EUROLITHOS European Ornamental Stone Resources

Eurolithos case study

The use of traditional crafts in the production of the Oppdal Schist, South-Central Norway

Thematic focus: Craft

Responsible partner(s): NGU, Minera, Oppdalsten

Author(s): Tom Heldal

Year: 2021

GeoERA RAW MATERIALS

Executive summary

The Oppdal schist production, being a cornerstone economic activity in the community, initiated when the Railway between Oslo and Trondheim opened in 1921. The schist remains one of the most widely used in Norway, but has also been applied in numerous projects abroad. In this case study, we have tried to identify the “craft” and the “technology” elements of the production from bedrock to finished products and explore how important the craft part is to the process.

The Oppdal schist probably represent Late Proterozoic continental margin sediments, later metamorphosed and deformed during the Caledonian orogeny. Arkosic sandstones were transformed to quartz-feldspar-mica schist, characterized by 1 to 4 cm domains of largely polygonal textured rock separated by thin layers of mica, a spaced cleavage along which the stone can be cleft to slabs of varying thickness. From a quarrying perspective, the workable schist occurs in homogenous sheets separated by more disturbed and folded ones.

In order to explore the work process in the Oppdal schist, we have first broken down the process in 4 steps: 1) block extraction from bedrock, 2) block reduction (splitting to slabs), 3) semi-finishing (formatting slabs), and 4) finishing (surface treatment). These steps have been described and the craft tradition part identified.

This case study shows that traditional crafts are still of great importance in the production of the Oppdal schist. There is evidence for this craft to be of ancient origin, perhaps as early as the 11th century. This should in itself create a wider attention by Norwegian authorities, as a case for documentation and preservation. Analysing the craft involved in production, by separating different steps in the production, works well in highlighting traditional crafts versus modern technology, and recommend the method for application in other stone producing settings.

Keywords

Ornamental stone, dimension stone, schist, Oppdal, Norway

Table of contents

Description of case study

The quarrying and processing of ornamental stone may, at first sight, look like any other mining or quarrying activity – one where old, locally developed crafts and manpower have been gradually replaced by technology. Thus, the human input to the production is reduced to 1) geology and mining engineering in the planning process, and 2) by controlling machines and other technology necessary for the actual production.

However, one important issue separates ornamental stone quarrying from other extractive industries: the rocks are not crushed and grinded, and unwanted elements and flaws cannot be removed. Extraction and use of ornamental stone is basically about the art of using the geological material as it is created, cut it to suitable formats and use it.

Our main research question here is: will ornamental stone production require a more fundamental approach to traditional crafts than other extractive industries?

This leads to a second question: are traditional crafts related to ornamental stone production necessary for efficient extraction and production, and thus for economic sustainability?

On this basis we have formulated a hypothesis:

The employment of traditional crafts can be critical for a cost-efficient production of ornamental stone.

For exploring this hypothesis, we have selected a stone producing area in Norway, where the following conditions are fulfilled:

- A quarry area of more than 100 years production, where traditional crafts have developed through generations of “trial and failure”
- A quarry area where there has been significant focus and investments on applying new technologies

These questions lead us to the Oppdal schist quarry area in Norway. The Oppdal schist, being originally a arkosic sandstone unit transformed during orogenic events to a quartz-rich schist, is widely applied for cladding and flooring. The stone is applied as slabs (raw split, honed or brushed), as bricks (as raw-split or sawed/brushed) as thick roofing slabs and as drywall stone.

Oppdal is a Norwegian town at the northern flank of the Dovre mountain plateau, known for its ski resorts but also for the schist production, being a cornerstone economic activity. Industrial scaled production of the Oppdal schist started when the Railway between Oslo and Trondheim opened in 1921, thus now celebrating 100 years anniversary. The schist remains one of the most widely used in Norway, but also in many projects abroad.

Methods applied

In this case study, we have tried to identify the “craft” and the “technology” elements of the production from bedrock to finished products and explore how important the craft part is to the process. The study consists of three parts:

- Geological description of the Oppdal schist – the geological properties of relevance to production
- Description of work processes, stepwise from quarrying to finishing
- Relate these to products and use

The geological descriptions are based on own field work in the area, combined with previous published work. The work process has been observed and described through visits to several quarries and factories.

Geology of the Oppdal schist

The Oppdal schist probably represent Late Proterozoic continental margin sediments, later metamorphosed and deformed during the Caledonian orogeny (440-400 Ma) (Krill 1980). Arkosic sandstones were transformed to quartz-feldspar-mica schist, characterized by 1 to 4 cm domains of largely polygonal textured rock separated by thin layers of mica, a spaced cleavage along which the stone can be cleft to slabs of varying thickness (Heldal and Lund 2000) (Figure 1, Figure 2). This cleavage is closely associated with thrusting and asymmetric folding resulting from the compressional ductile deformation within the deeper levels of the orogeny.

From a quarrying perspective, the “ore” (workable schist) occurs in homogenous sheets separated by more disturbed and folded ones (Figure 3). Such workable sheets can be tens of metres in thickness and have a significant lateral extension.

Thus, the workability and finally profitability of the schist strongly depends on the spacing of the mica layers and the homogeneity and lack of folding in the layers carrying it (Figure 4).

However, the mica layers alone do not define the totality of the workability of the schist. It is, for example, easier to put the drilling lines along the rift of the stone, meaning that lines of perpendicular drill holes follow a mineral lineation seen on the surface of the schistosity plane. The grain (or “hardway”) defines the last of the three directions, defining the most difficult direction for blasting or breaking (Figure 5).

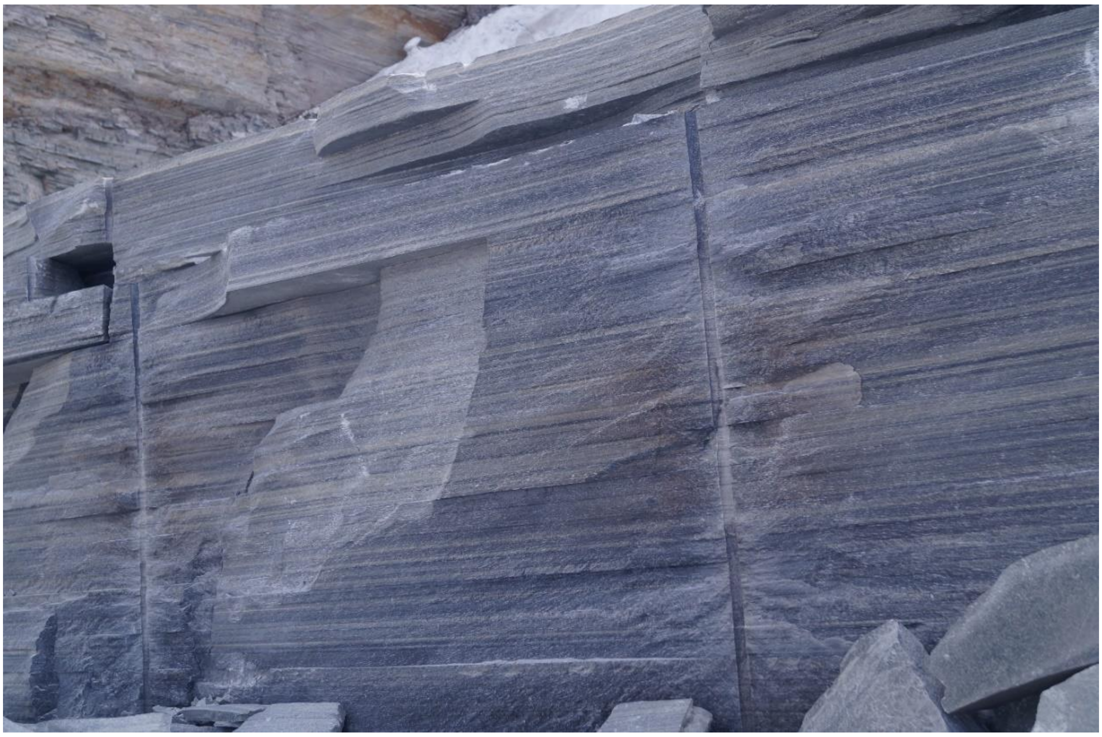

Figure 1. Workable layers within the Oppdal schist. Thin, black mica layers can be seen between more massive quartzofeldspathic domains.

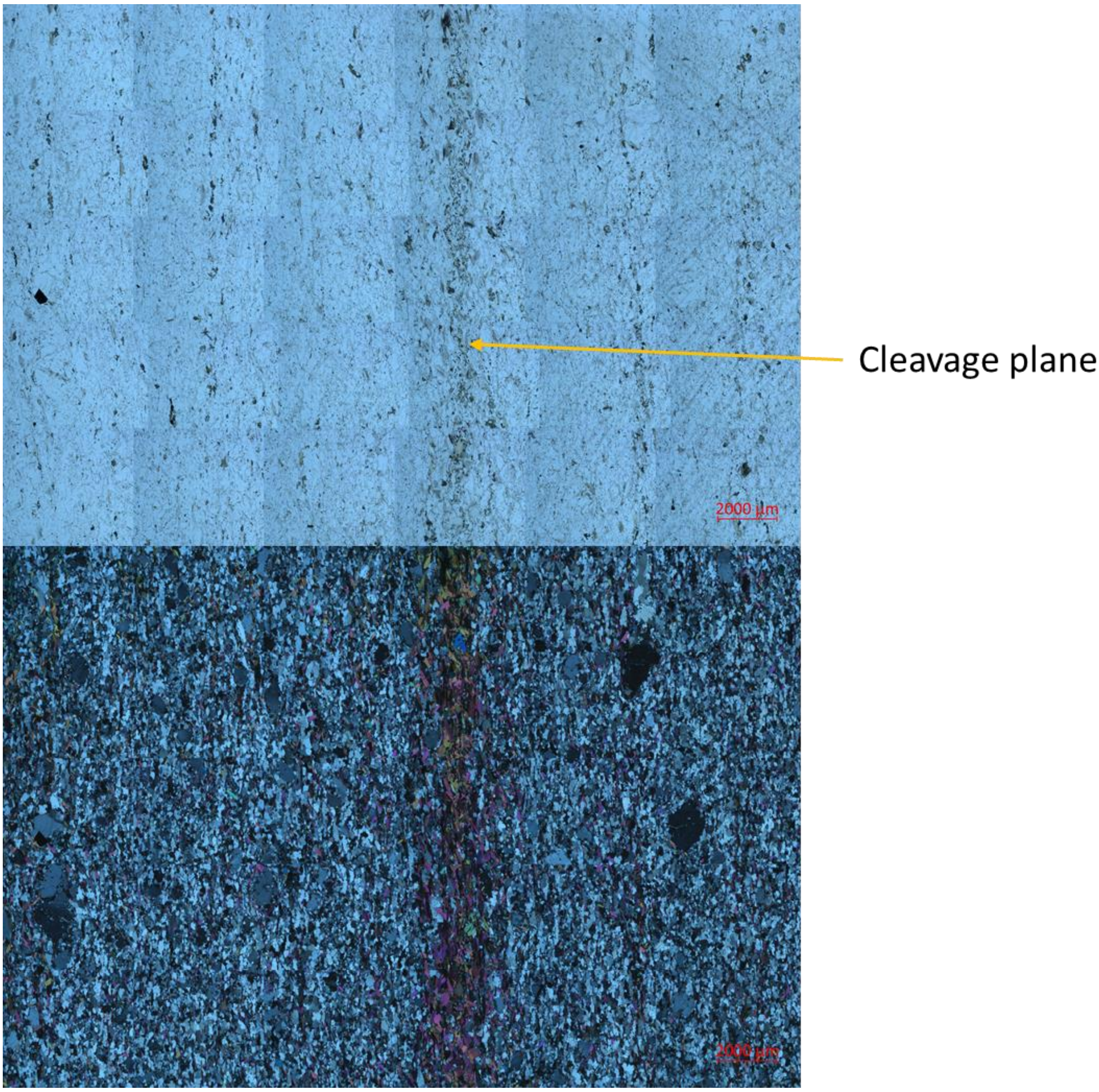

Figure 2. Thin section micrographs of the Oppdal schist. Top: plane-polarized light, bottom: cross-polarized light. Mica-rich field displays schistosity (cleavage plane). In between, the schist contains large grains of feldspar (porphyroclasts - deformed clastic grains), recrystallized polygonal quartz and lepidoblastic mica.

Figure 3. Non-workable layers of the Oppdal schist, disturbed by sheath folding related to thrusting.

Figure 4. Splitting of slabs along the thin mica layers

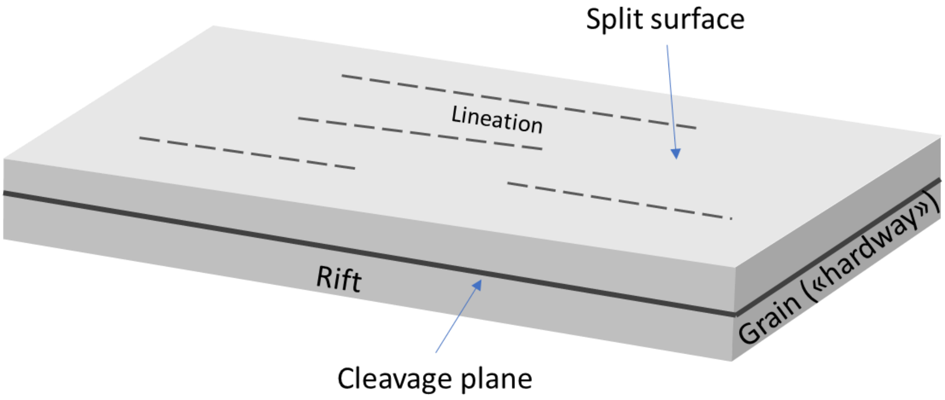

Figure 5. Three important directions in the Oppdal schist. Cleavage (mica layer plane for splitting slabs), rift (perpendicular to cleavage along direction of lineation (best blasting direction), and grain or "hardway" defining the most difficult direction for blasting.

Working the Oppdal schist: the process breakdown

In order to explore the work process in the Oppdal schist, we have first broken down the process in 4 steps (Heldal 2009): 1) block extraction from bedrock, 2) block reduction (splitting to slabs), 3) semi-finishing (formatting slabs), and 4) finishing (surface treatment). This is illustrated in Figure 6. Below, we will analyze each of these steps in the light of technology and crafts.

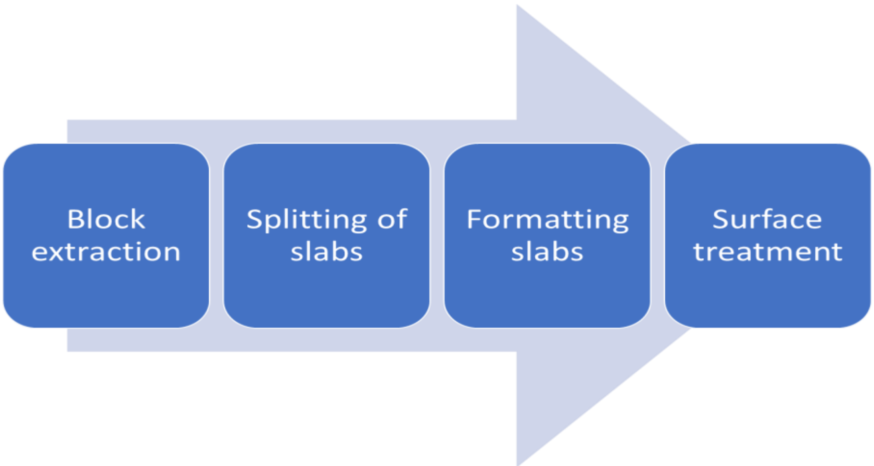

Figure 6. Production of the Oppdal schist broken down to four major steps.

Block extraction

The first step is to release blocks from the bedrock. In the case of the Oppdal schist, this means length 1-4 metres, width 1-2 metres and thickness (across schistosity) 0,5 – 1 metres. At present time, block extraction involves two main methods: drilling and blasting alone, and drilling and blasting combined with diamond wire sawing (Figure 7). Since diamond wire sawing just recently was applied in the Oppdal schist, we have considered only drilling and blasting as a "traditional" method.

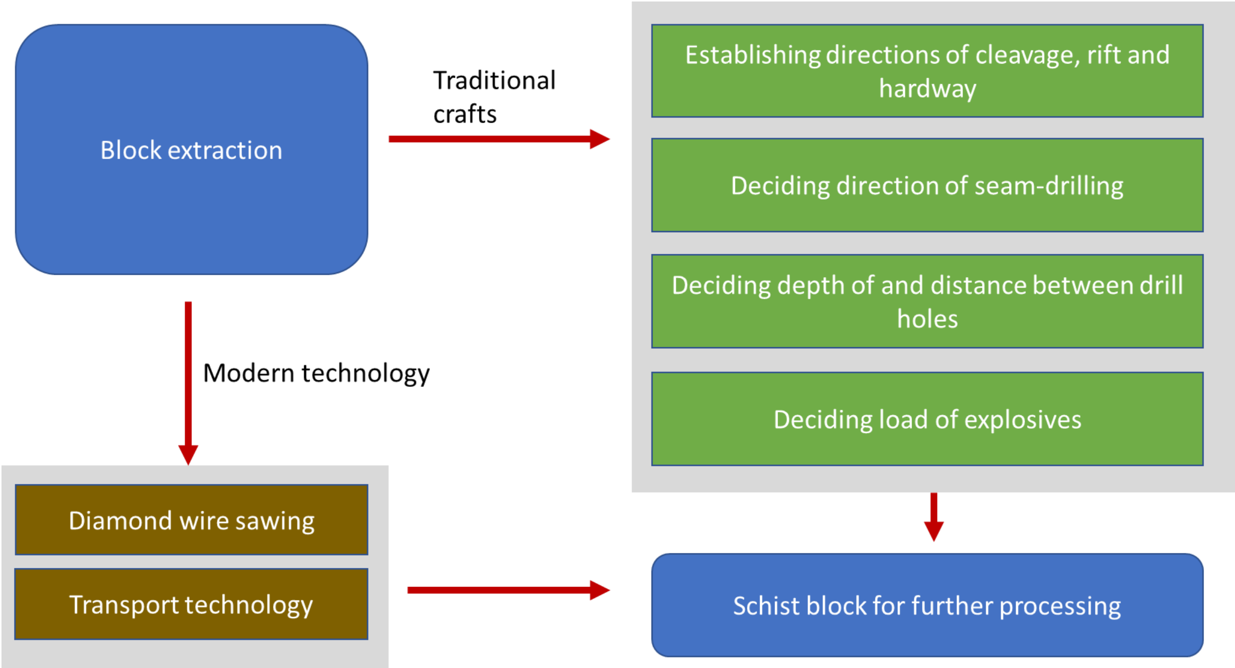

Figure 7. Flow chart for extraction of Oppdal schist blocks from bedrock.

Drilling and blasting

For drilling and blasting as method of block extraction, there are some fundamental principles employed for the Oppdal schist (see also Figure 8):

- Drilling of holes that will be loaded with explosives always take place perpendicular to the schistosity ("cleavage")
- The drillhole locations define a line on the map, coinciding with the main lineation structure seen on the surface of schist slabs ("rift")
- The direction/surface perpendicular to both rift and cleavage (the "hardway") is more difficult to open, and if possible, natural fractures along this direction are used as limitation of seam-drilling lines and thus primary blocks
- Employment of low velocity explosives (black powder) designed to split rather than crush based on experience; the use of black powder in Oppdal quarries is done in the same way as 70 years ago. Oppdal is thus perhaps the last place in Norway where such crafts are still actively used.

Figure 8. After blasting. Explosives employed in spaced, vertical drill holes defining a surface line along the rift of the schist. No need for horizontal drill holes, since the rock will loosen along the "plane of weakness), i.e. schistosity/cleavage plane. On the far side of the photo, a fracture along the grain defines a natural border for blasting.

Diamond wire sawing

In some Oppdal schist quarries, diamond wire sawing has been employed in recent years. Sawing is performed in cuts along the rift (Figure 9) or hardway. This reduces the dependency of the occurrence of suitably spaced natural cracks in this orientation and contributes to a more foreseeable and predictable extraction process.

Figure 9. Diamond wire sawing employed for making cuts along the rift and hardway.

Block reduction – making raw slabs

The extracted blocks are transported to local factories for production of raw slabs. Cleavable mica layers must be identified by the worker, before flat chisels gradually are inserted into cleavage planes, opening them gradually from one side towards the other. This can be done manually (traditional way) or aided by pneumatics. In either way, the proper identification of the cleavage layers, as well as the order in which to work them, is crucial to the result.

Ideally, the first cleavage to split should be selected at least ¼ into the block from the top surface, but preferable for thinner blocks close to the centre. This will be further divided into thinner slabs, starting as close to the middle of the newly cleft slabs as possible. The flow chart is shown in Figure 10, examples in Figure 11 and Figure 12.

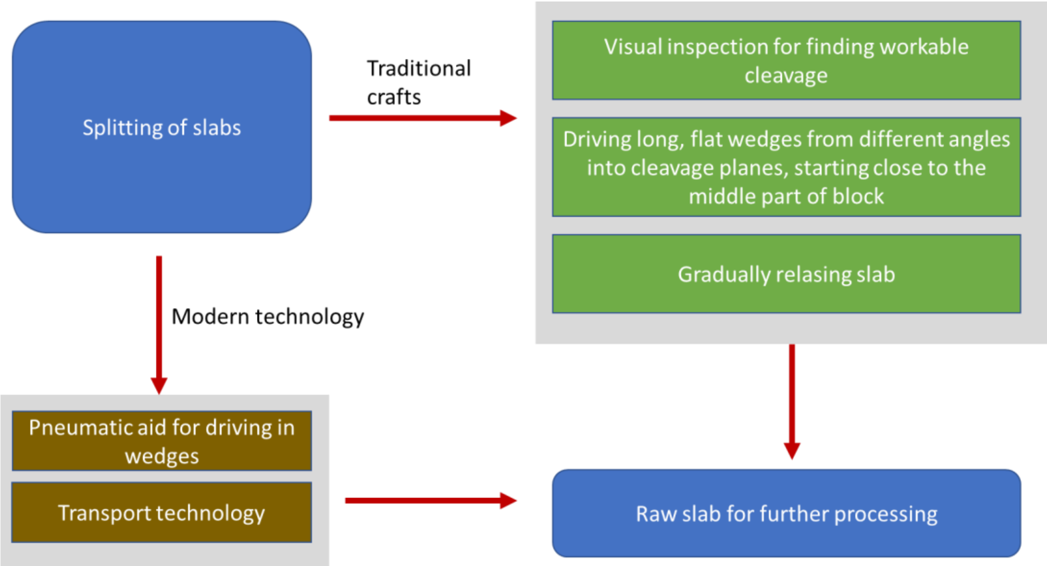

Figure 10. Flow chart for the process from raw blocks to slabs

Figure 11. Aiming pneumatic wedge to impact mica layers.

Figure 12. Using pneumatic wedge for splitting slabs. Note that the worker first split thick slabs, and then start splitting the thicker into thinner ones.

Formatting slabs

When the raw slabs have been produced, it is time to format them in the desired shape, being rectangular or curved. The Oppdal schist has some unique properties; due to the texture created by the rock-forming processes. For shaping slabs, it is possible to apply methods similar to the splitting of glass. A shallow groove is made on the surface either by applying a pointed pick (traditional) or a pneumatic circular diamond saw (recent technology). For cutting large slabs, a levelling technique is applied, for making bending stress along the groove line. For smaller or thicker slabs, or for complex shapes, impact by a chisel is applied repeatedly along the groove until the slab break (Figure 13, Figure 14, Figure 15, Figure 16).

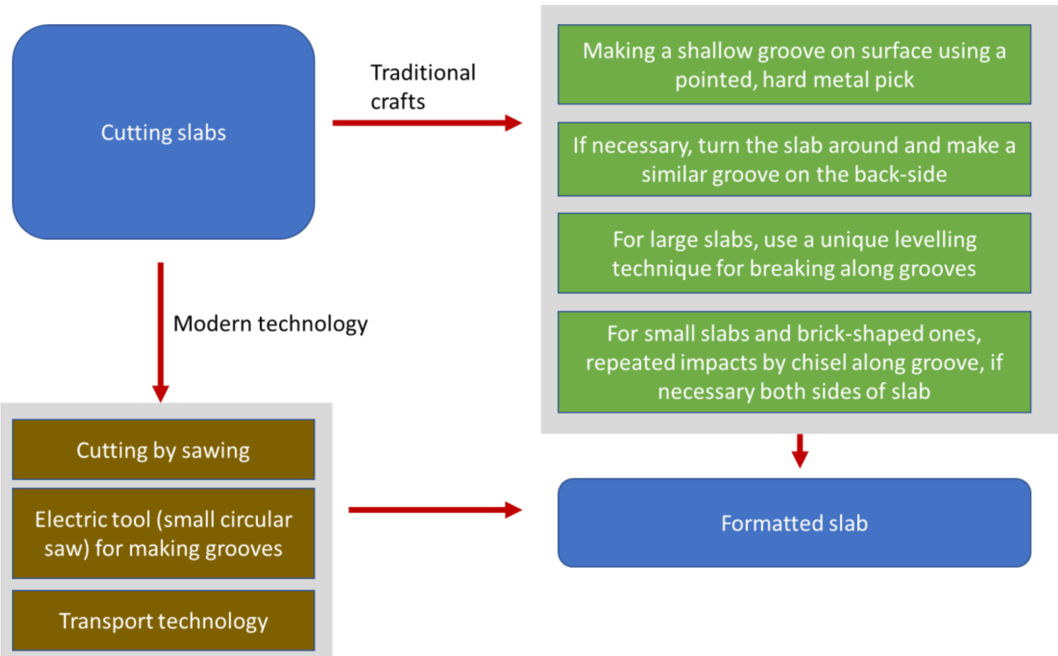

Figure 13. Flow chart for breaking slabs.

Figure 14. Breaking large slabs by levelling.

Figure 15. Breaking small slabs by chisel strokes along grooves.

Figure 16. Pneumatic tools with diamond saw blade for making shallow grooves.

Surface treatment

Traditionally, there were no need for surface treatment; the cleft surface was the only one to consider. In recent years, product development has created a variety of surface treatments, such as honing (Figure 17), sand-blasting and brushing (Figure 18).

Figure 17. Honed Oppdal schist (grey, structured) in a shopping centre, Trondheim

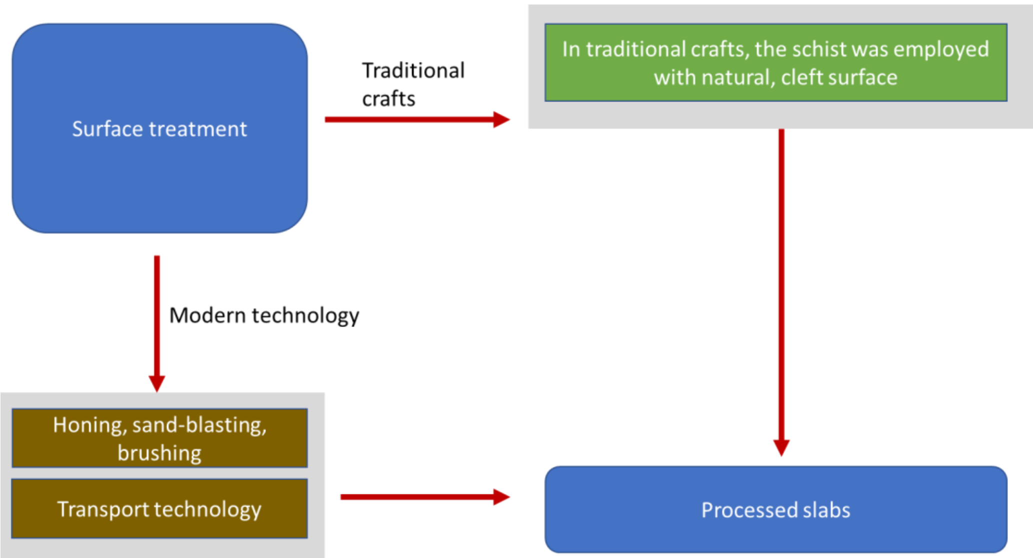

Figure 18. Flow chart for surface treatment. Traditionally, slabs were used with natural, cleft surface.

Case: making a circular coffee table

In order to summarize the crafts employed in the production of the Oppdal schist, we have selected an example of a process from rough block to a finished product. This involves block reduction (making suitable slabs), and Semi-finishing/finishing by breaking the slab into a complex shape. The whole process is illustrated in Figure 19, Figure 20, Figure 21, Figure 22 and Figure 23.

Figure 19. Making raw slab.

Figure 20. Breaking the slab in a rectangular shape.

Figure 21. Carving shallow grooves for making a circular slab.

Figure 22. Repeated chiseling along the groove, loosening the circular slab.

Figure 23. Coffee table finished!

Historical implications

Archaeological excavations have revealed one of the oldest stone floors in Norway, dating from around 1100 AD (Figure 24). This floor is situated in the Munkholmen Monastery, located on an island just offshore the city of Trondheim, excavated 1967-1970 (Lunde 1977: p152). The floor is made from schist similar to the Oppdal schist, with similar properties. The slabs on the floor are rectangular in shape, and display straight, broken edges (Figure 25), indicating that the craft of making shallow grooves to ensure straight breaking edges was applied this early.

If this is the case (as we propose), the crafts involved in the production of the Oppdal schist is one of the most long-lived ever described in Norway.

Figure 24. Excavated part of the monastery church floor: rectangular slabs of similar type as the Oppdal schist.

Figure 25. Left: rectangular slab from the church floor. Right top: broken sides and corner of slab from the church floor. Right bottom: broken sides and corner of modern slab of the Oppdal schist.

Case study conclusions

This case study shows that traditional crafts are still of great importance in the production of the Oppdal schist. Even though advanced technology is employed in the processing of the schist, crafts are needed for several modern day applications.

There is evidence for this craft to be of ancient origin, perhaps as early as the 11th century. This should in itself make it of interest to Norwegian authorities, as a case for documentation and preservation.

We think that the way of analysing the craft involved in production, by separating different steps in the production, works well in highlighting traditional crafts versus modern technology, and recommend the method for application in other stone producing settings.

Acknowledgments

Thanks to the management and workers at Minera AS and Oppdalsten AS for willingly and enthusiastically explaining and demonstrating their production and craftmanship by several occasions.

References

Heldal, T. & Lund, B. (2000) Fabrics and structure of metamorphic flagstones and implications for industrial quality, *NGU Bulletin* **436**, 137-146

Heldal, T. (2009): Constructing a quarry landscape from empirical data. General perspectives and a case study at the Aswan West Bank, Egypt, *In*: Abu-Jaber, N., Bloxam, E.G., Degryse, P. & Heldal, T. (eds.):

QuarryScapes: ancient stone quarry landscapes in the Eastern Mediterranean, *Geological Survey of Norway Special Publication* **12**, 125-153

Krill, A.G. (1980) Tectonics of the Oppdal area, Central Norway, *Geologiska Foreninqens i Stockholm Forhändlingar*, **2**, 523-530

Lunde, Ø. (1977) Trondheims fortid i bygrunnen, *Riksantikvarens skrifter*, **2**, 317pp