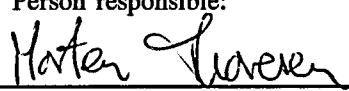


NGU Report 93.068

Aggregate Resources in Norway

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Summary: The Geological Survey of Norway 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 1993 and for the Hard Rock Aggregate database to be complete by 1996. The purpose of the deposits concerned, through identification of their location and quality and of possible land-use conflicts. 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. Keywords: Landuse conflicts, Superquarry, Aggregates, Analyses, Database, Sand, Gravel.					
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Aanalyser				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 1991 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 2,500,000,000. Annual consumption is c. 52.2 million tons of sand, gravel and hard rock aggregate. This corresponds to c. 13.4 tons/inhabitant, of which 5.9 tons is sand/gravel and the remaining 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 1992 was c. 5 mill. tons to Europe.

World production of sand, gravel and aggregates shows the 16 most important countries with Canada on top with c. 16 tons/year and Norway with c. 13 tons/year per capita.

The Gravel and Hard Rock Aggregate databases are computerized 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, 93.05.10



Peer-Richard Neeb
Programme manager

THE GROSS PRODUCTION VALUE OF NORWAY'S MOST IMPORTANT MINERAL PRODUCTS

(1991, MILL. NOK)

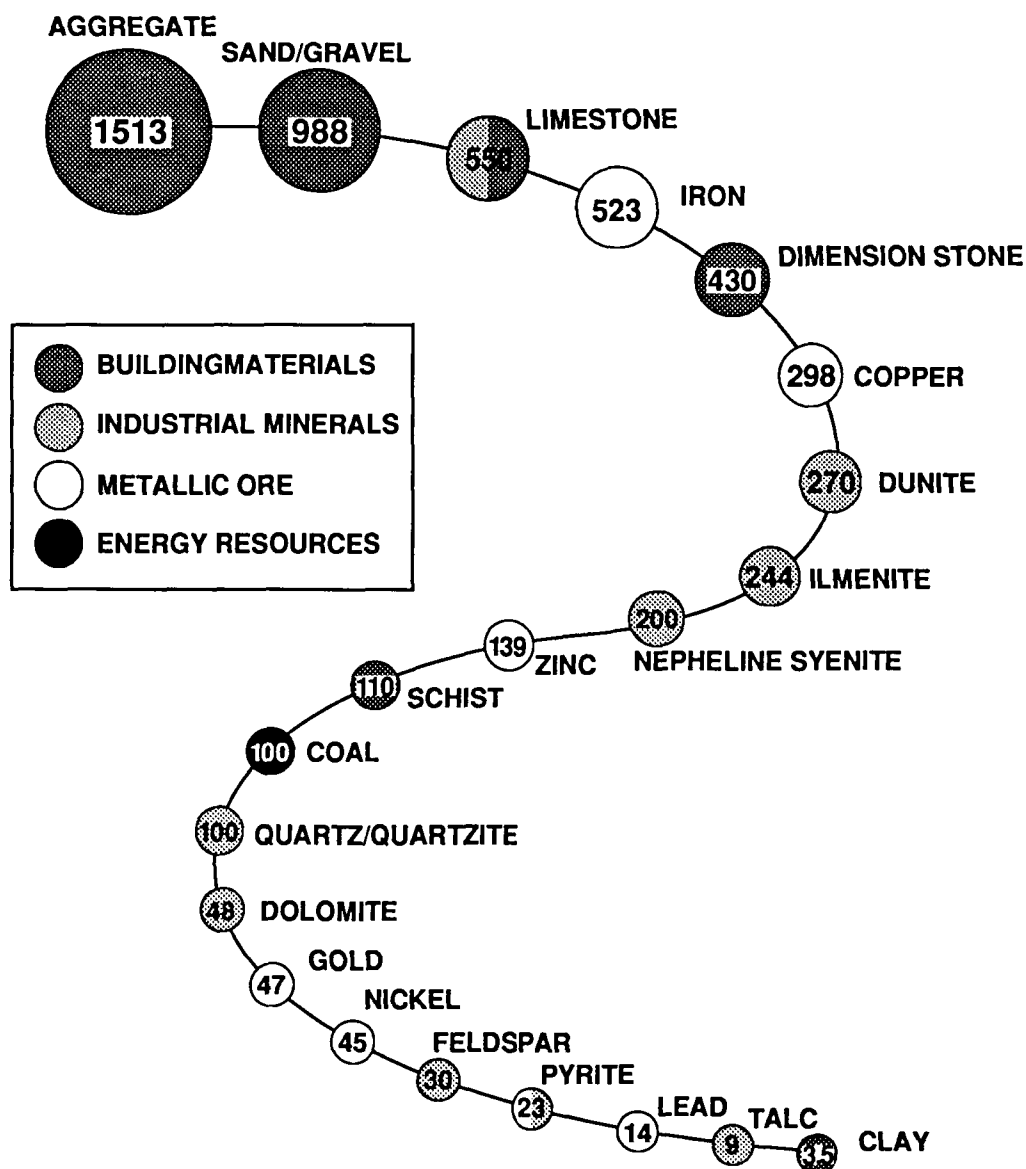


Fig. 1: The gross production value of Norway's most important mineral products

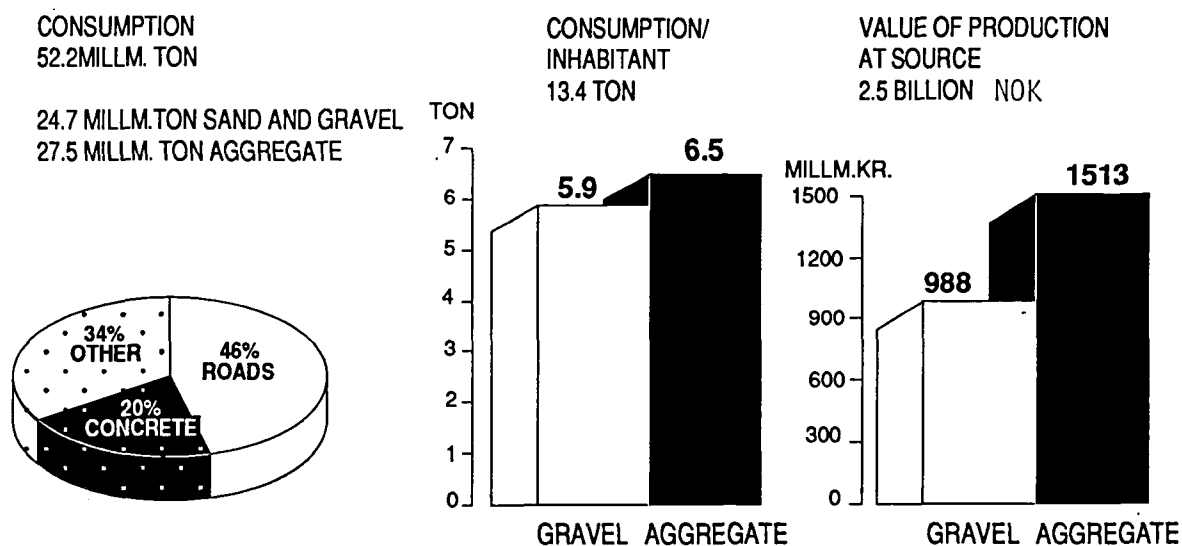


Fig. 2: Consumption and production value of sand, gravel and hard rock aggregate 1992/93

WORLD PRODUCTION OF SAND, GRAVEL AND AGGREGATE

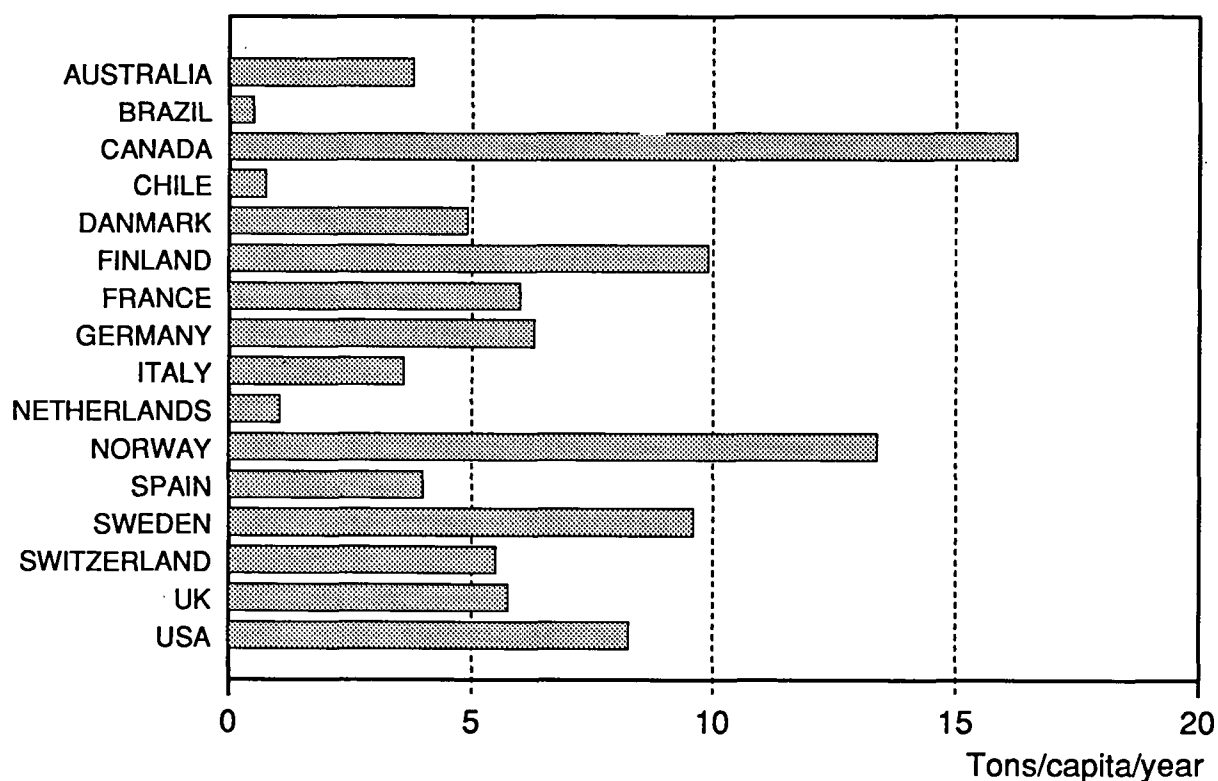


Fig. 3: World production of sand and gravel and aggregate (Rock Products International, February 1992)

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/m³. 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. Ground water is becoming an increasingly important component in our water supply. Important ground water 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, analyzed 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 becomes 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 m³ 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

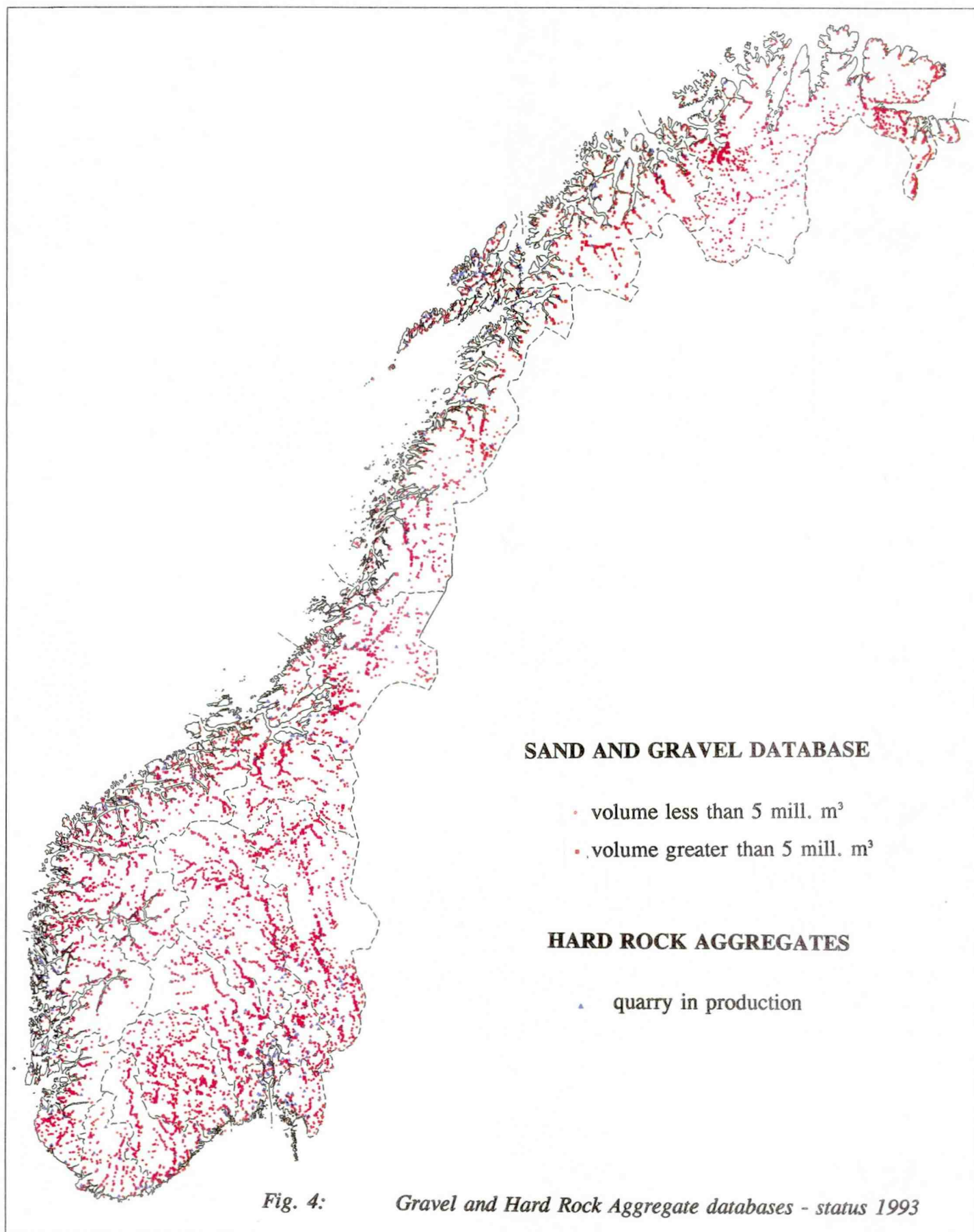
In the Gravel and Hard Rock database rocks are divided qualitatively to such criteria as **impact value, brittleness, resistance, abrasion value and ball mille value**. The content of mica, schist, mafic rock and grains of other types in the sand fraction is assessed.

The database also contains information on rock type(s) present, grain size, degree of compaction, quality classification, texture and petrography from thin section descriptions.

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



SAND AND GRAVEL RESOURCES IN NORWAY

Countrywise volume 1993

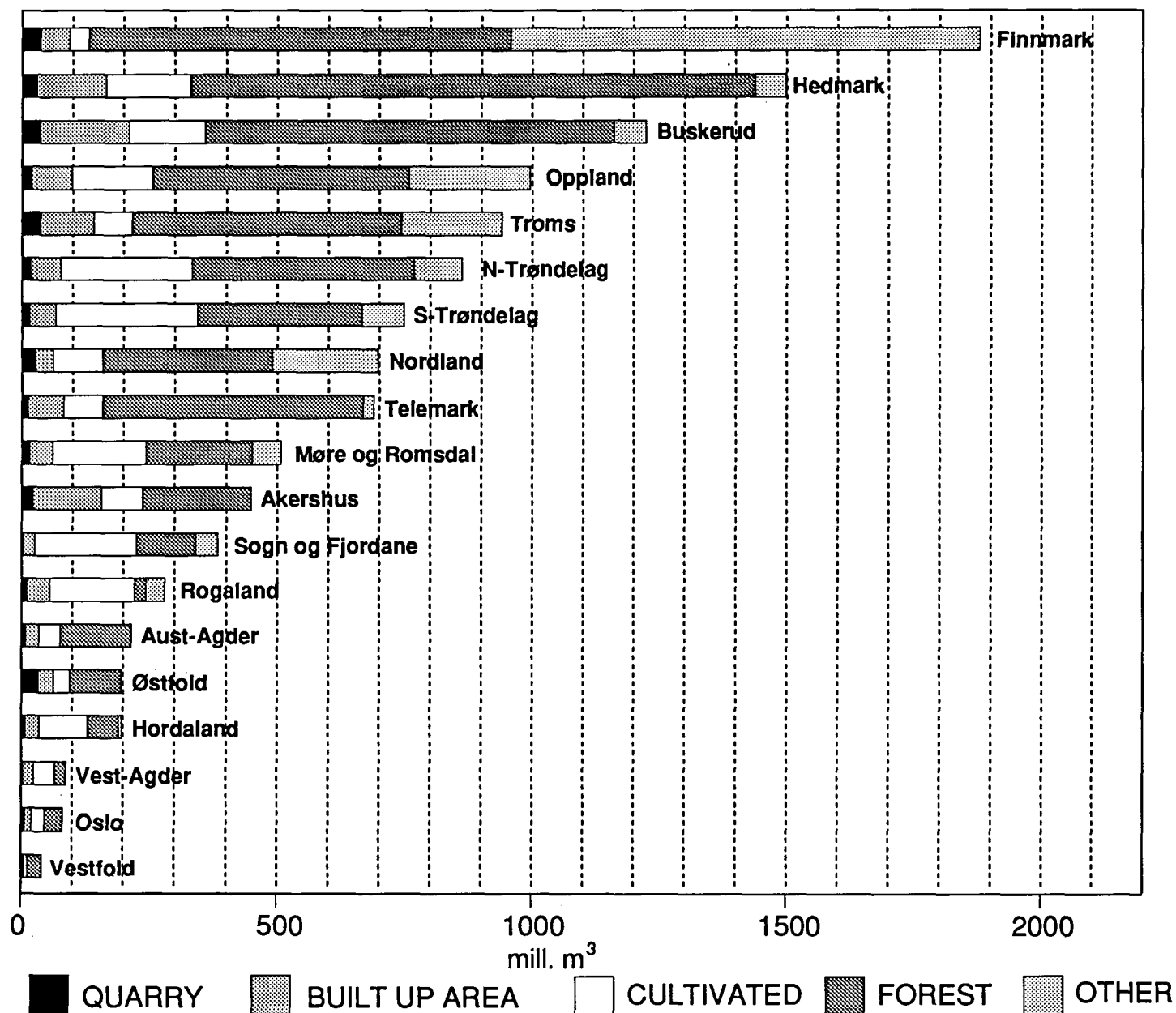


Fig. 5: Summary of volume from counties in which registration is complete

The databases will cover the whole country by 1993. The databases will thereafter be updated as required by NGU.

The Gravel database contains information on 8881 deposits. These include 832 active quarries, 4350 in intermittent production and 1602 abandoned quarries. 6784 quarries have been registered, Fig. 6.

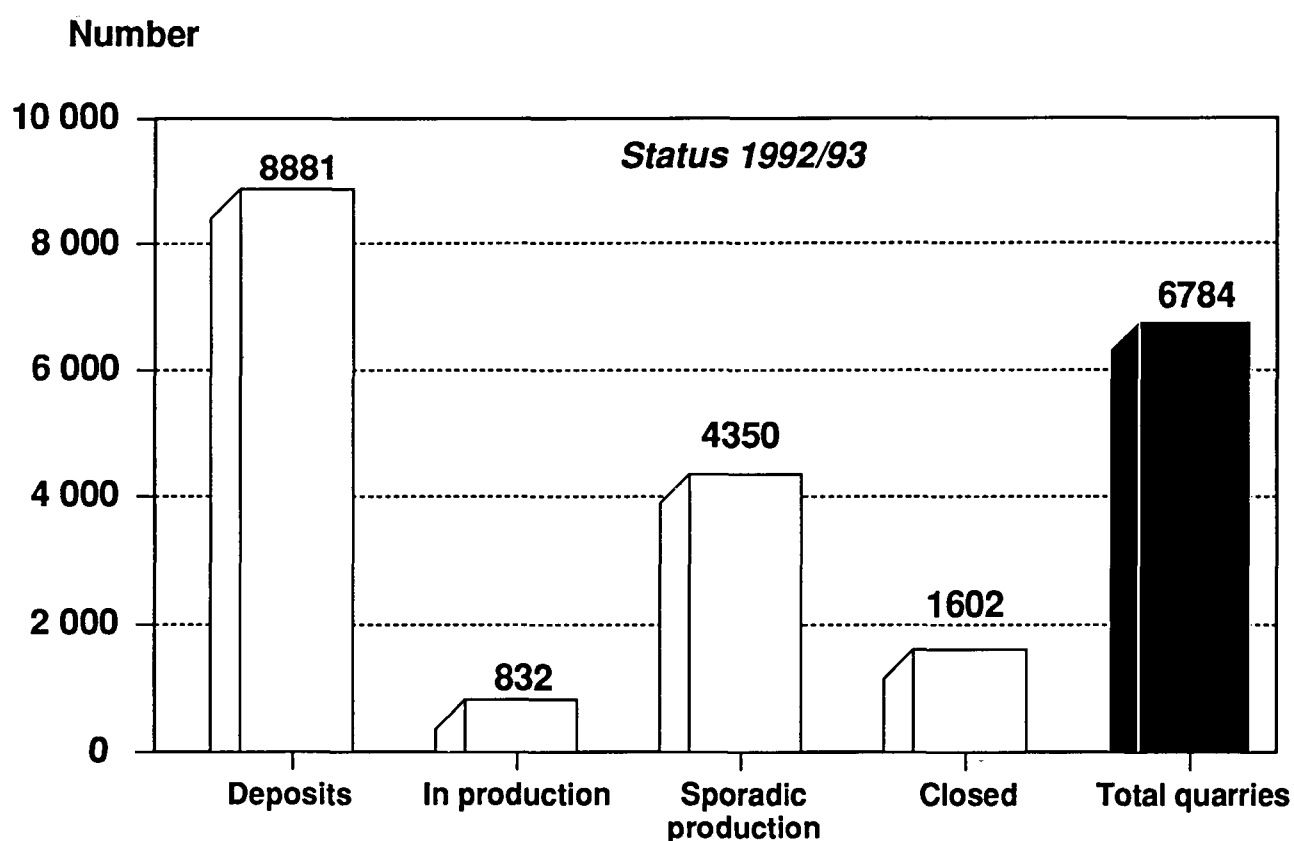


Fig. 6: Number of deposits registered in the Gravel database and their production status

The Hard Rock Aggregate database will cover special parts of the country by 1996 and contains now information on 934 deposits. 185 of these are in continual production, 114 in intermittent production and 201 have been in production but are now abandoned. 535 quarries have been registered, Fig. 7.

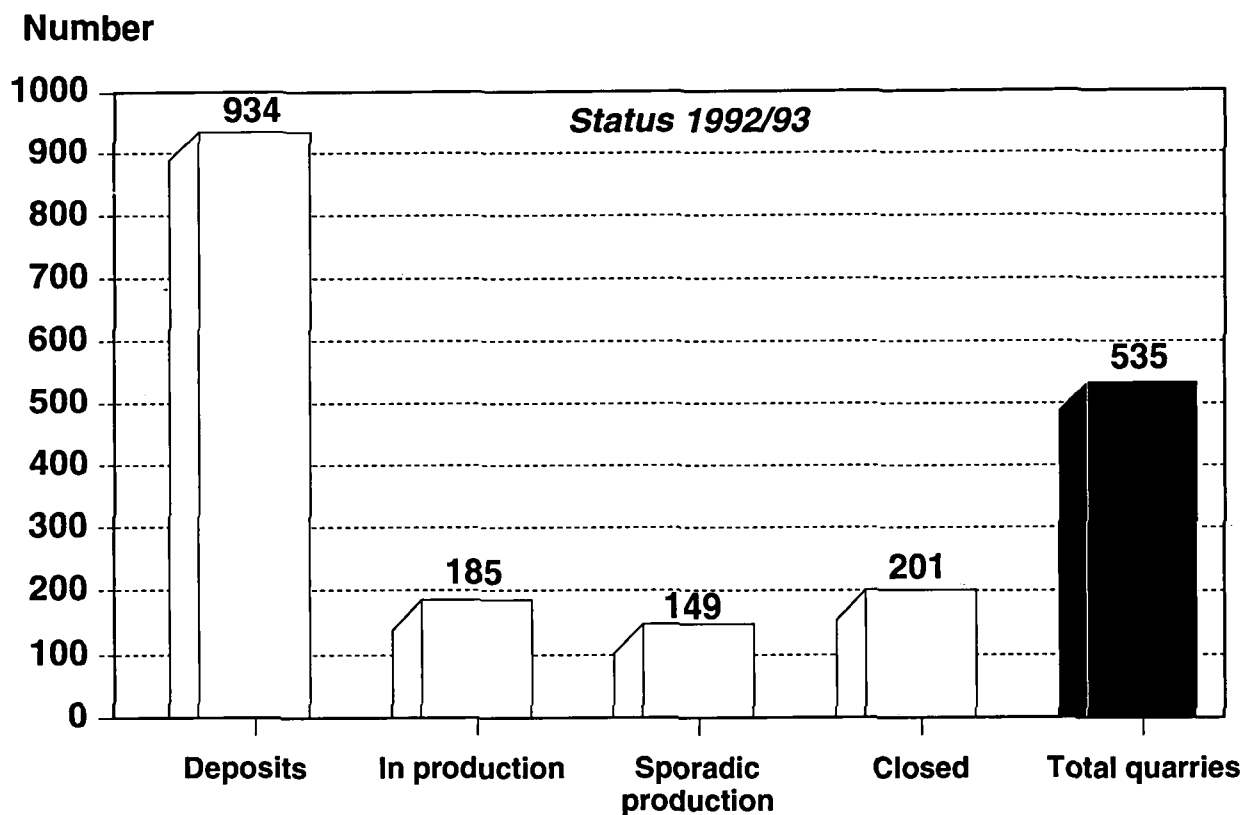


Fig. 7: Number of deposits registered in the Hard Rock Aggregate database and their production status

Total 7.319 quarries have been registered in Norway, Fig. 8.

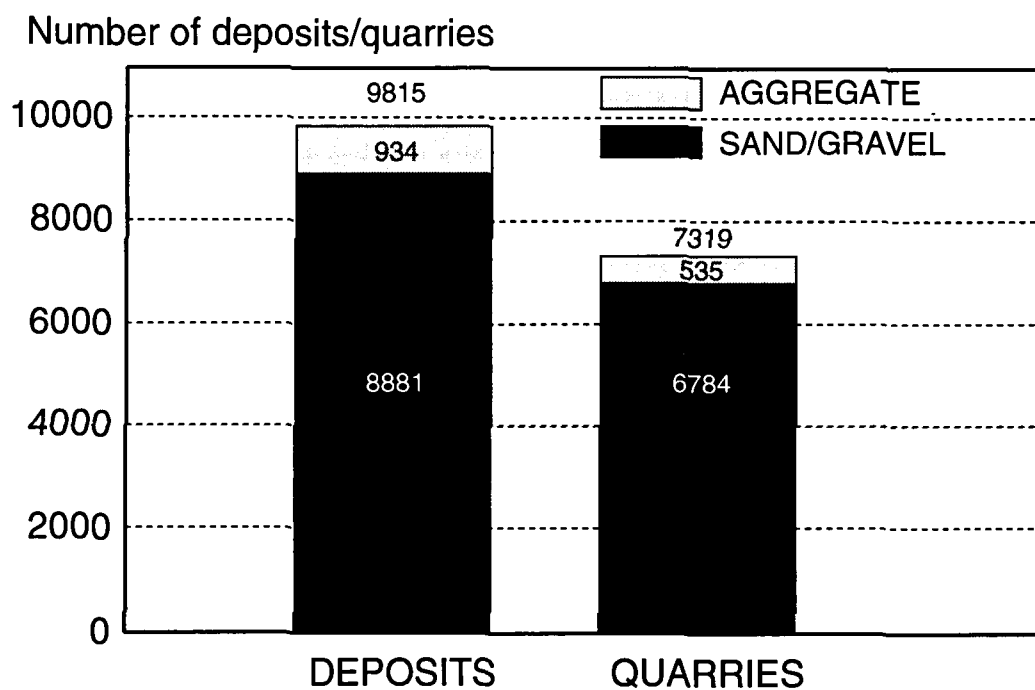


Fig. 8: Total number of deposits and quarries in Norway

Potential deposits of hard rock aggregate near major roads have been mapped in the county 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.

604 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.

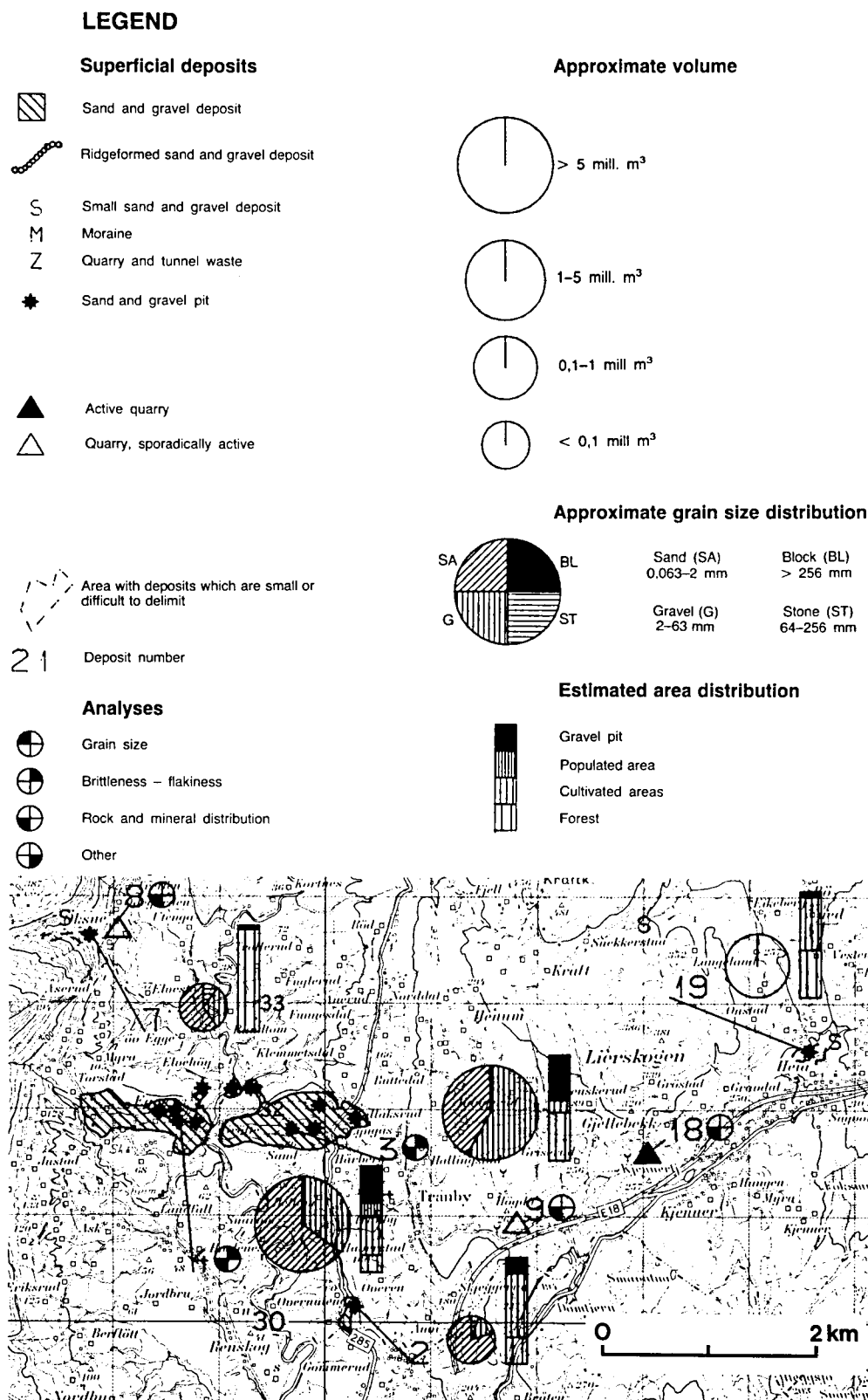


Fig. 9: Example of map of sand- and gravel resources and hard rock aggregates; part of the Lier map-sheet, 1:50,000

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.

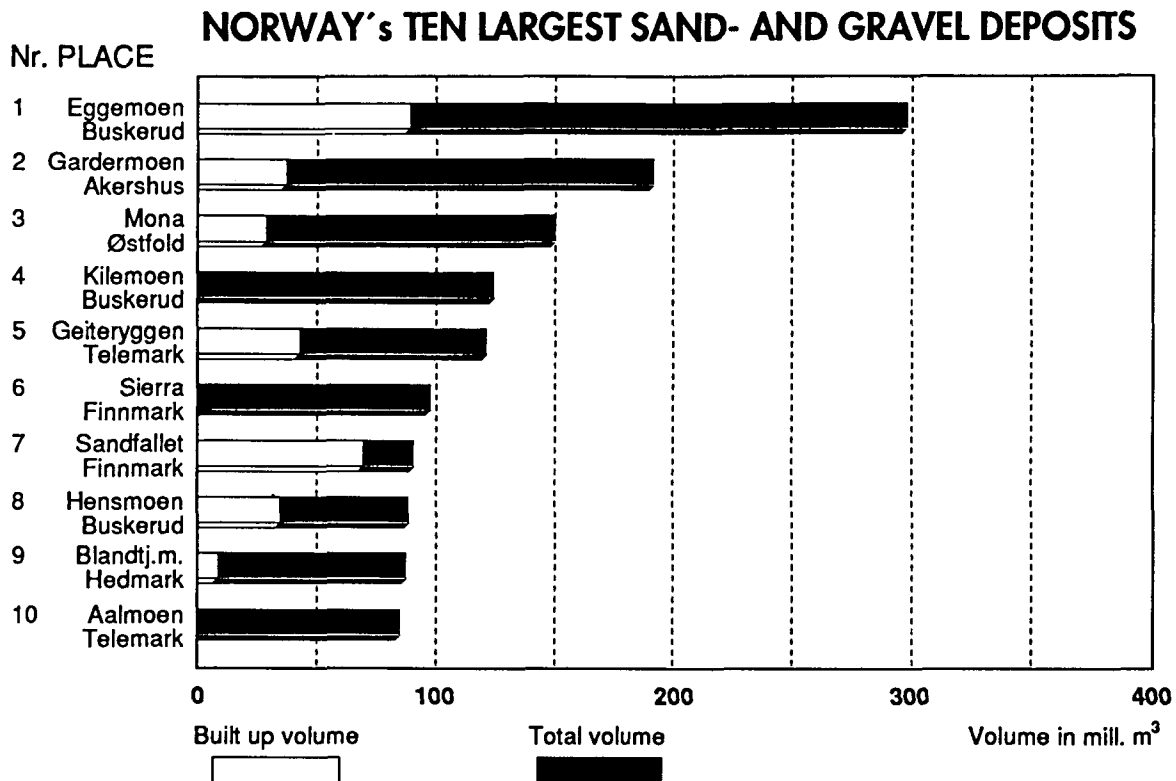


Fig. 10: Norway's ten largest sand- and gravel deposits - volume in mill. m³

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 considerable 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 higher water requirement. This, in turn, leads to reduced mortar strength after solidification. The mineralogical composition 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 southern part of Norway for export to Europe has increased in 1990, especially concerning 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 flow diagrams for each commune, based on the data in the databases, Figs. 11 and 12.

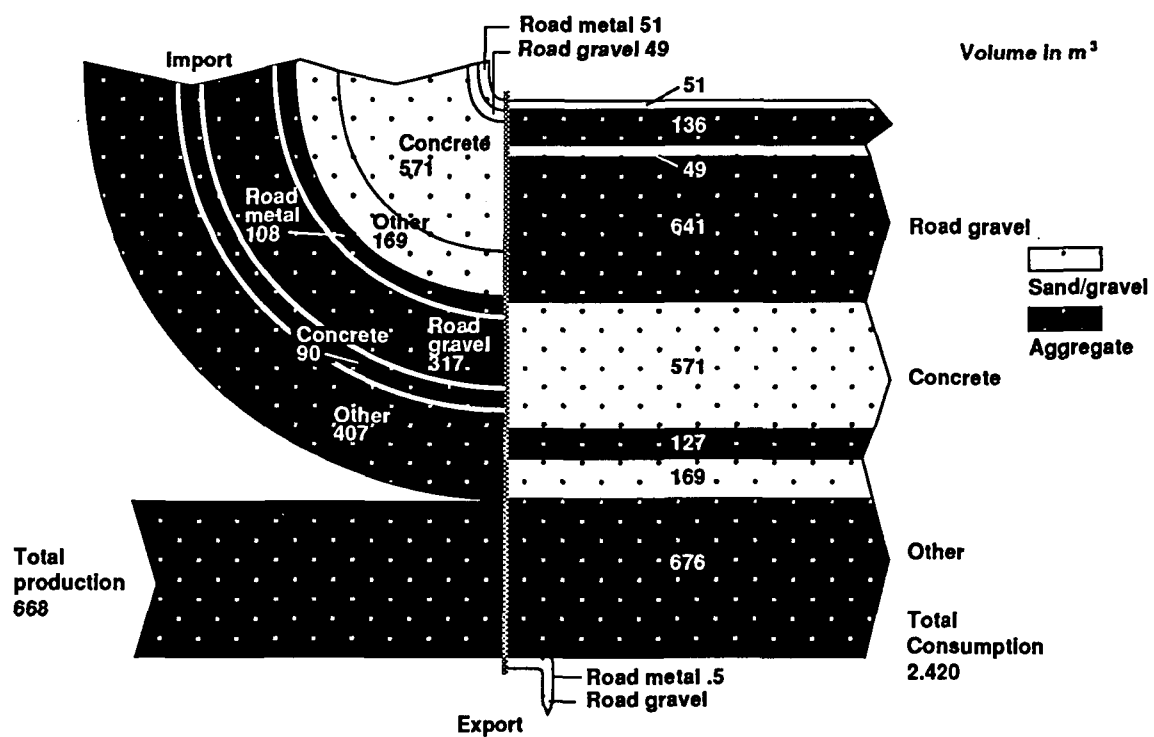


Fig. 11: Production and consumption of sand and gravel in Oslo commune, 1988
(1000 m³)

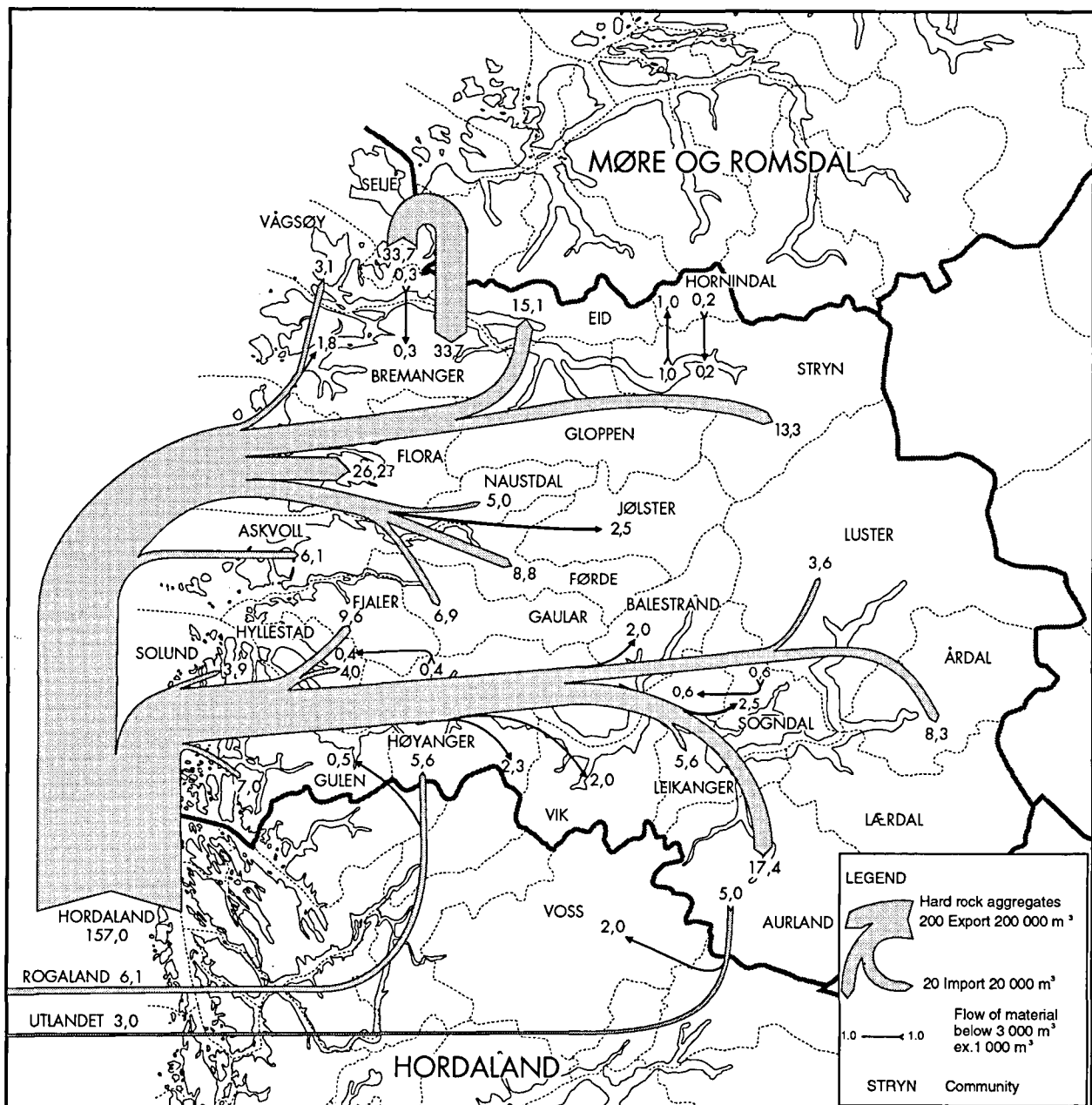


Fig. 12: Production and consumption of hard rock aggregate in Sogn og Fjordane county 1991

The diagrams show the type of material, its volume and application, both for production within the commune and import materials on the one side, and for consumption and export on the other.

The results from each commune are assembled and analyzed on a county or regional level. Table give 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 (Fig. 12).

There are geographical variations in consumption per capita, Fig. 13.

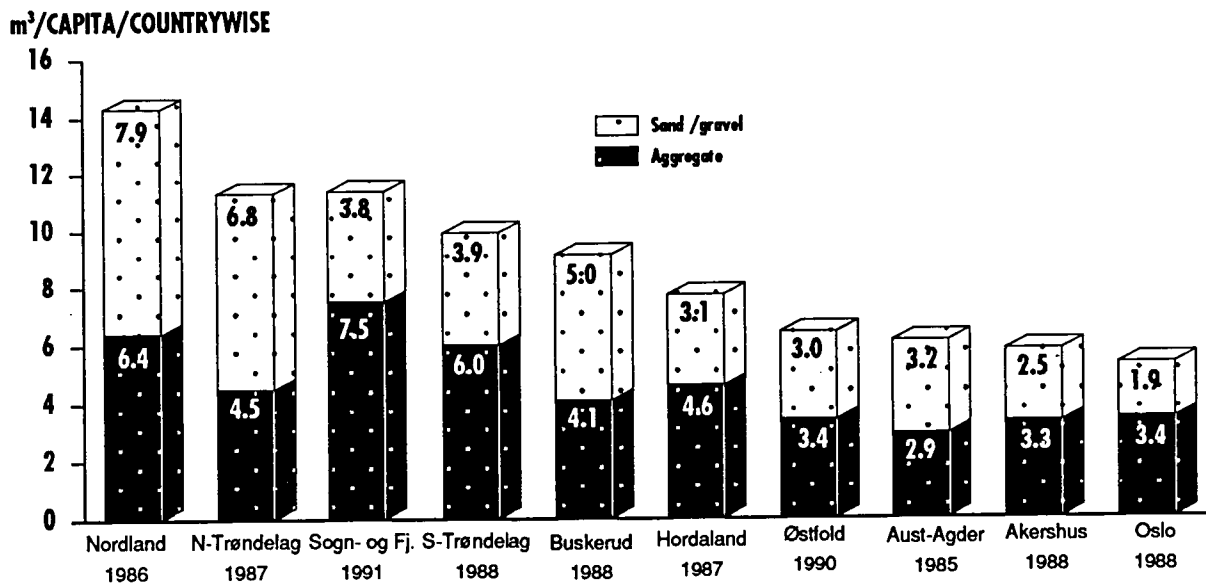


Fig. 13: Annual consumption of sand, gravel and hard rock aggregate/capita in selected counties

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.

An important aspect of annual resource is the possibility 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 pattern 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 the 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.

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 ADP-based map in the systems Arc-Info.

10 SUPERQUARRIES IN NORWAY

Market investigations show that there will be an increasing demand for raw construction materials in Northwest Europe. High population density and more stringent restrictions for mineral extraction imply that a larger proportion of the supply must be imported from further afield.

The extracted quantities for a future Superquarry are from 2-5 million tons/year, with a potential total resource of at least 150 million tons. Both Northwest Europe and parts of the USA can be important markets for Norwegian hard rock.

The Survey methods which must be developed in order to locate areas which are suitable for massive aggregates quarries should be based on topography, harbour access & possible conflicts with environmental interests. Existing municipal plans, county plans & conservation plans can indicate such possible areal conflicts.

NGU's preliminary conclusion on Superquarries in Norway is:

- Superquarries in Norway can be our most important mineral industry on land in the future.
- New mineral industries must be developed on the basis of increased knowledge of markets and products.
- Norway has currently 185 hard-rock aggregate quarries in production and 15 of these have a combined production for export of 5 million tons (total production c. 27 million tons).
- Consumption in Europe is c. 1,7 billion tons sand, gravel and hard-rock aggregates.
- Restrictions on the extraction of sand and gravel in a number of countries in Northwest Europe, and indeed exhaustion of supplies in a number of regions will increase the amount of crushed rock aggregate requirements.

- Europe needs 5-10 new superquarries in Norway for production of 2-5 million tons/unit/year.
- NGU must map all potential coastal rock units for which environmental, topographic and transport criteria would allow quarrying from the year 2000.

HARD ROCK AGGREGATE IN NORWAY



LEGEND

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

MESOZOIC ROCKS

Sedimentary rocks

- 56 Claystone, siltstone, some sandstone, marl and limestone
- 57 Dark mudstone and claystone, siltstone with some layers of limestone

PALAEOZOIC ROCKS

- 58 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)
- 79 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; autochthonous, 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

