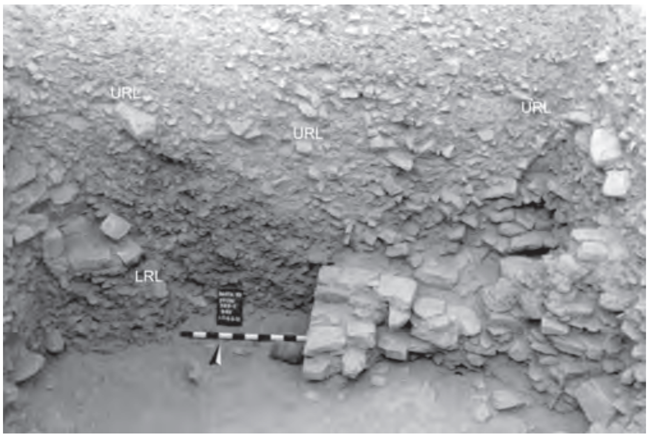

Fig. 11 Basta, Square B83: Top of ruined LPPNB wall (Locus 16) exposed underneath and in the Lower Rubble Layers (LRL), located at the same height as the flimsy FPPNB/ PPNC wall remains (Locus 10), to the left, in the LRL. Note the inclination of the mud flows to the E (downslope). View from S

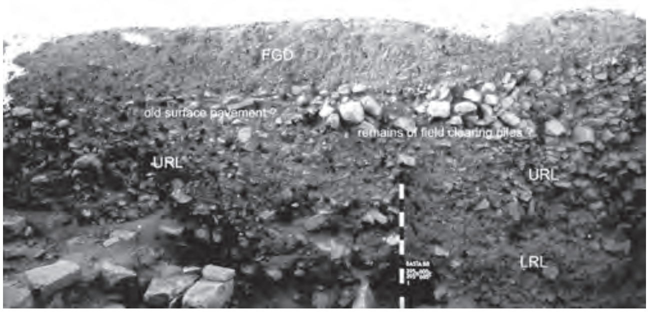

Fig. 12 Basta, Squares B86-87, S Section: Sequence of Fine-Grained Deposits (FGD), Upper and Lower Rubble Layers (URL-LRL) above the top of ruined LPPNB walls. Note the stone accumulations deposited after the URL formation, possibly representing an old land surface (pavement) and the remains of field clearing piles. View from N

cal BC	Basta Periods	Area A	Area B	Area C
		Fine-Grained Deposits (FGD)?	Fine-Grained Deposits (FGD)	?
				predominantly
6000				
		Upper Rubble Layers (URL)/	Upper Rubble Layers (URL)	
		downslope sedimentation of	with remains of clearing piles, debris	
	PNA	cultural debris	and mud flows	
				aeolian
		Lower Rubble Layers (LRL)	Architectural Phase B0 / Lower	
	PPNC-	downslope sedimentation of	Rubble Layers (LRL): curvilinear wall	
	related	cultural debris	fragments, fire places and surfaces	
			embedded in debris and mud flows	
6900				sedimentation
	FPPNB	Architectural Phase AI:	Architectural Phase BI: room fills,	(silts)
		rectangular rooms build of	burial ground, rectangular and	
		undressed cobbles	curvilinear rooms build of small slabs,	
			substructures	C208 and
		huge accumulations of		C217:
		workshop refuse (naviform	Architectural Phases BII-III	village fringe
		chipped stones)	room fills, large multi-roomed	activities
	LPPNB		and rectangular architecture,	(gardens,
		Architectural Phases AII-III:	substructures	burials,
		room fills, large multi-roomed		chipping floors),
		and rectangular architecture,		no buildings?
		substructures, "trash burials"	Architectural Phases BIV ?	
7500		in-room and in-channal burials		
		bedrock		bedrock (C217)

Table 1 Basta: Chrono-stratigraphical summary of the Post-LPPNB (after Gebel *et al.* 2006: Table 1).

deposits of Area C (Kamp 2004, Gebel 2006). Only in the 1992 campaign (Gebel *et al.* 2004) the post-LPPNB rubble layers at Basta received more devoted attention (on account of a planned deep sounding). Flimsy PPNC-related occupations (Fig. 15) were observed in the lowest parts of the Lower Rubble Layer, and for the first time Lower and Upper Rubble Layers (LRL, URL; Figs. 7-14)[2] were distinguished; these were separated frequently from one another by deposits/layers with a higher ratio of fine-grained sediment. In the campaigns prior to 1992 archaeological rubble layer observations were hardly carried out, and ironically they were referred to as the chebabian period, since the quick removal of these thick deposits required a high level of man-power. The rubble layers finding at Basta might be comparable with those at Wadi Shu'aib (Simmons *et al.* 2001; Rollefson, this issue: Fig. 5) where two such events seem to separate the PPNB from the PN.

The Lower Rubble Layers (LRL, Table 1) of Basta Area B contain PPNC artefacts, curvilinear wallets (Fig. 15), chipping floor dumps and *Tridacna* bead workshop remains, fire places, samagah installations/ surfaces, stone robbing pits dug into the LPPNB architecture (related hoard of stone figurines, *cf.* Hermansen in Gebel *et al.* 2004: 94, 101-102, Figs. 15-16), a pre-Yarmoukian arrowhead type, and very few intrusive? sherds showing a relation to Yarmoukian pottery, *etc.* (Gebel *et al.* 2004: Table 1); of course, they also contained re-deposited F/LPPNB materials. The LRL must have started to accumulate shortly after the abandonment of the settlement, since the walls of structures were still standing tall and the rubble layers migrated into the ruin, even penetrating through wall openings (*e.g.* Fig. 9). The Upper Rubble Layers (URL, Table 1) contain all sorts of re-deposited materials, including Palaeolithic to F/LPPNB and PN artefacts, re-deposited rubble of the LRL; in situ fire places and surfaces are less well preserved (compared with the LRL findings), and partially in situ finds of a PNA/ Yarmoukian chipped stone industry as well as isolated Neolithic pottery sherds were found (Gebel *et al.* 2004: Table 1). As Figs. 8-11 indicate, the ruined wall tops of the LPPNB basements were still poking out of the surfaces at considerable heights during the URL depositions. This is somewhat puzzling, since it would mean – in terms of our current absolute chronological understanding of the rubble layers at Basta (Table 1) – that some ruined wall tops of the LPPNB basements were still visible after some 700 years. Wouldn't this finding not indicate that the URL of Basta are somewhat older, *e.g.* dating around the mid of the millennium BC?

The Lower and Upper Rubble Layers of Basta

Fig. 13 Basta, Squares B104-105, N Section: Sequence of Fine-Grained Deposits (FGD), Upper and Lower Rubble Layers (URL-LRL) above (and between: LRL) the top of ruined LPPNB walls. Note the stone accumulations deposited after URL formation, possibly representing the remains of field clearing piles. View from S

Fig. 16 Basta, Square A12, NW Section (bulldozer cut): Huge silty rubble/gravel layers (Loci 61a-g of the NW Section), covering the top of the ruined western wall (Locus 2) of Room 16 and adjacent areas. The orientation of the rubble/gravel mixed with some cultural materials is oriented downslope. Possibly represents the fills of a seventh millennium BC runnel. View from E

Fig. 14 Basta, Squares B103-105, S Section: Sequence of Fine-Grained Deposits (FGD), Upper and Lower Rubble Layers (URL-LRL) above the top of ruined LPPNB walls. Note the inclination of the rubble flows to the E. View from WNW

Fig. 15 Basta, Square B83, Locus 5: Flimsy curvilinear PPNC/ FPPNB wall fragment embedded in the Lower Rubble Layers (LRL). View from S

seem not to represent two major isolated depositional events, rather they appear as two sets of locally restricted depositions. It seems that larger parts of the Basta slopes are covered by rubble layers, with only smaller areas having escaped this depositions. Layer thicknesses are varied and have the tendency to increase downslope; in general, the Basta rubble layers tend to form restricted extensions, like large lenses, accumulations on old surfaces, and even piles. The thickness of the uppermost Fine-Grained Deposits (FGD; Christoph Zielhofer: “Kolluvium”; Figs. 12-14) increases considerably downslope.

Before we discuss the various scenarios of rubble layer formation at Basta, the only radiocarbon date that exists from the context of the rubble layers at the site (from the earliest LRL, should be presented: KIA 30847 (Basta 47244) dates the remains of a fire place (Square B83: Locus 8) contemporaneous with the deposition of the rubble to cal BC 6749, 6721, 6702 calBC (radiocarbon age: BP 7911 ± 56; P.M. Grootes, Leibniz Labor für Altersbestimmung, Kiel, pers. comm.) (Fig. 17). The date reflects perfectly the archaeological PPNC-related evidence we have from the Lower Rubble Layers in Basta (Gebel *et al.* 2004, Gebel 2006, Gebel *et al.* 2006).

The understanding of the palaeo-topographical slope settings are essential for the understanding of Basta’s rubble layers (*cf.* Kamp 2004: Figs. 1-3; Gebel 2004a: Fig. 1C, 2004b: Fig. 1): The topographical unit Area A (Fig. 6) represents the NE parts of the Neolithic village on the slopes between a small gully (a present-day village street) in the SW and the bedrock outcrops with quartzite veins to the NE (Kamp 2004: Fig. 1). The lower parts of the slopes are very steep and border the bottom of Wadi Basta. The upper parts of Area A are rather flat and pass over into the flat topography of the former fields in Area C. Area B (Fig. 6) is located in the central, steeper and spur-like part of the Neolithic

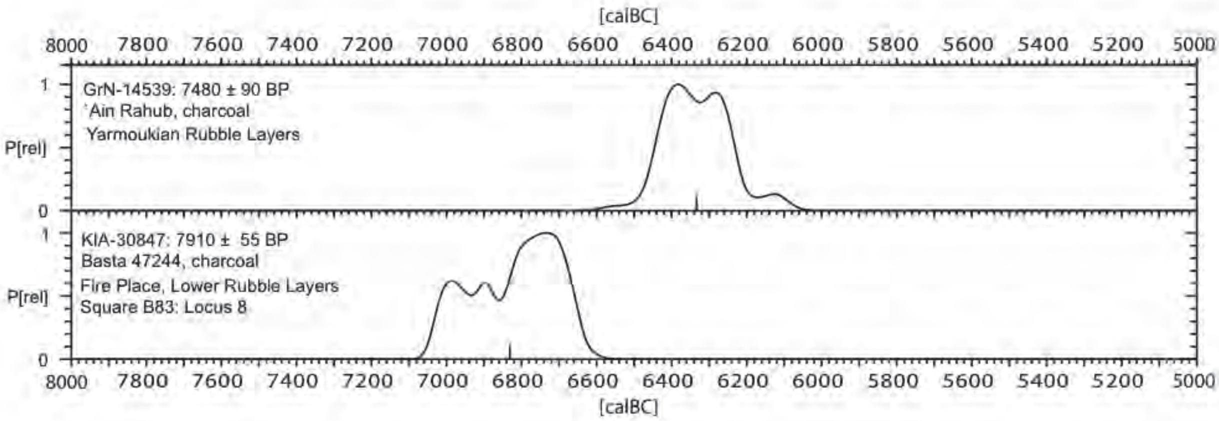

Fig. 17 Calibrated date from Yarmoukian-related rubble layers in ‘Ain Rahub (top) and from the Lower Rubble Layers in Basta (bottom). Graph prepared by B. Weninger

village. It is also located on Wadi Basta’s NW slopes between the aforementioned small gully (the present-day village street) in the NE and the flat slope areas in the W and SW. In the SE it reaches the bottom of Wadi Basta by a steep inclination. In the NW it meets a flat area which belongs topographically to Area C. The original spur-like topography of Area B seems to be the result of two Early Holocene drainages into Wadi Basta from the NW (Kamp 2004).

The post-LPPNB sedimentary stratigraphies of Basta are a sequence of depositional, re-depositional, and extraction events which modified the relief over the seventh millennium BC. While the natural impacts on the sedimentary environments of the slopes at Basta were reduced or controlled by F/LPPNB human occupation during the second half of the eigth millennium BC, natural causes and materials again gained the upper hand during the seventh millennium BC, *i.e.* following the close of permanent occupation at the site. During the F/LPPNB occupations at Basta a combination of domestic behaviour on the one hand, and natural alterations on the other (*e.g.* by drainage regimes, colluvial materials, heavy rain/snowfall, extreme temperature maxima/minima and other climatic parameters) impacted upon this particular landscape. Against this background, we have to expect (Kamp 2004, Gebel 2006, Gebel *et al.* 2006) the existence of protective structural measures, such as (terrace and barrier) walls and ditches, designed to offer some protection against both aquatic slope

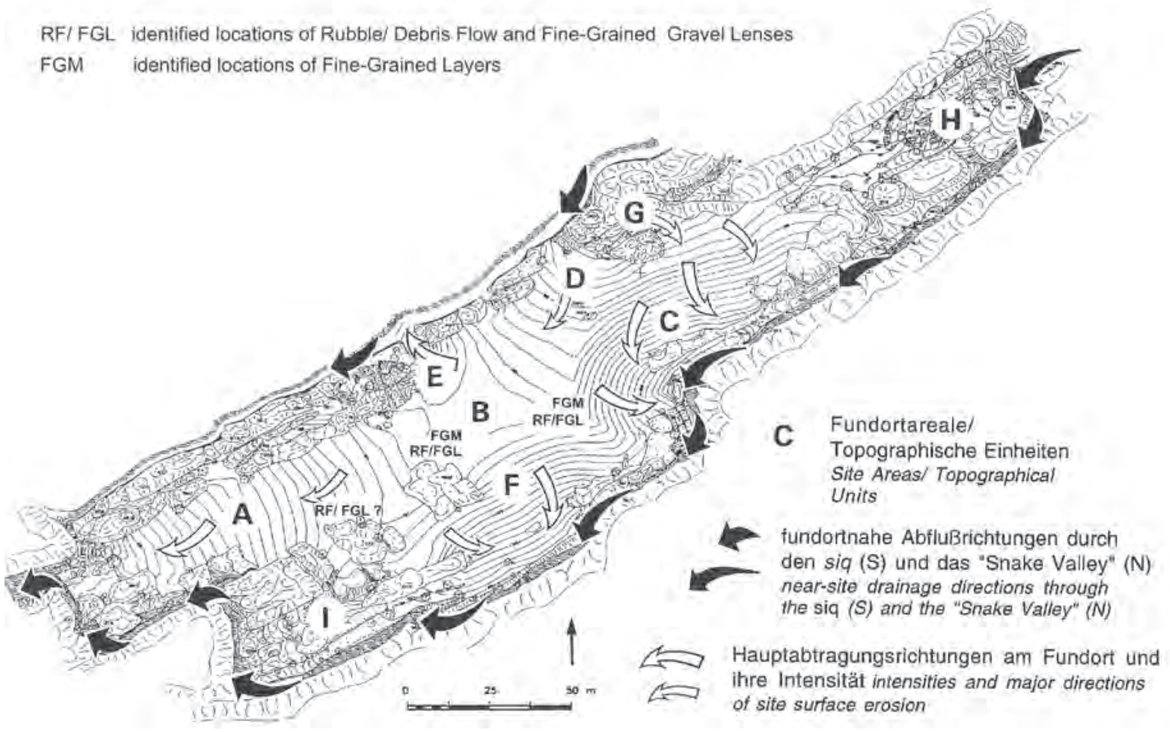

Fig. 18 Ba‘ja: Topography and identified locations of Rubble Flows/Fine-Grained Gravel Lenses (RF/FGL) and Fine-Grained Layers characteristic for the sub-topsoil layers (FGM), in contrast to the present-day surface drainage regime of the site

erosion and colluvial accumulation in LPPNB Basta; indeed, natural slope drainage represented a permanent threat to F/LPPNB villages on the slopes in the region. Intra-site rainfall and snow management, debris flow management, slope pressure management: All these factors should be reflected in the architecture, the architectural planning, and the stratigraphies at Basta. However, it is of note that the best evidence for protective walls, barriers, and ditches should be found on the fringes of the settlements.

In the lowest LRL at Basta, dated to the PPNC, rubble deposits were apparently used by squatters, still residing, manufacturing beads and chipping flints between the eroding ruins of F/LPPNB walls, *etc.* The decaying F/LPPNB structures produced thick, rather homogeneous, and consolidated fine accumulations and patches of disintegrating plaster and roof/ceiling materials, a characteristic of the LRL. In the upper LRL, fireplaces were still operated, and other in situ traces of human activities are in evidence; in fact, these layers witness some Yarmoukian-related features. In contrast, the URL show far fewer habitational traces; rather, they display locally restricted sequences of downslope sedimentation, possibly interrupted by (re-deposited) remains of field clearing piles. The URL may have become deposited around 6200 BC, if not earlier (*cf.* above).

The understanding of the huge silty rubble/gravel layers in Area A (NW Section, Loci 61a-g; Fig. 16; Gebel 2006; 69, Fig. 2.A), reaching thicknesses of 2-3 m and covering the ruined LPPNB wall tops is still premature. They do not contain much cultural debris at this spot, as opposed the section layers to the NE and the NE Section (Gebel 2004b). Their formation must have involved silty materials of Area C: it appears that they represent the fill of a seventh millennium drainage/runnel in at this spot (cf. the runnel's section/inclinations in Fig. 2A of Gebel 2006).

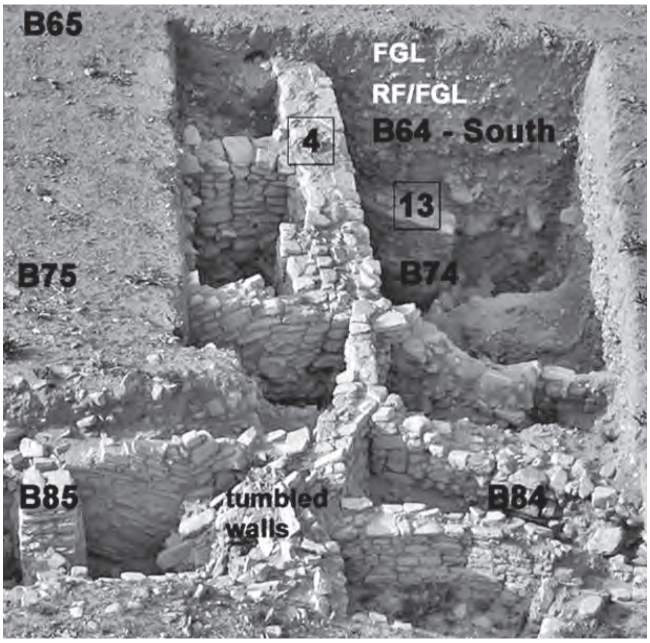

Fig. 19 Ba'ja, Area B-South: Evidence of Rubble/Gravel Flows with Fine-Gravel Lenses (RF/FGL) exposed in Square B64-South and tumbled walls (earthquake damage?) in Squares B84-85

Aside from the anthropogenic rubble of the village, physical weathering products (angular rock detritus from block size to sand/silt) and aeolian deposition were all important components to have contributed to the mass of material that developed in the catchments of Basta and penetrated into the settlement area (Kamp 2004). Today, the area witnesses torrential rainfall episodes, and we have every reason to assume that this was also the case in the seventh millennium BC; therefore, we must expect such events to still be visible in our squares and sections, too. The origin and important role of aeolian silt in the sedimentary environments of the site is still poorly known (*e.g.* a share of more than 30% was found in Area C, *cf.* Kamp 2004): dust storms may be the origin of these silts which accumulated for 2-3 m during and after the LPPNB in Area C, where even individual aeolian events could be traced. The site was subject to aeolian erosion in the seventh millennium BC, too (*cf.* also above the Area A silt evidence), but we do have yet a clue on the aeolian materials' share in Area's B rubble layers (Kamp 2004). In Area B the aeolian components seem to be of lesser importance.

The Ba'ja Evidence

Under the heading: Huge Rubble and Fine Gravel Flows, Wall Rubble and Air Hollows we opened discussions focusing on the extraordinary evidence for high-energy events to have occurred at Ba'ja and which were followed by LPPNB architectural reoccupation in Areas C and B-South of the site (Gebel and Kinzel 2007): Huge rubble deposits and other features characteristic of earthquake destruction were noted (Fig. 18). In addition to this, the – fluvial or seismic/ fluvial related – destruction of the eastern part of Area C by slope subsidence is also attested (Gebel and Bienert *et al.* 1997: Fig. 6), though it is still unclear as to the precise nature of the accountable high-energy event. The earlier earthquake in Area B-South (Figs. 21-22) was followed by thick depositions of stone rubble (RF, up to 1.5 m in height; Figs. 22-23) [2] with embedded water-

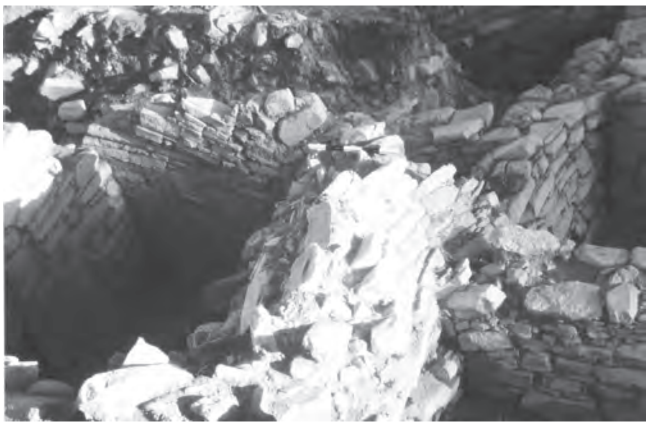

Fig. 20 Ba'ja, Area B-South, Squares B84-85: Tumbled LPPNB walls (earthquake damage?)

Fig. 21 Ba'ja, Area B-South, Square B64-South, Loci 21 and 23: LPPNB wall rubble found with air pockets (earthquake damage?)

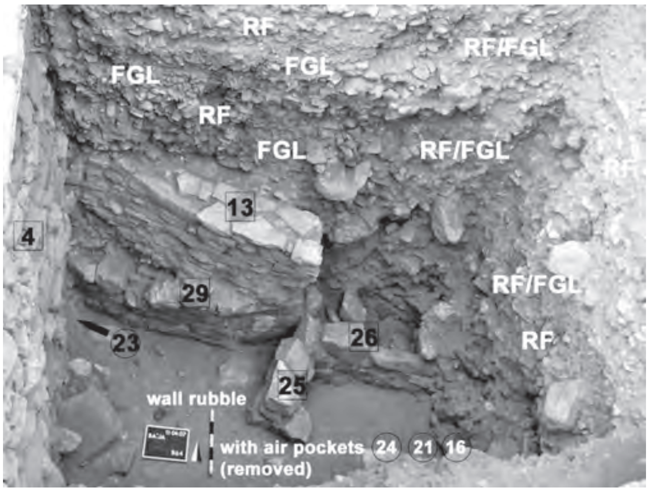

Fig. 22 Ba'ja, Area B-South, Square B64-South: Excavated earliest architectural remains (LPPNB) with partly removed wall rubble loci (earthquake loci with air pockets, *cf.* Fig. 17) and deposits of Rubble/Gravel Flows and Fine-Gravel Lenses (RF/FGL) above. View from S

deposited fine gravel accumulations (FGL) that rest against the tall standing wall (Locus 4) in Squares B64-South and B74 (Fig. 19) or were found under the later architectural re-occupation (Locus 5) in C-10/10 (Fig. 23); the water-deposited fine-gravel deposits/lenses are a strong indication of an aquatic slope erosion which took up and sorted floor/ ceiling components. Several spots provide indications for some deconstruction prior to the start of the latest architectural phase. Remarkably, there exists no catchment for a natural source of these RF/FGL materials at Ba'ja: Therefore, it must be concluded that they are of anthropogenic origin (contrary to an assumption in Gebel and Kinzel 2007, *cf.* below). The wall rubble resulting from the earliest earthquake (and from subsequent instabilities of house walls) were buried by these complex rubble and fine-gravel sequences in Squares B64-South and B74 and C-20/20. A further earthquake appears to be attested by the twisted walls in upper B84-85 (Fig. 20). Earlier considerations (Gebel and Kinzel 2007) that the RF/FGL flows result from flash floods reaching the central upper parts of the settlement from the gorge (Siq al-Ba'ja), and that the floor of the siq was much higher than today, require revision following new insights gained from recent fieldwork at the site (Christoph Zielhofer, pers. comm; spring 2010).

In the following we present and discuss the individual pieces of evidence for the rubble layers and related high-energy events. For a more detailed account of these findings, see Gebel and Kinzel 2007.

Area B-South (Figs. 18-22): The excavation in the southern half of Square B64 has provided insights into huge intra-site rubble and gravel flows (RF/FGL) resting against the aforementioned high wall Locus 4 in B64-South and B74 (Figs. 19, 22) and over the walls (Loci 13, 29, 25-26), and the wall rubble accumulations with air pockets (Loci 16, 21, and 24); similar features are reported from Area C – *cf.* below – at a distance of some 20-30 m). The wall rubble – sometimes still deposited in a fallen-domino arrangement – with air pockets was found to be mixed with a higher amount of loose, re-deposited material, including mortar/plaster/ceiling debris, containing charcoal, and appeared to have been, at least partially, intentionally buried. Wall 13 seems to have been reduced in height, probably during the erection of the upper phase of Wall 4 (= coarse-faced upper part of Wall 4). On top of Wall 13 rests the moraine-type flow of fist-sized stone rubble with embedded fine gravel lenses (RF/FGL) that is also attested in the east sections of B64 and B74 and reaches heights of 1.5 m. (Figs. 19, 22). In B74, fine gravel deposits migrated inside the "gate" of wall Locus 4, which was blocked during the RF/FGL events. Within these RF/FGL deposits, fireplaces and surfaces exist, proving that deposition happened in short episodes while the inhabitants were using the (temporary) surfaces. The whole accumulation, however, is rather homogeneous, contains aside the angular rubble occasionally fist-sized limestone gravel, and gives the impression of fast deposition in as restricted time. The third high-energy event in Area B-South is represented by the twisted walls in upper B83 and B84: The energy to which the walls were subjected causing them to lean in all directions, and therefore not abiding to a specific vector or pattern; this latter feature also leads us to conclude that this resulted from an earthquake.

Area C, Square C-10, Baulks C-20/20 and C-10/10 (Figs. 18, 23): Here, a stairwell in C-20/20 connects the two older occupational levels in C-10/10/-20/20/21, and a later occupation/building phase rests on the fist-sized stone rubble flow with embedded fine gravel lenses (RF/FGL). Similar to Area B-South, western Area C witnessed three major impact events: an extensive earlier wall rubble pile with air pockets in C20 (incompletely excavated) in a rather large open space, a huge rubble and gravel flow resting against high standing walls, and the reorganization of space and architecture during an upper architectural phase. During the latter, also the impressive stairwell in C21 (Bienert and Gebel 2004: Pl. 5) must have been erected. For the first time, we were able to isolate locally a distinct later architectural phase in Ba‘ja from an earlier occupation which represents a disruption of the site's architectural morphodynamic complexity of succeeding modifications that normally prevent the identification of clear sub-phases. Together with buttress Locus 114 of C10 and Wall 6 of C-10, this E-W running wall Locus 5 denotes the latest architectural phase in western Area C (Fig. 23). It is erected on a RF/FGL rubble flow with layers of small fluvial sorted and deposited gravel (8-15mm); this is also the case for buttress Locus 114, Wall 6, and buttress Locus 26. These water-laid fine gravels are also found in the north section of C20, where they accumulated against the E face of Wall 10 (former Baulk C-20/20). Here these fine gravels appear as lenses and layers inside the upper parts of a rubble flow, consisting of fist-sized stones. All the aforementioned wall remains and layers were covered by the light brownish fine-grained material (FGM) forming also the sub-topsoil layer in all Area B; its thicknesses reaches 60 cm. The RF/FGL rubble/ gravel seems to have terminated the earlier architectural occupation in western Area C, causing the reorganization of its space. The partial destruction of this phase appears to be evidenced by the deposition of the huge wall rubble in the open space of C20 and in the space between the Walls 120 in C20 and 5, 26 and 8 in C-10 (where many lintel stones were also found). The orientations of this wall rubble are various; the deposits feature a high frequency of air hollows, revealing a rapid and probably intentional filling of the space. It is assumed that this action relates to the deconstruction of walls in the area following an earthquake. This must also have twisted the complete stairwell Locus 129 in C20, simultaneously leaning it down by the height of one step: The earthquake, the subsequent deconstruction of architecture, and intramural filling of the large space in Area C20 preceded the migration of rubble/small gravel flows (RF/FGL) into the area. Water appears to be the agent of transport and movement of the RF/FGL before the walls of the latest occupation in western Area C were erected.

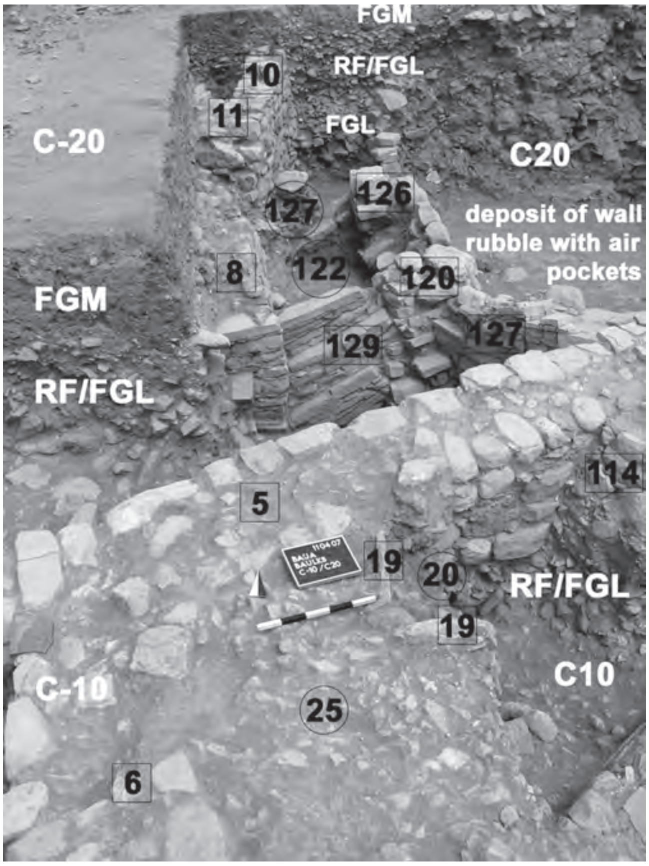

Fig. 23 Ba‘ja, Squares C10 and C20: Sequence of tumbled LPPNB stairwell, open space with LPPNB wall rubble showing air pockets (earthquake damage), Rubble/ Gravel Flows and Fine-Gravel Lenses (RF/FGL), latest LPPNB architectural phase remains, Fine-Grained Layers (FGM) deposits. View from S

Seismicity has so far been a rather neglected topic when discussing Neolithic rubble slides or the interruption/ abandonment of settlements. If we take as a measure the frequency of earthquake events to have affected the area in the last 2000 years, we can assume that every 200 years a medium-major earthquake should be expected; for example, in 551 A.D. Petra was almost totally abandoned after an earthquake destroyed its buildings, and Aqaba was twice destroyed in 363 and 1068 A.D. (Migowski *et al.* 2004, Korjenkov and Schmidt 2009). The LPPNB mega-sites are located along the Dead Sea Rift tectonics, and were therefore also vulnerable to destruction by such catastrophic events; however, and quite remarkably, our discussion of the descent of the mega-site phenomenon has until now failed to consider the role of seismicity in the related processes. Since LPPNB building units were mostly erected upon terraces or built on or into slopes, any leaning walls were simply explained away as the result of slope pressures, *e.g.* as was the case with the long wall in Ba‘ja's Area D; also, pronounced cracks in walls/pillars, *e.g.* in Basta B68: 18, were also subjected to this interpretation. Certainly, and without a doubt, this agglomeration of evidence calls for increased in-depth research into seismicity and its impact on our mega-site architectures.

In conclusion, the clearest evidence for LPPNB earthquakes affecting LPPNB sites stems from Ba‘ja Area B-South and western Area C. Here, it should also be noted that Area B-South lies between a southern sandstone outcrop and the northern sandstone ridge (Fig. 18), which are at a distance of some 15-20 m

Fig. 24 'Ain Rahub (site area dotted): Aerial view.

(Bienert and Gebel 2004: plan between Pages 122 and 123), and the lowermost architecture in these areas is probably in direct contact with the underlying bedrock. It follows that during an earthquake, shockwaves would have been transferred here directly into the walls of the structures. To summarise, the following earthquake features are attested in Ba'ja:

- walls pushed by perpendicular walls (tilting walls in various directions)
- wall rubble in fallen-domino arrangements; air pockets in their rubble
- lateral deflection and wall splitting

Blocked/inserted doorways/wall openings and wall reinforcements by adding parallel walls (*e.g.* the blocking and closure wall of the "gate" in B74) could very well be secondary earthquake evidence, meaning the result of space reorganization after an earthquake. There might then be a chance in Area B-South to find the skeletal remains of earthquake victims.

The 'Ain Rahub Evidence

At the Late Epipalaeolithic/Early Pottery Neolithic site of 'Ain Rahub (13 km NW of Irbid and 4,5 km NNE of Sal; Gebel and Muheisen 1985) Yarmoukian finds were encountered in rubble layers sealed within the stratigraphy of a terrace spur; the terrace remains belong to the lowest terrace in Wadi Rahub (Hannss' T1 Terrace, *cf.* Muheisen *et al.* 1988: 475ff.); the geomorphological setting of 'Ain Rahub (420 m a.s.l.) was studied by Christian Hannss in 1985 by stereoscopic analysis of aerial photographs. In the following years, much of the topography of the area, including the vicinity of the spring, was altered by street building, bulldozing, and rock blasting from the nearby licensed excavation of graves (Siegfried Mittmann, pers. comm.), finally hindering further excavations.

Physiographically, the location represents a terrace spur (Fig. 24: dotted area) between Wadi

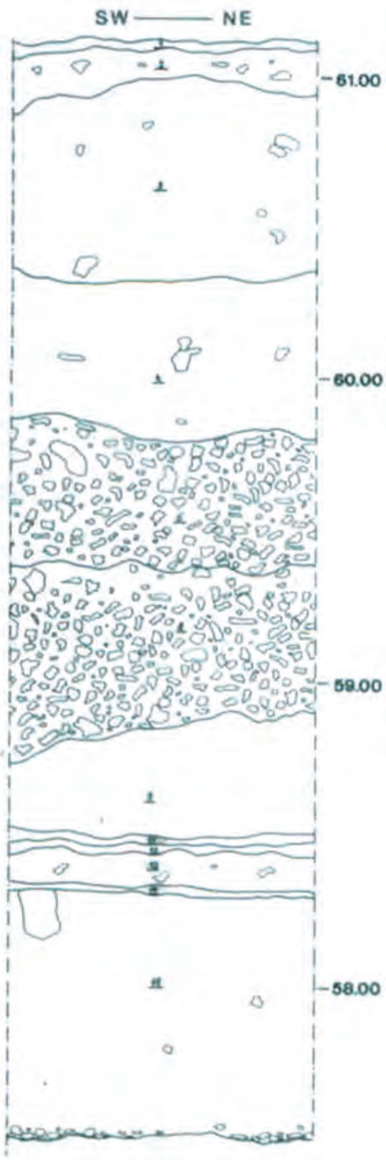

Fig. 25 'Ain Rahub, Test Unit, NW Section. (section width: 1,00 m)

Rahub and a tributary drainage. Its stratigraphy comprises alluvial, colluvial and cultural layers. In 1981, a final Natufian settlement (extending onto the spur) was exposed during bulldozing activities at the eastern foot of the spur. A test unit of 3x1 m cutting into the slope, carried out by Reinder Neef, was originally intended to reach the Natufian layers in order to determine the overall extension of the site in the spur's slope. To our surprise, the Test Unit (Fig. 25-26) revealed concentrations of mud brick debris, grinding tools, and Yarmoukian pottery (Kafafi 1989) at depths between 59.70 and 58.80 m (excavation-internal height) (some even occuring at depths of 58.20 m; *cf.* Fig. 25) which are partly embedded in the rubble layers between 59.90 and 58.90 m. At that time, these finds represented the second Yarmoukian site east of the Jordan River, and still the nature of the site is not clear as all of its layers were sealed within the spur. The rubble layers resulted from possibly two immediately succeeding events and were formed by densely packed stones (Figs. 25-26), apparently representing mud flows which took up Yarmoukian cultural materials including Yarmoukian pottery and brick fragments on their way to deposition. Final Natufian (12000-10200 calBC) finds occurred *c.* 1 m below the lowermost rubble layer, concentrated at depths around 57.70 m.

Christian Hannss commented (Muheisen *et al.* 1988: 479) that the „sediments and limestone debris" of the rubble layers „most likely are not of direct colluvial origin but were deposited as wadi accumulations. Major colluvial deposits cannot be expected here, as there are no extensive slopes above the lower terrace of 'Ain Rahub." While the good preservation of the Yarmoukian sherds contradicts the interpretation of wadi accumulations, Hannss' understanding that no direct colluvial origin of the rubble layers should be assumed appears plausible. Most likely, the 'Ain Rahub evidence represents one or two intense rubble slides moving onto the Final Natufian/Post-Final Natufian slope surfaces from the immediate slopes to the north. Here a Yarmoukian settlement must have existed, the material of which became a component of the rubble slides.

The Yarmoukian rubble slide at 'Ain Rahub is dated by one Quercus sp. charcoal date (GrN-14539: 7480 +/- 90 BP; W.G. Mook, Centrum voor Isotopen Onderzoek, Groningen and R. Neef, pers. comm. 1987). This 14C-age (Fig. 17), equivalent to a calibrated age of 6490 - 6170 calBC (95%), is in good agreement with other dates for the Yarmoukian (Weninger, this issue of *Neo-Lithics*). However, whether this date represents the date of the rubble slide itself (*e.g.* remains of a fire place during the deposition of the rubble), or not simply the (potentially earlier) date of transported charcoal from the Yarmoukian settlement, remains to be discerned. This interpretational problem applies to many of the available 14C-ages for the "Yarmoukian" rubble slides, and can – at the present state of research – only be resolved by application of direct (exposure) dating methods, *e.g.* OSL and 10Be, or by the radiocarbon dating of well-observed in situ features from within a rubble layer sequence.

Rubble Layer Archives: Research Perspectives

The intricacy of seventh millennium BC rubble layers at Neolithic sites in Jordan results from the polygenetic and polycausal elements that were involved in their formation. This should not make us ignoring their potential as an important source of information on climatic change. By this, we do not mean that the origin of rubble (be it anthropogenic or natural) is irrelevant to discussions, but we do suggest that even locally transported anthropogenic rubble may reflect a changed or changing climate regime. Due to the complexity of rubble layers, future analysis demands a multidisciplinary (*e.g.* prehistory, geomorphology,

Fig. 26 ‘Ain Rahub, Test Unit: Excavation of the lower parts of the rubble layers. View from SE.

pedology, radiocarbon and other dating methods) approach, and any interpretation based upon a single genesis must be disregarded. Future rubble layer research must not only concentrate on collecting more rubble slide archives from more sites in different physiographic locations and from different Early Holocene contexts, but rubble layers also need to be properly excavated and observed in terms of microstratigraphy, depositional events, and in situ features. The excavation of rubble layers at prehistoric sites must take the form of a joint infield cooperation between archaeologists and geomorphologists. It follows that the analysis of rubble layers without direct correlation with the surrounding natural sedimentary environments amounts to an incomplete and fragmentary enterprise.

Rubble layers occurring during and immediately after prehistoric occupations are a most important source for improving our comprehension of a region’s settlement history. Further, they not only provide us with an explicit understanding of the occupational fate of a given site, but they also help to identify (intra-site) areas within a site that were deserted during an otherwise permanent presence of humans at the same location. In the site’s natural environment they are one of the important sources of information on land use, vulnerability of biotic resources, and anthropogenic eco-impacts.

The main problem lies with the absolute dating of rubble layers. Raised awareness is needed to identify potentially undisturbed in situ traces of occupation and surfaces in the depositional succession of rubble layers; indeed, this task should not pose too great a problem. Otherwise, the dating of rubble layers is subject to the high risk of dating much older re-deposited material taken up from transformed cultural phases further upslope.

Rubble layer awareness is required in all respects.

Acknowledgements: I would like to thank Bernhard “Bernie” Weninger for initiating the recent rubble slide and subsequent RCC discussion, and for re-awakening our concern of these phenomena which, since our 1987 season in Basta, we simply referred to as rubble layers. B. Weninger initiated an infield project on the rubble slides of ‘Ain Ghazal, Basta, and Ba‘ja (financed by the Sonderforschungsbereich 806 at Cologne University), starting section sampling work at ‘Ain Ghazal in 2009. In Spring 2010, and in collaboration with us, additional geomorphological samples were taken by Christoph Zielhofer in Ba‘ja and Basta, as well as 3D Laser Scanning of the rubble layers and related architectures by D. Hoffmeister, Cologne University. Since 1987, I have discussed the phenomenology and morphology of our rubble layers with many colleagues: Ulrich Kamp, Hans-Joachim Pachur, Christian Hannss, Bo Dahl Hermansen, Hans J. Nissen, Henning Fahlbusch, and others, but only the recent rubble slide/ RCC debate brought a new impetus into the discussion of this hitherto mysterious phenomenon. Since the 1980s, Gary Rollefson and Zeidan Kafafi discussed internally the rubble layers for their sites, and Gary Rollefson was among the first who understood the potential and implications of this topic. Recently, discussions were joined by Christoph Zielhofer, Leipzig University, through his infield geomorphological and geoarchaeological cooperation in Spring 2010, which are awaiting supplementation by his laboratory results. The photos of Basta were taken by Margreth Nissen and Gerald Sperling; all others are by H.G.K. Gebel. Graphical assistance was provided by Jana Pokrandt, and language editing was carried out by Lee Clare, Cologne University. I thank Hamzeh M. Mahasneh, Muhammad Najjar, and Alan Simmons for the permission to use the photos of Figures 23-25. All our research on the Neolithic of South Jordan would not be possible without the support of the Department of Antiquities of the Hashemite Kingdom of Jordan whose constant support we gratefully acknowledge here.

Notes

[1] All absolute chronology in this contribution refers to calibrated radiocarbon dates BC. The chronological abbreviations used here and their current absolute chronological equivalents are:
LPPNB Late Pre-Pottery Neolithic B (*c.* 7500 - 7000/6900 BC)
FPPNB Final Pre-Pottery Neolithic B (*c.* 7000 - 6800? BC)
PPNC Pre-Pottery Neolithic C (*c.* 6800? - 6500? BC)
PNA (Yarmoukian) Pottery Neolithic A (*c.* 6500? - 6200? BC)
The contents of this contribution became the basis for infield discussions in the field in the course of B. Weninger's project (*cf.* the Acknowledgements) in Spring 2010. The delayed *Neo-Lithics* 1/09 issue allowed some reference to be made to this project, but could not consider fully its results.

[2] The following abbreviations were used for the characteristic stratigraphic units of the Basta/ Ba'ja sedimentary environments. Since the origin and composition of the sedimentary features are not exactly similar, for each site different abbreviations are used.
FGM Fine-Grained Layers, characteristic for the sub-topsoil layers (Ba'ja)
RF Rubble/Gravel flow (Ba'ja)
FGL Fine-Gravel Lenses (Ba'ja)
URL Upper Rubble Layers (Basta)
LRL Lower Rubble Layers (Basta)
FGD Fine-Grained Deposits, characteristic for the sub-topsoil (Basta)

References

Bienert H.D. and Gebel H.G.K.
2004 Summary on Ba'ja 1997, and Insights From Later Seasons. In: H.D. Bienert, H.G.K. Gebel and R. Neef (eds.), *Central Settlements in Neolithic Jordan. Studies in Early Near Eastern Production, Subsistence, and Environment* 5: 119-144. Berlin: ex oriente.

Gebel H.G. and Muheisen M.
1985 Note on 'Ain Rahub, a New Late Natufian Site Near Irbid, Jordan. *Paléorient* 11.1: 107-111.

Gebel H.G.K. and Bienert H.D. with contributions of Krämer T., Neef R., Müller-Neuhof B., Timm J., and Wright K.I.
1997 Ba'ja Hidden in the Petra Mountains. Preliminary Results of the 1997 Investigations. In: H.G.K. Gebel, Z. Kafafi and G.O. Rollefson (eds.), *The Prehistory of Jordan, II. Perspectives from 1997. Studies in Early Near Eastern Production, Subsistence, and Environment* 4: 221-262. Berlin: ex oriente.

Gebel H.G.K.
2004a Present-day Site Setting and Physiographic Units. In: H.J. Nissen, M. Muheisen and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 35-52. Berlin: ex oriente.
2004b Site Preservation and Site Formation Processes. In: H.J. Nissen, M. Muheisen and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 95-116. Berlin: ex oriente.

Gebel H.G.K. and Hermansen B. Dahl
2004 LPPNB Ba'ja 2003. *Neo-Lithics* 2/04: 15-17. Berlin: ex oriente.

Gebel H.G.K., Muheisen M., Nissen H.J., and Qadi N. with contributions by Becker C., Hermansen B. Dahl, Neef R., Shafiq R.M. and Schultz M.
2004 Late PPNB Basta: Results of 1992. In: H.D. Bienert, H.G.K. Gebel and R. Neef (eds.), *Central Settlements in Neolithic Jordan. Studies in Early Near Eastern Production, Subsistence, and Environment* 5: 71-104. Berlin: ex oriente.

Gebel H.G.K.
2006 The Stratigraphy and Locus Data. In: H.G.K. Gebel, H.J. Nissen and Z. Zaid (eds.), *Basta II. The Architecture and Stratigraphy*: 11-132. Berlin: ex oriente.

Gebel H.G.K., Kinzel M., Nissen H.J., and Zaid Z.
2006 Summary and conclusions. In H.G.K. Gebel, H.J. Nissen and Z. Zaid (eds.), *Basta II. The Architecture and Stratigraphy*: 203-224. Berlin: ex oriente.

Gebel H.G.K. and Kinzel M.
2007 Ba'ja 2007: Crawl Spaces, Rich Room Dumps, and High Energy Events. Results of the Seventh Season of Excavations. *Neo-Lithics* 1/07: 24-33

Kafafi Z.
1989 Late Neolithic 1 Pottery from 'Ain Rahub, Jordan. *Zeitschrift des Deutschen Palaestina-Vereins* 105: 1-17.

Kamp U.
2004 Geomorphological Site Setting and Geochemical Results. In H.J. Nissen, M. Muheisen and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 53-94. Berlin: ex oriente.

Korjenkov A.M. and Schmidt K.
2009 An Archaeoseismological Study at Tall Hujayrat al-Ghuzlan: Seismic Destruction and Chalcolithic and Early Bronze Age structures. In Lutfi Khalil and Klaus Schmidt (eds.), *Prehistoric 'Aqaba* I: 79-98. Orient-Archäologie 23. Rahden, Marie Leidorf.

Migowski C., Agnon A., Bookman R., Negendank J., and Stein M.
2004 Recurrence Pattern of Holocene Earthquakes Along the Dead Sea Transform Revealed by Varve-Counting and Radiocarbon Dating of Lacustrine Sediments. *Earth and Planetary Science Letters* 222: 301-14.

Muheisen M., Gebel H.G., Hannss C., and Neef R.
1988 'Ain Rahub, a New Final Natufian and Yarmoukian Site Near Irbid. In A.N. Garrard and H.G. Gebel (eds.), *The Prehistory of Jordan. The State of Research in 1986. British Archaeological Reports - International Series* 396.2: 472-502. Oxford, B.A.R.

Simmons A.H. , Rollefson G.O., Kafafi Z., Mandel R.D., an-Nahar M., Cooper J., Köhler-Rollefson I., and Roler Durand K.
2001 Wadi Shu'eib, a Large Neolithic Community in Central Jordan: Final Report of Test Excavations. *Bulletin of the American Schools of Oriental Research* 321: 1-39.

Weninger B., Alram-Stern E., Bauer E., Clare L., Danzeglocke U., Jöris O., Kubatzki C., Rollefson G., and Todorova H.
2005 Neolithisierung von Südosteuropa als Folge des abrupten Klimawandels um 8200 cal BP. In D. Gronenborn (ed.), Klimaveränderung und Kulturwandel in neolithischen Gesellschaften Mitteleuropas, 6700-2200 v. Chr. *RGZM Tagungen* 1: 75-117.

Weninger B., Alram-Stern E., Bauer E., Clare L., Danzeglocke U., Jöris O., Kubatzki C., Rollefson G., Todorova H., van Andel T.
2007 Abrupt Climate Forcing Bbserved at Early Neolithic sites in South-East Europe and the Near East. In H. Todorova, M. Stefanovich, G. Ivaniv (eds.), *In the Steps of James Harvey Gaul, 2. The Struma/Strymon River Valley in Prehistory.* Proceedings of the International Symposium 'Strymon Praehistoricus', Kjustendil-Blagoevgrad (Bulgaria) and Seres-Amphipolis (Greece), 27.09-01.10.2004, Sofia: 7-28.

Weninger B., Clare L., Rohling E.J., Bar-Yosef O., Böhner U., Budja M., Bundschuh M., Feurdean A., Gebel H.G.K., Jöris O., Linstädter J., Mayewski P., Mühlenbruch T., Reingruber A., Rollefson G., Schyle D., Thissen L., Todorova H., and Zielhofer C.
2009 The Impact of Rapid Climate Change on Prehistoric Societies During the Holocene in the Eastern Mediterranean. *Documenta Praehistorica* 26: 1-53.

Commentary

Gary O. Rollefson Whitman College, Walla Walla rollefgo@whitman.edu

Weninger's masterful compilation of paleoclimatic data clearly shows the occurrence of a number of episodes of rapid climate change (RCC), and it is expectable that such phenomena should have had environmental consequences across the globe. One RCC coincided with a phenomenon (the rubble layers) on a number of essentially contemporaneous archaeological sites in Jordan, and it was both tempting and obligatory to determine if the correlation offered some aspects of cause and effect.

The contribution by Barzilai covered the presence of "stone surfaces" in archaeological sites that might have originated from agencies other than natural ones, and this contention is certainly acceptable. One point that should be made is that when we have talked about rubble layers in the Late Neolithic/Yarmoukian period, we were not concerned simply with pavements, but with vast accumulations. The situation at Ard el-Samra appears to conform to such massive accruals, but it is not clear from Barzilai's article if the mounds of stones were beneath, above, or interspersed with Yarmoukian cultural debris; in other words, could this movement of angular debris be due to flash flooding and deposition of materials from the wadis and gentle hill slopes detectable in his Fig. 1?

Barzilai's description of anthropogenic sources of angular rock debris covers conditions that are well recognized throughout the Levant. At 'Ain Ghazal, for example, there are large and dense lenses of fire-cracked rock (FCR) – which is almost always fire-cracked flint – during the MPPNB in the Central Field, but such occurrences are of a very different character from the situation in the Yarmoukian period (as well as in the LPPNB and PPNC). In the Yarmoukian layers, the rubble is dense, deep, and virtually continuously distributed across the entire site, both within buildings (probably abandoned before the deposition) and in the broad spaces between the sparsely built-up Yarmoukian village area. In the MPPNB, FCR occurs densely but only sporadically in tightly defined clusters of debris, and always associated with ashy deposits.

The suggestions that FCR is associated with cooking is probably not the case, or at least not a complete accounting for the presence of the crackled flint. While many hearths include FCR in and around them, there are other hearths (particularly those inside the MPPNB houses) where FCR is absent or only intermittently present. Most of the FCR concentrations are in outdoor locations, so the association of FCR is likely concerned with some form of processing of materials other than food, but just what processing remains elusive.

Gebel also considers the likelihood that not all rubble deposits are due to climatic conditions, and that "prime movers" as explanatory devices are very often suspicious if not outright misleading and erroneous. Earthquake evidence at Ba'ja is particularly impressive, and much of the rubble that ends up in rubble layers may owe their ultimate origins not to natural causes, but to anthropogenic practices as well. Nevertheless, he notes that usually there are indicators that water transport was responsible at least in part to the accumulations.

What is important about the evidence from Basta, I think, is that the rubble layers occurred in layers equivalent to the final pre-ceramic period, thus antedating a Yarmoukian age[1]. This follows a refinement of the so-called "8.6-8.0 k.y.a. event" to indicate that it was a period of time that, while geologically speaking was a "sudden" development, actually spanned a relatively long time at its onset (see Weninger, this volume). This is also a strong piece of evidence that the "rubble event" actually consisted of several climatic pulses, and these pulses were not necessarily contemporaneous across the Near East but instead varied according to geomorphic and geographic elements affecting storm tracks. The suggestion Gebel makes, that the end of the large LPPNB occupation of Basta by the beginning of the 7th millennium BC, is also an excellent case for arguing that the LPPNB everywhere was as much affected by climatic deterioration as by cultural factors (*e.g.*, Rollefson and Pine 2007), although such cultural degradation certainly had a coeval impact of the environment.

Even so, the effects on the local environment at the end of the LPPNB/FPPNB/PPNC at Basta were clearly more powerful than in the north at 'Ain Ghazal and Wadi Shu'eib. This might relate to the differences in annual precipitation: the area around 'Ain Ghazal receives c. 250 mm rainfall each year, while the modern situation at Basta is only 160 mm (Neef 2004: 188). The PPNC occupation at 'Ain Ghazal continued, albeit across a much more reduced area of the site (less than three-fourths of the LPPNB site area and far below the density of residential structures and projected population levels)[2]. The population density declined even more at 'Ain Ghazal during the Yarmoukian period, although there was still a substantial population, perhaps as much as 300-400 people.

As was the case at Basta and Ba'ja, populations exploded during the earlier part of the LPPNB, and like the situation at the southern sites, there is a possible "sudden" impact on the site's people. While the population at MPPNB 'Ain Ghazal was modest and spread across the Zarqa River to the eastern bank to only a moderate degree, the sudden influx of LPPNB immigrants turned the East Field into a major "suburb" of the main site. But this eruption of settlement expansion may have been necessary; it is possible that the surge in population began to exhaust local resources, especially farmland and pasturage as well as wood resources for fuel for domestic use (Rollefson and Pine 2007). The extension of domestic buildings eastward across the Zarqa River was well-established, but before 7203 ± 95 cal. B.C. a large ritual structure was built, cutting into what appears to have been an essentially abandoned zone of ʻAin Ghazal by that time (Rollefson 1998: 51-54, but especially Footnote 24). The construction of this building, which required a major communal effort) may reflect deteriorating climatic conditions already before the beginning of the PPNC period, as was seen at Basta.

The situation that Gebel describes concerning earthquakes as a possible contributor to rubble deposits before the Pottery Neolithic period might also have a parallel at ʻAin Ghazal, although evidence remains weak at the moment. The final stage of the circular LPPNB "shrine" in the North Field appears to have suffered an architectural disruption that included severe damage and partial disintegration of the floor; a replacement of the circular building was rapidly undertaken about 5 m to the south, but the replacement appears to have been used for a brief time (Rollefson 1998: 47-48). The floor damage in the earlier building suggests the possibility of earthquake damage, although unrelated slope subsidence instead can't be dismissed at the moment. Another bit of evidence that might relate to earthquake damage at ʻAin Ghazal contemporaneous with the situation at Ba'ja comes from a two-story building in the south Field that dates to the LPPNB. In this case, the section exposed by bulldozer work shows an upper painted plaster floor that collapsed into the confines of a lower room. Such a collapse was seen in the North Field at ʻAin Ghazal, but this was certainly due to a fire that burned roof supports (Rollefson and Kafafi 1996: 13-14) and had little evident relationship to seismic activity.

The contribution by Kafafi, Lucke, and Bäumler leaves one somewhat nonplussed. Much of the article addresses architecture both prior to and within the period under consideration (the "8.6-8.0 k.y.a. event"). Two standing geological/archaeological sections were sampled (the eastern South Field and the western Central Field). Considerable effort is made to describe the composition and development of five very large and undefined archaeological layers (rarely identified as to archaeological age), but none of which deal with the layers that are evidently (from their illustrations) Yarmoukian in age. Much of the geological analysis relates to terra rossa development at ʻAin Ghazal, and this surely has little to do with the gray, rocky sediments that characterize Yarmoukian layers. The statement that "... it is not clear whether the 'Yarmoukian landslides' were indeed landslides or whether they were connected with heavy rains or earthquakes" is perplexing since it seems to be speculation that the research should have addressed in the first place. It is possible, of course, that the research project is ongoing and that this issue will be addressed in the future.

In summary, the discussion of the relationship of rubble layers with anthropogenic and natural agencies has shown that both could be responsible, and both kinds of activity could have been in play simultaneously at some sites, depending on topographical situation. And it is also possible, even probable, that the rare cloudburst that dumped enormous quantities of water on degraded slopes (either naturally, due to drought, or due to human activity due to deforestation and brush removal, or both) did, in fact, result in movement of masses of debris down the hillsides. The 8.6-8.0 "event" witnessed a long period of depressed temperatures and reduced rainfall, and over those 600 years it is likely that different combinations of natural and human agencies contributed to rubble layers in the hilly regions of the southern Levant.

Notes

[1] It is intriguing that Gebel inserts a couple of distinctions into the end of the late preceramic Neolithic period, using Late PPNB, Final PPNB, and PPNC subdivisions. This topic is deserving of more discussion in a later issue of Neo-Lithics.

[2] In their article, Kafafi *et al.* claim that ʻAin Ghazal's maximum area was c. 10 hectares; this is the case for the LPPNB settlement on the western side of the Zarqa River. There was also an LPPNB enclave of 3-4 hectares across the Zarqa River from the main settlement during this period).

References

Neef R.
2004 Vegetation and Plant Husbandry. In H.J. Nissen, M. Muheisen and H.G.K. Gebel (eds.), *Basta I. The Human Ecology*: 187-218. Berlin, ex oriente.

Rollefson G.
1998 ʻAin Ghazal (Jordan): Ritual and Ceremony III. *Paléorient* 24/1: 43-58.

Rollefson G. and Kafafi Z.
1996 The 1995 Season at ʻAyn Ghazal: Preliminary Report. *Annual of the Department of Antiquities of Jordan* 40: 11-28.

Rollefson G. and Pine K.
2007 Measuring the Impact of LPPNB Immigration into Highland Jordan. *Studies in the History and Archaeology of Jordan* 10: 473-481.

Submissions NEO-LITHICS, Prof. Dr. Gary O. Rollefson, Department of Anthropology, Whitman College, Walla Walla, WA 99362, USA, Email: rollefgo@whitman.edu.
NEO-LITHICS, Dörte Rokitta-Krumnow/ Jan Krumnow/ Christoph Purschwitz/ Dr. Hans Georg K. Gebel, ex oriente, c/o Free University of Berlin, Hüttenweg 7, 14195 Berlin, Germany,
Emails: lugal-kalaga@gmx.de · purschw@zedat.fu-berlin.de · hggebel@zedat.fu-berlin.de,
Fax 0049 30 98 311 246.

Orders please send to: ex oriente e.V., c/o Free University of Berlin, Hüttenweg 7, 14195 Berlin, Germany, www.exoriente.org · ex-oriente@gmx.net · Fax 0049 30 98 311 246.

Subscription Minimum of three years subscription requested = 6 issues, c. 40-50 pages each, 66 Euro for 6 issues/ minimum subscription period (postage included); back issues available; members of ex oriente receive Neo-Lithics free of charge (included in the annual membership fee: 40 Euro for employed members, 15 Euro for students/ unemployed members).

Deadlines twice a year: 15th of May and 15th of November

Submission Guidelines
Text formats: in Word without formatting; for the general style of text, bibliography, and captions consult this or a recent issue of Neo-Lithics - Illustration formats: individual EPS, TIFF- files or JPEG in high resolutions; illustrations should not be embedded in the Word file. Please, sent a hard copy of the manuscript in case of complex contributions; keep bibliographic references to the utmost minimum.

Subscription Information
In the upper right part of the address field (envelope) you will find the issue mentioned until which (included) you paid your subscription. If you find an invoice with this issue, a renewal of subscription is necessary for the next three years / 6 issues. If an invoice is not paid after two months it is understood that a prolongation of the subscription is not desired, and no further issues will be send.

Note
Authors of Neo-Lithics receive a pdf file of their individual contribution upon publication. Please, understand that your contribution is subject to the copyrights of ex oriente Publishers. However, you are licensed to circulate the pdf file of your contribution privately, but beyond this we ask you not to publish it (or parts of it) in the World Wide Web, or in any other form without our prior permission.

Neo-Lithics is published and distributed by ex oriente, Berlin. Printing House: dbusiness, Berlin
 - ISSN 1434-6990