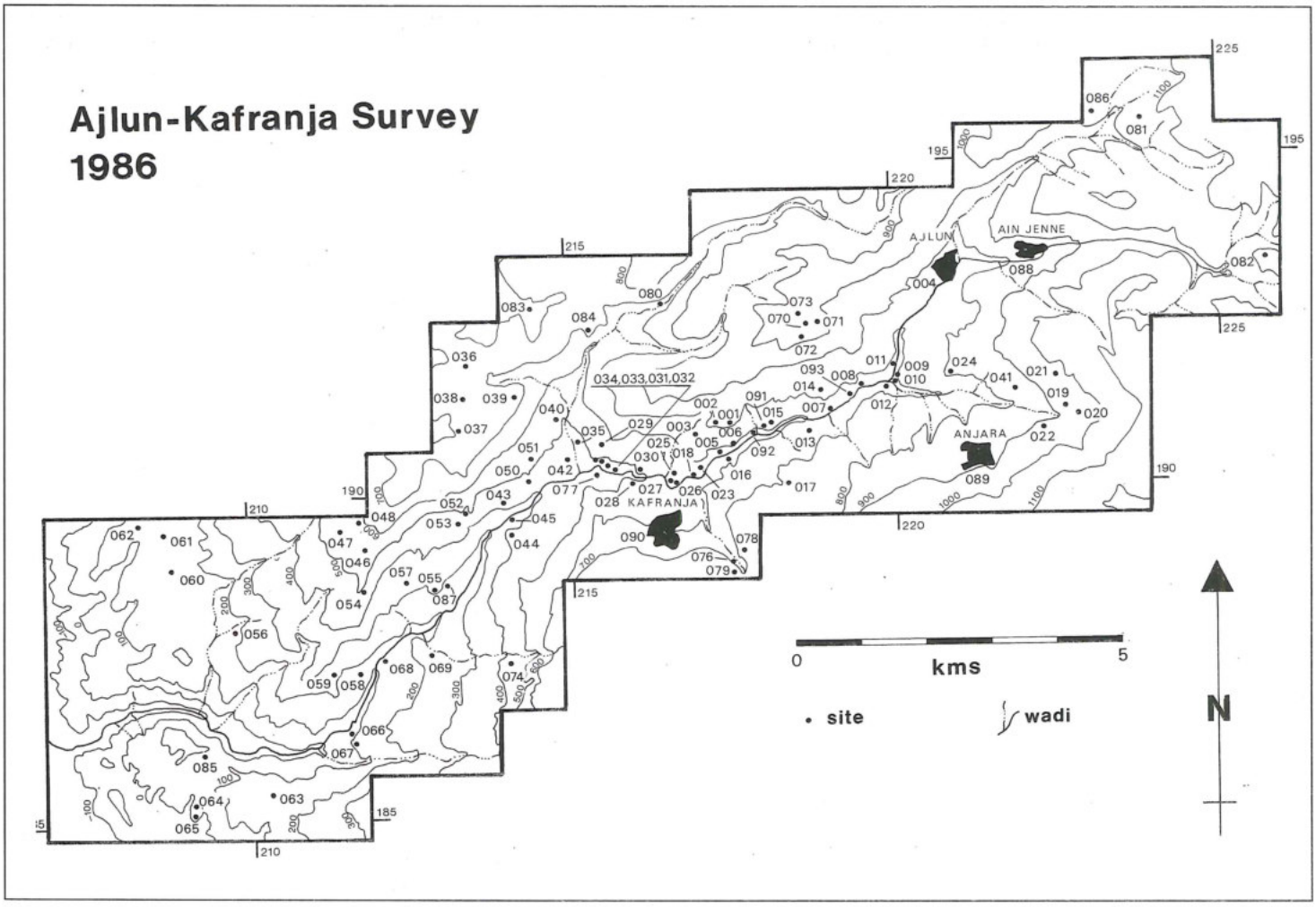
Joseph A. Greene
Harvard Semitic Museum
6 Divinity Avenue
Cambrige, Mass. 02138
USA

Joseph A. Greene

The Water Mills of the ʿAjlūn-Kufranja Valley: The Relationship of Technology, Society and Settlement

Ruins of water-driven grist mills are ubiquitous in the wadis on the eastern side of the north Jordan Valley. Until the middle of the twentieth century AD, these mills were an integral part of the traditional system of cereal agriculture in Jordan. Now they stand abandoned, but their remains are more than simply quaint reminders of a vanished way of life. They preserve direct evidence of the relationship of traditional technology, past society, and previous patterns of human settlement in Jordan.

This discussion focuses on a group of mills in the ʿAjlūn-Kufranja valley, a watershed on the western face of Jabal ʿAjlūn between Wādī al-Yābis and Wādī Rājib (FIG. 1). The mills were recorded during an archaeological survey of the valley conducted in 1986 (Greene forthcoming). While the 1986 survey compiled a comprehensive inventory of settlement sites, it also recorded



1. The ʿAjlūn-Kufranja Survey Area, showing all sites located.

non-site features that indicated past land use practices: rural cisterns, rock-cut basins for treading grapes or pressing olives, and, best preserved and most obvious of all, water mills.

Results of this survey provide evidence on the location and dating of past settlements associated with these mills. Additional information about the date and function of the mills can be gleaned from medieval Arabic and Ottoman documentary sources and the accounts of early western travelers, as well as from comparative studies of Mediterranean and European water mill technology. Finally, there are the eyewitness accounts of the older residents of the 'Ajlūn hills who observed mills in operation in the valley during the early decades of this century. What follows is an overview of the presently available archaeological, historical, technological, and ethnographic data on mills in the 'Ajlūn-Kufranja valley. In preliminary fashion it examines these mills and their relationship to past settlement and society in the 'Ajlūn-Kufranja region. Rather than definite conclusions, it sets forth a range of possible interpretations and proposes some directions for further research.

Landscape of the 'Ajlūn-Kufranja Valley

The 'Ajlūn-Kufranja valley consists of the drainage of Wādī Kufranja, the principal water course, and its main affluents, Wādī 'Ajlūn on the northeast and Wādī Ḥijla on the southwest. All are perennial streams fed by numerous springs issuing from the limestone slopes flanking the valley. Annual rainfall, varying from 600 mm in the hills at the eastern end of the wadi to under 300 mm at the wadi's juncture with the Jordan Valley, augments these sources. The wadi's greatest flow occurs in March and April with the springtime rains, dropping to a low at the end of summer.

The mountainous topography of Jabal 'Ajlūn isolates the valley from the plains north, east, and south and the Jordan Valley to the west. The Kufranja and its tributaries have deeply dissected the local limestone geology, forming a landscape of narrow, steep, interconnected gorges fringed by fluvial terraces of varying widths. Elevations range from 1100 m above sea level near the head of the wadi on the western face of Jabal 'Ajlūn to 100 m below sea level at its outfall into the eastern *Ghawr*, giving the wadi system a steep fall over its relatively short length.

This well watered, though remote landscape supports a range of cultivated and natural vegetation. Cereals, olives, and vines can be grown without irrigation on the light soils of the slopes and terraces at the eastern head of the wadi, while its drier southwestern tail is suitable for grazing. A secondary mixed forest of pine, pistachio and scrub oak cover the ridges that dominate the valley above the zone of cultivation.

These factors — rainfall and soils suitable for the dry cultivation of cereals, a year-round wadi flow over a relatively steep gradient and numerous, scattered small patches of arable land in a regionally isolated setting —

Table 1. Water mills located by the 'Ajlūn-Kafranja Survey 1986.

No.	*AKS Site No.*	*Extant Remains*	*Wadi Bank*
1)	011	Tower, complete mill house	north
2)	009	Arch with channel	-
3)	010	Tower	south
4)	008	Tower, partial mill house	north
5)	093	Tower	north
6)	007	Tower, partial mill house	north
7)	091	Tower, complete mill house	north
8)	092	Tower	north
9)	006A	Tower	north
10)	006B	Tower	north
11)	005	Tower	north
12)	018	Tower	north
13)	026	Tower	north
14)	027	Tower	north
15)	030A	Tower	north
16)	030B	Tower	north
17)	031	Tower, partial mill house	north
18)	033	Tower	north
19)	034	Tower	north
20)	045	Tower	south

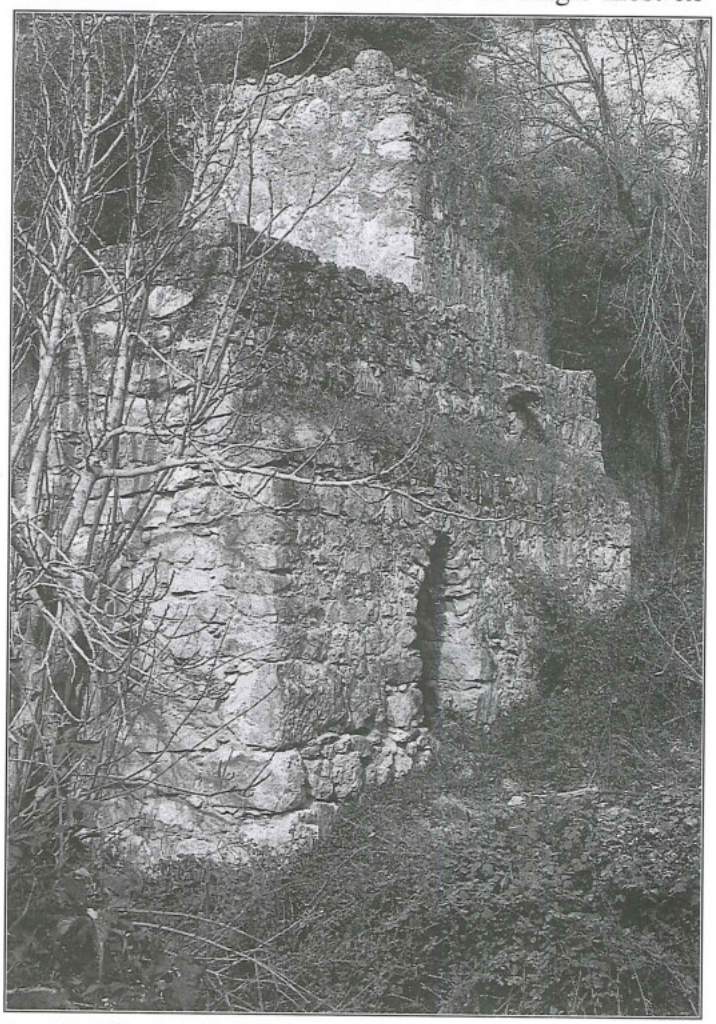
2. AKS 008: A typical mill in the ʿAjlūn-Kufranja valley, the so-called "Qidādī mill" perhaps identified by Schumacher in 1897-98.

combined to create conditions both favorable and necessary for the location of water-driven grist mills in the ʿAjlūn-Kufranja valley.

The Water Mills

There are remains of twenty water mills in the valley (FIG. 1, TABLE 1). All are built of local limestone blocks, roughly trimmed and mortared together (FIG. 2), in a design described as "raised-tower, horizontal-wheel type" (Gardiner and McQuitty 1987). This design, sometimes called a "Norse mill," is mechanically simple; in contrast to the more complex vertical water mill (Reynolds 1983). The "Norse mill" consists of a horizontal turbine wheel connected by a straight shaft to grinding stones lying in the same plane. A flow of water, its fall sometimes enhanced by a tower, is directed onto the turbine. Each revolution of the turbine wheel causes a single revolution of the grinding stone. Since the mill lacks gearing, its efficiency — the ratio of power input to work output — is low. Only five to fifteen percent of the energy applied to the turbine wheel by running water is transformed into power used to turn the millstone (Reynolds 1983: 14, 103-108). Its simplicity, however, make it economical to build and easy to maintain. Further, the design is ideally suited to streams with low volumes of relatively rapid flow over steep gradients, exactly the conditions found in the wadis of northern Jordan.

Most of the mills discovered were in an advanced state of decay, though in a majority of cases the most solidly constructed part of the mill, the tower, remained intact. At five sites (AKS 007, 008, 011, 031 and 091) the mill houses were wholly or partially preserved (see an example in FIG. 3), but all of the internal elements — millstones, turbine wheels, shafts, controls — were missing (for a contemporary description of these elements, see Wilson 1906: 249-250; for a detailed example from Turkey, see Sadler 1988). These mainly wooden components had been removed, either for reuse in other mills or for recycling into other applications. No intact or even fragmentary millstones were discovered in or around the mill structures. The millstones were the single most ex-



3. AKS 011: A mill with intact mill house, perhaps the so-called "Rabaḍī mill" identified by Schumacher in 1897-98.

pensive part of the mill apparatus, as the documentary evidence cited by Rogan (in this volume) suggests, and were therefore probably worth salvaging after the mill itself was abandoned. These millstones were perhaps removed to nearby villages and recut into smaller hand mills for household use or, much later, re-fitted onto the gasoline-powered mills introduced in the valley after World War II.

An intriguing feature associated with the mills is an aqueduct supported on stone-built arch (AKS 009, see FIG. 4) that carried water from the northern side of the wadi to the southern side. The aqueduct is located on Wādī ʿAjlūn downstream from the first mill (AKS 011) below ʿAjlūn town. The arch, constructed in masonry in the same style as the mills themselves, carried an open channel c. 50 cm wide that connected similar channels, partially rock-cut and partially built, on either side of the wadi. This system of water channels delivered water to a mill, AKS 010, located on the south side of the wadi. The extant tower of this mill had been neatly cross-sectioned in a road building operation sometime in the recent past, revealing its internal structure (FIG. 5; regrettably, this tower was completely destroyed in 1987 during construction of a new sewerage system in the valley).

4. AKS 009: Aqueduct across Wādī ʿAjlūn between mills AKS 010 and 011.

5. AKS 010: Cross section of a mill tower. Scale: 1.0 m.

Distribution of Mills

The mills in the ʿAjlūn-Kufranja valley are concentrated between a point upstream just above the confluence of Wādī ʿAjlūn and Wādī Ḥijla, and downstream at the southward bend in Wādī Kufranja about a kilometer below the modern village of Kufranja. None are located on tributary wadis. This distribution seems to depend on two factors:

1) Mills had to be located far enough down the wadi to guarantee a sufficiently strong flow of water to drive the turbine wheel. This consideration tended to place the mills are far downstream as possible to assure a continual flow powerful enough to turn the mill. A second factor, however, worked against this.
2) Mills could not be sited so far away from the grain fields and threshing floors as to make prohibitive the costs in time and effort of transporting the threshed grain down to the mills and the ground flour back up to the villages.

This may explain the concentration of the mills in a zone on the valley floor between the villages of ʿAjlūn and Kufranja. Emplacements higher upstream, though closer to concentrations of population, would have yielded too little head of water to drive the mills, especially in seasons of low flow. Though the flow further downstream would have been stronger, the precipitous drop in the valley floor below Kufranja village would have made the transport of grain to the mills and flour from them difficult and costly. For as-yet undetermined reasons, all but two of the mills (AKS 010, 045) are located on the north bank of the wadi.

Dating

The ʿAjlūn-Kufranja Survey recovered no datable pottery from in or around any of these mills. In fact, no surface pottery at all was associated with them, and no excavations were conducted at the mill sites. All of the mills were located in the valley bottom and the extant structures were thickly overgrown with shrubs and brush. This, no doubt, affected the visibility of any surface artifacts that may have been present. Even if surface artifacts had been visible and had been collected, it is by no means certain that they would have been chronologically indicative of the use phases of the mills, much less of their foundation dates. These structures were after all not inhabited or even in continuous use. While an artifact scatter might have accumulated in and around a mill during its active lifetime, the density and variety of such a

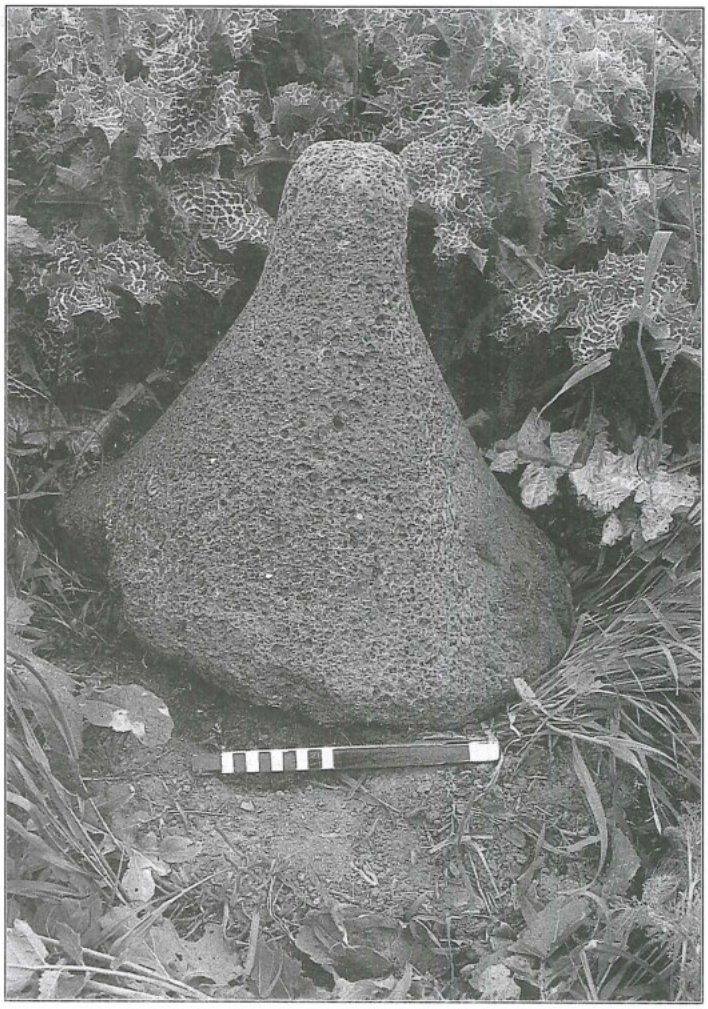
scatter, especially of its ceramic component, would probably have been quite limited. None of these structures then can as yet be conclusively dated from associated archaeological artifacts.

The suggestion that the initial phase of mill construction in Jordan may have occurred in the Mamluk period (Rogan, this volume; Malkawi 1994) is certainly plausible for the 'Ajlūn-Kufranja valley in light of the archaeological settlement evidence from the region. There are thirty settlement sites in the valley occupied in the "Ayyubid-Mamluk" period (TABLE 2), representing a 50 percent increase in site numbers over the preceding Abbasid/Fatimid phase. These sites are concentrated in the upper, eastern end of the valley and include settlements that continued into the Ottoman period: 'Ajlūn (AKS 004), Qal'at ar-Rabaḍ and its outliers (AKS 070-073), 'Ayn Jannā (AKS 088), 'Anjara (AKS 089) and Kufranja (AKS 090). This also coincides with the initial construction of the castle known today as Qal'at ar-Rabaḍ (Johns 1931: 21-25). The imprecision of the ceramic chronology for this horizon makes firm connection between the settlements and the mills difficult to establish. A Mamluk dating does however accord with the chronology of sugar production in the Jordan Valley, which employed a related technology of water-driven mills to grind the cane for the extraction of sugar (Ibrahim *et al.* 1976: 61-63; Hamarneh 1977-78).

Evidence of the medieval Arabic sources make even earlier datings feasible. There were water mills in greater Syria by the eleventh century AD: near Antioch (Ibn Buṭlān, AD 1051), in Damascus (al-Idrīsī, AD 1154), and at Imm between Antioch and Aleppo (Yāqūt, AD 1225) (Reynolds 1983: 117; citing Le Strange 1890: 375, 240, 457, respectively). Still earlier is the documentary evidence for water mills in Jordan itself. Writing c. AD 985, al-Muqadassī says of the al-Balqā' district, "[I]t also has many streams, the waters of which work the mills" (Le Strange 1890: 392-393, cited by Bennett 1982: 1). In all instances, however, technical details are lacking and no extant remains are known with certainty.

The connection between medieval Islamic water mill technology and that of late classical antiquity is more difficult to demonstrate (Reynolds 1983: 117-121; Yassin and Hill 1988: 52-54). It is unlikely that any of the mills in the 'Ajlūn-Kufranja valley represent survivals from the pre-Islamic period. Though Roman, Byzantine and transitional late Byzantine/early Umayyad settlement is well represented there (Greene forthcoming), commercial-scale grain milling in these periods was probably accomplished by large animal-driven mills of basalt. The conical bottom portion (*meta*) of such a mill was found at Mabarra (AKS 055, see FIG. 6; for intact examples, see Moritz 1958: 74-96; White 1975: 13-18).

The water mills recorded archaeologically in the 'Ajlūn-Kufranja valley can be connected very directly with one body of well dated documentary evidence derived from the region itself. Ottoman tax registers (*deftarlar*) from the end of the 16th century offer good evidence that certainly eight (and perhaps as many as sixteen) of the mills recorded in the 1986 survey were in operation c. 1596-97 (Hütteroth and Abdulfattah 1977: 162-163). The total is based on aggregate taxes imposed on mills in the valley and an estimate of the probable tax rate per mill. The aggregate taxes are given in TABLE 3.



6. Conical lower member (*meta*) of a large basalt mill from Mabarra (AKS 055). Scale: 25 cm.

The exact number of mills is not stated and it is not clear how many individual mills the total taxes represent. Issawi, citing evidence from a *deftar* for *liwā'* Ṣafad (also dated AD 1596-97) puts the tax rate at 60 *aqja* per annum per pair of millstones, supposing one set of stones per mill; or 30 *aqja* per half year, supposing that mills operated only during the winter, high water season (1991: 284; see also Hütteroth and Abdulfattah 1977: 72). While Issawi assumes average rate of 45 *aqja* for *liwā'* Ṣafad, the rate cited for *Manṣūr* in *nāḥiyāt 'Ajlūn*

Table 2. Ayyubid-Mamluk sites and water mills in the ʻAjlūn-Kufranja Survey area.

AKS Site No.	*Name*	*Surface Remains*
1) 004	ʻAjlūn	modern town
2) 005	*none*	mill tower
3) 006A&B	*none*	mill towers (2)
4) 007	*none*	mill tower, partial mill house
5) 008	*none*	mill tower, partial mill house
6) 009	*none*	arch with channel
7) 010	*none*	mill tower
8) 011	*none*	mill tower, complete mill house
9) 012	Khirbat Qidādī	settlement ruin
10) 014	Abū Hāshim	settlement ruin
11) 015	Khirbat Abū Ḥāmid	settlement ruin
12) 016	Safit	settlement ruin
13) 018	*none*	mill tower
14) 019	Sālūs I	settlement ruin
15) 020	Khirbat Khamad	settlement ruin
16) 021	Sālūs II	sherd scatter, terrace walls
17) 024	*none*	field tower
18) 026	*none*	mill tower
19) 027	*none*	mill tower
20) 029	Mshayrfa	settlement ruin
21) 030A&B	*none*	mill towers (2)
22) 031	*none*	mill tower, partial mill house
23) 032	Brādiya	sherd scatter
24) 033	*none*	mill tower
25) 034	*none*	mill tower
26) 035	Sidr Smīn	settlement ruin
27) 041	*none*	field tower
28) 045	*none*	mill tower
29) 047	Stura	cistern, rock cuts
30) 060	Khirbat Qāfṣa	settlement ruin
31) 063	Khirbat az-Zaytūna	settlement ruin
32) 068	Khirbat an-Nimr	settlement ruin
33) 070	Qal'at ar-Rabaḍ	castle
34) 071	Qal'at ar-Rabaḍ I	settlement ruin
35) 072	Maqām al-Khaḍr	settlement ruin
36) 073	Qal'at ar-Rabaḍ II	settlement ruin
37) 074	Khirbat al-'Uqda	settlement ruin
38) 076	Khirbat al-'Āmiriya	sherd scatter
39) 077	Khirbat Manṣūra	settlement ruin
40) 079	Dabat Kannas	sherd scatter
41) 080	Khirbat al-Jubb	settlement ruin
42) 083	ʻAlī Mashhad	saint's tomb
43) 084	*none*	settlement ruin
44) 088	ʻAyn Jannā	modern village
45) 089	ʻAnjara	modern village
46) 090	Kufranja	modern village
47) 091	*none*	mill tower, complete mill house
48) 092	*none*	mill tower
49) 093	*none*	mill tower

Table 3. Water mill taxation in nāḥiyāt 'Ajlūn* (AD 1596-97).

Name in deftar	*AKS Site No.*	*Aggregate Tax*
'Ajlūn	004	300 *aqja*
Kufranji (Kufranja	090	140
Manṣūr (Kh. el-Manṣūra)	077	30
Totals		470 *aqja*

* *nāḥiya 'Ajlūn*: one of six administrative subdivions of *liwā' 'Ajlūn* (hutteroth and Abdulfattah 1977:17-20; FIG. 1).

(30 *aqja*) suggests that in this case the semi-annual rate prevailed. Applying this assessment to the entire valley, the total tax for *'Ajlūn* represents ten mills, that for *Kufranji,* approximately five, and that for *Manṣūr*, one; yielding a total of sixteen mills. Rogan (this volume) cites differential rates for milling flour in high-water versus low-water seasons, suggesting that milling went on year-round. If the *Manṣūr* mill was an exception, in use only half the year, and the *'Ajlūn* and *Kufranji* mills operated year round (and were taxed accordingly), this would cut the total in half, from sixteen to eight mills.

For subsequent centuries such detailed information is lacking, though travelers' accounts from the late nineteenth and early twentieth century do supply some data. In his visit to the valley in 1897-98, Gottlieb Schumacher reported only two mill sites, though he was able to identify them by name: "*ṭāḥūnet er-rabaḍīje*" (the Rabaḍī mill) and "*ṭāḥūnet ḳedādi*" (the Qidādī mill). He located the Rabaḍī mill opposite a ruined settlement named "*ḳedādi*" (called Khirbat Qidādī [AKS 012] in 1986), while placing the Qidādī mill 300 m farther downstream (Schumacher and Steuernagel 1925: 313). The names given are presumably those used locally at the time. The Qidādī mill is so-called perhaps for its association with a named ruin and the Rabaḍī mill either for its proximity to Qal'at ar-Rabaḍ or its possession by a local clan of the same name. Schumacher gives no other description and he does not say if the mills are still functioning. The details he does provide, however, make it likely that the Rabaḍī mill is to be identified with the complex of remains recorded in 1986 as AKS 009, 010 and 011 while the Qidādī mill is probably AKS 008.

Other accounts are far less detailed and much more impressionistic than Schumacher's. Still, it is certain that some of these mills were in use early in the twentieth century. Wilson, in addition to his detailed written description of a water-powered grist mill, publishes a photograph showing a mill in operation (1906: facing p. 260). The caption reads: "A Water-Mill, Jebel Ajlun." Whether this particular mill is actually in the 'Ajlūn-Kufranja valley is unknown.

There is ethno-historical evidence for modern use of water mills in the valley. In the course of the 1986 survey, elderly residents were questioned who recalled accompanying their fathers down to mills on the wadi floor to have threshed grain ground into flour. Though they were not specific as to which mill or mills they visited in their childhood, they did state that there were four mills in operation in the valley in the 1920s and 1930s and at that time a further twelve existed but were not in active use. (The total is sixteen, comparable to the higher number derived above from the Ottoman *deftarlar.* Compare also the numbers of derelict mills given by Selah Merrill, cited below). According to these informants, during World War II, one mill was still working and it processed all of the flour needed in the valley. Shortly after World War II, this mill ceased to function and was replaced by gasoline-drive models located in the villages.

These informants added that the millstones for the old water-driven mills were made of basalt and were brought by camel from Ḥawrān in southern Syria. This corresponds exactly with the account of basalt mill stone quarries in Ḥawrān given by J. S. Buckingham, a nineteenth-century traveler in Syria (1825: 166-167, 283-284; cited by Rogan, this volume). The millstones were brought into the valley as rough cut blanks and finished by a local mason before installation. Furthermore according to these men, the mill wheels required redressing every three to four months and replacement every four to five years. For his labors, the millstone mason was paid in cash (if possible) but might also be compensated in ground floor.

It is unlikely that all twenty mills in the valley were ever in simultaneous use. The cereal producing capacity of the valley and the demand for ground flour (even if external demand is taken into account) would not have called for so many mills. It is doubtful that the mills in the 'Ajlūn-Kufranja valley served anything but local needs, though local demand in an era of high population (as in the Mamluk period) could have been considerable. At other time, factors of location and landscape militated against regular trafficking of grain and flour into or out of the valley. The valley is isolated both from the rest of the surrounding 'Ajlūn highlands and the Jordan Valley to the west. The route of the ancient road from Jarash to Ṭabaqat Faḥl passed east and north of the valley, in the vicinity of modern Sūf and into the neighboring Wādī al-Yābis. At the other end of the drainage, the outfall of Wādī Kufranja into the Jordan Valley is a small gorge, too narrow and steep-sided to permit easy access from the *Ghawr*. Even the modern asphalt curves away to the south and enters the Jordan Valley well below the wadi mouth.

In the middle 1870s Selah Merrill noted a mixture of working and abandoned mills, counting at least a dozen flour mills in the 'Ajlūn-Kufranja valley, not all of which

were in active use (1883: 373-374; cited by Rogan, this volume). Such a situation arose from a variety of reasons. Merrill (1883: 395) attributed abandonment to such causes as insecurity or "unprofitability." The latter cause may be a case of "surplus capacity," i.e., more mills built or restored in a given producing region than could be supported by local demand for ground flour or justified by external traffic. Rogan (this volume) make the useful distinction between commercial-scale milling for towns and local-scale milling for villages. The later condition certainly prevailed in the 'Ajlūn-Kufranja valley.

Future Investigations

The immediate need is to record fully the extant remains of the mills in the 'Ajlūn-Kufranja valley, as well as those in other wadis throughout northern Jordan, before they are damaged or destroyed by modern development or further deteriorate of their own age (see now Malkawi 1994). But this is only a first step. One or more of the better preserved examples ought to be investigated archaeologically. Soundings sunk against mill house or mill tower foundations could yield ceramic data that would help date the tower's original construction. This assumes, of course, that the sounding would recover pottery, that the pottery would be diagnostic and datable, and finally that the ceramic datings would be more precise that merely "Ayyubid-Mamluk" or "Ottoman." Clearly, the ceramic chronological tools for the likely periods of mill construction and use require refinement.

Better ceramic chronologies would also make it worthwhile to undertake intensive, complete and carefully controlled surface collections in and around mill structures. Such controlled collections would help define the correlation between the history of a mill's use, abandonment and reuse and any detectable surface artifact scatter. The phenomenon of mill repair and reuse detected by Rogan in the late Ottoman court records is particularly important. Once built, a mill might go out of use, fall into disrepair and then be restored some years, even decades, after its original construction. Though the documents cannot be conclusive on this point, such a sequence of abandonment and reuse might have been repeated more than once.

Complete recording of extant structures will make it possible to document archaeologically a mill's construction history (so Gardiner and McQuitty 1987: 31), potentially yielding evidence for periodic rebuildings and restorations referred to in the sources. It may be possible eventually to identify the very mill structures whose rebuilding or restoration is recorded in the written sources. Closer dating may also help clarify the technological patrimony of horizontal water mills in greater Syria, their relationship to similar hydraulic devices of classical antiquity (see Reynolds 1983: 117; Yassin and Hill 1988: 31-35) and the role of the Crusades and their aftermath in the transmission of technical innovations back and forth between Christian Europe and the Islamic Near East (see von Wartburg 1983: 313).

Ultimately what is required is a comprehensive research strategy that integrates archaeological investigation and recording of the mills themselves and of their settlement contexts, thorough analysis of the documentary and ethno-archaeological sources and ingenious use of environmental data to reconstruct the social, economic, and technological systems of which these mills were a part.

Works Cited

Bennett, C. M. 1982. Early Islamic Amman. *Levant* 12: 1-8.

Buckingham, J. S. 1825. *Travels Among the Arab Tribes.* London: Longman.

Gardiner, M. and McQuitty, A. 1987. Water Mill in Wadi el Arab, North Jordan and Water Mill Development. *PEQ* 119: 124-132.

Greene, J. A. forthcoming. Ajlun-Kafranja Survey, 1986: Final Report. *ADAJ.*

Hamarneh, S. 1977-78. Zirā'at Qaṣab as-Sukkar wa Ṣinā'atahu 'ind al-'Arab al-Muslimīn. *ADAJ* 22: 12-19.

Hütteroth, W.-D. and Abdulfattah, K. 1977. *Historical Geography of Palestine, Transjordan and Southern Syria in the Late 16th Century.* Erlanger Geographische Arbeiten, Sonderband 5. Erlangen: Frankischen Geographischen Gesellschaft.

Ibrahim, M., Sauer, J. and Yassine, K. 1976. The East Jordan Valley Survey, 1975. *BASOR* 222: 41-66.

Issawi, C. 1991. Technology, Energy, and Civilization: Some Historical Observations. *International Journal of Middle East Studies* 23: 281-289.

Johns, C. N. 1931. Medieval 'Ajlun I: The castle (Qal'at er-Rabad). *QDAP* 1: 21-33.

Le Strange, G. 1890. *Palestine Under the Moslems.* London: Alexander P. Watt.

Malkawi, M. S. 1994. *The Water Mills of Wadi Kufranjeh during the Period between Late Mamluk and Early Ottoman: A Technological Study.* M.A. Thesis. Yarmouk University.

Merrill, S. 1883. *East of Jordan: A Record of Travel and Observation in the Countries of Moab, Gilead and Bashan.* New York: Scribners.

Moritz, L. A. 1958. *Grain Mills and Flour in Classical Antiquity.* Oxford: Clarendon Press.

Reynolds, T. S. 1983. *Stronger than a Hundred Men. A History of the Vertical Water Wheel.* Baltimore: Johns Hopkins University Press.

Sadler, S. 1988. Le moulin hydraulique à conduites forcées de Karapina (Turquie). *Techniques et culture* 12:

121-49.
Schumacher, G. and Steuernagel, C. 1924. Der ʿAdschlun. *ZDPV* 47: 191-240.
___ 1925. Der ʿAdschlun. *ZDPV* 48: 191-392.
___ 1926. Der ʿAdschlun. *ZDPV* 49: 167, 273-303.
Wartburg, M-L. von. 1983. The Medieval Cane Sugar Industry in Cyprus: Results of Recent Excavation. *AJ* 63: 298-313.
White, K. D. 1975. *Farm Equipment of the Roman World.* Cambridge: Cambridge University Press.
Wilson, C. T. 1906. *Peasant Life in the Holy Land.* London: John Murray.
Yassin, A. Y. and Hill, D. R. 1988. *Islamic Technology: An Illustrated History.* New York: Cambridge University Press.