Introduction

Significant ancient millstone quarries have been identified at three places in the Salten district of Northern Norway (Fig. 1): Setså and Saksenvik (Saltdal municipality) and Seljeåsen (Sørfold municipality). Historical records are limited, but according to an ecclesiastic cadastre from 1432 (Aslak Bolts jordebok; Jørgensen 1997), the Archbishop of Nidaros (medieval Trondheim) had a certain share of the Setså quarries. Three centuries later, the military officer Peter Schnitler in his authoritative account on trade, agriculture and industries in the district, stated that “mineral resources […] are unknown” (Qvigstad & Wiklund 1929, Monsen 1997), suggesting that quarrying had ceased or was strongly reduced by this time. A detailed and comprehensive description of the Saltdal district, written in the 1820s by the clergyman and natural scientist Søren Christian Sommerfelt, notes that extensive quarrying of millstones took place at Setså in ancient times but that “only one single, very old man is still quarrying” (Sommerfelt 1827, Monsen 1997). According to Titland (2003:41), the last millstone was produced by Sakarias Befring, who lived at Setså between 1859 and 1869.
The millstone quarries at Setså and Saksenvik were rediscovered recently, thanks to Helge Titland (2003), who mapped many of the quarries and entered their location into the national cultural heritage database. The new attention also led to a rescue excavation of two of the quarries at Saksenvik, due to construction of a road and a dam for hydroelectric power. The excavation, directed by Bjørn H. Helberg at the Tromsø Museum, uncovered large quarries and recorded a mass production of rotary hand querns. Charcoal samples provided radiocarbon data that was interpreted by Helberg (2007, 2010, 2011a, 2011b) to suggest dates ranging from the middle Viking Age into the High Middle Ages¹. The Seljeåsen quarry area in Sorfold was discovered in 2010, based on observations of millstone blanks found during construction of a ski trail.

Significantly, the excavations and Titland’s (2003) observations, combined with the later surveys conducted by the present authors, demonstrate a magnitude of production which suggests that it was not only for local or regional markets but that the Salten quarries were important also in a larger context. This is supported by the identification of large numbers of medieval millstones from the area in various museum collections in Norway (Grenne et al. in prep., see also Millstone Project 2013, http://millstone.no/).

In the present study, we address some key questions based on previously published and new data, combining archaeology, geology and historical records:

- Can the chronology of activity and heydays of the different quarries be better delimited?
- Is it possible to identify an evolution of quarrying technology through time?
- Was quarrying technology and organisation based on a locally developed tradition or was it adapted from other quarry landscapes?
- Were products other than millstones of any significance?
- Were there connections between the Saksenvik, Setså and Seljeåsen quarry areas?
- Is it possible to estimate the volume of the production and significance of the Salten quarries compared to other millstone quarry landscapes in Norway?

Methods and approaches

Much of the quarry remains are covered by dense vegetation. The results are based primarily on mapping...
of exposed areas by hand-held GPS, combined with integrated key observations that could potentially reveal similarities and differences between quarries, and likewise between the Salten district quarries and other millstone production areas in Norway. Such observations include surficial archaeological features (tool marks, remnants of carved channels, shape and size of roughouts, spoil heaps, work areas, transport routes and constructions) and geological characteristics (rock quality, inclination of layering/cleavage, structural and compositional features), in addition to available data from previous excavations and historical evidence. Details of the documentation are presented in a separate field report (Grenne & Meyer 2013).

For studying the actual quarrying process, we have used similar methods as Grenne et al. (2008) applied to the Hyllestad and the Selbu quarry landscapes, and as described by Heldal (2009) in a more generalised context. Studying the quarry walls and the surface of surrounding spoil heaps gives information about the primary extraction steps. The location of designated work areas (if existing) tell much about the secondary production steps (semi-finishing or finishing) and the spatial/logistical relationship between primary and secondary production.

The architecture of the quarries gives further indications of how quarrying was organised. At Hyllestad, the earliest stages involved carving millstones side by side on the cleavage plane (Grenne et al. 2008). At a later stage, the quarries became larger and deeper, extracting almost vertical columns of millstones. This shift may reflect a higher level of organisation of quarrying, resulting in a higher yield of millstones per area (Grenne et al. 2008, Heldal & Meyer 2011).

Quarry faces and spoil heaps are the best sources of information for interpreting what objects were produced. Although we use millstones as a collective term, it is important to distinguish between the small, rotary hand querns and larger, water-driven millstones. We have used a diameter of 60 cm to distinguish the rotary hand querns and larger, water-driven millstones. Tool marks and channels on ancient quarry faces indicate the extraction of large slabs, it is necessary to test if these were actually reduced to millstones or used for other purposes, such as slabs for paving or roofing, or even gravestones.

Landscape and geology

The morphology of the area is characterised by narrow, NE–SW striking hill ridges and valleys bordering on the fjords of Saltwaldstaden and Sørhvald (Fig. 1). Landscape forms are largely related to contrasts between resistant rock units (such as amphibolite, quartzite and mica schist) and less resistant marbles. The rocks belong to a major geological unit termed the Fauske Nappe (Kollung & Gustavson 1995, Gustavson et al. 2004), representing probably Late Precambrian marine sediments and local volcanic units that were metamorphosed and emplaced in their present position during the Caledonian Orogeny. In some areas, tight to isoclinal folds have led to repetition of individual units in parallel zones.

Millstone quarrying has targeted several, relatively narrow units of garnet-mica schist, hence the quarries commonly plot along nearly straight lines on the map. The foliation (the natural cleavage, representing the plane along which the rock will easily split) in general is nearly parallel to the boundaries of the mica schist, dipping steeply to the southeast. Consequently, on the SE side of ridges, the foliation commonly parallels the hillside (dip slopes), while on the NW sides, the foliation dips into the hillside and leads to many overhang cliffs. This has consequences for the quarrying, as discussed below.

The millstone schist is composed essentially of muscovite (white mica), quartz, garnet, biotite and occasionally hornblende. Garnets are typically less than 2 mm across. Biotite (dark mica) commonly forms porphyroblasts appearing as black specks less than 1 mm. In some places, the schist displays a distinct crenulation cleavage due to small-scale folding (crenulation) of the main cleavage. Another common feature is remains of the original sedimentary layering (seen as light and dark banding), which may also occur at different angles to the main cleavage.

The Salten millstone rocks can be readily distinguished from schists of other Norwegian quarries by visual petrographical criteria. Compared to other significant production areas based on garnet-muscovite schist, such as Hyllestad and Vågå (Fig. 1) (Heldal & Bloxam 2007, Grenne et al. 2008, Grenne et al. this volume), the Salten schists are characterised by e.g.
their finer grain size and the abundance of biotite specks. On a local scale, the Saksenvik, Setså and Seljeåsen millstone schists are visually similar; nevertheless, they are readily distinguished from each other by geochemical discrimination criteria. While the full significance of the petrographical and geochemical fingerprints in provenance studies will be dealt with in a forthcoming paper (Grenne et al. in prep.), some implications relevant for the Salten district quarries are briefly outlined below.

The quarries

About 50 individual extraction sites have been identified and mapped in the present survey. Of these, 12 may be considered as quarries in the sense of significant production (Saksenvik 5, Setså 6 and Seljeåsen 1). However, the number of both large and small extraction sites may be higher, since many quarries are not readily discernible due to overburden, dense vegetation and a rugged topography. This is illustrated by two of the Saksenvik quarries and the Seljeåsen quarry, which are largely incidental finds due to road construction and land development.

Essentially, two types of extraction techniques have been observed in these quarries: direct carving and slab splitting. Direct carving aimed to produce a more or less finished millstone blank by carving a circular channel directly on the quarry face, before the blank was loosened using a chisel along its base. Slab splitting, by contrast, was based on carving of millstone blanks from large, appropriately thick stone slabs that had previously been loosened from the quarry face.

Saksenvik

The quarries at Saksenvik (Fig. 2) are all aligned along one layer of garnet-mica schist, bordered by quartz-rich schists to the WNW and conglomerate and then marble to the ESE. They lie on ESE facing hillsides and thus are all dip-slope quarries, with cleavage planes more or less parallel to the natural terrain surface (Fig. 3). The quarries are concentrated in four main clusters over a total distance of nearly 2.5 kilometres, with the south end of the quarry zone lying in the small settlement of Saksenvik, close to sea level, and the north end near the hilltop of Vassliheia at 500 m a.s.l.

The southernmost group of quarries, here referred to as Saksenvikelva, are located on steep, 3–4 m high cliffs immediately west of the Saksenvik River (Fig. 2). The northern part of the 80–90 m long quarry shows subcircular channels from direct carving of 50–55 cm quernstone blanks, whereas the southern part has been worked by slab splitting.

The Kalvgarden quarry (Fig. 2) was excavated in 2006 by Helberg (2007). The exposed part is 31 m long and up to 3 m high along the western riverside. The entire quarry face is covered with remnants of channels from circular to subcircular millstone blanks carved directly from the bedrock surface. Many are carved side by side, but in some places rows of up to ten blanks have been carved successively inwards on the quarry face, leaving imprints that look like tilting piles of coins (Fig. 4). All blanks were apparently meant for hand querns, with diameters of ca. 40–60 cm and a typical thickness of 10–12 cm. Four samples of charcoal dated by Helberg (2007) gave calibrated \(^{14}C\) dates of 960–1190 (at 95.4 % confidence); these data will be discussed below.

The Hestgarden quarry (Fig. 2) was subject to a rescue excavation in 2009 (Helberg 2011a), revealing a quarry face at least 40 m long and more than 5 m high (Fig. 5). Extraction techniques and quernstone products were identical to those at Kalvgarden. Three samples of charcoal dated by Helberg (2011a) gave calibrated \(^{14}C\) dates of 1040–1270 at 95.4 % confidence; see discussion below.
In the Heimersurpan quarries (Fig. 2), remnant channels on the quarry faces reveal the use of two different extraction techniques: 1) direct carving of circular blanks, and 2) splitting of rectangular or variably shaped stone slabs with a thickness similar to the millstone blanks and a width of 50–60 cm. The two types can be found side by side on the same cleavage plane (Fig. 6), and there is no doubt they were contemporaneous techniques. Several of the circular blanks are from water millstones, with diameters up to 120 cm.

The Vassliheia quarry area (Fig. 2) is 650 m along strike, with scattered, small extraction sites at the ends and more densely spaced, larger quarries in the middle. The main quarry is 110 m long with an exposed face up to 4 m high, parts of it forming a prominent landmark near the top of a ridge (Fig. 7). All quarries in the area show evidence of contemporaneous slab splitting and direct carving, mostly for hand querns but also for water millstones, i.e. similar to the Heimersurpan quarries. The upper parts of the main quarry take an intermediate position with respect to technique, with extraction of hand quern blanks that were only roughly shaped; the significance of this is discussed below.
Fig. 5. Excavated quarry face at Hestgarden, showing numerous remnants of circular channels after direct carving of quernstone blanks. The exposure is ca. 5 metres high.

Fig. 6. Minor extraction site at Heimersurpan, where different techniques can be observed on the same quarry face: Direct carving of circular blanks on the left, channel walls from splitting of slabs on the right (yellow arrows).

Fig. 7. Vassliheia quarry viewed from the east.
Setsâ

The Setsâ quarries (Fig. 8) are irregularly distributed within a relatively thick zone of garnet-mica schist. These rocks have a strike and dip orientation similar to the Saksenvik millstone schist and a similar visual appearance although they belong to different geological units within the Fauske Nappe (Kollung & Gustavson 1995). Since the garnet-mica schist is on the SE side of the Setsâ valley, most outcrops lie on NW-sloping terrain where foliation dips into the hillside, and many quarries have typological characteristics controlled by the nature of overhang cliffs (Fig. 9). The six main quarries and several smaller extraction sites are found mostly within an area of around 1 km by 0.5 km, 1–2 km from the sea and at altitudes of ca. 100–200 m.a.s.l.

Several large and medium sized quarries around the knoll Bjørnholten (Fig. 8) were worked mainly on overhang cliffs (Fig. 10) that were 2–5 m high and up to 100 m long. Tool marks show evidence of wedging and splitting of slabs. A few minor quarries in the same area were worked on dip-slope surfaces and show traces of both direct carving of circular blanks, evidently for the production of water millstones (up to 117 cm), and contemporaneous wedging of slabs. The quarries of the Langholten area (Fig. 8) were apparently worked only by slab extraction, both on overhang cliffs and on dip-slope surfaces.

The largest of the Setsâ quarries is found around the prominent knoll Forsholten (Fig. 8 and 11), where stone extraction took place primarily on steep, tall cliffs on the sides of the knoll. Some additional production was based on huge blocks from rock-falls in talus below the cliffs. Direct carving of circular blanks seems to have been very limited even though the knoll had abundant dip-slope surfaces, and nearly all production was based on the extraction of variably shaped, elongate slabs that were some 45 to 65 cm wide.

Seljeåsen

One quarry has been identified in the Seljeåsen area, located ca. 1.5 km from the sea, at the southernmost end of the fjord Sorfjordâ (Fig. 1), in a SW–NE trending zone of garnet-mica schist surrounded by marble units. It comprises a ca. 400 m long row of steep dip-slope extraction sites along a 2–4 m high SE-facing cliff. Parts of the quarry were worked by splitting of slabs, other parts by direct carving of circular to subcircular, roughly shaped blanks on the quarry face. Most of the production was for hand querns (<55 cm), with a minor amount of small water millstones (up to 65 cm). Most of the cliff displays traces of the two different techniques side by side, similar to that seen in some of the Saksenvik quarries (Fig. 6).

Tool marks and quarry techniques

Direct carving

Direct carving at Salten was essentially similar to the technique used in the majority of the Hyllestad quarries in the Viking Age and Early to the High Middle Ages (Heldal & Bloxam 2007). After outlining a circular channel on the cleavage surface with the help of a compass-like device, a channel was carved either by a pick or by a pointed chisel. Along the base of the channel, densely spaced pits, a few centimetres deep, were directed inwards on the perimeter of the millstone blank. Similar to the so-called pointillé technique, which had been in use from the 6th century BC onward for precisely controlled splitting of rocks (Waelkens et al. 1990), the stone was then loosened along the base by sequentially and repeatedly hammering a pointed chisel into the pits. The millstone’s surfaces were
smoothed and the centre hole (eye) was carved after the stone was loosened.

The excavated quarries at Kalvgarden and Hestgarden in Saksenvik are the best representatives of this technique in the Salten district; similar traces are seen also in parts of the Seljeåsen quarry. Although the majority of channels have a circular outline on the steep surface, some have a sharp-pointed shape in the lower part that probably result from the difficulty in wielding the heavy pick sidelong on the quarry wall. This shows that at least some of the extracted millstones had to be trimmed to their final shape after extraction. Slanting tool marks on the channel wall indicate that a sharp-pointed pick was used, apparently by carving parallel, 2–4 cm deep grooves followed by removal of the intervening ridge, as described from Hyllestad by Heldal & Bloxam (2007). This process was repeated until the channel had reached the desired depth (typically 12–15 cm), leaving 4–5 recognisable “shifts” on the channel wall. The pointillé pits at the base of the blank perimeter (Fig. 12) were apparently made with a pointed chisel. The blanks were mostly extracted side by side on approximately the same cleavage plane, leaving large planar quarry faces with circular outlines.

**Carving from slabs**

This technique is basically comparable to that of the Selbu millstone quarries in Central Norway (Fig. 1) that were worked mainly after the Middle Ages (Grenne et al. 2008), i.e. large slabs of schist were split from the quarry wall and subsequently carved and trimmed to millstones. Similar quarrying was common at Vågå in South Norway (Fig. 1) from the early 15th century...
(Grenne et al. this volume). In the Salten district, this was the predominant technique in nearly all the Setså quarries. However, it was also widely applied in several of the Saksenvik quarries as well as at Seljeåsen, in many cases concurrent with direct carving. In all these places, splitting was done almost exclusively by the pointillé technique along the top and sides of the slab, using a sharp-pointed chisel at a pitch of 10–15 cm along certain cleavage planes (Fig. 13).

In dip-slope quarries, slab extraction was often facilitated by channels that were carved vertically to produce nearly rectangular slabs or, quite commonly, the channels were curved to join at the bottom to avoid wielding the heavy pick sidelong on the steep quarry face. Marked shifts on the channel walls (Fig. 14) denote that they were carved as parallel grooves followed by removal of the intervening ridge, a technique basically similar to that of direct carving of circular blanks (see above).

The actual millstones were shaped by carving circular, V-shaped channels on the slab (Fig. 15), apparently from both sides in order to minimise the risk of breakage. Tool marks are perpendicular to the blank surface and indicate the use of a chisel, in contrast to the slanting tool marks in circular channels made by direct carving with a pointed pick. Compared to the use of picks, chiselling would obviously allow more careful carving when millstones were finished from breakable slabs. Interestingly, channels for extraction of slabs from the quarry face also have perpendicular tool marks that denote the use of a chisel rather than a pick (Fig. 14). The relationships may suggest that within this type of quarry the technique required for secure finishing of the millstones from slabs was transmitted to that of primary extraction; alternatively, it reflects a general temporal shift from the ancient pick carving technique to later chiselling.

Spoil heaps below this type of quarry comprise numerous mounds, with local accumulations of fine rock debris on their top and scattered failed blanks around, representing sites where millstones were carved from the stone slabs. Locally, shaping of the millstone took place on a low “workbench”, a rough drywall structure of piled waste rock that provided a stable fundament (cf. Fig. 9), serving to reduce breakage during millstone finishing.

**Intermediary techniques**

At Vasliheia, in the Saksenvik area, a significant part of the main quarry displays traces of stone extraction that was apparently transitional between direct carving and slab extraction. Other quarries that show traces of a similar intermediary technique are found at the Saksenvikelva and Heimersurpan quarries (Fig. 2). All these sites are closely associated with slab extraction.
Extraction as well as carving of both hand querns and water millstones.

Remnants of channels indicate extraction of blanks that were only roughly shaped (Fig. 16), some with many-sided straight outlines and others with variably curved outlines. In contrast to the typical direct-carving quarries at Kalvgarden and Hestgarden, where blanks were carved mostly side by side on the same cleavage layer, production at Vassliheia left a characteristically stepped surface, i.e. blanks on lower parts of the quarry face consistently cut the traces after higher blanks and were obviously extracted from consistently deeper cleavage layers. The difference between the two production schemes is outlined in Fig. 17.

Like in the typical direct-carving quarries, blank extraction started at the top and moved downwards on the quarry wall. However, in contrast to the former,
the intermediary technique was based on establishing a quarry face that was somewhat steeper than the cleavage plane. This made it possible to access the base of the blank from below with no need of prior channeling (Fig. 17); channelling was required only above and on the sides of the blank. In many cases, remnants of only two or three pointillé pits are found on the sides, suggesting that the principal splitting force was gained from below. Tool marks on this lower side of the blanks are not seen because they were removed by the subsequent extraction further down; hence, we do not know whether wedges or chisels were used. In any case, the technique allowed the use of splitting tools focused directly along the cleavage plane. Obviously, this was more efficient than chiselling at the base of channels, since the limited width of the channels required chisels (or wedges) to be held at an angle oblique to the cleavage plane.
Discussion

Age constraints

The main phase

Radiocarbon data published by Helberg (2007, 2010, 2011a, 2011b) for charcoal from the two quarries excavated at Saksevik include four samples from Kalvgarden and three from Hestgarden. All samples were from birch (Bjørn Hebba Helberg, pers. comm. 2012). Calibrated dates (Fig. 18) are calculated by the OxCal software (Bronk Ramsey 2009; version 4.1.7) using the calibration curve of Reimer et al. (2009). Two of the Hestgarden samples give nearly similar ages. At 68 % confidence (1σ), it is likely that they date between 1159 and 1220. The third sample is overlapping but covers a wider possible time span. Given that birch, in contrast to potentially old trees like pine, gives almost negligible inbuilt age effects on radiocarbon data, it is likely that working at this particular site took place at least some time after 1160 and before 1270. The four Kalvgarden samples are slightly older; three of them have nearly identical calibrated dates within the relatively wide possible range of 1015–1154 (at 68 % confidence), while the fourth sample gives a narrower time interval and probably dates between 986 and 1036 (Fig. 18). In view of their close spatial association within the quarry (Helberg 2010:114), the samples most likely may be considered as a group represented by overlapping dates in the interval of about 1020–1050, implying that work at this site took place at least some time after 1020 and before 1100.

Since the samples come from restricted parts of the two quarries (Helberg 2010, 2011a), the above dates represent only brief time windows and give no clue to the timing of start-up and ending of activity in the respective quarries. Hence, it is possible that the dates signify an early phase of quarrying at Kalvgarden and a relatively late phase at Hestgarden, and the overall activity in the two quarries may well have been completely overlapping in time. Indeed, contemporaneity is substantiated by the great similarity in extraction techniques. It is also possible that quarrying started much earlier, but this remains purely speculative.

An ongoing analysis of the petrographical and geochemical provenance of medieval and pre-medieval artefacts in museum collections (Grenne et al. in prep.) has served to identify a large number of Salten district millstones (used as a collective term for any of the three quarry areas described above). Of particular interest in
this context is data from Trondheim, where our study included a significant number of millstones and millstone fragments in well-dated medieval contexts from the town of Nidaros. While post-medieval artefacts are almost exclusively from the Selbu quarries, as would be expected from historical data (Grenne et al. 2008), the late Viking Age and the Middle Ages were dominated by Hyllestad and, subsequently, Salten millstones. The first Salten millstones appear in the archaeological record from 1150–1175. Interestingly, these were all from the Saksenvik quarries, while Setså millstones do not appear until 1225–1275. Moreover, data from studied museum collections in Norway and Denmark indicate that nearly two thirds of all Salten millstones came from Saksenvik. The rest were primarily from the Setså quarries, while Seljeåsen apparently provided only a fraction of the stones from the district.

The above data are significant with regard to timing the activity in the different quarries and the evolution of technology over time. We know from radiocarbon dating that the most pristine form of direct carving was applied in two Saksenvik quarries – Kalvgarden and Hestgarden – at least by the late 11th and 12th centuries. From historical records (Aslak Bolt’s Jordebok of 1432; Jørgensen 1997), we also know that the Setså quarries, worked almost exclusively by splitting and carving from slabs, were still exploited in the 15th century. On a broad scale, the development from direct carving at Saksenvik in early days, to carving from slabs as the primary technique in later times, is in accordance with previous studies of the Hyllestad and Selbu millstone quarries. Together, these major production landscapes, both based on mica schist, record a shift from exclusively direct carving in the Viking Age and well into the Middle Ages, to splitting and carving of slabs after the Middle Ages (Grenne et al. 2008). The Kalvgarden and Hestgarden quarries fit well into this scheme.

A more difficult question is when splitting and carving of large slabs took over as the primary production method. Field relationships show that, at Salten, the latter technique is temporally associated with production of water millstones at least occasionally. At Hyllestad, production of water millstones may have taken place as early as the late Viking Age and certainly in the Early Middle Ages (Baug 2013:334); however, production of hand querns was important long after that and saw only a slow decline as watermills gradually took over through the Late Middle Ages and Early Modern Period, making it difficult to use this change as a time marker.

Better constraints on the timing of slab splitting are provided by the presence of Setså millstones in the 1225–1275 archaeological record of the town of Nidaros. Since this is by far the predominating extraction technique in all Setså quarries, it is very likely that the Setså stones in Nidaros were produced by slab splitting in the same time period or somewhat earlier.

![Fig. 18. Calibrated 14C dates for samples from Hestgarden (blue) and Kalvgarden (red), Saksenvik. Dates and probability intervals at 1σ (horizontal bars) are calculated using OxCal version 4.1.7 (Bronk Ramsey 2009). Calibration curve from Reimer et al. (2009). Sample numbers refer to Helberg’s (2007, 2011 a) original samples analysed at Waikato University, New Zealand; measured data in parenthesis.](image-url)
By analogy, we can also infer that slab quarries in Saksenvik were worked at the same time and not before about 1160, when direct carving was apparently still prevailing. The abundant traces of mixed techniques in many Saksenvik quarries, with direct carving and slab splitting employed virtually side by side, denote that this was a transition period where the traditional techniques were still extensively used, rather than a total changeover. This applies not least to the intermediary techniques seen at Vassliheia, where variably shaped blanks were split from the quarry face before final trimming.

The decline
In his detailed record of properties belonging to the Archbishop of Nidaros in 1432, Aslak Bolt states that the Archbishop owned either all or parts of the two farms at Setså and the two farms at Saksenvik (Hutchinson 2006:20–21). The Archbishop also claims a certain share of a millstone quarry at Setså, while the quarries at Saksenvik are not mentioned at all. The Setså and Saksenvik farms were all assessed at very high values compared to other farms in the district, and according to Hutchinson (2006:20) it is likely that these tax assessments were related to the presence of millstone quarries on the premises.

While it is likely that there was still activity at Setså in 1432, Aslak Bolt’s cadastre leaves some doubt as to whether the Saksenvik quarries were still in operation, since only the Setså quarries are mentioned specifically. One possible interpretation is that, while both quarry areas were known as past and potential producers, only the Setså quarries were actively worked by the time of Aslak Bolt. On the basis of tax records, Hutchinson (2000:207) suggests that the Saksenvik farm was abandoned after the Black Death in 1349/1350 and that farming resumed only shortly before Aslak Bolt’s records. In this case, it is likely that also the adjacent quarries were abandoned. At any rate, the relatively high tax assessment of the Saksenvik farm in 1432 implies that the Archbishop was probably fully aware of the economic potential of the quarries. Hence, while it is likely that the Saksenvik quarries were abandoned for a few decades, it is quite possible that millstone production resumed at some stage, not least because quarrying on the dip-slope surfaces at Saksenvik must have been easier than on the overhang quarry walls at Setså. Our provenance data for the Trondheim archaeological record is limited after the 13th century, but they clearly show that Saksenvik millstones were present at least until the 16th century.

Historical sources indicate that the decline of quarrying occurred long before the 18th century (see above), but the start of the decline is not well constrained. Grenne et al. (2008) suggested that the Norwegian millstone trade was left practically in ruins after the Black Death and recurrent plague outbreaks throughout the late 14th and early 15th centuries, due to the partial collapse of social and trade structures that accompanied the dramatic drop in population and a consequently low demand for new millstones. The authors concluded that this was the historical backdrop for the apparent decline at Hyllestad after the High Middle Ages, and the subsequent rise of Selbu quarrying in the 16th century when the population started to increase again. It is likely that such arguments apply also to the decline of quarrying in the Salten district. This would imply that the bulk of production at all Salten quarries was prior to 1350 and that only limited quarrying took place after that. Like Hyllestad, quarrying at Salten never recovered, except for local use, because when the Norwegian millstone trade started to grow again in the 16th century, the Selbu quarries “produced millstones of better quality than anywhere else in the kingdom and [...] the stones were widely distributed throughout the country”, as noted in a travelogue from 1591–1592 by the clergyman Peder Claussøn Friis (Friis 1632:97).

Geological factors were significant in this regard, partly in terms of the grinding properties of the different stone types, but also because geological characteristics (especially cleavage and natural fractures) were far more favourable for production of large water millstones at the Selbu quarries (Grenne et al. 2008). It is also possible that reduced ecclesiastic power after the Reformation had some effect on the decline. The Salten quarries (like Hyllestad) had been controlled by the Church and were possibly also protected with respect to trade. This link did not exist after the Reformation in 1537, leaving the market more open to newcomers in the millstone trade.

Quarrying technology and organisation
An intriguing question is the possible driving force for the development in quarrying technology. Obviously the Setså quarries, with their predominantly overhang quarry walls, could hardly be worked by the traditional direct carving method. This may explain why the Setså quarries were exploited mainly after the splitting technique had been introduced; the new extraction method could be readily applied also on overhang faces. However, the shift in technology cannot be seen just as an adaptation to available resources, since there were still vast supplies of suitable millstone rock to
be exploited on dip-slope quarry faces at Saksenvik and also the latter area experienced a parallel shift in technology.

It has been noted elsewhere that the long-range evolution from direct carving to slab splitting was a consequence of the gradually increasing demand for water millstones, which were more readily produced from slabs (Grenne et al. 2008). While we consider this to be significant also for the Salten quarries, it still remains to explain why the new technology was so extensively used already in the 13th century, apparently long before it came into common use elsewhere in Norway (Heldal & Bloxam 2007, Grenne et al. 2008). One possible clue to this issue is the cleavage properties of the rocks. In general, the Salten garnet-mica schists have a well-developed cleavage, well suited for splitting relatively large slabs. In contrast to this, the cleavage of Hyllestad schists is typically less marked and is frequently complicated by cleavage planes of different orientations (Heldal & Bloxam 2007). The presence of two distinctly different cleavage planes is found only locally in the Salten quarries, notably at Hestgarden and Kalvgarden, and may be the reason why these particular sites were never developed as slab quarries.

What appears to represent the earliest phase at Salten (Kalvgarden-Hestgarden at Saksenvik and parts of the Seljeåsen quarry) reveals carving and quarrying techniques very similar to those of the Hyllestad quarries in the Early Middle Ages (Heldal & Bloxam 2007). Since the Hyllestad quarries had been Norway’s dominating millstone producers already from the early Viking Age (Baug 2002, Grenne et al. 2008), one can argue that the similar techniques and craft skills at Salten were acquired from Hyllestad. Comparable carving techniques had also been used in the quarrying of soapstone vessels already in the Viking Age in this part of Norway, as well as outside the region (Skjolsvold 1961), but some distinctive features in the Kalvgarden and Hestgarden quarries, including the characteristic “coin pile” extraction (see above), seems more akin to the Hyllestad techniques.

Other features of the direct carving technique are apparently unique to the Salten quarries and seem to be more locally developed traditions, such as the tendency to carving subcircular channels with a sharp-pointed, arch-like shape at the bottom or top. While this probably developed from the difficulty in wielding a heavy pick sidelong on the steep quarry wall, it is noteworthy that similar features are never seen at Hyllestad, not even on equally steep surfaces. We know from petrographical investigations that the Hyllestad schists have significantly higher contents of mica and therefore are softer than the Salten schists. Direct carving of perfectly circular channels, even on steep quarry faces, was obviously easier in the softer Hyllestad schists, while subcircular shapes were developed by adaptation to the harder schists of the Salten district.

Hence, the evolution in extraction techniques in the Salten quarries may be viewed as a continuous path from direct carving of circular blanks to slab splitting. The starting point may have been inspired by Hyllestad, but a local skill tradition gradually developed, which was better adapted to the geological and morphological features. Already at an early stage, the operational chain in the Salten quarries took a significantly diverging course compared to Hyllestad, in that imperfect blanks (subcircular to irregular) were trimmed at designated work areas before they were brought down to the settlements. Once this extra step had been introduced in the production chain, the path further towards extracting larger, variably shaped slabs, required only moderate adjustments. This may explain why production of millstones from split slabs was introduced so early and why the two methods were used contemporaneously in some places.

It is also possible that new technology was introduced as a consequence of knowledge input from new owners. Millstone quarrying commenced before ecclesiastical economic power became significant in this part of Norway, and initially must have been controlled by local chiefs. It is commonly thought that the Salten district was ruled from the settlement at Skjerstad, further west on the opposite side of the fjord (cf. Fig. 1). We know that by 1432, a significant part of the economically important property was in the hands of the Archbishop of Nidaros, but it is unclear when the Church first acquired this power in the region. Aslak Bolt’s cadastre is generally considered as an attempt to re-establish and confirm property and tax conditions as they were before the chaotic period following the Black Death, and as such it is likely to reflect ecclesiastical economic influence at least back to 1349. Further back, the Archbishop’s ownership of the Saksenvik and Setså quarries is unknown. However, it is tempting to suggest that it went back to the early 13th century, because that was a time when the Church resumed and strengthened its position in Norway after the long lasting conflict with King Sverre (1177–1202). Potentially, this could imply a parallel to the influence that growing ecclesiastical power had on the introduction of new technology to the Hyllestad millstone quarries in the Early to High Middle Ages.
(Baug 2002, Heldal & Bloxam 2007); although the path of development was driven largely by practical adaptation to local geological and topographic conditions and market demands, it is possible that the introduction of slab splitting was to some extent also promoted by ecclesiastic building stone quarry traditions related to the construction of many stone churches during the same period.

It is noteworthy that the Seljøasen quarry shares the above peculiarities in carving and extraction techniques. The similarities are so conspicuous that they may be regarded almost as fingerprints of the quarrymen, hinting at a direct link between the Saksenvik, Setså and Seljøasen quarries with regard to ownership and labour force.

Production and significance
Helberg (2010, 2011a) suggested that a total of about 5,000 stones were produced from the excavated quarry at Kalvgarden. These figures were based on estimated quarry volumes and traces of blanks on the quarry face, allowing for a loss of 30–40% due to breakage. However, the loss of rock material that must be removed between each stone would be more than 60% even if only their circular shape and intervening channels are taken into account. Total loss must have been much higher due to breakage of blanks during carving, extraction and finishing. A more realistic estimate based on typical loss in natural stone production elsewhere is that only 10–15% of the total quarry volume resulted in finished millstones (Heldal & Bloxam 2007). On this basis, we interpret total production at Kalvgarden to be on the order of 1,000 millstones (calculated from an average diameter of 55 cm and a thickness of 12 cm). For the other main quarries in the Salten district, quarry volumes must rely on approximate assessments based on the morphology of the quarry edges and surrounding topography. Such calculations indicate that 30,000 to 40,000 stones may have been produced from the Salten quarries. Setså and Saksenvik account for at least 95% of this volume, at approximately equal proportions.

Admittedly, estimates of millstone production are affected by considerable uncertainties in quarry volumes and production loss. Nevertheless, it may give an idea of the relative significance of various quarry areas. The Hyllestad district, which is generally believed to have dominated millstone production in Norway (Grenne et al. 2008), is assumed to have delivered on the order of 100,000 to 200,000 hand millstone equivalents (Heldal & Bloxam 2007). If the smaller size of Hyllestad stones (40–45 cm) is taken into account, the above estimates imply that total production in the Salten quarries could be somewhere between 25 and 70% of that at Hyllestad based on similar-sized millstone equivalents. Significant in this context is also the far longer history of the Hyllestad quarries, dating back at least to the 9th century (Baug 2002). This means that the significance of the two quarry areas may have been comparable during the heydays of the Salten quarries in the Middle Ages.

A medieval gravestone slab (Fig. 19) at Skjerstad church (Fig. 1) is made of garnet-mica schist visually identical to that of the millstone quarries, raising a question as to the relative significance of production other than for millstones at the Salten quarries. Based on its ornamental style, the Skjerstad gravestone is generally thought to be from the first half of the 13th century (Engen 2010). A similar stone is found at Bodin church, further west in the Salten district (Fig. 1). According to Øystein Ekroll (pers. comm. 2012), medieval gravestones in Norway were in general made from rock types softer and more suitable for carving, such as marble and soapstone. Except for the two Salten gravestones, comparable stone monuments find their counterparts only in the West Norway stone crosses made of garnet-mica schist from the Hyllestad millstone quarries (Baug 2013:238–242, 322–323). A complete lack of gravestones made from garnet-mica schist, even in medieval Nidaros where the Archbishop had his seat (Øystein Ekroll, pers. comm. 2012), denotes that this was never an important by-product from the millstone quarries. Nevertheless, their occurrence clearly demonstrates that slab extraction was applied very early in the Salten quarries, although mostly for millstone production.

Conclusions
Mapping of millstone quarries based on garnet-mica schist in the Salten district, including studies of typology, tool marks, spoil heaps, millstone blanks, work areas, ancient trackways, millstone provenance and the actual geological resource, has provided information that places Salten – along with Hyllestad – as one of the most significant production areas of Norway in the Middle Ages. Brief time windows into the early history are provided by radiocarbon data from two quarries (Kalvgarden and Hestgarden, Saksenvik), representing the oldest phase in terms of extraction methods and reflecting activity at some time between
used in the town of Nidaros already by 1225–1275, implying that the slab splitting technique dates back at least to the middle of the 13th century.

Technology development at the Salten quarries, from direct carving of circular blanks to slab splitting, may be viewed as a continuous path driven largely by practical adaptation to local geological and topographic conditions. The starting point could have been inspired by Hyllestad, but the greater difficulty of carving perfectly circular blanks from the harder mica schist on the steep quarry faces at Salten gradually obliged the quarrymen to adjust towards carving subcircular to irregular blanks that were subsequently trimmed at designated work areas. The path from subcircular blanks to larger, variably shaped slabs may be seen as a further extension of this development.

It can be inferred from historical records that the Archbishop of Nidaros had gained control of at least the Setså and Saksenvik quarries some time before the Black Death in 1349–50. We suggest that this ownership goes back as far as the early 13th century, when the Church strengthened its position after the long lasting conflict with the king, an ownership that could have provided an additional driving force to the introduction of new quarrying technology and organisation. Striking similarities in carving and extraction techniques at Saksenvik, Setså and Seljeåsen hint at a direct link between all these quarries, with regard to ownership and labour force.

Together, the Salten quarries provide a continuous record of millstone quarrying and technology development through the Middle Ages, possibly with a brief interruption at Saksenvik after the Black Death. Aslak Bolt’s cadastre from 1432 shows that production at Setså continued into the Late Middle Ages, and provenance data indicate that Saksenvik also delivered millstones outside of the local market until at least the 16th century. Historical sources seem to suggest that production came to an end in the Early Modern Period, with the exception of limited quarrying for local use.

Production estimates and provisional provenance data indicate that the Salten district was one of Norway’s most important production areas for millstones in the Middle Ages, possibly equalling the significance of the Hyllestad millstone quarries during this period.

Acknowledgements
We are grateful to Helge Titland and Ingvør Lindahl for field guiding and help in localising the Saksenvik and Setså quarries, and to Halvdan Haug for showing...
us the Seljøasen quarries. We thank Bjørn Hebbø Helberg for information on the excavated quarries at Hestgarden and Kalvgarden, Øystein Ekroll for discussions on the significance of ecclesiastic influence and graver-buttons, and Lars Holger Pilø for comments on 14C data interpretation. The manuscript benefited greatly from the constructive comments from two anonymous referees. We also wish to acknowledge the logistical support and guiding from many people living in the area – none mentioned, none forgotten.

References


