Industrial minerals - towards a future growth

TOR ARNE KARLSEN & BRIAN STURT†

Karlsen, T.A. & Sturt, B.A., 2000: Industrial minerals - towards a future growth. *Norges geologiske undersøkelse 436, 7-13.*

The Norwegian mineral industry has shown pronounced growth in recent years, and production and export of industrial minerals (*sensu stricto*), aggregates and dimension stone have all increased, whilst the production and export of metallic ore has decreased. This is a trend that has been going on for many years. The trend for industrial minerals is to a large degree related to the increased production of calcium carbonate slurry for paper. The total production value of Norwegian industrial minerals reached around 2370 mill. NOK in 1997. In terms of volume around half of the produced industrial minerals are exported. The export value in 1997 was 2260 mill. NOK – including some minor imported minerals, an increase of 20.5 % over 1996. This figure can also be compared to a total export value of approximately 700 mill. NOK in 1989. An understanding of the real value of domestically produced industrial minerals is not gained purely from production value and export figures of the minerals. In fact, domestically produced industrial minerals form the basis and are important for many other industries, including the production of ferrosilicon, Mg-metal, TiO_2-pigment, paints, fertilisers, chemicals and cement. Together with the production of aluminium, paper and Si-metal, which to a large degree is based on imported raw materials, these industries have a total annual turnover probably in the order of 40,000 mill. NOK.

Tor Arne Karlsen & Brian A. Sturt, Geological Survey of Norway, N-7491 Trondheim, Norway.
† Brian Sturt died on 15 September 2000.

Introduction

Traditionally, the focus in economic geology has been on metals, whilst the concept of industrial minerals has been somewhat hazy for many people including also geologists. The great variety of industrial minerals and the profusion of end-uses may be a reason for this. However, industrial minerals have become a major factor in economic geology and are increasingly important in Norway's economic development.

Globally, the industrial minerals industry is continuously on the move due to technological progress leading to development of value added products and new usages and also to changing supply of raw materials and environmental concerns. Industrial minerals surround us everywhere in the normal life; in houses, paper, plastics, paints, glass, ceramics, cars and even as additives in food. As the world consumption of manufactured products increases, so will the production of industrial minerals, and additionally new end-uses are being developed. The annual growth of the industrial mineral market is difficult to estimate due to the extreme versatility. There are, however, reasons to believe that it is higher than the global economic growth, due to the following: 1) new uses are being developed. 2) More stone materials are being added to certain filler products, e.g. paper. 3) More and more countries (developing countries) are using industrial minerals in products for domestic use, as a consequence of increased industrialisation.

The availability of a wide range of minerals is a key factor in economic development in any nation and it is increasingly recognised that industrial minerals are essential for future economic growth (see also Highley 1994).

The production of industrial minerals can be used as a measure of the industrial maturity of a country: the later the point at which the industrial mineral production exceeds that of the metalliferous minerals, the more recently industrialised the country has become (Bristow 1987, Highley 1994). This is of course a very general and oversimplified rule, as the types and numbers of deposits vary between countries. However, Norway met that critical point in the 1970s, and since then industrial mineral production has continued to increase, whilst that of metallic ores has decreased. Typical for the industrialised countries is that the production of industrial minerals is not limited to construction materials, but includes a great number of other minerals mainly exploited for export purposes. Concerning Norway, there are several reasons for this positive development; 1) the existence of a diversified geology, including many big mineral deposits, 2) a good geographic position relative to the most important markets, 3) a long coastline with excellent shipping possibilities, and 4) the increasing role of multinational companies, adding know-how and market access.

Definitions

Industrial minerals can be defined as minerals, single or group, where their physical or chemical properties, and not their metallic, energetic or gem properties are the main basis for industrial purposes. Examples of typical industrial minerals (and rocks) are calcium carbonate, dolomite, olivine, feldspar, nepheline syenite, quartz/quartzite, talc, apatite, graphite and mica. All of these are, or have been, produced in Norway.

Internationally, it is quite common to use the term *non-metallics* as a synonym for industrial minerals. In this meaning, the industrial minerals are classified into 1) Construction materials (e.g. crushed rock, aggregates, sand, gravel, building-stone), and 2) Non-construction materials. At NGU, mineral resource research is organised into Construction materi-

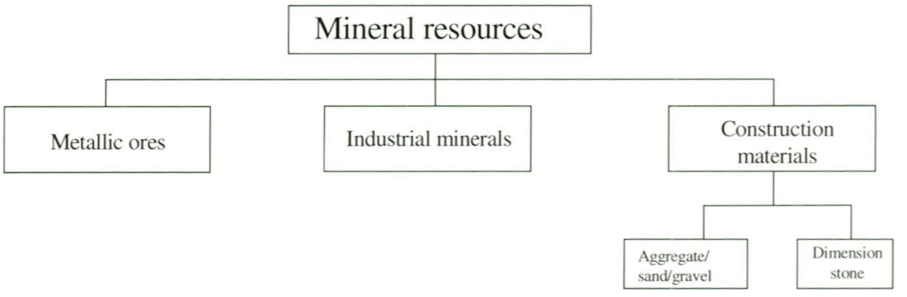

Fig. 1. Organisation of mineral resource research at NGU.

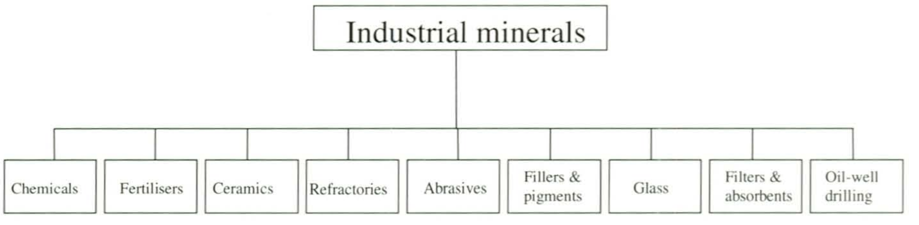

Fig. 2. Simplified classification of industrial minerals (*sensu stricto*) by their end-uses. There are actually many more classes than shown in this figure.

als, Industrial minerals (non-construction) and Metallic ore deposits (Fig. 1). We propose to discuss Industrial Minerals in this context. For further information on mineral resources in general or other mineral resources, the reader is referred to Sturt et al. (1995), Neeb & Karlsen (1997), Sturt & Neeb (1997), Karlsen (1998), Bjørlykke et al. (1999) or Heldal & Neeb (this volume) for more details. For more information on industrial minerals than presented in this paper, see Olerud (1993, 1995) and Karlsen (1998).

It is a common practice to classify industrial minerals according to their end-uses (Fig. 2). In terms of the end-uses, there are a number of important though different parameters e.g. particle size distribution, chemistry, whiteness, hardness, specific gravity, chemical inertness, insulating properties, heat resistance, etc., that make the basis for different uses and the extreme diversity of products. As stated by Bates (1994): *"the diversity is about all they have in common"*. Most industrial minerals have a large number of different uses; for example, the mineral calcium carbonate is used as a filler in paper, paints and plastics, in cement, ceramics, fertilisers and chemicals and as a pH-regulatory material. In each of these uses there are a great number of different calcium carbonate products with different specifications. In the definition of 'industrial minerals' there is also room for metallic minerals, when properties other than their metallic properties are important; e.g. ilmenite and magnetite are both used in colour pigments and therefore fall within the definition. However, in the Norwegian mining law all metallic minerals, including ilmenite and magnetite, follow the rules for metals which means that they are claimable. Non-metallic industrial minerals, on the other hand, belong to the landowner. A new mining law was proposed in 1996 (NOU 1996), but has not yet been approved. The new proposal will include a more favourable position for *industrial minerals*, in the regulatory framework. It is proposed to establish a *system of acquisition* for a large group of non-claimable minerals (i.e., most industrial minerals); which will be defined as minerals *subject to registration*. The acquisition system will have certain similarities to the system existing today for the claimable minerals. According to the proposed new law, anyone will be permitted to search for minerals subject to registration, both on his own and on other persons property, although a search permit will be needed. It is expected that the new mineral law, if approved, will come into operation in the year 2000.

Domestic production trends

The production of industrial minerals in Norway reached new heights in 1997, and more than 12 million tonnes were produced (Table 1) from 32 mines and quarries (Fig. 3). The production of limestone/calcium carbonate, olivine, dolomite and graphite have all shown significant increases in recent years (Fig. 4). Back in 1975 the production of olivine was only around 180,000 tonnes (Fig. 5). At that time, olivine, produced by A/S Olivin, entered the steel- and iron-making market as a slag former at the expense of dolomite. Today, Norwegian olivine accounts for more than half of the world market with a 1997 production at 3.34 mill. tonnes.

The economically most important industrial mineral in Norway is limestone/calcium carbonate with a production of around 5.7 mill. tonnes in 1997. A very positive trend relates to the increased production of calcium carbonate slurry by Hustadmarmor A/S. The company has increased its production every year since 1984, when it was < 100,000 tonnes, to around 2.2 mill. tonnes in 1997. Recently, a large new mine for calcium carbonate production was established at Velfjord in Nordland, by Hustadkalk A/S. The mine will be the major supplier of raw material to Hustadmarmor A/S. The increased slurry production has made Hustadmarmor A/S the most important among the pure mineral producers in Norway, and the world leader for production of calcium carbonate slurry for paper. Internationally, calcium carbonate has now become the most important mineral used as filler material in paper production, essentially at the expense of kaolin (Curtis 1999). One of the reasons for this is that the paper-producers have changed from acid processes to alkalic or neutral proc-

COMMODITY	PRODUCTION 1997	% OF WORLD PRODUCTION	NO. OF MINES/ QUARRIES
Limestone & calcium carbonate	c. 5.7 mill. tonnes	?	11+
Olivine	3.34 mill. tonnes	66	3
Dolomite	1.03 mill. tonnes	?	4
Quartz/quartzite	0.90 mill. tonnes	0.8	5
Ilmenite concentrate	0.56 mill. tonnes	14	1
Nepheline syenite	0.31 mill. tonnes	25	1
Feldspar & anorthosite	0.11 mill. tonnes	1.4	2
Talc	0.03 mill. tonnes*	0.5	2
Magnetite	c. 0.065 mill. tonnes	?	2
Graphite	0.007 mill. tonnes	1.2	1
High-purity quartz	< 0.01 mill. tonnes	?	1

Table 1. Estimated production of industrial minerals in Norway 1997. Source: a) production numbers: Producers/Karlsen (1998), *Harben (1999), b) World production: Harben (1999).

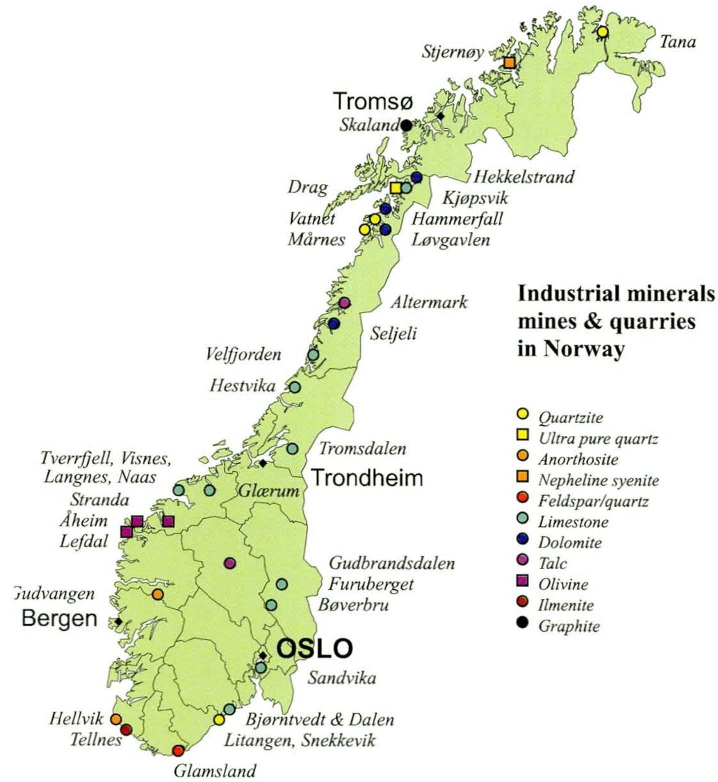

Fig. 3. Exploitation of industrial minerals in Norway.

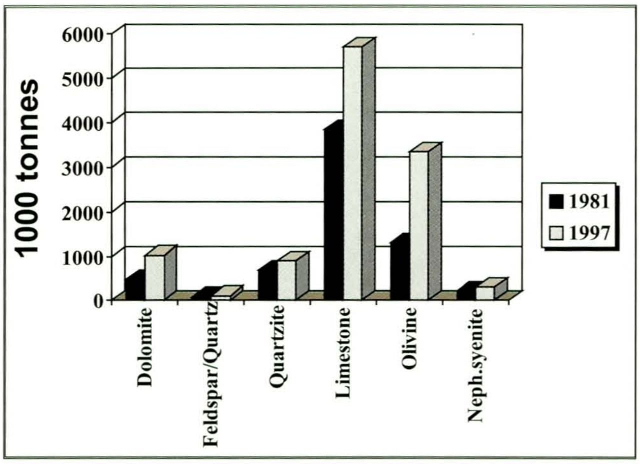

Fig. 4: Comparison of production between 1981 and 1997 for some of the most important industrial minerals. Source: 1991 data from NOU 1984:8; 1997 data from producers.

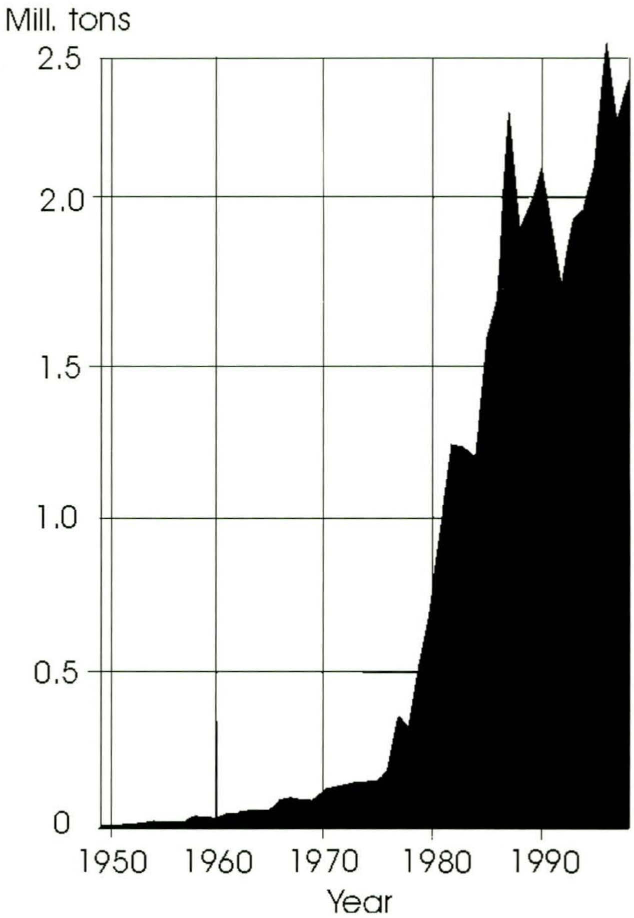

Fig. 5: Production trend of olivine from A/S Olivin. Source: A/S Olivin.

esses, and made it possible to use the cheaper and whiter calcium carbonate instead. Though the calcium carbonate for slurry is important, another application of considerable importance should also be mentioned; the company Norcem produces limestone/calcium carbonate mainly for cement. The production of ore reached 2.75 M tonnes in 1997. The need for calcium carbonate will continue to grow in Norway,

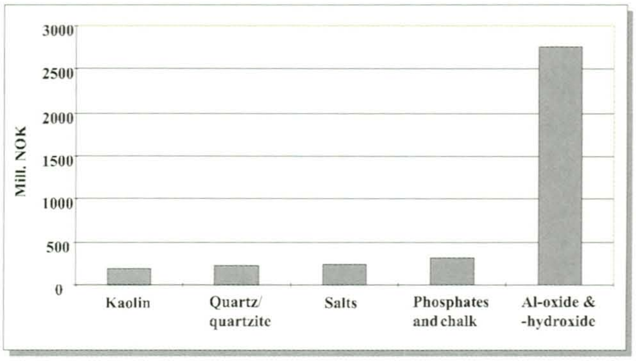

Fig. 6: Major import of industrial minerals. Source: Statistisk sentralbyrå / NGU.

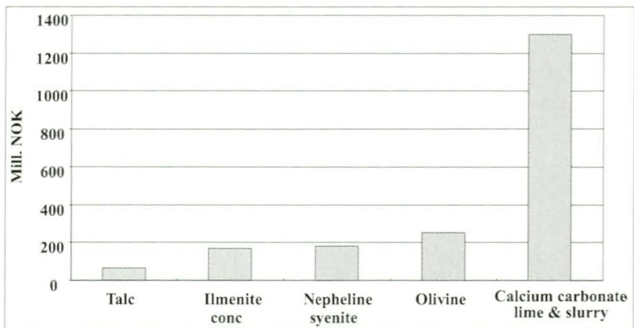

Fig. 7: Major export of industrial minerals. Source: Statistisk sentralbyrå / NGU.

firstly due to a planned increase of slurry production, but also to a planned increase of the production of raw material for precipitated calcium carbonate (PCC).

The production of nepheline syenite, quartzite, talc and feldspar is rather stable, though in 1997 ilmenite production was somewhat reduced. New developments in industrial minerals include minor production of high-purity quartz, white anorthosite and magnetite (as an industrial mineral). Other minerals that may be mined in the near future include rutile and garnet (Karlsen 1998).

The use of Norwegian magnetite as an industrial mineral has increased during the past years due to development work by *Rana Gruber A/S*, at Mo in Rana in Nordland county. From being purely a metallic ore producer, Rana Gruber A/S has, more recently, concentrated on the development of new sophisticated products from naturally occurring magnetite using traditional as well as innovative new manufacturing methods. Several products for non-metallic uses have been developed, including pigments (Prieseman 1997). Of the 1997 production of 680,000 tonnes, a total of 40,000 tonnes were treated for such special uses.

International trading

As the large deposits of the different kinds of industrial minerals are scattered around the world, trading of industrial minerals is a highly international business. Norway has a substantial import of industrial minerals; the most important imports in 1997 were 1) *alumina* to a value of > 2.7 Bill. NOK imported for the aluminium production, 2) *apatite* and *salts* for fertilisers, 3) *quartz* and *quartzite* for production of silicon metal and Fe-silicon, and 4) *kaolin* for paper and ceramics, 5) *barytes* and *bentonite* for use in drilling mud for the oil industry (Fig. 6). The total import value was ca. 4.8 Bill. NOK in 1997, representing an increase of 4.4 % over 1996.

Substitution of four of these commodities by Norwegian raw materials might be possible in the future. Alumina can potentially be exploited from Norwegian anorthosites but, as yet, at a higher cost than the imported bauxite. The Institute for Energy Technology is at present doing important development work on this matter. A number of low-grade phosphate deposits occur in Norway, and may well be of economical value in the future, especially if coexisting minerals such as ilmenite and magnetite can be found with appropriate quality. Quartz and quartzites are quite common in Norway,

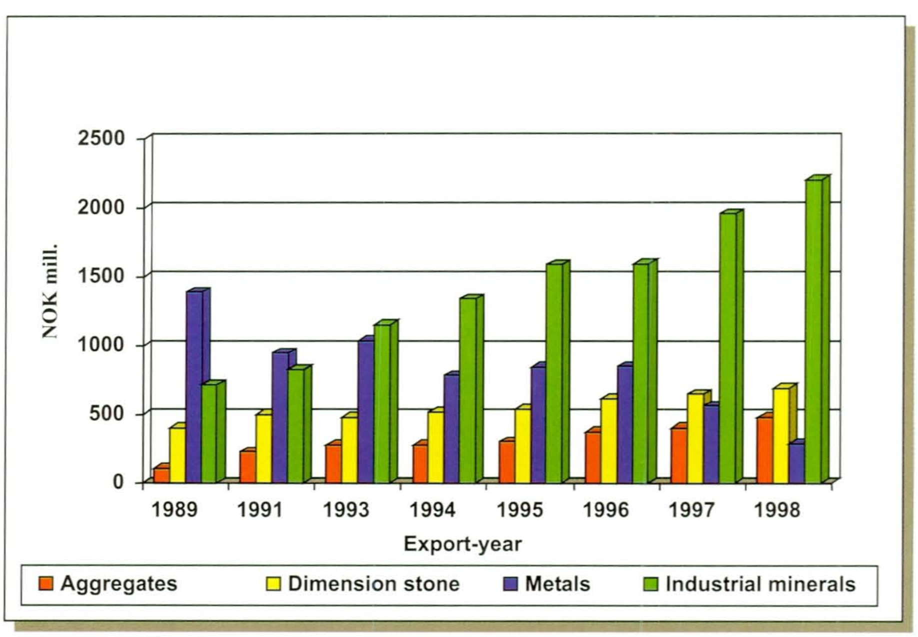

Fig. 8: Export trends of industrial minerals, metallic ores, aggregates and dimension stone. Source: Statistisk sentralbyrå / NGU. Ilmenite is defined as a metal in this figure. Cement and pigments (as well as fossil fuels) are not included.

though similar grades to the imported materials have not yet been found.

On the export side, the major volume of domestically produced *olivine, nepheline syenite* and *feldspar* is exported. *Calcium carbonate* in the form of slurry is, however, the most significant export mineral in economic terms (Fig. 7). *Dolomite, ilmenite concentrate, graphite* and micronised *talc* are also of considerable importance. The total export value of industrial minerals shows a pronounced positive trend (Fig. 8), and exceeded 2.26 Bill. NOK in 1997. This increase is mainly due to increased export of calcium carbonate slurry. Not all of the exported minerals are produced in Norway as a few companies import minerals for dressing and processing and then re-export the products (Karlsen 1998). All in all, Norwegian industrial mineral products are exported to at least 84 countries worldwide. The commodities with the largest number of destination countries are olivine, calcium carbonate (slurry), talc and nepheline syenite. The most important destinations in 1997 were Germany, Netherlands and the United Kingdom.

Value of manufactured products that are based on industrial minerals

Industrial minerals form the basis for many other domestic industries, e.g. refinement into TiO_2-pigment, production of ferrosilicon, Si-metal, Mg-metal, aluminium and cement. In addition major amounts of industrial minerals go into other products, e.g. fertilisers, paints, paper and chemicals as well as sectors such as agriculture and environmental protection. The total annual turnover for all of these sectors is probably > 40,000 Mill. NOK.

The total export value for processed products where industrial minerals play a primary role is estimated at around 25 – 35,000 Mill. NOK (Table 2), which interestingly is higher than that for the export of fish products.

The above figures show that the industrial mineral industry is a major economic player in Norway. In addition production sites are widely spread throughout the country and for this reason the industry is important for employment and development in district Norway.

Short-term vs. long-term prospecting and development of deposits

Prospecting for new deposits can be regarded as having either short-term or long-term aims. In the short-term, one is often searching for a specific quality for the immediate needs of industry, e.g. satellite deposits close to an existing operation. In longer term prospecting strategies, greater efforts are made to achieve a thorough understanding of the regional geological settings for future benefits. Such prospecting is not dependent in the same way on the present needs of industry, but more on future requirements and possibilities. In both short-term and long-term prospecting there might be a need for comprehensive investigation and testing of the market, the infrastructure and the economics of the operation, in addition to advanced geological investigations. In such cases it is more appropriate to talk about the development of a deposit or a deposit-area.

PRODUCT	1997 EXPORT (Mill. NOK)
INDUSTRIAL MINERAL-BASED/BEARING PRODUCTS:	
Inorganic chemicals (silicon, calcium carbide, other carbides)	2,952
Dyeing, tanning and colouring materials (TiO_2 pigments and preparations, paints and lacquers)	908
Fertilisers, manufactured	2,844
Chemical materials and products n.e.s.	2,766
Paper, paperboard and manufactures thereof	8,821
Non-metallic mineral manufactures	1,293
Ferro-silicon	2,219
Other Fe-alloys	1,704
Aluminium	15,152
Cement	139
PRODUCTS BASED ON METALLIC ORES:	
Non-ferrous metals, incl. Mg-metal, excl. aluminium	7,744
Manufacture of metals	3,721
Iron & steel, incl. ferro-alloys	7,807
SUM, manufactured mineral-based/bearing products	57,070
EXPORT OF OTHER PRODUCTS CONSIDERED TO BE IMPORTANT:	
Electric current	613
Fish, crustaceans and molluscs, and preparations thereof	23,355
Gas, natural and manufactured	32,525
Petroleum, petroleum products and related materials	151,028

Table 2. Export values of *some* products where industrial minerals play an important role (uppermost field). Pure mineral products are not included. Also shown: export values of metals (second field), and export values of products that are considered to be of great economic value for Norway (lowermost field). Source: Statistisk sentralbyrå.

The industrial mineral business meets steadily increasing demands for industry's products, and some of the prevailing trends nowadays that affect the needs of investigations are:

- Expansion of the uses of industrial minerals, especially on the filler market.
- Stricter specifications for purity and whiteness for filler materials such as limestone, dolomite and talc.
- Restrictions against mineral products that contain fibrous minerals.
- Restrictions against mineral products that contain free quartz.
- Demand for a higher chemical purity in lime and quartzite for the chemical and metallurgical industry.
- Environmental demands, e.g. acid rain, lead to increased lime spraying of water-catchments and forests, and a substantial use of pH-regulatory lime.
- Regulations regarding areal protection.

Most of the trends present a great challenge, both in the prospecting for new deposits and in obtaining a better knowledge of deposit mineralogy. This is true also in the development of new mineral products, mineral dressing, market analysis, economic analysis, etc.

Two important points that a prospecting geologist has to be aware of are;

- Deposits regarded as non-economic may change to become economic ones, and *vice versa*.
- Deposits apparently well suited for exploitation cannot be termed economic until a market exists for the product.

The exploitation of calcium carbonate in Velfjord is an interesting example of development that contains elements of geology, technical development and market development. Although the deposit has been known since the last century, successful exploitation started only in 1994. Some of the important factors which made exploitation possible were as follows. 1) Plüss Staufer bought part of the Norwegian company Hustadkalk og Marmor in the late 1970s to establish slurry production; 2) development and establishment of satisfactory mineral processing routines at the slurry plant; 3) the conclusion that the Velfjord deposit was of greater interest than other deposits (Hustadkalk AS/NGU) in 1991; and 4) the change from acid to neutral processes by paper producers, allowing calcium carbonate to be used.

AS Olivin has also had an interesting history that is related to development (Aarøen 1998): first, Professor Goldschmidt was the pioneer in the olivine investigations and industrial utilisation. His investigations in the beginning of the 19th century led to the discovery of the significant refractory properties of olivine. He also mapped the Almklovdalen deposit at Åheim. In the period 1948-1975, the Almklovdalen deposit was exploited for the use of olivine as a refractory material. In 1972, the former director, Olav Øverlie, started to look into the possibility of delivering olivine to steel producers for the use as a slag-former. Such a use had already been applied, from 1937, at Bremanger Smelteverk. Øverlie succeeded in his work, and from 1976 deliveries started to grow significantly; and today, use as a slag-former is the primary use of olivine.

An example from Finland can also be mentioned. Finland has a large domestic production of paper, and until 1969 most of the minerals used in the processes of paper production were imported. However, after considerable experimental work by United Paper Mill, processes were developed to use Finnish talc in paper. In 1969, the first plant for talc for the use as filler in paper was established in Sotkamo. During the following years new products were developed, new markets were established and a substantial increase in the production followed. Today, the annual production of floated talc, in Finland, is more than 400,000 tonnes, and talc constitutes around 10-15% of the minerals used in the Finnish paper industry.

The above examples are meant to underline the many components involved in the development of an industrial mineral deposit, and the complex interplay of external factors, especially the need for an extensive knowledge of market possibilities and developments.

It is also appropriate to mention examples of development work, in Norway, that have not yet led to exploitation. These include: anorthosites in various areas, in western and southern Norway (several periods from ca. 1909 until present); the low-grade apatite - ilmenite – vanadium bearing magnetite deposits (unexplored); and rutile in West Norwegian eclogites (1976 – until present), talc in Stølsheimen, western Norway (1982 - 1994), and talc in the Nakkan-Esjeklumpen area in Altermark, northern Norway (1990 – until present), as well as the many calcium-carbonate and dolomite deposits located in Nordland.

In purely geological terms, a specific deposit is developed through increased knowledge of its geology, geometry, mineralogy, chemistry and other aspects that are important for future exploitation. In order to focus on the most relevant aspects of his work, the geologist must also be aware of the possible applications for the materials. In more long-term regional studies the emphasis involves increased knowledge of the general geology of deposit-rich provinces and perhaps to a lesser degree, detailed information concerning specific deposits and products.

In the present *Norges geologiske undersøkelse Bulletin*, papers are presented that represent different levels of development and regional knowledge. These include short-term studies where specific deposits have been investigated, and long-term studies where larger provinces are investigated. Not all of the deposits mentioned in the present papers are believed to have economic significance at the present time, but they provide examples of prospecting or on the status for a specific task.

Future possibilities

Norway has a rather unique geology, in a European context, and indeed could be referred to as Europe`s principal *hard rock* country. It has a great variety of metamorphic, igneous and sedimentary rock types, developed over a considerable geological time-span. This considerable diversity in rock types, mineral contents and the variety of geological processes affecting them, has given rise to many major and smaller mineral deposits. Many of these deposits are being or have been commercially exploited, and there is still a great deal of potential for the future. Research into mineral characterisation, and into the more detailed geology of individual deposits, is of particular importance, as indeed is the improvement of our knowledge of the regional geological framework of regions with deposit potential. The continuous changes in the supply and demand situation, the rapid rate of technological change, and the search for new and better value-added products provides an exciting challenge to the Norwegian industrial minerals sector. It is thus of considerable importance that NGU and indeed other Norwegian institutions keep at the forefront of research and development in the industrial mineral and construction material fields.

There is a growing awareness of the environmental problems attendant on any new industrial development, and the need to minimise potential environmental impacts. NGU with its extensive databases, concerning all aspects of geoscience, is in a unique position to recognise these problems; and together with partners in both the public and the private sectors to find ways to mitigate and minimise such impacts.

It is hoped that, in the future, NGU will increase its cooperation with industry, and also with the public sector, in its R&D work on industrial minerals towards a common goal : *to realise the potential for this sector to make an increasing contribution to the national economy and to society in general, in an environmental friendly framework.*

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