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RESEARCH ARTICLE

Early watermills – an archaeological indication of taxation?

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ABSTRACT
The introduction of watermills in Southern Scandinavia has often been linked to the advent of the Cistercian Order and regarded a kick-starter for the so-called medieval revolution. In the present article, the archaeological evidence for watermills predating the religious order will be investigated and an earlier and alternative origin laid out. Here, the increased specialisation and centralisation pertaining to the Late Iron Age and Viking Age will be introduced as a significant cause for the initial construction of watermills, and the extensive excavations at Viking Age Omgaard, Denmark, will figure as case in point. Also, essential social mechanisms such as taxation and elite privileges will be highlighted as overlooked triggers in the Viking Age employment of watermills.

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The chronological definitions of the Middle Ages vary greatly, and almost every country has produced more than one chronological demarcation of the period. This is testified to the great temporal gap between the traditional Italian definition, which contrasts with that used in Scandinavia, illustrating the different ways in which the Middle Ages has been defined. The former regards the establishment of Christianity as official state religion during the reign of Constantine the Great in AD 323 as a suitable starting point for the medieval era, whilst the Scandinavian definition usually views the Battle of Stamford Bridge in AD 1066, and the end of the Viking expansion, as a useful dividing line (Le Goff 1985, Näsman 2000). Behind any academic attempt to pinpoint societal changes or chronology lies the necessary definition of cardinal parameters which represent a comprehensible description of such developments. This is of course also the case with regard to a 'middle age'. Such parameters as religious (introduction of Christianity), governmental (removal of the last Roman emperor), academic (writing), economic (capitalism) or demographic (Arabic expansion) reasons have been presented as valid markers (Hermann 2002, Carelli 2004, Wickham 2005, Moreland 2010). This article will instead focus on the gradual introduction and advancement of new technological developments, which might have contributed to long-term changes in the political and legal systems. It is argued that new material phenomena can serve as markers of change in the social structure, because technology itself can contribute to societal transformations. More specifically, the early use of watermill technology in South Scandinavia will figure prominently in the paper, as well as the context of its introduction. The renewed excavations and research on the West Jutlandic Viking Age settlement at Omgaard will serve as a case study, because this location provides some of the earliest dating of watermill components in South Scandinavia and is located in a large settlement.

Technological development and social change

The introduction of the watermill has been central even to earlier academic studies of technological development and has often been combined with political viewpoints and statements. Depending on the view of the author involved, mills have been portrayed as, for example, the dark instrument of oppression. As stated by Karl Marx, mills were the obvious extension of the capitalist powers and an agent in their never-ending striving for hard cash

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and profit. He therefore states that 'The hand mill generates a society with feudal lords, the steam mill, a society with the industrial capitalist' (Marx 1907, p. 130),[1] thus clearly highlighting the inter-related nature of technology and socio-political structure. In a similar, yet also somewhat alternative vein, several historians of technology have focused on the opportunities presented by the watermill. For example, mechanical mills have been hailed as an integral part of technological evolution and one of the main reasons for the modern prosperity of mankind. The idea that 'medieval waterpower technology in large part laid the foundations for the late eighteenth-century industrialization' belongs to this latter type of viewpoint (Basalla 1988, p. 147). Either way, the underlying message in both statements is clear: for better or worse, technological innovations change society. This intertwined development of society and the advances made in the technological resources humans make use of is indeed recognisable in the case of the watermill.

The effect of the watermill

As early as 1935, Marc Bloch described the social history of the watermill, in which he related the development of a particular technology to another development at the social level (Bloch 1935 [1967]). Bloch highlighted the relationship between the increasing centralisation and control of production, and at the same time a decrease in the dependency on traditional animal or human sources of power, leading to a freeing of production. Bloch believed that the reason behind this development could be identified by the introduction of the watermill. Most importantly, Bloch also pointed out that the technological development of the watermill was not an autonomous historical development, but needed to be understood in relation to the general social negotiations and changes taking place in the period in question.

In addition, Lewis Mumford's (1934) publication *Technics and civilization* suggests that the medieval watermill was extremely vital to the later prosperity of Western society. The more dominant hypothesis in Mumford's research was that a long development towards an industrialised society in the 19th century should be regarded as the most plausible scenario. The point of origin was therefore identified in the medieval period and specifically so to the monastic communities. Unlike in earlier periods and societies, the medieval monasteries, with their strict order, discipline and tradition of practical, as well as theoretical, education, promoted a change of mentality which in turn led to a cultural climate that encouraged mechanisation and industrialisation. Mumford therefore introduces the idea of particular religious communities providing the foundation for social progress. In essence, despite their different line of argument, both Mumford and Bloch advocated the idea of a medieval industrial revolution, based on the introduction of water-powered tools and new types of manufacturing processes. At the hub of this process was the watermill, which provided an almost never-ending supply of power.

In the wake of their research, there arose a general agreement that not only did the historical and material record represent a medieval revolution, but also to a great extent that this revolution was generated by the spreading of monastic communities across Western Europe. Furthermore, it was believed that this type of watermill production and its different applications (fulling, hammering, sawing, etc.) was based on the inventiveness of the monks, and that they therefore were the main protagonists behind the industrial revolution of the Middle Ages and later on (Carus-Wilson 1941, Reynolds 1983). For these reasons, it was argued that Christendom possessed an intrinsic mechanism of ingenuity and technical fertility upon which Western society was founded (White 1969). However, recent research has begun to question both the monastic and the geographical origins of the watermill. Let us therefore take a closer look at the most recent information concerning the spread of the use of the watermill.

The technological origin of mills

One of the earliest descriptions of a watermill is made by the Roman master builder Vitruvius in his major work de *Architectura* of around 25 BC (see Figure 1). His description is evident of a rather elaborate type of watermill, which is equipped with gearing and a vertical wheel (see Rowland and Howe 1999, p. 124 for a translation of the original text).

Furthermore, Vitruvius portrays the watermill as a new invention and an uncommon phenomenon. It has therefore been speculated that the invention of

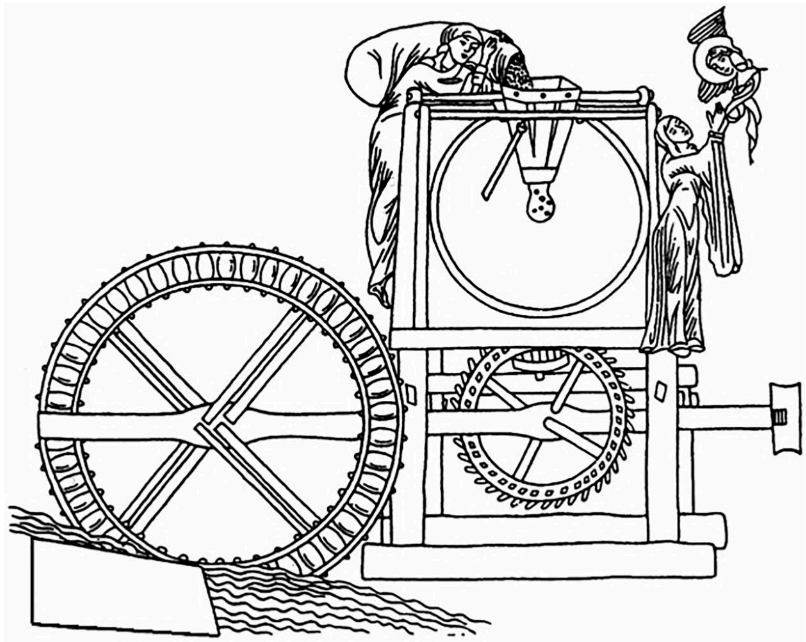

Figure 1. One of the more complete illustrations of a geared watermill is found in Abbess Herrad von Landsberg's 'Hortus Deliciarum' (c. 1170). The design is virtually the same as that described by Vitruvius 1200 years earlier, attesting to the very well thought out Roman construction. Divine intervention in the building of intricate machinery is regularly expressed in hagiographic writings, and in the Landsberg illustration, such a relation can also be found with the miller's wife (?) showing gratitude to a celestial being.

the watermill belonged to the 1st century BC. However, the most recent research, particularly by Örjan Wikander (2000, 2008), Michael Lewis (1997) and Adam Lucas (2006), indicates that watermilling was invented in Alexandria during the 3rd century BC, a century characterised by a general flourishing of experimentation and appetite for invention. The archaeological evidence for watermills from the Roman Empire is abundant, as well as widespread, and the material and the written records agree with one another. For example, a very well-preserved example has been found at the Zugmantel fortress (see Figure 2), east of Cologne, which used the power of the Rhine (Jacobi 1912, Spain 1987, p. 341). This watermill is of a very comparable type to the one described by Vitruvius and has been dated to before AD 300,[2] and two similar constructions from Kanton Zug, Switzerland (Speck 1961) and München-Perlach, Germany (Volpert 1997) can also be dated to the 2. and 3. Cent. AD.

In addition, from the northernmost regions of the Roman Empire, the very recently excavated Romano-British watermill at Cockermouth, Cumbria (see also Wikander 1980, p. 29–30 concerning the Haltwhistle watermill on Hadrian's Wall) bears witness to the widespread use of watermills following the expansion of the Roman Empire (Graham 2010). As far as the archaeological record indicates, it seems as if every part of the Roman Empire must have been knowledgeable about the use of watermill technology. The idea of the medieval technological revolution seems therefore to have been exaggerated and even in areas outside the Roman Empire watermills have been recorded predating the traditional medieval period (see below).

In terms of material composition and function, what these types of buildings represent is a technological innovation which is based on specialised craftsmen – builders as well as operators. More precisely, the introduction of the watermill in South Scandinavia has to be viewed as a link in the chain of continuous specialisation characterising the Late Iron Age and the following centuries. In the archaeological record, this process is particularly recognisable as more and more buildings have an increasingly unique architecture (Jessen 2012). This is due to the specific single-function status of the buildings, such as stables, smithies, temples and other specialised areas. Prior to this several functions could be carried out under the same roof and

Figure 2. The excavation at the Roman fort at Zugmantel revealed several parts from a watermill. One of the more obvious parts was this complete lantern-type pinion with six staves and still attached to its millstone spindle, which must have belonged to a geared vertical waterwheel located on the frontier of the Roman Empire. As these parts are dated to the second half of the 2nd century, the diffusion of the watermill technology must, accordingly, have taken place quite soon after the invention of this elaborate machinery. (After Jacobi 1912).

apparently also performed by the same personnel. But also the watermill was previously believed to consist of two different types, which led to the idea that it also might have involved two different use models.

Different types, different use?

Regarding the technological refinement of the watermill itself, a consensus has long existed that there was a gradual development from the smaller horizontal models to the larger vertical wheel type. It can be argued that the horizontal wheel is of a simpler construction because the power transfer runs directly from the hub of the waterwheel to the tool intended to be driven, usually a grinding stone, and the only difficult component to manufacture is the big stub holding the blades (Rynne 1989, p. 23). The vertical wheel is more complicated as this needs some sort of transmission in order to function properly, such as a spindle pinion driven by a toothed drum. This latter construction entails a more intricate design and more parts have to be assembled, and knowledge about how gearings works is imperative; thus, a logical conclusion would be that the simpler horizontal wheel mill would have been a forerunner of the vertical wheel. However, the problem is that such a chain of development cannot be recognised for the original and early advancement of milling technology as it is recorded for the Levant: in this area, the simpler vertical wheel might have been developed as a response to particular environmental needs (Wikander 1980, p. 104ff.). Therefore, as argued by Fischer (Fischer 2004, p. 30–31), there are no decisive reasons supporting this developmental distinction, because several other factors might lie behind the construction of the different types of watermills. For example, the social framework surrounding the early watermills in South Scandinavia, which were closely connected to the upper echelons of society, such as the clergy and aristocratic levels, would generally favour bigger and more efficient types of mills, such as the vertical wheel version. In other words, because the watermills in Southern Scandinavia were introduced during a time of increasingly centralised systems of production, the smaller farmstead-sized horizontal watermills were not efficient enough to handle the amount of grain to be processed, thus making the vertical water wheel the more preferred version. Also the emerging towns and cities would generate a bias towards constructing bigger mills as the need to serve larger proportions of the population in a limited area grew.

A hitherto disregarded factor would also be the different environmental settings into which the mills were placed. One of the challenges with installing a horizontal wheel and making sure it has a longer service life is to avoid the undermining of the wheel. As these types of mills mostly operate using fast-running streams of water (i.e. under high pressure), this also potentially generates severe erosion if the ground underneath does not consist of a durable material like hard rock. Apparently, the distribution of the horizontal mills is closely connected to areas where the bedrock frequently surfaces, such as Northern Scandinavia, Scotland, Ireland and the Danish island of Bornholm. Using a horizontal water wheel is no great problem in such areas. In the rest of South Scandinavia, however, which is completely dominated by sand and moraine deposits, such a construction as the horizontal wheel, will quickly be undermined and thus become dysfunctional and demand a considerably higher level of maintenance, or further modifications of the immediate environment such as sett-laying under the wheel. Furthermore, it can even be questioned whether the type of streams accessible in South Scandinavia can even muster the required flow to actually drive a horizontal wheel altogether. The vertical wheel, on the other hand, is mainly driven by a combination of the pressure of the water and the angle of the blades on the wheel (i.e. momentum), which can be provided by a much slower running waters. Such a solution is very much suited to the bigger rivers and streams of the South Scandinavian lowlands. Also, such an influx of energy can easily be managed by the construction of wheel casings around undershot vertical wheels. These types of construction have been found archaeologically at several places in South Scandinavia, which are characterised by vertical wheel watermills. No essential components, such as the robust paddle stub, suggesting the presence of horizontal watermills have so far been recorded in the South Scandinavian lowlands. In conclusion, the vertical-wheeled watermill must have been the preferred type of mill to be constructed in South Scandinavia – both with regard to the social framework and the environmental setting.

Furthermore, as the earliest dated finds of watermills in the South Scandinavian lowlands testify, there can be no doubt that the first types of wheels were of the vertical type (Linde-Laursen 1989, Fischer 2004, p. 107; Andersen 2011, p. 28f.). The very early finds from Ljørring (^{14}C date of 767–1220 AD cal.,[3] average AD 990) and Omgaard (after AD 917, dendrochronological date) included diagnostic types of paddle blades (see Figure 4), which would have been attached to a vertical wheel (Eriksen *et al.* 2009, p. 79ff.). The Ljørring watermill was long believed to be of the horizontal type (Steensberg 1959) due to the excavations of a similar mill at the Irish Mofett site (Lucas 1953). Both have, however, been reinterpreted as of the vertical type (Rynne 1989, p. 24–5, Fischer 2004, p. 84ff.). In fact, there have been no definitive finds, epigraphically or archaeologically, of horizontal wheels dating to before the 7th century AD, making this type a rather late invention (Wikander 2000, p. 376). When the absence of machine parts from horizontal wheels at the several excavations undertaken at watermill locations in South Scandinavia also is taken into account, there is no longer any proof of the use of the horizontal type of watermill in early medieval is this area.

Social consequences of watermill technology

The opportunities presented by the watermills and the new type of energy source were obviously taken very seriously and figured prominently in the management of the medieval state. The proclamation made in the 14th century by the Danish King Valdemar IV Atterdag that *The streams should not run to the beach without first having served the country*[4] bears witness to the central position occupied by this particular energy supply.

Depending on which level of the overall social hierarchy one was on, such milling machines also presented different political opportunities, because they could be exploited as a means of taxation. This resulted from the 'suit of mill' principle, in which a group of people were obliged to use particular mills, which were under the management of the king, aristocracy or the Church, and in turn pay a toll to the owners (Madsen 1986, Carelli and Kresten 1997). It was a principle that ensured a steady and tidy profit for the privileged class to whom the suit of mill was granted. The consequence was that the continuously increasing legal bonding between peasant and mills, due to the various suit of mill legislations, directly resulted in a system of taxation, as by governmental means the upper strata of society could dictate where the farmers had to get their grain milled. Preferably, this should be done at the king's, the Church's or the aristocracy's own mills, thus providing them with the attractive revenue this would give. Peasants had to pay a fee known as multure to get their grain processed. For this reason, it is clear that the mills became a political instrument for two main reasons. Firstly, the technology itself forms part of the power relations defined in early medieval society, and it is quite clear that 'the powers that be' are quick to exploit the new technology. Secondly, the people to whom the innovative technology is turned against as a means of control presumably regard the milling machine as a deviation from customary law and traditional rights. Consequently, in the case of the watermill, this combination of technological innovation and social negotiation results in a new form of dependency, through the use of force and monopolisation of the new technology, and leads to a manorial-type system of taxation.

In the case of the watermill, this conflict between the different strata of society took a very concrete material manifestation, because in certain areas and in order to maintain the legislative privileges, private querns were banned and then collected with the purpose of preserving the privileges of the major landowners.

At the monastery of St. Alban in Gloucestershire, this resulted in a century-long dispute between the monks and the local peasants, culminating in The Peasant's Revolt in 1381. Unlike at the urban centres such as Newcastle, Cardiff and Tewkesbury, the monks of the monastery of St Alban refused to grant the citizens any concessions in relation to the mills administered by the monastery (Lucas 2006, p. 166). The conflict entailed a series of legal acts, and in 1331, the Abbot was granted the right to confiscate all querns, hand-driven and otherwise, on the property of the monastery, in order to enforce the monastery's suit of mill. The local quernstones were then collected, broken and re-used in the floor of the Sacristy of the monastery, in order to emphasise its privilege. During the revolt, this pavement was dug up and the broken querns were carried home by the peasants as tokens of victory and freedom (Wagner 2002, p. 219).

The environment of the milling machine

It is important to bear in mind that watermills not only involved combining intricate machinery, such as the waterwheel, gearing and grinding stones, but also meant alteration and adaptation of the environment in the vicinity of the building. Watermills are heavily dependent on location and on suitable types of water supply, and natural watercourses, as they flow through the landscape, are rarely sufficient to provide an adequate power supply to push and run the wheel. Sluices, dams, penstocks and building platforms regularly accompany the buildings in order to manage the flow of water, as well as the amount of water sent to the wheel. The impact of milling on the immediate environment can be quite significant and completely change the natural flow of water, in particular just before the mill or just after it. In a similar vein, the construction of dams and weirs to further enhance the control of the flow of water also entails quite elaborate earthworks, which involve additional alteration of the natural environment.

This is also the reason why a great deal of legal effort is put into determining who is allowed to use the stream and to what extent. From the Middle Ages and after, there would have been a change in the environmental setting downstream from a watermill, as well as a different supply of water and flooding of low-lying areas. This is also the reason why the legislative side of milling provides a couple of interesting points in the South Scandinavian area. For instance, there are the general outlines presented in the Law of Jutland book 1, chapter 57, stating that individuals are not allowed to build a mill unless they possess right of use to the stream and that the dam or lake around the mill does not interrupt the further use of the water for other persons downstream. This is further developed in the Law of Denmark book 5, chapter 1 (of AD 1683), where it is made illegal to build new mills, unless it is done at a location where a mill was formerly located. Presumably this would strengthen and consolidate the different suits of mill and make it easier to monitor the processing of grain. Equally, making it illegal to have a private mill within a mile of the privileged mills would encourage the same effect (book 5, chapter 4).

Until the end of the 17th century, it can therefore be assumed that there were several smaller mills, which presumably only served a handful of farmsteads. These were eventually banned by law. The first common Danish law of 1683, during the reign of Christian V, contains a chapter 'Concerning Mills and Water', in which it is stated that mills placed less than a mile from a mill paying tax should be removed. The same rule applied to windmills. Furthermore, it is stated that the peasants under the king's jurisdiction are bound by certain milling obligations. This meant that a peasant tenant of one of the king's farms was obliged to have his grain milled at one of the king's own mills. The milling obligation had already been commanded by royal decree in 1617.

Legal tracts and watermills

In tandem with the diffusion of the technology, the legal programme also adapted to the effects of the watermill. Because watermills have quite an impact upon their immediate surroundings, regulations concerning how much environmental disturbance to be tolerated figure prominently in the law codes. The texts themselves therefore often targeted the smaller private mills, as they were difficult to control for the central administration.

A great deal of the confusion surrounding the identification of the earliest types of watermills also seems to originate from etymological misreading of the written records from the period. In particular, the word 'skvatmølle', which frequently appears in the written records, has mistakenly been taken to exclusively denote a horizontally wheeled mill. However, the research of ethnologist Anders Linde-Laursen (1989) has clearly shown that 'skvatmølle' does not relate to any specific type of mill (the word can even refer to windmills), but instead points towards the size of the mill, as well as its context. 'Skvatmøller' are therefore to be understood as smaller mills, which are mainly privately owned and usually belong to a single farm or just a few farmsteads. For these reasons, the previous tendency to equate 'skvatmøller' with horizontal wheels is therefore erroneous (Steensberg 1959). It is, as previously mentioned, unlikely that watermills with horizontal wheels would have had any significant distribution in Southern Scandinavia, as they cannot function sufficiently well in sandy or clayish subsoil, due to rapid undermining of the wheel.

With regard to the practices advocated in the legislation there is, however, clear evidence in the written sources that different types of suits of mill were used prior to the general legal definitions mentioned above. In a Royal letter as early as 1175, describing the exchange of property between the monastery of St Knud in Odense and King Valdemar the Great, we recognise the granting of milling privileges. In the latter, the king grants the monastery a plot of land and at the same time instructs the citizens of Odense to use the mill of the monastery to process their grain. This letter provides evidence of two things. Firstly, there must have been a mill in Odense before 1175 and, secondly, that at this point in time suits of mill had already been introduced at certain locations in the country. Perhaps such privileges were already held by the King (Madsen 1986), and in the British Isles, such privileges seem to have been in operation as early as the 9th century and a similar situation appears to have prevailed on the continent, in France in particular (Lucas 2006, p. 167ff.).

The practice of collecting the local and private means of milling, such as the rotary hand querns (see the monastery of St Alban example above), is of course difficult to identify through excavations. However, there are a few indications that such a practice was carried out in connection with mills. This also applies to mills of early origin. In his description of the watermill at Tovstrup, and apparently also at the nearby Humle Mølle, Christian Fischer mentions a conspicuously large amount of quernstone fragments within the premises of the watermill. The excavator interprets this as a possible indication of deliberate collection of the local and private quernstone in order to make sure all grain was milled at the watermill (Fischer 1984, p. 8). This phenomenon indicates that milling obligations might have applied to the mill at Tovstrup and that the proprietor actually had the power to collect the private equipment, thus maintaining his own privileges. The dating of the Tovstrup mill to the middle of the 12th century corresponds with the written evidence from Odense.

The reason for examining the significant alterations in the area around the mill is because they are often the starting point for archaeological excavations, as these larger structures may still be visible on the modern-day surface. Together with other robust materials, such as grinding stones, which are often found in connection with the watermills, they constitute the most frequent finds. I will therefore turn to the excavation of the Late Viking Age settlement at Omgaard, Western Jutland, where several of the previously mentioned watermill indicators have been registered.

Milling and the Viking Age settlement at Omgaard

The excavations at Omgaard have not been straightforward. To begin with, Omgaard was one of the high-profile research excavations of the National Museum in the early 1980s, but eventually became the life's work of a single person, the excavator Leif Christian Nielsen. Unfortunately he died at a young age, leaving behind a great deal of interesting finds and complicated plans, but without having finished a more complete work on the site (Nielsen 1987). This challenge was taken up in 2007–2009 as a joint venture by the local Ringkøbing-Skjern Museum and the University of Aarhus (see Figure 3). A lot of the records from the original excavations are hard to decipher, and the finds material and house plans, for example, can be difficult to come to grips with. For these reasons, the current and preliminary research results of the Omgaard settlement should be regarded as work in progress.

The Omgaard watermill

Amongst the major finds from Omgaard are several fundamental parts of a watermill. They were found preserved in the wetland areas around the Pøl Bæk, and mainly the southern bank, which forms the northern border of the settlement. Seemingly there was at least one watermill at this location, and possibly a series of watermills, perhaps even in continuous used for a period of up to 500 years.

Figure 3. Omgaard is a Viking Age settlement (c. 700–1050 AD) consisting of three farming parcels and a series of long houses within each parcel. The northern border of the settlement is outlined by the Pøl brook, and it is in this stream that the different watermill parts have been excavated.

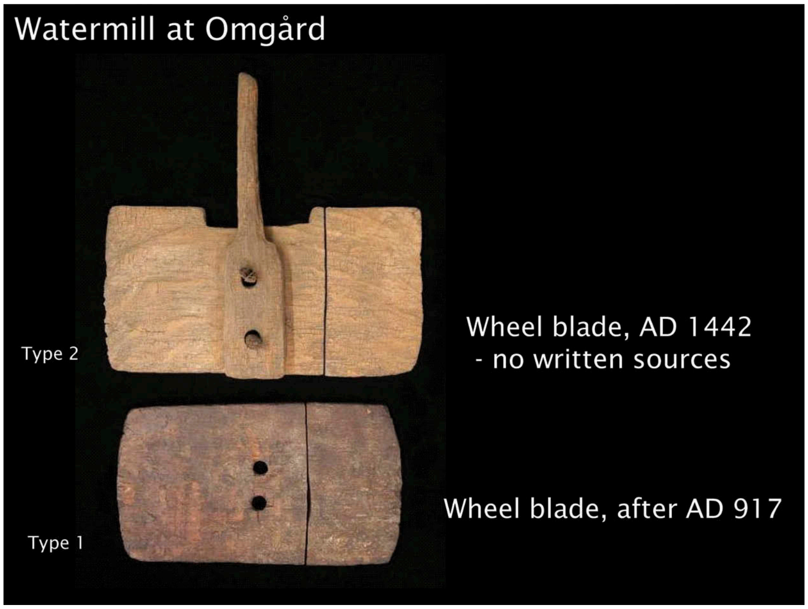

Figure 4. The blades have been dated at the National Museum of Denmark using tree-ring dating. As with numerous other early mills, there is no historical record available to verify the age of the mill and only scientific evaluation and measurement of the finds can be used to date the Omgaard mill (Photo courtesy of Torben Egeberg, ArkVest).

The more significant finds are two blades from a waterwheel (see Figure 4). They are of different types, but are both made of oak and originate from a single-ringed waterwheel, which is the earliest type of vertical waterwheel that has been recorded in southern Scandinavia. Type 1 is the simplest type and consists of a flat blade, with a central anchoring in the middle of the blade made with a small peg, by which it was fastened directly onto the waterwheel.

Type 2 is a slightly later type, which also features the central anchoring, but has an additional fastening where the blade itself gripped the waterwheel or a mortise was fixed directly into the wood of the wheel.

With regard to the dating of the wood, the Type 1 blade is of course the more interesting piece due to the very early date of AD 917 or after. However, some reservation is necessary with regard to the dating, due to the fact that the tree-ring date of the oldest blade is a *terminus post quem*, which only indicates the earliest possible dating of the wood. As we are dealing with oak, the date of the actual felling of the tree could be considerably later – 100 or 200 years – because the outer growth layers could have been chopped away in the process of constructing the blade. However, according to the dendrochronologist (Niels Bonde, pers. comm.), the builders of watermills would have been highly skilled craftsmen, as such machines are complicated to build. When making these types of blades, the woodworkers would avoid chopping off too much wood from the oak log in order to make the blades in the most economical way, thus only chopping away the outer sapwood of the log and the inner core. Therefore, a dating of the use phase of the Type 1 blade to around AD 1000 would be the more plausible interpretation. In any case, even a very conservative date 200 years after the last measurable growth ring would still make the Omgaard watermill one of the oldest excavated watermills.

Waterwheel casing

In addition, the find of a sluice beam indicates the presence of a watermill. This wooden log apparently functioned as part of the casing of the waterwheel and controlled the flow of water into the wheel. It should be mentioned that the finds from Omgaard and the context of the mill have been dismissed in the latest overview of South Scandinavian watermills made by Christian Fischer (2004, see also Andersen 2011, for a similar conclusion), mainly due to the dismissal of the casing for the wheel, on the basis that the sluice was actually a doorstep. However, by comparison with the existing examples of excavated wheel casings, it seems evident that the plank may

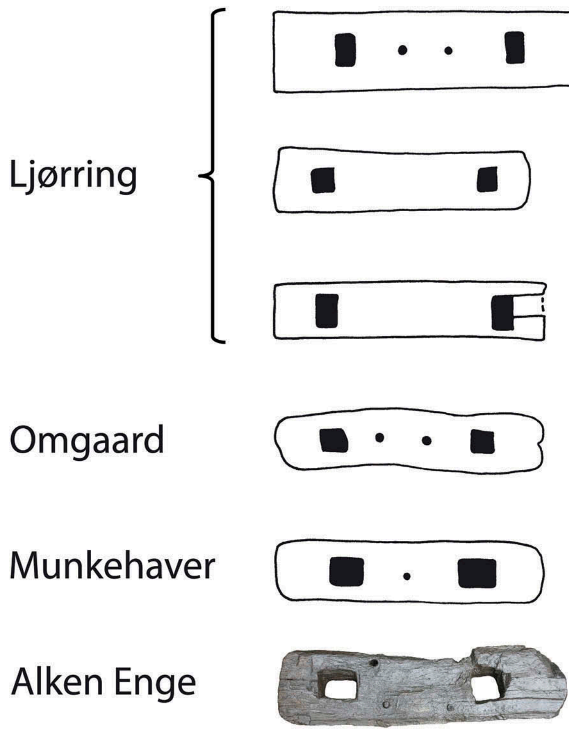

Figure 5. When comparing the beams from Ljørring and Omgaard, which are chronologically and geographically close to one another, the similarities in design are evident. They share the same patterning of big and small holes, as well as dimensions. The single find of sluice beams from Munkehaver (C14-dated to 655–690 e.kr. (AAR-5478), see (Eriksen and Olesen 2000, p. 171ff.) and Alken Enge (dating pending) also underline the morphological similarities as well as early dating. For these reasons, it is valid to identify the Omgaard plank as part of the sluice from a waterwheel casing (After Eriksen *et al.* 2009, fig. 5.17 and photo by Ejvind Hertz, Museum Skanderborg, Alken Enge Project).

easily originate from a wood-built casing controlling the stream of water to the wheel. Secondly, it seems highly unlikely that worn-out parts of a dismantled mill would have been carried across land and dumped in Pøl Bæk. These parts must stem from a watermill located somewhere along Pøl Bæk, and in particular, the find spot of the sluice beam would indicate the actual site of the watermill (see Figure 5).

This interpretation is further supported by the road construction crossing Pøl bæk around 100 m further downstream (Nielsen 1987, p. 184ff.). This is the location where the stream would widen as a result of the functioning of the wheel and dams, and presumably some kind of road construction was needed in order to cross the stream this close to the mill. Hence, the watermill must have been located somewhere along the bank of Pøl Bæk, where the Omgaard settlement has also been registered.

What is particularly interesting in the case of Omgaard is that firstly we are dealing with one of the earliest watermills in Denmark, and secondly we also have the fortunate situation where it can actually be related to a settlement of the same period. There is therefore a unique opportunity to observe what type of rural environment such an early watermill would have been related to, as well as the social changes this new technology might have brought with it.

Grinding stones and social changes

As we have been informed by the historical sources, the introduction of the watermill technology might have influenced, or even dictated, the way the milling of grain was carried out in the vicinity of such an apparatus. Certain privileges usually accompanied the construction of the watermills and different suits of mill might have affected the distribution of milling equipment in the local environment. In order to evaluate the effect of the introduction of the watermill and associated regulations, I will examine the correspondence between the frequency of quernstone fragments at the Omgaard settlement, their dating and the possible introduction of the watermill at this location.

If we follow the idea in the medieval legislation, we might expect that the construction of a watermill in a settlement such as Omgaard would change the way the individual farmsteads handled their grain and the milling of it.

With regard to the ‘materiality of milling’, the presence of small hand-powered and private grinding equipment would perhaps vanish with the introduction of a watermill. Private flour production was made superfluous or perhaps even illegal; thus, the private querns would presumably vanish from the finds record, or at least change in composition.

Another characteristic of the development of milling is the introduction of new types of grinding stones. The first new type to be used in South Scandinavia, besides the traditional local granite, was volcanic basalt – the Mayen lava. This type of stone is mostly mined in the western part of present-day Germany, more specifically in the Eifel region, and was presumably introduced as the main type of grinding stone for rotary hand querns as part of the Romanisation of Southern Europe. From the latter area, the grinding stones then spread to the north via the traditional trading routes. This is also the reason why these stones are found as commercial items at the major trading centres of Hedeby and Ribe (Schön 1995, Parkhouse 1997, Feveile and Jensen 2000, Feveile 2010). It would be a reasonable interpretation to assume that the Omgaard settlement obtained its stones from these localities or comparable trading centres.

A slightly later type of imported grinding stone is represented by the mica schist, which often originates from a more local source, namely the Norwegian mountains and in particular the Hyllestad quarry (Baug and Løland 2011). The Norwegian stone is presumably imported from the mid-10th century onwards and occasionally in connection with mechanised types of milling, such as the watermill (Carelli and Kresten 1997, Jørgensen 1998).

Both these types of stones have a naturally rough surface, but the grains do not detach easily, and therefore, the material being ground does not become gritty. Using these rocks makes it possible to use larger types of millstones, which do not need to be re-cut frequently for improved grinding capacity. These types of stones are therefore ideal for mechanised grinding. From a chronological point of view, these two types of grinding stones also provide an indirect means of dating as they, or at least the schist, have a rather well-established date of introduction.

For these reasons, the Omgaard finds catalogue have been examined in order to determine what kind of grinding tools were excavated at the settlement and from where they originated (see Table 1).

The distribution of the different types of grinding stones is not surprising but there are a couple of points that should still be mentioned. Firstly, there are conspicuous quantities of volcanic basalt, and where the provenance can be registered to a building, they can be connected to House II at the settlement. This house is interesting because it belongs to the only farmstead without access to the nearby waterway, which may indicate that this household made a different choice in terms of grain milling, whilst the two northern farmsteads made use of the mill and the watercourse (see Figure 6). Secondly, as the architectural features of the house can be compared with the Sædding-type houses, we must expect that this particular house was not present after AD 950 (Stoumann 1980, Skov 1994). The dating of the house therefore indicates that the use of the house, and therefore also the use of the basalt quernstones, predates the introduction of the mill.

Table 1. The quantities of quernstone fragments from the Omgaard settlement. The position of Omgaard is worth noticing as it is placed very close to the northernmost distributions of the Mayen lava imported from the Eifel area (see Carelli and Kresten 1997, fig. 18). However, neither the slightly later Norwegian schist nor the basalt fragments have been registered in any context dated after approx. AD 1000.

Quernstone and fragments	Number	Comments
Granite (local)	15 fragments	2 in pavements and 2 complete
Basalt (early import)	39 fragments	context House II, none with striation
Schist (late import)	1 fragments	From Oven II, after AD 950

The question is therefore why the use of rotary hand querns, to which the basalt fragments presumably belong, did not continue on a more regular basis after the Sædding-type house had gone out of fashion. As these types of rock are not indigenous to the area, they are easily recognisable and it is not likely that they would have been overlooked during excavation. As the granite fragments may be from an older settlement, we seemingly face a situation where we actually have no quernstones from a defined context that can be related to the younger phases of the settlement. Even though the rotary basalt quern was a more efficient tool compared to the earlier saddle-type querns, they seemingly only had a very limited use phase at the Omgaard settlement. This absence in the latest part of the settlement coupled with the fact that mica schist is virtually absent might be related to the fact that the mill was introduced at a point at which a general transition in milling strategy was taking place at Omgaard. At the time when the mill was introduced into the settlement organisation, presumably sometime around the year AD 1000, private grinding equipment might have become superfluous and hand grain milling was replaced by a different initiative – the watermill. A possible interpretation would therefore be that around the turn of the first millennium the settlement at Omgaard had a centralised milling organisation, in which the mill functioned as the dominant source of grain processing. In support of this interpretation is the fact that the only complete quernstone was seemingly found in the water raceways (find location unclear), and the excavator interprets this stone as having been used in the watermill (Nielsen 1987, p. 187 + 194f.). However, as the thorough research made by

Figure 6. House II is the main building in one of the phases of the southernmost land parcel. This particular plot did not have access to the stream, but the construction of the water-powered mill apparently still resulted in an end to the use of basalt quernstones.

Carelli and Kresten (1997) shows, the diameter of ca. 42 cm on the Omgaard quern places it significantly under the standard of proven watermill querns having a diameter above 70 cm (Carelli and Kresten 1997, p. 118). The registration of a quernstone intended for hand use in the vicinity of the watermill certainly bears resemblances to confiscation of quernstones (as the Tovstrup case mentioned above), in order to promote a soke of mill and install privileges to exclusive groups. In any case, whether the operation of the mill was organised from one of the three farming parcels or from an external power is difficult to clarify, but the consequence of constructing the mill nevertheless seems to have been a centralised grain processing taking place at the watermill. The find at Omgaard being very early does, however, open up for the interpretation of the complete quern being used in the mill; it would not seem unlike that the initial watermills would mix the new technological knowledge with traditional equipment already in use, thus incorporating a 'small' quern in a new mill. Conclusively, the interpretation of the find of a complete (gneiss)quern points in different directions, but with the common denominator of phasing out the private processing of grain.

Related influences of technological and social change

Relating the development at Omgaard to the early medieval societal changes necessitates a look at the general development of the watermill in South Scandinavia. In particular, two aspects of development which originate in two separate, but related, spheres are of relevance to the local development at Omgaard. The first is the introduction of a new type of milling technology, resulting in the spread of watermills in Southern Scandinavia. The second is the implementation of certain privileges, known as suit of mill or soke of mill, which apparently followed quite rapidly after the introduction of centralised grain milling.

Regarding the first threshold, the development of the watermills into a widely used type of technology has traditionally been associated with the introduction of the monastic communities, and particularly the Cistercian Order, as they were founded in South Scandinavia during the middle of the 12th century. However, as has been demonstrated in particular by the work of Anna Götlind (1993, see also Sterum 2010), the role of the Cistercians in the introduction of various technological innovations has been exaggerated and lacks empirical support. The Cistercian Order was obviously very well informed about the most recent technological innovations and quickly incorporated new ideas into their own constructions. However, the notion of the Cistercians as the main agents behind the technological development of the Middle Ages per se seems to be an overstatement. Other institutions would have had a significant influence upon the diffusion of new technologies. For example, secular groups, such as the military, merchants and the entire agricultural community, would likewise have influenced how new technologies were introduced into South Scandinavia (Sawyer 1987). Already in 1133, the Archbishop Asser, purchased a manor in Värpinge in Scania, Sweden, thereafter donating the entire manor, complete with at mill, to the cathedral in Lund. It is clear that the former owner was a local magnate and therefore also a layman (Hybel and Poulsen 2007, p. 203–4). Conclusively, and contrary to the ideas of Fischer (2004, p. 26 ff.), the spreading of the Cistercian order should perhaps be associated with a more effective dissemination of the watermill technology into South Scandinavia, but evidently not regarded as an initial point of origin.

Combined with the early dating of the watermills from Omgaard, Ljørring, Tovstrup and others, which predate the Cistercians settling in South Scandinavia, the argument stressing the importance of the monks' technological role cannot be sustained any longer (see Figure 7). The technological knowledge of constructing and operating the mills came from elsewhere and earlier on. As is the case with any type of diffusion and spreading of knowledge, the precise process of development is virtually impossible to trace and in many cases has a complex

Figure 7. Distribution of watermills dating to before 1150 AD. Only numerals = excavated sites, with question marks = written evidence. 1: Omgård, 2: Ljørring, 3: Munkehaver, 4: Galten, 5: Tovstrup, 6: Kalbygårds Eng, 7: Løgumkloster, 8: Kirke Værløse, 9: Nymølle, 10: Borup, 11: Varde, 12: Odense, 13: Næstved, 14: Roskilde, 15: Värpinge, 16: Vittskövle (Based on Carelli and Kresten 1997, Fischer 2004, Eriksen *et al.* 2009; and recent excavations).

and multifaceted history. Furthermore, the very early mills just mentioned can at no point in time be connected to monasteries, and they were therefore not part of the clerical sphere of technological diffusion.

With regard to the second threshold, which effectively presents a development from a centralised to a regulated type of organisation, an obvious socio-judicial reason lies behind this process (as mentioned above). Therefore, the legislative development of the various types of privileges and decrees accompanying the watermills is part of a secondary progression in the general mode of watermill diffusion. Seemingly, the technology was present already and it provided a clear opportunity for the dominant groups in society to expand and consolidate their powerbase. The technology was not initially introduced as a means to administer the production, but was nevertheless quickly incorporated into the manorial-type organisation of the settlement structure and the general institutionalisation taking place after AD 1000. This necessitated a clear demarcation of the privileges which the proprietors sought. Such a demarcation could only be maintained if it became a verified legislative act. As the technology itself provided the possibility of introducing a system of supervision and taxation, the legislation regarding the different kinds of suits of mill could be introduced. It was, however, not the introduction of the watermill which generated legal privileges. These were rather the result of the process of centralisation, combined with a growing hierarchisation and institutionalisation of the South Scandinavian society in the Early Middle Ages.

Why did the introduction of the watermill take place then, if it was not because of its introduction by a group of people already knowledgeable about the benefits of waterpower, such as the Cistercians? Perhaps a general change in the attitude towards technological investments might be a basic premise for the widespread introduction.

Also, turning the question around, what type of society rested on a cultural platform and a certain type of mentality in which it became both fashionable and acceptable to benefit from technological innovations? Apparently, there was no extensive tradition in prehistoric South Scandinavia of investment in technological improvements. Landholders were more likely to save their money, or invest in conventional items, rather than speculate upon

Table 2. General development of milling in South Scandinavia which illustrates how the social, economic and technological spheres are interconnected. Two thresholds are especially important to the present study. Firstly, there is the introduction of the watermill, because it represents the final and most profound change in a series of advances in milling technology that took place in the Viking Age, and presumably close to the end of the 10th century. This change takes place mainly in the technological sphere and can be regarded as the most profound upgrading of the ways grain is being processed. The second threshold is the introduction of the legislative privileges given to certain social groups during the Middle Ages, and positively taking place from the middle of the 12th century and onwards. Neither of the two thresholds derives directly from the economic sphere, but nevertheless causes changes in the financial organisation, thus testifying to the hybrid character of societal development of taxation. The fourth level is a rather special Danish constellation where the late 19th centuries witnessed an enormous upsurge in a co-operative movement (Andelsbevægelsen) where individual, small-scale farmers in solidarity supported each other by investing collectively in expensive production machinery such as mills or dairies.

Development of Milling	Social	Economical	Technological
First Level	Private	Household	Local ↓ ***Upgrading 7-10th century***
Second Level	Centralised ↓ ***Privileges 12th century***	Surplus Trade	Imported
Third Level	Regulated	Proto-Industrial	Imported
Fourth Level	Co-operative	Industrial	Transnational
Fifth Level	Private	Capitalistic	Global

untried technologies. Furthermore, such mills required a considerable amount of investment, in particular for the more elaborate constructions, such as the vertical watermill.[5] Watermills involved a reduction in labour investment, and perhaps more importantly, the mills could be turned into a source of additional profits. Thus, they provided a perfect solution to the increasing demands of trade and marked the initial steps towards a capitalistic spirit and private enterprise taking place around AD 1100 (Carelli 2001). The legislative outcome expressed in the different types of suits of mill, in which the king, the Church and the aristocracy exercised their privileges over the people working the land, follows the same line of argument. As these institutions grew in power and property, an easy way to progress further was to take advantage of technological developments and to compel people to use particular grain mills and pay in kind for their use. Such privileges would also result in a rather steady type of economic platform. In this way, the new technology stimulated new social relations.

However, it is important to note that the presence of the watermill did not cause the introduction of taxation, and evidently taxation could be administered by other means (see Table 2). Nevertheless, taxation based on centralised milling and a privileged class (a production-dependent type of taxation) was made much easier by the technological advances afforded by the introduction of the watermill itself. Therefore, the actual physical tool that the watermill represents, and which we as archaeologists under fortunate circumstances can record, provided the dominant class with a concrete platform for social negotiation. In effect, the watermill improved and eased the introduction of a centralised system of taxation.

The history of the watermill has shown us that the actual technology did not change considerably over almost two millennia of use, and with only minor alterations the Vitruvius-type mill has been registered from antiquity until the Industrial Revolution. Nevertheless, the actual societal formations, which were generated around the use of this particular type of technology, were considerably more dynamic phenomena. Clearly, a deep interaction and dynamism existed between the development of society and the development of technology. It is therefore crucial that these two dynamic factors are regarded as having a related historical course of development. On the one hand, we recognise a physical structure – the mill – as a tangible, but normative parameter, which facilitates and administers the social structure through its sheer physical presence, and on the other hand, we can register vigorous socio-judicial negotiations taking advantage of the possibilities afforded by the technology of the watermill.

Notes

1. Author's translation of: 'Die Handmühle ergibt eine Gesellschaft mit Feudalherren, die Dampfmühle eine Gesellschaft mit industriellen Kapitalisten'.
2. See also Speck (1961) for a similar (but rather fragmented) find from Switzerland dating to the 2. Cent AD.
3. K-2716, the National Museum of Denmark. Three samples: 1040 ± 110, 1030 ± 110 and 1040 ± 85. Original samples from 1976 have been re-calibrated using Calib 7.0, thus providing the date used in the present text.
4. Author's translation of: 'Han [King Valdemar IV] vilde ikke, at Aaerne skulde løbe i Stranden uden først at have gjort Landegavn' From *Chronica Sialandie* 1356.
5. In the Mediterranean area the very large and early constructions, such as at Barbegal and Janiculum, also seem to have been produced by public capital and only later does a wider distribution of private mills begin to prevail (Wikander 2000, p. 393–4).

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