EUROLITHOS European Ornamental Stone Resources

# Eurolithos case study

## The Iddefjord granite quarry landscape

**Thematic focus: Value assessment of large quarry areas**

**Responsible partner(s): NGU**

**Author(s): Tom Heldal**

GeoERA RAW MATERIALS

**Foreword**

*«Wedging of granite also depends on weather; it works better when the stone is moisted, poorer in dry weather, but quite sure but somewhat heavy when frost. But if the weather change rapidly between frost and mild, the splitting is poor, and the seem* [plane of intended splitting] *goes sideways.»*

The above is an example of quarrymens' description of the complexity of working granite. Around 1900, approximately 5000 people worked directly in the granite industry in the far southeast of Norway, the Iddefjord area. High quality granite from this particular resource were employed in buildings and constructions all over Norway, and in many other countries as well. Skilled people from these quarries also spread their knowledge all over Norway, contributing in establishing granite quarrying numerous places. Thus, the direct and indirect influence of the Iddefjord granite resource on Norwegian architecture in the industrial age is significant.

We have tried to take a closer view on the resource and its quarry landscape, and finally made an attempt to assess its values.

**Executive summary**

Throughout Europe, there are large industrial and cultural landscapes originating from the exploitation of ornamental stone through history. Such landscapes may contain a range of potential values; as cultural and industrial heritage, as areas for recreation and tourism, as geological heritage, and as areas for future exploitation of stone. The Iddefjord granite, SE Norway, has been exploited since the middle ages, but the main phase came with the industrial revolution. During the last half of the 19th Century, the granite industry here grew to a considerable size, culminating around the turn of the century when more than 5000 people worked in the quarries, producing paving and building stone. At present time, only one active natural stone quarry remains, but the quality of the granite should encourage some further future developments. The study summarizes the geology and evolution of quarrying and quarry technology and provides an insight in the economic and non-economic values within the quarry landscape.

This case study seeks to enlighten the following generic aspects of historic quarry landscapes:

- Provide a framework for the description and characterization of quarry landscapes
- Develop a toolbox on how such a characterization can be applied for assessing important values related to the quarry landscape
- Explore the influence of other land uses and land use planning on quarry landscapes

**Keywords**

Granite, Ornamental stone, Natural stone, quarry, quarry landscape

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# Description of case study

This case study involved a broad study of a large granite quarry landscape in SE Norway (Figure 1): from the geological resource to the use of it, from the historical evolution of exploitation to the remains to be seen in the landscape today.

In particular, we have explored two aspects of the quarry landscape:

- A framework for description and characterisation of the quarry landscape
- Testing methods for assessing significance of the quarry landscape, with particular emphasis on the aspects of importance to secure future quarrying

Key stakeholders in this case study have been local stone producing companies. However, we expect this study to be relevant also for cultural heritage authorities and local/regional land-use management. We also hope that the study can provide input to generic guidelines and inspiration to other similar areas in Europe.

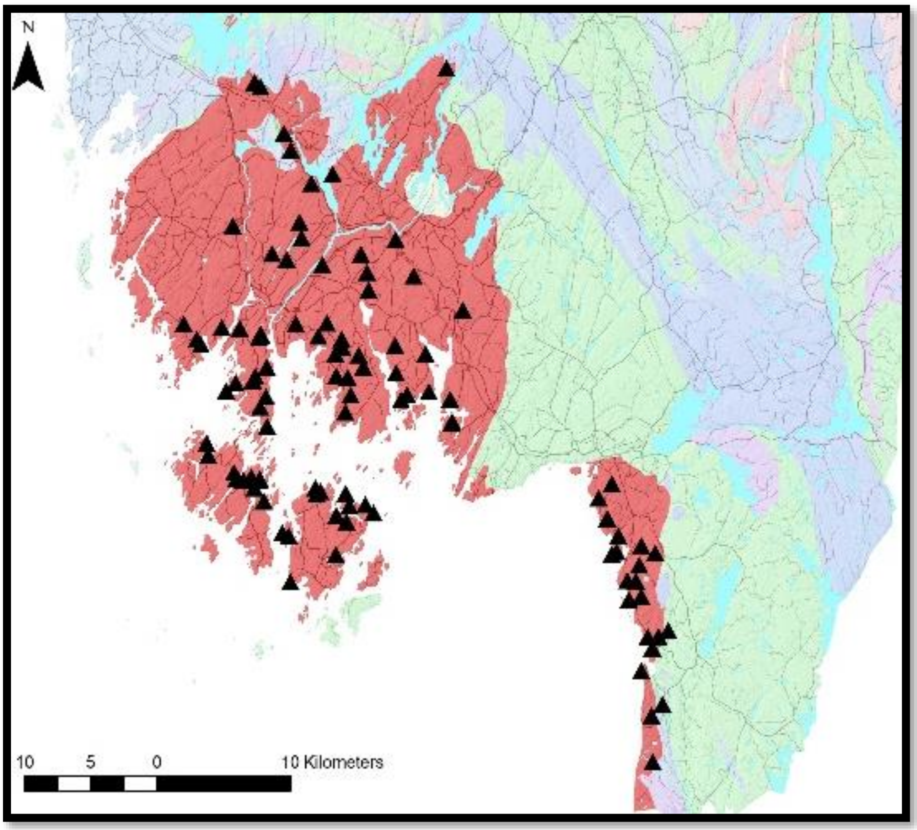


**Figure 1. Distribution of the Iddefjord Granite (red colour) and granite quarry areas (black triangles)**

# Methods applied

In this study, we have described and analysed the Iddefjord Granite resource and quarry landscape.

**For geological interpretation** we have predominantly relied on geological maps from the Geological Survey of Norway, and in addition a study by Pedersen & Maaløe (1990). A report about the dimension-stone potential in parts of the area has also been useful (Gautneb et al. 1999), as well as the NGU database on natural stone.

**For the history of the quarrying**, we have used written sources (predominantly Oxaal 1916, since there are very few written sources), and for the use in buildings we have used some written sources (i.e. Heldal & Jansen 2000), some web sites (i.e. the geologist Tom Andersen's walks through Oslo and in addition own observations.

**For the interpretation of quarrying** methods and changes through time, Oxaal (1916) has once more been useful. We have in addition used own observations in historical buildings and quarries. In the latter, we have applied a "production chain perspective" developed in the FP7 project QuarryScapes and other methods provided in the guidelines of that project, some of it published in Heldal (2009). In addition, a documentary made by Vincent Bull-Rytter in 1966 is very useful, giving an insight in the craft-based quarrying techniques at that time. Bull-Rytter did this film as a thesis at the Norwegian Broadcasting's film school, and actually named it "a disappearing craft". The film stands out as a rare piece of testimony about European granite quarrying before the big machines and new technology took over.

**For the more physical description** and analyses of the quarry landscapes, we used Lidar-data from the Norwegian mapping authorities and checks in the field for making a rough characterization on how to recognize quarry features.

We did a rough characterization of land-use in the area, using data from various Norwegian agencies openly published on GeoNorge.

Last, but not least, our assessment of values is strongly inspired by the QuarryScapes guidelines and Bloxam (2009).

# Geology of the granite resource

The Iddefjord Granite (sometimes referred to as the Østfold Granite) forms a part of a huge batholith (Bohus Batholith) divided by the Norwegian-Swedish border. On the Norwegian side, 13 unique plutons have been identified (Figure 2), ranging in composition from diorite to granite, most of them of granitic composition. The intrusion age is established to c. 918 million years (Pedersen & Maaløe 1990), corresponding with the aftermath of the Sveconorwegian orogeny.

These plutons cover significant areas in the most southeastern part of Norway. Most of these 13 plutons have, at some stage in history, been subject to granite exploitation (Figure 1). According to Pedersen and Maaløe (1990) the plutons intruded in deep crustal conditions (low temperature difference with surrounding, gneissic rocks). This is also supported by indications of a prolonged cooling history of the granites.

Most of the plutons are composed of microcline-plagioclase-quartz in addition to minor and accessory minerals. They vary from fine- to coarse-grained, are mostly equigranular (except the Fredrikstad and the Brekke plutons, which are slightly porphyritic) and display colours from cold and warm grey to pink.

In the beginning of the 19$^{th}$ century, almost 5000 people were employed in the granite industry of the area. On the Swedish side, even more. So, what made this complex of granites that attractive for exploitation?

Proximity to the sea was of course a big advantage. A large number of the quarries are situated less than 2 km from sea or waterway leading to the sea, and many are literally by the sea. Another advantage is the lack of deep weathering due to the glacial erosion rock surfaces. Granites are usually fresh and sound within centimetres from the surface.

Oxaal (1916) revealed some other aspects: 1) high technical performance: compressive strength 235 MPa, bending strength 14,1 MPa (producer's information); 2) high durability, which Oxaal related to the "freshness" or un-altered stage of feldspar crystals. In many cases, feldspars in granite display an initial alteration due to either deep chemical weathering (i.e. yellow granites) or to late igneous phase alteration. Altered feldspars will deteriorate much faster In atmospheric conditions than un-altered; 3) terrain-parallel joints with increasing frequency toward the surface made perfect granite "layers" of suitable thickness easy to separate from the rock mass; 4) excellent workability, i.e. with some skills and tools, anyone could start quarrying and producing sought-after products. No need to depend on rich investors.

The workability is highly connected to some "invisible" properties of the granite. Although it may look isotropic, there are technically preferred directions for splitting hidden inside the rock. Quarrymen often develop local terminology for such, given that this information is so crucial for passing on crafts from generation to generation. In English, we use rift, grain and hardway about the three directions of splitting, mostly occurring perpendicular to each other. Rift is the easiest, hardway the most difficult (or even not working at all). In the Iddefjord granite, these corresponds to the quarrymen terms: Rift = "kløv" or "bunnkløv", Grain = "bust" and Hardway = "villkløv".

Already in 1916 and before the origin of these directions were disputed among geologists. But, they agreed on one aspect: that these directions reflected either micro-fracture or fluid-inclusion orientations (Oxaal 1916 and references therein). But how were these formed? When cooling, granites must contract, resulting in an orthogonal pattern of joints. However, there are also other mechanisms involved. One of them is stress release after erosion. Rapid erosion by glaciers removes much of the rock mass. This creates a rebound mechanism causing the rocks (at least brittle ones like granites) to develop surface parallel joints, increasing in frequency towards the surface.

In the Iddefjord granite, we probably see a combination of origins of microfractures and thus workability of the rock, resulting in a granite resource extremely suitable for production and use.

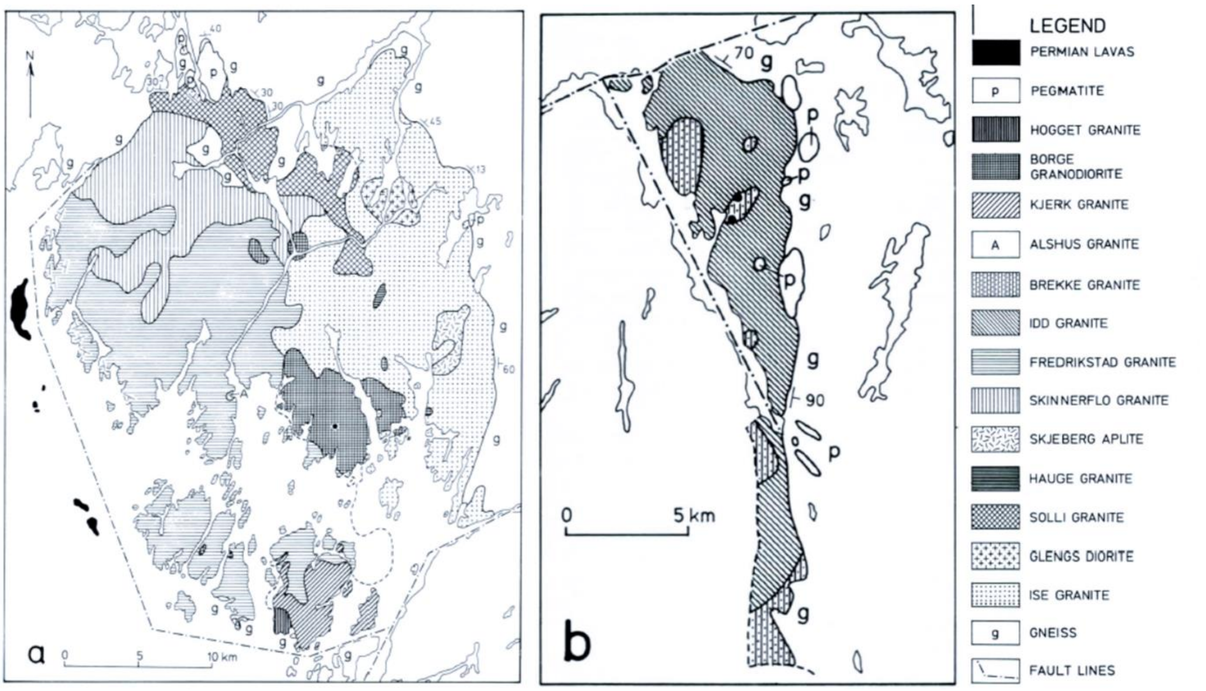


**Figure 2. Different plutons in the Iddefjord Granite. North (a), South (b) and legend. From Pedersen & Maaløe (1990).**

## History of quarrying and use

We do not know how long the Iddefjord granite has been employed for building and other purposes, but we do think that organised quarrying started in the Middle Ages. The earliest sophisticated stone buildings in Norway, involving deep crafts and techniques, were medieval churches (Figure 3). Christianity predominantly arrived in Norway during the 11th century, and from the beginning of the 12th century, construction of stone churches spread throughout the country. There are several churches in the region where the Iddefjord granite has been employed in the construction.

One of these churches, the Skjeberg Church, was constructed in several steps, the first in the early 12th century. A granite block from a later construction phase (late 13th century) carries a runic inscription, saying:

*Stein þenna gerđi Botolfr steinmeistari*

In English, "*Bottolf the stone mason made this stone*". This is the first record we have of the early craftsmen working the Iddefjord Granite.

**Figure 3. Rygge Church (1170 AD) is built predominantly of Iddefjord Granite and brownish syenite. Right: detail of relieff carving in granite lintel.**

After the great plague in 1348-49, several hundred years passed without visible traces of any sophisticated use of the granite. Wars in Europe made a change. During the 17th and the 18th centuries, several fortresses were constructed in the region, as a part of Denmark-Norway's defence structures against the Swedish armies.

Fredriksten Castle in Halden is one example (Figure 4). Constructed in several phases, but we know the Iddefjord granite became heavily employed since 1664. In the same year, the construction of Akerøy fortification began, on a tiny islet containing its own granite quarry. During the years, several more fortresses were made, and not to forget the fortified old, fortified town of Fredrikstad.

**Figure 4. The Fredriksten Castle/fortress. Walls and paving stones predominantly made from the Iddefjord Granite.**

From this “military exploitation period” huge amounts of granite were employed in the construction. We do not know much about quarries and techniques, but from the rocks in the buildings we may learn a lot. In the 1664 walls of Fredrikssten Castle, we see wedge holes and wedge grooves similar to Roman techniques in some granite quarries. In the slightly later walls of the Fredrikstad Old Town, we see short and wide drill holes for inserting wedges.

After the military period, there was a gap until the 1840s. According to Oxaal (1916) «A German named Waitz from Hamburg came” after a great fire in Hamburg in 1842, for exploiting granite for the rebuilding of the city. In 1844, 5500 cubic feet of stone were exported. This was a short time effect, and after some years of export it was quiet until around 1860. But from that year and onwards, the industrial revolution discovered the full potential of the Iddefjord granite. Numerous quarries opened, to feed markets in Norway and abroad.

Since the first modern period quarrying in the 1840s, the development of the granite industries in this part of Norway remained international. Dutch, German and British capital financed many quarry operations. However, there were also numerous local people using their skills to get into the business. Quarries spread all over the region.

Thanks to Oxaal (1916) we have good records of export between 1840 and 1913. In the early period, Germany was the main buyer. Then came Great Britain. Among the many buildings and places were the granite from Iddefjord was applied, Ritz Hotel, London (1906) is perhaps the most famous. However, a strong stone-working environment developed in Aberdeen, Scotland. They preferred to import raw blocks and process stone in their own workshops, leading to a peculiar system of re-branding Scandinavian stones with Scottish names (i.e., the “Balmoral Granite” from Finland). Moreover, it was difficult for the Norwegian companies (and even the British companies operating in Norway) to compete with the highly efficient Aberdeen environment particularly regarding paving stones and kerbs. So, the export to Great Britain declined from around 1908, leaving a gap for new export grounds.

Argentina became the new main export country. In the peak years, more than 70 000 tons of paving stone and kerbs were exported to Argentina. In the early 20$^{th}$ century, approximately 5000 people were employed in the granite industry in the region.

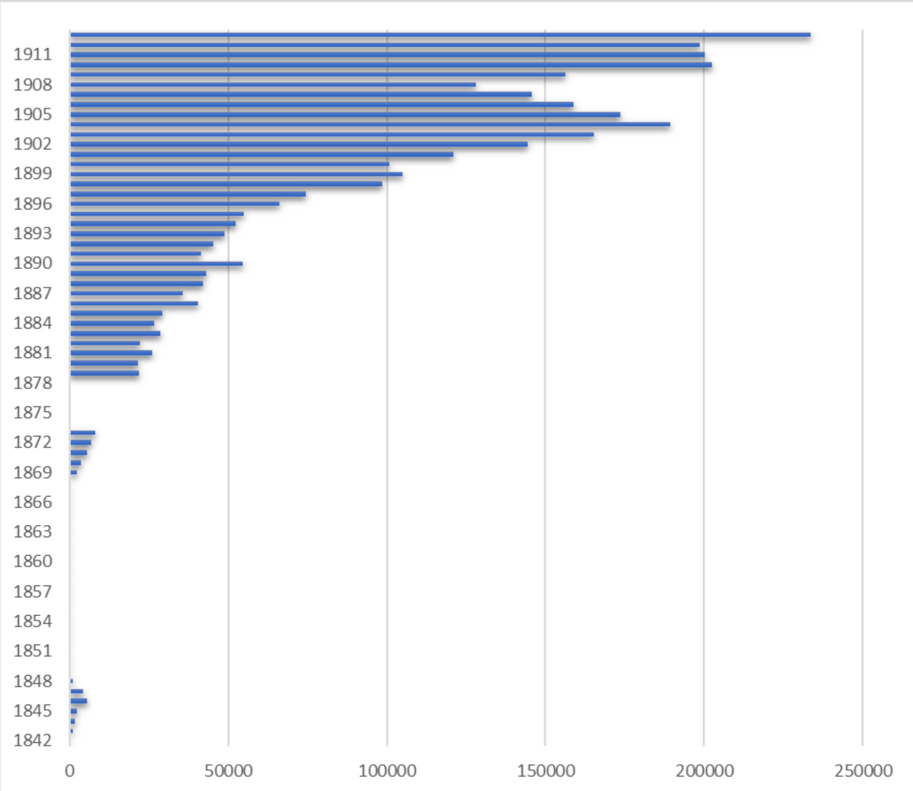


**Figure 5. Export of the Iddefjord granite (tons) from 1842 to 1913.**

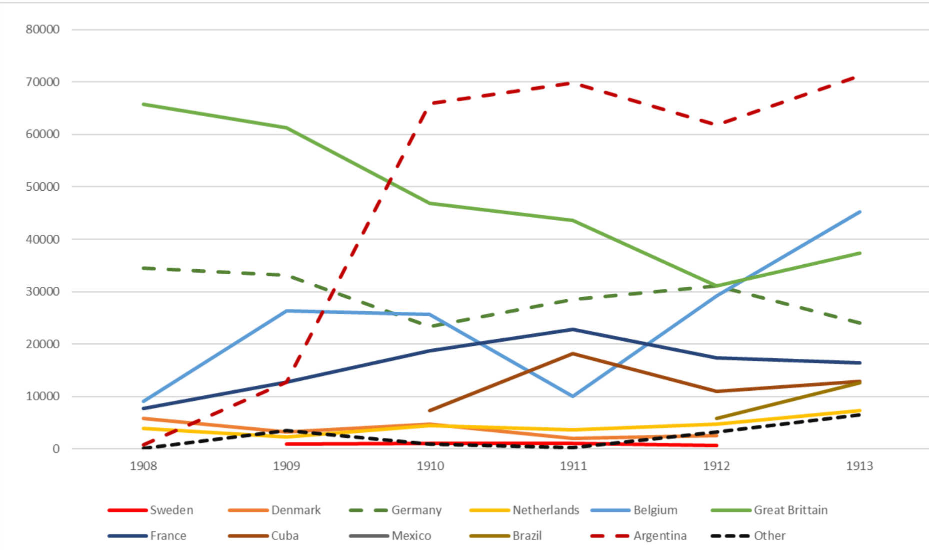


**Figure 6. Export of the Iddefjord Granite by country from 1908 to 1913.**

The first world war put an end to the great expansion of the Iddefjord Granite. The following years, much of the production went to Norwegian markets, and both paving stone and finely carved building stone spread out to Norwegian towns and cities. However, the decline should be even more severe during the depression in the 1930s.

The Iddefjord granite is not only suitable for building stone, it became quickly a sought-after stone for sculptures and monuments. Gustav Vigeland made the granite his favourite, and all the stone sculptures in the Vigeland sculpture park in Oslo was made from this granite. The most famous piece, the Monolith, was carved from one single, 17 metres tall granite block.

World War II did not put an end to the stone production in Iddefjord. The German occupation force identified early on important resources for the third Reich, including the Iddefjord Granite. Massive production of stone was supposed to feed the builders in Berlin, making the new monumental city fulfilling Albert Speer's dreams. Of obvious reasons, that was cancelled, and many pre-fabricated building blocks were left in the quarries when the war ended. Such "Hitler-stone" (local expression) can still be found in some of them.

Although the post-world war II did not recreate the greatness once found in the granite production near Iddefjord, a small but stable production did take place, and at the time of writing one quarry still produces blocks for use in Norway and abroad and a few workshops still keep the old crafts alive, aided with new technology.

However, most of the Norwegian paving stone and kerb production, once the main products from the quarries, have died out. When Norwegian salaries increased from the 1970s onwards, it became too difficult to compete with low cost countries. But who knows, in a post-corona time where environmental footprints are severely monitored, ethical considerations and requirements will influence the supply chains, there may be a new revival for the Iddefjord granite industries.

## Two large stones

The Monolith, a 17 metre tall granite sculpture, is the centre of gravity at the Vigeland sculpture park, Oslo. It is made from one granite block, originally 17,4 metres and weighing 270 tons. Totally 121 human figures are carved into the block. The stone was quarried in the Iddefjorden area in 1922, but it would still take 6 years with painstakingly slow transport before the block was raised on the site and the carving could begin. This finished in 1943, and the Monolith uncovered in 1944.

Today, there is an outdoor museum at the quarry site; made in exactly the same size as the original stone block, and filled with exhibitions about the operation.

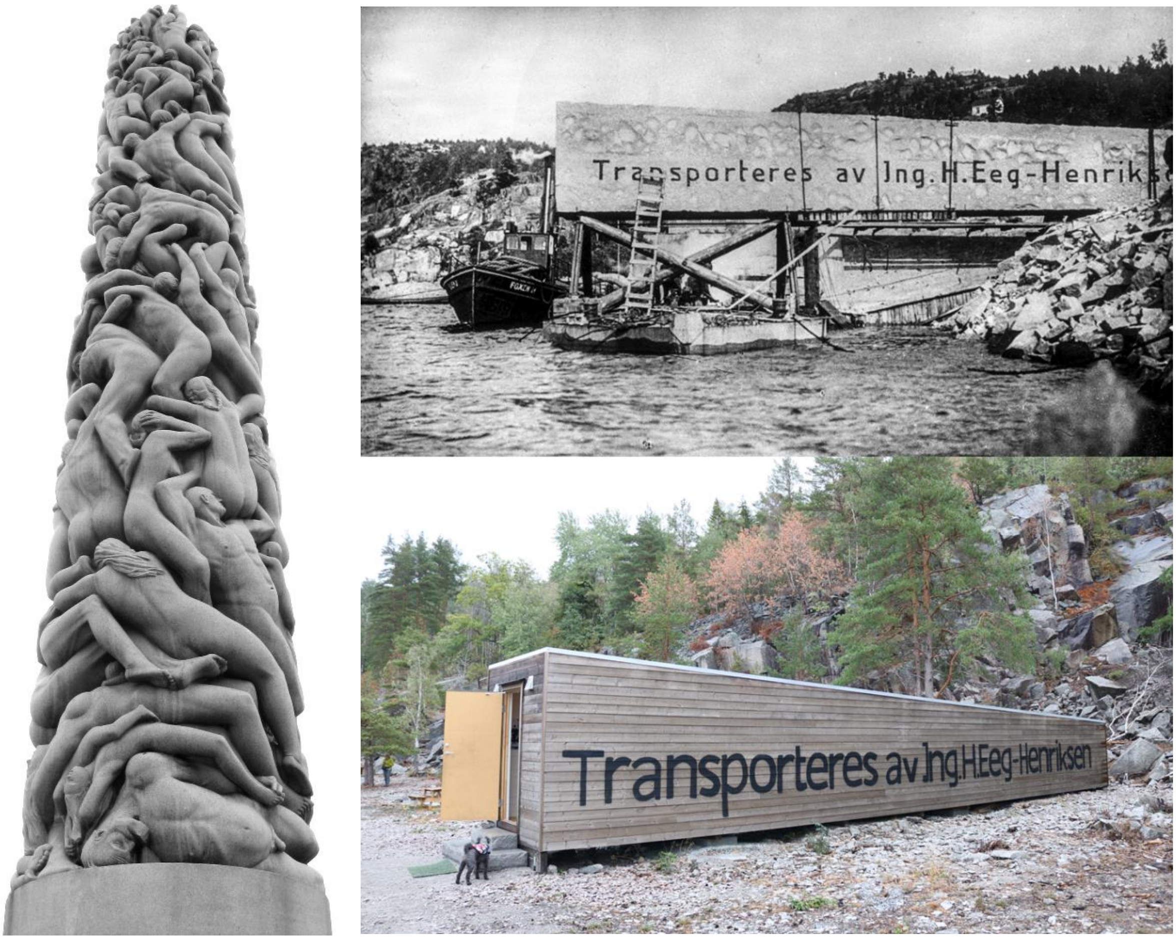


**Figure 7. The Monolith (left), the original block being moved from the quarry (top-right) and the small museum at the quarry site of exactly same size.**

When the Nordic countries moved their embassies from Bonn to Berlin in 1999, a new building stood ready for housing them. In the Norwegian part, one of the walls (15 metres tall, 120 tons) was made from one single block of Iddefjord Granite. One side (the front) displays natural, glacial-eroded rock surface.

**Figure 8. The granite block making a complete wall in the Norwegian Embassy, Berlin (photo from the Norwegian Embassy's web)**

# Technology and crafts

From the historical overview, we have defined four phases of quarrying: Medieval quarrying (churches) 1150-1250, Military period (fortifications and castles) 1550-1850, Industrial age quarrying 1850-1970 and post-industrial quarrying (1970-). For each of the periods, we have tried to analyse the production methods, either from quarries or from constructions. We have used a four-step model (Heldal 2009) starting with extraction from bedrock and ending with final finishing (Figure 9).

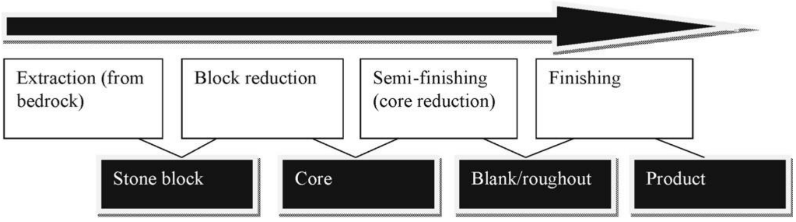


**Figure 9. Generic four step model for describing stone quarrying and processing.**

## Phase one: Medieval quarrying and use

We know very little of the quarrying and production methods in the medieval period. We know that erratic blocks must have been employed, due to the great variation of colours in some churches and use of various rock types. The Rygge church (Figure 10 and **Feil! Fant ikke referansekilden.**) is built from both local/semi-local Iddefjord granite and gneiss, possible from erratic blocks, and a brown monzonite with origin on the other (western) side of the Oslo Fjord, most likely from bedrock quarries. Conclusively, we cannot rule out bedrock quarries in the Iddefjord area. The assumed chain of operations is summarised in Table 1.

**Table 1. Operational chain (assumed) for medieval stone building.**

| Extraction from bedrock | Block reduction | Semi-finishing | Finishing |
|---|---|---|---|
| Unknown, but likely wedging of small blocks directly from bedrock displaying free sides (natural cracks) | From rounded, erratic blocks and possibly angular, quarried blocks, most likely by wedging with short iron wedges. Rough shaping of ashlars. | Fine shaping to ashlars by chiselling | Bush-hammering of visible surfaces, chiselling of carvings and reliefs. |

**Figure 10. Rygge medieval church polychrome portal (left). Stones in the portal: Iddefjord granite (grey), oxidised monzonite from the western Oslofjord area (brown) and local, Precambrian gneiss (banded). Right: Wedge holes in granite ashlar (red arrows)**

## Phase two: Military production 17th and 18th centuries

During the military phase of exploitation, we assume (based on the shape and appearance of stone blocks in the walls) that irregular granite blocks was extracted from bedrock mostly along natural fractures and joints and direct wedging (Table 2). Joints were widened by the use of levers, wedging seem (from the appearance of building stones) to have been carried out by chiselling trapezoidal holes (approx. 10 cm deep) narrowing downwards, and long grooves (Figure 11). One may speculate if the rather large and wide wedge holes do suggest the use of wooden wedges; in some parts of Norway, it is oral knowledge that dried oak wedges were inserted in wedge holes and then soaked with water. When expanding, the rock split. Some buildings display more sylindrical wedge holes, possibly introducing hand-drilling (Figure 12). Most of the period only employed rough granite blocks in construction, so there were little need of sophisticated finishing.

**Table 2. Operational chain (assumed) for military period stone building and extraction**

| Extraction from bedrock | Block reduction | Semi-finishing | Finishing |
|---|---|---|---|
| Most likely levelling along fractures for primary blocks | By wedging (wide wedge holes and grooves, possible wooden wedges) | None; using rough blocks | None |

Figure 11. **Fredrikssten Castle. Left: pre-1664 wall made from local field stones (mainly hydrothermally altered granite), centre: 1664 wall made from quarried granite with distinct trapesoid wedge holes and long wedging grooves, right: 19th century wall made of ashlars of granite displaying the typical wedging technique of the industrial age (short drill holes for inserting wedges).**

**Figure 12. Fredrikstad Old Town. Granite blocks displaying marks from short and wide drill holes.**

## Phase three: Industrial revolution

During the latter half of the 19th century, the industrial revolution reached the Norwegian granite quarries. New technology (particularly skilled use of explosives and rails and lifts for transport of heavy loads) paired with sophisticated skills for granite quarrying, made a revolution in the quarries. From being a necessary evil to overcome for making solid constructions, quarrying became a lucrative investment opportunity. Mass production of high-quality crafted granite products triggered the specialisation of companies and quarries, some deposits were most profitable for making paving stone, others for large building blocks. Export initiated.

The knowledge of the rock properties increased; of how to use the rift and grain when drilling holes for explosives, on the amount and placing of black powder for maximising block extraction and minimising waste, on sophisticated splitting techniques.

“Smart” blasting was applied for extracting large stone blocks from bedrock, implying minimal use of drilling and black powder and taking advances of the natural splitting directions already present in the rock (Figure 13). Sometimes, rimming (carving grooves in the drill hole along the natural splitting directions) was applied.

Block reduction was carried out by drilling short holes (1,5 cm diameter, up to 10 cm deep) in seems along rift or grain and applying wedges and feathers in the holes (Table 3, Figure 13). Sometimes, wedge holes for broad/flat wedges could be made by a pointed pick. As written by Oxaal (1916): "*Wedge holes for round wedges are 10-12 centimetres deep, and are set by a horizontal distance of 15-30 centimetres between them. Holes for "broad" or "flat" wedges, carved by a pointed pick, are 6 centimetres deep*."

Semi-finishing implied a range of techniques depending on the end product, for finishing an even greater range of techniques. A film documentary of some of the skills and techniques employed was made in 1969.

**Table 3. Operational chain in the industriesl period.**

| Extraction from bedrock | Block reduction | Semi-finishing | Finishing |
|---|---|---|---|
| Blasting along pre-existing planes of weakness in the rock | Splitting with short drill holes and "plug and feather" wedging, or chiseling wedge holes for flat wedges | Further splitting by chiselling or impact by sledge hammer | Making surfaces: bush hammering, honing and polishing, final splitting |

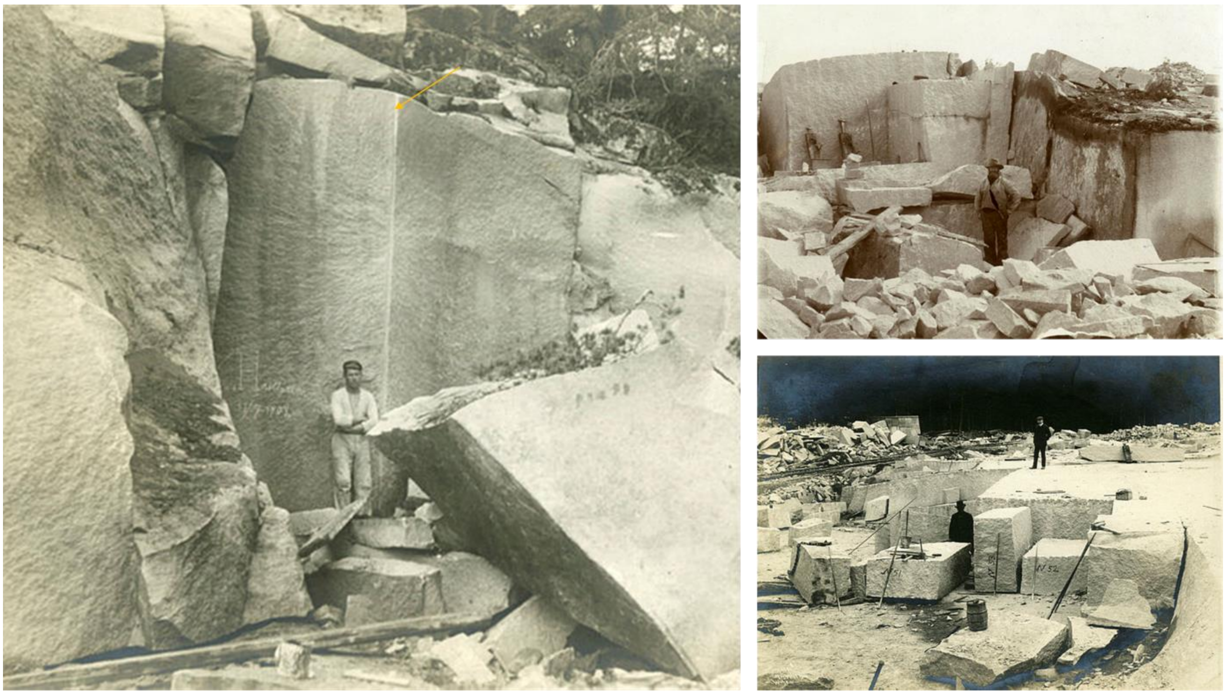

**Figure 13. Left: single drill hole black poweder blasting, relaesing a large block of granite. Right: block reduction using horisontal and vertical wedging seems. All photos: NGU archive.**

## Phase four: post-industrial age

Since the turn of millennia, diamond wire sawing took over as main extraction method in the one quarry still remaining operational. One vertical and one horizontal cut are made, and the last cut is carefully blasted (Table 4, Figure 14). Once released from the bedrock, the primary extraction block (perhaps 250-400 m$^3$) is subdivided by drilling and wedging. The usable blocks are moved to a factory for further works, involving a range of methods.

**Table 4. Operational chain for modern quarrying in the granite.**

| Extraction from bedrock | Block reduction | Semi-finishing | Finishing |
|---|---|---|---|
| Diamond wire sawing of huge blocks along hardway and grain (horizontal), blasting along rift plane | Splitting by wedging along rift plane to large blocks. Further splitting by wedging to rectangular blocks | Diamond blade sawing in factory, other manual and semi-automatic splitting and formatting methods | Surface treatment be bush hammering, honing/polishing, flame treatment |

**Figure 14. Diamond wire sawing of two surfaces (horisontal and vertical perpendicular to photo plane) and drilling/blasting of one direction (vertical parallel to photo plane)**

# Leftovers in the landscape

The massive amount of quarrying through 150 years has left a significant imprint on the landscape. Oxaal (1916) made a map showing the granite outcropping area and areas of high production around 1915 (Figure 15). Many places, the natural landscapes has been completely reshaped by quarrying. In the forest on the hills, remains of historical quarries are seen, some places as a continuous cover, other places as monumental, artificial hillsides.

Based on historical records and the nature of the quarring leftovers compared to "pristine" granite surface on LIDAR (Figure 16), it is possible to make a rough division of three groups of quarry landscapes: shallow artisan quarries, deep industrial quarries and deep post-industrial quarries.

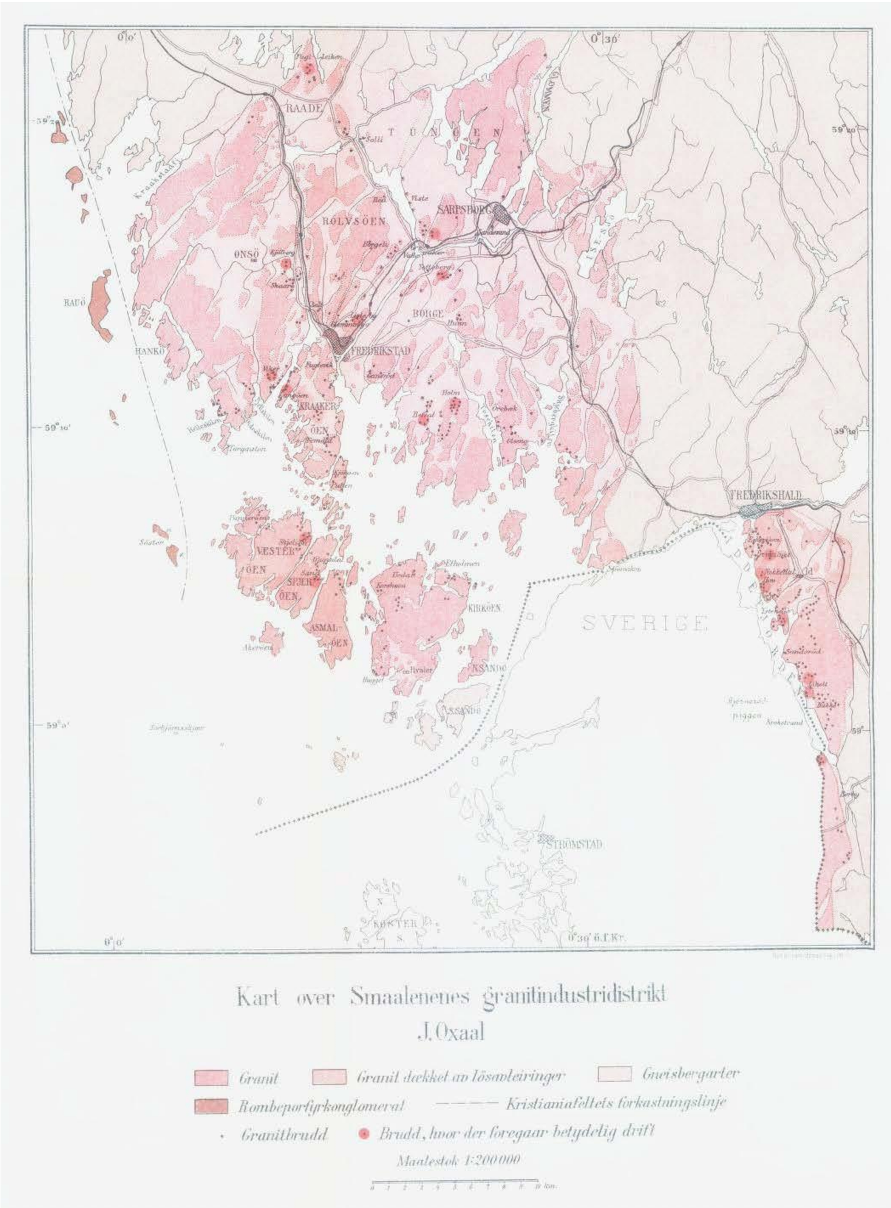


**Figure 15. Map showing the quarrying situation around 1915; points illustrate quarries, dark coloured areas with points high production areas. From Oxaal (1916)**

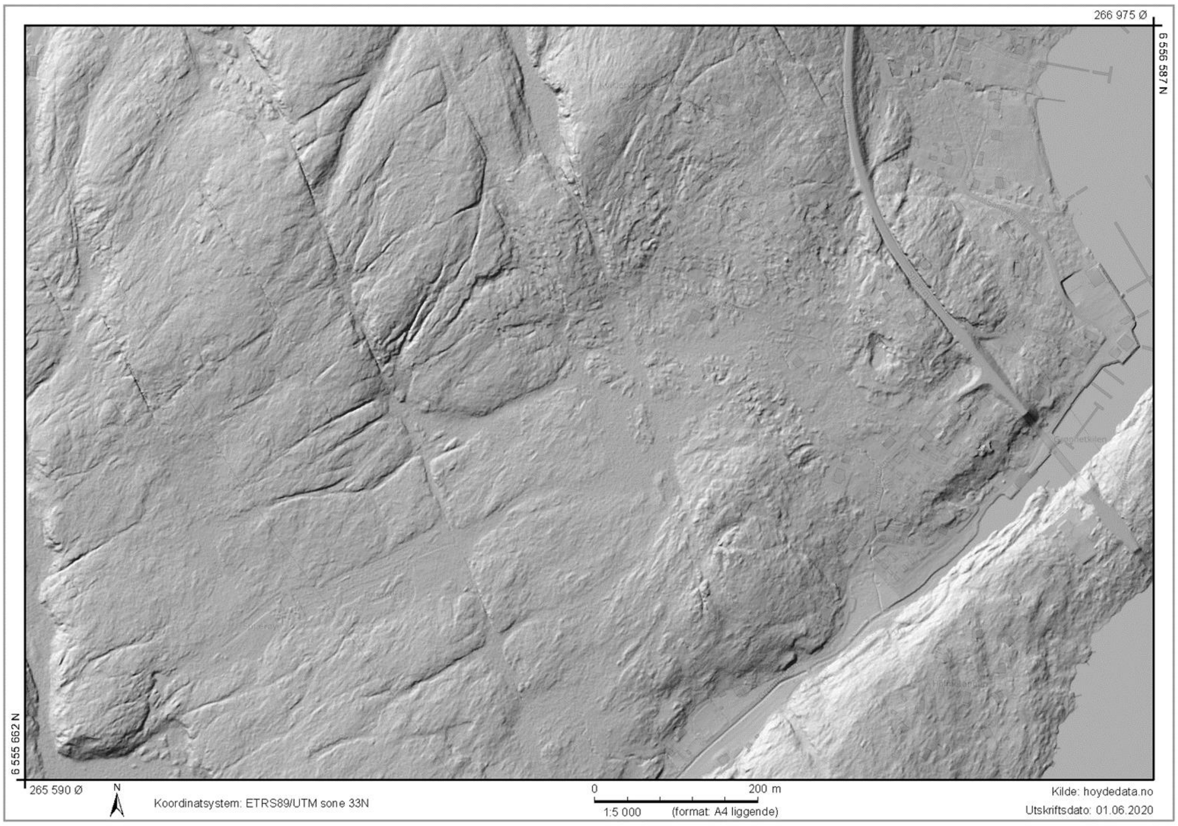


**Figure 16. LIDAR image showing mostly pristine granite landscape, with exception of some small quarries close to the road on the right side.**

Type 1: shallow artisan quarries

Shallow, artisan quarrying involved small units of people and little heavy technology. Most of these quarries were employed for producing paving stone and drywall-stone, the latter mostly for local markets. In LIDAR images, this type of quarries appear as numerous small extractions, often bordering each other, with low quarry faces and small or not recognizable spoil heaps. Two examples are shown, one in a hilly woodland (Figure 17) and one along the coast (Figure 18). Most of the artisan quarries dates between 1860 and 1950. This is assumed by production periods for paving stones (mostly before 1960) and technology marks in the quarries, such as transmission from hand-held to early pneumatic drilling.

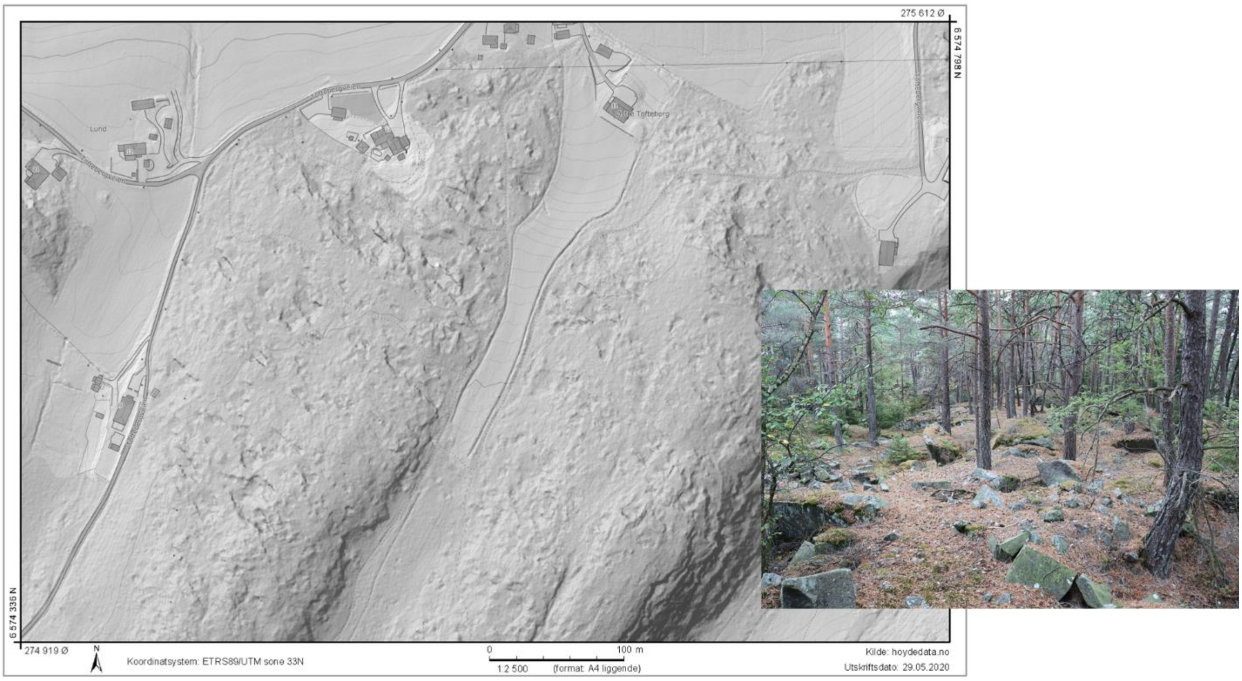


**Figure 17. LIDAR image and photo from the Holm area (central part of Figure 15) displaying numerous, shallow workings.**

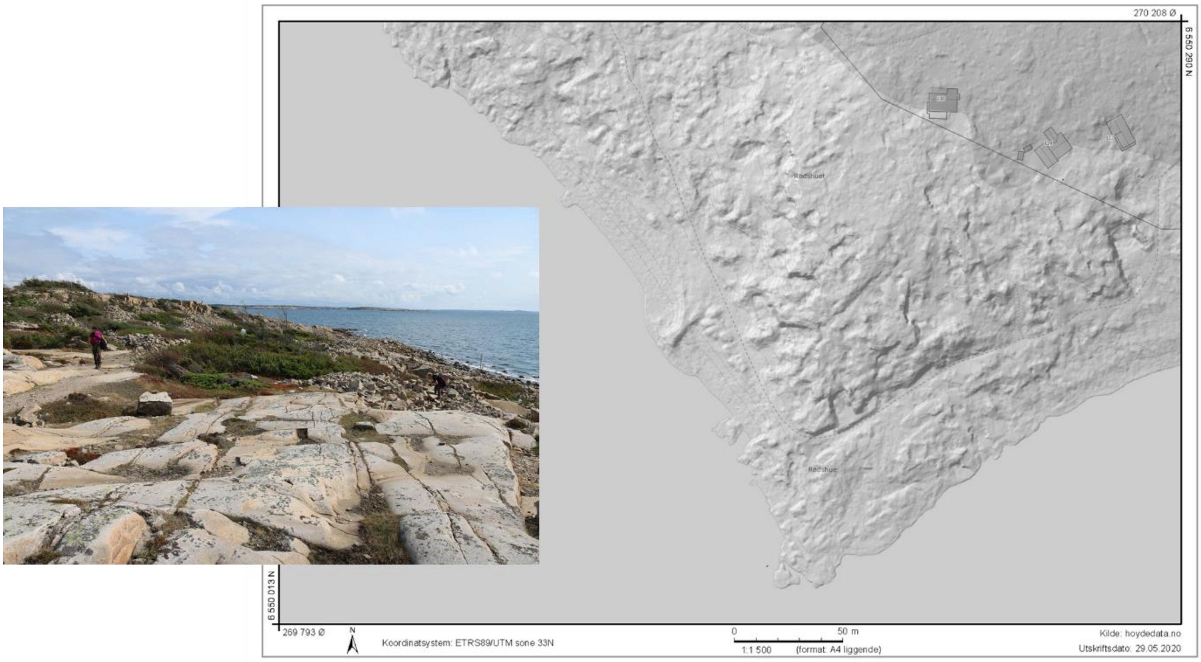


**Figure 18. Coastal, artesan quarry area, photo and LIDAR image. Numerous small quarries scattered along the coastal path. From Hvaler, southwest part of Figure 15.**

<u>Type 2: deep industrial quarries</u>

These are large quarries from the industrial period, from around 1880 to 1970. Typically, they are narrow and deep, due to the use of stationary cranes for lifting blocks. Some have railway lines for internal transport and transport to harbour. The majority of these are enterprise quarries, involving heavy investments in technology and labour. In these quarries, a range of objects were produced, including building stone, other masonry stone, sculpture blanks, paving stone and quay-stone.

It is interesting to note that a large portion of the industrial quarries are situated on the eastern shore of the Iddefjord, indicating a concentration of enterprise quarries in that area. This could relate to differences in quality (for masonry and large blocks) in favour of the Iddefjord area.

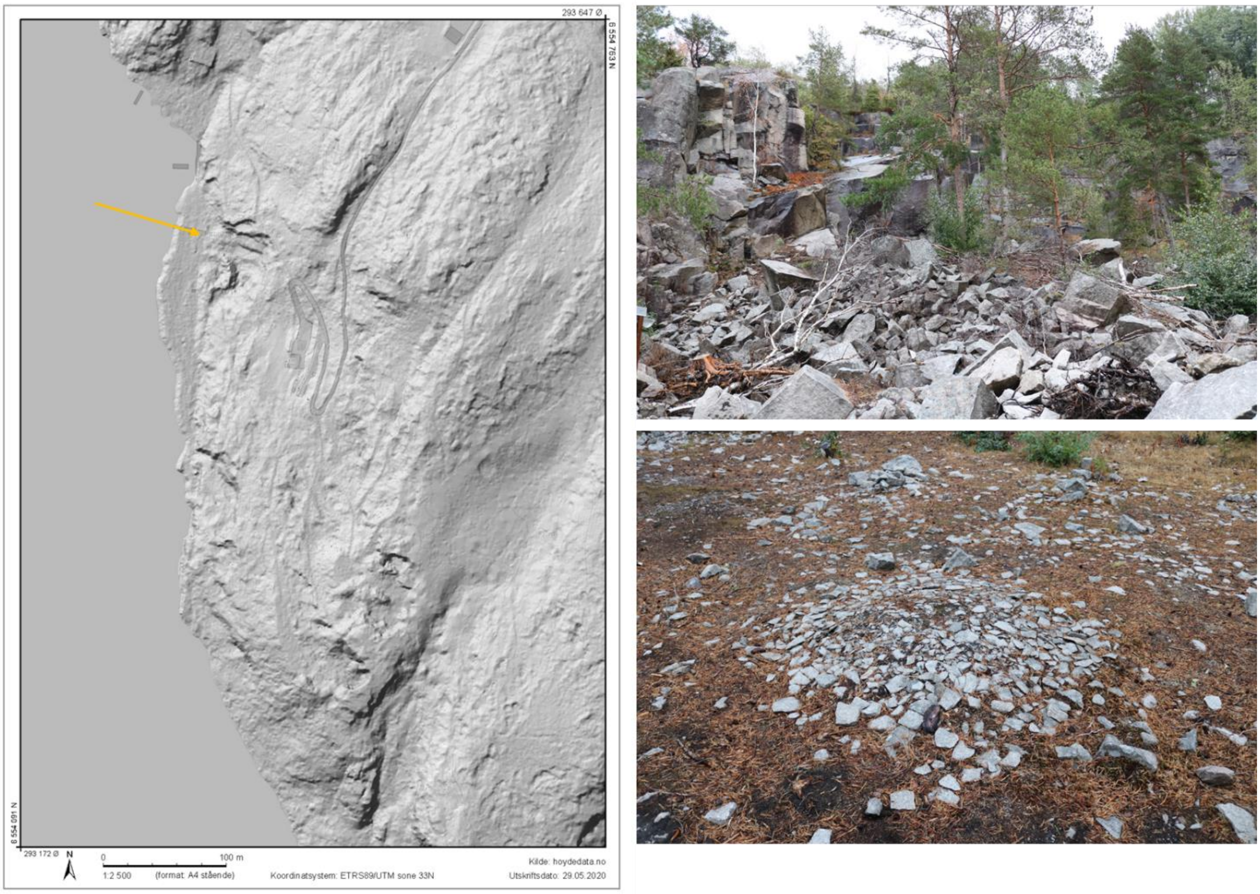


**Figure 19. collection of deep, industrial quarries at Hove, recognised by tall quarry faces and designated spoil disposal areas. Left: LIDAR image (arrow points at site for Monolith extraction), top right example of quarry with spoil heap in front, low right typical work area for carving objects.**

Type 3: Post-industrial quarries

This is another word for modern quarries (post industrial age), employing typical extraction methods seen all over the world: diamond wire sawing, combined with seem-drilling and blasting. In the Iddefjord granite, only one active quarry remains, applying such methods (Figure 20). Although the primary extraction looks as many other granite quarries, there are still crafts and deep knowledge involved in selecting directions for sawing or blasting, and the sub-division of blocks. For example, knowing to use short drill holes and wedges for splitting save money compared to sawing or long-hole seem drilling.

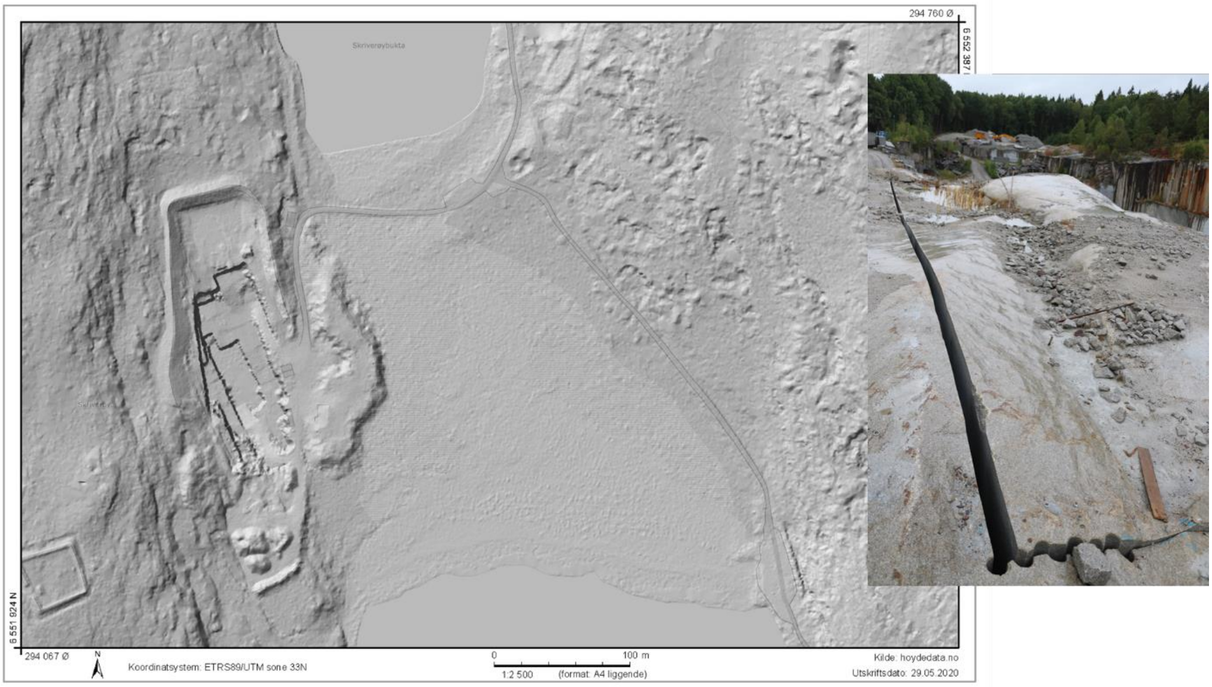


**Figure 20. Post industrial quarrying using diamond wire sawing combined with drill seems and blasting. In the LIDAR image (left) the Skriverøya quarry is clearly visible (lower right part of Figure 15). Numerous shallow, artesan quarries are seen on the right part of the LIDAR image. Right photo: combined wire sawing and seem drilling/blasting are applied for extracting large, primary blocks.**

<u>Synthesis</u>

By using some areas within the Iddefjord granite resource, it is possible to give a rough division of the quarry landscape into three major parts. It is important to remember that these are all from the industrial age and onwards; the previous quarrying (medieval and military period) is largely invisible in the landscape. The Medieval one because the volume of quarrying was low, whilst it is likely to assume that the quarries of the military period are partly hidden beneath the constructions they contributed to.

A concentration of enterprise quarries to the southern part may indicate a favourable geology, coinciding with the particular granite plutons in that area (Figure 2). Thus, during the industrial age, we saw a gradual evolution of enterprises moving south, and artisan quarrying spreading in the north. This may be viewed as of enterprises feeding of the best quality, leaving small producers to poorer. However, the two sides had probably different views on quality. Enterprises needed a straight production line involving a undisturbed chain from large blocks to a range of products within a small site. Artisan quarrymen were probably more concerned about getting high enough easily produced granite (without need of heavy machinery) to earn their daily needs. In other words, working a quarry were small blocks were easy to extract, and a quality of granite that could easily be split to paving stone.

This may have lead to "a natural selection" of suitable areas for quarrying not competing with each other: that artisan quarrying did not have the same needs as the enterprises. There are still many questions regarding the granite quarry landscape, and further research will hopefully shed more light on this.

# An approach to value assessment of the Iddefjord quarry landscape

When viewing the quarry landscape as a hole, it is rather obvious that there are numerous values connected to it: economic, historic, morphologic and even aesthetic. The challenge is to view the multiple values in the quarry landscapes as connected. There are numerous historical remains of quarrying that can be appreciated, but there is also a rich architectural heritage that will need maintenance, and thus newly quarried stone. And, perhaps also the continued production and availability of the Iddefjord granite in itself is a value beyond the employment and wealth of the producers.

We have chosen to use the approach given by Bloxam (2009), with minor modifications. Bloxam's model is shown in Figure 21.

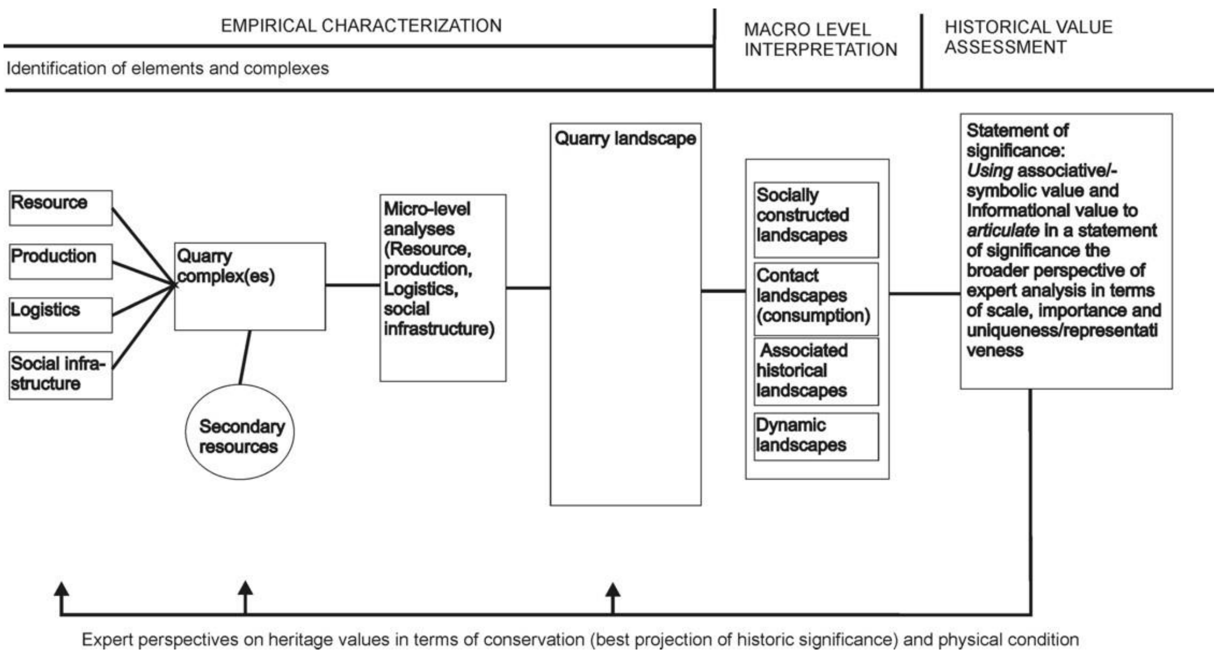


**Figure 21. From characterization to interpretation and value assessment of quarry landscapes. Modified from Bloxam (2009).**

We have already identified "elements and complexes" the latter being "medieval complex", "military period complex", "industrial age complex" and "post-industrial complex". The two former are (until present day) largely invisible in the landscape, with the exception of the actual constructions resulting from them. However, if clear remains were identified, they would by of high importance. The "industrial age complex" is very visible, and composes the most prominent part of the total quarry landscape. On the macro-level interpretation part of Figure 21, the four axes of interpretation may help us to assess values.

Socially constructed landscape: this perspective focuses on the social construction within the quarry landscape. From the industrial age, there is a lot of information and sources that can tell us something about the people involved in the quarrying: crafts, organization, labour, stories of hard-life. We have some primary sources, Oxaal (1916) and the documentary for TV. And, we have some loosely founded information about migration, work conflicts and family life connected to the booming of the granite industries. If this lead is followed with more research, it is likely that one may conclude that the Iddefjord quarry landscape does tell an important part of the Norwegian story, as the starting point of the industrial age stone production in the country, and that knowledge spread from this area to other parts of Norway. We do not, however, have a complete picture and cannot make a clear statement of significance.

Contact landscapes: "contact" means connection, and in the case of quarry landscapes – where the resource has been used and the shared significance between resource and its end-use. We have already mentioned the Vigeland Sculpture park, and with reference to this, we may propose that the highly acknowledged significance of the sculpture park add values to the granite quarries involved. Moreover, since the Iddefjord granite has been applied for numerous, historically important architectural sites in Norway, we may conclude that there are good reasons for national importance. Furthermore, the international "contact" – the use of the Iddefjord granite as a global material as early as the Late 19$^{th}$ century, being the Ritz Hotel in London or the paving of Buenos Aires. Added together, there are strong reasons to suggest global significance of the Iddefjord granite caused by its prominent use in international architecture shaping the industrial age.

The aspect of "contact landscapes" does not only relate to a kind of mutually enforcing value assessment. It also raises a question about future production. Buildings deteriorate, and there may be future needs of authentic replacement material. This is perhaps the most outstanding argument for stimulating future production, in addition to purely economic ones.

Associated historic landscape: this relates to the value of the quarry landscape as a representation of one or several processes connected to historic periods. Does the Iddefjord quarry landscape provide a representative case (among others) in describing the industrial revolution? Is it a part of the the big industrialization story, but on which scale? This we do not know, since we have few documented areas for comparison. However, we may propose that this quarry landscape is an important marker of the industrial revolution in Norway.

Dynamic landscapes: this perspective aim at viewing quarry landscapes as dynamic landscapes through time. In the Iddefjord area, the mutual engagement between the granite resource and human use has, through different periods the last 900 years, had different impact on the landscape. During the Medieval and the military periods, impacts on the landscape were highly centred around the constructions (local quarrying for erecting a church or a castle) whilst the industrial period involved a complete transformation of large parts of the landscape. In the post-industrial period quarrying has continued within some small parts, but the major part has either been left for nature to take over, or used for other purposes (Table 5).

**Table 5. «After-use» of industrial age quarries and quarry landscape, some of the directly connected to the resource, others not**

| Use | Comments |
|---|---|
| Stone quarrying ornamental stone | One significant area |
| Stone quarrying aggregate | Several stone quarries transformed to aggregate quarries |
| Housing and residential areas | Houses and holiday cabins situated in historical quarry sites |
| Industrial areas | Some quarry sites have been transformed to various industrial and commercial uses |
| Cultural uses | Quarries re-used as i.e. open air amphitheatres or playgrounds |
| Historical sites | Mostly related to preserved quarry areas or walking paths in historical quarry landscapes |
| Other infrastructure | Roads, qays and other land-use intensive infrastructure |

Conclusively, we may propose a statement of significance along the four concepts described above. As shown in Table 6, the global distribution and use of the granite through the industrial period and beyond, is a good argument for international significance.

On other concepts, it is less clear. It is likely that the quarry landscape forms a such important case about Norwegian industrial history and "birth place" for hard-stone crafts and technologies that national significance may be valid. It may also be that it, as a well preserved landscape, can be of international significance as a window to a huge, early industrial site of exploitation.

**Table 6. Proposed statement of significance for the Iddefjord quarry landscape.**

| Concept | Local | Regional | National | International |
|---|---|---|---|---|
| Socially constructed | | | X? | |
| Contact | | | | X |
| Associated historic | | | X | ? |
| Dynamic | | X | | |

## Fragmented values in play for land use management

The value assessment may provide arguments for land-use management. Knowing that the Iddefjord granite was applied for a number of constructions in Norway of national and international importance, and that it was applied abroad in numerous countries, should lead to an active and positive engagement into securing future ornamental stone production. Parts of the resource should therefore be assigned for future production. At present time, this applies for one deposit, but one should also consider others.

There are already several initiatives that collectively bring forward the other concepts of the quarry landscape through outdoor museums (i.e. Figure 7), walking paths (i.e. Figure 18), protected quarry areas and space for the quarrymen in local museums. However, these are mostly fragmented initiatives, and there is potential for bringing these together and view the Iddefjord granite landscape in a more holistic way, including the connection to the numerous building, sculptures and other constructions made from it.

# Conclusion: lessons learned

The Iddefjord granite resource and its quarry landscape has been investigated and characterised along several axes: geology, historical evolution, evolution of crafts and technology and physical impact on the landscape. Such characterisation resulted in the definition of four historical phases, or complexes. In addition, we found reason to divide the industrial age quarries in deep, industrial sized sites and shallow artisan ones (Figure 22).

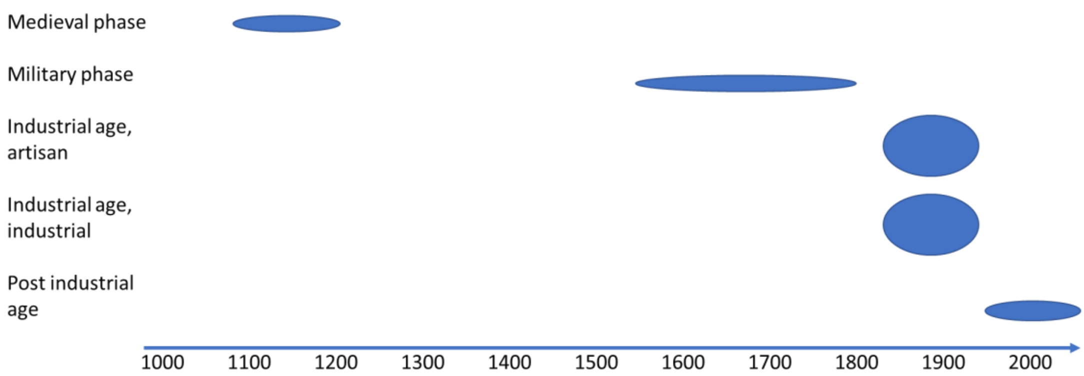


**Figure 22. Phases or historical complexes related to the quarry landscape.**

In this work, it has been particularly valuable with a uniform schematic depiction of the quarrying process in four steps (Figure 9) and LIDAR data for morphological characterization.

On the basis of the characterization, we performed an attempt for value assessment of the Iddefjord quarry landscape using the method developed in the project Quarryscapes. We were able to make a rather clear statement of significance based on the extensive use of the granite nationally and globally. The significance related to other concepts are still difficult due to fragmented information.

# Acknowledgements

We are grateful to two stone producing companies in the Iddefjord area, for providing valuable information about past and modern quarrying and granite production: Johansen Monumenthuggeri AS and Natursteinskompaniet.

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