GRINDING IMPLEMENTS AND MATERIAL FOUND AT TALL DAYR 'ALLA, JORDAN: THEIR PLACE AND ROLE IN ARCHAEOLOGICAL RESEARCH

by

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Introduction

Until recent days, grinding stones have been one of the essential components of the Levantine household equipment. Their importance has long been archaeologically neglected, in spite of the fact that in almost every site from the Upper-Palaeolithic onwards these stone tools can be found. Several archaeologists have noticed the need for further research concerning this artefact, but only a few have tried to remedy this neglect, most of them in relation to plant-domestication processes and the development of agriculture (Solecki 1969; Kraybill 1977; Hersh 1981; Wright 1992a).

There are numerous reasons for this omission. In the beginning of the century, artefacts were mainly used for sequence dating. Unfortunately, unlike pottery, grinding stones are not time and place-specific, and they are difficult to date typologically (Ben-Tor and Portugali 1987:237-238). The lack of typological change, probably due to long periods of use and a clearly defined functional shape, gave grinding stones a poor place in archaeological studies. Another problem concerning the grinding stones is the limited knowledge of geology and mineralogy among archaeologists: a complete study in grinding stones has to include a good archaeological background as well as an up-to-date regional geological base. A third reason is the confusing list of different and erroneously used nomenclature for this artefact (Hole, Flannery and Neely 1969; Carter 1977:694-695; Kraybill 1977:487-488). Many names and definitions, when given, are multi-variable and/or functionally incorrect. A last reason has to do with the context,where the stones are found. It is rare to find grinding stones in primary context, in situ, and they are therefore, not an easy means for the reconstruction of the society.

Surprisingly, this lack of interest occurs at a time when archaeology has become more of a social science, stressing the significance of human activity. This article intends to present a study of grinding stone artefacts from the Late Bronze and Iron Age contexts found at Tall Dayr 'Alla, in order to demonstrate its significant contribution to archaeological research.

Methodology

a) Research Objectives

Tall Dayr 'Alla is located on the eastern part of the Jordan Valley, near the entrance of the Wādī az-Zarqa' into the Jordan Valley. From 1960 onwards several excavations have been carried out on the tall, at first directed by H.J. Franken (Franken 1969; 1992) and succeeded by G. van der Kooij, both from the University of Leiden (The Netherlands) and M. Ibrahim, succeeded by Z. Kafafi from Yarmouk University, Irbid in Jordan (Kooij and Ibrahim 1989). One of the main goals is to provide a detailed stratigraphic sequence of the tall, correlating social behaviour of the inhabitants. Such a detailed investigation makes it possible to deal with spatial analysis and the connection with production, diffusion and use of artefacts.

This study does not aim at analysing typological changes within time, or frequencies within a particular period (see however Hovers 1996:171-172), but is rather a case-study, dealing with a large number of grinding stones from one place and of a short period (see however Wright 1992a:43-

44). The clarification of the relationship between the tools - the grinding stones - and the inhabitant - the users - is the main purpose of this report.

b) Terminology

Typologies, descriptions and analysis, concerning ground stones are usually technological (Wright 1992a:4). Because this study is dealing with function rather than with form and the phases to provide this form, the term grinding stones is more useful in this report. Grinding stones are defined as: every human-worked stone (=artefact) used for grinding (=an activity performed by using two objects).

Several authors have already noticed the wide range of terminology, sometimes even false (see introduction). This wide range of terms reflects the function-related analyses. Ethnographical as well as experimental and archaeological sources (Wright *et al.* in press:2) have pointed out that most of the stones are multi-functional (in contrast to Kraybill 1977:Table1; Hovers 1996:173), which makes classification rather difficult but not impossible. The attempt to avoid a functional typology (Wright *et al.* in press:2) is an option, but complicates analysis of the social aspect of the settlement or region.

In the case of Tall Dayr ‘Alla, four basic categories in the grinding tools assemblage can be distinguished, namely the upper and lower grinding stones, as well as the mortar and pestle (Table 1).

Typology

Multi-functionality can also be seen in morphological characteristics: a continuity in shape from one type to the other.

The difference between an upper and lower grinding stone is sometimes hard to see, often because of the fragmentary condition of the artefact. Apart from size, one has to look at the modification of the face opposite the working surface. A rough surface makes it impossible to serve easily as upper stone - because of the uncomfortable grip - well as a lower part where the rough surface prevents slipping away (Hovers 1996:173). The curve of the working surface as well as the section are characteristic elements.

Moreover, the distinction between a basin-like lower grinding stone and a mortar are the wear data. A mortar shows round grooves, while the lower grinding stone has in general parallel grooves. Although the ratio between depth and diameter differs between the two types (Hovers 1996:174), the terminology in relation to the mobile parts is generally based upon function and not on morphological grounds. The same difficulties of distinction may arise with a small upper grinding stone and a big pestle. A multi-functional analysis is possible, but this is only made clear by wear patterns. In addition, experiments of handling give indications of the function.

This study presents a typology based on functional, rather than on morphological or material variables (Table 2). Most of the

Table 1. Definitions, concerning the four different grinding stone types. The terms mobile and immobile are limited to the period of use.

Upper grinding stone = a mobile implement, characterised by one or more grinding surface(s), with which material can be ground on a lower grinding stone;
Lower grinding stone = a immobile implement, characterised by a rough lower surface and one or two grinding surface(s), on which material can be ground with an upper grinding stone;
Pestle = a mobile implement, which can be used with one hand to ground material inside a mortar;
Mortar = a immobile implement, characterised by a smaller or deeper hollow in which material can be ground (pounding and grinding movements) with a pestle;

main types are thus divided on the basis of the used stones, the application and the period of use being of great importance. In all of the examples, an artefact is placed with the most-heavily used surface either facing up towards the observer (type 2 and type 4) or facing directly toward the observer (type 1 and type 3). By the description of each type, a general idea about the morphology, production and function is given, based on the comparison of archaeological features with ethnographical ones. Then, the material of Tall Dayr 'Alla is presented (all the grinding stones from the excavation seasons 1984, 1987, 1994 and 1996), and finally reference material from a few other sites in the Southern Levant.

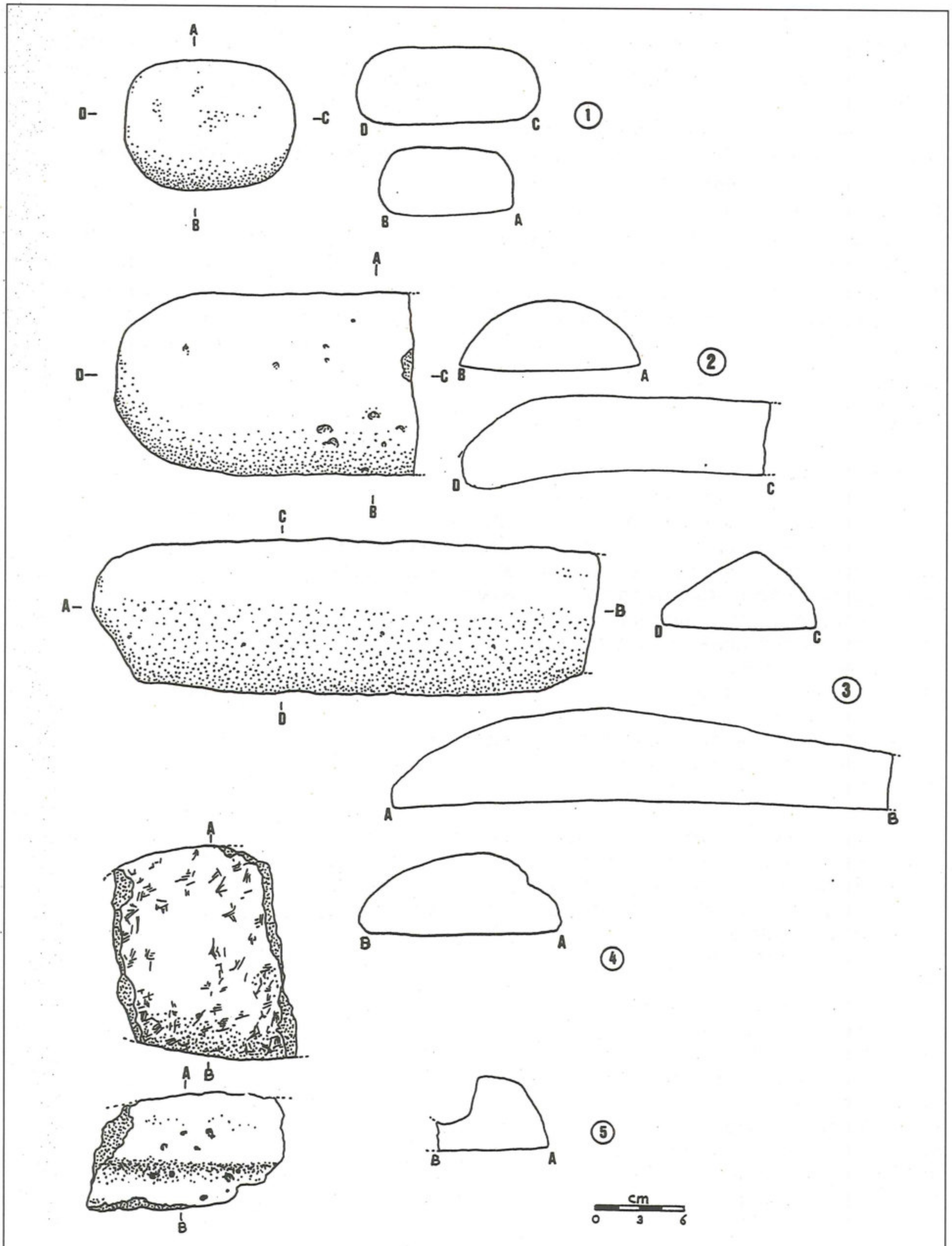
Type 1: Upper Grinding Stones

Type 1a (Fig. 1:1)

This upper grinding stone is small and can be used with only one hand (Morris 1990). These characteristics are not only obtained from their morphology, but also from the wear pattern, which shows the specific

Table 2. Types, numerics and statistics.

Type		N	%
Upper grinding stones			
1a.	One-handed upper grinding stone;	22	10.1
1b1.	Two handed upper grinding stone with symmetric cross section;	27	12.4
1b.2	Two handed upper grinding stone with asymmetric cross section;	57	26.2
1c1.	Upper grinding stone as part of an installation- egg-shaped;	3	1.4
1c2.	Upper grinding stone as part of an installation- round;	0	0
1d.	Irregular upper grinding stone;	0	0
1e.	fragments of upper grinding stone;	8	3.7
Lower grinding stones			
2a.	Flat lower grinding stone;	12	5.5
2b.	Sloping lower grinding stone;	15	6.9
2c.	Lower grinding stone as part of an installation- round;	0	0
2d.	Irregular lower grinding stone;	0	0
2e.	fragment of lower grinding stone;	7	3.2
Pestles			
3a.	Pestle: height is longer than width and length;	13	6.0
3b.	Pestle: height = length = width;	13	6.0
3c.	Pestle: length>width, height = length;	4	1.8
3d.	Pestle: length=width, height is smaller than length;	6	2.8
3e.	Irregular pestle;	1	0.5
3f.	Fragment of pestle;	1	0.5
Mortars			
4a1.	Tripod mortar;	12	5.5
4a2.	Mortar with four legs	0	0
4b.	Mortar with a ring base;	5	2.3
4c.	Mortar with a footed base;	1	0.5
4d.	Mortar with a flat base;	5	2.3
4e.	Mortar with a round base;	0	0
4f.	Mortar with a concave base;	0	0
4g.	Irregular mortar/basin ;	2	0.9
4h.	Bedrock mortar;	0	0
4i.	Fragment of mortar;	4	1.8
TOTAL		218	100



1. Upper grinding stones (1=Type 1a; 2= Type 1b1; 3= Type 1b2; 4= Type 1b2; 5= Type 1c1).

movements, made by one hand (see paragraph Function).

In Dayr 'Alla, this type is most often made of local sandstone (77%). The length ranges between 95 and 153 mm, the width between 55 and 94 mm and the thickness between 30 and 63mm. One of the characteristics which is generally well preserved is the width (in the Dayr 'Alla collection no type 1a grinding stones wider than 94 mm were found). The weight varies between 0.39 and 1.48 kg. (c.f. Yadin and Geva 1986:Fig. 38.6; Hovers 1996:Fig. 29.1-2; James and McGovern 1993:Fig. 125:2-5,7).

Type 1b1 (Fig. 1:2)

This upper grinding stone has a symmetric cross section in contrast with type 1b2. In Dayr 'Alla, the producer had used coarse grained sedimentary rock, as well as vesicular basalt. The stone is too big to use with one hand, and because of its weight and the possibility of using large pressure, the stone gets sharp edges instead of round edges. The weight, the pressure, the size of the working surface and the chosen raw material are all determinants of the productivity (Wright 1992a:72). Beside this productivity, it might say something about the function for grinding coarse hard dehusking grain (like emmercorn).

In Dayr 'Alla, this type is made of local sandstone (70.4%), travertine (3.7%) and basalt (25.9%). The length ranges between 195 and 305 mm, the width varies between 93 and 204 mm and the thickness between 34 and 114 mm. The weight varies between 1.91 and 10.50 kg. (c.f. Yadin and Geva 1986:Fig. 39.9; Chambon 1984: Pl. 77.18; Hovers 1996:Fig. 29:4; James and McGovern 1993:Fig. 126-7) .

Type 1b2 (Fig. 1:3-4)

This upper grinding stone has an asymmetric cross section and sharp edges, caused by grinding with two hands (see functional analysis). These movements are comparable with type 1b1, but because of this asymmetric shape, the 'miller' can use more pressure on the stone. The steep sides make it easy to press with the palms of the hands, when moving downwards (considering the lower ground stone is sloping down). Because of this pressure, one side will wear off quicker, causing more asymmetry. It is difficult, concerning functional analysis, to draw a sharp line between type 1b1 and type 1b2.

The length of the grinding stones in the Dayr 'Alla collection varies between 168 and 393 mm, the width varies between 100 and 180 mm and the thickness between 38 and 93 mm. Sandstone (mostly course grained) is used in 67% of all cases, beside basalt (31%) and flint (2%). It is the most frequent artefact in the ground stone collection of Tall Dayr 'Alla. The fragmentary condition of the specimens makes a weight measurement not possible. (c.f. Yadin and Geva 1986:Fig 38.2, 9-11,12; Chambon 1984: Pl. 77.19; Hovers 1996:Fig 25.6-8 and Fig. 29.3).

Type 1c1 (Fig. 1:5)

A groove is made in the upper surface of the stone for a wooden stick (Amiran 1956). The 'miller' uses two hands to move this upper grinding stone on top of the lower one. The stone has an asymmetric cross section, comparable with type 1b2.

This type of grinding stone is only known in Dayr 'Alla from fragments and because of that, we know only a little of the outer shape. The thickness ranges between 54 and 63 mm. All of them are made of basalt. The fragmentary condition of the specimens makes a weight measurement not possible.

This type of installation appeared in the Iron Age II, and is probably comparable with objects found in Tall Michal, Tall Zakariyeh, Tall Judeidah, Samaria and Tall Halaf (Amiran 1956:46-49; Oppenheim 1931:Tafel 49b).

Type 2: Lower Grinding Stones

Type 2a (Fig. 2:1)

A lower grinding stone with the same thickness at both ends, which gives no limitations to the position of the user. Within this type we can distinguish two subtypes, a lower stone with a flat surface and one with a basin-like surface, both characteristics seen from the longitudinal section. The equal height at both ends gives the impression that the stone could be turned around, when one side was too worn off to be useful (e.g. Hovers 1996:176). Although the lower surface was made roughly flat, it is possible that this stone was placed between stones and/or clay (polishing at the bottom of the stones may indicate this), to hold the lower stone steadily and maybe a little inclined. This sloping position, which is natural in type 2b, improves the homogeneity of the powder, because the grinding material will roll slightly downwards during milling. But it is known, from ethnographic evidence (e.g. Reynolds 1969:Pl/ V) as well as from archaeological material that this type is also used in a perfectly horizontal position. The advantage of a flat stone, as already said, is the possibility to reverse the sides, so the stone can be used optimally in grinding before repecking is needed.

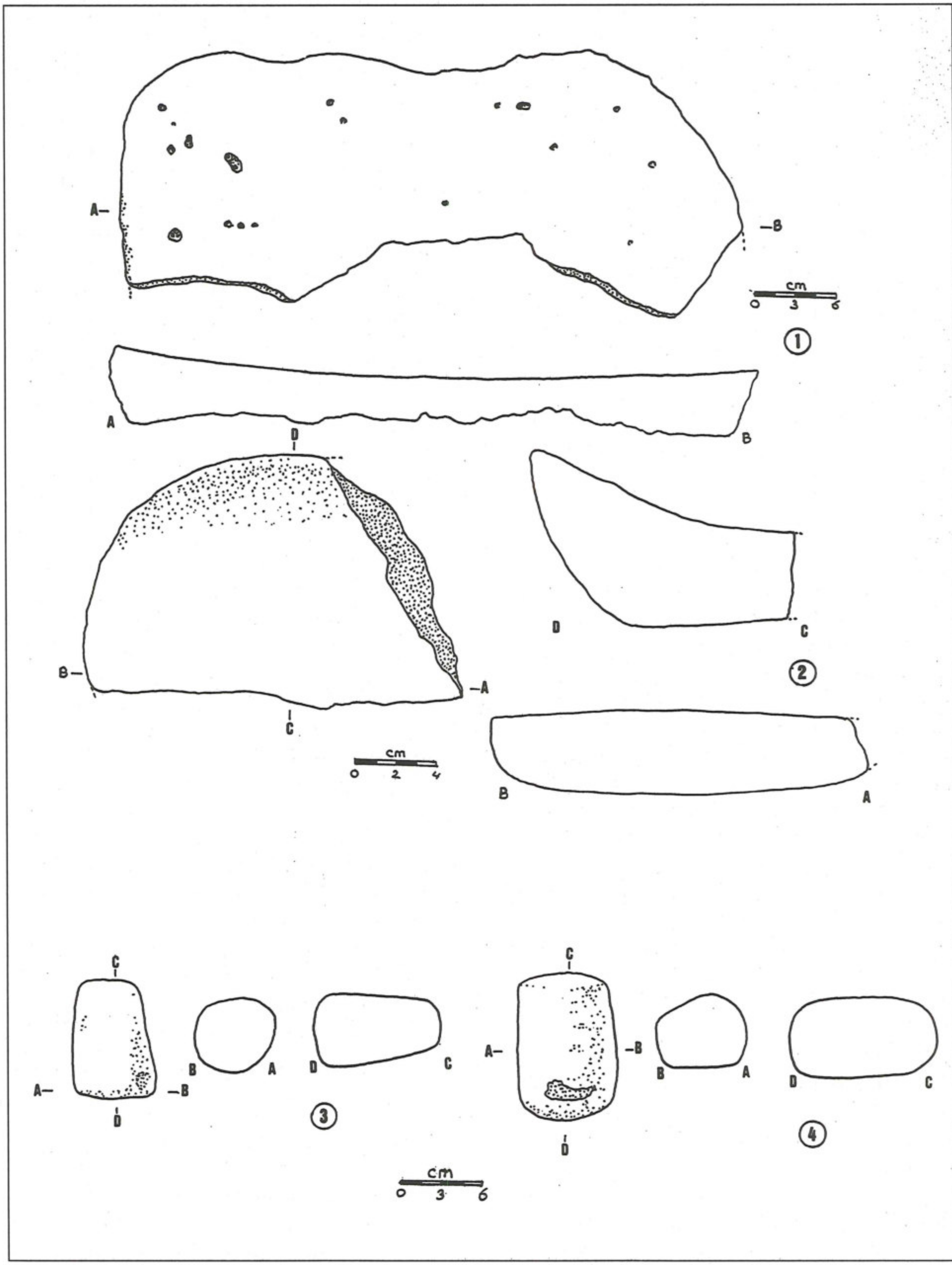
The more basin-like lower grinding stones of this subtype are difficult to distinguish from mortars. In general, the movements of the upper stone prescribe the type of the immobile part: wearing with rounded grooves makes it a mortar, while wearing with mostly parallel grooves gives it a function as lower grinding stone. Of course, this distinction has to do with the ratio of the depth of the hollow part to the diameter of the opening (e.g. Hovers 1996:176-177), but there is too little comparable information to prove this.

The artefacts found at Tall Dayr 'Alla are made of basalt in most cases (N=10) with two examples of quartzarenite. The basin shape has been found frequently. Almost all the examples (except for three stones with a flat width) have been used in relation with type 1a and sometimes with type 2b. The length varies between 219 and 459 mm, the width between 150 and 335mm, and the thickness between 72 and 24mm (of the whole objects). The weight which is between 3.0 and 20.0 kg, is in most cases enough to make it stable and held in place by clay or stone beds. (c.f. Herzog, Rapp and Negbi 1989:Fig. 76:7; Hovers 1996: Fig. 26:1,2).

Type 2b (Fig. 2:2)

The morphology of this type indicates the position of the miller towards the stone. The higher side has to be pointed at the miller, as seen from ethnographic sources (Bartlett 1933; Bornstein-Johanssen 1975:287-295) and from archaeological evidence (Darby *et al.* 1977:508-509; Erman 1971). Depending on the choice of the upper stone, the stone will be worn off flat or basin like, although a slight primary shape has already been given by the stone-worker. The difference between the two ways of use, related to the use of a special upper grinding stone, will follow in the paragraph about function. On Egyptian paintings, even flat lower grinding stones, as type 2a, are placed in a sloping direction (Darby *et al.* 1977:508-510). This 2b type has the disadvantage that every time the stone will be used, the same side is away from the miller. The stone has to be repecked more often than type 2a, which reduces the time of use.

In the Dayr 'Alla collection this type is made of quartzarenite (60%) and of basalt (40%). The length ranges between 333 and 515mm, the width between 165 and 465mm and the thickness between 28 and 121mm. The weight varies between 12.850 and 9.410 gram of the whole objects. The stone is in most cases hollow in length and flat or round in width-direction, what can indicate a grinding process together with type 1b. Only



2. Lower grinding stones and pestles (1= Type 2a; 2= Type 2b; 3= Type 3a; 4= Type 3a).

four examples have a hollow shape, like most of the 2a examples and could be used together with a one-handed upper stone. (c.f. Pritchard 1985:Fig. 45; McNicoll *et al.* 1992: Pl. 72.4; Franken and Steiner 1990:Fig. 2-24.1; Steiner 1994:Fig. 7-30; Hovers 1996:Fig. 26.3 and Fig. 25.2).

Type 3: Pestles

Type 3a (Fig. 2:3-4)

This type has a height greater than the maximum length and the maximum width. The vertical section can be of any shape, triangular as well as rectangular. In most cases there are two use-surfaces (the lower and upper end), but sometimes more. This type is the most popular one, and can be used for pounding and grinding.

Of the Dayr 'Alla collection, 62% of this type is made out of basalt (compact) and the others of local limestone and local sandstone. It is possible that the basalt pestle is produced and distributed together with the related basalt mortar. The height varies between 60 and 122 mm, the width and length between 34 and 74 mm. The weight ranges between 0.10 and 0.80 kg. Traces of manufacture are often covered or worn off by use-marks, but the regular shape may indicate an artificial origin of the tools. Some of these stones are used for pounding, while all are used for rubbing processes, as the wear patterns indicate. (c.f. Yadin and Geva 1986:Fig. 38.7-8; James and McGovern 1993:Fig. 124:1,2,5 and Fig. 126:1,2,3; McNicoll *et al.* 1992: Pl. 73.2; Chambon 1984: Pl. 77.10,13; Franken and Steiner 1990:Fig. 2-23.5, Fig. 2-29.11 and Fig. 2-35.3-4; Herzog, Rapp and Negbi 1989:Fig. 31.7:29-33; Hovers 1996:Fig. 30:1-6,8 and Fig. 24:2,3,4; Finkelstein 1993:Fig. 9:13(1-3,8) and Fig. 9:14 (1)).

Type 3b (Fig. 3:1)

This type is characterised by a round or squarish shape, with the same measurement for the width, length as well as the height. Often, this type has been called hammer stone. Also, a function such as stone-work instrument has been suggested by archaeologists and anthropologists (Jeffreys 1966:57-58; Lucas 1962:80; Waelkens et al. 1988:5-11) The function depends on the raw material and the wear pattern of this type.

In 62% of all the examples flint is used. The hardness and sharpness of these stones, makes a function as hammer stone possible. Flaking is not a problem, when using the hammer indirectly on the working surface, for example with a chisel. Multifunctionality has to be kept in mind. Some of the flint stones show grinding polish and small grooves, caused by pounding and grinding. The other materials used were limestone and basalt. The diameter varies between 40 and 90 mm. The weight ranges between 0.10 and 1.30 kg. (c.f. McNicoll *et al.* 1992: Pl. 72.7 and 73.5; Chambon 1984: Pl. 77.8-9, Pl. 77.11-12 and Pl. 78.12 (beside the mortar); Herzog, Rapp and Negbi 1989:Fig. 31.7:35-38; Hovers 1996:Fig. 24.5; Finkelstein 1993:Fig. 9:13 (4-6) and Fig. 9:14 (10)).

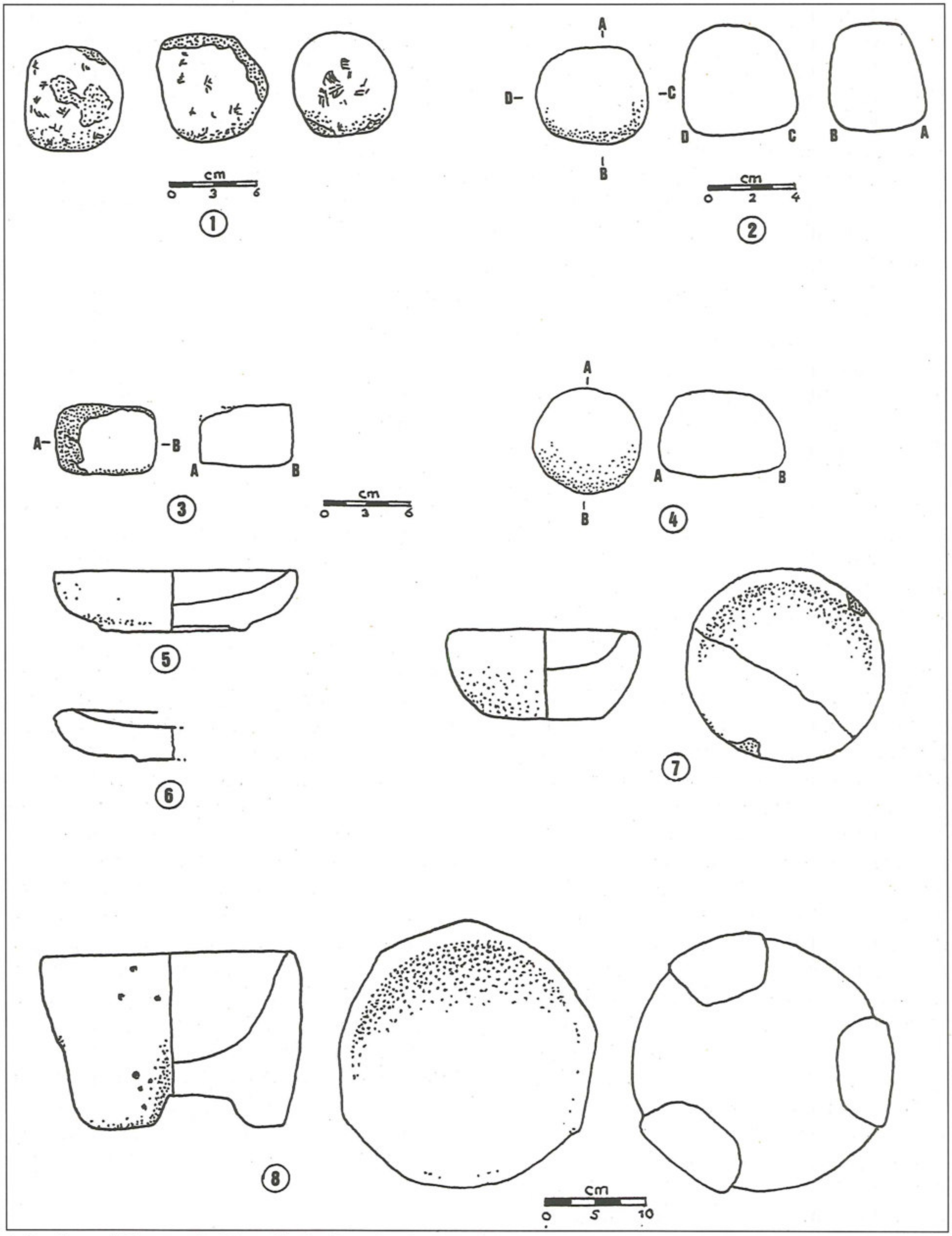
Type 3c (Fig. 3:2)

This type has the same height as length, but a smaller width. In most cases, the vertical section is triangular, but also rectangular or quadrangular shapes occur.

The length and height range between 40 and 105 mm and the width ranges between 51 and 87 mm. One object is made of basalt, two of sandstone (coarse) and one of limestone. The weight varies between 0.25 and 1.40 kg. (c.f. James and McGovern 1993:Fig. 124:3,4; Hovers 1996:Fig. 30:7,9,10).

Type 3d (Fig. 3:3)

This type is characterised by a lower height than width and length. Because the grip is not well formed, for example to grind with some force, this type has been called in most publications rubbing stone. The prob-



3. Pestles and Mortars (1= Type 3b; 2= Type 3c; 3= Type 3d; 4= Type 3e; 5= Type 4b; 6= Type 4c; 7= Type 4d; 8= Type 4a1).

lem with distinguishing this type from 3c is the main position of use, especially when more than one surface shows polishing. Therefore one stone can belong to both types.

The height varies between 23 and 58 mm, while the length and width between 40 and 80 mm. The weight ranges between 0.15 and 0.50 kg. In all cases, vesicular or light-vesicular basalt has been used as raw material. Vesicularity in particular, gives the idea of a grinding activity rather than polishing or rubbing. (c.f. Chambon 1984: Pl. 77:6,7,14; Franken and Steiner 1990:Fig. 2-16.3; James and McGovern 1993:Fig. 126:5; Finkelstein 1993:Fig. 9:13 (7)).

Type 4: Mortars

Type 4a1 (Fig. 3:8)

This type is a bowl with three legs (Buchholz 1963:1-77). The legs are going down straight from the rim but vary in shape and length. In general, the cross section of the legs is triangular with the smallest end pointing at the centre of the 'bowl'.

The sizes differ, but all of the objects are made of compact and light-vesicular basalt. The height ranges between 72 and 175 mm and the diameter between 135 and 480 mm. A mortar of this type has a regular shape and shows only by exception traces of manufacturing. The weight varies between 0.82 and 13.05 kg. (c.f. James and McGovern 1993:Fig. 122.1+3 and Fig. 123.9; Rowe 1940:Fig XXIII.6,7,8; Pritchard 1985:Fig. 18.5 and Fig. 8.27; Chambon 1984: Pl. 78.5-8; Herzog, Rapp and Negbi 1989:Fig. 31.2:1-7)

Type 4b (Fig. 3:5)

This mortar has a ring base. In general this type is small and shallow.

The Tall Dayr 'Alla examples have a diameter up to 162 mm and a height between 36 and 99 mm. The only complete example weighted 0.78 kg. The effort to make this shape indicates an experienced stoneworker, who wanted to make this particular shape. All examples are made of basalt. Not only the inside is smoothed by use, but also the ring base, as a result of moving over hard surfaces. (c.f. James and McGovern 1993:Fig. 121:3-8,11 and Fig. 123:1-2; Rowe 1940:Fig. XXIV.5,10; Pritchard 1985:Fig. 8:26; Herzog, Rapp and Negbi 1989:Fig. 31.3:15).

Type 4c (Fig. 3:6)

This type is very rare in the Levant. The shape shows close relation with ceramic examples of the Iron Age II (Tufnell 1953: Pl. 79:3,4 and 80:64; Amiran 1969: Pl. 62:8, 64:10 and 67:12; Chambon 1984: Pl. 57:23-24).

The one example is made of basalt and has a diameter of 110 mm and a height of 30mm. This mortar is well made and polished on the inside as well as on the base.

Type 4d (Fig. 3:7)

A mortar with a flat base. This base makes it difficult to stabilise the mortar when grinding. Therefore this type was probably used for grinding small amounts and soft materials.

Three of the examples are made of compact basalt and have a diameter of 120 mm and a height ranging between 52 and 84mm. The limestone examples are larger (350mm diameter) and higher (115 mm). Limestone is easier to work, but it shows more informal traces of production than the basalt mortars. This could indicate the difference between full-time specialists and part-time local stoneworkers, with less experience and time. The weight varies between 1.15 and 4.95 kg. (c.f. James and McGovern 1993:Fig. 121:10, Fig. 122:2,4 and Fig. 123:8,10,11; Chambon 1984: Pl. 78.13; Herzog, Rapp and Negbi 1989:Fig. 31:3,13-14; Hovers 1996:Fig. 26.5 and Fig. 24.1).

Type 4g

This type is characterised by an irregular shape and by being roughly made. In most cases, a river boulder was chosen. It can be assumed that this kind of mortar was only used for a limited period, when a better stone was not available.

Two examples were found at Tall Dayr 'Alla, both made of limestone. Some manufacturing traces are visible, but most of the surface is unworked. The length of these two stones varies between 225 and 95 mm, the width between 188 and 96 mm and the thickness between 65 and 54 mm. This type is often very heavy (more than 5 kg).

Raw Material

The general characteristics of grinding stones reflect the limited choice of raw material and shape. It seems that both variables were defined in advance. Even if the stone cannot be found in the close surroundings, people try to get that particular kind. This process of selection and modification of raw material in order to achieve a desired product, offers the possibility to understand the relationship of the material and non-material aspects of culture.

At Tall Dayr 'Alla, both local stone and non-local stone are used. This dichotomy is also found ethnographically, for example with the Aboriginals (Roth 1904; McCarthy 1941; Kraybill 1977:489). The inhabitants of Tall Dayr 'Alla were able to get coarse and fine grained sandstone, limestone, travertine and flint easily around the tall, especially from the nearby az-Zarqā' Valley (Bender 1968:geological map). Only basalt and andasite are, except for a few very small spots, rare in the direct surroundings (Wright *et al.* in press:11; Bender 1968:104). It is still difficult even with a microscope to identify exactly the place of origin of magmatic rock.

The Tall Dayr 'Alla percentages are: basalt and andasite (45.4%), sandstone (44.0%), limestone and travertine (5.1%), flint (4.1%) and others (1.4%). The popularity of basalt and andasite shows the economic value of this material that is not locally available. The value is bigger than the expenses, connected with transport and/or trade.

The local stones can be found in the az-Zarqā' Valley, and some of them even in the river, which runs at a distance along the tall (geological survey by the author in 1996). Pebbles are easily chosen and picked up because of their associated forms with the end-product (McCarthy 1941:329-333; Howchin 1934). However some sources (Hersh 1981:358) show that river stones have disadvantages. On one hand the stones show a weathering crust, which makes it rather difficult to work, and on the other hand, samples of sedimentary rock taken from the az-Zarqā' river show traces of the dissolution of the chalk matrix, which makes the stone often too weak to use as a grinding tool. A better material can be obtained from the side-hills of this wadi and this gives the idea of an industrial or individual quarry. Until now, no signs of this industry have been found, and judging from the irregular and somewhat unprofessional manufacturing techniques, an individual quarry on a small scale is to be expected.

Manufacture

a) Introduction

The two sources of the raw material for the Tall Dayr 'Alla stone tools suggest two different production places: one for basalt in the north of Jordan and the other one close to the settlement.

Both working places may show their own techniques, instruments and fashion. Although the raw material differs, it is important to distinguish several variables in the manufacturing process to support the idea of dichotomy. One of the main variables is the formality, the regularity of the result of the process. Training, experience, kind of instruments, workplace, etc. may be reflected in the artefact.

b) Manufacturing Processes

Traces of the manufacturing process are

difficult to recognise, and are in most cases removed by finishing work or wear. Another problem in recognizing such traces is to distinguish between traces of wear and traces of manufacture.

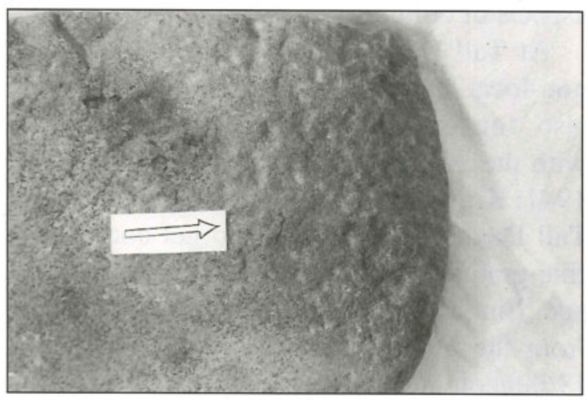
Fortunately, one of the stones found on the site was not finished, probably due to premature breaking (Fig. 4). It shows the different phases of the process as well as the traces of the stone-working instruments. Apart from this example, only a few traces are found, especially on spots where it was not essential to smooth the surface or where the function prescribes a rough surface.

The upper grinding stones are in most of the cases well-finished. In Table 3 a few manufacturing phases are distinguished. Pecking is the most general technique and is reflected by small traces, mostly as half-moon shapes, caused by medium-hard knocks with a hammer(stone) and chisel. Figure 5 shows these peckmarks very well. The chisel was placed probably obliquely on the surface in order to limit the danger of breaking. Although the chisel was probably round shaped, the marks are half-round, because only on one side stone-pieces were chipped off. The stone shows that the upper side was worked first and later the lower side. Finishing work has been done (cf. Fowke 1985:199-200; McBryde 1945; Pond 1930:1-149; Hersh 1981:354-376) probably with a sandstone rough boulder (Hersh 1981:358). This technique does not give a polished or smooth surface.

The lower grinding stones differ from the upper-stone especially in the rough bottom surface. This surface did not undergo phases two and three in the process. The rough surface gives the lower stone the stability it needs during grinding. The upper surface is hand shaped and went through all the production phases.

The pestles are in general made of small natural pebbles (or remains of other stone artefacts), which do not need much change. In relation with the so called natural, not formed, pestles we can assume that only a few pestles were planned and made on or-

4. Unfinished upper grinding stone with production traces.



5. Traces of pecking.

Table 3. Manufacturing phases by upper grinding stones with their supposed techniques, instruments and marks.

phase	techniques	instruments	marks
1)	rough hitting	- hard stone	- big flake-marks
	pounding	- sharp stone	- small irregular damage marks
2)	pecking	- chisel/hammer	- small round or half round traces
		- sharp stone	- rough irregular damage marks
3)	rubbing	- sandstone	- formal surface

der. Probably phase 2 was not performed.

The *mortars* are well formed and suggest a trained and experienced worker in most cases, especially with the basalt examples. An extra phase, or technique is the saw, which was not necessarily made of metal, but could also have been made with a rope using quartz sand. Traces of this technique have been found on several Tall Dayr 'Alla stones, especially the tripod mortars. Probably, the stone was first hollowed, and after that the legs (or other bases) were made.

c) Place of Manufacture

The unfinished upper grinding stone (Fig. 4) indicates a working place on the site. It seems quite possible that every household made their own tool from the locally available raw material, when basalt was not available or too expensive.

When there was the possibilty of choosing between different raw materials, the stoneworker's place, which produced the grinding stones, was probably situated very close to the basalt source, which in this case is the north of Jordan. The stoneworker did not have to be a specialist in grinding stones only, but could have also been the producer of other stone (basalt) artefacts, like architectural stones, altars, weights and anchors (Bullard 1969; McGovern 1989:269). A surplus of several stones would be needed for the irregular demands of the consumers.

It may be assumed that there were several of these basalt/andasite stoneworker's places, or maybe full-time craftsmen without a stationary place. The number of basalt artefacts found in Late Bronze Age and Iron Age sites show the enormous industry, which cannot be the work of only agricultural based households.

Diffusion and Trade-Patterns

One can divide, at least tentatively, a local group and an imported group of grinding stones at Dayr 'Alla. The local stones are individually made and used while the imported stones are made by full-time stone workers in the north or northeast of Jordan.

Here, we are mainly concerned with the imported objects. The tools are made in the north and transported to the south (e.g. Dalley 1984:170). Considering the period of use for 10 years (Morris 1990:181) of an upper grinding stone and 20 to as much as 1,000 years for a lower one (Wright 1992a:96), the people do not often need new grinding stones. One can imagine an order list to the production centre, when several people of one village or small region needed new grinding stones. Temporarily, the locally collected stone may have been individually worked and used. The differences between local and imported products do not necessarily reflect different classes in this society, although they are expected to have existed.

Chronological information about the occurrence of grinding stones at Dayr 'Alla shows an increase in the use of imported tools around 750 BC (from 30% to 60% of all examples out of one occupation phase). Although this increase is not only based on information acquired *in situ*, a change in import activity is visible. This change is probably due to changes in political, economical and/or social situation at that time.

The northern production centres distributed their products over the country. Taking trade links into account, the farther the basalt tool is found from the source, the more value it gets. Assuming that magmatic rocks were more suitable for grinding than other rocks, settlements closer to the basalt-source (closer to the production centre) would have a higher percentage of magmatic rock than the places farther away (the longer the distance the more the expenses). Although real statistics are missing, the excavation at Tall Rehob (Mazar, pers. comm.), a few kilometres from the basalt-region in north-Israel, shows almost 90% basalt grinding stones.

Function

Functional analysis must extend further

than a general grinding activity, especially at a time, when wear patterns analysis has become a normal procedure in artefact studies (Keeley 1980; Gijn 1990), although today the validity of using micro wear polishes alone for identifying ground materials has been questioned altogether (Newcomer *et al.* 1987:262; Grace 1989). Beside wear patterns, morphology and associated remains (such as chemical residue analysis (Anderson-Gerfaud 1986; Jones 1990; Hillman and Davies 1990:207)) can also be used to complete this analysis.

From the early periods and until the end of the Iron Age, the inhabitants of the Levant used the same basic shapes and the same limited range of raw materials. Even today, ethnographical evidence shows comparable forms in certain areas (Australia: McCarthy 1941; Roth 1904, America: Aschmann 1949; Bartlett 1933; Woodbury 1954, Levant: Dalman 1933; Hillman 1984a). Hovers (1996:183) mentioned correctly that changes in fashion did not affect the shape or the chosen raw material of the grinding stones. But in spite of this morphological conservative character of the stones, there are variations in form in relation to function.

Material and Function

The selection of material for grinding stones does not only depend on the availability of the stone, but also on the texture and structure of the stone itself. When looking at archaeological (Moorey 1994:23; Yoffee and Clarke 1993:226-239) as well as ethnographic evidence (Weinstein 1973:275; Kraybill 1977:489), it is clear that the inhabitants of a particular region are not bound by the local availability of a stone type, but try very hard to get the best stone even when they have to travel long distances.

There are many products which can be ground (see below) that differ in hardness, toughness and shape. Theoretically, all of these qualities can be related to a special stone type, with its own texture and structure. The relation between the product and the qualities of the stone reflects the need for an intensive study of the material, as well as of the grinding products found in any historic and prehistoric site.

There are three important qualities of a stone that affect the result of grinding: the bending of the minerals, the vesicularity and the grain size (Hovers 1996:181). When two stones make contact, small parts wear off. The more pressure exerted, the more the stone will transform. Unfortunately, this wearing will contaminate the product and therefore has to be avoided.

In general, the inhabitants of Dayr 'Alla used two stone types: magmatic and sedimentary rock. The first kind is harder (tougher), because the minerals are very small and closely bound. This is in contrast with most of the sedimentary rocks which have larger and less closely bound minerals. When applying the same pressure, the last will contaminate the product more than the magmatic kind. The grain size is important for the toughness of the stone, and for the cutting or grinding qualities. Because of the fine-grained mineral structure, magmatic rocks are less irregular, and therefore less useful for quick grinding. The last quality which affects the grinding result is the vesicularity. This quality is formed in magmatic rocks when the air-supported magma is hardened. The roughness of the magmatic rock makes the edges of these holes as sharp as knives and can be a counterpart for the sharp minerals of most of the sedimentary rocks. The usefulness of a stone type depends on its different characteristics, and indirectly depends on the grinding product.

Type 1a, the one handed upper grinding stone is mostly made of fine or compact material. The stone is light and has no real 'cutting facilities', in contrast with high-vesicular or coarse grained samples. Much of the grinding activity has to be done with the pressure applied by the miller. The product is probably fine and easy to grind (or maybe this type is used for finishing grinding).

Types 1b and *1c* have more vesicular and coarse grained samples. The 'cutting' edges, from the natural holes in magmatic rocks and the quartz minerals in sedimentary rocks, together with the weight of the stone, suggest a difficult and tough grinding product. More pressure can be given by the miller in contrast with type 1a. The grinding product cannot be too small in relation to the high-vesicular materials, because the product will 'escape' in the holes.

Type 2 is in most cases coarse grained or highly vesicular. The same analyses can be given as for types 1b and 1c. The few compact stones as well as fine grained sedimentary rocks can be associated with type 1a.

Types 3a, 3c and *3d*, are mainly made out of compact or fine grained sandstone or limestone and indicate the need for a tough and regular surface, probably in relation with a mortar. The function is more an alternation between pounding and grinding and is less dependent on the 'cutting' facilities of the texture (Wright 1992a:53). The pressure given by the miller determines the grinding result.

Type 3b, is of a different stone, that is mainly made out of flint. The hard and rough characteristics of the stone make hammering possible, but it does not exclude a function as grinding tool together with a mortar.

Types 4a,b,c, and *d* are mainly made of compact basalt. The mortar has to be bowl-shaped and compact to hold the product and does not need to play a more active role in the grinding activity.

The relation between raw-material and function is clear when looking at Table 4. Grain size, vesicularity and binding of the minerals are characteristics, that affect the grinding activity and will be realised by the stone worker, when making a certain grinding tool.

Form and Function

The second relation with function is the form, already mentioned in the first part of this paragraph. The division between a one-handed and a two-handed stone reflects the function and the way it has been used. The movements are reflected by the traces on the stone itself. Type 1a has, in almost all of the stones, a round (in both direction) grinding surface. This has been due to the fact that, when you push the stone downwards at the end, the stone will rise a little because of the movements of the wrist. The same movement will appear when the stone is at the top of the lower grinding stone. This is in contrast to the two-handed stone, where this round movement does not occur. The one-handed stone is probably used for material that is softer or grinds more easily , because the miller cannot apply all his force in the activity. Types 1b and 1c can grind harder and tougher material. The two-handed stone has mostly sharp edges and a flat (or hollow) surface, especially in length. Another difference between these two tools are the movement marks on the grinding stone. The one-handed stone has traces in a variety of directions, sometimes even rounded, while the other types have straight grooves along its width. The movements of the upper stone leave also traces on the lower stone. The lower stone is made or placed with a sloping surface, with the higher side positioned towards the miller. This can also been seen on Egyptian paintings (Darby *et al.* 1977:508-510; Baines and Malek 1980:195) and from ethnographic sources (Bartlett 1933; Bornstein-Johanssen 1975:287-295). The grinding material will roll downwards during grinding, which stimulates an equal flour. When the stone is used with a one-handed upper stone, the lower stone becomes hollow in all directions. The mortar is always used together with another tool, in most cases a pestle, with which the material can be

Table 4. Raw-material and the diffusion over the typology.

	basalt v.	basalt l.v.	basalt c.	sandst. coarse	sandst. fine	limest.	flint	other
upper grinding stones								
type 1a	1	3	1	5	12	-	-	-
type 1b1	7	-	-	14	5	-	-	1
type 1b2	15	3	-	32	6	-	1	-
type 1c1	3	-	-	-	-	-	-	-
type 1e	4	-	-	3	1	-	-	-
lower grinding stones								
type 2a	10	-	-	-	2	-	-	-
type 2b	5	-	1	6	3	-	-	-
type 2e	4	-	-	1	1	-	-	1
pestles								
type 3a	-	2	6	-	1	3	-	1
type 3b	-	1	2	-	-	2	8	-
type 3c	-	1	-	2	-	1	-	-
type 3d	1	1	-	1	1	-	-	2
type 3e	-	-	1	-	-	-	-	-
type 3f	-	1	-	-	-	-	-	-
mortars								
type 4a1	-	5	7	-	-	-	-	-
type 4b	-	3	2	-	-	-	-	-
type 4c	-	1	-	-	-	-	-	-
type 4d	-	-	3	-	-	2	-	-
type 4g	-	-	-	-	-	2	-	-
type 4i	-	2	2	-	-	-	-	-
Total	50	23	25	64	32	10	9	5

pounded or ground (but in most cases it is a combination of these two movements). These activities can be shown by the polishing and damage patterns on top of the pestle. The depth of the mortar gives an idea about the amount of grinding material and the roughness of the movements. A shallow mortar is more suitable for a very small amount of soft material, where only small movements give the best results. If the miller has to enforce the crushing, he needs a deeper or larger grinding basin, like type 4e. If we consider that also grain (like emmercorn and barley, see below) has to be crushed and de-husked before grinding, then this type, or a wooden example is needed, as seen in ethnographic sources (Jeffreys 1966; Wulff 1966:151f). Several studies indicate that cereal de-husking is best accomplished with a pestle of wood, which avoids crushing the seeds (Foxhall and Forbes 1982:77; Hillman 1984a:129-130). One observation is that the pestle is very vulnerable to damage and wear during use. Except for type 3b, which is rather a hammer, the other pestles have been used for pounding as well as for grinding (often in combination during one 'job'). This multi-functionality has been described also in ethnographical evidence (Bartlett 1933; Wright *et al.* in press:2).

Grinding Products

Functional analysis has to include the possibility to grind material with the excavated artefacts, as well as the availability of the grindable materials. Paleobotanic material is always considered for these stones (e.g. Wright 1992a; Hersh 1981), but beside these, also non-vegetable products can be ground.

When looking at archaeological remains, there is a very limited range of possible grinding products, mainly caused by the decay of the products. It is necessary to understand that the range of the material, which is found in Dayr 'Alla, does not reflect the whole range of grindable products, and what is found does not always have to be the consequence of direct human consumption (Hillman 1984a:1-41). This observation has been supported by ethnographical evidence (Kraybill 1977).

Paleobotanic Remains Suitable for Grinding Activity

Most of the botanical samples of Tall Dayr 'Alla have been collected from phase IX-strata, in which several fires preserved the samples as charcoal. A clear archaeological relation between the grinding stones and these plant remains cannot be established yet, but ethnographical as well as textual sources makes it more than possible.

The largest sample, found in Dayr 'Alla, was *triticum aestivum,* a two-row wheat (Neef 1989:30-36). *Triticum aestivum* is highly cultivated, and without bran and chaff, it can be ground into a white, sweet flour. This flour can be obtained by smashing first the wheat-grains in a mortar with a wooden pestle (see above), causing de-husking, after which the seeds can be ground. The mortars, found in Dayr 'Alla are too small and low for de-husking and crushing wheat. Biblical (Num. 11:8) and ethnographical sources (Reynolds 1968:82; van der Kooij 1976:85) show the importance of this pounding/grinding activity.

Another grain found at Tall Dayr 'Alla is emmercorn (*triticum dicoccum*), which has a harder bran than *tr. aestivum.* It has to be crushed several times before the grain is ready to be ground. After that movement, again the two-handed stones are needed to grind these seeds.

Barley (*hordeum distichum*) is also part of the plant material found in Dayr 'Alla (and in other places in the Jordan Valley, like Pella: McNicoll *et al.* 1992; Tall as-Sa'dīyyeh: Pritchard 1985). It does not belong to the 'cereal' family, but can be prepared in the same way. Again the chaff and the bran are difficult to remove form the endosperm. It is almost impossible to make a white flour out of it. A remarkable discovery was a large quantity of broken barley grains, smashed probably in a mortar and directly used as food in Dayr 'Alla.

Other Grinding Materials

Beside these vegetable products, minerals, especially those used for producing pottery temper and for the major substance of glass and faience, could also be ground. The grinding of temper (or even the clay itself) has been widely accepted (Hayden 1987:191; Franken 1969:73 and 76) and is visible by looking at the sherd, by evidence of very sharp angular fragments. Even coarse quartz sand could be crushed inside a mortar with a pestle. This activity has also been recorded in Egypt, for making glass and faience (Lucas 1962:157 and 178), where quartz pebbles or crystals have been ground to make the substance as fine as possible. The basalt remains inside the Dayr 'Alla pottery (Franken 1992:108) can be due to the basalt fragments (which could have been parts of grinding stones), that were abandoned and used for temper. But as Kolb (1988:211) pointed out, these particles may have been accidentally added during the crushing of clay or grinding the temper when the abrading surfaces of the implement were worn off. Shells and chalk could also be ground in a mortar and pestle for the preparation of the temper (Franken 1969:76).

Wear Patterns

This part of archaeological science has been promoted by flint analysis (Keeley 1980; Gijn 1990). The difference between flint and other stone artefacts is the clearness of these traces. Other stone types, like basalt have a vesicular and rough surface, on which very tiny traces are difficult to recognise. But apart from these, the movements make grooves in the working surface, which shows the way of grinding and sometimes evidence for special grinding products (Richards 1989). Comparing these grooves with other evidence, as described above, it is possible to read a functional description of each stone.

Like the pestles, the patterns of type 1a are not regular and parallel. This is a major sign for the way the stone has been used. The movements of the stone were irregular and with less force than type 1b. The one handed upper stone can be compared with the one handed pestle. Real grinding activity would have been alternated by crushing and stamping movements, with their typical wear patterns (damage patterns). These signs are different from the two handed stones, which have a regular groove pattern, due to the great forceful movements of the miller.

All of the stones show polishing and even when they were mostly crushing tools, the stone obtained polish. Contrary to Hersh (1981: 125 and 471), the writer has not seen differences between quick movements and slow regular activity (see also Hayden 1979:189). Polishing is an additional phenomenon, when two stones were rubbed against each other (and probably even when wood or other material is used in connection with a stone).

The wear pattern as pointed out by the mobile parts of the grinding implements, are similar to the immobile parts. Mortars have irregular grooves while lower grinding stones, especially type 2b have regular parallel grooves (type 2a has sometimes irregular pattern, because it has been used as a basin).

Discarding and Re-use

There are many reasons for discarding grinding stones. Breaking or damaging of the stone, which makes it useless, is probably the most frequent cause, since the stone was used till grinding can no longer be done. Primary contexts of finds of grinding stone are rarely published, which makes a spatial and temporal analysis almost impossible.

At Dayr ‘Alla stones were in general reused in architectural construction, especially in stone foundations and pit-lining. Grinding stones enter the archaeological record quite infrequently (Aschmann 1949:685; Horne 1983:18). Beside architectural reuse, the stone parts were also reused as grinding stones, hammers, polishing stones or rubbing stones. These functions have to be defined by wear pattern analysis and comparison.

Conclusion

The role of grinding activity has been pointed out as an important aspect for the inhabitants of Tall Dayr ‘Alla and an essential element of any archaeological project.

Tall Dayr ‘Alla is located in an agriculturally fertile environment along a main trade route. During the Late Bronze and the Iron Age, external contact seems normal and almost essential. Bearing this in mind, there must have been a distribution pattern of basalt grinding stones in north Jordan. Although many scholars limit trade to luxury goods, it has been cleared that normal household equipment was as important a commodity for daily needs. The inhabitants of Tall Dayr ‘Alla were dependent on their usual tools, more than on luxury and treasures. Detailed stratigraphic documentation, as well as chemical and microscopical analyses of the soil surrounding the artefacts are necessary. Beside artefact analyses, also attention has to be paid to waste material of production. Manufacturing places inside the settlement hold fragments of stone, which may be found during fieldwork.

Grinding activity has been known, but has not been studied systematically. However, Hovers (1996) mentioned that 'it appears to be a rewarding effort' and with the awareness of our lack of knowledge, one is on the right track to remedy the situation.

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