# Earth Sciences Research at Norwegian Universities and Colleges

*A review*

*Volume I: Assessments, recommendations and conclusions prepared by the Review Committee*

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## To the Research Council of Norway

The members of the Review Committee on Earth Sciences at Norwegian Universities and Colleges hereby submit the following report.

Our task has been to make an adequate, comprehensive, and fair review of the research activities in Earth Sciences in Norway during the last five years, and to make remarks about possible future developments. This task has been demanding in view of the short time available, and the fact that most committee members were unfamiliar with the Norwegian academic scene before beginning this assignment. The Committee hopes that the review will nevertheless be a worthwhile source that can be used by the Research Council of Norway, as well as by the faculties, institutions, departments, sections, and research groups concerned.

The views expressed in this report are the consensus views of the Committee. The members of the Committee are in collective agreement with the assessments, recommendations and conclusions presented.

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Chairman

André Berger

Simon Klemperer

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# Preface

This is the report of an *ad hoc* international committee formed by the Research Council of Norway to review and assess the research in Earth Sciences at Norwegian universities and colleges. This report has been prepared specifically for the Research Council of Norway, which reserves the right to use the content as it sees fit.

The Committee was given reports from the departments and research groups about three weeks prior to their November 2, 1997 meeting in Oslo where the overall structure of Earth Sciences in Norway was summarised. Meetings took place between November 3 and 6 with about 60 staff faculty members representing 16 institutes, departments and museums. The more than 60 oral presentations of research activities and the discussions between presenters and Committee members were very informative.

The Committee was able to discuss research-related issues with a significant number of responsible staff and thus obtained sufficient information on which to base a well-balanced and fair assessment. The Committee is confident that its analysis and recommendations are generally well founded. We hope that this report will not be regarded as a final ”judgement”, but rather will be looked upon as a constructive basis for future improvement, change, and development of the Earth Sciences in Norway.

# Contents

# 1. Conclusions and recommendations

The Committee has found the quality of Earth Sciences in Norway to have a good standard comparable to that of most countries of similar size and economic power. Norway is a country with more earth scientists per capita than the USA and all states of EU. The Earth Sciences in Norway have strong links to and are of great importance for the petroleum industry in the country.

Training and research activities in Earth Sciences are mainly organised at the regional level and often involve only small groups of students. To enhance efficiency and productivity, collaboration should be strengthened by inter-university contacts and co-operation in several of the fields. Forming centres of excellence for the major fields might be better than doing everything everywhere. The Committee is of the opinion that both the productivity of research and the education in Earth Sciences at the Norwegian universities are above average compared to other countries when calibrated for population differences. This statement is supported by statistics on the number of people who complete their degrees, rate of publication and number of citations in scientific journals.

The exploration and production of oil and gas in the Norwegian sector of the North Sea has made the research and teaching in Earth Sciences strongly industry driven. A total of 84 million Norwegian crowns was invested by the Research Council of Norway in a petroleum-related basic research programme between 1985 and 1992. The programme was successful and most of the goals of the programme were achieved. The Research Council was launching an additional programme 1992-1997 (total of 74 million Norwegian crowns) and is planning to start a new programme in petroleum-related research this year. The Committee would like to stress the need for long-term basic research. The funding of basic Earth Sciences research at the very least has to be maintained, and if possible increased.

The Committee found support from industry to be excellent. However, the reliance on the petroleum industry for funding, and the emphasis on research subjects relevant to the petroleum industry, results in a serious problem for the Universities to retain the most innovative and excellent scientists.

The Committee met about 60 faculty members representing sixteen institutes, departments and museums. It is evident that several of the institutions suffer from a lack of strong leadership. This may be a result of the excessively democratic process by which leaders are appointed within Norwegian institutions. The democratic system should be such that excellent scientists of vision should be appointed to positions of leadership, and given powers needed to provide leadership, for an extended term (5-6 years). It needs to be stressed that the head of departments and/or senior professors are responsible for the development of their disciplines and their departments and must more actively be involved in making decisions for future directions and appointments of faculty members at all levels of the university system.

The Research Council of Norway should support initiatives from excellent individual scientists and well-organised groups of scientists; it should not attempt to steer or direct the university system. The Research Council can take a much stronger role in supporting new national facilities, or re-organising existing dispersed facilities into national facilities. Also the Council can take an active

part to stimulate hiring of international stars in Earth Sciences by providing start-up resources on a case-by-case basis.

Summary statements from each of the topics discussed follow.

- International collaboration must be sustained and even enhanced to increase intellectual resources for Earth Sciences research in Norway. Only a few scientists from Norway are leaders of international programmes in the Earth Sciences, although they contribute significantly to their success.

- Training and research activities in the Earth Sciences are mainly organised at the regional level, with few national collaborative programmes. Collaboration in glaciology should be strengthened by inter-university contacts with the Institute of Geology, University of Tromsø. We note with interest the constructive discussions relating to the possibility of setting up a marine science faculty within the University of Bergen, and of transferring the mineralogical laboratory from the Mineralogical-Geological Museum to the Department of Geology, University of Oslo.

- A serious problem recognised by the Committee, as well as by many of the departments, is the persistent selection of new faculty from a department's own graduate students. Appointment (search) committees should be established and should include representation of faculty members from the appointing department as well as international experts. All permanent and effective tenure-track positions requiring a doctorate should be advertised internationally.

- To ensure greater educational diversity among potential candidates for faculty positions, the recommendation should be made that only two of their degrees should be obtained from any single institute or university (the two-degree rule).

- The peak age distribution of Earth Sciences faculties on the whole consists of people in their 50s. The statistics also show that most departments have been consistent in hiring young people to fill open positions, and that few older faculty (>65 years) remain actively employed. We encourage this recruitment of young faculty, but we would also like to see more active mentoring and support of early-career faculty, and we would like to encourage mobility of mid-career faculty between departments.

- To reduce the excessive teaching load, each department should seriously consider a complete curriculum revision, combine faculty efforts across departmental boundaries to avoid duplication, and consider teaching small classes only in alternate years.

- University salaries in the Earth Sciences should be raised substantially to enable recruitment and retention of first-class individuals in the face of industry competition. The Committee recognises the intellectual value to faculty of outside consultancies, but recommends that Norwegian universities adopt formal policies restricting the limits of outside consultancies (20% time, analogous to a professor-II appointment, seems a generous maximum).

- Professor-II (20 %) appointments are a splendid innovation in the Norwegian university system, and should be strongly promoted as an excellent way of bringing industry and research-institute expertise into the university research and teaching community.

- The Committee is sceptical as to whether or not external examiners (censors) are routinely necessary for all graduate and undergraduate class exams. It should be sufficient if each course is externally audited once every three years.

- The Earth Sciences have a prominent position in the overall publication profile in Norway. Norway produces more than twice as much as the expected number of publications in this field and is the country with the highest production of publications per capita in Earth Sciences after Iceland.

- Norwegian scientific publications in Earth Sciences are cited less frequently than the average. The citation frequency even has a weak decreasing tendency from the middle of the 80s. A small number of journals concentrate the bulk of the Norwegian publications in Earth Sciences. The journal *Norsk Geologisk Tidsskrift* is the most important journal for Norwegian visibility in these fields.

- The Norwegian publication profile in Earth Sciences is quite internationally oriented. About 50 per cent of all Norwegian publications in Earth Sciences are co-authored with researchers from other countries. The USA, UK and Germany are the countries with which Norwegian researchers co-operate the most. In addition there is considerable publication activity in non-geosciences fields involving Norwegian institutions in Earth Sciences.

- The Committee sees a need for Norwegian geoscientists to formalise major future instrument investments as national facilities. Major capital equipment should be jointly proposed by a consortium of two or more departments but run by one responsible research group.

# 2. Introduction

## 2.1 Mandate

Following the decision by the Research Council of Norway to review Norwegian research in the Earth Sciences, the Council invited seven qualified scientists representing various fields within the Earth Sciences to undertake this task. A Committee was established and charged with the mandate presented in Appendix 1.

According to the mandate, ”the general review should clarify which fields are represented in Norwegian Earth Sciences research, the structure of the academic departments of Earth Sciences, the personnel on different levels, age structures, the funding of the research groups, the situation concerning equipment, publications and citations and degree of mobility”. In addition the following main aspects were to be considered:

- scientific activity and quality;
- international and national collaboration;
- training and mobility;
- relevance of the scientific research.

## 2.2 Panel Members

The evaluation Committee consisted of the following experts (their CVs are presented in Appendix 2):

| | |
|---|---|
| Professor Ove Stephansson Chairman<br>Division of Engineering Geology<br>Department of Civil and Environmental Engineering<br>Royal Institute of Technology<br>SE-100 44 STOCKHOLM<br>SWEDEN | |
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Adviser Are Birger Carlson of the Research Council of Norway played a key role in presenting the instructions to the research groups, arranging the meetings with the groups, and collecting statistics of research activity and results of the research groups. He also participated in processing the final report.

Maria Ask, doctoral student in Engineering Geology at the Royal Institute of Technology (KTH), Stockholm, assisted the Committee in compiling and organising the submitted reports from the research groups, recorded and typed the memos from the Committee meetings, and compiled and edited the final report. Associate professor Joanne Fernlund at the Division of Engineering Geology at KTH assisted in correcting the English in the final report. Executive Secretary Signe Dahle Urbye of the Research Council of Norway assisted the Committee in processing the report.

## 2.3 Key Information and Major Issues of the Review Process

In spring 1997, the Research Council of Norway informed the relevant institutions of its plan to review, on an institutional level, the Earth Sciences research at Norwegian universities and colleges. Professor Ove Stephansson of the Royal Institute of Technology, Stockholm, was appointed chairman of the Committee and met with the Advisory Committee for Chemistry, Earth Sciences and Biology (KGB) in the spring of 1997. The Review Committee was established in June 1997.

The institutions were informed of the information that was required by the Committee, in a letter from the Research Council in July 1997 (Appendix 3). The reports from the institutions were compiled and sent to the members of the Committee for review. The Committee met in Oslo on November 2 to plan the meetings with the research groups. The review took place at the Radisson SAS Park Hotel, Fornebu, November 3-7, 1997. In total, the Committee met more than 60 scientists and reviewed 19 institutes/departments/museums. The review of each institution began with a presentation by the head of department or the leader of the research group who summarised the main characteristics, strengths, and weaknesses of the institute/department/museum. Thereafter, each research group within an institution presented their main research activity, results, and plans for the future.

### 2.3.1 Outline of the Review Report

The report first presents some general information relating to the Committee and the procedure for the review. A ”national portrait” of the Earth Sciences in Norway is presented, in which the Committee expresses its general view of critical issues such as collaboration, integration of groups and topics, department structure, mobility, inbreeding, and productivity. These statements are based on the outcome of the written information submitted by heads of department and the oral presentations to the Committee. The review of the institutions presented in Chapter 4 gives a brief description of the organisation of each institute and its main characteristics, productivity with respect to publications and production of master and doctoral degrees, and finally, a general assessment and recommendations. The institutes, departments and museums evaluated, standard figures about expenditures of R&D, scientific personnel in Norwegian Earth Sciences, and publications and citations are presented in a separate report (Volume II).

# 3. National Portrait

Under this heading, the Committee has made conclusions that we consider to be of general importance for the Research Council.

## 3.1 International Collaborations

Most Norwegian scientists are collaborating with colleagues from other countries. This is primarily or exclusively through personal contacts with experts working on the same topic or having a common interest or expertise. Collaboration is mostly through participation in international programmes, and although few Norwegian scientists lead international programmes, they do contribute significantly to their success.

International collaborations should be sustained and even enhanced to increase resources for research in Norway (finance, equipment, researchers). In addition to the direct benefit of experience working with highly regarded groups, this participation prevents scientific isolation, stimulates the continuation of local research activities, increases the visibility of Norwegian research abroad, and enhances the general activity of individual scientists.

As a consequence, mechanisms should exist in Norway to help and encourage scientists to participate in such collaborations, in particular by funding national programmes based at different institutes that are working on similar projects.

## 3.2 Integration of Groups and Topics

Training and research activities are mainly organised on a regional level; few national collaborative programmes exist (two exceptions are Climate and Ozone and Petroleum Research). Each of the five following locations have the potential for at least one centre of excellence: Meteorology and Geophysical Fluid Dynamics in Oslo (1), Palaeoceanography and Marine Sciences in Bergen (2), Earth Resources in Trondheim (3), and Arctic Environment in Tromsø (4) and UNIS at Svalbard (5). There is also a strong potential for intensifying collaboration between different Norwegian departments, mining and oil industries. In particular, in Bergen, the Institute of Solid Earth Physics, and the tectonics, petroleum geology, and sedimentology groups of the Department of Geology; in NTNU, the Departments of Geology, Mineral Resources Engineering, Petroleum Engineering and Applied Geophysics; and in Oslo, the Department of Geology.

Very often, collaboration between the departmental subgroups in a single university is poor (e.g., within the Division of Mechanics at Oslo; the Departments of Geophysics at Oslo and at Bergen; within NTNU). Most often co-operation with scientists in other departments and universities is conducted on a personal level. This freedom claimed by some scientists certainly has advantages, but it is also a source of weakness, particularly when no new university resources are available to the departments. In such cases, planning should be based on consolidation of activities, and the selection of new fields of research should be based on setting of new priorities and/or sharing resources at both the department and faculty levels within the same university. This policy may be

extended to collaboration between institutions and universities, at least for some very specific topics where a complementary approach might be the goal, instead of duplication or competition. Closer contacts between the Earth Sciences departments, including both the same disciplines and across them, brings benefits with respect to teaching, research, administration, and large equipment facilities (including computing power, with proper software and programmers).

For small groups, national and international collaboration is probably necessary for survival and should be emphasised so as to enable them to perform research of an international standard (as achieved in collaboration with NOPEX and FRIEND, for example, by the hydrology group at the Department of Geophysics in Oslo).

In all cases, strengthened national collaboration in teaching and research will help to (1) increase efficiency, (2) prevent isolation, (3) decrease costs, (4) reinforce priority research, and (5) achieve better results more rapidly using complementary expertise.

A good and efficient collaboration between some departments already exists, e.g., the Department of Soil and Water Sciences of the Agricultural University of Norway in which scientists with different backgrounds work together and co-operate with the Departments of Geophysics and Geology at the University of Oslo on the Gardermoen project. These three departments have also fully integrated their curricula in hydrogeology, thereby avoiding duplication. Arctic research at the University of Tromsø, Institute of Geology, is conducted collaboratively with other institutions from regions adjacent to the Arctic Ocean. The Department of Hydraulic and Environmental Engineering at NTNU is particularly well integrated in projects with SINTEF on Hydrology and Water Resources. The Strategic University Programme on realistic ocean waves recently submitted by the Division of Mechanics at the University of Oslo in co-operation with the Department of Geophysics might be a good opportunity for closer collaboration between these two groups and could eventually lead to their merger.

We have listed below areas where more collaboration is recommended. We recognise that some of our recommendations may not be relevant since some departments have recently been evaluated and already restructured, i.e., the Department of Geography at the University of Bergen, the newly created Institute of Geology at the University of Tromsø, and the Department of Hydraulic and Environmental Engineering, NTNU.

### 3.2.1 Glaciology Throughout Norway

Only one glaciologist now holds a permanent position at a Norwegian university. Because Norway is a country where field research in glaciology is possible, this field should be reinforced. This could be done at any of the following university departments: the Institute of Geology at the University of Tromsø; the Department of Physical Geography at the University of Oslo, which already participates actively in glaciological studies through EU programmes; the Quaternary and Marine Geology Group at the Department of Geology, University of Bergen; and the Department of Geography at the University of Bergen. In addition, close collaboration should be fostered between the different groups involved and the Norwegian Polar Research Institute at Tromsø.

### 3.2.2 Marine Sciences at the University of Bergen

The creation of a Marine Sciences Faculty at the University of Bergen is being investigated. This initiative deserves special consideration, not only by the Quaternary and Marine Geology Group of the Department of Geology that is directly concerned, but also by the Departments of Geophysics and Geography of the University. With regard to the Geophysical Institute, a further focus on climate modelling and a strengthening of the collaboration between oceanographers and meteorologists would be very desirable.

### 3.2.3 Earth Sciences in Oslo

Earth Sciences at the University of Oslo is among the largest groups in Europe. It is divided into three departments and contains two museums. This results in problems, such as inadequate and overlapping teaching and inefficient use of resources. The decision to move the isotope laboratory from the museums to the Department of Geology must therefore be strongly encouraged since this is a necessary step towards addressing a basic problem. A final joint Earth Sciences department might be the optimal situation.

The Oslo region is the focus of substantial international geological and palaeontological interest. Increased use of the Oslo region in academic education and as a petroleum research field laboratory should be a future target. Such an improved utilisation of resources can be reached by merging the individual museums into one single Natural History Museum.

## 3.3 Department Structure

A world-wide concern is how to develop traditional faculty and departmental structures (developed around traditional training disciplines) so they can respond to new intellectual challenges, and particularly interdisciplinary opportunities. We cannot continually reinvent administrative units, but we recommend that universities consider how they can best recognise interdisciplinary activities, especially with regard to giving credit for teaching and thesis supervision outside the home department. In this context, we particularly commend the University of Bergen for establishing the Centre for Studies of Environment and Resources to facilitate interdisciplinary research.

Too-democratic governance in university departments acts to dampen initiative, vision, intellectual growth, and discourages active and visionary scientists from seeking to lead. We suggest that appointment of department heads by the cognisant dean, in consultation with the departmental faculty, is more likely to result in dynamic leadership responsive to changing research modes and opportunities than appointment by democratic elections. While we applaud the involvement in departmental governance of temporary academic and non-academic staff, and students, professors must be given primacy in decision making if research quality is to be maximised.

Public expenditure should carry with it an expectation of public accountability. Publicly owned research institutions need periodic assessment, say every fourth or fifth year, by professionally qualified teams that include foreign members. They do not, however, need repetitive and disruptive inspections and reorganisations. This trend, coupled with perceptions of decreasing funding, and

redirection by the Research Council with an emphasis on applied science, has lowered the morale at the universities. Research and teaching assessments provide valuable experience to motivated departments, but they substantially increase the transaction costs of research funding, and they are an added burden on the research worker.

## 3.4 Mobility, Inbreeding, and Attracting New Faculty

A serious problem recognised by many of the departments concerns the selection of new faculty from among a department's own graduate students. Such a tendency leads to the lack of infusion of new concepts, ideas, and methods, and the maintenance of the status quo. This practice contrasts with that of other top-ranked university departments outside Norway whose faculty members have diverse educational backgrounds. Upgrading of department faculties is unlikely to prove successful if this traditional inbreeding practice is maintained. In several instances that came to our attention, advertisement of new faculty positions was limited to Norway or to the Scandinavian countries, and commonly led to selection from a small pool of candidates, often dominated by persons trained at the advertising department.

Appointment ("search") committees should include significant representation of faculties from the appointing department and international experts. The present practise of largely removing selection responsibility from the appointing department in the interest of reducing pfarochiality and nepotism has produced an unintended result: the choice of "safe" (typically internal) candidates, rather than "imaginative" (early career, still-developing) scientists offering different strengths, experiences, and visions.

All permanent and tenure-track positions requiring a doctoral degree should be advertised internationally. This requirement can be satisfied at low cost by advertising in *EOS* (*Transactions of the American Geophysical Union*), *Nature, Science, Geotimes*, and other appropriate avenues having wide dissemination. Industry journals (e.g., *Leading Edge, First Break, AAPG Explorer*) are not sufficient in this context. The potential downside is that a search committee will have to review a greater number of applications. The upside, however, is that the department will be required to present itself to the international community, and thereby receive international attention, and that the search will have increased legitimacy.

We emphasise that we do not advocate widespread hiring of foreign nationals to the exclusion of Norwegian scholars. Attracting "fresh blood" for five to ten years at a time will help to revitalise Norwegian science; non-Norwegian scientists attracted from overseas may not spend their entire career in Norway.

A further measure that can be taken to ensure greater educational diversity among potential candidates for faculty positions is to restrict the number of degrees that can be obtained from any single university. The so-called "two-degree rule" used in some other western countries should be applied, namely that no student should receive more than two, of three, degrees from any single university (i.e., a student could be awarded a bachelor's and master's degree or a bachelor’s and doctorate degree from one university, but not all three degrees from a single university). B.Sc. candidates desirous of completing the Ph.D. in their home university should therefore be assisted (as well as expected) to take the M.Sc. degree elsewhere. Furthermore it would be constructive if a significant component of new faculty received at least part of their training outside Norway, such as advanced degrees from foreign universities or several years of post-doctoral study abroad.

University faculty should be strongly encouraged and financially supported to take regular sabbatical leaves abroad in order to help revitalise and reorient departmental research programmes, as well as update their classroom offerings. Persons granted sabbatical leave should be required to submit plans prior to, and summary reports following, their leave, detailing both the justification for and achievements of the leave experience.

## 3.5 Faculty Age Distribution

The age distribution of Earth Sciences faculties (Fig. 3.5), on whole, resembles a slightly skewed Gaussian curve, with peak numbers represented by people in their 50s, the decade when many earth scientists reach their most productive level. In comparison with those of disciplinary units, this summary curve most closely resembles that of geology, which also is of Gaussian character and with a peak in the early 50s. However, other disciplines display a more bimodal distribution (e.g., geophysics) with age peaks in the early 40s and 50s, or display a rather uniform age distribution (oceanography, physical geography, engineering geology).

The statistics indicate that most departments have made a rather consistent effort to bring in young people to fill open positions, and that few older faculty members (over 60) remain actively employed. While there is a wave of people in their 50s moving through the ranks, it seems unlikely that many will retire for at least another decade, meaning that few opportunities to replace existing faculty will arise until well into the next century, assuming a no-growth situation. Accordingly, faculties presented with vacancies should vigorously debate how best to fill these positions in order to meet future priorities, rather than merely replacing retiring faculty with people in the same sub-discipline and trained in the same department.

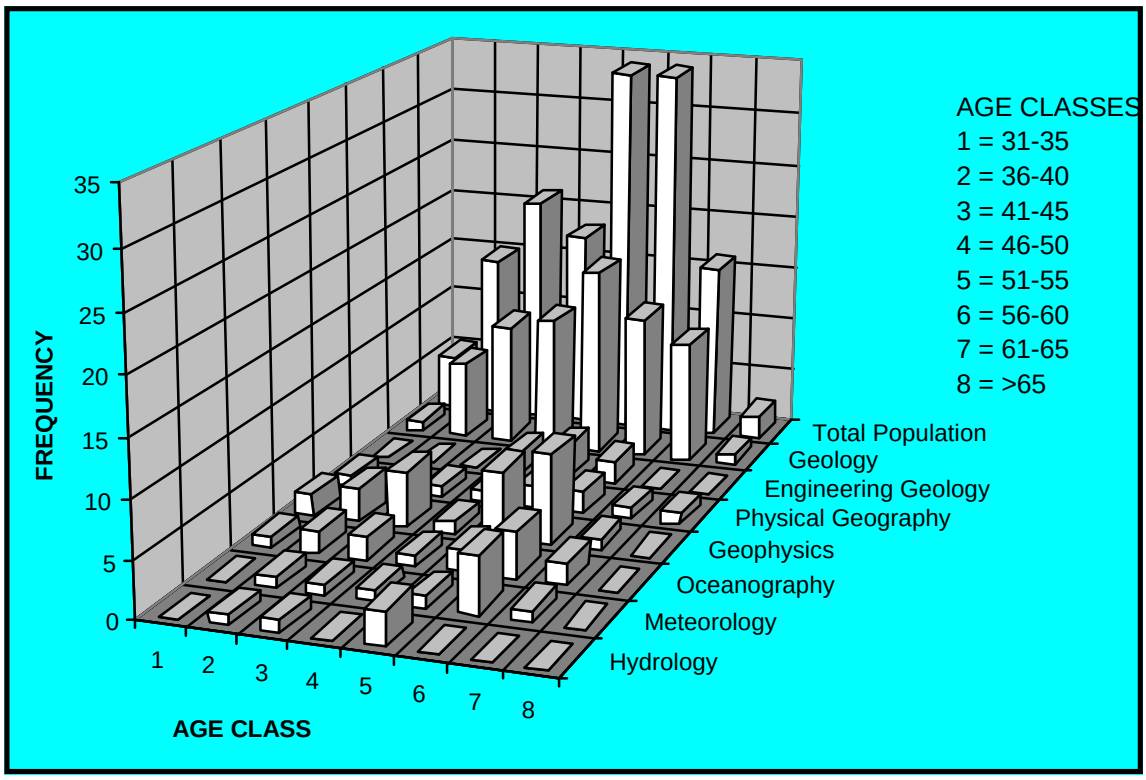


Figure 3.5.1 ***Age distribution of Norwegian Earth Sciences faculties***

## 3.6 Teaching Load

Many university groups complained of excessive teaching loads. We could not evaluate these concerns in any detail. We suspect that all university professors world-wide would raise the same issue; however, several departments claimed their load exceeded university-mandated limits. The solution cannot be to add more faculty across all disciplines in all departments. Instead, we would like to see evidence that each individual department has undertaken:

- a complete curriculum review. Which courses are truly fundamental to an undergraduate Earth Sciences degree (bearing in mind that as knowledge expands some traditional courses must be dropped, for example, we can no longer expect that all geology graduates will have taken separate classes in igneous, metamorphic, and sedimentary processes)? Which classes are most appropriate for those specialities in which the Cand. Scient. Degree is offered?

- discussion on combining faculty effort across departmental boundaries, to avoid duplication (e.g., glaciology may not need to be taught separately by a department of physical geography and a department of geology in the same university); and

- alternate-year teaching of classes with low annual enrolment, or converting such lecture classes into seminar or directed-reading formats.

## 3.7 Salary

In Norway, university salaries are governed by equity, with a small (often negligible) component related to merit. There is no attention paid to market forces. In some universities in other countries, equity, merit, and market forces are given equal weight in setting salaries: e.g., doctors are paid more than engineers, who are paid more than scientists, who are paid more than humanists. At present in Norwegian Earth Sciences, the best, the brightest, and the most ambitious often go to industry, not because the intellectual opportunities are greater but because the financial rewards are more substantial. University salaries cannot (should not) be equal to industry salaries, but they must be sufficiently remunerative that a committed intellectual can justify (to self, and to family) following an academic career. University salaries in the Earth Sciences must be raised substantially, by 25 to 50%, to allow recruitment and retention of first-class individuals.

## 3.8 Lack of Policy for Consultancy

Industrial and research consultancies should be encouraged for the intellectual opportunities they provide, for faculty and graduate students alike. Such consultancies are not appropriate when the attraction is dominantly financial rather than intellectual, and so contracts should generally be via the university, not the individual. (In at least one department we examined, fully 50% of the tenured professors were ‘moonlighting’, supplementing their income by outside employment, as much as two days each week.) The Committee strongly recommends that Norwegian universities adopt formal policies regarding limits on outside consultancies (hours per week or days per quarter), on

conflict of interest (particularly regarding employment of graduate students through personal companies), and on assignment of patents developed (to the university, albeit with a significant proportion of royalties going to the investigator and to associated department). Such policies can only be introduced if salaries are considerably increased. The potential for development of new technology to enhance Norwegian industry and international competitiveness is one significant reason for strong government funding of research universities. It is important to create mechanisms which positively encourage creation of new inventions and help them move to the marketplace. We recommend that Norwegian universities develop formal mechanisms for retaining rights to inventions by its faculty, and for dividing royalty shares equally between the individual, the department and the university.

Professor-II (20%) appointments are a splendid innovation in the Norwegian university system, and should be strongly encouraged as an excellent way of bringing industry and research-institute expertise into the university research and teaching community. Other countries would do well to copy this approach. However, the Committee is more sceptical of professor-II appointments of professors from other universities, since university academics already exist in a culture that encourages free exchange and research visits to other institutions. This is particularly true when a professor-II appointee does not take a corresponding reduction in compensated responsibility at his/her home institution, in which case the outside appointment can only lead to a dilution of teaching and administrative effort, and potentially also in research performance, within the home institution.

## 3.9 Training of M.Sc. and Ph.D. Candidates

At least some of the graduate Earth Sciences classes should be taught in English (i.e., 300 level classes). Efforts should be made to teach other specialist (200 level) classes in English whenever possible as a way to introduce undergraduates to English as ‘the international language of science’.

We applaud and endorse the practise of using external examiners (opponents), where possible from other countries, for all Ph.D. and M.Sc. thesis defences. We are sceptical that routine external examiners (censors) are appropriate for all undergraduates and graduate class exams. Given the Norwegian system in which a degree is awarded based on success in a large number of exams (following each class, each semester) rather than based on a single series of exams at the end of the degree period (as in the UK), it should be sufficient if each course is externally audited (‘censored’) once every three years, with a corresponding large saving in administration burden for all professors.

We recommend that both Dr. Scient. and Dr. Engineer candidates in Earth Sciences be encouraged to publish peer-reviewed research papers together with a summary and explicatory material. This should constitute an acceptable thesis, as this mode of scholarship represents the truest apprenticeship for a scientific career. We encourage this approach in preference to the traditional and still common practice of writing a single tome that must later be re-written as individual papers if it is ever to receive recognition outside the home university.

## 3.10 Productivity

There are three main aspects to research production in universities, namely (1) Training future research scientists, (2) Production of international-quality research, and (3) Production of frequently-cited research.

(1) *Training future research scientists*: this is commonly measured by the numbers of graduate degrees, and there is an important difference between masters (i.e., Cand. Scient.) and doctorates. Masters are generally preferred by industry, and Ph.D.s are preferred by government surveys, laboratories, museums, and by universities. Masters' programmes generally include a large course-work component (up to 50% or more), so departments with high masters productivity may complain that this requires extensive teaching effort which leaves them less time for research.

The statistics (for 1992 - 1996: see Volume II) clearly indicate that the production of masters in Norwegian Earth Sciences is mainly borne by the Department of Geology and Mineral Resource Engineering, NTNU; Department of Geology, Bergen; and the Department of Geology, Oslo. Substantial number of degrees in meteorology and oceanography are produced at the geophysical institutes.

Production of doctorates is highest at the Department of Geology, Bergen; the Department of Geology, Oslo; and the Institute of Geology, Tromsø. Substantial numbers are also produced by a number of geophysical, oceanographic and meteorological institutes (Volume II).

The Committee's impression is that, at present, there is a strong demand in Norway for almost *all* graduates from both masters and doctoral programmes in the Earth Sciences. In view of the limited future growth in government laboratories and universities, it may be anticipated that the demand for doctorates will decrease somewhat in the future. The strong skew towards older ages in the age distribution of permanent faculty at universities, may, however, ensure a fairly strong demand for Earth Sciences doctorates over the next 10-15 years.

(2) *Production of international-quality research*: this is commonly measured by counting the number of publications produced in refereed international journals. Though CVs commonly list all refereed publications, there is no doubt that the academic community now generally distinguishes between international journals and other refereed publications (e.g., special publications, memoirs). It is not always clear exactly what constitutes an "international journal"; for example, highly regarded "national" journals (like *Norsk Geologisk Tidskrift*) are generally regarded as international journals.

Statistics on the production of articles are hard to extract from CVs, and were not available to the Committee for individual departments in Norway. They are available from the *Norwegian Institute for Studies in Research and Higher Education* (NIFU) for the "geosciences" in Norway (Volume II). The main conclusions from this study are that the Earth Sciences have a prominent position in the overall publication profile in Norway. The country has the highest production of publications per capita in Earth Sciences after Iceland.

(3) *Production of frequently cited research*: this is commonly measured by counting the number of citations to publications in international refereed journals, as measured by *Science Citations Index* (published by ISI). The value and limitations of citation analysis are now well understood by

sociologists of science, but the data are often misinterpreted by working scientists. Like all descriptive statistics, such data may be misleading when applied to individuals, or smaller groups of scientists, but when applied to larger groups (or to small groups over long time periods) they have some validity as measure of the *impact*, rather than the *quality*, of scientific research. "Impact" is, of course, not quite the same as "quality" – but true quality is not susceptible to quantitative measurement.

Data available to the Committee indicate that Norwegian publications in Earth Sciences are cited frequently. The numbers are particularly impressive when normalised as citations per million population, though this normalisation exaggerates the impact of Norwegian Earth Sciences, because Earth Scientists are numerous in Norway, relative to the total size of the population. This large number of Earth Scientists reflects the economic importance of the Earth Sciences in Norway, as compared with their importance in larger nations with a more diversified economy and larger population.

The Norwegian publication profile in Earth Sciences is quite internationally oriented. The study performed by NIFU shows that about 50 per cent of all Norwegian publications in Earth Sciences are co-authored with researchers from other countries. The USA, UK and Germany are the countries with which the Norwegian researchers co-operate the most. In addition there is a considerable publication activity in non-geoscience fields involving Norwegian institutions in Earth Sciences.

The statistics for average number of citations per article show Norway in 13$^{th}$ position (somewhat below the world average), with citation frequencies comparable to those of New Zealand and Sweden, rather than with countries such as USA (2$^{nd}$), Switzerland (3$^{rd}$) or Denmark (4$^{th}$). Citation frequencies for the Earth Sciences are comparable with those of other sciences in Norway; however, meaningful comparisons between sciences are difficult, because of different publication and citation frequencies in different sciences (for example, the statistics for molecular biology are always much higher, and for mathematics are always much lower, than for Earth Sciences).

The statistics for citations to individual research workers in the period 1992-1997 show 27 individuals whose senior-authored papers received more than 100 citations. More than 20 citations per year can be considered a rather high rate of citation to a research worker's total production of papers. Though the statistics are probably not meaningful for any one individual, it is worth noting the numbers of highly cited individuals in each discipline:

| | Highly cited | Total number investigated |
|---|---|---|
| Geology | 16 | 40 |
| Geophysics: | | |
| - solid earth | 3 | 20 |
| - oceanography | 3 | 6 |
| - meteorology | 3 | 4 |
| Total | 9 | 30 |
| Physical Geography | 2 | 3 |
| Total | 27 | 73 |

Figure 3.10.1 ***Highly cited individuals***

## 3.11 Infrastructure and Investments for the Future

University scientists committed to intellectual discovery are attracted to research opportunities as much as to personal reward. There must be sufficient annual funding for major research infrastructure developments so that scientists with worthy proposals have a reasonable chance of success, and thus are encouraged to develop proposals for innovative instrumentation. It is not necessary to fund all proposals for new ships, spectrometers, and super-computers; but possibilities must exist for governmental funding irrespective of industrial applicability. (It should be recognised that capital investment serves a dual purpose: it stimulates the domestic economy and also enhances Norwegian research and development.) Much infrastructure (especially computers and software) is now donated by the oil industry to the universities. However, it must also be realised that such donations carry costs that must be met by the recipients.

Major capital equipment is increasingly important in modern quantitative Earth Sciences fields. This applies particularly to research vessels, geophysical equipment (land-based and sea-going), and lab-based analytical equipment (e.g., mass-spectrometers for trace element and isotope analysis). Even though there are many examples of excellent collaborative use of facilities in Norway, we see a need to formalise major future instrument investments, and preferably also some existing facilities, as national facilities. These facilities should be jointly proposed by a consortium of two or more departments but run by one responsible research group. To ensure optimal use of and fair access to the facility, a committee composed of representatives from all consortium departments should continually assign priorities and time allocations. The Research Council should allocate special funds for development of national facilities in response to joint applications that would include a specific management plan.

Technical and specialist scientific support staff for special equipment should be planned as part of the same process of major investment for national facilities. In general, technical support staff gradually need to be enhanced in the areas of computer hardware, networking, and software support. The total level of technical staffing is generally adequate, even generous, in some departments, but distributed on the basis of tradition rather than present needs.

Although we did not review all possible needs, a specific major capital investment needed over the next five years may be a new isotope geochemistry facility to include an ICP-MS for trace-element analysis, a multi-collector ICP-MS for isotope geochemistry, and an AMS facility for precise $^{14}C$ dating. The proposed lab for experimental petrology at Tromsø is of smaller magnitude, but could in the future be expanded to a national facility, e.g., by addition of micro-analytical equipment (microprobe, laser-ablation ICP-MS).

Earth Sciences in Norway is the ”goose that laid the golden egg” for the offshore oil and gas industry, on which the national economy depends, and Earth Sciences continues to provide the human capital and the scientific advancement necessary for nurturing and maximal development of this resource. Yet, academic Earth Sciences in Norway risks marginalisation with respect to the industry, because of governmental policies towards the universities that fails to recognise the special needs in Norway and special status in Norway of Earth Sciences.

While having high regard for the democratic and egalitarian social tradition in Norway, we believe the high standard of living (the GNP per capita) on which this tradition thrives can only be sustained

in the future by substantial increases in investment in the Earth Sciences, and by governmental recognition of the special place of this academic discipline in Norway.

## 3.12 New Initiatives and Directions

Experimental petrology is an important field in hard-rock geology and until recently it has been present at the University of Bergen. We support the initiative from the University at Tromsø to establish a new, modern, and well-equipped laboratory in experimental petrology. The integration of experimental petrology with the hard rock geology group at Tromsø has great potential for performing original and well-founded research activities.

We noted a rather weak representation of mineralogy and crystallography in Norwegian universities. However, this does not mean that the subject needs to be introduced in Norwegian research unless there is a need for strengthening research in, e.g., modern material sciences.

Glaciology and process geomorphology are important and relevant fields of the Earth Sciences in Norway. Glaciology is represented at the Department of Physical Geography at the University of Oslo. We note the requests to strengthen glaciology at the Departments of Geology at both Bergen and Tromsø. The move of the Norwegian Polar Institute to Tromsø and the potential for collaboration favours strengthening glaciology at Tromsø.

Hydrologic and hydrogeologic research has experienced a major development in Norway during the last decade. The activity started at the Department of Soil and Water Sciences at the Agricultural University of Norway (AUN) and was followed by activities at the Departments of Geology and Geophysics at the University of Oslo and the Department of Hydraulic and Environmental Engineering, NTNU. There is a perceived need to strengthen these subjects at these university departments. The Committee supports the idea of establishing bedrock groundwater hydrology at the Department of Geology, University of Bergen, and urban hydrology with an emphasis on soil at the Department of Hydraulic and Environmental Engineering at NTNU.

The University of Bergen has important research programmes in the marine sciences. At present, the different activities are conducted in several small units and as elements of the total research activity in large departments. While we think that the initiative to establish a marine faculty at the University of Bergen deserves careful consideration, attention should nevertheless be given to the special needs and concerns of the units involved. Although this initiative might help the university become more widely recognised for its research in marine sciences, it should not be undertaken to the detriment of the present strong and internationally recognised programme in Quaternary geology, which contains an important marine component. The possibility of including subjects on marine technology in the existing or any new curriculum should also be given consideration.

The 22 stations of the Norwegian National Seismic Network is operated by the Seismology Group of the Institute of Solid Earth Physics at the University of Bergen. Such permanent responsibilities are not easily accommodated by small research groups at universities and can impede their flexibility to respond to new scientific opportunities and instrumentations. In many countries seismic networks are run by national Geologic Surveys. The University of Bergen is suggested to investigate the possibility to relinquish the operation of the net and has it run by the Geological Survey of Norway (NGU).

In retrospect it could have been more appropriate for the University of Oslo to withdraw from Solid Earth Physics while it had no faculty in post, and instead to build up their other three groups.

Ore geology, or economic geology, was a regular research activity at the Department of Geology, University of Oslo, until three years ago when the professor in this field left. We believe that this sub-discipline can be well-represented in Norwegian Earth Sciences at NTNU, and we recommend that the Oslo position be used to develop new research areas rather than to continue in ore geology.

# 4. Evaluation of Institutes

## 4.1 University of Oslo

There are four departments or parts of departments and two museums that have been evaluated at the University of Oslo: the Departments of Geology, Physical Geography, Geophysics and Mathematics, and the Mineralogical-Geological and the Palaeontological Museums. Volume II presents the research activities at these departments and museums in detail.

### 4.1.1 Department of Geology

The department consists of about 10 professors, 4 adjunct professor, 9 associate professors, 6 post-doctoral fellows/researchers and 20 research fellows. It is organised into four research groups; 1) Sedimentology Group, 2) Bedrock Geology Group, 3) Stratigraphy and Palaeontology Group, 4) Geophysics Group.

The largest group in the department is the Sedimentology Group that specialises in diagenesis, Quaternary geology, and micropalaeontology (with applications in marine geology and environmental studies). Another large group is the Bedrock Geology Group that studies fluid-rock interactions, in both metamorphism and diagenesis, and co-operates with scientists in physics at the University of Oslo who are interested in numerical modelling of natural phenomena. This has resulted in an unusually high degree of internal research interaction and co-operation.

It is difficult to generalise about the work of such a large department; nevertheless, it does appear that much of the departmental effort is devoted to topics in sedimentary petrology, stratigraphic palaeontology, structural geology and geophysics. The topics chosen constitute basic research that is of particular interest to the petroleum industry, and so it is not surprising that a significant part of the external funding is provided by this industry and that graduates from the department are mostly hired by petroleum companies.

The Sedimentology Group consists of four professors, two adjunct professors and two associate professors. Their research includes a broad variety of topics including (1) petroleum geology and petroleum geochemistry, (2) environmental geology, (3) geotechnology, (4) Quaternary geology, and (5) general sedimentology. The main areas of research in the group are on petroleum geology/petroleum geochemistry and environmental geology.

The Bedrock Geology Group consists of 3 professors, 1 adjunct professor and 1 associate professor. Research is concentrated in three thematic disciplines that are presented in more detail below: Structural geology and tectonics, Mineralogy and metamorphic petrology, and Ore geology.

The main field of research in structural geology and tectonics has been the tectono-metamorphic evolution of orogenic belts, primarily the Scandinavian Caledonides. The research has also included extensive field activities in the Eastern Greenland Caledonides and the Tertiary fold- and-thrust belt in Svalbard. The research activities require the use and integration of many different geologic

disciplines (sedimentology, thermochronology, geophysics, geochronology) besides structural geology.

The research in mineralogy and metamorphic petrology, including fluid-rock interactions is concentrated within two projects: (1) Fluid-Rock Interactions, which is a Strategic University Programme, and (2) Metamorphic fluids during orogenic collapse.

The objective of the project ”Fluid Rock Interactions (FRI): A cross-disciplinary project in Geology and Physics” is to develop a better understanding of fluid-rock interactions in sedimentary and metamorphic systems.

The Stratigraphy and Palaeontology Group consists of one professor and three associate professors; at present, one additional position is vacant. The present faculty work on microfossils, namely forams, dinoflagellates, and diatoms. The scientific work is concentrated on biostratigraphy, palaeoecology and faunal distribution patterns in modern assemblages and on the application of microfossils to stratigraphy, palaeoecology, and environmental geology.

The Geophysics Group consists of three professors, one associate professor (currently vacant), one adjunct professor, and, during the last five to six years, two staff scientists. Additionally, the group includes several doctoral candidates and one post-doctoral fellow. Scientifically, the group has its strength in developing integrated evolutionary models using both geophysical and geological data. The main research themes are within (1) marine geophysics, (2) sedimentary basin history and geodynamics, (3) seismology and lithosphere, and (4) method and programme development. The geophysics group maintains an extensive collaboration with well-known international groups and oil companies. Several members in the group play a very active role in the Ocean Drilling Program (ODP).

## *Assessments and Recommendations*

Productivity within the department is very high, both in regards to publication in refereed journals, and to the production of masters and doctoral degrees. Research topics that are closely related to the petroleum industry tend to attract more students, particularly master's students, and so supervision duties fall more heavily on some members of the department than on others. In general, however, this is a very active research-oriented department.

The Committee was impressed by the work of the Bedrock Geology Group on fluid-rock interactions. This group is interacting very fruitfully with researchers in physics to develop original models of complex natural systems. This group is also doing excellent, but somewhat more conventional, work on evolution of tectonic belts (Caledonian, Grenvillian) in Norway and Greenland, as well as their subsequent collapse and formation of passive margin structures.

The Stratigraphy and Palaeontology Group is doing good work in two main fields of biostratigraphy, and environmental studies.

The Sedimentology Group is doing excellent work on diagenesis in sedimentary basins and its consequences for the evolution of pores and pore fluids (water, petroleum). The research conducted on diagenesis impressed the Committee as top rank in both originality and quality. The

environmental work, carried out on modern samples and shallow core samples, provides a much-needed time perspective in case studies of recent water pollution.

The Geophysics Group is carrying out a range of significant studies of basin history and geodynamics, using an integrated approach to data collected mainly on the Norwegian shelf and margin. This work, although fairly conventional in approach, is of great importance for the petroleum industry. The Committee was impressed by the broad integrative scope and high quality of research.

In summary, the Department of Geology at Oslo is producing an exceptional range of research that is both strongly interdisciplinary and focused on four main areas: fluid-rock interactions, diagenesis, tectonics of orogenic belts and sedimentary basins, and environmental (water pollution) studies. In at least the areas of fluid-rock interactions and diagenesis, the research is of world-class quality.

### 4.1.2 The Mineralogical-Geological Museum

Both the Mineralogical-Geological and Palaeontological museums are about to be integrated with Botany and Zoology, in a renovated "Natural History Museum".

The Mineralogical-Geological Museum (MGM) at Tøyen is part of the University of Oslo. Historically, it was one of the world's leading research institutions in mineralogy and geochemistry, and was organised separately from the Department of Geology at Blindern. The museum hosts major collections of minerals, meteorites, Norwegian ores and rocks, and some other special collections, which traditionally have been a major research resource. The institution also has an important array of laboratory facilities, some of which are unique in Oslo and even in Norway.

In the last few decades, the connection between exhibition and research activities at MGM has become less obvious, while the links with the Department of Geology have grown.

The prime duty of the curatorial staff consisting of 3 scientists, is the maintenance and innovation of exhibitions and interaction with the public visiting the Museum. These scientists have a high profile in public education, through talks, media contributions, and public excursions (which is exceptional in comparison with similar museums in other European countries).

Most members of the research-oriented staff in the Petrology and Isotope Geology Group, consisting of 7 scientists, including the present museum director have little direct involvement with exhibition activities, but contribute actively to teaching at the University of Oslo and to the supervision of graduate and postgraduate students. The group attracts significant funding from the Research Council. The group also maintains an active international collaboration, which clearly is of high quality and intensity, based on the group's success in attracting support for post-doctoral fellows from highly competitive European funding schemes.

The major analytical facilities run by this group include mass spectrometers, clean laboratories, and an electron microprobe. They offer a full range of major radiogenic-isotope methods, including single-zircon U-Pb geochronology. With respect to dating facilities in Norway the only other facility is in Bergen, which only recently started. Plans are being discussed regarding when and how the petrology and isotope geology group, with their analytical facilities, can be physically moved from Tøyen to the Department of Geology at Blindern.

Scientific research in mineralogy (i.e., by the curatorial staff) is of good quality, but has mainly been published in national journals, except for the description of new discoveries of rare minerals. Publication quantity and scope is limited, due to the fact that the priority of the curatorial staff is placed on popular media and service to the public. Research in igneous and metamorphic petrology and in isotope geochemistry reflects a high international standard of quality. The main articles appear in the top international journals of their field, and the publication rate is good.

## *Assessments and Recommendations*

If handled carefully, the move will provide possibilities for the new museum as well as for the research scientists of the old MGM, although the termination of a famous tradition going back to V. M. Goldschmidt is sad. The decision to separate the research-oriented petrology and isotope geology group from the Museum and move it into the Department of Geology seems wise.

It is important that the mineralogists maintain a basic research infrastructure for microscopy and XRD determination of minerals on site at the mineralogy section of the new museum. In the long term, a revival of research in the Museum, with a new professorial appointment focused on modern mineralogy and perhaps with a specialisation in mineral physics or a slant towards the materials sciences, might be desirable. But in the present economic climate this cannot be considered a top priority. We recommend that, in the process of reorganisation, the new museum could establish a reorganised administrative structure, perhaps in the form of a management board that includes not only museum and university staff, but also some external representatives with high public profile. Invitation of industry leaders to this board could open new forms of funding through corporate sponsorship.

The planned merger of the petrology and isotope geology groups with the Department of Geology clearly opens opportunities for both partners. Representatives of both partners agree on this merger and the basic plan for integration, but the museum's petrology and isotope group is rightly concerned that their future scientific livelihood must be assured, which depends on space and long-term support for their specialised facilities.

An essential condition for a successful merger is a clear commitment by the University to create adequate laboratory space in the Geology building at Blindern. This will require some refurbishing of existing laboratory space, especially for clean laboratories dedicated to chemical sample preparation. The necessary planning should be carried out with a view to establishing a small but modern isotope facility that will serve the department, and the country, for the next 10-20 years. If possible, space for future acquisition of an additional mass spectrometer of a newly emerging type (e.g., MC-ICP-MS) should be earmarked in this plan. In light of the prime strengths of the Department of Geology in petroleum geology and fluid/rock interaction, the inclusion of a stable isotope laboratory would ideally complement this new facility.

The personnel policy regarding the petrology and isotope geology group is another key factor bearing on the future success of this important field of quantitative geosciences. Being one of the most "high-tech" laboratory-based components of the Earth Sciences, the isotope geology group is probably best maintained as a distinct scientific entity with a degree of administrative and financial independence, even in a department that otherwise has a very strong vision for problem-oriented rather than discipline-oriented research and teaching. To strengthen the new isotope geology group

within the Department of Geology, it is a high priority that the currently vacant position in MGM should be filled, not by a pure mass-spectrometry operator but by a professor with a proven record of high-precision isotope analysis and geochronologic research. Ideally, this person should be recruited soon, in order to be able to provide input with respect to imminent laboratory planning.

## 4.1.3 The Palaeontological Museum

There are 7 permanent faculty members, of which 3 are non-scientific positions, and 2 adjunct professors. The museum currently has 3 research fellows and 6 graduate students.

Individual staff members participate in external research groups, and join groups at other (national or international) research centres. They work within the following research areas: (1) Palaeoceanography, Biodiversity and Radiolarians, (2) Ordovician and Cambrian Faunas, Trilobites, (3) Pteraspidis, Mammoth, the Fram expedition and Ichthyosaur, (5) Upper Palaeozoic and Triassic Stratigraphy, and (6) Industrial Projects.

### *Assessments and Recommendations*

The palaeontology group should remain as part of the Natural History Museum. The present studies strike the Committee as diverse and unfocused, but a nation like Norway should be prepared to devote some of its funds to research on the history and evolution of life on Earth.

## 4.1.4 Department of Physical Geography

The department is organised into four research groups: (1) Glacial Geomorphology and Glaciology, (2) Geographic Information Technology (Geometrics), (3) Hydrology and Fluvial Geomorphology, and (4) Resource Geography and Landscape Ecology.

There are 9 permanent faculty members (four professors (one of whom is Emeritus), and five associate professors), and three non-scientific staff. Four of five research fellows enrolled in the department are in fields considered in this review. All of the permanent faculty received their highest degree from the University of Oslo. The department currently has 64 graduate students, about 30 percent of whom graduate each year. Employment opportunities are good.

Glacial and periglacial geomorphology and glaciology have a long history in this department and are clearly its principal current strengths. The advent of GIT (geometrics) in geography has resulted in a new departmental emphasis in this area, which has important applications to other fields. The faculty is competent and productivity is about average. Most of the research is traditional, rather than innovative, likely reflecting the fact that all members of the regular faculty received their graduate education at the department in which they are now employed.

Research in Glacial Geomorphology and Glaciology includes the study of processes in active glaciers as well as landform evolution and sediments related to former mountain glaciers and ice sheets. The latter investigations have contributed to an understanding of the dynamics and deglaciation history of the Scandinavian ice sheet in different regions of Norway.

Two among the many applied projects are 1) construction of thematic maps of glacial geomorphology and 2) Quaternary geology at different scales covering whole counties. These provide a basis for planning resource management and environmental protection of interesting and/or vulnerable areas.

For many years, this department has been a main centre of glaciological teaching and research in the Norwegian university system maintaining strong links with the Norwegian Polar Institute. The primary objectives have been to study glacier mass balance and its relationship to climate change, the thermal regime of glaciers, glacier surges, glacier hydrology, and erosion and sediment transport by glaciers.

Glaciological research has been conducted at Engabreen (Svartisen Glaciological Observatory) in Norway, where an artificially excavated tunnel system has been constructed in collaboration with glaciologists from the USA, Sweden, and Finland beneath 200 m of ice which provides unique access to a glacier bed. A new 3-year EU project involving 7 European Union countries, Russia, and Poland focuses on future response of Arctic ice masses to changing climate.

The research group in Geographic Information Technology (Geometrics) is concerned with data sampling and analysis of digital geographic information involving the Laboratory of Remote Sensing and utilising Geographic Information Technology (GIT). Activities fall into two main categories: (1) GIT in support of geomorphological, glaciological, and hydrological research efforts, and (2) research into analysis of satellite imagery, development of interpolation methods, and digital relief analysis (geomorphometry).

The small research group in Hydrology and Fluvial Geomorphology, administered by one associate professor, has a low ratio of faculty to students. Research is devoted largely to applied aspects of the subject and emphasises such topics as physical impacts of human regulation on river channel hydraulics and construction of flood zone maps. Related investigations include snow mapping and modelling, and regional analysis of floods in large watersheds.

The unit of Resource Geography and Landscape Ecology, which studies problems related to resource utilisation and resulting environmental implications, was not assessed in this review.

## *Assessments and Recommendations*

The department has the only degree programme in glaciology in Norway, and is complemented by a faculty experienced in the related disciplines of glacial geomorphology, glacial geology, and geocryology. Among the other major fields of geomorphology, only fluvial processes is represented, and at a much lower level of activity. This degree of specialisation may be justified because Norway, being a glaciated country, bears an extensive mantle of glacial sediments on which the nation's towns, cities, agricultural fields, and infrastructure are built; a large fraction of its power system is based on a hydrologic system related active to its alpine glaciers; and many basic environmental concerns, including geologic hazards, are linked to Norway's glacial history.

The programme in GIT (geometrics) brings modern quantitative tools to bear on many topics of concern to departmental research. Digital Terrain Models have great potential in this field, and are being applied imaginatively in the department's studies of modern glaciers. Students with advanced

training in these techniques will be very attractive to potential employers, and so this area of the department's teaching and research is likely to grow.

Scientific productivity is variable; several of the faculty are reasonably well known outside Scandinavia and routinely publish in a limited number of international journals, whereas others appear to be much less productive in research, publishing almost exclusively in Scandinavian journals and (or) in unrefereed reports and proceedings.

The department has reduced its course offerings in response to a teaching load that was considered too great. It has also expressed the desirability of generating closer ties to the Department of Geology. In this regard, it has reacted favourably to a proposal that would combine Physical Geography with Geology and Geophysics into a single Earth Sciences department on campus, thereby affording greater interaction with geological colleagues and a more effective organisation of course offerings that now partly overlap. However, closer ties and interaction need not be conditioned on such an administrative reorganisation, and potentially fruitful collaboration is encouraged. Recognising the minimal role of hydrology and fluvial geomorphology in the curriculum and research activities of the department, an expansion of this field is a future objective.

The department is well equipped for field studies but expresses a need for new digital photogrammetry work stations and software to increase the effectiveness of its GIT programme.

The department is effective regarding its traditional approach to glaciology and glacial and cryogenic geomorphology, which are the areas of principle strength. It intends to continue a strong emphasis on field-based research, utilising new measuring techniques (i.e., geometrics). However, there is little indication that serious consideration has been given to how it might engage in new and developing areas of research in glaciology and geomorphology (e.g., modelling, ice-core research, applications of cosmogenic nuclides). In addition, there could be fruitful collaboration with the strong Quaternary Geology group at the University of Bergen, which is engaged in an array of palaeoglaciological investigations but lacks a glaciologist on its faculty. The department expresses the intention of expanding its geometrics component and increasing the hydrology programme, especially with respect to snow hydrology and linkages to remote sensing. In seeking future additions to the faculty, serious effort should be directed toward attracting highly qualified persons outside their own university faculty.

### 4.1.5 Department of Geophysics

The Department of Geophysics at the University of Oslo is organised into four research groups: (1) Meteorology, (2) Hydrology, (3) Physical Oceanography, and (4) Solid Earth Physics.

The primary research aims are to understand physical and chemical processes in the atmosphere below 50 km, in the hydrosphere, and in the solid earth. Research is predominantly theoretical in nature, emphasising quantitative results based on solutions of mathematical equations formulated from the physical laws of nature. Experimental data needed for the calibration and validation procedures are obtained from collaboration with other groups; field research is only conducted in hydrology and physical oceanography.

The Department of Geophysics has seven full-time professors, four associate professors, and one assistant professor with a permanent position. There are five adjunct professors (20% position) and

three research fellows financed by the University of Oslo. There are also a variable number of externally financed research fellows (presently 6) and researchers (presently 4). The department has also a senior executive officer, one officer assistant and 1.5 computer engineers paid by the University of Oslo and two office assistants paid by external sources.

The four research groups differ in size and level of international reputation, but all produce top quality research. The largest group and the one with the oldest tradition is Meteorology; the smallest and "youngest" is Solid Earth Physics.

The Meteorology Group traditionally encompasses all research related to the atmosphere. For logistic reasons, it is split into atmospheric dynamics and physics, and atmospheric chemistry, but there are good contacts between the two sub-groups, with common projects.

The Atmospheric Dynamics and Physics Sub-group has a strong tradition in dynamic meteorology, but has broadened its scope to include studies on aerosols, and regional climate modelling.

Ten research projects are conducted by the group, all made in collaboration with other institutes on an international level. Some privileged contacts exist with the Norwegian Institute of Air Research (NILU) and the Norwegian Meteorological Institute (DNMI). This group focuses on numerical modelling of a wide range of atmospheric phenomena, to a large extent related to climate-change problems.

The Sub-group in Atmospheric Chemistry works on global modelling of the chemistry and radiation in a changing atmosphere, and benefits from the international expertise of a professor who also works 50% at the Centre for International Climate and Environmental Research Oslo (CICERO). Owing to the leadership of this professor, the global modelling studies are performed in close collaboration with other research groups at the national (CICERO) and international levels (NASA, DOE, and EU), which contributes greatly to the reputation of the Department of Geophysics.

Future work will be based on 3-D models which will focus on ozone loss processes in the lower stratosphere at middle and high latitudes, chemistry-climate interactions, and biospheric-atmospheric interactions with methane and impacts of aircraft emissions. The group lacks resources for handling the large amounts of data required for validating the models.

The Hydrology Group has two permanent scientific positions, two researchers and two research fellows. This group has a strong position in Norway; they place emphasis on national and international collaboration. The hydrogeological research is centred around three main topics: (1) flow of water and pollutants in the unsaturated zone, (2) regional hydrogeology, and (3) coupling of hydrogeological and meteorological models at a mesoscale.

The common frame for the research work of the different topics are tools from stochastic and statistic analysis, with special emphasis on variation patterns in time and space, hydrogeological variables and landscape characteristics, and the modelling and parameterisation of hydrogeological processes at different scales. The Hydrology Group participates actively in the Gardermoen national project concerned with flow of water and pollutants in the unsaturated zone. In the future, the group plans to participate in the new EU project about regional low flow and drought analysis (ARIDE), which will strengthen the environmental issues within the group. Although much of hydrology research is data driven and calls for high-quality field data the group is lacking the fundamental research equipment required for collecting such data.

The group in Physical Oceanography consists of one professor, one associate professor, and one adjunct professor. Its main affiliations are with the Research and Development Division at DNMI. It currently has five Ph.D. students, and the number of students at the undergraduate degree level has decreased dramatically in recent years. However, the number of Cand. Scient. and Dr. Scient. students in the group has been fairly stable over the last five years. The job opportunities for the candidates are considered to be very good. Although the group is critically small, it has been able to offer a full course plan in physical oceanography for the Cand. Scient. degree.

There is a clear difference in research interests between the two full-time professors. One is mainly dealing with field observations using marine-optical techniques, the other with theoretical studies on topics such as air-sea interaction, convection and mixing processes, sea-ice formation, topographic waves, and wind and wave-induced currents. The adjunct professor's main interest is numerical modelling, in particular mesoscale ocean circulation and related problems.

The direct connection to DNMI through the adjunct professor is of mutual benefit. In addition, there is a good co-operation with the Division of Mechanics at the University of Oslo. There is a lot of synergy in this "triangle", reflected by their access to good students, choice of research topics/theses, and high standard of scientific production. Due to their limited size, broad field of research, and the dependency on external funding for the Ph.D. candidates, the group is very vulnerable. This is something that should be considered in future strategic planning.

It is recommended that future activities emphasise research on air-sea interaction rather than marine optics, if a priority has to be made. This will fit well into the strategic research plan at the department and enhance the co-operation with DNMI and Division of Mechanics, and thereby reduce the vulnerability that such a small group represents.

The Solid Earth Physics Group is small (one professor, one associate, one assistant, and two adjunct professors), and a ”young” group (both the full and the associate professors began at the University of Oslo within the last 12 months).

In retrospect, it would have been more appropriate for the University of Oslo to withdraw from Solid Earth Physics while it had no faculty in post, and instead build up their other three groups. We regard this experience as symptomatic of apparent Norwegian practice, i.e., uncritically to continue research in themes pioneered by exceptional Norwegian scientists (in this case Durk Doornbos) without regard to ongoing relevance or need. Instead, every vacant position should be competed for by all research areas within a department or faculty.

The current reality is that the Department of Geophysics has two competent scientists active in solid earth geophysics. Because they are only two scientists, working in significantly different areas from each other (D’’, diffraction tomography) and from their two adjunct professors (seismic hazard, seismotectonics, seismic exploration) there is no real possibility of building up these areas into centres of excellence. They must therefore strive to develop liaisons, both in research and teaching, with other groups in their Department of Geophysics and with geophysicists in the Department of Geology.

## *Assessments and Recommendations*

Scientists at the Department produce research results of high quality mainly through individual international collaborations. With a few exceptions results are published in international peer-reviewed journals. The faculty have a real theoretical skill in basic research, but they request freedom and independence to pursue their individual interests. The only common points between all groups, and even between the individual scientists themselves, are their theoretical approach to the study of processes at work in the Earth system and their basic training in physics.

Creating programmes with a common target with other colleagues at Norwegian universities and institutions is in general not of very high concern (although there are exceptions). This lack of interest in collaboration is true even for activities related to their own in other departments at their own university.

This independence is reflected in the number and diversity of research activities within each group, more or less one per scientist, covering a very broad spectrum. The ratio of the number of professors to researchers implies that the recruitment to doctoral training is satisfactory. The number of students in the Department of Geophysics is quite high, numbering more than 30 graduate and postgraduate students.

The department claims that its main characteristics, of working in basic research with considerable freedom for each scientist to choose his/her field and mode of work, is a strength. But we also recognises it is a weakness because there is

- a danger of scientific isolation;
- a problem of identification, which may make it hard to attract young scientists;
- a failure to compete for the increasing external resources available for applied and dedicated programmes;
- a lack of research fellows;
- a problem of computer facilities, in particular system and software support;
- difficulty in obtaining data;
- an increased administrative load from the University and increased time spent in applying for funds and maintaining externally funded projects;
- a request of a 3%-cut in the total budget from the University.

Despite these issues, the department plans not to change its traditions and even plans to expand in order to cover a wider range of fields. However, they do plan to concentrate on environmental and human-induced climatic change problems to ensure more external support. They recognise their vulnerability, and ask for more faculty positions to decrease it: a request that we believe is unrealistic.

Despite its theoretical character, research in the department frequently involves practical applications that require large amounts of computer power. In general, there is a lack of hardware resources and programme engineers to assist in dedicated programming. The Hydrology Group lacks the equipment to record hydrogeological field data.

Part of the department’s problems might at least be ameliorated through a regrouping of effort by creating groups of scientists with a common research focus (topic-oriented programmes initiated within the department, but which might look for active collaboration with other departments and institutions in Norway and abroad). This would give more external visibility and power, and would also give each member more flexibility (more time) for seeking external funding, for taking

sabbatical leaves, for participating in field experiments, and requesting more computer facilities. The co-location of experts in meteorology, oceanography, and hydrology provides the opportunity to create a strong Fluid Earth Science group centred on a few well-focused research topics, in particular at the frontiers of the traditional groups.

### 4.1.6 Division of Mechanics, Department of Mathematics

The Division of Mechanics is part of the Department of Mathematics, which also includes divisions for pure mathematics and statistics. The research related to earth sciences covers topics like geophysical fluid dynamics, marine hydrodynamics, and wave theory and flow in porous media. The research activity has a clear focus on basic studies based on numerical and analytical solutions of equations describing fluid flow. A well-equipped hydrodynamic model tank is also available in the department.

This research involves three professors, one professor emeritus, one senior lecturer, and three to four research fellows.

All the scientists produce research results of very high quality. They have extensive co-operation with several research groups and with industry as well, especially the offshore industry. Scientific productivity is very good; articles are published in international peer-reviewed journals. The external funding for the research projects comes from the offshore oil industry, The Research Council of Norway, and EU-research programmes.

This division is an important national resource carrying out high-quality research of great importance and is producing candidates that are attractive on the job market, both for academia and the R&D institutes. A Strategic University Programme has been formulated recently and is run co-operatively with the Department of Geophysics of the University of Oslo. The project is challenging, very interesting, and of such importance that it deserves to be supported.

The division produces top-quality research dealing with (1) waves (genesis and impact of tsunami waves on European coasts; internal waves; wave-current interaction; and generation, propagation, and run-up flood waves from landslides), (2) tidal flows (drift and spreading in tidal flows in Norwegian coastal waters; and simulation of tides and wind-driven currents), (3) fluxes across narrow shelves, and (4) vortex dynamics.

#### *Assessments and Recommendations*

The Division of Mechanics has high scientific competence and strong theoretical skills, which are documented by their strong productivity and publication of results in leading peer-reviewed journals. Generally the research focus is on problems having geophysical applications and on interaction between fluids and floating structures. The problems are of interest in many connections, e.g., for offshore industry, resource management, and environmental studies.

It is important that this group is able to maintain their strong position in their field. In view of the importance of research in fluid mechanics and environmental flow processes, particularly in relation to the offshore activity, there will definitely be a need for research and training of students in these

fields in the future. One possible obstacle is a lack of support from service personnel (computer engineers, technicians).

## 4.2 Agricultural University of Norway (AUN)

The Department of Soil and Water Sciences at the Agricultural University of Norway (AUN) was evaluated. Volume II presents in more detail the research activities in this department.

### 4.2.1 Department of Soil and Water Sciences

Since 1987, the department has been organised into two sections: (1) Geology & Water, and (2) Soil & Plant Nutrition.

The permanent Geology faculty consists of two professors and two associate professors; a fifth position is currently vacant. One faculty member is on temporary leave with UNIS on Svalbard. Four faculty in Fresh Water Sciences include one professor and three associate professors. 12 research fellows are currently enrolled in the department, of whom three are in hydrogeology, Quaternary geology, and environmental geology. Employment opportunities are good; the principal employers are mapping authorities, geological institutes, and private firms, including software developers.

Teaching is given high priority in this department; it offers the most comprehensive programme in hydrogeology in the country. A major focus is on sustaining agricultural production in Norway. Despite the small number of faculty, the breadth of research activities is impressive, with projects spanning a wide range of disciplinary themes and geographic areas.

The geologists conduct research in the following fields:

In Hydrogeology, the group focuses on three major research fields: (1) Natural groundwater quality in glacial sediments; (2) Transport of pollutants in unsaturated and saturated zones of Quaternary sediments; and (3) Palaeogroundwater studies and modelling in permafrost areas.

In Quaternary Geology, four research projects concern the following topics: (1) Mineralogy, geochemistry, and weathering of Quaternary deposits; (2) Mapping Quaternary deposits; (3) Quaternary studies in southeastern Norway; and (4) Landscape evolution in central Tanzania during the last glacial-interglacial cycle.

The Secretariat of the International Union for Quaternary Research (INQUA) was located in the Department of Soil and Water Science between August 1995 and July 1997 under the supervision of INQUA Secretary Sylvi Haldorsen.

In Environmental Geology, research is carried out in three major areas: (1) Surface water acidification programme (SWAP); (2) Pollution from sulphide mines; and (3) Sustainable agriculture.

## *Assessments and Recommendations*

The department is active in a number of important areas and has a wide network of co-operative arrangements with scientific organisations in Norway and abroad. Much of the research is related to environmental concerns, including groundwater flow, water quality, soil chemistry and soil physics, and climatic change. While they maintain some basic laboratories, they also routinely use specialised facilities in other institutes (Animal Sciences, Forest Resources, Chemistry, Soil and Environmental Research) and in oil companies. Department faculty members also collaborate with the Earth Sciences departments of the University of Oslo (including co-ordinated teaching) and with several national organisations (Geological Survey of Norway, The Norwegian Water Resources and Energy Administration). The group is enthusiastic about their role in the Gardermoen project, which has become one of the key areas for interdisciplinary hydrologic studies in Europe.

This faculty publishes almost exclusively in Norwegian and other Scandinavian journals, often in Norwegian. Thus, their scientific impact outside Norway is likely to be minimal. With the movement toward participation in international projects, this may change in a few cases. The overall level of productivity, as measured by publication output, appears to be average.

The department suffers from a lack of technical staff in their laboratories and is concerned about the low level of financial support that limits their ability to undertake basic research, including student travel in connection with research projects. They also regard their faculty as too small to be effective in establishing this unit as the premier centre of hydrogeologic studies in Norway and to handle the increasing number of students selecting this field as a career path.

In general, hydrogeology appears to be a relatively minor component of university programmes in Norway, despite its obvious and increasing importance to the population. Norway has been fortunate in being able to use a plentiful surface water supply for human consumption and industrial and agricultural requirements, but eventually a growing population will force underground water resources to be increasingly exploited. Therefore, Norway, like most other advanced nations, will need an adequately trained scientific base in hydrogeology to meet societal needs and address concerns related to water quality and environmental pollution. As the country's most visible academic department concerned with these issues, adequate support, both human and financial, will be necessary.

## 4.3 University of Bergen

There are two departments and two institutes that the Committee evaluated at the University of Bergen: (1) Department of Geology, (2) Department of Physical Geography, (3) Institute of Solid Earth Physics, and (4) Geophysical Institute. Volume II presents their research activities in detail.

### 4.3.1 Department of Geology

The department is organised into four main groups, of which the two largest are 1) the Quaternary and Marine Geology Group, with about 9 permanent faculty, 3 adjunct professor, 5 post-doctoral fellows/ researchers, and 6 research fellows 2) the Petroleum Geology and Sedimentology Group, with 7 permanent faculty, 2 adjunct professors, 5 post-doctoral fellows/researchers and 3 research fellows. There are 26 permanent faculty, making this department the second largest Earth Sciences department in Norway. The other two groups are 3) the Mineralogy and Petrology Group with 6 permanent faculty and 4) the Tectonics Group with 4 permanent faculty.

The main characteristic of the department is the heavy involvement with Quaternary and Marine Geology investigations. The department has access to an ocean-going research vessel, Haakon Mosby, and is involved in numerous international research projects. Development of these projects is supported by a University administrative unit (the Centre for the Environment and Resources).

The Quaternary and Marine Geology Group is heavily involved in investigations of natural climatic change, and is the largest group pursuing palaeoclimatic research in Norway. In addition to publishing through scientific channels, the group is much used as a provider of background material on climate change to the Government and, via the media, to the general public. Research is focused both on long-term climatic change utilising records from the Ocean Drilling Program (ODP), and the land record of glaciation and ocean sediments. The groups have a Strategic University Programme, with the objective of developing climatic and environmental records of high-latitude climate change and investigating climate variability on decadal to century time scales. Other fields of intensive work are water resources and environmental issues. The group is subdivided into two sub-groups, Continental Quaternary Geology and Marine Geology.

A significant part of the Petroleum Geology and Sedimentology Group's research effort is directed towards problems relevant to petroleum exploration and production. Some of the staff and graduate students are extensively involved in the geological interpretation of seismic multichannel data in order to locate petroleum reservoirs, and in regional tectonic and stratigraphic studies. New methods of correlation and basin analysis are being established through sequence stratigraphic investigations and combined micropalaeontological and geochemical techniques. Modelling techniques are being increasingly applied to studies of such fields as basin evolution and petroleum source-rock maturation histories. The group has recently made significant investments in the computing facilities necessary for advanced geological modelling, and wishes to extend its research and teaching activities in this direction.

One of the fundamental problems studied by the Mineralogy and Petrology Group is the origin of basaltic magmas. The petrogenesis of basaltic magmas can be evaluated from studies of in-situ abyssal crust, ophiolite complexes on land, volcanic oceanic islands, and layered intrusions. In

recent years the group has investigated these rock types in Norway, in the East Pacific (ODP), on Jan Mayen, on Hawaii and Samoa, in Oman, and in the Himalaya. The accumulation of magma in the mantle has been treated using dynamic and geochemical modelling. Members of the group, for many years, have investigated layered alkaline rocks and boninitic intrusions. This group is pursuing the recent discovery that the vigorous bacterial life in the oceanic crust may have consequences for the composition of the upper oceanic crust and possibly of ocean water.

Traditional field-based studies by the Tectonics Group have recently been upgraded by the introduction of more quantitative techniques, and have been expanded to include detailed studies of post-Caledonian faulting and fracturing, especially in relation to off-shore studies, such as the North Sea rift system. The group has close research ties with the petroleum geology group and with various oil companies. At the same time, the group has conducted applied research in the onshore, non-oil sector (radioactive waste disposal, stability of underground excavations and rock slopes, neotectonics, and in-situ stress), and is in the process of introducing ”hard rock” hydrology and engineering geology as a major area of teaching and research.

## *Assessments and Recommendations*

The department is training a large number of graduate students, both at the masters and doctoral levels. This instruction is mainly in Quaternary and Marine Geology, in Sedimentology, and in Structural Geology, although other subjects are represented.

Research productivity, as indicated by publications in refereed journals, is strongest in Quaternary and Marine Geology and in Mineralogy and Petrology, although other groups are also active.

The Quaternary and Marine Geology Group is the largest and most active university group engaged in these studies in Norway. They are working on well-integrated projects, the results of which are well-known internationally. The Marine Geology group has strength in micropalaeontology, applied to palaeoceanography, and is engaged in several international projects. Although our Committee was sympathetic to the idea of a proposed "marine studies institute", we think the activities of the existing marine group might be weakened if it is separated from the Quaternary group, which is also excellent, has received funding as a "strategic university programme" together with the marine group, and is active in many international projects.

The Petroleum Geology and Sedimentology Group includes several individuals who are doing good research, but who operate independently or with collaboration elsewhere; they do not constitute a well-integrated group within the department. In particular, the Committee noted the Quaternary and palaeoclimatic implications of their work on African lakes, and encourage these researchers to develop closer links to the department's Quaternary group. The group has recently widened its expertise by adding a sequence stratigrapher. Sequence stratigraphy is an important addition to traditional stratigraphic methods, first widely applied within the petroleum industry, but now forming an essential part of the training of anyone specialising in sedimentary geology. Somewhat surprisingly, the new faculty addition at Bergen is the only permanent faculty member now specialising in this field in Norway.

The Tectonics Group includes several active research workers. Some projects might be more closely linked with the structural geologic research being carried out in the Marine Geology group. The Committee was pleased to hear that the Tectonics Group intends to add an Research Council senior-

researcher specialising in hard-rock hydrogeology. Expertise in this area should be further developed in Norwegian universities.

The Mineralogy and Petrology Group includes a number of active, closely focused, researchers, who are carrying out interesting work, particularly on the mechanics of magma chamber evolution.

The Committee was enthusiastic about the Centre for the Environment and Resources developed by the Faculty of Science, to assist groups, such as the Quaternary and Marine Geology Group, to develop and co-ordinate inter-disciplinary research and educational activities related to the environment. Its efforts seem to be successful, and should be maintained.

## 4.3.2 Department of Geography

Drawing on the three traditional areas of geographic research - i.e., human and regional geography, physical geography, and environmental geography - the geography department at Bergen has organised itself into the following sections: Local and Regional Development; Man-Environment; Physical Geography; Economic Geography.

The fourth area of study, Economic Geography, falls under the purview of the Norwegian High School of Economics and Business Administration (NHH). Of these four groups, only Physical Geography has been considered in this review.

The permanent faculty in physical geography at the university include three associate professors, an assistant professor, and an affiliated senior lecturer (permanent position in the Nansen Centre). Three received their highest degrees from Norwegian universities (Bergen, Oslo) and the other two from Canadian and American universities. During the past five years, second-year undergraduate students in physical geography averaged about ten.

Faculty research interests in physical geography fall into several distinct areas:

- Distribution, variations, and chronology of glaciers during the last glaciation and the Holocene in Norway, including palaeoclimatic inferences based on studies of glacier equilibrium-line altitudes; vertical extent of the last ice sheet in Scandinavia and northern Britain; assessment of glacial erosion rates in selected drainages; and Holocene mass-wasting phenomena in southern Norway
- Application of geographic information systems technology (GIS) to coastal-zone management (including Kara Sea), geomorphic reconstructions, and monitoring and integration of GIS and numerical models
- Arctic sea-ice distribution and relationship to climate variability, using satellite remote sensing

### *Assessments and Recommendations*

The basic strength of this unit in the Department of Geography rests with its several active young faculty, two of whom have gained international recognition for their research. However, not surprisingly, the work they do closely overlaps that being done in the Quaternary and Marine Geology groups of the Department of Geology at Bergen, from which they received their advanced

degrees. As a result, this component of the faculty has far more in common with the geology faculty than with the bulk of the social-science oriented geography faculty.

The department has seen a recent marked increase in research activity, in part resulting from a comprehensive review three years ago. A reduction in teaching load has been made to encourage greater research activity, and special emphasis is being placed on publication in international journals.

The research being done is of high quality, but is largely traditional in scope. As in virtually all geography departments, GIS is recognised as a critical tool, and is being implemented in departmental teaching and research. However, there is no evidence that its application in this department is particularly innovative, rather than conventional.

Two young physical geographers, both products of the university's Department of Geology, account for the bulk of the recent scientific output in physical geography and are responsible for this unit of the department having the highest publication rate.

A recognised problem with this unit is the integration of physical geography, a physical-science-based subject, into a department dominated by social scientists. Nevertheless, the department chairman recognises the opportunity for cross-disciplinary co-operation and is making an effort to foster a "common departmental culture". Consistent with this objective, the department plans to make Man-Nature (environmental geography) a focus of activity and is hoping to develop an interdisciplinary research programme in the Nepalese Himalayas. While this is a worthy research objective, a comparable broad interdisciplinary effort could also be developed in Norway, thereby enabling greater student participation. This would be consistent with the stated dual commitment to an emphasis on Norwegian landscape development and to the application of GIS methodology.

The imminent departure of the most productive member of the department to assume a professorial position in the Department of Geology opens the possibility of acquiring a new faculty addition. In view of the stated departmental interest in climate- and landscape-related research, serious consideration should be given to seeking a person with expertise in land-surface biological processes that have a relationship to climate. This important emerging area of research, which would encompass biological (ecological) subjects not presently represented on the faculty, would strengthen the climate and palaeoclimate components of faculty research and would involve GIS applications as well.

### 4.3.3 Institute of Solid Earth Physics

The institute has many strong individuals. Improved co-operation and integration between individual professors could greatly increase the impact of this department on science. The department consists of three research groups. Two are small, Palaeomagnetism and Seismology, and one is large, Petroleum Geophysics. At least one faculty member in each group has international stature and is cited, on average, at least ten times annually.

The Palaeomagnetism Group has three tenured professors, one term-appointment professor, and one adjunct professor-II conducting research in the following areas: experimental investigations of the magnetising process, magneto-stratigraphy, development of instruments, palaeomagnetic reconstructions, and maintenance of the geomagnetic observatory at Dombås.

The group is clearly not as productive as it should be for a group of this size, a situation that can apparently only be remedied by retirements and a focusing of energies on a more limited range of research topics (presumably from the top of the preceding list). Although it is important that the Dombås geomagnetic observatory be maintained (to continue the internationally valuable time-series measurements), responsibility should be moved elsewhere - either to the University of Tromsø (which we were told by persons from the University of Bergen would welcome the task) or perhaps, even more appropriately, to The Geological Survey of Norway (NGU).

The Palaeomagnetism Group is well equipped with instrumentation, some developed in house, and is extremely well-supported by technical staff (2.5-3 FTE). If the tenured professoriate of the palaeomagnetic group shrinks by retirement, and if responsibility for Dombås is transferred, then some of this technical support should be made available to support other areas of geophysics.

In the Seismology Group, two tenured professors and one term-appointment professor (presumably will be converted to a permanent appointment), conduct research in the following areas: CTBT-related studies, seismic source classification, automating and integrating local network operations into CTBT monitoring, responsibility for the Norwegian National Seismic Network, and development and installation of Seislog and SeisAN networks as a world-wide initiative.

The group clearly forms two opposed factions, to their mutual detriment. There are obvious potential synergies to be exploited between the network-installation "sub-group" and the nuclear-monitoring "sub-group"; in addition, there are obvious potential synergies to be exploited between the Seismology Group and various more theoretical studies being carried out in the Petroleum Geophysics Group; however, our Committee cannot attempt to micro-manage personal relationships.

It is not clearly in the best interests of Norwegian science for the 22 stations of the Norwegian National Seismic Network to be operated by the University of Bergen rather than by NGU; such permanent responsibilities are not easily accommodated by small research groups and greatly impede their flexibility to respond to new scientific opportunities. (In many countries the equivalent networks are run by national Geologic Surveys.) Certainly, we were not made aware that University of Bergen faculty take advantage of opportunities presented by their operation of the National Seismic Network, in which case the university might do well to relinquish this task.

The Petroleum Geophysics Group has seven tenured professors (one currently Dean of Natural Sciences), one term-appointment professor, and one adjunct professor-II conducting research in the following areas: acquisition and interpretation of marine MCS and OBS data, acquisition and interpretation of land vibrator data, drilling technology, seismic inversion and modelling, reservoir geophysics, gravimetry, and heat-flow.

It befits the research group with the closest links to the hydrocarbon industry (active-source seismology) that they additionally employ three post-doctoral scientists (it was 6, until this last year when three were lured away by higher salaries in industry) on grants raised from the oil industry. On the other hand, it seems an anomaly that perhaps the most visibly active sub-group in Petroleum Geophysics is led by a scientist without a tenured position, and that this sub-group must therefore function at the whims of industry funding. The active-source seismology group is remarkably well equipped, with ready access to the University of Bergen ship Haakon Mosby, and with four seismic vibrators of their own. While it is very positive that such equipment can be deployed on industry-

funded scientific projects, a potential danger is that industry may come to define the projects. We hope that university and Research Council funding will allow this group to keep their intellectual freedom. Already the group cannot continuously maintain its vibrators, being able only to operate them when significant outside money becomes available.

Reservoir geophysics has good potential for growth with the support of the oil industry, but some of the other research areas seem isolated and scientifically ineffective. We urge individual professors to look for ways to build their science in conjunction with each other.

## *Assessments and Recommendations*

Over the years 1992-1996, the department graduated 10 Dr. Scient. and 42 Cand.Scient. or M.Sc. students. This number would be reasonable, though not high, except that 12 of the Cand.Scient. graduates were produced by a professor-II and by a post-doctoral scientist without a faculty appointment, so that the overall contribution of the department in awarding advanced degrees seems poor. Perhaps too much energy is expended in teaching small-enrollment classes; of 31 classes listed, nine were taught to less than 10 students, and an additional nine to less than 20 students, cumulative over a four-year period.

The strength of the department is a few individuals whom are firmly established international-calibre scientists. The department has remarkable endowment of experimental and observational facilities, including the National Seismic Network, a well-equipped palaeomagnetic laboratory, access to the flagship of Norwegian research vessels, and ownership of OBSs and vibrators.

The two small research groups in palaeomagnetism and seismology flourish, based on the excellence of one individual in each; as such they represent centres of regional excellence in Norwegian Earth Sciences, albeit in each case barely of critical mass. Although it is desirable that each speciality continue to be represented in Norwegian Earth Sciences, the unavoidable concern at present must be that the loss of a single individual in either case could spell the intellectual death of a whole group. Seismology of a similar (not identical) flavour is found in Oslo and at the Norwegian Seismic Array (NORSAR), and palaeomagnetism (again, in a different sub-field ) is established at NGU. When it next becomes possible to hire, it is imperative that either young and active faculty be hired in these areas, or that a conscious decision is taken to move away from research in these areas in the interests of strengthening other sub-disciplines.

The Petroleum Geophysics Group has a few active researchers leading a few active areas, but more than half the group is invisible at the international level. Thus, the department is of very mixed quality.

The weakness of the department is that it is composed of individuals rather than of teams. Some rivalries are sufficiently divisive that department's overall impact on Norwegian science is seriously weakened. The few international-calibre scientists need more support from the University ("merit" awards whether of technical support or financial support) in order best to project their abilities.

Remarkable technical facilities should allow Bergen to make itself the premier Norwegian university in observational geophysics. These areas should be developed in preference to the more theoretical studies that proliferate elsewhere in Norway and in which University of Bergen may compete but does not clearly excel. Other opportunities are the strong links with the petroleum

industry, which provide junior scientists with post-doctoral/research scientist experience, thereby keeping open the pipeline of Norwegian scientists.

An immense success story of the Petroleum Geophysics Group is their contributions to new technology. The development of hydrostatic corers, marine shallow-drilling rigs, and snow/sand streamers are all exceptional results that risk being overlooked by conventional measures of scientific achievement (e.g., publications and citations). We recommend that the University of Bergen develop formal mechanisms for retaining rights to these and future inventions by its faculty, dividing royalty shares equally between the individual, the department, and the university. We see such mechanisms as a way to encourage positive creation of new inventions and to help them move to the marketplace.

A divided group of faculty with culturally mandated weak leadership risks flight of its best, most active members to lucrative industry posts. This is a serious threat to the department and Faculty.

### 4.3.4 The Geophysical Institute

The Geophysical Institute is organised in two research groups: (1) Oceanography and (2) Meteorology.

The organisation is built around the institute steering committee. There are 16 permanent scientific positions (3 vacancies) and 3 adjunct professors and three research fellows financed by the university. 17 research fellows and 7 researchers on external contracts have their place of work at the institute. In addition, there are 10.7 technical and four administrative positions. The Geophysical Institute has the administrative responsibility for the operation of the research vessel, Haakon Mosby, and its crew (18 people).

The Geophysical Institute produces highly qualified candidates in geophysics; the institute offers the most extensive programme of courses in oceanography in Scandinavia.

The main characteristic of research is a large number of projects covering a broad spectrum; some in collaboration with other Norwegian and international groups. Most of the scientific personnel are involved in more than one research group/project. The research activities can be grouped into three main areas: Oceanography, Ocean-atmosphere interactions, and Meteorology.

Research in Oceanography consists of 11 projects covering more than 30 topics. Most of the 11 projects are carried out by one to two faculty members and a post-doctoral fellow, one to five doctoral students, and at most six Cand.Scient. students. The oceanography research mostly deals with thermodynamics of the polar seas, fluxes of European and Arctic coastal and shelf waters, chemical oceanography, and convection. Considering the geographic location of Norway, studies of the Norwegian seas, coastal waters, and fjords are very important and will continue to receive much attention.

Research in the field of Ocean-atmosphere interactions covers air-sea interactions, climate and changes of the ocean-atmosphere, and mesoscale and regional modelling of processes in ocean and atmosphere.

Research in Meteorology concerns mainly mesoscale and regional modelling of climate and climatic changes, radiation-climate studies and argometeorology, and near-ground and local meteorology, flux above snow and ice covers, ice accumulation and structures.

A recent evaluation of research at the University of Bergen recommended that mesoscale modelling should receive high priority. We agree that the models developed for mesoscale processes are very original, and that this activity deserves special attention. Some of the other existing projects (ozone in Tibet, sound propagation, wave-type classification) are, through the adjunct professor in charge of them, related to UNIS and do not require high priority.

## *Assessments and Recommendations*

The Geophysical Institute participates in six international programmes and collaborates with many institutes abroad. However, the list of publications is not as impressive as might be expected; few are prominent in peer-reviewed journals. Moreover, a real co-operation between meteorologists and oceanographers, and the Geophysical Institute and other institutes at the University of Bergen, is lacking.

Considering the large number of projects and the broad spectrum of topics concerned, it might be advisable to concentrate on fewer more-specific areas of research. Concerning the possible creation of a Marine Faculty (Institute), it would be appropriate to focus on ocean and ocean-atmosphere related problems. This is even truer with respect to the size and the localisation of the institute, as well as its broad orientation towards field, theoretical, and modelling research activities.

The Committee is of the opinion that the following topics deserve particular attention:

- Climate modelling, including ocean and atmosphere, and in particular at a regional scale;
- Mesoscale phenomena in the atmosphere and the ocean;
- Air-sea interactions;
- Circulation of water masses in the Norwegian and Barents seas;
- Chemical oceanography, including carbon flux and $CO_2$ studies;
- Circulation in fjord and coastal waters.

It is important that each group reach a critical mass as soon as possible, especially if a new marine faculty is created. Future faculty openings should be advertised widely and internationally. They should be directed to the subjects that are deemed to be of the highest priority (climate modelling, ocean chemistry, air-sea interactions, mesoscale phenomena).

Some of the project areas (climate and chemistry) should be discussed in depth with other groups at the University of Bergen, the Marine Geology group in the Department of Geology, in particular, in order to define topics within these areas for possible collaboration.

Even though the Geophysical Institute has been allocated considerable resources to establishing a geophysical modelling laboratory, more should be done to provide researchers with sufficient access to computers, including super-computers. Most importantly, programme engineers should be available for re-programming the parallel-machine codes. The network of workstations for pre- and post-processing of large sets of data should be preserved.

As for the field of radiation, it would be advantageous to transfer the routine observation duty to an official national service. A transfer of this duty will save time for the members of the Geophysical Institute.

## 4.4 Norwegian University of Science and Technology (NTNU)

Three departments are evaluated at NTNU: Departments of Geology and Mineral Resources Engineering; Petroleum Engineering and Applied Geophysics; and Hydraulic and Environmental Engineering. Volume II presents the research activities in more detail.

### 4.4.1 Department of Geology and Mineral Resources Engineering

The Department of Geology and Mineral Resource Engineering resulted from a merger in 1988 between a small geology department and two engineering departments (Mining and Mineral Processing). Despite this formal change in organisation, the three former departments have not been integrated into a new working structure.

The department has 17 faculty members (full and associate professors) and three adjunct professors (2 engineers connected with SINTEF, and 1 professor emeritus in ore geology). The 17 full and associate professors are organised into three groups, which largely reflect the three former departments: Resource and Petroleum Geology (7); Engineering Geology (4); and Mineral Resource Engineering (6).

As in other engineering departments, the number of Dipl. Ing. graduates (average 27 per year since 1992) is high compared with the Dr. Ing. degrees (average 4 per year). Most research activity, in all fields, is funded externally, mostly from industry sources.

In the Resource and Petroleum Geology Group, geologic and mineralogic studies of metallic and non-metallic resources have been concentrated on the metamorphism of sulphide deposits and regional metallogenesis of the Caledonian orogeny. With the recent new appointment in economic geology, the group is expanding their study to modern ore-genesis research, having established co-operation with top international groups working on the application of new isotopic techniques (Re/Os) for dating ore formation. The research in petroleum geology flows to some degree into the hydrocarbon assessment work, but the petroleum geologists primarily focus on applied research in the mineralogical and petrophysical properties of cap rocks. They apply mineralogic techniques in the characterisation of natural rock samples. The kinetics of diagenetic mineral reactions is studied using standard autoclave experiments.

The projects in the Engineering Geology Group deal with technology used in large underground excavations. They investigate aspects such as rock stress, and blasting optimisation. An investigation of rock-bolt technology recently won an international award. Related projects deal with process mineralogy, grinding technology, and resource recycling. A technology pool for the stone industry addresses common problems of the contributing companies.

In Mineral Resource Engineering Group, resource assessment both for hydrocarbon and mineral resources, is carried out by a team of engineers, who are applying state-of-the-art statistical and 2D spatial models to existing regional data. Their methods and results are adopted as a basis for policy decisions by Norwegian government agencies.

Little contact seems to exist between the high-quality work of this group of engineers and the ore-genesis geologists, despite the obvious potential for mutually beneficial collaboration.

## *Assessments and Recommendations*

Although now formally merged into a single department structure, the physical separation and the traditionally different approach to their work has hampered the development of a common identity for research. The graduates (mining + petroleum engineers) that the department produces are in very high demand by the petroleum and other resource industries. This obvious success is associated with a heavy teaching load, which is part of the reason for the low level of communication within the department. A basic difference in scientific culture is reflected by the different standards by which engineers and geologists measure the success of their work outside the classroom: successful projects and reports to industry and public community vs. publication of research results in peer-reviewed journals. Nevertheless, at least some representatives of the engineering groups now recognise an urgent need for longer-term, more fundamental research in their fields. They also recognise the potential for building a strong research group at NTNU with a clear common theme around scientific and technological aspects of earth resources in the widest sense. The representatives at the interview admitted that the preparation of their submission to this Committee was the first step towards better communication. A major obstacle to overcome is the apparent unwillingness of the technical and administrative staff to support any change in their work practice.

In terms of Earth Sciences research this department must be rated as rather weak, but it has potential for future development. The department is split; the members are well aware of this problem. We feel that their difficulties are not so much due to their perceived high teaching load or lack of research money, as to the differences in the current teaching curricula and the immediate aim of the work of geoscientists vs. engineers.

With their joint expertise, the department is in an excellent position to develop a highly visible research and technology development programme, directed to the basic understanding and the long-term use of earth resources in the widest sense. Although geotechnical and petroleum applications are of most immediate use today, industrial minerals are of growing importance in the Norwegian economy. With regard to metallic resources, there is renewed international interest in the exploration potential for base metals, gold, and diamonds in Scandinavia. Metal exploration is increasing in demand on international markets, and Norway, as a net importer and processor (e.g., aluminium) of these essential resources has a vital interest in maintaining a global geologic expertise in ore geology and mineral resource assessment. The department at NTNU is the obvious institution to carry this role in the future, in collaboration with the Geological Survey of Norway (NGU) which is located in the same city.

Many of the individuals, in all groups of the department, are obviously very effective and highly regarded in their fields, nationally as well as internationally. The output of the engineers is difficult for this Committee to measure, but it is apparent that not all staff members among the engineering groups are equally productive.

The members of the Engineering Geology Group, likewise, vary with regard to publication output, with at least some members being largely concerned with activities other than research. Compared to other geology departments, the publication and citation rates are low, but the higher-than-average teaching load may be partly responsible for this.

To initiate serious discussions of the opportunities, we suggest that the department's professors be granted some ”seed” money to organise a number of ”retreat meetings”, in order to develop a strong multi-disciplinary research programme of long-term interest. This might be best proposed as a Strategic University Programme.

As opportunities for new professorial appointments arise in the coming years, the department could become a unique and highly visible research centre for the geology and technology of earth resources. The successful creation of such a centre will depend on fully dedicated professors, who collaborate with industry, but do not depend on personal financial reward from consultancy contracts to an extent that it detracts from their primary academic role. For this department, in particular, a reconsideration of remuneration policy would be highly advisable (see introduction).

### 4.4.2 The Department of Petroleum Engineering and Applied Geophysics

The department consists of two research groups. Our Committee only reviewed the Applied Geophysics Group; we neither interviewed nor reviewed the Petroleum Technology Group.

The Applied Geophysics Group currently has five active professors (one split between applied geophysics and petroleum technology; one, an assistant without masters or doctoral qualification) and two vacant posts; also one current professor-II (soon to be replaced) and two vacant professor-II positions (2 of 3 professor-II positions anticipated to be funded by industry); also one post-doctoral fellow.

The department is of mixed quality. Only one professor publishes widely in international journals, while two others have research activities that are strong only in the national context. The two junior professors show more promise, and we urge senior faculty to consciously assist them in their career development by providing sufficient relief from onerous teaching, and to provide personal guidance, in order to help them develop promising lines of research.

Most research is quite appropriately in the highly applied areas that are also the focus for teaching. We are concerned that this dedication to applied research should not be expressed only within consultancies at SINTEF, but instead should be more broadly pursued within national and international university and industry collaborations.

The pepartment operates a modest suite of computers, valued at 44M NOK, but probably matched in value by software donations from industry. The biggest lack is Research Council recognition of the need for continuous updates of hardware and software (including technical support), for which a reasonable budget, as elsewhere in the Norwegian university system and in other countries, would be 15% of the initial capital cost, per annum. The Formation Physics Laboratory deserves special mention, as does the soon-to-be-appointed senior faculty member in Formation Evaluation. These twin developments are the outcome of a fruitful collaboration with the Norwegian oil industry and

reflect industry-university interaction at its best. We endorse the department's hope that NTNU will permanently establish the professorial position in Formation Evaluation following the four-year industry funding already secured.

### *Assessments and Recommendations*

While we do not believe that the Applied Geophysics Group at NTNU has achieved its claimed "international recognition in Petroleum Seismic and Rock Physics", we believe that the department has the potential to do so if it makes wise appointments in its open positions, seeking to build on existing strengths and rejecting any parochial considerations. The maintenance and further development of IPTs international M.Sc., and its Pomor University (Arkhangelsk) teaching collaboration, are important aspects of the push for international stature.

The strong focus on industrially applicable petroleum geophysics is the strength of the department. The weakness is the potential that individual department members are drawn into contract work and SINTEF-funded research applications at the expense of following the most intellectually challenging lines of research.

Training a truly international group of M.Sc. students, and their Russian counterparts at Pomor University, and returning them to positions of influence in their home countries to develop a Norwegian influence on the energy industry world-wide, is a great opportunity for the department.

The Committee sees the following threats to this department:

- Additional appointments of faculty members who have received all their training at NTNU would further dilute the international potential of this group.
- Any failure of NTNU to capitalise on the opportunities presented by strong industry support for new directions, or to accept proffered senior research fellowships and capital infrastructure, would not only miss opportunities but could also jeopardise further collaboration.
- The potential failure of the Research Council to maintain the hardware and software infrastructure necessary for state-of-the-art teaching to master's level will jeopardise IPT's ability to prepare Norwegian students for industry jobs.
- Any neglect by Applied Geophysics Group of intellectual opportunities and of their primary research mission, in favour of personally lucrative industry/SINTEF consultancies, will further diminish the potential for international stature of the department.
- The existing university salary structure jeopardises the independence of the Norwegian Earth Sciences mission. It is not relevant that academics earn less than their industry counterparts; we expect this, but university professors must earn enough that they need not moonlight but instead can turn full attention to their research. It is a serious indictment of the university funding system that market forces are not at all considered in setting salaries.

## 4.4.3 Department of Hydraulic and Environmental Engineering

The department belongs to the Faculty of Civil and Environmental Engineering and consists of four research groups, each headed by a full professor. Even though there is not a formal research group in hydrology, the research group working with hydrological problems consists of two professors, two associate professors, three assistant professors, three doctoral candidates, and one technical

assistant. The group has close co-operation with the Department for Water Resources within SINTEF Civil and Environmental Engineering and most of the large research projects conducted in hydrology are run from within SINTEF as Dr. Ing. projects. The SINTEF group was evaluated by a team from the Research Council in 1996. The department has good international contacts and co-operations in Europe and Africa.

The Department of Hydraulic and Environmental Engineering has listed seven main research areas: urban hydrology and water management, Arctic hydrology, hydrological modelling, flood hydrology, habitat hydraulics, and hydropower hydrology. In addition, the department has just started two new projects related to human encroachment on catchments and river systems (HYDRA project) and hydrological effects of land-use changes with application to the Pangani River in northern Tanzania. The large number of projects in different areas of hydrology in relation to the number of scientists listed, indicates the need for concentration on a few of the most relevant and interesting topics; focusing will lead to more in-depth research. This strategy can be combined with the intention of developing hydrology as an engineering subject. It also allows the department to combine hydrology, hydraulics, and computer science and form the new subject hydro-informatics.

## *Assessments and Recommendations*

Hydrology is not the only research topic in the department. On the contrary, it is often a supplement to the other more applied topics. This is a policy which is meant to prevent the staff members from focusing on pure scientific problems. This results in a problem of raising funding since the Research Council is demanding more basic research in order to fund grants. This situation appears to be a Catch-22. An evaluation of the productivity based on publications shows that the number and rate of publications are average. However, most contributions are published in national and international conference proceedings, departmental technical reports, and similar report series. In order to achieve recognition at the Research Council and other national and international funding organisations, the standard of publishing needs to be improved. NTNU has introduced a system whereby researchers receive university funding based on the rate of publication and type of journals for publication. The existence of this ranking system is a strong reason to hope the publishing strategy will change.

The department will have one associate professor vacancy in the near future. The Committee recommends that the department focuses attention on urban hydrology. The department has ongoing research in that field, and none of the other Earth Sciences departments in Norway has a programme in urban hydrology, so that this will fill a gap in the overall structure of hydrologic research in Norway. Urban hydrology at NTNU provides the opportunity to co-operate in the fields of water resources engineering and water treatment technology.

A particular problem facing the department is the financing of the Risvollan and Sagelva research stations. They are important both for research in hydrology and for teaching. Normally, state meteorological and hydrological institutes are responsible for basins of this type. The teaching part of the running cost has to be supported by NTNU. First-class research projects with problems that can be studied at either of the two stations have a fair chance of being funded by the Research Council.

## 4.5 University of Tromsø

The Institute of Geology and the Museum of Tromsø are evaluated at the University of Tromsø. Volume II presents the research activities in detail.

### 4.5.1 Institute of Geology

The Institute of Geology consists of 11 tenured faculty members (5 professors and 3 associate professors). They are formally organised into two sections, Exogene Geology (marine geology, sedimentology, terrestrial Quaternary geology) and Endogene Geology (orogenic evolution, structural geology, petrology). In practise, the institute operates in a matrix structure, whereby most of the faculty members contribute significantly to several of these six disciplines in the two sections.

The position of vice-chancellor of the University is currently held by a professor of the institute, which may reflect, to some degree, the dynamic nature of the department as well as the high significance of Earth Sciences in this university.

Research at the institute is conducted primarily in northern Norway, Svalbard, and adjacent continental margin areas, including the Barents Sea shelf and slope. Collaboration with other institutions includes adjacent regions, such as northwestern Russia, the Norwegian-Greenland Seas and Arctic Ocean, and a few more-distant localities in Europe and North America. Research in the fields of marine geology, sedimentology, and terrestrial Quaternary geology (Exogene Geology) is closely related, as is research in structural geology, regional bedrock geology, and experimental petrology (Endogene Geology). Some overlap exists between exogene and endogene geology in the fields of structural geology, marine geology, and sedimentology. Applied geophysics at the institute is conducted primarily in the field of marine geology.

Research areas in Marine Geology include the fjords of northern Norway and Spitsbergen, the continental shelf and slope off the coast of northern Norway, Spitsbergen, and the Barents Sea east to the Kara Sea, and deep-sea areas of the Arctic Ocean. The main research themes are listed in Volume II.

Data for the projects are obtained from several sources: cruises carried out using the three research vessels owned by the university, through collaboration with scientists at other research institutes as part of larger programme, and with the petroleum industry.

The main research themes in Sedimentology are modern and Holocene depositional environments, clastic and carbonate sedimentology, and diagenesis of pre-Holocene sediments in northern Norway, Spitsbergen, the Barents shelf, and elsewhere.

This research uses the outstanding field opportunities of the large Arctic deltas and well-exposed, undeformed sediments on Svalbard. Tromsø has the only group of sedimentologists in Norway with a balance between clastic and carbonate sedimentology, carrying out interesting comparative work on carbonate petrology in Palaeozoic strata on Svalbard and Cenozoic sediments in Greece.

Research in Terrestrial Quaternary Geology has been focused on applied geophysics, sedimentology, and marine geology, mainly in three projects: postglacial sea-level change in northwestern Russia, raised-beach morphology and facies architecture indicating sea-level and climate change, and valley-fill stratigraphy, deglaciation history, and sea-level change in fjords.

The last project contributes to the land-based part of the SPINOF (Sedimentary processes and paleoenvironment in northern fjords) Strategic Programme. It involves collaboration with the Kola Science Centre in Apatity as well as the Tromsø Museum, and aims at obtaining well-dated relative sea level curves for the Russian coast of the Barents Sea.

Research in Structural Geology concentrates on the post-Caledonian structural evolution of Spitsbergen, where the plate margin between the Norwegian and Greenland shelves was active in a major transform structure during the Palaeocene opening of the North Atlantic. The project includes collaboration with the University of Nebraska in order to compare this structure with more recent structures in western North America.

The research group in Bedrock Geology and Orogenic Evolution carries out original, collaborative research aimed at unravelling the geological history of the northwestern part of the Baltic Shelf and the deeper sections of the Caledonian region. The following projects are currently active: Precambrian crustal evolution of the West Troms Gneiss Region, the Caledonide Orogens of northern Scandinavia, high- and ultrahigh-pressure metamorphism in the Western Gneiss Region, and age, petrogenesis, and tectonic setting of late Caledonian Granitoids in Sunnfjord.

The research group in Experimental Petrology conducts work in research fields where experimental data are important. Although the research is strongly related to geologic problems in Norway (in particular northern Norway), the experimental work focuses on fundamental problems of general interest. The group has listed six projects in progress at the experimental laboratory.

## *Assessments and Recommendations*

Thanks to the gradual build-up of geology at Tromsø, the department has a good age structure with a high proportion of younger professors. They present themselves as a well-run teaching and research unit, covering a relatively broad and well-balanced range of expertise, including bedrock geology. This favourably complements the larger departments in Norway, which have a heavy involvement in petroleum-related earth sciences. The main common interest of the department at Tromsø is their focus on various aspects of Arctic geology. They make excellent use of their geographic setting to undertake geologic studies of under-explored areas, and successfully underpin this regional work with experimental studies in the laboratory. They have an international perspective, reflected in their choice of specific research topics, and collaborate actively with other research groups, both nationally and internationally.

Full support for all main research areas is justified, with particular emphasis on continuing the SPINOF Strategic Programme, and strengthening experimental petrology. The latter activity depends on special support for additional equipment to permit this dynamic group to reach critical mass. Their expectation of building a laboratory of international standard, which will attract researchers nationally and internationally, is realistic if they are given priority support as the prime experimental petrology laboratory in Norway.

Publication output is good and consists of a high number of papers in top international journals, as expected from a relatively youthful department. However, even older faculty members are highly productive and there is not a single scientist who does not contribute to refereed publications.

The department actively recruits Ph.D. students from all over Norway and has had a high, but strongly fluctuating, intake and output of cand. scient. students over the short life of this university.

### 4.5.2 The Museum of Tromsø

This review is based solely on the written document submitted by the museum.

This is a non-faculty unit responsible to a Museum Board, directly under the University Board. The department is administered by three elected staff members (two scientists, one technician/administrator). Two categories of scientific staff exist: curators and museum lecturers, each with a 50 percent research obligation. The staff consists of a museum lecturer (professor), two curators (associate and assistant professor), and one research fellow (doctoral student).

The staff's primary concerns are with museum display and curation, as well as with limited Arctic research involving various scientific disciplines.

Research is focused on several minor interdisciplinary projects and co-operative association with the Archaeology Department. Current projects include: palaeoshorelines and climate, Palaeozoic palaeontology and modern high-latitude corals, and tectonic and stratigraphy of metamorphic rocks in northern Norway, with emphasis on P-T conditions and chronology

#### *Assessments and recommendations*

The limited scientific output of this small unit, whose main focus is on museum curatorial work and public outreach education, is not surprising. Nevertheless, research activity might clearly benefit from closer contact and collaboration with the Institute of Geology.

This faculty publishes almost exclusively in Norwegian journals, although several international journals appear in one bibliography. The overall level of productivity, as measured by publication output, appears to be on the low side.

## 4.6 University Courses on Svalbard (UNIS)

University Courses on Svalbard (UNIS) is an institution founded by the four Norwegian Universities, and it is regarded as a common part of them. The main goals are to provide university-level teaching, conduct high quality research, and contribute to the community of Longyearbyen. UNIS is organised into four departments. This evaluation covers only the Department of Geology and half of the Department of Geophysics, namely the oceanography and meteorology activities. Volume II presents the research activities in detail.

The Department of Geology has four full-time scientists and two adjunct professors. In oceanography there are two full-time scientists, one adjunct professor, one post-doctoral fellow, and one Ph.D. scholarship recipient. The full-time positions are for a maximum term of six years, whereas the adjunct professors are on five-year contracts.

The research activities are based on the special possibilities that are provided on Svalbard, and in the Svalbard region, so that the main scientific and teaching is directed towards Arctic-related sciences.

UNIS offer students a one-year study as part of their education at a Norwegian or foreign university. The total capacity of 100 students has now been reached. UNIS has an international profile (approximately 30% of their students are foreign), and all teaching is in English. All courses have a field component. Access to helicopters and research vessels exist for the field excursions and measurement programmes.

The primary fields of research within the earth sciences are presented below:

The research agenda in Geology and Physical Geography Group of the Department of Geology is determined by the composition of the faculty at any given time. At present, the following areas are being emphasised: Late Cenozoic geology and physical geography, Late Palaeozoic to Cenozoic stratigraphy and sedimentology, and climatology.

A number of research projects covering a wide range of topics in Meteorology and Oceanography are conducted by the scientific staff. Some of these projects are apparently projects that were started before UNIS was established and probably initiated without the objectives of UNIS in mind. The primary fields of research within the oceanography/meteorology activities are listed in Volume II.

Some of the projects are carried out in collaboration with external institutions and scientists. One of the projects is part of a larger project that is receiving funding from the European Commissions (EU).

Several of the topics listed above are both interesting and of primary importance for environmental understanding, both on local and global scales. All of these projects are ongoing, but results and conclusions are not yet available. A later evaluation of the research would therefore be more appropriate.

## *Assessments and Recommendations*

UNIS is a young institution (four years old) which is now moving from a typical build-up phase to a consolidation phase. This is also reflected in the production of research results. However, according to plan, the research activity will be given a top priority in the years to come.

One of the most interesting aspects of the UNIS profile is the joint ownership by the four Norwegian Universities together with the international recruitment of students and guest lecturers. This can lead to enhanced co-operation between the universities in Arctic-related research and the development of a place where different schools and thoughts meet new ideas.

During the short time UNIS had existed, there has been a growing interest in starting research projects in this region. One of the possible threats that have been pointed out is the danger of becoming a local infrastructure and logistics partner rather than a research partner. It is evident that UNIS has very often contributed with logistics, accommodations, and office facilities for various research projects. A stimulation of the scientific co-operation will require an active policy to attract well-qualified personnel to UNIS.

The age distribution of the faculty members at UNIS is such that they should be a very productive unit in the university system. According to the publication record and scope, however, this is not fully true, although there are individual exceptions that are of very high quality.

Due to the temporary character of the employment, a good mobility is secured that prevents inbreeding in the institution. On the other hand, it is important that some continuity be maintained; key personnel should remain with the projects until they return to their home institutions. The system with adjunct professors can be a way of maintaining contacts with the scientific employees after their contract period with the institution is completed.

## 4.7 Sogn og Fjordane College

The Institute of Resource and Environmental Geology is evaluated at the Sogn og Fjordane College. Volume II presents the research activities in detail.

### 4.7.1 Institute of Resource and Environmental Geology

This review is based solely on the written document submitted by the institute.

The institute employs four associate professors in permanent positions. One holds a Ph.D. degree and two hold Masters degrees. A two-year (1997-99) 25% professor-II position was added in 1997. The faculty instructs undergraduate students, with ca. 15-20 students admitted to the programme each year. During the past two years, four Norwegian students were involved in an international exchange programme with the UK.

The institute provides the only geology education in Sogn og Fjordane county. It has developed a four-year environmental- and resource-geology programme that trains students for employment in environmental management, geologic consulting, and resource exploration careers. The staff is small, and covers the disciplines of Quaternary geology, environmental geology, bedrock geology, and hydrogeology. The institute is involved in the EU Erasmus and Socrates exchange programmes with the University of Wolverhampton, UK.

Research priorities reflect the composition of the staff at any given time. Currently the emphasis in basic research is on Quaternary stratigraphy and climate, mass-wasting processes, hydrogeology, and geochemistry of marine and fluvial sediments. Applied research focuses on mapping of Quaternary sediments and bedrock, marine pollution, and groundwater resources. In addition, the faculty are involved in various consulting projects.

## *Assessments and Recommendations*

The primary focus of this small institute is on instruction in environmental geology, regarded by the faculty as an alternative to traditional geology education in programmes offered by other Norwegian Earth Sciences departments. The objective is to "develop a regional centre of environmental geologic research," involving increased co-operation with the University of Bergen and the HSF-College Engineer Education Department in Førde with respect to research activities and with the University of Wolverhampton (UK) and the University of Oldenburg (Germany) in co-operative educational programmes. To achieve the research goal, the institute must attract stable, well-educated faculty with specific research goals consistent with the primary objective of the programme.

The bulk of the research output, as summarised in faculty bibliographies, is in the form of abstracts and unrefereed reports, including popular articles aimed at the general public. Research results published in national and international journals are minimal; fewer than a dozen papers of the four-person primary faculty have appeared in international journals during the past five years.

# 5. Appendices

# Appendix 1

# MANDATE

## for the review of Earth Sciences research in the Norwegian Universities and Colleges

**Purpose of the review**

The Division of Science and Techonology at the Research Council of Norway, which is funding basic research in the universities and technological research institutes in Norway, has decided to draw up strategic plans for the research in its various fields of interest. As a part of this process, a review by an international group covering Earth Sciences will be carried out to obtain nescessary background information. The review should include the following subfields of Earth Sciences: Geology, Solid Earth Physics, Physical Geography, Hydrology, Meteorology and Oceanography, and lead to a set of concrete recommendation to the Research Council concerning the future developments in the field of Earth Sciences Research in Norway.

**Aims of the review**

A general review should clarify which fields are represented in Norwegian Earth Sciences research, the structure of the academic departments of Earth Sciences, the personnel on different levels, age structures, the funding of the research groups, the situation concerning equipment, publications and citations and degree of mobility. Other aspects to be considered are:

*1. Scientific activity and quality*

- Which fields of research have a strong scientific position in Norway?
  Which have a weak position?

- Is there a reasonably balance between the different fields in the Norwegian Earth Sciences research? Or

- is research lacking in any particular fields, are some fields underrepresented? Or

- are some fields over represented, in view of the quality or scientific relevance of the research performed?

- How is the balance between theoretical and empirical studies within the various fields? How does it compare to the situation in other countries?

- Do the research groups have a strategy/plans for the research which are carried out?
- Is the size and organisation of the research groups reasonable?
- Are the academic departments organized in an adequate way?

*2. International and national collaboration*

- Do the research groups take part in international programmes or use facilities abroad, or could the utilization be improved by introducing special measures?
- Is there sufficient contact and co-operation with other research groups nationally and internationally?
- Which role do Norwegian groups play in international co-operation in various sub-fields? Is there any significant difference between Norwegian Earth Sciences research and research in other countries?
- Is there a reasonable co-operation and division of research activities on the national level? Or could it be improved?
- Is there any co-operation related to the use of expensive equipment?

*3. Training and mobility*

- Is the recruitment to doctoral training satisfactory?
  Or should higher emphasis be put on recruitment in the future?
- Is there education and training opportunities for PhDs in industrial research?
- Where do the finished candidates go?

*4. Relevance of the scientific research*

- Do the research groups have contacts with the Norwegian technical research institute sector or the Norwegian industry?
- Is today's Earth Sciences of relevance to the needs of the Norwegian industry and society?
- Are the research groups prepared to solve tomorrow's problems, both nationally and internationally?

# Appendix 2

## Curriculum Vitae for Members of the Committee

### Ove Stephansson

Ove Stephansson received his Ph.D. in Mineralogy and Petrology (1972) from the University of Uppsala where he worked on theoretical and experimental tectonics at the Hans Ramberg Tectonic Laboratory. He then had a post-doctoral position at the CSIRO in Sydney, Australia where he worked on granite diapirism in the Northern Territories. In 1974 he was appointed professor in Rock Mechanics at Luleå University of Technology, Sweden. There he initiated the study of rock mechanics in the mining school, and worked on brittle rock deformation, rock stress measurements and applied rock mechanics to radioactive waste disposal and hard-rock mining. In 1991 he was appointed professor in Engineering Geology at the Royal Institute of Technology, Stockholm where he formed research groups on image analysis of various geological materials, rock stresses, and modelling of jointed rock masses. He has edited four books on mechanics of joints and jointed rock masses and has recently co-authored a book on Rock Stress and Its Measurement.
He has served two three-year terms on the Earth Science Board of the Swedish Natural Research Council, has been vice-president of the International Society for Rock Mechanics, 1991-95. He is currently head of the Secretariat of the international DECOVALEX project about coupled hydro-thermo-mechanical properties of jointed rock masses. Ove Stephansson serves on the editorial board of the leading international journals of rock mechanics and rock engineering.

### André Berger

André Berger received his M.Sc. in Meteorology from M.I.T. (1971) and D. Sc. from the Université Catholique de Louvain (Belgium) (1973). He is ordinary professor and head of the Institute of Astronomy and Geophysics Georges Lemaitre at the Catholic University of Louvain where he lectures on meteorology and climate dynamics, and was a professor at the Vrij Universiteit, Brussel, and Université de Liege.

His main research is about modelling climatic changes on the geological and centennial time scales. He has made notable contributions to the astronomical theory of palaeoclimates which explain the recurrence of glacial-interglacial cycles from the long-term variations of the Earth's orbit around the Sun. The climate model that he has developed with his team is also used for simulating the response of the climate system to human activities and the possible impact of anthropogenic perturbations on the natural course of climate on the geological time scale. He is a cited pioneer of the interdisciplinary study of climate dynamics and past climate history.

Berger was chairman of the International Climate and Palaeoclimate Commissions and of some NATO scientific Panels. He was vice-president of the European Geophysical Society. He serves on several national and international scientific committees dealing with climate and global change. He is a member of the scientific council of Gaz de France. He received a doctor *honoris causa* from the

University of Aix-Marseille III, and he is member of the council of the Academia Europaea and foreign member of the Koninklijke Nederlandse Akademie van Wetenschappen.

Berger is the author of "Le Climat de la Terre, un passé pour quel avenir ?". He has edited 10 books on climatic variations and has published more than 150 papers on this subject. He is associate editor of *Surveys in Geophysics* and editorial board member of *The Holocene*, *Climate Dynamics*, and *Earth and Planetary Science Letters*.

**Gunnar Furnes**

Gunnar K. Furnes is Chief Research Engineer at Norsk Hydro Research Centre, Department of Marine Technology.

He received his Dr. Philos degree from the University of Bergen where he worked for 13 years before taking a position at Norsk Hydro Research Centre in 1985. Furnes has spent several periods of more than six months as Visiting Scientist/Lecturer at universities and research institutes such as Proudman Oceanographic Laboratory, Cornell University, Denmark Technical University, and IBM Research Centre.

His main present research interest is Computational Fluid Mechanics with application to offshore industry. This involves studies of environmental forces on structures, fluid-structure interaction, vortex induced vibrations, and advection-diffusion of emissions from drilling and production platforms.

**Christoph A. Heinrich**

Christoph A. Heinrich studied geology and petrology at ETH Zürich in Switzerland. He completed his Ph.D. in 1983 on high-pressure metamorphic petrology in the central Alps. He then emigrated to Australia to study economic geology at the Commonwealth Scientific and Industrial Research Organisation in Sydney, and was awarded the first Paul Niggli Medal in 1988. After working for nine years as a research scientist (hydrothermal geochemist) at the Australian Geological Survey in Canberra, he returned to Switzerland to assume the joint chair of mineral resources geology of ETH and the University of Zürich. His current research concentrates on the chemical, thermal and mechanical aspects of fluid transport in the Earth’s interior, with the aim of understanding hydrothermal ore formation more quantitatively. He and his group are combining field studies with experimental and numerical modelling simulations, and they have a particular interest in developing new techniques for microanalysis of fluid inclusions in minerals. Chris Heinrich serves on the editorial board of *Economic Geology*, and he is a Councillor of the Swiss Geotechnical Commission and a member of several international societies.

**Simon Klemperer**

Simon Klemperer was born in the U.K., and studied first at Cambridge University (BA (Cantab) in Mineralogy and Petrology), then at Cornell University (Ph.D. in Geophysics, 1985) where he worked on COCORP deep seismic reflection profiles across the Basin and Range province. He returned to Cambridge University to work on the tectonics of the North Sea and the Caledonides

while a Royal Society University Research Fellow with the British Institution's Reflection Profiling Syndicate (BIRPS) group, an effort that culminated in preparation of his book "The BIRPS Atlas: Deep seismic reflection profiles around the British Isles." In 1990 he moved to Stanford University and has since led the Crustal Geophysics Group there in multi-disciplinary geophysical experiments in active tectonic regions of California, Alaska, and Tibet. He has made research and/or lecturer visits to Bergen, Oslo and Trondheim.

Current service activities, in addition to participation in this Committee, include membership of the NSF MARGINS Steering Committee and Director of the IRIS-PASSCAL Instrument Center. Klemperer received the President's Award of the Geological Society of London in 1988, was elected Fellow of the Geological Society of America in 1995, and is currently also a member of AGU and SEG.

**Gerard V. Middleton**

Gerry V. Middleton was born in South Africa and studied geology in England, completing his Ph.D. in stratigraphic palaeontology at Imperial College, London (1954). After working in Canada for a year as a petroleum geologist, he taught at McMaster University, Ontario, for 41 years before retiring in 1996. Gerry's main field is physical sedimentology, but he also has interests in mathematical geology, including (most recently) nonlinear dynamics and fractals. He has co-authored three books: "Origin of Sedimentary Rocks" (with Blatt and Murray), "Mechanics of Sediment Transport" (with Southard), and "Mechanics in the Earth and Environmental Sciences" (with Wilcock), and has recently completed the text to another book (to be entitled "Data Analysis in the Earth Sciences, using MATLAB").

He has served two three-year terms on Canada's National Research Council Grant Selection Committee for Earth Sciences, has been President of the Geological Association of Canada, and has held various offices in SEPM (Society for Sedimentary Geology) and the International Association of Sedimentologists. He is an honorary member of these two societies, and a Fellow of the Royal Society of Canada. He was recipient of the Logan Medal (the highest award of the Geological Association of Canada). He now enjoys golf and curling (a sport at which both Canadians and Norwegians excel).

**Stephen C. Porter**

Stephen C. Porter was born in southern California and completed undergraduate and graduate study in geology at Yale University, receiving his Ph.D. degree in 1962. Since joining the University of Washington faculty that same year, he has carried out Quaternary geologic studies in the Washington Cascades, southern Alaska, the Himalaya, the southern Alps of New Zealand, the island of Hawaii, the Andes of Chile and Argentina, the Italian Alps, the Antarctic Dry Valleys, and the Bolshoi Annechag Range of northeastern Siberia. The primary focus of this research has been the stratigraphy and chronology of Pleistocene alpine glaciation, palaeoclimatic reconstructions based on glacier equilibrium-line altitudes, and the pattern and causes of recent (Neoglacial) glacier fluctuations. He also has worked on Holocene sea-level fluctuations in the Marshall Islands and in southernmost South America, on volcanic subsidence, landscape evolution, and subglacial volcanism in Hawaii, and on giant rockfalls and rockfall hazards in the Alps. His studies in volcanic regions have included investigations of Quaternary tephra layers and the use of tephrochronology

for dating surficial deposits. Porter's current activities involve continuing work on the glacial history of the Cascade Range and collaborative research with Chinese colleagues on the late Quaternary record of palaeomonsoons in central China. The latter work has involved field studies on the Loess Plateau, the northeastern Tibetan Plateau, and along the desert margin in Inner Mongolia.

Porter was a Senior Fulbright-Hays Research Fellow in New Zealand in 1973-1974, and has served on the Board of Governors of the Arctic Institute of North America and on the Board of Earth Sciences of the U. S. National Academy of Sciences. Since 1987 he has been a guest professor in the Chinese Academy of Sciences. He is Director of the Quaternary Research Center in the University of Washington, the editor of the interdisciplinary journal *Quaternary Research*, and is President of the International Union for Quaternary Research (INQUA). In 1988 he spent an academic term at the University of Bergen in connection with the University of Washington/University of Bergen faculty exchange programme.

# Appendix 3

## Letter from the Research Council of Norway to the Norwegian Universities (July 1997)

# Appendix 4

## Review of Research in Earth Sciences in Norway

**Radisson SAS Park Hotel Oslo**
**2 – 7 November**

## Time-table

### Sunday 2 November:
17.00 – 20.00 Committee planning meeting

### Monday 3 November:
09.00 – 10.30
Department of Physical Geography, University of Oslo:
Jon Ove Hagen (head of department), Leif Sørbel and Bernt Etzelmuller

10.30 – 12.00
Department of Soil and Water Sciences, Agricultural University of Norway, Ås:
Per Jørgensen (section leader), Sylvi Haldorsen and Michael Heim

13.00 – 18.00
Department of Geology, University of Oslo:
Anders Elverhøi (head of department), Bjørn Jamtveit, Knut Bjørlykke, Jan Inge Faleide, Bjørg Stabell, Per Aagaard, Arild Andresen, Elisabeth Alve and Sverre Planke

The Mineralogical-Geological museum, University of Oslo:
Tom Andersen (head of department) and Else-Ragnhild Neumann

The Paleontological Museum:
Hans Arne Nakrem and Natascha Heintz

### Tuesday 4 November:
09.00 – 12.00
Department of Geophysics, University of Oslo:
Trond Iversen (head of department), Lars Gottschalk, Ivar Isaksen, Jon Egill Kristjansson, Valerie Maupin, Jan Erik Weber and Lena Tallaksen

Mechanics Division, Department of Mathematics, University of Oslo:
Geir Pedersen

13.00 – 14.00
Department of Hydraulic and Environmental Engineering, University of Trondheim:
Ånund Killingtveit

14.00 – 16.45
The Geophysical Institute, University of Bergen:
Hermann Gade (head of department), Martin Mork, Harald Svendsen, Truls Johannesen, Sigbjørn Grønås and Yngvar Gjessing

16.45 – 18.00
University Courses on Svalbard:
Jarle Nygard (director), Jon Landvik and Peter M. Haugan

## Wednesday 5 November:

09.00 – 12.00
Institute of Solid Earth Physics, University of Bergen:
Eystein Husebye, Reidar Løvlie, Yngve Kristoffersen, Rolf Mjelde, Andrzej Hanyga and Eirik Sundvor

13.00 – 18.00
Department of Geography, University of Bergen:
Roger Bennet (head of department) and Atle Nesje

Department of Geology, University of Bergen:
Sven Maaløe (head of department), Eystein Jansen, Jon Inge Svendsen, Mike Talbot, Wojtec Nemec, Harald Furnes and Alan Milnes

## Thursday 6 November:

09.00 – 12.00
Department of Geology and Mineral Resources Engineering, University of Trondheim:
Elen Roaldset (head of department), Arne Myrvang, Richard Sinding-Larsen, Bjørn Nilsen and Krister Sundbla

13.00 14.30
The Department of Petroleum Engineering and Applied Geophysics, University of Trondheim:
Rune Holt and Ole Bernt Lile

14.30 – 17.30
Institute of Geology, University of Tromsø:
Geoff Corner (head of department), Steffen Bergh, Tore Vorren, Morten Hald and Kjell Skjerlie

## Friday 7 November

09.00 – 16.00
Committee meeting