NGU Report 95.062

Aggregate Resources in Norway
Superquarries an important mining industry of the future

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REPORT

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Aggregate Resources in Norway. Superquarries an important mining industry of the future

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Summary:

The Geological Survey of Norway (NGU) is in the process of carrying out an inventory of deposits of sand, gravel and hard rock aggregate throughout the country. The goals are for the Gravel database to be complete by 1995 and for the Hard Rock Aggregate database to be complete for small local quarries by 1996.

In 1978 the Department for the Environment took an initiative to assemble the information from these files into a central, complete, computer-based register at NGU.

Superquarries in Norway can be our most important mineral industry on land in the future. NGU is planning to map all potential coastal rock units for which environmental, topographic and transport criteria would allow quarrying from the year 2000.

Keywords: Landuse conflicts, Superquarry, Aggregates, Analyses, Database, Sand, Gravel.

Keywords:	Arealkonflikter	Pukk
Analyser		Database
Sand	Grus	Fagrapport

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MAP: Hardrock aggregate in Norway. Scale 1:2 millions

1 INTRODUCTION

Aggregates used in Norway are mainly Quaternary glaciofluvial deposits of sand and gravel and crushed hard rock aggregates. The bedrock geology of Norway is complex and is described in the bedrock map at a scale of 1:2 mill. at the back of this report. The bedrock is dominated by Precambrian gneisses, igneous rocks and metasediments, and Cambro-Silurian metasedimentary and metavolcanic rocks. In Norway most aggregates for building and construction purposes are composed of lithologies with good mechanical strength, and which do not experience problems with mineralogical alteration (weathering).

The gross production value of Norway's most important mineral products in 1993 with sand, gravel and aggregate is presented in Fig. 1.

Sand, gravel and hard rock aggregate are Norway's most important building materials, with an annual market value of c. NOK 2,300,000,000. Annual consumption is c. 50 million tons of sand, gravel and hard rock aggregate. This corresponds to c.12 tons/inhabitant, of which 5.7 tons is sand/gravel and the remainder is hard rock aggregate. 46 % of the consumption goes to road construction, 20 % to concrete and the remainder to other uses, fig. 2. The export of aggregate in 1994 was c. 5.5 mill. tons to Europe with an export value of c. NOK 270 million.

World production of sand, gravel and aggregates shows the most important countries with Iceland, Canada and Finland on top with c. 34 tons/year and Norway with c. 12 tons/year per capita.

The Gravel and Hard Rock Aggregate databases are computerised databases giving an inventory of all known deposits in the country and information on their volume and quality. The databases are a significant contribution to better management of important non-renewable national resources and are a part of the Survey's information system.

Trondheim, 20.04.1995

Peer-Richard Neeb
Programme manager

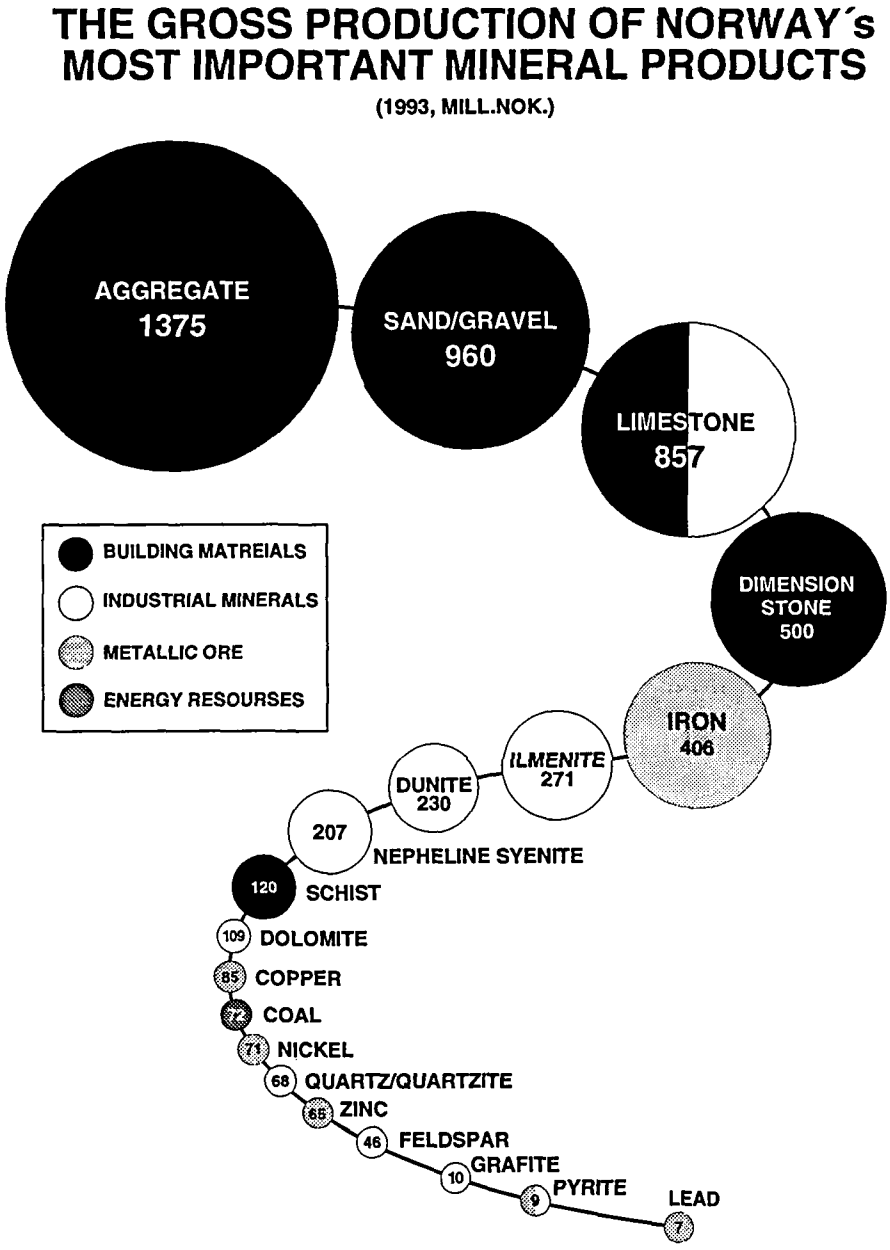


Fig. 1: The gross production value of Norway's most important mineral products, 1993

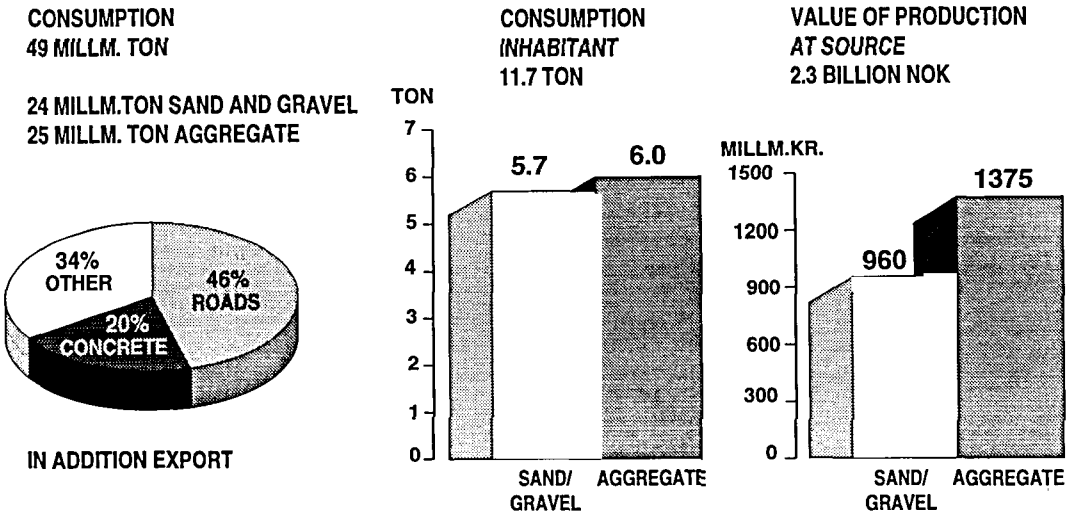


Fig. 2: Consumption and production value of sand, gravel and hard rock aggregate 1993/94

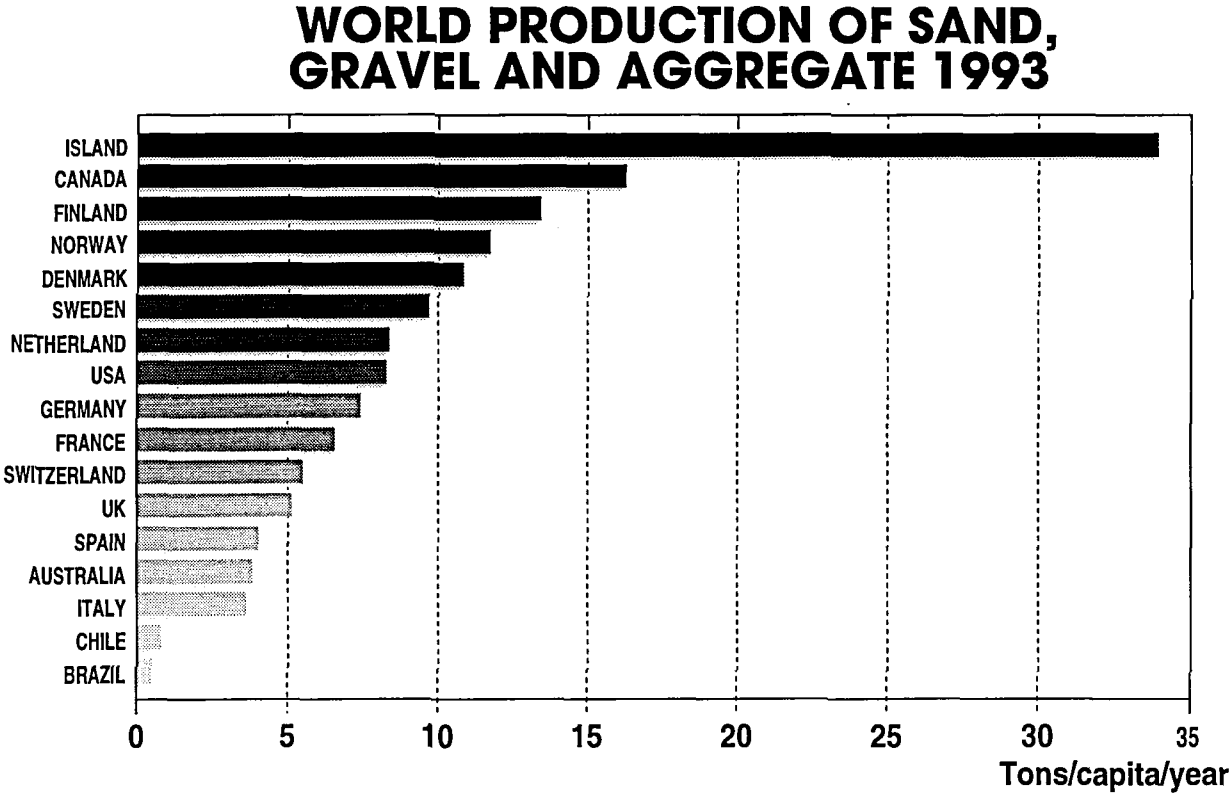


Fig. 3: World production of sand and gravel and aggregate (Rock Products International, February 1992 and PGL reports 1994)

2 LAND-USE CONFLICTS AND RESOURCE ECONOMICS

The construction industry and the State Road Authority are the most important consumers of sand, gravel and hard rock aggregate in Norway. Developments within recent decades, e.g. within concrete technology and road construction, have led to increasingly stringent requirements as regards the quality of the construction materials, and thus to a demand for more knowledge about the location, volume, composition and properties of the deposits available.

Sand, gravel and hard rock aggregate are relatively inexpensive resources measured in kroner/m^3. Because of the frequent need for large volumes of these materials the distance from source to consumer is an important economic factor. This leads to pressure on, and rapid exploitation of deposits found near the larger cities.

This is most obvious in the Oslo region where the most conveniently located deposits are nearing exhaustion. Continued rapid growth in the construction of new housing, business developments, roads, railway lines and not least, a new major airport, will necessitate the use of raw materials from an increasingly wide catchment area.

Similar problems are found in many towns where the only sand and gravel deposits are in built-up areas.

3 ENVIRONMENTAL FACTORS

Increasing environmental consciousness limits the amount of inconvenience which is regarded as acceptable in the vicinity of important housing and recreational areas. The quarrying of building materials leads to scars in the countryside and to noise, dust and a considerable traffic of heavy goods vehicles.

In addition, there is increasing interest in the protection of both typical and rare land forms in the vicinity of the larger conurbations. Groundwater is becoming an increasingly important component in our water supply. Important groundwater magazines were often located in sand and gravel deposits which leads to difficult strategic decision-making and increases the need for adequate attention to be given to natural resources in local planning.

Sand, gravel and hard rock aggregate have traditionally been regarded as more or less inexhaustible resources in Norway but this myth is continually being disproved by economic, technical and environmental factors. This has led to an increasing need for a tool which gives both an overview of, and detailed information on the resources available. The Gravel and Hard Rock Aggregate databases are such tools.

4 HISTORICAL BACKGROUND

Files on sand, gravel and hard rock aggregate deposits have, in the past, been held by a number of local and regional governmental bodies, arising from their differing needs for information on the location, volume, composition and quality of the deposits. The Civil Defence Force, the Road Authority, the State Railways and the Geological Survey (NGU) have maintained separate files.

In 1978, the Department for the Environment took an initiative to assemble the information into a central, complete, computer-based register at NGU. The information in the databases is available to users via the county map offices, part of the State Cartographic Service. Data are collected, analysed and entered into the database by NGU. This work is financed by the Departments for the Environment and Industry, with contributions from county and local authorities and the road authorities.

5 HARD ROCK AGGREGATE OR NATURAL GRAVEL

Selection of hard rock aggregate or natural gravel as building material is determined by factors such as bulk quality, economics and the quantitative and qualitative particle distribution of the natural gravel. Hard rock aggregate is a natural substitute in areas with inadequate supplies of natural gravel. This presupposes that there is a local source of aggregate which would be more competitive than imported natural gravel. The same applies in areas in which the available resources of natural gravel do not comply with the general or specific quality criteria for construction purposes.

Hard rock aggregate has taken over most of the market for material used in road pavement and road metal. Consumption of hard rock aggregate is thus likely to increase more than that of natural sand and gravel in the future.

The information is stored in separate databases, Gravel and Hard Rock Aggregate. In the course of 1986/87, all hard rock aggregate quarries in the country were registered and samples were collected from almost all quarries in continual or sporadic production. The Hard Rock Aggregate database is updated annually as information on new quarries and changes in production status become available. The aim is to map relevant parts of all counties in order to find suitable areas for extraction for road building or other forms of construction uses.

Existing information on deposits, in the area being considered, is evaluated along with information from Quaternary and bedrock maps and reports. An aerial photo interpretation is made of the area and a field study with sampling is carried out on the deposits. The databases

are built up by systematic assessment of all available material - commune by commune and county by county. The relevant information is entered on a standard data sheet.

Data collection is focused on areas within an acceptable distance from the existing communication network and population centres. Deposits are registered if the probable total volume above the water table, moraine, silt, clay or rock exceeds 50,000 m^3 and the average thickness exceeds 2 m. These criteria are applied with discretion in areas where smaller or thinner deposits would have particular significance, e.g. along the coast where superficial deposits are very limited.

The following information on the individual sand, gravel and hard rock aggregate deposits is entered into the database:

- Coordinates
- Volume (area x thickness), except for deposits of rock
- Quality (see below)
- Present land use, except for deposits of rock
- Land use conflicts in the event of exploitation
- Production status and description of deposits where there already are quarries
- References for reports by the Geological Survey, the State Road Authority, consultants and others.

6 ANALYSES

In the Gravel and Hard Rock database rocks are divided qualitatively based on such criteria as **impact value, brittleness, resistance, abrasion value, ball mille value, Los Angeles value and for export, PSV.** The content of mica, schist, mafic rock and grains of other types in the sand fraction is assessed.

The database also contains information on rock type(s) present, grain size, degree of compaction, quality classification, texture and petrography from thinsection descriptions, and possible alkali reactive aggregates (more than 20 % of counted grains).

7 STATUS AND RESULTS

Development of the Gravel and Hard Rock Aggregate databases began in 1978. The Gravel database encompasses sand and gravel deposits with a combined volume of 12,000,000,000 cubic metres. 10 % of the area covered by the deposits is built-up and is therefore not available for production, Figs. 4 and 5.

GRUS- OG PUKKREGISTERET STATUS

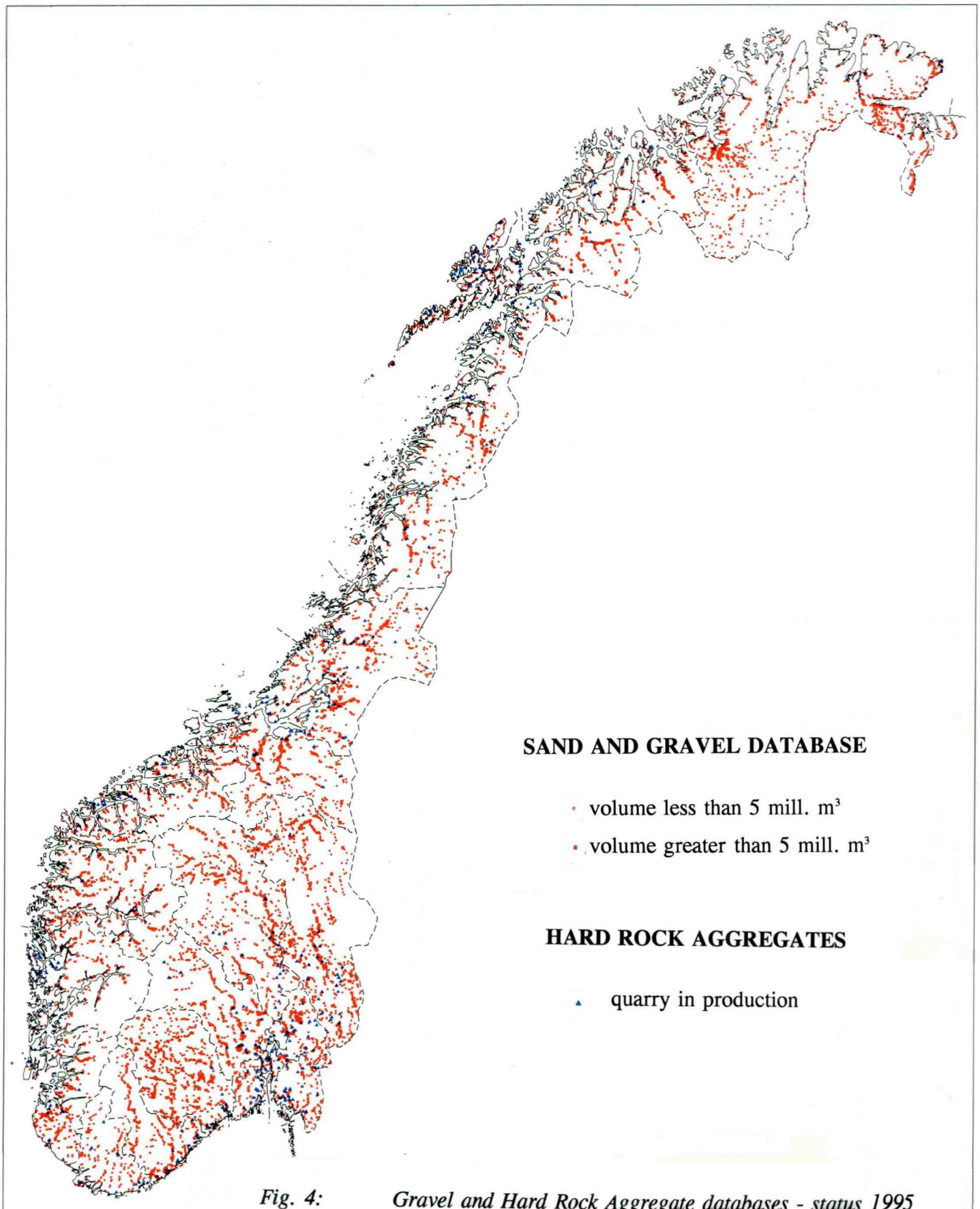


Fig. 4: *Gravel and Hard Rock Aggregate databases - status 1995*

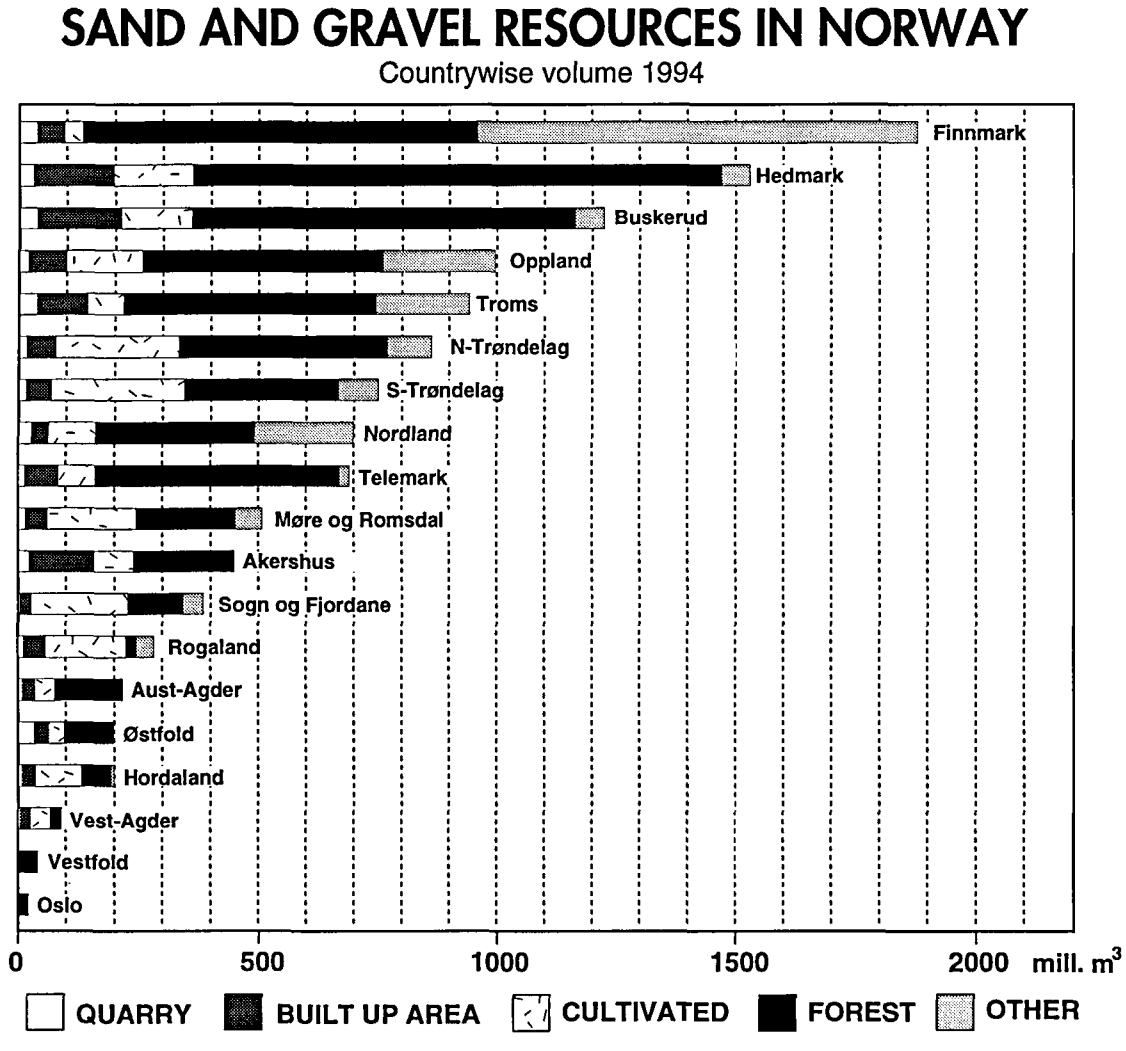


Fig. 5: Summary of volume from counties in which registration is complete

The databases will cover the whole country by 1995. The databases will thereafter be updated as required by NGU.

The Gravel database contains information on 8790 deposits. These include 810 active quarries, 3865 in intermittent production and 1871 abandoned quarries. 6546 quarries have been registered, Fig. 6.

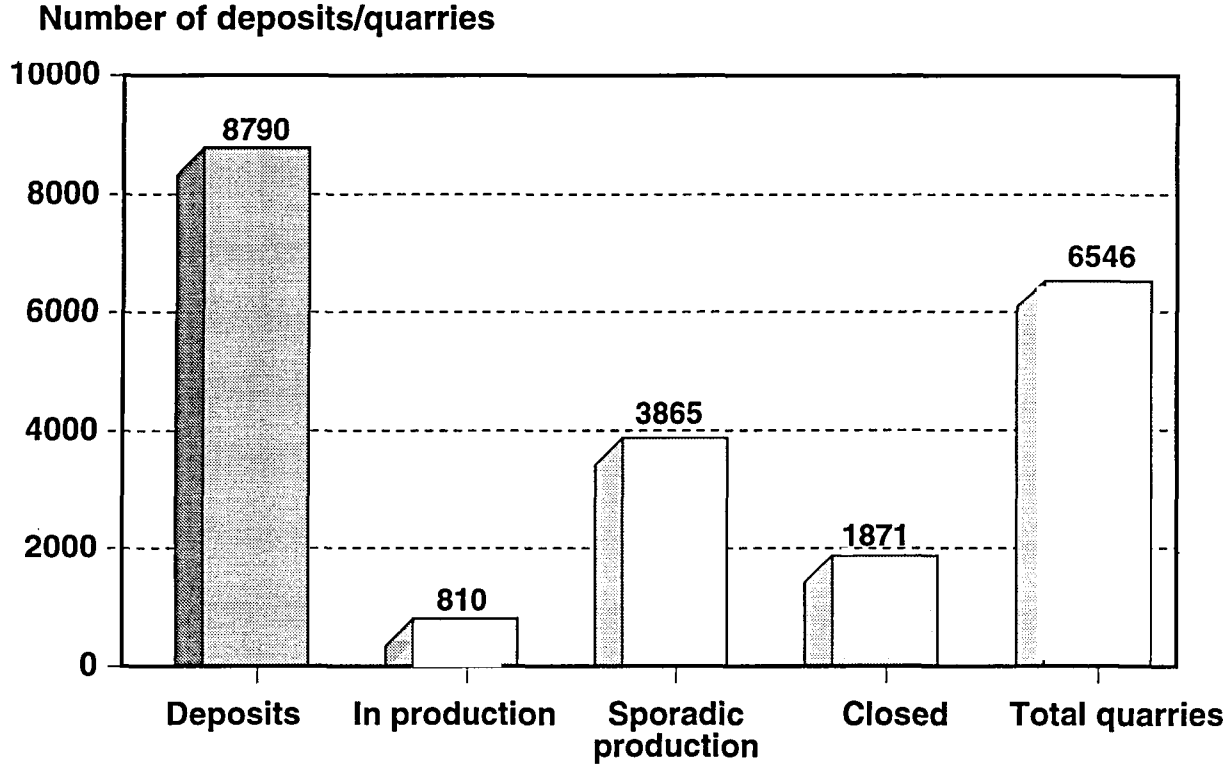


Fig. 6: *Number of deposits registered in the Gravel database and their production status 1995*

The Hard Rock Aggregate database will cover special parts of the country by 1996 and contains now information on 934 deposits. 186 of these are in continual production, 149 in intermittent production and 237 have been in production but are now abandoned. 572 quarries have been registered, Fig. 7.

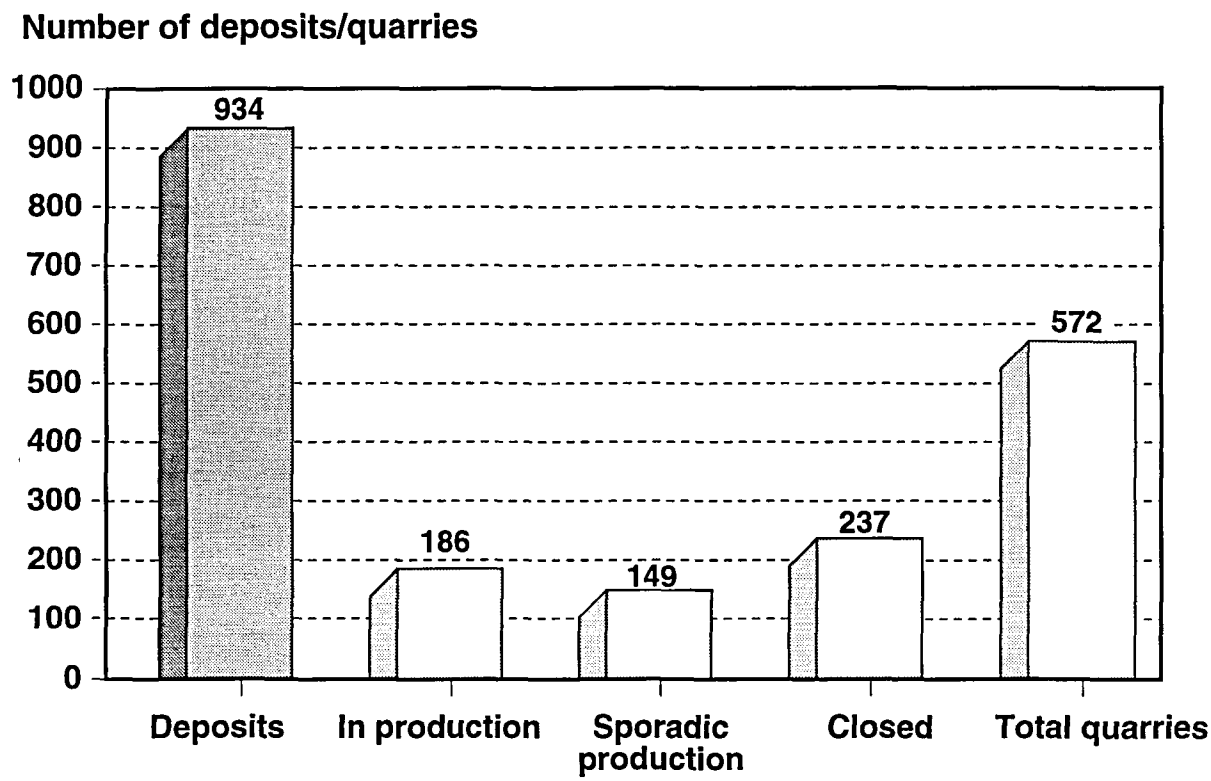


Fig. 7: *Number of deposits registered in the Hard Rock Aggregate database and their production status 1995*

Total 7.118 quarries have been registered in Norway, Fig. 8.

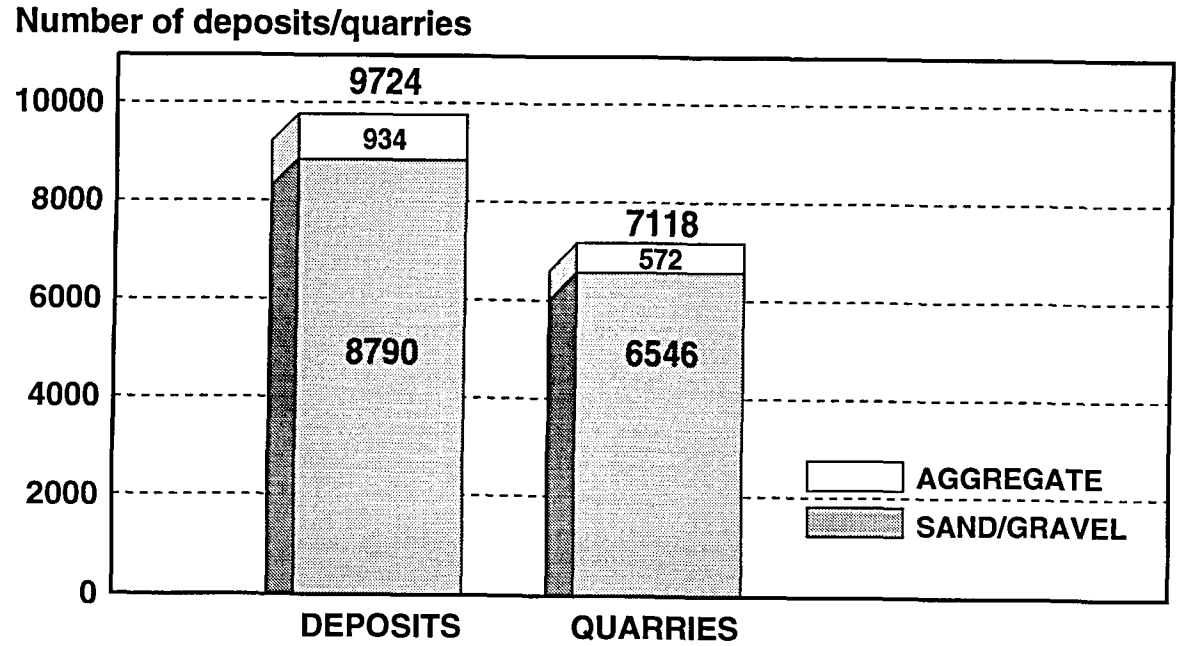


Fig. 8: *Total number of deposits and quarries in Norway*

Potential deposits of hard rock aggregate near major roads have been mapped in the counties of Aust-Agder, Rogaland, Buskerud, Akershus, Østfold, Oppland, Hordaland, Sogn og Fjordane, Sør-Trøndelag and Nord-Trøndelag for the local road authorities and county authorities.

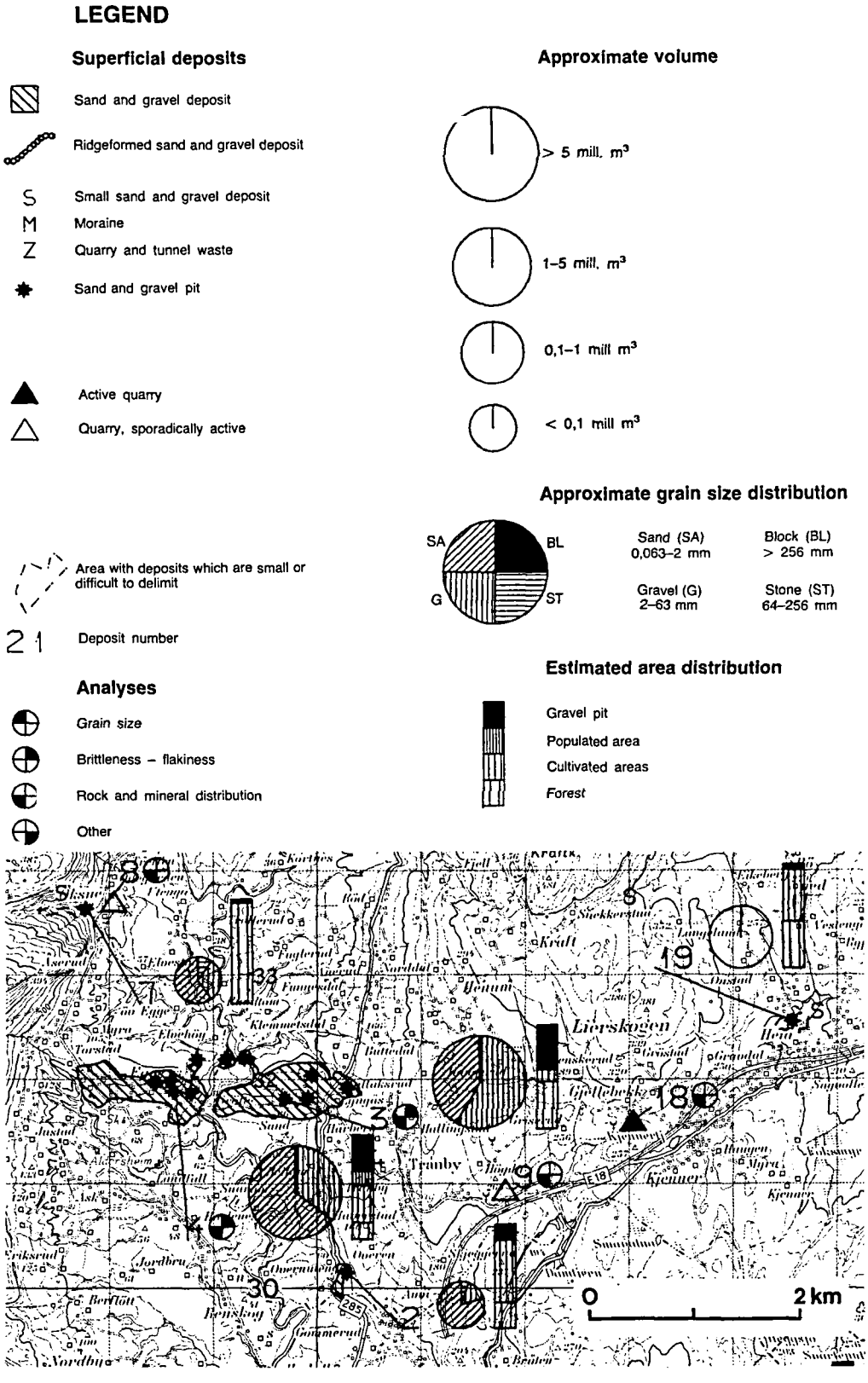


Fig. 9: *Example of map of sand- and gravel resources and hard rock aggregates; part of the Lier map-sheet, 1:50.000*

636 maps of sand and gravel resources at a scale of 1:50,000 have been issued, some of them printed in colour. The maps also contain information on hard rock aggregate deposits and their production status, Fig. 9.

7.1 Norway's largest sand and gravel deposits

The extent of the database allows us to define and rank the ten largest sand and gravel deposits in the country: most of them are in production, Fig. 10.

The largest deposits are located near to Oslofjord, Buskerud county, Østfold county, Telemark county and in the counties of Finnmark and Hedmark.

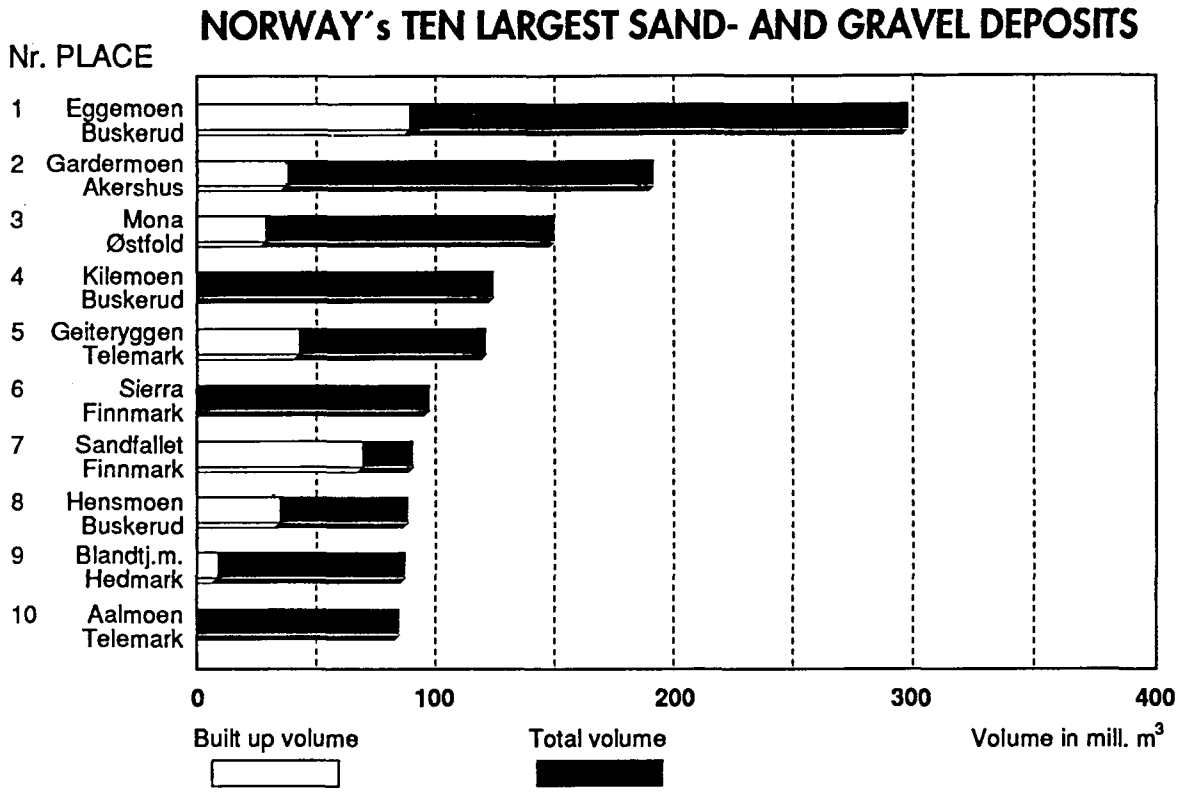


Fig. 10: Norway's ten largest sand- and gravel deposits - volume in mill. m^3

7.2 Sand and gravel for use in concrete

The petrographic character of the material in a sand and gravel or hard rock aggregate deposit is dependent on the nature of the local bedrock. Material with a high content of mica can pose problems if it is used in concrete. The deposits registered in Norway show

variations from deposits with almost no mica in southernmost Norway to micaceous sands in the county of Nordland. Concrete in which sand with a high mica content has been used has reduced workability and a higher water requirement. This, in turn, leads to reduced mortar strength after solidification. The mineralogical compositions of aggregates are important properties also with relevance for potential alkali reactivity.

8 RESOURCE ACCOUNTING

Sand, gravel and hard rock aggregate are important resources and are non-renewable. Consumption is nevertheless rapid, especially in densely populated areas. A shortage of resources is already presenting problems in some parts of the country. NGU has developed a system for resource budgeting and accounting which gives a picture of the extraction and subsequent transport flow of building materials. This gives us a better chance of reserving high quality deposits for future generations.

There is an acute shortage of building materials in several of our communes at present, either because the originally available resources were very limited or because they have been exhausted. This leads to transport of the necessary materials over increasing distances with correspondingly increased costs.

Long term national planning thus requires the mapping of our resources of building materials and a more sensible management of these non-renewable resources.

NGU has now assessed the consumption and transport flows of building materials in 10 counties in Norway, based on the data in the Gravel and Hard Rock Aggregate databases. This gives an overview of the availability of resources and of annual consumption in these areas and may reveal present or potential supply problems in relation to existing or planned construction activity.

The interest for aggregates in the southern part of Norway for export to Europe has increased in recent years, especially concerning Denmark, the Netherlands, Great Britain, Belgium and Germany.

8.1 Presentation of results

Each commune to be covered in the resource account is assessed with respect to availability of raw materials, production, import/export and consumption. The resource account is presented in the form of diagrams for each commune, based on the data in the databases for any one year, Fig. 11.
The diagrams show the type of material and production within the commune.

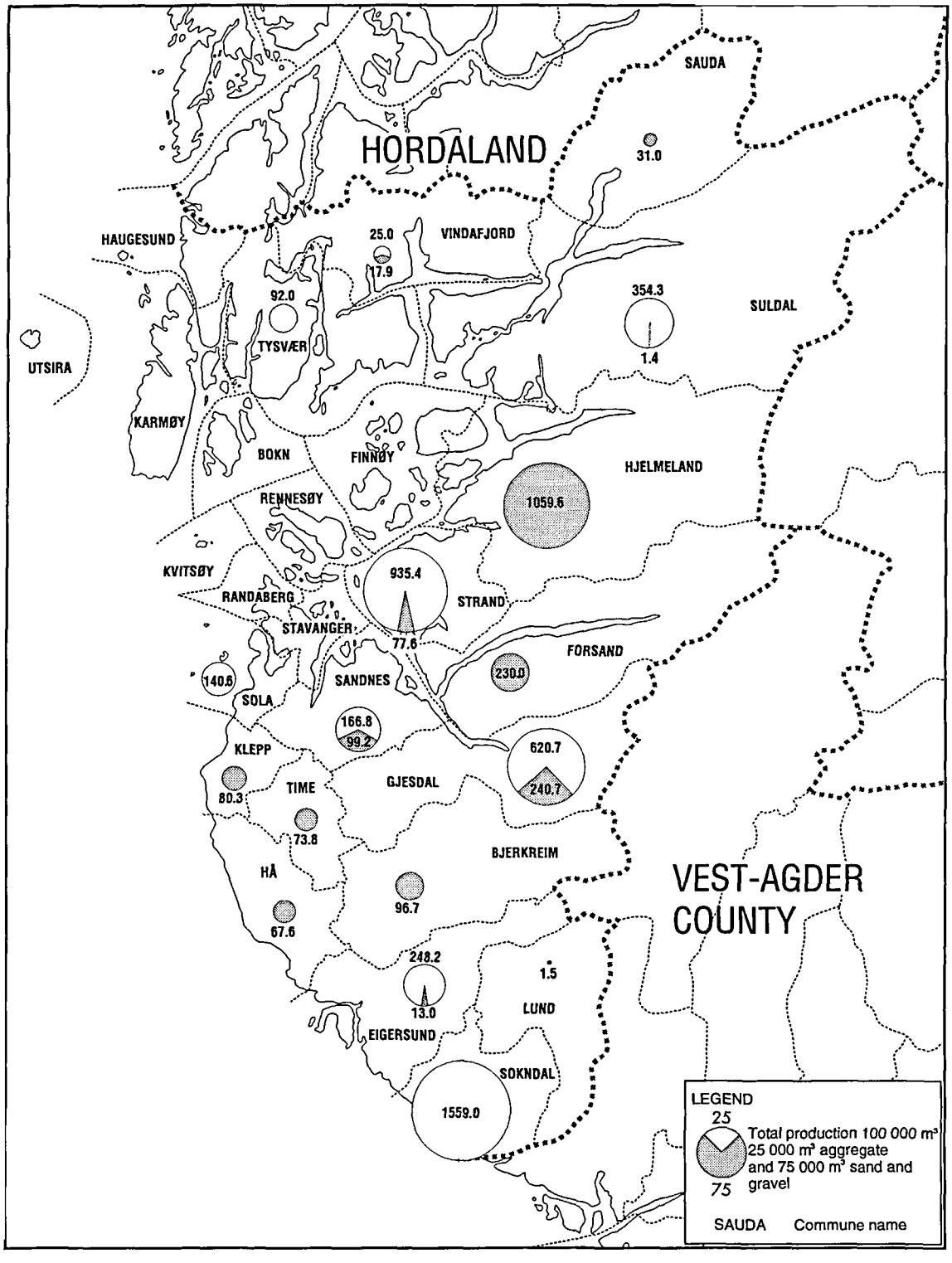


Fig. 11: *Production and consumption of sand, gravel and hard rock aggregate in Rogaland county, 1992 (1000 m^3)*

The results from each commune are assembled and analysed on a county or regional level. Table gives a summary of the number of deposits, their volume and current land use. The flow of the materials can also be presented on a map giving a readily understandable picture of the supply situation.

There are geographical variations in consumption and production per county, Fig. 12.

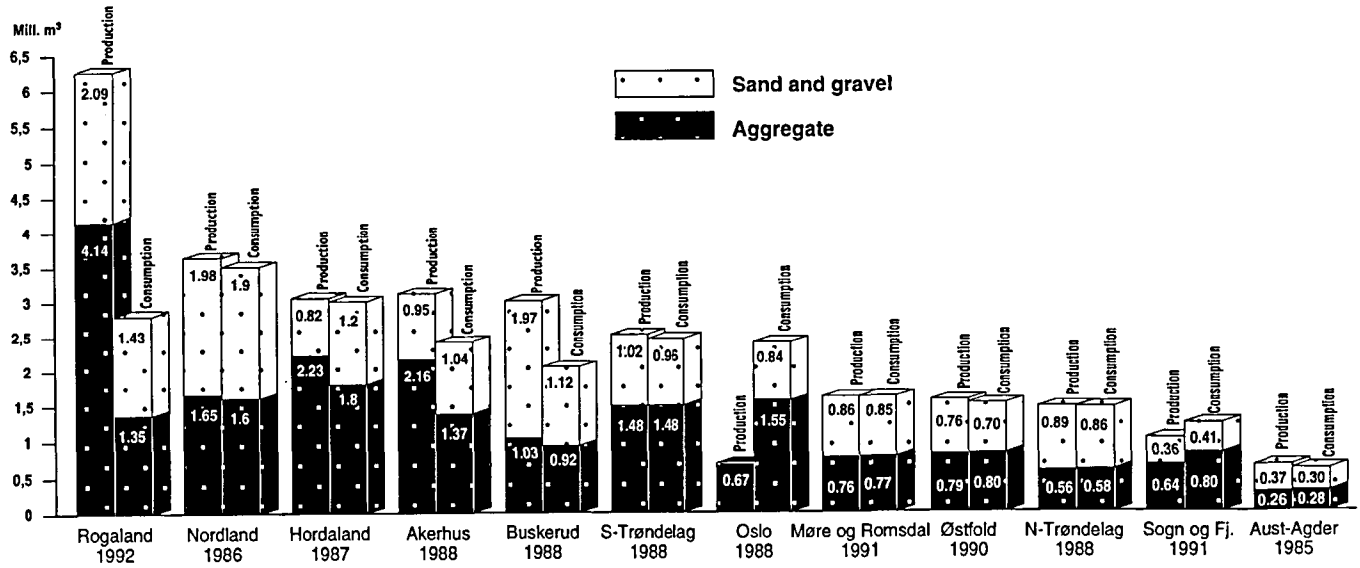


Fig. 12: Annual consumption and production of sand, gravel and hard rock aggregate in selected counties

9 USE OF THE GRAVEL AND HARD ROCK AGGREGATE DATABASES

The Gravel and Hard Rock Aggregate databases contain a range of data which allows different user groups to extract information for their separate purposes. Communal, county and national planning and development authorities can obtain information, maps and data relevant to land planning, communications and industrial developments from the databases.

Figure 13 illustrates the rock aggregate production and quarries - potential deposits of hard rock aggregate in Rogaland county.

An important aspect of annual resource accounting is the possibility it provides they give for projection of the future situation and thus the ability to tackle future supply problems in a more effective manner. Sound information on consumption patterns enables the erection of prognoses for future demand for sand, gravel and hard rock aggregate. This demand is heavily dependent on the level for activity in the building and construction industries, and on plans for the construction of new roads and the maintenance of the existing road network.

Good prognoses allow the prediction of the areas in which the demand for raw materials will be greatest in the years to come. This information, along with data on the availability of resources and on the transport of raw materials, allows local and regional authorities to delimit appropriate areas for production and to work out plans for how and when it is to take place.

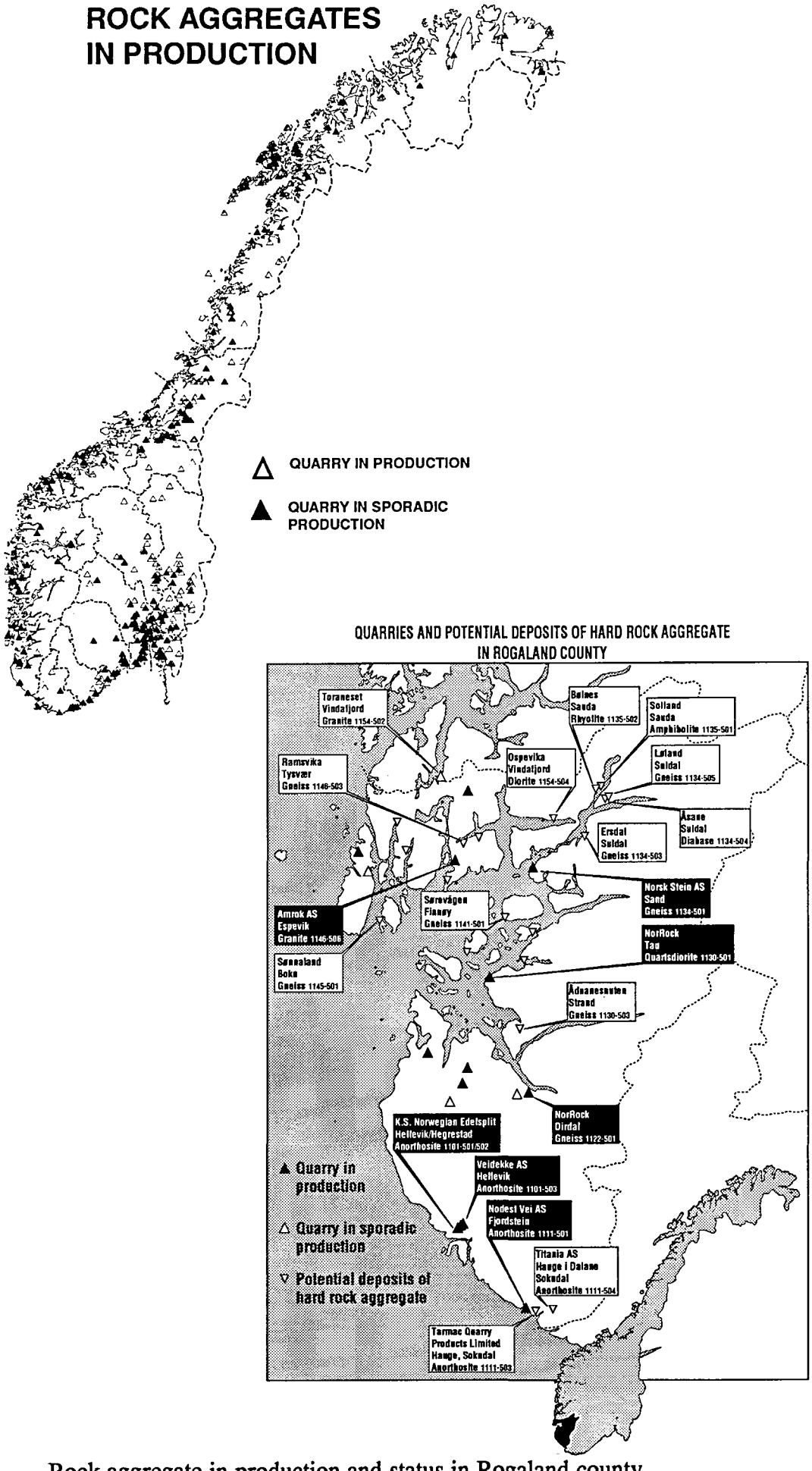


Fig. 13: Rock aggregate in production and status in Rogaland county

The combination of data on sand and gravel, and hard-rock aggregate in the same database provides information on the total resource situation for the building industry in any region. Users may evaluate alternative resources in relation to land-use conflicts and transport economics using an ADP-based map in the Arc-Info system.

10 SUPERQUARRIES IN NORWAY

Increasing international demand for raw building materials and stricter environmental requirements for aggregate production on the continent may lead to the situation whereby Norway becomes a major exporter of aggregate.

The western industrialised nations on the continent of Europe have a large and increasing need for raw building materials, i.e. sand, gravel and aggregate. At the moment their needs are satisfied through their own production and imports.

However, the increasing demand on the continent will, in the near future, face new environmental restrictions on exploitation. The most important reason for this is that many of the sources of supply are situated in areas with high population densities. In several European countries there are growing restrictions on exploiting gravel because of environmental conflicts. Gravel pits and aggregate quarries disturb the neighbourhood, because of the noise and dust. There is also a somewhat disputed exploitation of raw building materials from the sea-bed of the North Sea. In this case, large areas of sand and gravel are 'vacuumed' up. This destroys the breeding grounds for fish, and leaves large, submarine, desert-like areas. There is reason to believe that the North Sea countries will introduce in restrictions against this activity in the future.

Development and maintenance of settlements, roads, airports, harbour areas and other constructions are totally dependent on supplies of good quality raw building materials. New environmental restrictions in some areas will therefore increase the pressure on resources where the environmental consequences of exploitation are less. The search for more remote, but still accessible reserves has already begun. In this light, Norwegian stone stands out as an interesting possibility.

The branch has expanded internationally with the establishment of large, financially strong, industrial companies who themselves produce, sell and use building raw materials. Such companies, amongst them Tarmac, ARC, Redland and McAlpine in Europe and Vulcan in the USA, consider Norway as an especially interesting raw material supplier for the future. In the autumn of 1994 NGU received enquiries from a number of British companies on the possibilities of establishing aggregate plants along the coast.

Norwegian export

About 21 % of Norwegian aggregate production was exported to the continent in 1994. In 1982, the value of 500,000 tons of exported aggregate was ca. NOK 15 million. Ten years later, the volume had risen to 7 million tons with an export value of NOK 347 million, not including transportation. In 1993, export of aggregate decreased to 5.8 million tons, and in 1994 to 5.5 million tons.

The present-day export is supplied by c. 15 large aggregate quarries in the south of Norway, and goes mainly to buyers in England, Denmark, Germany, The Netherlands and Belgium. These countries together have a total consumption of 280 million tons of aggregate, Fig. 14.

Estimate analysis shows that the growth in aggregate consumption may increase by ca. 2.5 % per year. In that case, the markets in the above-mentioned countries will increase to ca. 460 million tons of aggregate by the year 2010.

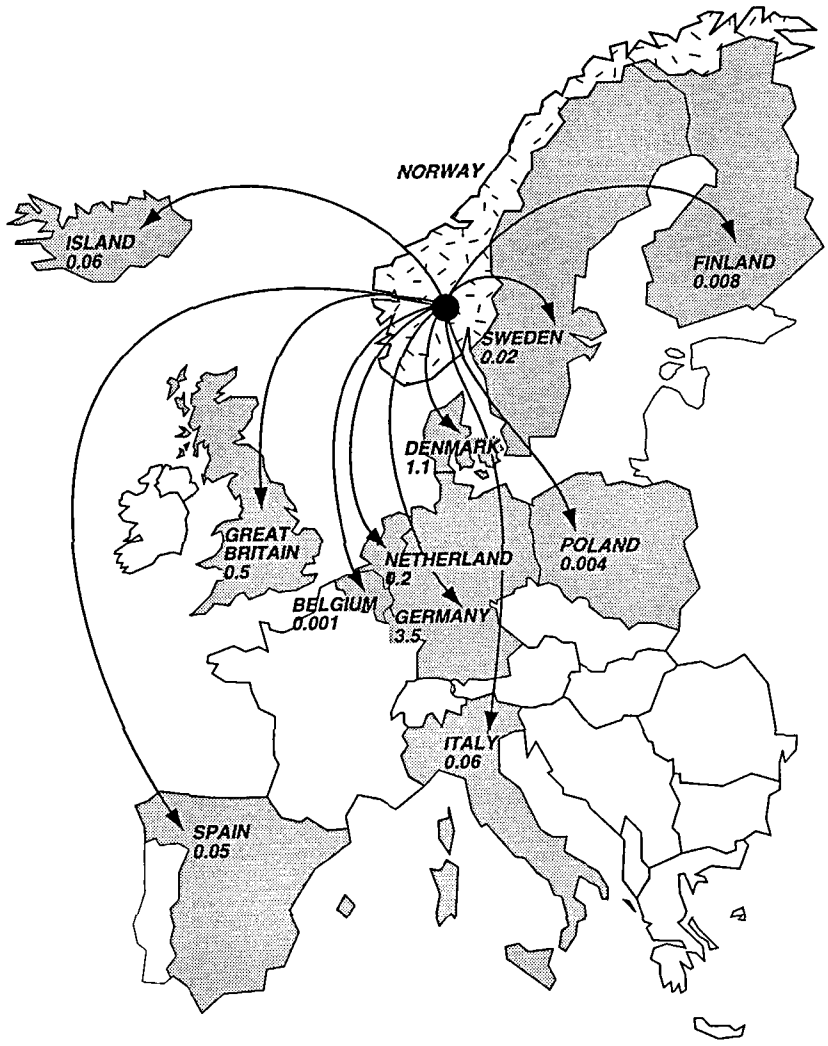


Fig. 14: About 21 % of Norwegian aggregate production, 5.5 million tons, was exported to the Continent in 1994

With today's share of the market and stable prices, Norwegian raw material sources may represent an annual production of 9.2 million tons in the year 2010, and an export value of ca. NOK 460 million.If we assume that the companies who base their production on Norwegian raw materials are capable of conquering 5-10 % of the market, then the consumer growth in Europe may form a basis for the establishment of several Norwegian superquarries with a total yearly production of 20-30 million tons of aggregate. In this case this will represent an export value of NOK 1.5 billion. In addition, there is the employment and income created by the transport. International companies also consider Norway as an interesting future raw material supplier for markets on the North American east coast, a perspective which is not included in this calculation.

It is important already today to clarify whether or not the natural, physical conditions in Norway are appropriate for establishing superquarries, such that Norwegian companies daring to take a risk will have a realistic basis for a long-term market and investment strategy.

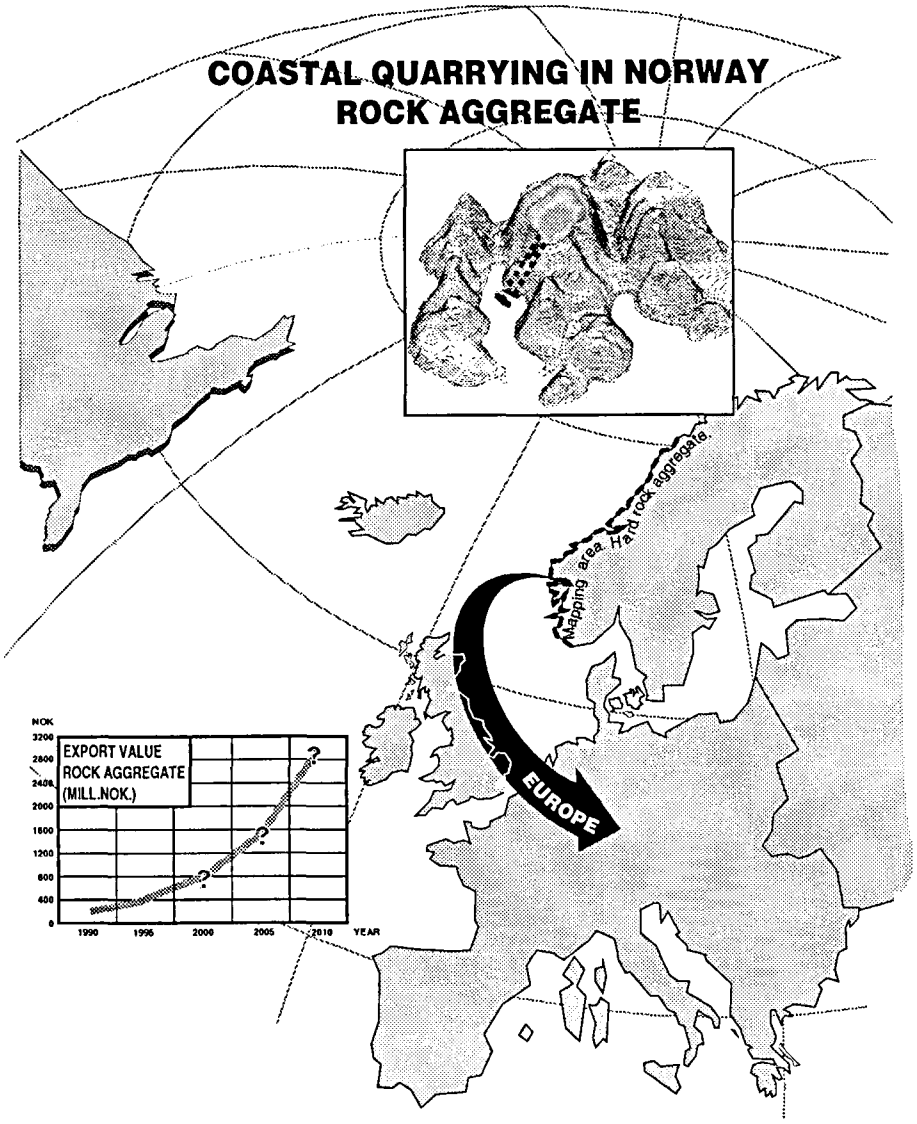


Fig. 15: Coastal quarrying in Norway of rock aggregate

Natural qualifications

Norway has the natural qualifications to enable it to play a major role in the international aggregate market. We have several different rock-types which are interesting in an export context, see enclosed bedrock map with hard rock aggregates in production. Parts of the Norwegian coastline are situated in a favourable manner so that transportation has a competitive advantage for the European market.

In a proposal to the authorities, NGU, has suggested a five-year project for mapping the best suited areas along the coastline from West-Agder to Troms, Fig. 15z. Central and North Norway are also included in the proposal to cover the possibilities of an export of aggregate to the American east coast. Even though the transport distance is great, it is a fact that most ships on the North American route travel with ballast. If this advantage is utilised, it could open up the market along parts of the east coast of the USA. The main objective of the mapping is to find the most suitable areas for establishing superquarries, as a basis for the local and county authorities' planning councils dealing with area planning. For instance, it may be necessary to place restrictions on certain areas with regard to future commercial developments. This must be seen in conjunction with the ongoing coastal zone planning which may set barriers for new exploitation in the future.

Environmental aspects

Superquarries will involve environmental inconveniences such as noise and dust emission, as well as creating large visible scars in the landscape. The big environmental challenge will be to establish production methods which will not be visible from the sea. This will entail the excavation of bedrock in mountainous terrain in quarries which are sheltered from view. The rock mass will be processed in an underground crushing/sifting plant and stored in silos inside the mountain itself. The transport of the aggregate will be done on conveyor belts through a tunnel out to the shipping area. In this way, the landscape maintains its form, noise is locked inside the mountain, and the dust can be dealt with in closed storage systems.

A major challenge for the aggregate industry will be to find a use for the fine fraction (material < 2mm). Many aggregate quarries store this part of the production material today, without any means of disposing of it. With a production of the size of a giant aggregate quarry, the lack of a suitable market for this material could represent a not inconsiderable environmental problem. Possible areas of application could be industrial mineral products (quartz, feldspar, mica), fine material additives (asphalt, concrete, plastic, ore), rock-wool materials, etc.

The mapping programme that NGU has proposed will concentrate on the following:
- Geological conditions
- Topography and harbour conditions
- Mapping of environmental conflicts
- Analysis of existing infrastructure

The mapping will not provide any specific appraisal of the market potential. NGU's task is to point out possible exploitable reserves of geological resources. This includes deposits which are not actual targets at the moment, but may attract interest in the future. Through such mapping, NGU plays a vital role in compiling the knowledge which is necessary to enable us to take the right decisions, both for areal planning and for the mining industry. When the day

comes, and the market is there, timing will be a crucial factor for success. It is therefore important that the preliminary mapping work is finished in good time. In that case, the aggregate quarries could then become the most important mining industry in Norway in the future.

Conclusions

Norway has many rock-types along its coastline which are interesting in terms of export potential.

Aggregate is being exported today from the south of Norway to England, Denmark, Germany, The Netherlands, Belgium, Island, Sweden and Finland.

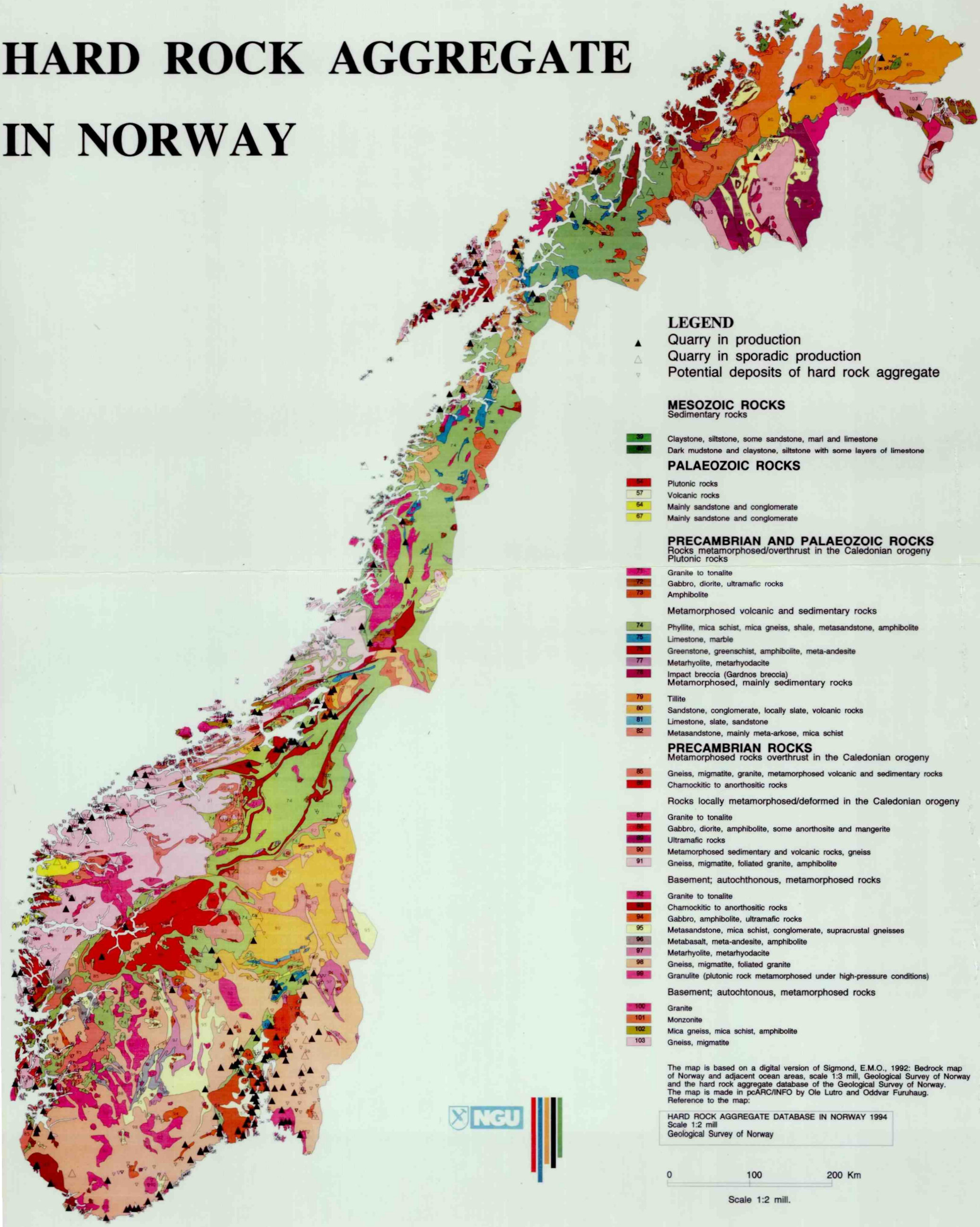
Norway has 17 large aggregate quarries which exported in 1994 a total of ca. 5.5 million tons valued at ca. NOK 270 million, exclusive of ship transport. The bedrock is dominated by gneiss, granite, anortosite, mylonite, gabbo, syenite and quartz-diorite.

Demand for aggregate is expected to increase towards the year 2000 in the most interesting countries for export in western Europe because of stricter environmental controls, especially in England.

There is reason to believe that coastal superquarries can provide the basis for Norway's most important mining industry in the future.

NGU, in collaboration with the aggregate industry, is planning to map the bedrock and rock-types along parts of the coast where environmental criteria, harbour conditions and topography are of potential interest for the mining industry.

HARD ROCK AGGREGATE IN NORWAY



LEGEND

- ▲ Quarry in production
- △ Quarry in sporadic production
- ▽ Potential deposits of hard rock aggregate

MESOZOIC ROCKS
Sedimentary rocks

- 39 Claystone, siltstone, some sandstone, marl and limestone
- 40 Dark mudstone and claystone, siltstone with some layers of limestone

PALAEOZOIC ROCKS

- 54 Plutonic rocks
- 57 Volcanic rocks
- 64 Mainly sandstone and conglomerate
- 67 Mainly sandstone and conglomerate

PRECAMBRIAN AND PALAEOZOIC ROCKS
Rocks metamorphosed/overthrust in the Caledonian orogeny
Plutonic rocks

- 71 Granite to tonalite
- 72 Gabbro, diorite, ultramafic rocks
- 73 Amphibolite

Metamorphosed volcanic and sedimentary rocks

- 74 Phyllite, mica schist, mica gneiss, shale, metasandstone, amphibolite
- 75 Limestone, marble
- 76 Greenstone, greenschist, amphibolite, meta-andesite
- 77 Metarhyolite, metarhyodacite
- 78 Impact breccia (Gardnos breccia)

Metamorphosed, mainly sedimentary rocks

- 79 Tillite
- 80 Sandstone, conglomerate, locally slate, volcanic rocks
- 81 Limestone, slate, sandstone
- 82 Metasandstone, mainly meta-arkose, mica schist

PRECAMBRIAN ROCKS
Metamorphosed rocks overthrust in the Caledonian orogeny

- 85 Gneiss, migmatite, granite, metamorphosed volcanic and sedimentary rocks
- 86 Charnockitic to anorthositic rocks

Rocks locally metamorphosed/deformed in the Caledonian orogeny

- 87 Granite to tonalite
- 88 Gabbro, diorite, amphibolite, some anorthosite and mangerite
- 89 Ultramafic rocks
- 90 Metamorphosed sedimentary and volcanic rocks, gneiss
- 91 Gneiss, migmatite, foliated granite, amphibolite

Basement; autochthonous, metamorphosed rocks

- 92 Granite to tonalite
- 93 Charnockitic to anorthositic rocks
- 94 Gabbro, amphibolite, ultramafic rocks
- 95 Metasandstone, mica schist, conglomerate, supracrustal gneisses
- 96 Metabasalt, meta-andesite, amphibolite
- 97 Metarhyolite, metarhyodacite
- 98 Gneiss, migmatite, foliated granite
- 99 Granulite (plutonic rock metamorphosed under high-pressure conditions)

Basement; autochtonous, metamorphosed rocks

- 100 Granite
- 101 Monzonite
- 102 Mica gneiss, mica schist, amphibolite
- 103 Gneiss, migmatite

The map is based on a digital version of Sigmond, E.M.O., 1992: Bedrock map of Norway and adjacent ocean areas, scale 1:3 mill, Geological Survey of Norway and the hard rock aggregate database of the Geological Survey of Norway. The map is made in pcARC/INFO by Ole Lutro and Oddvar Furuhaug.
Reference to the map:

HARD ROCK AGGREGATE DATABASE IN NORWAY 1994
Scale 1:2 mill
Geological Survey of Norway

NGU

0 100 200 Km

Scale 1:2 mill.