041

utredning

Earth Science Conservation in Europe

Proceedings from the Third Meeting of the European Working Group of Earth Science Conservation

Lars Erikstad (ed.)

NINA

NORSK INSTITUTT FOR NATURFORSKNING

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Preface

An Introduction to Earth Science Conservation in Europe

The European Working Group of Earth Science Conservation was established in 1988 at a meeting in the Netherlands. Its aim is to obtain mutual support in the conservation of threatened sites as well as promote earth science conservation in general. At the 2nd Meeting in Austria in 1989, several papers were presented (Andersen et al. 1990. Jb Geol. B.-A. 133: 653-669) focusing on several general topics within earth science conservation as well as case studies. In a more popular form the group contributed to a special issue of Naturopa (Council of Europe 1990. Naturopa 65-1990) on the issues of soil conservation and earth science conservation.

The third meeting of the working group was held in Lom, Norway, in 1990. The field excursions consentrated on the conservation plan for fossil sites in the Oslo region as well as recent glacial processes and landforms and quaternary glacial landforms of different scales. The main theme was how to deal with geological systems when planning for nature conservation. In the business meetings the group continued the work of building a formal organization (the Lom Convention). From the articles §2 is quoted: «The purpose of the Group is to improve the status of Earth-science conservation and the protection of Earth-science sites and landscapes in Europe by: -the preparation of a coordinated international policy for Earth-science conservation; the holding of meetings to promote the exchange of ideas; providing information and advice on all matters relating to Earth-science conservation; the promotion of Earth-science conservation education for the purpose of improving the awareness of the peoples of Europe; the advancement of the documentation of Earth-science sites to produce a unified information system in Europe; running research projects in furtherance of all the above; the production of a regular Newsletter and other published material as a means of communication between the nations of Europe; the production of a European Code for Earth-science fieldwork; and the promotion of a European Convention on the Conservation of Earth-science sites.» This process was continued at the 4th Meeting in Digne, France, last year and will be the main issue of this year's meeting in the UK.

In Digne the first international symposium on the protection of our geological heritage was held. Abstracts from the symposium were published in Terra Abstracts (Supplement to Terra Nova 3, 1991), the proceedings will be published later.

This issue of NINA Utredning contains the proceedings of the Lom meeting. Naturally these papers concentrate on the process of protection of earth science sites, by the different authors also called geo-sites, geological sites or geotopes.

In the first paper Gerard P. Gonggrijp introduces us to the development of earth science conservation in the Netherlands and presents the new nature conservation plan and its implications for earth science conservation. In the next paper Michael F. Stanley examines details in the British system of geological site documentation and its importance for our concern. The third paper by P. Jacobs and J.F. Geys introduces the legal framework of earth science conservation in Belgium and also presents a system for site classification, useful when a conservation strategy is established. Ulrike Pistotnik underlines in the fourth paper the importance of education and nature experience for conservation work. In the fifth paper Gerard P. Gonggrijp makes a case study of a successful local campaign resulting in the conservation of old river systems.

The last two papers from the meeting have already been published in the Norwegian Journal of Geography and are included here in facsimile. In the first Stein-Erik Lauritzen gives a comprehensive discussion on the conservation needs for Norwegian karsts. In the second Lars Erikstad discusses the clay landscapes in southeast Norway threatened by modern agricultural activities.

Together with the other publications produced by the group, this issue of NINA Utredning hopefully will contribute to fulfill its aim in exchanging information and will push the field of earth science conservation a step forward.

The European Working Group of Earth Science Conservation is grateful to the Norwegian Institute for Nature Research (NINA) for hosting the Lom meeting and to the Norwegian Council of Nature Conservation, Norsk Hydro and Mobil Exploration Norway Inc. for financial support. We are also grateful to the Norwegian Journal of Geography for permission to print the two articles formerly published in the journal.

Lars Erikstad

Oslo, June 1992

Contents

1 Nature Policy Plan, New Developments in the Netherlands

Gerard P. Gonggrijp

1.1 Introduction

In June 1990, the Dutch government published a nature policy plan, which differed fundamentally from previous ones. The main goal is the creation of a sustainable structure for nature in the Netherlands, through a so-called national ecological network. The plan also includes biotop development of areas with high potential ecological value, stimulation of social support for the Dutch nature policy and reinforcement of landscape conservation, including earth science conservation.

1.2 Historical Review

The first steps

Governmental involvement in nature conservation started with the institution of the State Forest Service in 1899 (Zonderwijk & van Bohemen 1970). The main task of this new department was the promotion of forestry and afforestation of waste land owned by the state. The director of the State Forest Service influenced by his activities in the private nature conservation society (since 1905) commissioned several areas owned by the state as nature reserves because of their scientific interest.

In 1929, the duty of the State Forest Service was officially expanded with the responsibility for nature conservation in general; endorsed by law, like the Forestry Act (1922, 1961) and the Estates Act (1928).

Currently with the development of its own efforts, the government encouraged nature conservation on a regional level by the promotion of provincial nature conservation societies. The foundation of the «Utrechts Landschap» in 1927 was the first result of that policy.

The opinion that nature reserves should also be managed resulted in 1927 in the director of the service establishing an Advice Committee for Nature Monuments of the State Forest Service. Gradually this so-called «Weevers Committee» named after its president became involved in advising other state services of the Ministry of Agriculture as well. Ten years after its establishment the Contact Committee for Nature and Landscape Protection, an umbrella organization of the private nature conservation societies, attained a further extension of the tasks of the «Weevers Committee». From then on this committee should be consulted on nature conservation by all Ministries.

Growing influence

The Nature Conservation Decree of 1940 ordered that all land development projects should need a ministerial approval controlled by the «Weevers Committee» and that natural beauty was not be damaged (**Figure 1**). The Ministry of Education, Arts and Sciences became unofficially responsible for the nature conservation policy.

The position of the authority of the State was improved in 1942 when public expropriations of land for nature conservation and governmental sponsoring of nature conservation societies were legalized. The postwar development can be characterized by a growing awakening of nature conservation consciousness.

In 1957 the nature conservation, landscape and forestry sections of the State Forest Service got their own regional consultants, which was an important step forward in regional attention. The organization itself turned into an external service of the Ministry

Abstract

Gonggrijp, G. P. 1992. Nature Policy Plan, New Developments in the Netherlands. - NINA Utredning 41: 5-16.

The paper reviews the official Dutch nature conservation policy from the beginning of the century until the present. After a modest start the government has developed a more active role within nature conservation. This development has been particularly strong during the last two decades. The growing pressure on nature was the incentive for a socially integrated nature policy, voiced in the Nature Policy Plan (1990). For quite a long time earth-science conservation was not part of the nature conservation policy. Most initiatives on the preservation of geo(morpho)logical and pedological sites were private actions. In the Nature Policy Plan, however, the foundation was laid for a sound earth-science conservation strategy. The plan also supports research projects in this field. This new approach gives hope for the future.

Key words: Legal framework - Nature conservation policies

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Figure 1
Extensive parts of the Dutch landscape are very vulnerable because of low relief. Several of the Late Weichselian-Early Holocene river-dune systems have been levelled or even changed into lakes for sand extraction.

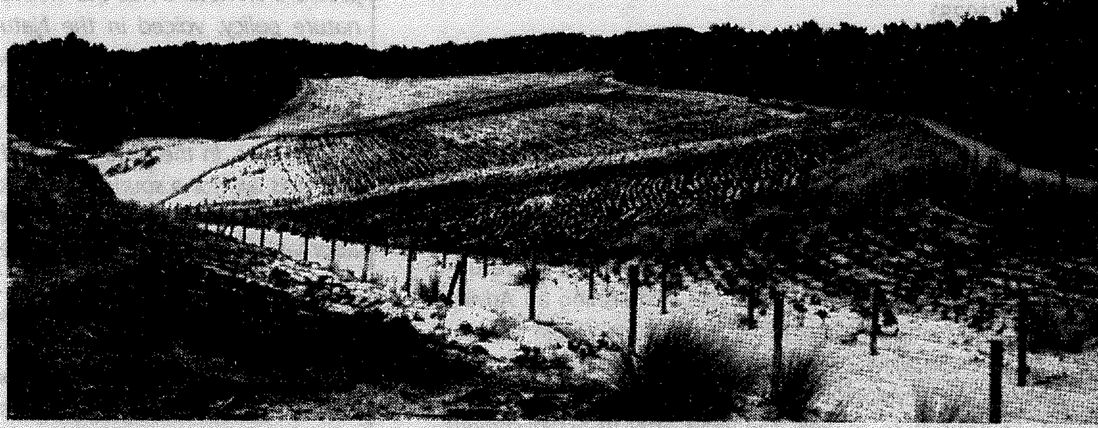

Figure 2
Sometimes even in protected coastal dune areas the morphology has been adjusted locally to allow mechanical tree planting.

of Cultural Affairs, Recreation and Social Welfare. Nature conservation became more and more integrated into society and this resulted in the ratification of the Nature Conservation Act in 1968. This demanded that nature conservation should be taken into account in policy plans at all levels.

In spite of this political progress, the practical problems increased. The fast population growth and the technical progress led, especially during the last decades, to a rapid change in nature and landscape qualities (**Figure 2**). Urbanization and the improvement of the infrastructure by expansion of the road systems occupied more and more of the rural areas. Increasing outdoor recreation and the intensification of agricultural and military use of the countryside enhanced the pressure on nature.

The growing need for water supplies resulted in a gradual drying out of ecologically and geological vulnerable areas and the exploitation of minerals and aggregates radically changed the landscape.

These activities caused a severe deterioration of ecological and landscape values and functions in the Netherlands by a decrease of the functional area, a diminishing of the diversity and increase of external influences.

Integrated surveys

The serious situation activated private and governmental institutions to intensify their inventories focused on nature conservation and to carry out more or less integrated environmental mapping projects.

The Colours of the Southwest Netherlands, Vision on Environment and Space (Contact Committee for Nature and Landscape Protection 1972) was the first project on a large scale. The basic principle was environmental quality. Biological and cultural historical data were confronted with aspects of physical planning, resulting in advice for planning development. A study on the forelands of the rivers IJssel, Rhine, Waal, and Meuse (De Soet 1975) was carried out by several governmental services. Data on geomorphology (for the first time), landscape, botany, ornithology, hydrobiology and zoology were inventoried, evaluated and integrated in order to use the results for planning decisions and the formation of foreland landscape reserves.

A second detailed governmental study (Ten Houte de Lange 1977), was executed in the Veluwe area which is a glacially developed and hilly landscape in the Central Netherlands. In the Veluwe project, nature values were inventoried and then integrated and confronted with different forms of recreational pressure which is one of the main threats in this area. These basic data should be used in physical planning.

Integrated policy

This development stressed the need for integration of nature and landscape conservation into the policy plans of other ministries. The first modest move for such a policy was taken in 1975 when the ministry in charge presented the so-called «Three Green Notes» on National Parks, National Landscapes and the relationship between agriculture, nature, and landscape conservation. These notes were signed by the Ministers of Agriculture and Fisheries, Cultural Affairs, Recreation and Social Welfare, and Housing and Regional Development.

The «Relation note» introduced a new important concept in conservation of valuable rural areas: Landowners who voluntarily concluded management agreements received financial support. As a next step, the three notes were worked out into the Structure Plan for Nature Conservation and Protection of the Countryside (Ministry for Culture, Recreation and Social Work and Ministry for Housing and Regional Development 1981), preceded by a Structure Vision in 1977. In this plan, the geographical integration with the other policy fields like physical planning and environmental management were thought out more carefully.

The continuing destruction of nature and countryside changed the conservation policy from a defensive one into an offensive one, which was translated into the objectives of the plan:

- Natural and cultural historical diversity in the rural areas as well as their manifestation will be maintained, restored or developed (**Figure 3**).

- Natural and cultural historical values and connected values, such as the scenic value, will be maintained, restored or developed, considering their mutual relationship. This includes not only striving for tangible results but also promoting the social and political framework that brings these aims within reach.

Human influence on nature and countryside is not an isolated aspect. Socioeconomic, political, governmental and demographic factors should therefore be taken into account in the policy. The objectives of nature and countryside policy can no longer be attained by purely protective measures. It is also unrealistic to think that acquisition and management of areas of natural significance would be unnecessary. For these reasons nature conservation policy worked out the following proposals:

«The realization of maintenance of nature and countryside val-

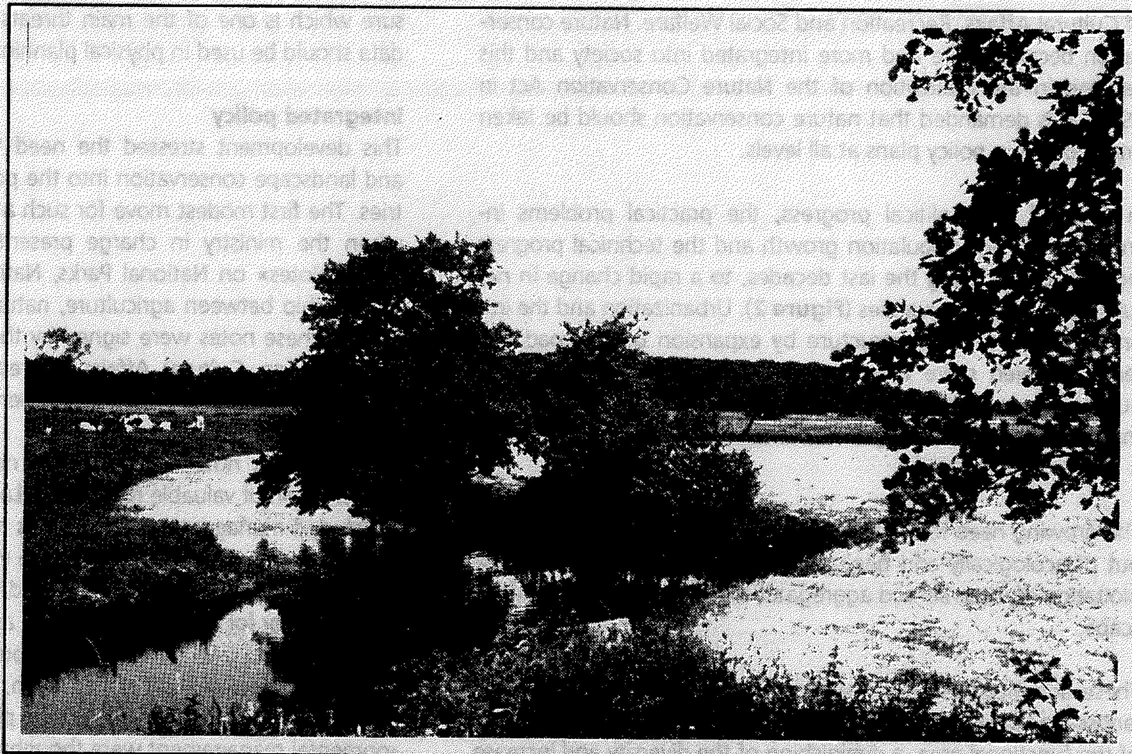

Figure 3
Most of the Dutch brook and river systems are canalized. Only parts of some systems are still natural. In the frame of «nature development projects» plans are worked out to reshape some of the «canals» into meandering waters.

ues should be reached by protection and management. Integration in planning, legislative regulation and acquisition will serve as instruments for protection. Management particularly by private land-owners will be financially supported to encourage conservation.

The development and restoration of nature and countryside values cover a wide range of items, varying from introducing new or lost landscape elements to improving the quality of flora and fauna for the arrangement of new extensive natural areas in new polders, the cut-off arms of the sea, etc.

An important contribution to nature conservation is expected from steering the public's behavior by instruction and education. The strengthening of involvement of other governmental policy sectors in the field of nature and countryside is another essential aspect.»

These proposals were worked out in detail for all nature conservation sectors and integrated with relevant aspects of the other policies. This first Dutch policy plan on nature and countryside protection was formally accepted in 1984 (Ministry for Agriculture and Fisheries and Ministry for Housing, Regional Development and the Environment 1984), but in the meantime new ideas had been evolved.

1.3 Nature Policy Plan

The problem

The Structure Plan for Nature Conservation and Protection of the Countryside was a product of data, experiences, and policy atmosphere of the seventies. The environmental problems such as water, soil and air pollution became more and more obvious and their impact could not be seen apart from nature conservation. The first impulses to translate these problems into policy were given in the Structure Plan. That included aspects such as a policy on species, a policy on increasing public involvement in environmental problems and the relationship between nature conservation policy and the other policy fields like physical planning, but these aspects were not well enough developed.

For that reason the Ministry of Agriculture, Nature Management (since 1989) and Fisheries (1990) started with the elaboration of a new policy plan on nature conservation, shortly after the determination of the Structure Plan. This plan was published in 1990 (first version 1989).

The aim

The main objective of this new nature policy is the sustainable conservation, rehabilitation and development of nature and landscape. This applies primarily to the Netherlands, but also to international nature conservation policy. The general framework should be a base for the safeguarding of nature and landscape values in general and the development of elements with a special ecological or scenic value.

To create the conditions for the maintenance of these values, the policy will be focused on an adequate environmental and water policy by means of supporting measures. Increase of public awareness of responsible behaviour in respect to nature and landscape forms, is however, an essential contribution to the success of the policy and is of course part of the policy.

The policy stresses four aspects:

- Ecological values are selected on three criteria (diversity, naturalness, and characteristics).
- Geomorphological and geological structures are based on three evaluation criteria (rarity, non-replaceability, and recently topicality).
- Cultural heritage is selected on the criteria rarity and coherence of landscape parts.
- Scenic values are included with priority for traditional small-scale and open spatial patterns.

With respect to the international aspect of nature conservation policy, the Dutch government gives priority to internationally important areas in the Netherlands and vulnerable and threatened areas abroad: tropical forests, seas and coastal areas and Antarctica.

Strategy

The policy plan distinguishes two levels of responsibility in the realization of nature conservation:

- General ecological and landscape values which are of regional (provincial) and local importance are left for the provincial and municipal authorities.
- Special ecological and landscape values which are of (inter)national importance have a national governmental concern.

This national responsibility has been worked out as follows: In order to establish a durable basis for (inter)nationally valuable ecosystems and species a coherent network of areas has to be extended. This network throughout the country should include core areas, large (inter)nationally important areas, areas for nature development (potentially valuable) and ecological corridors as connections between core and development areas mentioned before.

The realization of this national ecological network will be supported by a number of policy instruments such as:

- application of the Nature Conservancy Act; acquisition of areas with actual and potential (development) value; on a provincial level the authorities can use the powers provided by the Soil Protection Act (1987) and by designing soil protection regions;
- expansion of environmentally sensitive areas and areas covered by the Regulation of farmers in hilly and mountainous areas;
- completion of the system of National Parks.

To maintain the diversity of landscapes in the Netherlands a number of areas apart from the ecological network have been selected with specific geological, cultural-historical and aesthetical values for conservation, restoration, and development.

Implementation and financial regulations

The Nature Policy Plan has a scope of about thirty years, in which the national ecological network has to be realized. To support this goal 23 geographically defined projects have been formulated. These projects will stimulate the collaboration required among various administrative bodies, pressure groups and the general public.

Some examples are: Nature development of river forelands, Wadden Sea area, Grasslands in peatland areas, and Heathland management and conservation. Fourteen other projects are thematically defined. In general the thematic projects aim at a specific type of habitat or area that occurs in several locations with very similar problems so that a nationwide approach can be applied.

One of these projects deals with earth science values and implements the up-dating of the inventory of geologically, geomorphologically and pedologically important sites and a «bottleneck analysis» in respect to vulnerability and threats. Some other examples are: transboundary nature areas, forests (enhancing their ecological values), cultural heritage of nature and landscape, and nature-friendly farming methods. Moreover, the projects will contribute to gather the information required for the final delineation of the national ecological network and the special landscape values. Besides these projects, 42 action issues in the field of species policy, research, National Parks, education and public support and the environment will be implemented. Both projects and actions are being carried out for the first eight years of the plan which started in 1990.

In order to implement the objectives, projects and actions for the realization of the Nature Policy Plan extra financial support has been set aside. For the first five years DFL 500 million extra will be spent, starting with DFL 41 million rising to DFL 155 million in 1994. This means a doubling of the budgets in that year for nature conservation and landscape protection.

1.4 National Earth science Conservation Policy - History

Earth science conservation in the Netherlands started as a private initiative. The Society for Nature Protection in the Netherlands founded in 1905 was the first organization that paid attention to this aspect. Due to the efforts of the Society and some private initiatives a few typical earth science sites have been protected (Gonggrijp & Boekschoten 1981).

In the beginning the governmental efforts in this field were poor. In 1908 the State Forest Service the former official department for nature conservation declared the active inland dune area «Kootwijker Zand» to be a reserve mainly because of its geological value. The plea of Van Baren (1908) did not reach the Government's ears. The «Weevers Committee» (established in 1927 and mentioned before as an advisory committee of the State Forest Service) should have examined the biological and geological aspects of the monuments. Later on, its task was widened with nature in general. In 1936 the same service instructed the Geological Survey to make an inventory of all important earth science sites in the southern part of the province of Limburg. But it did not result in an earth science conservation policy neither on a regional nor on a national level. Even the voice of Van Rijsinge (1953) asking for a national inventory of earth science sites at a meeting of nature conservationists in 1945 was not loud enough. State efforts resulted in the protection of two pingo-remnants in forests, a former creek system and a small site with Pliocene littoral sands.

The poor basis for Earth science conservation in the seventies was illustrated by the informal check list (1970) used by the Ministry to select sites for acquisition. This list reported all categories of important sites. The Earth science values were mentioned somewhere at the end and in practice they could only be implemented in combination with other categories. There has been one exception: in the case of the type locality of the Tiglien, the geological value of this site prevailed, and so the site was purchased. Since 1969 the activities of the Working Group under the name of «Gea» (Gonggrijp & Boekschoten 1981) which was in charge of a national inventory of Earth science sites, gradually influenced the authorities. This resulted in some attention for such sites in the Structure Plan for Nature Conservation and Protection of the Countryside, which was published as a policy intention in 1981. Three years later the governmental decision was taken.

The Structure Plan distinguished geological, geomorphological and pedological sites, which had to be selected by criteria such as rarity, condition and diversity. Besides fossil land forms and deposits, attention would be paid to areas with active processes.

The responsible Ministry admitted the arrears in the protection of these sites and mentioned the necessity of the maintenance of Earth science sites. All type of negative activities in valuable areas should be avoided and (inter)nationally important sites, which are under heavy pressure, would be acquired. The provinces were asked to make or complete Earth science site inventories and to incorporate this category into the regional planning schemes. The Structure Plan was not carried out because the ideas on nature conservation in general had evolved quickly, and therefore a new more broadly based plan was developed: The Nature Policy Plan.

1.5 Earth Science Conservation and the Nature Policy Plan

Background report

This time Earth science conservation received more attention. The Research Institute for Nature Management was asked to compile a background report on the subject. This document, «Nederland in Vorm» (The Netherlands in Shape) (Gonggrijp 1989a), reflects the present state in Earth science conservation. Attention is paid to the geological development of the Netherlands, the evaluation of the landscape, the threats and vulnerability of landscape elements. Finally recommendations for landscape management, policies and further research are mentioned.

In a background report on the international importance of Dutch nature a detailed chapter on Earth science conservation has been added (Gonggrijp 1989b). Based on the inventories of the Working Group Gea (Gonggrijp 1975-1988) 119 sites of (inter)national importance have been selected (**Figures 4-6**) (**Appendix 1**). This list does not include pedological topics and geological exposures (**Figure 7**).

Figure 4
Map of (inter)nationally important geological areas listed for the Nature Policy Plan (NPP).

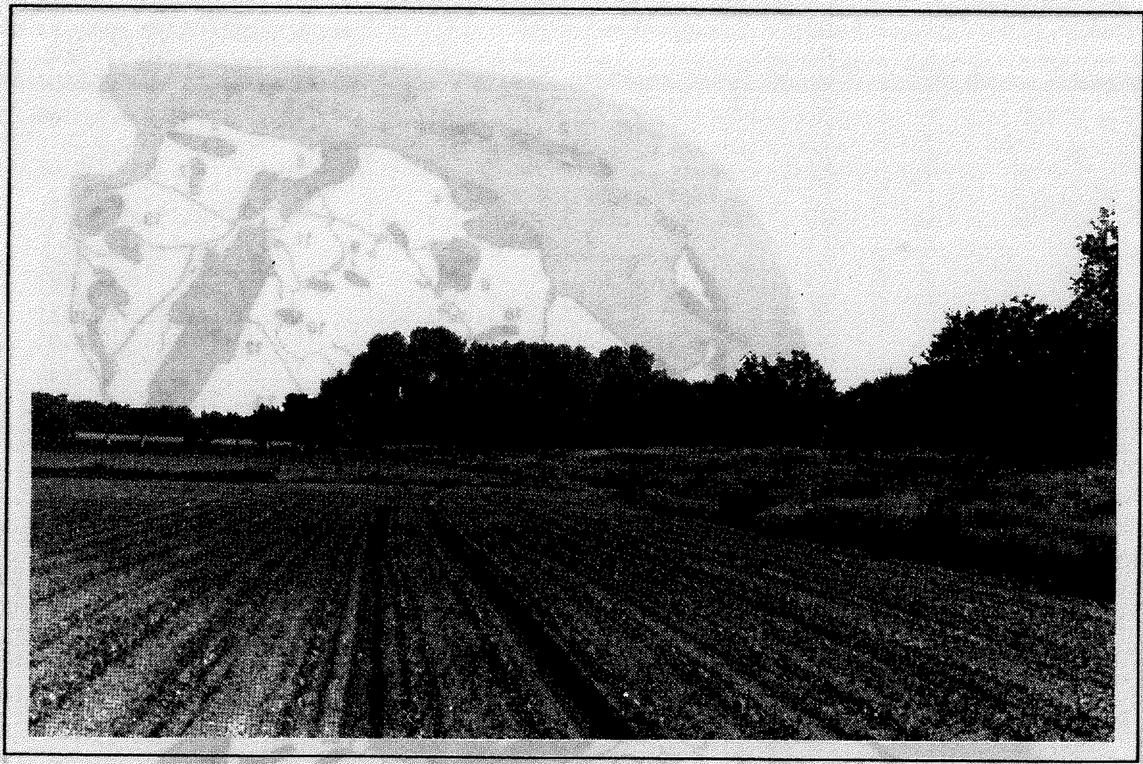

Figure 5
Small step fault along the still active «Peelrand» fault near Uden (province of Noord-Brabant). The higher grassland situated on the horst is marshy because of the presence of clay, the lower arable land in the graben is dry. This site is one of the selected areas on the NPP list.

Figure 6
The doline is part of a karst area in Zuid-Limburg mentioned in the NPP list. These phenomena are very vulnerable and many are used for dumping refuse.

Figure 7
Quarry in Zuid-Limburg showing Cretaceous limestone. The wall was cleaned as part of a geological conservation project (In the Nature Policy Plan exposures and erratic boulders are not listed because of their size)

Instruments
To protect these 119 (inter)nationally valuable areas against a wide range of human activities like tillage, change of watertable or land use, aggregate extraction, hydrotechnical interventions, house and road building and destruction of vegetation, the Nature Policy Plan mentions several instruments:

- The Physical Planning Act enables the provinces and communities to protect valuable areas in their Regional respectively Local Plan.

- Based on the Nature Conservation Act the National government can commission areas of great earth scientific value as a Nature Monument or a State Nature Monument.

- The Soil Protection Act forces the provinces to indicate relatively untouched areas as Soil Protection Areas.

- Acquisition is a possibility to protect heavily threatened sites.

- The Aggregates Act pays attention to the balance of the values of extraction and nature conservation. If extraction is necessary, the license may include regulations for reconstruction to conserve important geological and pedological outcrops.

- On a voluntary basis land-owners can get grants for nature conservation friendly management.

Until now only a few of these instruments have been used for the protection of Earth science conservation sites and the practical experiences regarding the concrete possibility are limited, but the future execution of the policy plan will teach us more.

Education
The protection of fossil and active Earth science features is one way to ensure their future existence. Maybe public awareness is the most important base for conservation. Although this aspect gets more and more attention, there are still neglected areas compared with biology and archaeology. The National Government will encourage environment and nature education among others by the support of non-governmental organizations working in this field. Both the public and the organizations working in the field of nature education have, however, little knowledge of earth sciences and should be educated. In this context popularization of Earth science knowledge is very important, because there is too little simplified literature available for these nature organizations. Professional earth-scientists should put more energy in writing for the general public. A recent weekly series on fifteen geomorphological elements in a national daily was very successful and met much response.

Research

Continuation of Earth science conservation research is a necessity to evaluate this aspect as an equal item to the other conservation objects. For that reason the report «Nederland in Vorm» suggests further research:

- Development of a classification and evaluation system. The selection of Earth science sites for the Gea-project was not based on an earth-scientific classification system. The evaluation should be more objective and standardized.
- Updating of the Gea-inventory based on the new classification and evaluation system. The first report was published in 1975, but since then a lot of new data has become available.
- Inventory of national soil-science type localities. Until now these data were not handed over by scientists.
- Development of a national geomorphological type locality system based on type inventories.
- Inventory of big boulders. These boulders are very popular as decoration objects for engraving.
- Inventory of pits and quarries. The data on pits and quarries changes very quickly, so there should be a national database for these sites.
- Development of an Earth science data system to increase the utility for general purposes.
- Development of an impact-vulnerability matrix to confront sites with a large range of human impacts.

Two projects in the National Nature Policy Plan in principal cover most of these suggestions.

1.6 Conclusion

The way the Nature Policy Plan has adopted Earth sciences in general nature conservation is a big step forward. It should, however, be wise to follow developments carefully.

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Appendix 1

(Inter)nationally important Earth science sites

1. North Sea: marine processes
2. Waddeneilanden: different dune forms, dune formation, «moving» islands, drumlinized push moraine, creeks
3. Waddenzee and Dollard: shallows and marine processes
4. Barradeel-Het Bildt:
5. Rietdiep: meandering tidal river system, «new» and «old» land with tidal creek systems
6. Uithuizen: barrier
7. Loppersum: former meandering Fivel channel

8 Middelzee area: former inland sea with barriers, area with tidal-creek system
9 Bergum, Duurswoude, Ureterp: boulder clay area with pingo remnants
10 Fochtelooerveen and Esmeer: peat-moor and pingo remnant
11 Roderwolde: area with Elsterian clay
12 Hondsrug: glacial megaflutes, tertiary and lower pleistocene sediments, boulder clay area, meltwater deposits, drift sands, Drentse Aa river system, Hunze valley, Kame, pingo remnants, glacial kettle, lake
13 Winschoten: drumlinized push moraines
14 Dollard: marine clay series
15 Westerwoldse Aa: brook valley, coversand ridges, drumlinized push moraines
16 Den Helder-Monster: varied coastal dune area
17 Wieringen: drumlinized push moraines
18 Sandfirden-Langweer: coversand ridge partly covered by peat
19 Gaasterland: drumlinized push moraines, boulder clay cliff, coastal barriers
20 Kalenberg: peat-bog, river dunes
21 Steenwijk: drumlinized push moraines, drift sands
22 Omval: spit system
23 Twisk: broad fossilized creek system
24 Zandwerven: dune, lake barrier
25 Benningbroek: fossilized creek system
26 Kromme Leek: low-land river
27 Polder Mijzen: peat-bog area
28 Urk: push moraine with boulder clay, marine abrasion flat
29 Schokland: former peat island covered with clay
30 Land van Vollenhove: drumlinized push moraine, coversand ridge, coastal barriers, marine abrasion flat
31 Kampereiland: young delta
32 De Reest: brook valley
33 Hoogeveen: kames in boulder clay area, pingo remnants
34 Zuidwolde: glacial ridge
35 Klazinaveen: peat-bog
36 Spaarnwoude: coastal barrier
37 Waterland: peat-bog, creek system
38 Hoophuizen: coastal barriers
39 Utrechtse Heuvelrug-Kromme Rijn-Veluwe: push moraine complex outwash plains and terraces, lake sediments, dry valleys, kettle holes, pingo remnants, parabolic coversand ridges, active drift sand areas, brook valley, Kromme Rijn
40 Hoenwaard-Polder, het Lieder- en Molenbroek: river with natural levee, parabolic coversand ridges
41 Lemelerberg-Overijsselse Vecht: push moraine, erosional features, point-bar systems, drift sand areas
42 Radewijk: coversand ridges
43 Fortmont: foreland with river dune
44 Wesepe: coversand ridges
45 Holterberg etc.: push moraine complex, deep erosional valleys
46 Scharrebelt: coversand ridges, boulder clay hill
47 Daarle: push moraine, coversand ridges
48 Sibculo: push moraine, peat-moor
49 Bruinehaar-Almelo: esker remnants, coversand ridges
50 Tubbergen: «replaced» push moraine
51 Ootmarsum: push moraine, dry valleys, brooks
52 Bergvennen: braided brook system, coversand ridges
53 Saasveld: snow-meltwater valleys, peat forming
54 Brummen-Deventer: river forelands, point-bar systems
55 Harfsen: coversand ridges
56 Lochem-Neede: push moraines, boulder clay hills, coversand ridges, river dune
57 Markelo: push moraines, meltwater forms, coversand hills
58 Rietmolen: parabolic coversand ridge
59 Dinkelsystem: glacial modified ridge, old formation
60 Weipoort: river-inversion ridges
61 Polder Zevenhoven, Wassenaarsche Polder, Leimuiden, Ter Aar: fossil creek-ridge systems, peat-bog remnants, peat-bog
62 Loenen-Hilversum: river-inversion ridge, lake, peat-bog, coversand hills
63 Achterveld: coversand ridges
64 Commandeurspolder: creek-ridge systems, peat-bog
65 Akkerdijkse Polder: creek-ridge systems
66 Alblasserwaard-Schoonhoven: river-dune systems, peat-bog, natural levee
67 Hoogblokland-Hoornaar: river-dune systems
68 Uiterwaard Vogelsang: river foreland
69 Schoonrewoerd: river-dune systems, former riversystem
70 Polder Biert: «old» land, fossil creek systems
71 Strijen: «old» land, fossil creek systems
72 Biesbosch: inland delta
73 Brakelsche Benedenwaarden: former river beds
74 St. Andries: natural overflow
75 Land van Maas en Waal: river foreland, river dunes
76 Winssensche Waarden: natural levees, point bars, former river beds
77 Wychen: river dunes, drift sands, fens
78 Rijk van Nijmegen: push moraine, dry valleys, outwash plain
79 Huissensche Waarden: river foreland, point bars
80 Lobith-Pannerden: former river beds, river forelands
81 Montferland: push moraines, dry valleys, coversand ridges
82 Oude-IJsseldal: valley with former braided river system, river dunes
83 Halle: coversand ridge
84 Varsseveld: coversand hills

85 Achterhoek: terrace, old formations, brook valleys, cover-sand ridges, moors
86 Polder Dirksland: «old» land, fossil creek systems
87 Oude Tonge: creek system
88 Dintel: former tidal river
89 St Maartensdijk: (fossil) creek systems
90 Voorne-Zeeuws-Vlaanderen: coastal dunes, tidal inlet
91 Goes: creek systems
92 Nisse-Heinikenszand: «old» land, «new» land, fossil creek systems
93 Yerseke Moer: fossil creek systems, salty soils
94 Aardenburg-IJzendijke: creek system, coversand ridge
95 Nieuw-Namen: erosion remnant, Pliocene beach sands
96 Verdronken land van Saeftinge: tidal flat
97 Westerschelde, Oosterschelde, Grevelingen, Haringvliet: creeks, tidal flats
98 Ossendrecht-Lepelstraat, Kalmhoutse Heide: terrace, dry valleys, creek systems, drift sands, parabolic dunes
99 Aadal: brook valley
100 Chaamsche beek: brook valley
101 Het Merkske: brook valley
102 Loon op Zand-Haaren: drift sands
103 Oisterwijk: brook valleys, fens
104 Middelbeers: fens
105 Het Goor: peat-moor
106 Westerhoven-Malpievennen: brook valley, fens
107 Dommeldal: brook valley
108 Uden: step fault, drift sands (Figure 5)
109 Bakel: fault step
110 Strabrechtsche Heide: drift sands, fens, pingo remnant(?)
111 Cuyk: Weichselian braided river system, terrace
112 Gennep-Venlo: river dune complexes, terraces
113 Deunse Peel: peat-moor
114 Meijel: fault step, peat-moor, pingo remnant(?)
115 Venlo-Roermond: terraces, brook valleys, type locality Tiglian
116 Roermond: Roer valley, terraces, Weichselian Roer meanders
117 Meinweg: step fault, drift sands, brook valley, fens
118 Sittard-Brunssum: step fault
119 Zuid-Limburg: peneplain remnants, terraces, dry valleys, erosion basin, sources, dolines (Figure 6), old formations, type locality Maastrichtian

2 The National Scheme for Geological Site Documentation

Michael F. Stanley

2.1 Introduction

The natural and man-made geological heritage of Britain is being damaged and slowly destroyed by new «development», waste disposal, afforestation and people erosion. The restoration of derelict land and the building of new houses, roads, motorways and other civil engineering projects can remove, sometimes for ever, vital clues to the geological history of an area. New exposures revealed by these works, often only for a short period of time, are not always recorded. The infilling of quarries may obscure important and rare exposures, and many sites may be «reduced» by the continual tread of tourists' feet as they walk to see a famous landmark, such as Langdale Pike in the English Lake District, or «removed» by the collection of horizons of limited extent by hundreds of field parties as once seen with the Ludlow Bone Bed. Even in the days of observation rather than collection orientated fieldwork much tonnage is removed from exposures, often destined never to go further than a student's garage, cellar, attic or garden shed.

The situation will probably persist as student fieldwork must increase as earth science now forms a substantial part of both the geography and science national curricula for 5-16 year olds in Britain. Further pressure will be exerted on the 2,200 SSSI's (Sites of Special Scientific Interest) identified in the Nature Conservancy Council's Geological Conservation Review. However, their RIGS (Regionally Important Geological/Geomorphological Sites) initiative, launched on 5th December 1990 as part of an Earth Science Conservation Strategy for Britain, will go a substantial way to lessening the impact on SSSI's. A key role will be played by Local Record Centres within the National Scheme supplying data to enable RIGS groups to select these important local sites.

2.2 National Scheme for Geological Site Documentation

The National Scheme has its origins in the constitution of the Geological Curators' Group (GCG) which was drafted in 1974. Article 2 notes that «The purpose of the Group shall be to improve the status of Geology in museums and similar institutions, and the standard of geological curation in general». This was to be achieved by a number of tasks including «the advancement of the documentation and conservation of geological sites».

This statement reflected the growing awareness that museum geologists have a responsibility to the geological environment generally as well as for their collections and visitors. Indeed most collections held in museums contain specimens from the local area and willy nilly site information has been documented ever since specimens began to find their way into museum collections.

Many museum services, since local government reorganization in 1974, have undertaken responsibility for environmental recording and have systematically accumulated the information relating to geological sites. The GCG proposed a National Scheme in 1975 in order to ensure that the local initiatives would contribute effectively to the Nature Conservancy Council's (NCC) conservation policy of reducing the burden of educational use on the relatively small number of SSSI's. The scheme, initiated in 1977 with the aid of NCC finance and in close co-operation with the then Geology and Physiography Section of NCC, is based on 53 Record Centres, almost all museums, each collecting and recording information on sites according to recognized methods and standards laid down in the Geological Record Centre handbook and the Geology Locality Sheet instructions published by the Museums Documentation Association to accompany the scheme in 1980.

Each centre is responsible for its own records, covering a specified area usually of county status, and the dissemination of information.

Abstract

Stanley, M. F. 1992. The National Scheme for Geological Site Documentation - NINA Utredning 41:17-22.

Britain, where the record of conservation of sites is good, still continues to have sites damaged by new «development», waste disposal, afforestation, people erosion and over-collecting. The National Scheme for Geological Site Documentation was initiated to help conserve sites by supplying more full records to better standards of recording. Currently data held by Record Centres is being computerized by the British Geological Survey through a two year contract from the Nature Conservancy Council. Also being developed is a Geology Locality Record form and a field guide for recording, to be used by both amateur and professional earth scientists.

Key words: Site documentation - Site information - Database systems

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The Annual Reports of the Scheme show that about 20,000 site records are held in centres. These include data on boreholes, mines, disused and active quarries and pits, restored sites, geomorphological features and natural and temporary exposures. Each site has a site file containing information obtained initially through fieldwork and/or literature searches plus all additional material known, i.e. site maps, photographs, sections and photocopied publications etc. From the site file a Summary Record sheet is produced, which, as its name implies, gives a convenient summary of the contents of the file. The sheet provides an ideal document for copying and distribution and saves considerable time and duplication of effort in repeated searching and collating of site information.

Site information is used by centres to provide a consultancy service for NCC, County Nature Conservation and Wildlife Trusts, County Planning Departments, researchers and others concerned with site conservation management and use. Centres offer an advisory service to teachers regarding the educational potential of sites and to direct those users away from over-used SSSI's, research and other vulnerable localities. Site information is also used as a resource for internal use supplying easy access to local geological information for specimen documentation, collecting policies and research for exhibitions and publications.

The work undertaken by museum curators in recording geological sites is seen as a most important part of their work within the science of geology and as an invaluable resource for their work within their museum.

The development of the National Scheme is monitored by two sponsoring organizations, the GCG and the Conservation Committee of the Geological Society, who receive regular reports of progress from the National Co-ordinator. The Scheme is also supported by the NCC, as part of their RIGS initiative, and the Geologist's Association.

2.3 Geological Records Centre

The aim of the National Scheme has been to encourage geological site documentation as an information resource for the conservation of sites, the identification of «alternative» sites, and for the dissemination of data relating to those sites for research, monitoring, education and general information. From the outset, computerization of site records was envisaged and this has now taken place on a national basis. The NCC awarded a contract to the British Geological Survey (BGS) to undertake the input, storage, manipulation and output of site records from Geological Locality Record Centres. The contract commenced in April 1989 and runs for just over two years with the possibility of a further contract to maintain a stratigraphic and a lithological index.

BGS at its Kingsley Dunham Centre at Keyworth, Nottinghamshire, commenced inputting data from Local Record Centres in August 1989. Following an initial analysis of sample data a prototype entry methodology was produced, but was subsequently modified, to speed entry and improve consistency and accuracy, by the use of templates. The standardized Geological Locality Summary Record sheet has 66 fields and all information is being computerized. The majority of fields contain only a few words while the geological description field may contain up to 300.

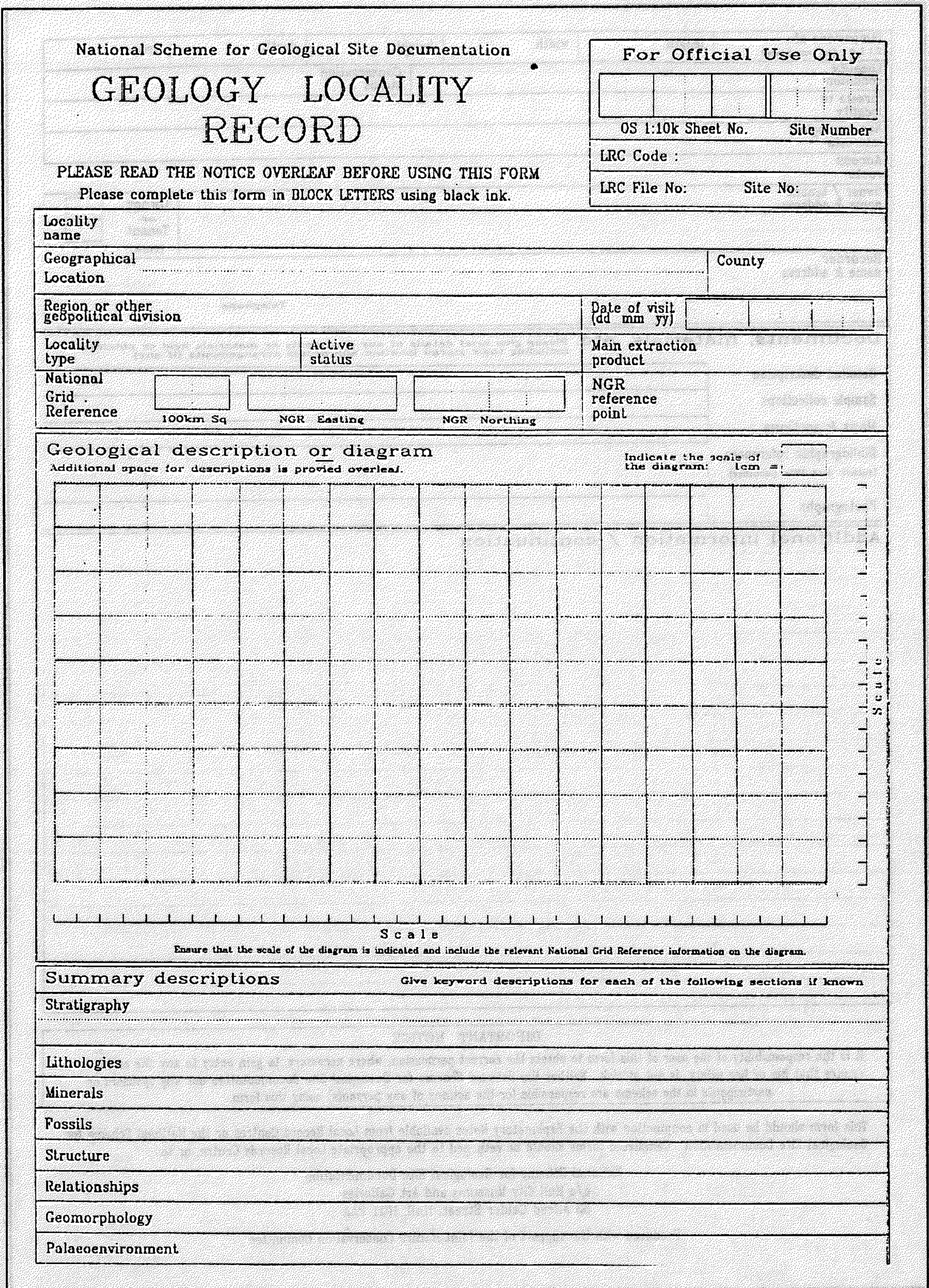
The data is input in ASCII form using IBM compatible PC's and commercially available word processing software, enabling data to be easily transferred to other computer systems. It should be straightforward to load data directly onto a wide variety of software packages including «dBASE III», «MODES», «ORACLE» and «RECORDER» (using Advanced Revelation).

Some 8,000 records, out of a total of about 20,000, had been input by April 1990 with another 6,000 held in digital form. It is anticipated that data entry should be completed by March 1991.

To facilitate the continual flow of geological data to Local Record Centres and the GRC, it was realized that a standardized «national» recording format, the Geology Locality Record, was needed. This new form (**Figure 1** and **2**), together with instructions (**Figure 3** and **4**), will be used by amateur and professional geologists, associated with schools, colleges, universities, societies, companies, local authorities and government departments, enabling them to capture data in the field and pass it directly to their Local Record Centre or to the GRC if a Local Centre is not in operation. The GRC will effectively be at the centre of an information network acting as a clearing house and also providing an open channel between the Record Centres and BGS.

Thousands of site records are held by individuals and organizations up and down Britain and a standardized national recording format is seen as the only method of capturing that information. It is realized that to aid recorders of sites there is also a need for a Field Handbook to recording and this is currently being produced by the GRC and will be made available for any individual or organization to use in the field. This will be the first attempt of its kind to bring together all the many and varied pieces of information on field recording.

Acknowledgement
The author wishes to thank the Geological Society and the Geologist's Association for funding to allow attendance at the Lom Convention of the European Working Group on Earth Science Conservation.



National Scheme for Geological Site Documentation

GEOLOGY LOCALITY RECORD

PLEASE READ THE NOTICE OVERLEAF BEFORE USING THIS FORM
Please complete this form in BLOCK LETTERS using black ink.

For Official Use Only

OS 1:10k Sheet No. Site Number

LRC Code :

LRC File No: Site No:

Locality name			
Geographical Location		County	
Region or other geopolitical division		Date of visit (dd mm yy)	
Locality type	Active status	Main extraction product	
National Grid Reference	100km Sq / NGR Easting / NGR Northing	NGR reference point	

Geological description or diagram
Additional space for descriptions is provied overleaf.

Indicate the scale of the diagram: 1cm =

Scale

Scale

Ensure that the scale of the diagram is indicated and include the relevant National Grid Reference information on the diagram.

Summary descriptions — Give keyword descriptions for each of the following sections if known

Stratigraphy
Lithologies
Minerals
Fossils
Structure
Relationships
Geomorphology
Palaeoenvironment

Figure 1
Front of Geology Locality Record A4 Sheet

Dimensions of site (in metres)	length:	width:	height:	depth:	area:
Locality condition			Conservation status		
Threats to locality					
Non-geological interests					
Access route					
Owner / tenant name & address					Owner or Tenant (tick)
Recorder name & address				Telephone	

Documents, materials, etc. Please give brief details of any documents or materials held or obtained, including their stored location and access arrangements (if any).

Detailed description	
Sample collections	
Maps & sections	
Bibliographic references (author: date: title: publisher)	
Photographs	

Additional information / continuation

IMPORTANT NOTICE

It is the responsibility of the user of this form to obtain the correct permission, where necessary, to gain entry to any site and to ensure that his or her safety is not at risk. Neither the National Scheme for Geological Site Documentation nor any sponsors or participants in the scheme are responsible for the actions of any person(s) using this form.

This form should be used in conjunction with the Explanatory Notes available from Local Record Centres or the National Scheme for Geological Site Documentation. Completed forms should be returned to the appropriate Local Records Centre, or to:

National Scheme for Geological Site Documentation
c/o Hull City Museums and Art Galleries
83 Alfred Gelder Street, Hull, HU1 2AA

Produced with the support of the Joint Nature Conservation Committee

Figure 2
Reverse of Geology Locality Record A4 Sheet

GEOLOGY LOCALITY RECORD

EXPLANATORY NOTES

Information about permanent and temporary geological exposures is held by Local Records Centres under the National Scheme for Geological Site Documentation.

These explanatory notes are intended for use with the Geology Locality Record form which may be used to make an initial record of geological localities. Completed forms, plus additional documents or materials, may be sent to the appropriate records centre listed overleaf: additional forms can be obtained from most Local Records Centres. Enquiries about geological records held by local centres should, in the first instance, be addressed to the appropriate centre.

LOCALITY INFORMATION Basic reference information, including the locality name and type, National Grid Reference and date of visit must be provided for all sites.

Locality name Name of the locality, or of an appropriate feature marked on a large scale Ordnance Survey map (preferably 1:10,000 or 1:25,000 scale).

Geographical location & county Location of the site, including parish, town, district and Post Code (if known); give the current county.

Region or other geopolitical division Other geographical/political divisions which may apply. Examples: National Parks, 'old' pre-1974 counties, regions

Date of visit Day, month (01, 02, etc) and year of the visit.

Locality type Examples: outcrop, stream or river section, cliff, landslip; road or railway cutting, tunnel; quarry, opencast mining, mineshaft or adit, mine dump or spoil-heap; trial pit, trench, excavation; boring or borehole, well; fissure or hole, cave.

Active status Examples: active, temporary, disused, restored, historical.

Main extraction product Types of materials extracted for further use. Examples: sand & gravel, brickclay, limestone, coal, iron, lead.

National Grid Reference (NGR) Quote the NGR as described on current Ordnance Survey maps, using the 100km square reference letters. The NGR should be given to a precision of 10 metres wherever possible.

NGR reference point The exact point to which the National Grid Reference refers. Examples: 'centre of site', 'western corner'. Indicate the reference point(s) on any diagram.

GEOLOGICAL DESCRIPTION OR DIAGRAM Use this space for a concise description of the locality, or diagram: include additional locational information, history, and geological observations. Diagrams, sketches or sections, should include relevant locational data (National Grid Reference points), measurements & scales.

SUMMARY DESCRIPTIONS Brief 'interpretive' geological descriptions (using key-words) may be given for the following sections. Please indicate any conjectural information clearly using a question mark: for example, *?Yoredale Beds*, *?bryozoa*. Detailed descriptions should be included in the previous section.

Stratigraphy If known, list the principal stratigraphic units present, (oldest to youngest) in increasing detail. Examples:

Carboniferous, Millstone Grit, Huddersfield White Rock.
Triassic, Sherwood Sandstone Group, Chester Pebble Beds.

Lithologies The principal rock types seen. Examples: shelly limestone, conglomerate, granite. If rock types cannot be adequately identified, indicate whether sedimentary, metamorphic, or igneous.

Minerals & Fossils The mineral types & fossil groups occurring at the locality. Examples: galena, barytes, haematite, fluorite; brachiopods, rugose corals, goniatites. More detailed lists should be provided as a separate document.

Figure 3
Geology Locality Record Explanatory Notes

Structure Any major structural features, including: faulting, folding, jointing, dip & strike; sedimentary features, etc.

Relationships Relationships between different rock units, including: unconformities, cross-cutting dykes, buried channels, etc.

Geomorphology Significant geomorphological features, including: periglacial features, ox-bow lakes, screes, weathering effects.

Palaeoenvironment If known, note the main geological environments represented. Examples: lacustrine, desert, reef, delta.

OTHER INFORMATION

Dimensions Give these (in metres) here and on any diagram.

Locality condition A brief statement on the condition of the locality. Examples: flooded, filled, overgrown, obscured by scree.

Conservation status Details of any recognised geological or non-geological categorisation of the locality. The following abbreviations may be used; other categories should be given in full.

AM	ANCIENT MONUMENT	ONR	OTHER NATURE RESERVES & WILDLIFE SANCTUARIES
AONB	AREA OF OUTSTANDING NATURAL BEAUTY	RIGS	REGIONALLY IMPORTANT GEOLOGICAL / GEOMORPHOLOGICAL SITE (or local 2nd tier equivalent)
CA	CONSERVATION AREA	SSSI	SITE OF SPECIAL SCIENTIFIC INTEREST (add 'G' for geological sites)
LNR	LOCAL NATURE RESERVE		
NNR	NATIONAL NATURE RESERVE		
NP	NATIONAL PARK		
NT	NATIONAL TRUST PROPERTY		

Threats to locality Describe any obvious threat to the locality likely to arise in the future. Examples: imminent closure (dates), tipping, reclamation, building, over collecting.

Non-geological interests Indicate any non-geological interests recognised. Examples: archaeological implements/remains, historic site, flora and fauna. Beware of unwittingly recording confidential or sensitive information.

Access route The route to the site, access restrictions, permissions required, etc, as indicated by the site owner/tenant. Please read the 'Important Notice' below, and on the Geology Locality Record form.

Owner/tenant name and address Accurate details of owners and/or tenants. Indicate whether the contact is the owner or tenant.

Recorder name address Your name and full postal address and telephone and number (optional). Please indicate whether you are a member of any geological society, etc.

DOCUMENTS, MATERIALS, &c Brief details of further documentation relating to the site, or of samples obtained, may be recorded here. Indicate if these are being lodged with a Local Records Centre or, if retained by the recorder, how the information/materials may be accessed.

IMPORTANT NOTICE

It is the responsibility of the individual undertaking any geological survey and using the Geology Locality Record form, to obtain the correct permission, where necessary, to gain entry to any site and to ensure that his or her safety is not at risk. Neither the National Scheme for Geological Site Documentation nor any sponsors or participants are responsible for the actions of any person(s) recording information using the Geology Locality Record form or this leaflet.

National Scheme for Geological Site Documentation,
c/o Hull City Museums and Art Galleries,
83 Alfred Gelder Street, Hull, HU1 2AA.

Produced with the support of the Joint Nature Conservation Committee.

Figure 4
Geology Locality Record Explanatory Notes

3 Theory and Practice of Earth Science Conservation in Belgium

Patric Jacobs and Joris F. Geys

3.1 Site Typology in Belgium

Internal relationships

There has always existed contacts between professional and amateur geologists, perhaps not friendly, sometimes even hostile. Professional geologists regarded themselves as «official employees» because most of them work in Universities and Scientific Institutes and «have an official diploma».

Amateur geologists regarded themselves as excellent «connoisseurs» of collections with much field experience and not being bureaucratic.

In Belgium, it took a certain time before both parties realized they both were right and wrong. Both groups now work towards complementarity, and found a new and common enemy in «the authorities». With environment as a recent fashion, both suspect «the authorities» to be ineffective, even inactive, corrupt in an economic and political way, and lacking scientific basis for both long and short term policymaking.

Professional and amateur geologists try hard to bridge the last part of their gap by setting up a strategy for the use of collecting (mostly palaeontological) sites to the benefit of both. Rules to be observed in collecting samples from valuable palaeontological sites were, more or less, generalized by developing a theoretical background for a clear and user friendly system to be used as a scientific criterion for an adequate authority policy in site conservation in Belgium.

Theoretical background

The model departs from a «site typology» as a sort of classification based on 2 criteria:

- the nature of the site is an objective criterion dealing with time, place, processes and the enumeration are nonlimited.

- the scientific value of the site is a subjective criterion dealing with mineralogical, palaeontological, sedimentological and physical-geographical considerations.

The nature of the site (**Figure 1**) can be:

- non-temporary or timeless:
  I. self-rejuvenating natural outcrops: cliffs, hilltops
  II. self-rejuvenating artificial outcrops: active quarries
  III. non-rejuvenating outcrops: hillslopes, abandoned quarries, railway cuts

- temporary:
  IV. temporary outcrops: building sites
  V. non-outcrops: farm-land
  VI. ex-situ sites: dumps, terrils

- a special position: subsoil (subcrops)
  VII. caverns: characterized by their special location, restricted area or special ecosystems, they require special conservation techniques; even research might here be destructive!

Abstract

Jacobs, P. & Geys, J. F. 1992. Theory and Practice of Earth Science Conservation in Belgium. - NINA Utredning 41: 23-31.

Geosites are regularly visited by both professional and amateur geologists, for study and for sampling respectively. This pressure on sites of all kinds calls for protection and conservation rules. Site typology is based on 2 criteria: site nature and scientific value. Together with natural or man induced damage it provides a grid for user's good behaviour, enabling an active interplay between the authorities on the one hand and the amateur and professional geoscientist on the other, as a prerequisite for modern site conservation. The law in Belgium has created possibilities and some facilities for conservation, but most monument and landscape conservation has been mostly through private initiatives. It has been ruled by a mosaic of laws and procedures, suffered from political obstruction and has been neglected by the public. Recent developments, however, demonstrated a growing interest for considering geological arguments of equal importance in conservation policy as are fauna and flora.

Key words: Site classification - Criteria - Legal framework

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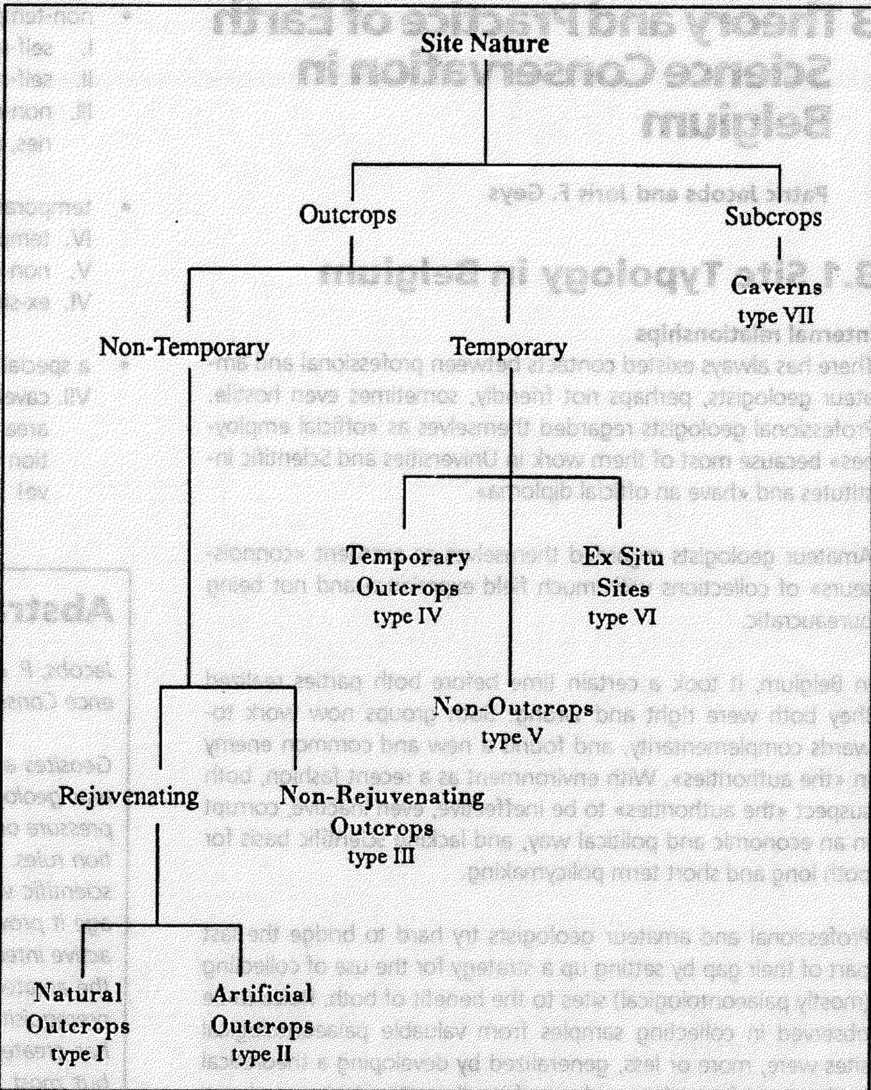


Figure 1
Site nature

The value of the site can be scientifically evaluated (**Figure 2**):

a Sites with objects of exceptional conservation such as Messel, Burgess Pass, Bundenbach and Ediacara with fossilized soft parts, have an exceptional depositional history and therefore occupy a key position in palaeobiology and palaeontology. They require special conservation techniques.

b Sites with fossil vertebrates such as the Robiac, Dinosaur, Messel, Agate, Laetoli, Olduvai and Plan de Canjuers sites occupy a restricted area, are very vulnerable and document on the history of mankind.

c Stratotypes: national and international scientific standards for palaeontology, mineralogy, sedimentology, stratigraphy.

d Sites with minor scientific value: wide-spread, not typical.

The decreasing scientific value from a to d (**Figure 2**) results in increasing collecting possibilities for all types of site.

Damage (**Figure 3**), be it natural or man induced, exerts a major influence:

1 Type I sites gain profit from natural decline (caused by physical,

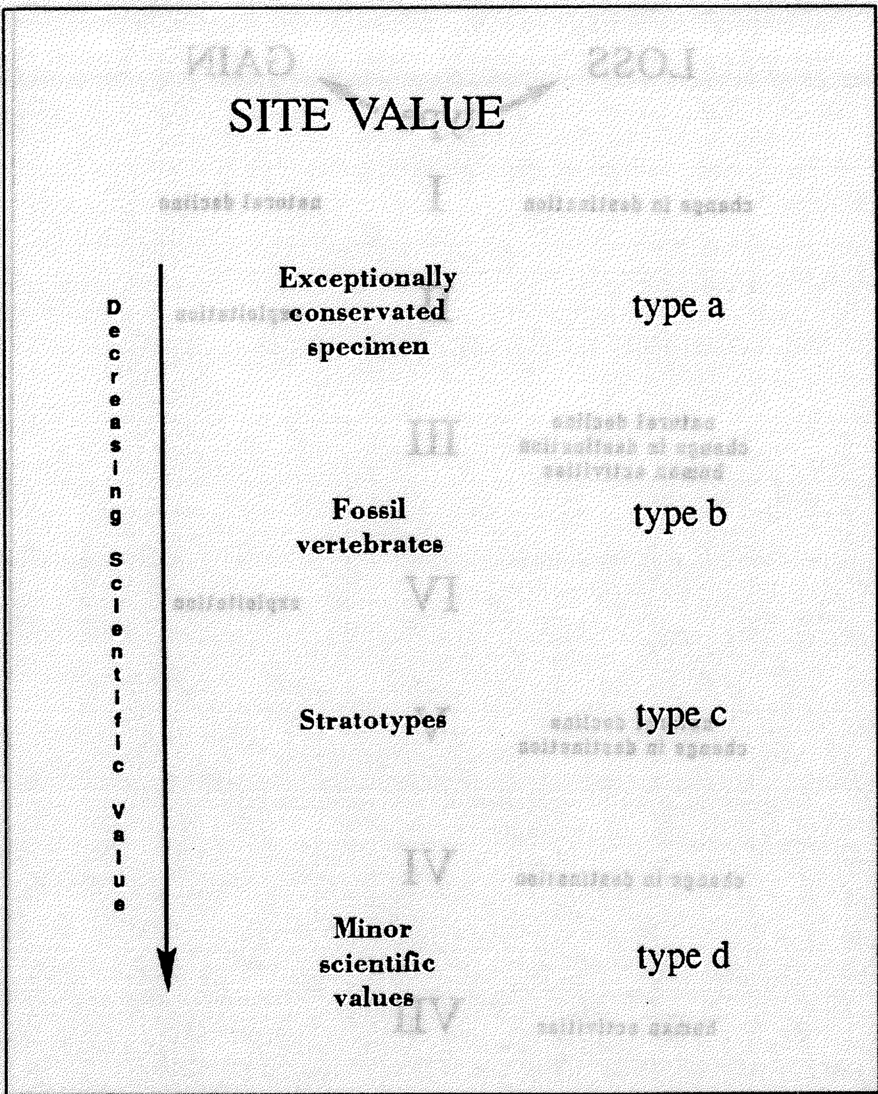


Figure 2
Scientific site value

chemical or biological weathering, and enhanced by transport), but might be ruined by change in use (canalizations, coastal engineering constructions, military domains, urbanization)

2 Natural resources exploitation favours type II and type IV sites. It resembles natural decline, but acts much faster. Important findings or discoveries might necessitate a transformation into type III sites

3 Type III sites suffer of course from natural decline and from change in use (waste disposal and water infill in abandoned quarries and natural decline of abandoned railway cuttings). Human activities (recreation, sports, education and research) are mostly not welcomed

4 Type IV sites on the other hand are favoured by exploitation (otherwise they never would have been there). Important findings may necessitate a transformation into type III sites

5 Natural decline deteriorates type V sites, as does change in destination. In exceptional circumstances, a transformation into a type III site might be necessary.

6 Change in destination ruins type VI sites.

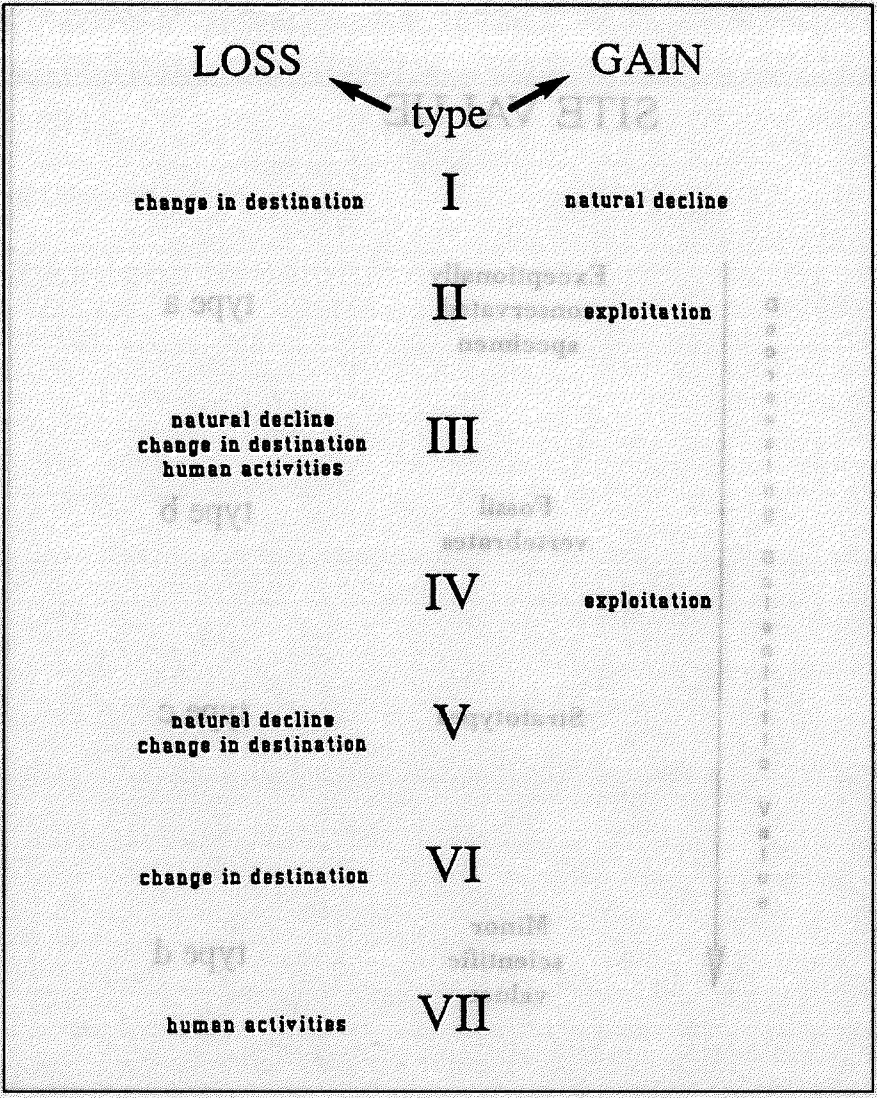


Figure 3
Site value can be (positively or negatively) influenced by man or nature induced changes

7 Human activities (even scientific research included) put a serious stress on type VII sites and must thus be forbidden or regulated at a maximum.

Overcollecting and abuse of mechanical tools (or even explosives!) should be banned from all site types.

Grid
Combination of site value (vertical) and site nature (horizontal) provides a grid (**Figure 4**) of different types of sites, for which a specific user's behaviour might be recommended. In this context, «user» stands, more or less, for amateur geologists in the case of collecting (mostly palaeontological samples) and «authorities» in the case of protection. Combining site nature and value on the one hand, and possible damage or decline on the other, outlines some recommendations for user's behaviour.

In general, it is obvious that type a and b sites (**Figure 4**) require maximum care and protection (except for type VI of course). Protection does not only include prohibition of sampling, but also implies maintenance taking into consideration education needs, accessibility, and sometimes even isolation of the objects.

Type I sites undergo natural decline exposing new specimens that

	type I	type II	type III	type IV	type V	type VI	type VII
a	collecting of displaced objects allowed	transformation into type IIIa	complete protection	transformation into type IIIa	transformation into type IIIa	no limits to sampling	complete protection
b	collecting of displaced objects allowed	transformation into type IIIb	complete protection	transformation into type IIIb	transformation into type IIIb	no limits to sampling	complete protection
c	moderate collecting allowed	moderate collecting allowed	moderate collecting allowed	-	-	-	complete protection
d	no limits to sampling	no limits to sampling	moderate collecting allowed	no limits to sampling	no limits to sampling	no limits to sampling	moderate collecting allowed

Figure 4
Site typology and recommendations for user's behaviour

are subsequently destroyed. So displaced specimen removal and moderate collecting are allowed. As type II sites exist because of exploitation, all interesting specimens must be collected.

In type III sites protection prevails over collecting because of a serious danger of the site being totally exhausted. Natural decline necessitates a thorough maintenance of these site types. Normally type IV sites do not require protection, but discoveries with a highly important scientific value might necessitate temporary cessation of all construction activities, or even complete protection (archaeological findings) by incorporation of the site into the construction. If impossible, sampling is a matter of first order importance due to the temporary character of the site. Type V sites display the same problems as type IV ones. Of course stratotype definition is out of order for type IV, V and VI sites.

For type VI sites sampling prevails over protection which is practically excluded because of the nature of the site. Exceptions might, however, force protection (e.g. Writhlington: Carboniferous fossil insects in terril). In type VII sites, human activities are the only threat. Autochthonous thanathocoenoses and ecosystems require absolute protection and do not tolerate any activity whatsoever.

3.2 Site Conservation in Belgium

Historical background
The Royal Commission on Monuments and Sites (**Figure 5**) was established in 1837 by King Leopold I, and is thereby Belgium's oldest official advisory board, directly reporting to the Minister having the responsibility for monument and site conservation.

With the Monument and Landscape Conservation Act of 1931, monuments (buildings with artistic or historical value) and landscapes could be conserved by means of a procedure that regulated changes, limited owner's rights, and usage, in order to assure maximum protection.

	National		Communities	Regions	
	Monuments & Landscapes	Environment	*Monuments & Landscapes*	*Land Survey* Economy, Agriculture, Urbanisation	Environment
1830	Belgium!!!				
1837	*Royal Commission Monuments & Landscapes (RCMS)*				
1931	*M & L* Conservation Act				
1950's	*RCMS* Provincial Commissions				
1970			Transfer Mon&Landsc Split RCMS Flemish + French Brussels	Local	
				&	
1973		Nature Conservation Act + *Nature Conservation Council*		District	
1976	*Village sights* Conservation Act			Land	
1980				Survey	Transf. environment
1982	Art Objects Conservation Act			Plans	
1985					
1991				Revision	*Nature Management Institute (Flemish)*

Figure 5
Legislative, administrative and political structure of conservation policy in Belgium since 1830

Since 1976, «village sights» conservation has been added. Art object (the so-called «moving cultural Patrimonium») protection completed the scene in 1982.

Federalization of Belgium transferred monument and landscape conservation to the Flemish and French Communities (1970), together with the administration and the budget. Some topics are still ruled by national laws, other than Community laws (decrees). The Royal Commission has split into two totally independent Flemish and French divisions which advise their respective Community Ministers. Joint meetings on conservation problems are still held in Brussels; both Communities retain an interest, both divisions together advise the National Minister, who is still in charge of the national monuments.

Administration up to then was kept at a minimum, with help from a temporary but devoted staff which was politically nominated, and organized in provincial sections with the Governors as chairmen of the Provincial Commissions on Monuments and Sites. In the meantime, the Nature Conservation Act of 1973 has protected fauna and flora, and a new advisory Nature Conservation Council has been installed.

It is a miracle that the mechanism of monument and site conservation in Belgium still works, taking political inertia and budget limitations into account.

Procedure

Every Belgian citizen, organization or Local Authority can make a demand for the conservation of a monument or site (in Belgium commonly called a classified monument). The Administration of Land Survey and Environment, Directorate of Monuments and

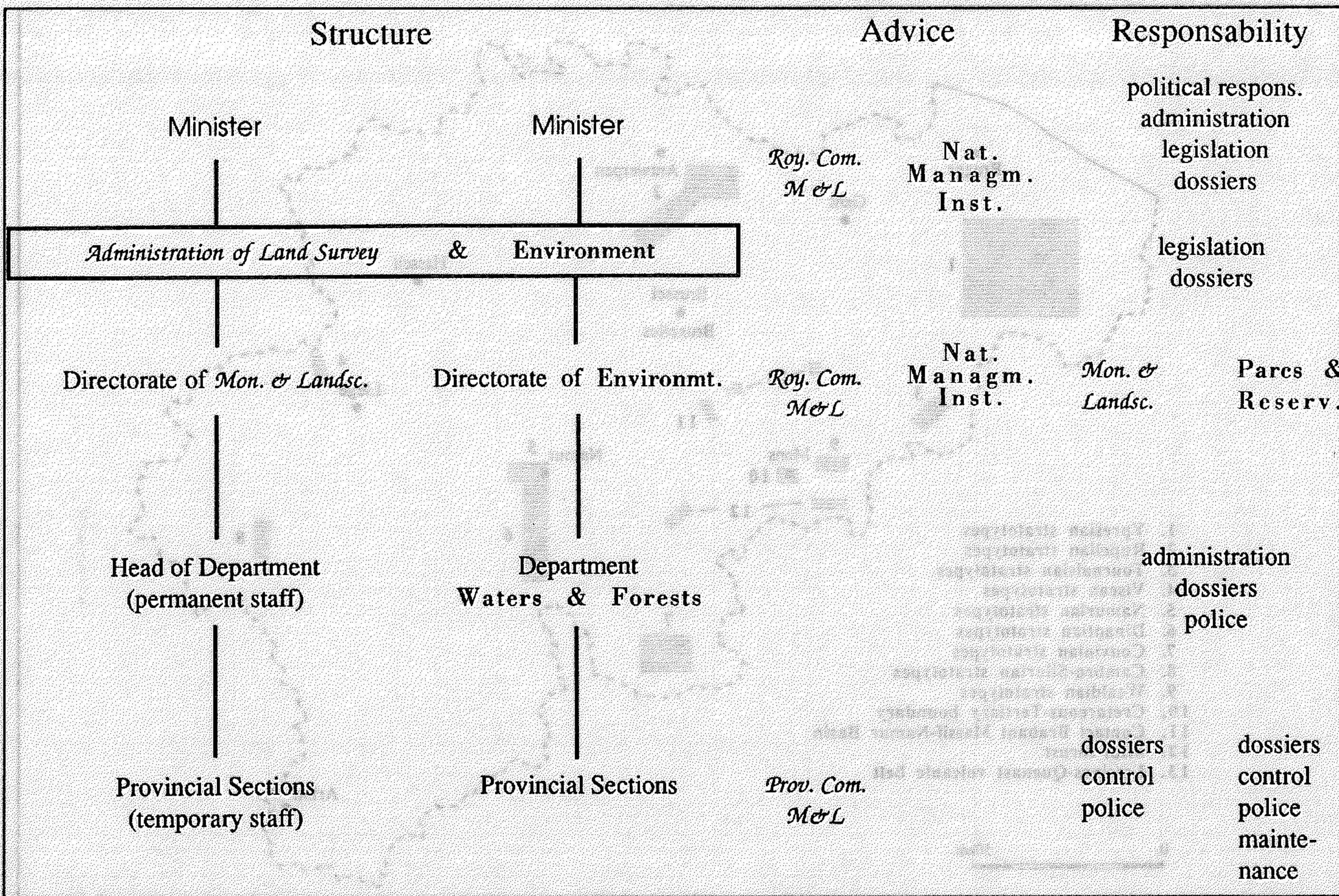


Figure 6
Actual political and administrative structure of conservation policy in Belgian Communities and Regions

Sites (**Figure 6**) investigates and produces a preliminary dossier on historical background, ownership, conservation necessity and urgency. On the basis of the Royal Commission's advice, the Minister takes an initial decision on temporary conservation, regulation and limitation of the owner's rights. All owners (or, if known, all land users) are informed, with the possibility of objection within a fixed period of 60 days. The Monuments and Sites Directorate answers any objections from private individuals and deals with advice from all concerned authorities (town, province, etc.).

Following this procedure by the Directorate and production of a completed dossier, the Royal Commission advises the Minister to take a final and definitive decision within 90 days. If not, the procedure has to be started all over again. It is obvious that the basic philosophy of the law and the procedures is the defense and protection of the owner's rights. However, a lot of monuments have been conserved.

Future plans

Up to now nothing has been done about geological site conservation, but it is obvious that the law (and decrees) affords possibilities. Important quarries, now under threat from waste disposal or flooding, could be saved for observation, study and education, by making use of the interplay of different conservation laws. Internationally reknowned boundaries or facies could be kept accessible to authorized persons, the owner being obliged to assure the maintenance of the observation point.

The geological community in Belgium will have to help the administration by providing a complete list of sites requiring conservation, and a dossier on each site's historical and scientific in-

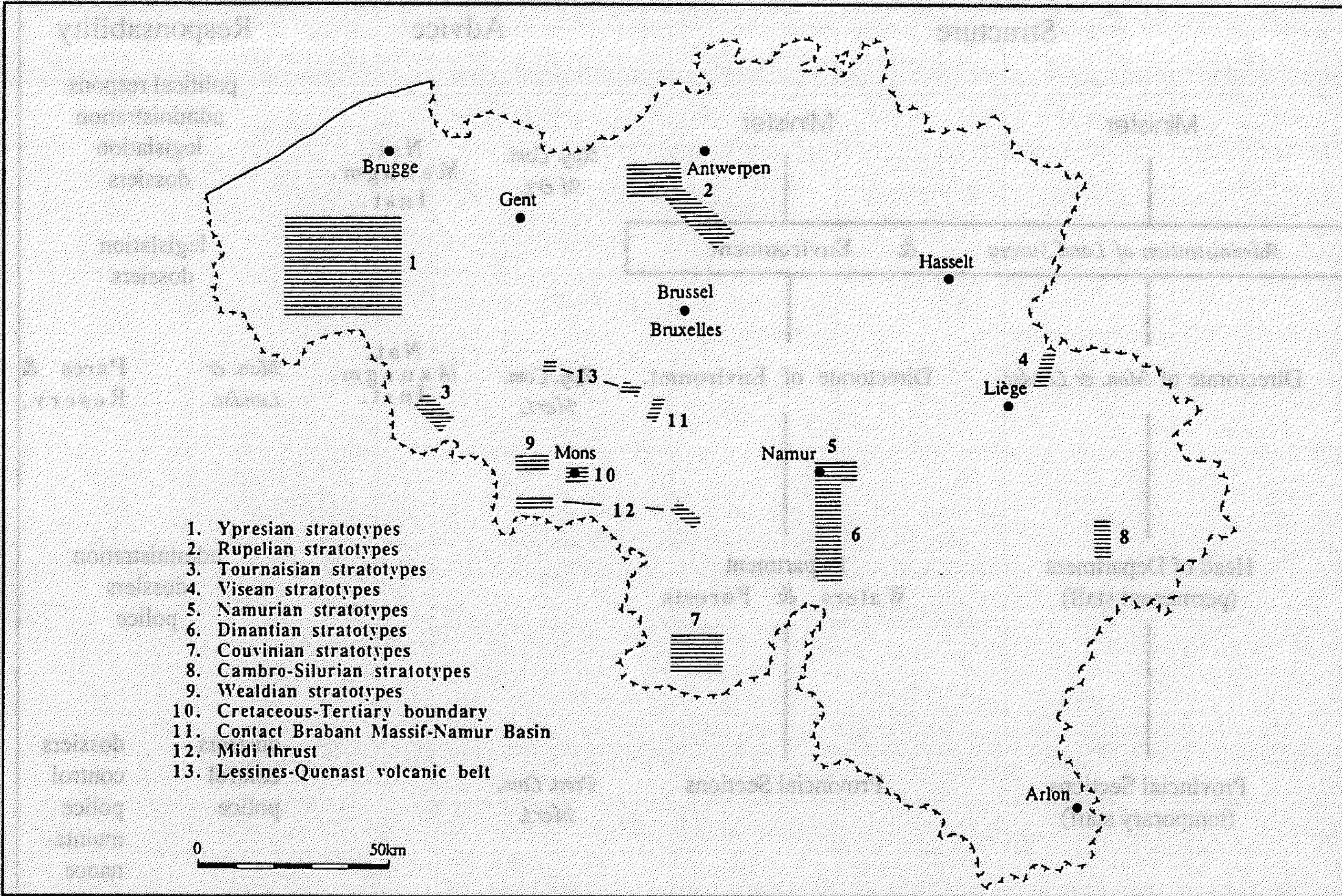


Figure 7
Strategic geological sites in Belgium

terest, as the administration has never dealt with this type of conservation before.

Steps have already been taken to acquire the full support of the Administration and the Royal Commission. The main work that remains to be done is the compilation of dossiers on sites of national and international conservation interest.

From a geological point of view (**Figure 7**), the national stratotype localities of internationally accepted stages like the Tournaisian, Visean, Dinantian, Namurian, Ypresian, Rupelian, etc. are to be protected. Also the only volcanic and plutonic rocks in Belgium, belonging to the Silurian Quenast-Lessines volcanic belt, are to be considered as a priority, favoured by the positive attitude of the extraction industry for this project and its importance for education and regional economy. The mudmounds, the Cretaceous Tertiary boundary, the Midi thrust, the continental Lower Cretaceous reptile subcrops of Bernissart, the Namur Basin contact on the Brabant Massif at Ronquieres, and last but not least the Balegem quarry, with the famous Balegem stone used as a building stone for most of the cathedrals and castles in the old County of Flanders and the Duchy of Brabant from late Gothic times, are also important.

Within the physical geography framework, attention must be paid to all typical landscapes where ancient and modern sedimentary processes are responsible for the actual landscape formation. Of course the complete coastal zone (**Figure 8**) with the Flemish Banks in the North Sea, the beach, the dunes, and the polders with the submerged peat land form a priority target, being constantly under threat of industrialization and tourism infrastructure expansion. The polders and creeks of the Westerscheldt

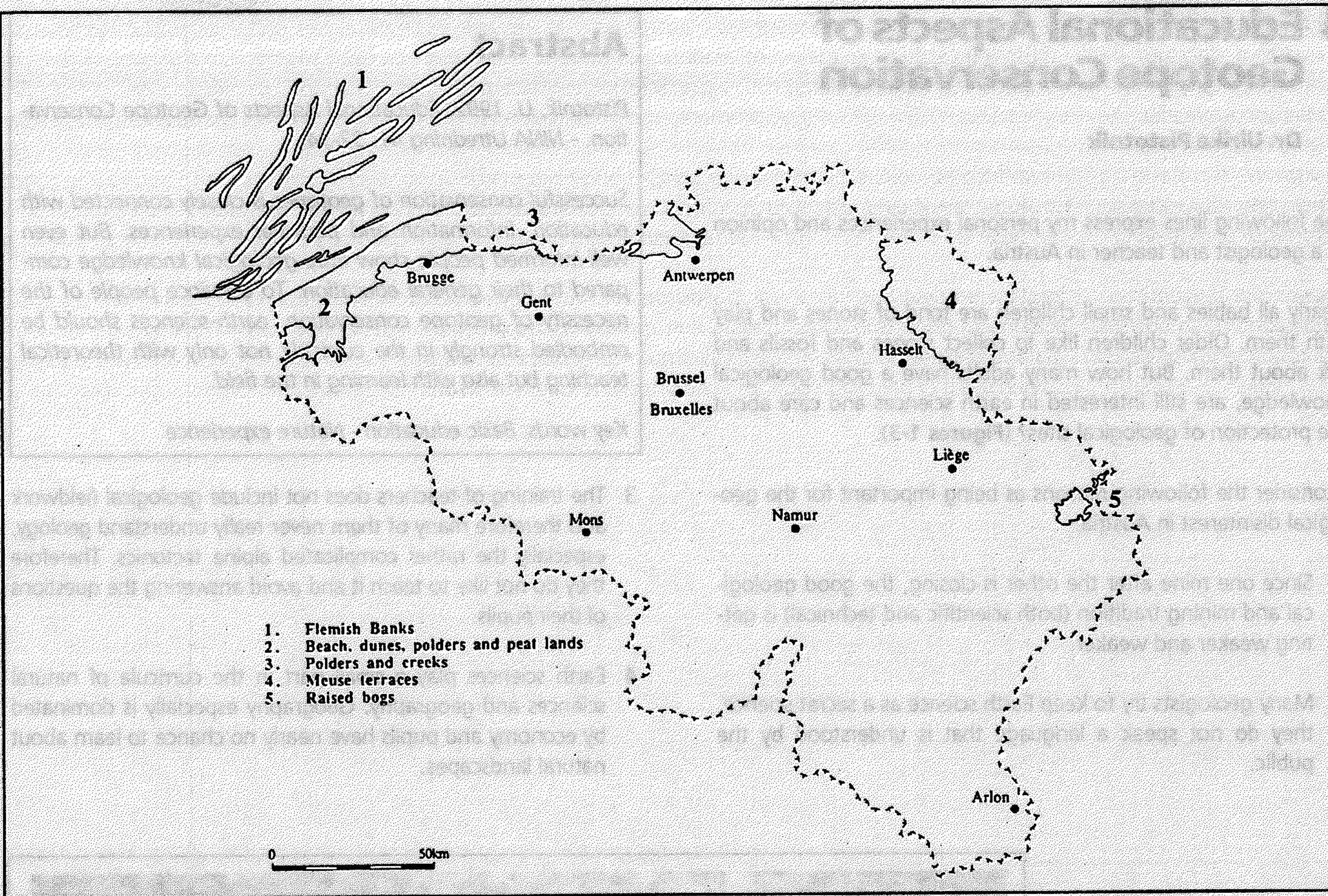


Figure 8
Strategic physico-geographical sites in Belgium

river with its tidal flats, the Meuse river terraces, the Ambleve and Ourthe rivers meanders and ox bows suffer from the same problems. Only the precious raised bogs of the Hautes Fagnes are protected as a natural park and reserve be it from a faunal and floral point of view and not from a geological and physical geographical one.

Conclusion

Some sites (e.g. type VII, III) require complete protection, maintenance included, while others (type II, IV) benefit from sampling all sorts of available specimens.

The aim of the grid is not to provide a complete set of precise tools; therefore it is far too incomplete, too general and it lacks nuances. It is but a first attempt to conciliate amateur and geologists' concerns and to provide a platform for a common attitude towards the «authorities». It only depicts a possible theoretical background for a conservation policy of the «authorities» (based on «sampling» and «protection» needs), requiring further discussion and more precise definitions.

The idea of earth science conservation is progressing in Belgium. Regulations and legislation allow initiatives, but the federalization of the country might complicate procedures, enhance inertia, and thus form a serious obstruction for an effective conservation policy. Professional and amateur geoscientists try to pass on to the authorities the message that geo-conservation is as important as faunal and floral. Well chosen pilot projects in the domain of geology and physical geography might convince the authorities to enlarge existing regulations and legislation and force them to develop an adequate conservation policy and attitude, making good use of the environmental protection reflexes of the public.

4 Educational Aspects of Geotope Conservation

Dr. Ulrike Pistotnik

Abstract

Pistotnik, U. 1992. Educational Aspects of Geotope Conservation. - NINA Utredning 41: 32-34.

Successful conservation of geotopes is closely connected with education, information and personal experiences. But even well-informed people show little geological knowledge compared to their general education. To convince people of the necessity of geotope conservation, earth-sciences should be embodied strongly in the curricula not only with theoretical teaching but also with learning in the field.

Key words: Basic education - Nature experience

The following lines express my personal experiences and opinion as a geologist and teacher in Austria.

Nearly all babies and small children are fond of stones and play with them. Older children like to collect stones and fossils and ask about them. But how many adults have a good geological knowledge, are still interested in earth sciences and care about the protection of geological sites? (**Figures 1-3**).

I consider the following reasons as being important for the geological disinterest in Austria:

1 Since one mine after the other is closing, the good geological and mining tradition (both scientific and technical) is getting weaker and weaker.

2 Many geologists try to keep Earth science as a secret science, they do not speak a language that is understood by the public.

3 The training of teachers does not include geological fieldwork and therefore many of them never really understand geology, especially the rather complicated alpine tectonics. Therefore they do not like to teach it and avoid answering the questions of their pupils.

4 Earth sciences play a small part in the curricula of natural sciences and geography. Geography especially is dominated by economy and pupils have nearly no chance to learn about natural landscapes.

Figure 1
All babies like to play with stones.

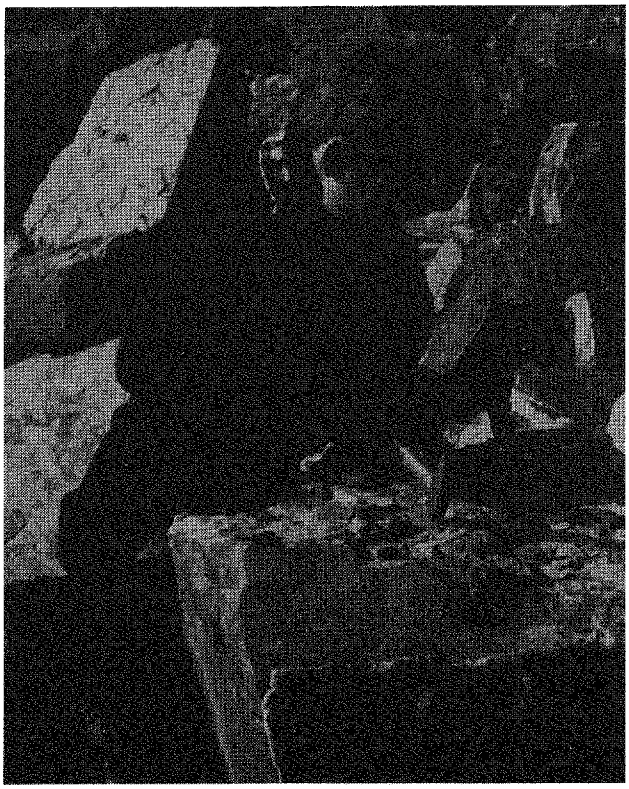


Figure 2
Many children collect minerals or fossils.

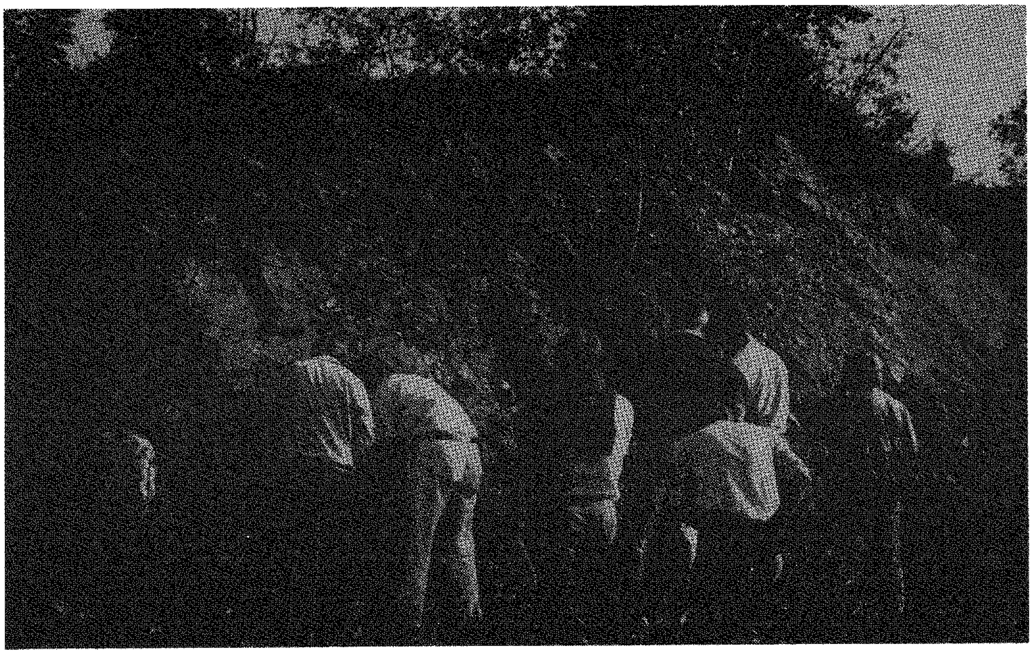


Figure 3
Adults at a geological site - for specialists only?

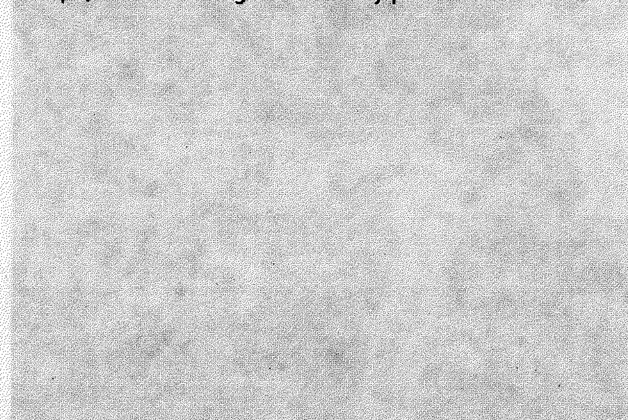
5 Lessons at school usually are theoretical and in a class-room. Pupils seldom go outdoors to collect experiences in nature. Especially in Earth sciences such training is boring, incomprehensible and even a deterrent.

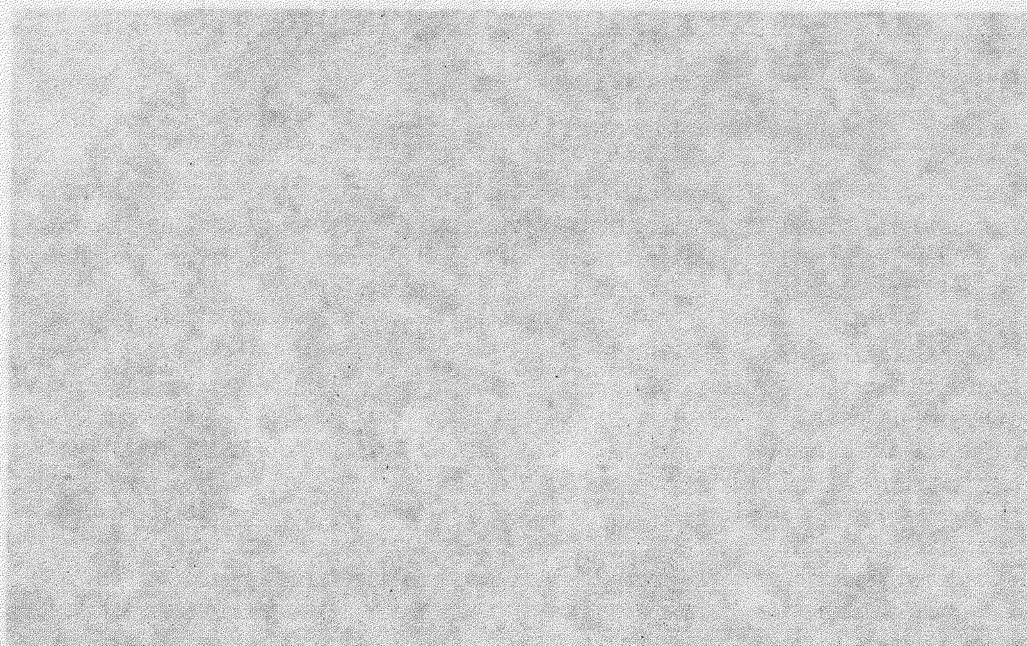
6 There are seldom good and attractive geological contributions in the media (but this is probably already the result of the above-mentioned points 1 - 5).

Conservation is only possible if you know and feel the value of the objects. Therefore it is necessary to give earth sciences a good position in the curricula of schools and universities and educate the teachers as the basis for good teaching in the schools.

But learning facts is too little. Nowadays many people know nature only by television, they have no personal contact. Teachers and pupils need a chance to experience nature, to have a little adventure, to feel nature with all their senses, to have fun in nature and then they will start to like it and to find it worthwhile to protect it. Geology offers a big variety of sensations: active volcanoes, deserts, high mountains and ocean bottoms. They should be able to rouse the interest of many people.

Studying the ages of geological and biological development of the earth gives you a feeling of respect and love for the natural landscape, that is in danger in so many places of the world.





5 River Meanders or Houses: A Case Study

Gerard P. Gonggrijp

5.1 Introduction

South of the City of Roermond an interesting landscape, obviously differing from the surroundings, is situated between the river Meuse and the Roer valley. It shows a gently undulating surface partly covered with forest but for the most part in agricultural use. On closer consideration the undulating character is determined by a meandering system of shallow channels and by the presence of several low sandhills. Research so far has shown that the area is unique as to its geological phenomena. For that reason the area was listed in the report «Nederland in Vorm» (Gonggrijp 1989), an Earth science conservation background paper for the recent Nature Policy Plan (Ministry of Agriculture, Nature Management and Fisheries 1990).

5.2 Geological History

The Roer basin is situated in a tectonically unstable part of The Netherlands. Movements along faults has formed a horst and graben structure running northwest to southeast. The Central Graben in the southern part, called the Roer-Valley Graben, is part of the Rhine-Graben system. This Rhine-Graben has influenced considerably the fluvial development in the area. About 2 million years ago the river Rhine used the Roer-Valley Graben to find its way to the North Sea. In those days the river Roer was a tributary of this Rhine system such as the river Meuse. The rising of the Ardennes massif caused uplift and inclination of the area in the north and forced the river Rhine to change its course in a northerly direction. So about 600,000 years ago the Roer-Valley Graben was used by the river Roer, at that time a tributary of the Meuse, which also had changed its course because of the geological events in the Ardennes.

South and west of the recent Roer valley we find several indications for the existence of a medium-sized river system like the Roer, because these remnants are too small to be created by the river Meuse (**Figure 1**). South of the river Roer exists a dry valley, the valley of Posterholt which continues «upstream» into Germany and joins the recent valley near Heinsberg. This dry valley shows several well formed meanders cut out in the northern valley side, probably due to the tectonic inclination. To the northwest the gently undulating area between St. Odiliënberg and Linne and south of Roermond shows a wide zone of meandering channels (Gonggrijp 1977, 1979). These channels often start and end rather suddenly, and besides they are at some places interrupted by small sandhills built up by coversands (**Figures 2, 3**) partly affected by Holocene eolian action. The southern limit of the Roer area seems to be influenced by the occurrence of the Beegden fault; to the north the Peelrand fault forms a boundary.

We are not sure what happened exactly, because detailed research has so far not been carried out. But presumably the following events took place: At the end of the Pleistocene, the river Roer followed the valley of Posterholt and took up the area between St. Odiliënberg and Linne. Possibly at the same time the recent river area was used too. Tectonic movements activated by the Ardennes rising caused a gradual removal of the Roer to the northeast. Under periglacial conditions, sand-drift from the Meuse valley system probably also contributed to the relocation of the river Roer. Due to this sand invasion the former Roer could have tried to find a temporary way westward through a small valley to Montfort. During the Holocene, the river-bed followed the recent valley, and built up a system of terraces, cutoffs, natural levees, and point bars.

5.3 Unique Area: Threatened and Saved

Nowhere in the Netherlands can we find such a geological landscape. In the Roer area fluvial, periglacial and tectonic features are present and related to each other. The late glacial meander-

Abstract

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The paper examines the case of the old fluvial landscape of the river Roer in the Netherlands. At the beginning of 1990, a modification of the city boundaries was presented by the provincial authorities. In the proposal the northern part of this unique area would be assigned to the city of Roermond to allow house building in the future, but a prompt conservation campaign from of the local authorities and population preserved the area from destruction.

Key words: Old fluvial landscape - Town development - Local action

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Figure 1
Former Roer channel partly filled with Weichselian eolian coversands.

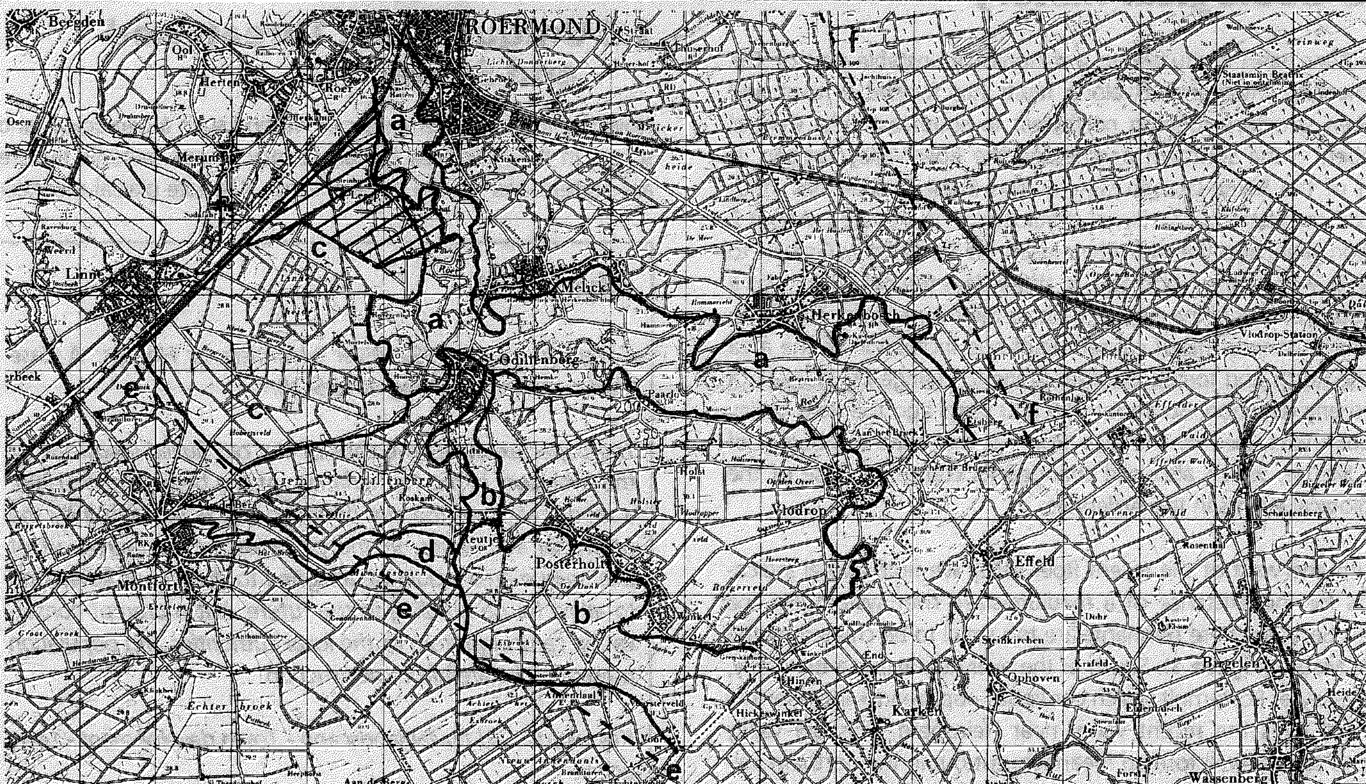

Figure 2
Roer area, a- recent Roer valley, b- old valley of Posterholt, c- area with former Roer channels, d- «overflow channel» of the river Roer, e- Peelrand fault.

Figure 3
Areal photo of the threatened area. The former Roer channels are dark toned because of the wet conditions. Some of the channels can not be recognized because of the thick coversand filling. (Folcokhech Topografische Dienst. Emmen).

ing system of the Roer is the only one we have. The system is closely related to the tectonic movements along the Roermond Valley Graben and the uplift of the Ardennes, and it is the only distinct Dutch example of a «slip off» river system.

The area shows the causes of sand-drift on a river system by the filled up parts of the channels. Next to the more general coversand forms, some well developed examples of parabolic coversand dunes can be distinguished in the southwestern part.

The recent Roer valley is one of the rare uncanalized river systems (**Figure 4**), furnished with unspoilt terraces, etc. and a beautiful and unique example of a landscape of fault-stepping, with connected features such as seepage borders the Roer area. Each of these phenomena is of great national importance. Therefore, these areas are listed as (inter)nationally important Earth science areas in the Nature Policy Plan.

In the course of time several municipalities in the Netherlands

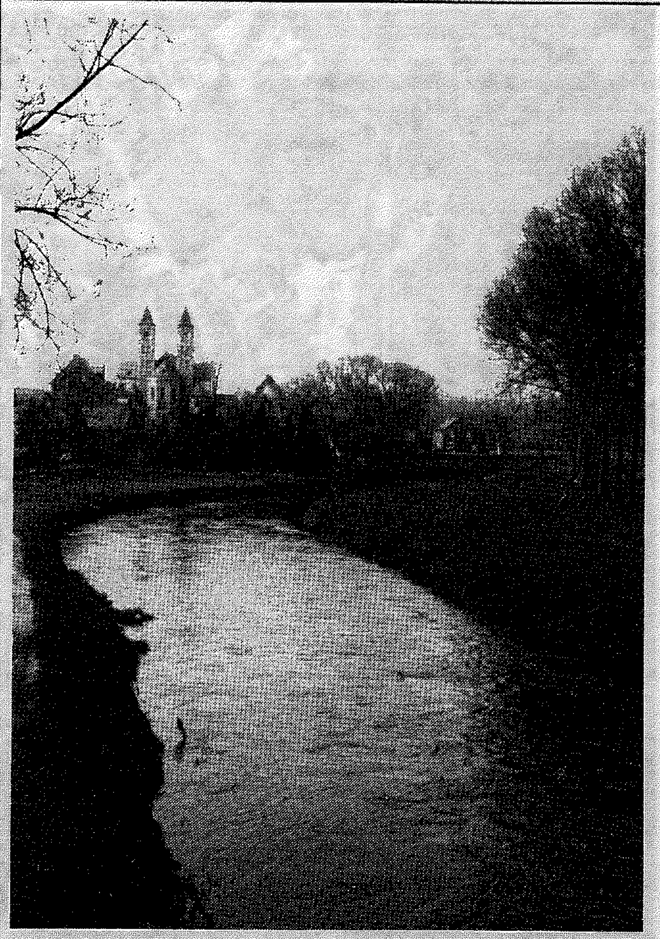

Figure 4
The recent Roer valley near St. Odiliënberg.

were combined or got new boundaries. In the beginning of 1990, the provincial government of Limburg proposed a redrawing and combining of the boundaries of some municipalities in the Central part of Limburg. Such decisions very often lead to emotional reactions of the local people. But mostly they do not harm nature. In this case the combination of two small municipalities was not the problem. The assignment of part of the agricultural municipality of St. Odiliënberg to the city of Roermond caused the trouble. This city declared that it needed that agricultural area for town-development on the southern border of the Roer.

Agricultural arguments for keeping the status quo were not sound enough. So the authorities of St. Odiliënberg supported by the inhabitants looked for other possibilities to prevent this move. The only valid argument was the geological importance, i.e. the listing in the official Nature Policy Plan. But would it be enough? Twenty-four years before, a safeguarding action for a unique part of a late glacial braided river pattern failed and the area was used for houses. The authorities of St. Odiliënberg started an intensive publicity campaign in the press and the parliament, with scientific support from the author. In June 1990 when the author joined the Lom meeting, this action resulted in a favorable decision made by the Minister for the Home Department. For the first time in Dutch history, an area had been saved only because of its earth-science value.

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Karst resources and their conservation in Norway

STEIN-ERIK LAURITZEN

Lauritzen, S.-E. 1991. Karst resources and their conservation in Norway. *Norsk geogr. Tidsskr.* Vol. 45, 119–142. Oslo. ISSN 0029-1951.

A brief review of the distribution, types and qualities of the Norwegian karst landforms is presented. Karst is a rare phenomenon in the country, but of an exotic quality. 'Stripe karst', i.e. narrow, but laterally extensive bands of intensively karstified marble zones, is the typical 'Norwegian' karst type. The total population of karst caves was estimated by a fractal approach. There are probably less than about 600–700 caves of more than 100 m length in the country, of which only 182 are presently known. Several of them contain unique and pertinent information about climatic change, biology, geomorphology, and perhaps also archaeology, down through the Pleistocene. Their pristine atmosphere and vulnerability to human impact require extraordinary protection and management, and it is suggested that all caves become protected as a phenomenon. In the future, particularly vulnerable sites can only be effectively protected by gating. The management of other objects may be further differentiated according to their scientific, aesthetic, didactic and/or recreational value.

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The spectacular topography, the powerful springs and the alien atmosphere of underground caverns in karst areas are fascinating for most visitors. At the same time, karst landforms provide scientific information of unusual quality and quantity. The formation of karst is due to delicate equilibrium processes of a chemical and biological nature. These equilibria are easily disturbed by man. The lack of filtration effects in karst conduit and fissure aquifers makes them more vulnerable to pollution than other ground-water bodies. The underground environment of total darkness supports highly specialized ecosystems which are sensitive to disturbances. The brittle and intricate corrosion forms on the surface and, in particular, the pristine atmosphere of the cave interiors, with their often very old deposits, are vulnerable to the impact from visitors. Caves may be regarded as unique and irreplaceable data bases for geomorphology, archaeology, palaeobiology, ecology and palaeoclimatology. Hence, karst landforms may need protection and management to a much larger extent than most other geomorphological phenomena, which in turn are dependent upon evaluation and a consistent strategy. On both a national and international scale, Norway displays a relatively modest amount of karst, but of an exotic quality. The purpose of this paper is to summarize the outcome of a national registration programme and discuss the further management of the Norwegian karst (Lauritzen 1988).

Karst in Norway

The regional extent of carbonate rocks and thereby potential for karst is shown in Fig. 1. The carbonate outcrop area converts roughly to 1% of the total land surface. For comparison, the regional distribution of water-filled (streamsinks and springs) and air-filled caves are depicted in Fig. 2. The correlation with carbonate outcrops is apparent, in contrast to the earlier distribution maps (Lauritzen 1983) which correlate better with the communication network (i.e. the railway system) than with the carbonate outcrops. Almost all carbonate outcrops have now been systematically assessed with respect to karst and the older, explorational bias is significantly reduced. Hence, discussions of density and quality distributions have become more meaningful.

Metamorphic marbles

With the exception of a few areas outside the Caledonian orogenic belt (i.e. the geological 'Oslo-region'), where limestones are relatively unaltered and have only suffered limited contact

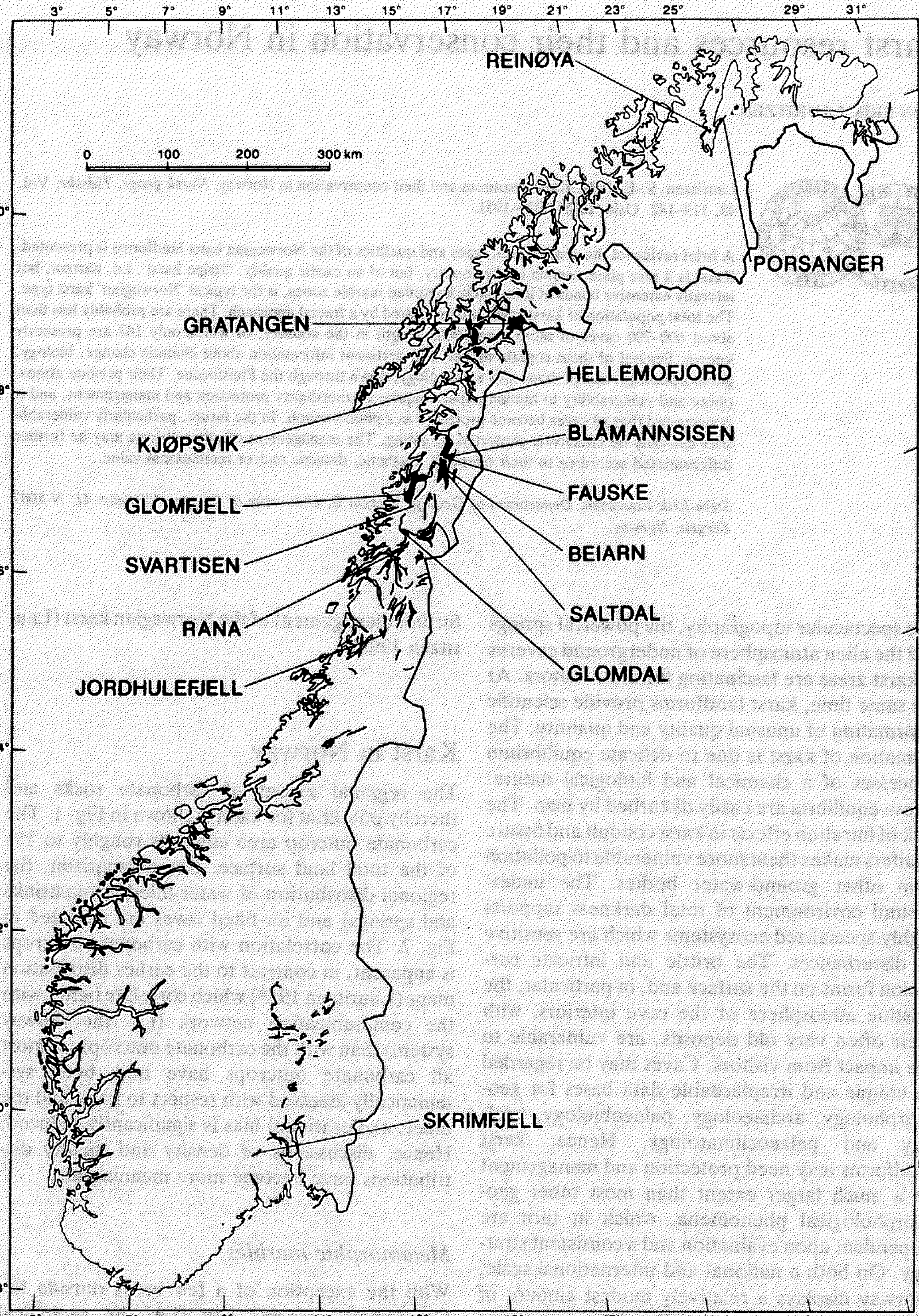


Fig. 1. Outcropping carbonate rocks in Norway and key map of the main areas discussed in the text.

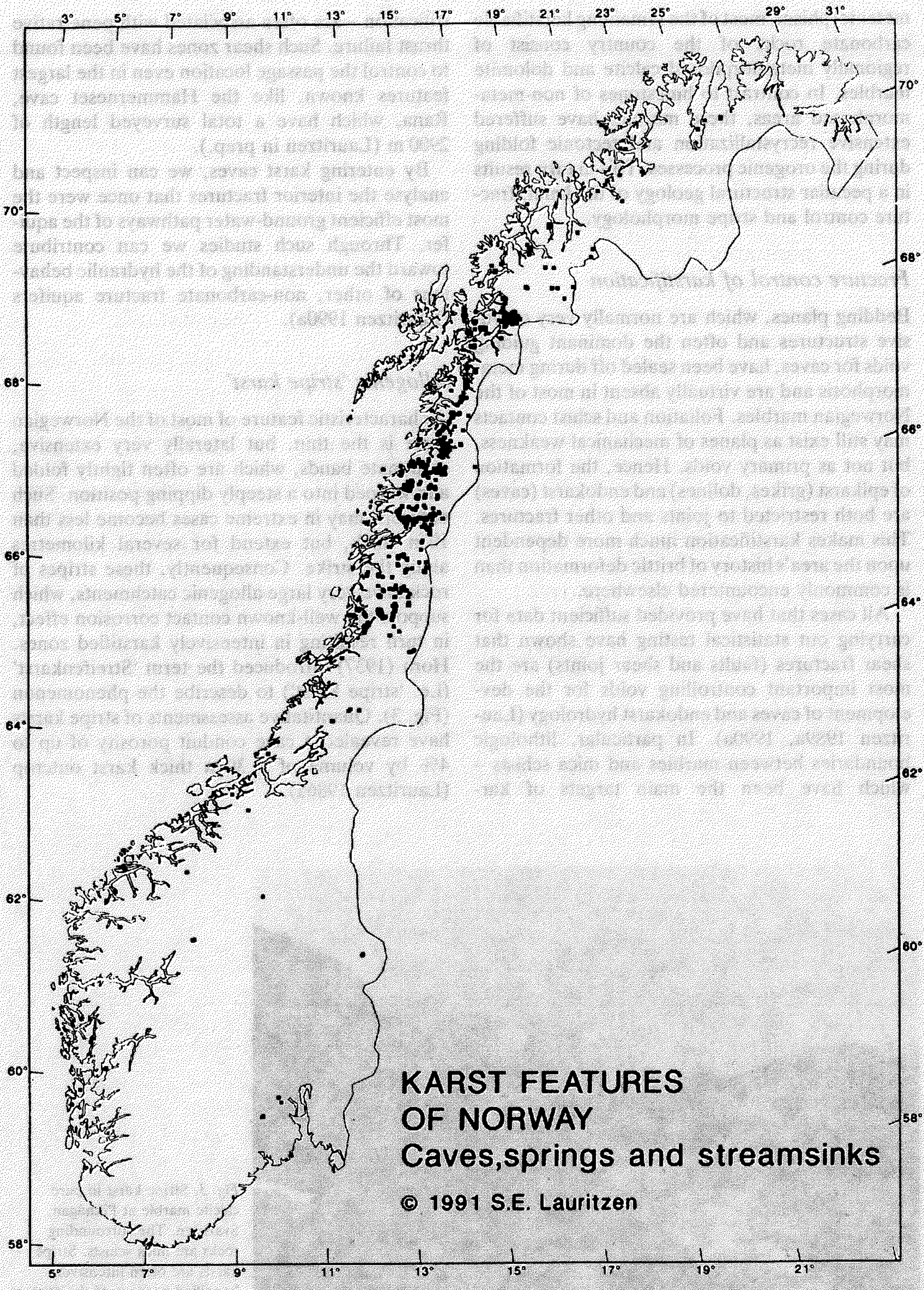


Fig. 2. Distribution of karst in Norway, comprising 1900 objects. This is an updated and more complete version of the corresponding map in Lauritzen (1984).

metamorphism, most of the remaining karstifiable carbonate rocks of the country consist of regionally metamorphosed calcite and dolomite marbles. In contrast to limestones of non-metamorphosed areas, these marbles have suffered extensive recrystallization and tectonic folding during the orogenic processes. This in turn results in a peculiar structural geology of the karst: fracture control and stripe morphology.

Fracture control of karstification

Bedding planes, which are normally very extensive structures and often the dominant guiding voids for caves, have been sealed off during metamorphosis and are virtually absent in most of the Norwegian marbles. Foliation and schist contacts may still exist as planes of mechanical weakness, but not as primary voids. Hence, the formation of epikarst (grikes, dolines) and endokarst (caves) are both restricted to joints and other fractures. This makes karstification much more dependent upon the area's history of brittle deformation than is commonly encountered elsewhere.

All cases that have provided sufficient data for carrying out statistical testing have shown that shear fractures (faults and shear joints) are the most important controlling voids for the development of caves and endokarst hydrology (Lauritzen 1989a, 1990a). In particular, lithologic boundaries between marbles and mica schists – which have been the main targets of karstification – are often associated with penetrative thrust failure. Such shear zones have been found to control the passage location even in the largest features known, like the Hammerneset cave, Rana, which have a total surveyed length of 2900 m (Lauritzen in prep.).

By entering karst caves, we can inspect and analyse the interior fractures that once were the most efficient ground-water pathways of the aquifer. Through such studies we can contribute toward the understanding of the hydraulic behaviour of other, non-carbonate fracture aquifers (Lauritzen 1990a).

Allogenic 'stripe karst'

A characteristic feature of most of the Norwegian karst is the thin, but laterally very extensive, carbonate bands, which are often tightly folded and warped into a steeply dipping position. Such outcrops may in extreme cases become less than 10 m thick, but extend for several kilometres along the strike. Consequently, these stripes of rock have very large allogenic catchments, which support the well-known contact corrosion effect, in turn resulting in intensively karstified zones. Horn (1937) introduced the term 'Streifenkarst' (i.e. 'stripe karst') to describe the phenomenon (Fig. 3). Quantitative assessments of stripe karsts have revealed a cave conduit porosity of up to 4% by volume of a 30 m thick karst outcrop (Lauritzen 1986a).

Fig. 3. Stripe karst in pure calcite marble at Pikhågan, Svartisen. The surrounding rocks are mica schists. Stripe karsts are often intensively karstified because of the contact effect of allogenic drainage.

Autogenic karst

A central issue in comparative karst research is the study of denudation rates and their relation to climatic, hydrologic and lithologic conditions. In the cases of allogenic drainage basins where karst rocks occupy only a fraction of the total area – which is particularly true for stripe karst – there are problems in distinguishing between the contribution of denudation rate from carbonate and that from non-carbonate outcrops (Ford & Williams 1989). Although this problem may be handled by the 'multiple basin method' (Lauritzen 1990b), the results will inevitably have lower precision than studies in autogenic basins, which are therefore highly preferable.

In Norway, very few areas of karst rocks are broader than 1 km, and a few, but good examples of karst with autogenic drainage of several square kilometres are known at different altitudes and topographic settings. Although these catchments may display few caves and modest underground drainage, they serve as very valuable natural laboratories for standardized determination of karst denudation rates. An outstanding example is the alpine Navnlausvatn catchment of the Glomfjell plateau, Svartisen. The watershed (4.1 km^2) contains about 90% marble and, most important, continuous runoff records over the last 30 years are available. The record is quite unique for an area of alpine karst of this latitude, and the catchment is autogenic enough for all practical purposes.

A natural hydraulic laboratory

On the other hand, allogenic drainage of stripe karst may also have some merit. Because of a narrow marble zone, the underground outlet of lake Glomdal, Rana, consists of a single phreatic conduit, 560 m long and 5–6 m in diameter (Fig. 4). The catchment area that feeds into the conduit is 27 km^2, which displays discharge variations over a recorded range of 0.5–51 m^3sec^{-1}. The cave has been accurately surveyed by cave divers, and therefore serves as a full-scale flume laboratory, where experiments on hydraulic friction (Lauritzen et al. 1985), dissolution kinetics (Lauritzen 1986b) and tracer dispersion (Atkinson et al. in

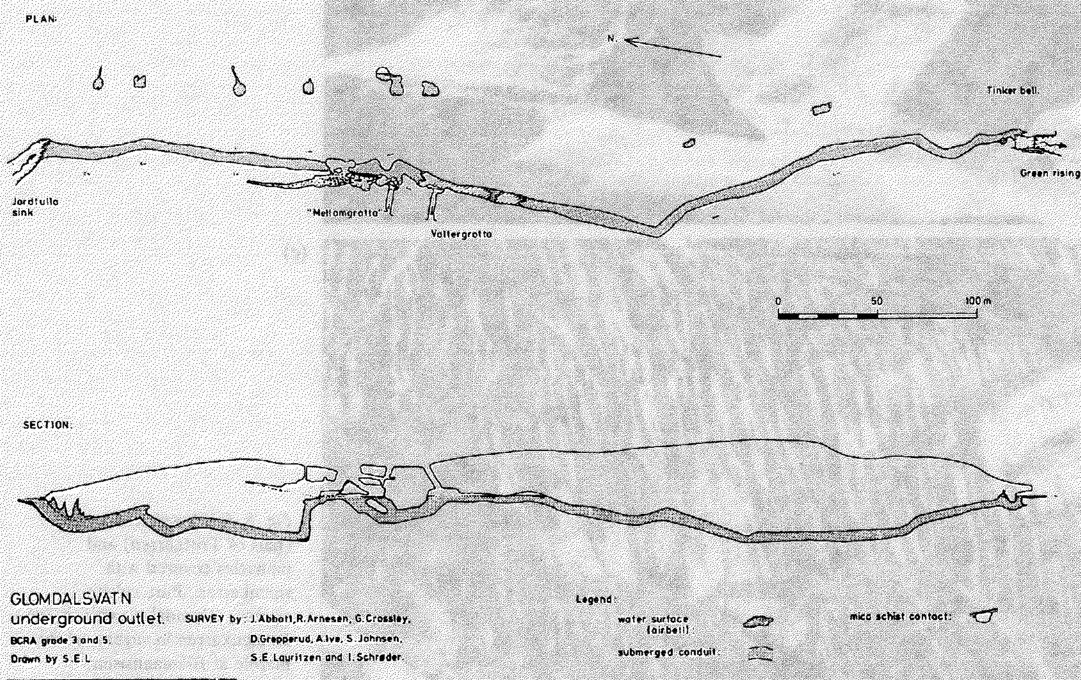


Fig. 4. The Jordtulla phreatic cave system, Glomdal, at Svartisen. All drainage must pass through a single conduit of 5–6 m diameter, forming an almost ideal, natural flume laboratory (from Lauritzen et al. 1985).

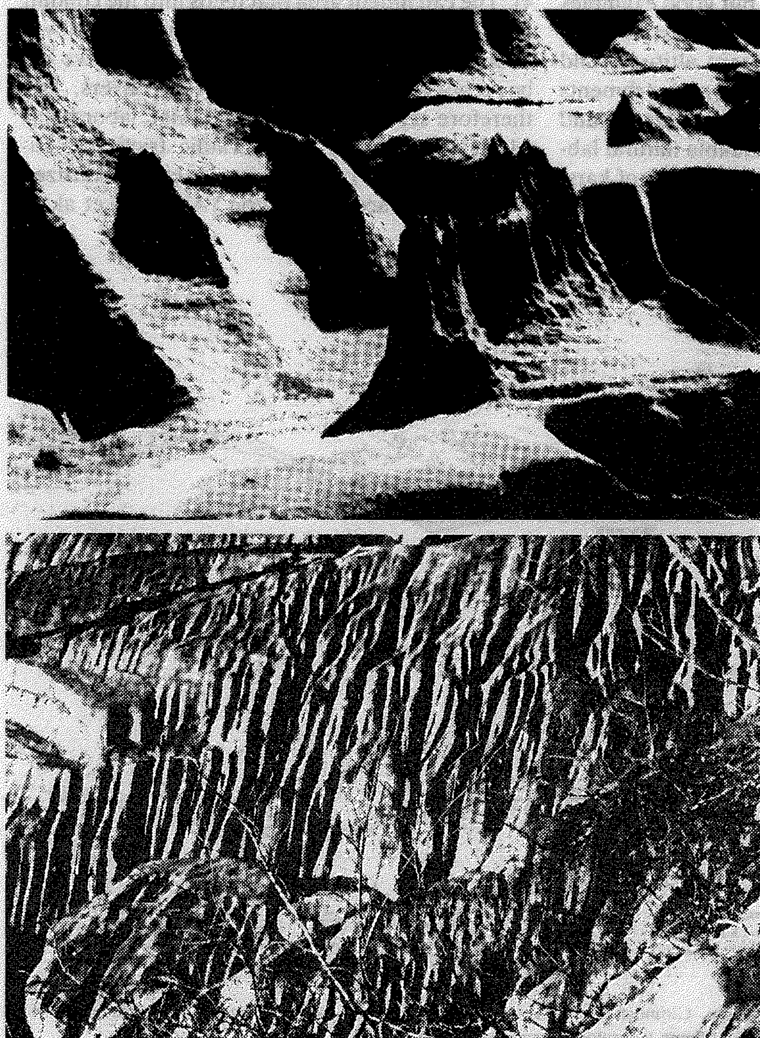
prep) have been performed under various hydrological conditions. So far, this natural laboratory is unique, as such well-defined boundary conditions of a single conduit system in stripe karst are difficult to find anywhere else in the world (see also references by Ford & Williams 1989).

Surface karst forms

Although many Norwegian calcite marbles can attain purities of 97–99% $CaCO_3$, they often display a coarse-crystalline 'sugary' surface texture where the grains fall apart rather than supporting smooth corrosion microforms. Sites of well-developed karren forms are therefore rarer than outcrops of pure marbles, in particular sites with rillenkarren, trittkarren and kamenitzas (Fig. 5a). Needless to say, such sites are vulnerable to trampling by visitors. Lapies with rinnenkarren and grikes are more common, as their development is much more tolerant to sugary textures and impurities (Fig. 5b). Several marine sites, but only a few inland lakes, have so far been shown to display well-developed biokarst forms.

Larger doline forms (5–50 m diameter) seem quite common below the tree line, but because of the difficult logistics in the dense birch forests that

(a)



(c)

Fig. 5. (a) Ausgleichsflachen (part of Trittkarren) and pinnacles covered with rillenkarren. Pure calcite marble, Glomdal, Svartisen. (b) Rinnenkarren in sugary calcite marble at Blåmannsisen, Nordland. (c) Wallkarren in pure calcite marble, Glomdal, Svartisen.

cover many of these areas, no good quantitative assessment of the intermediate forms has been made so far. However, larger forms that may be detected photogrammetrically and are thereby represented on the map series in the scales 1:5000 and 1:50 000 allow some quantification. The largest closed depressions of a probable karstic origin measure several square kilometres, and these are all located within the paleic, presumably preglacial landforms of Gjessing (1967) (Fig. 6). Some of them may be regarded as glacially dissected, paleic randpoljes. Smaller, but still very large dolines show a preferred concentration on high plateaux rather than deeper into glacial valleys. This type of distribution is in agreement with the fact that the formation of such large solutional landforms would require longer timespans than the post-glacial period, hence we should expect them to be located in sites where glacial erosion rates have been at a minimum. Moreover, smaller areas with cockpit topography and Kleinkegelkarst have been found (Fig. 7a).

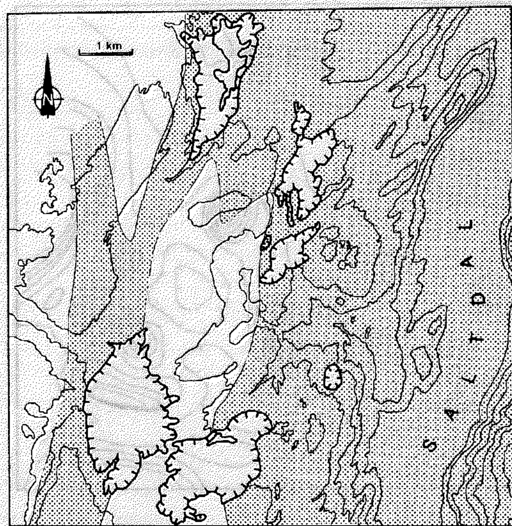
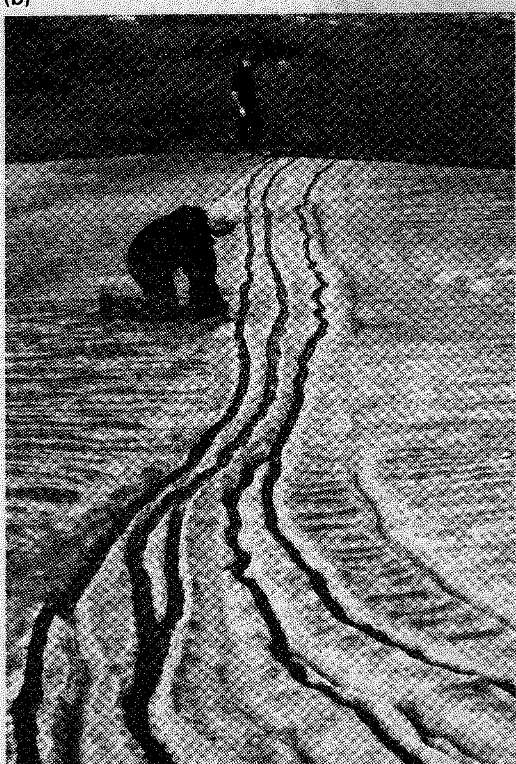


Fig. 6. Paleic megadepressions on the plateau between Saltdal and Beiarn, Nordland. These forms are extremely large, situated within a paleic plain and have in part suffered glacial fragmentation from westwardly directed ice movements. Shaded areas: marble outcrops. Contour intervals: 100 m.

(b)



Such peculiar and controversial forms have also been reported from northern Sweden (Rassmusson 1958).

Dolomite karst is a common type to outcrop on a global scale. In Norway this karst type forms a separate, minor class. The Porsanger dolomites provide the largest areas and forms known. Here, complex uvalas of about 1 km in diameter exist. The Reinøya karst in Porsangerfjorden is an outstanding example, covered with pavements, grikes and dolines, one of them a 60 m deep form (Fig. 7b). Judging from the dissolution rates of dolomite and the probable precipitation rates in the palaeo-catchment, this depression would take some 6–12 million years to form by solution alone.

Caves

About 1100 karst caves are recorded in the country, of which only about 600 can be said to be sufficiently documented for quantitative purposes. The longest cave is over 11 km in length, and the deepest system is 580 m deep (Fig. 8). A striking and interesting feature of many of these marble caves is that they display a looping behaviour (Ford & Ewers 1978), with a loop frequency

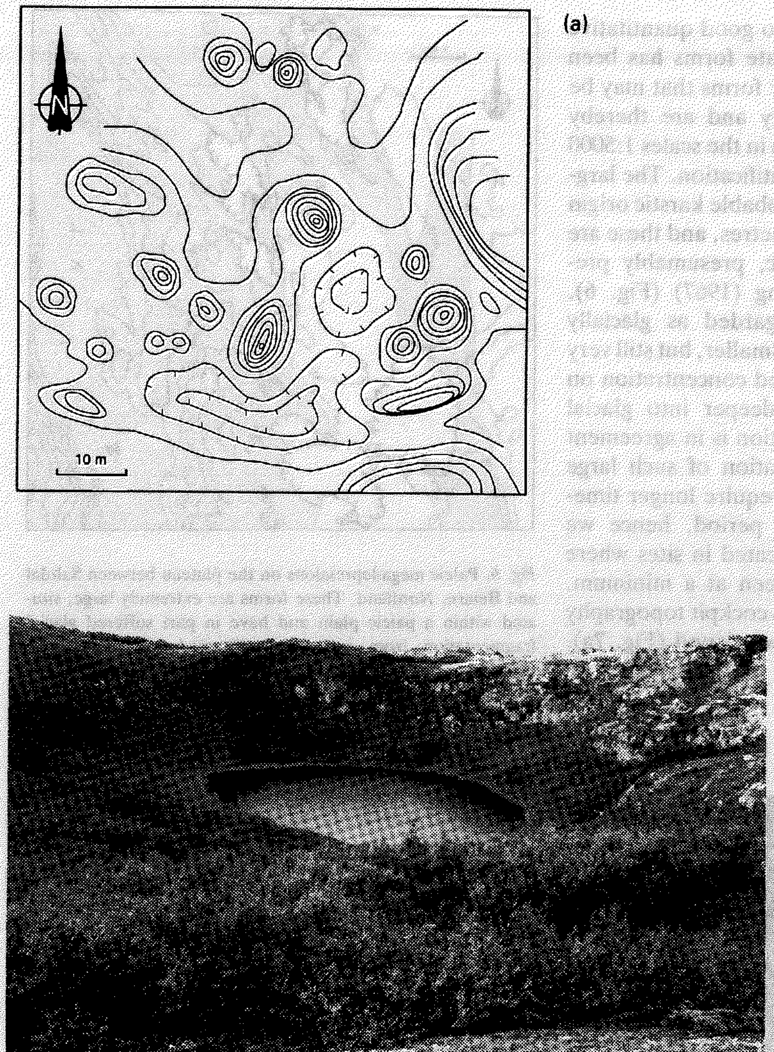


Fig. 7. Surface karst forms. (a) Kleinkegelkarst, Gratangen, Troms. The cones are up to 3 m high and are organized in a polygonal manner around dolines of similar size. The contour interval is about 0.5 m. (b) Råggeluok, the largest depression in the dolomite karst on Reinøya, Porsanger, is 200 m wide and 60 m deep.

that can easily be compared with the type locality, Swildon's Hole in the Mendips, UK (Ford 1965).

The most common Norwegian cave is the active, vadose streamway cave which in most cases can be ascribed to having developed in the post-glacial or during the last glacial cycle. Much rarer are the hanging, glacially truncated and relict phreatic fragments which may be ascribed to ages of a million years or more before the present (Lauritzen 1989b, 1990c) (Fig. 9). The two features are often combined, the phreatic fragments often carrying streams in vadose passages at lower levels. Even rarer are the few sites within them where old deposits of sediments, speleothems or bones have chanced to be preserved down to our time (Fig. 10). These sites have an irreplaceable scientific value, as they are presently unique databases for the oldest dateable, continental palaeoclimatic information of the Pleistocene in Norway (Lauritzen et al. 1990). Uranium series dating of speleothems (cave dripstones) have so far enabled us to identify 10 separate warm periods on the Norwegian mainland (interglacials and interstadials) during the last 600 ka (1 ka = kiloannum, 1000 years) (Lauritzen 1991a). A speleothem growth probability curve, which reflects the corresponding climatic changes for the last 350 ka, is shown in Fig. 11.

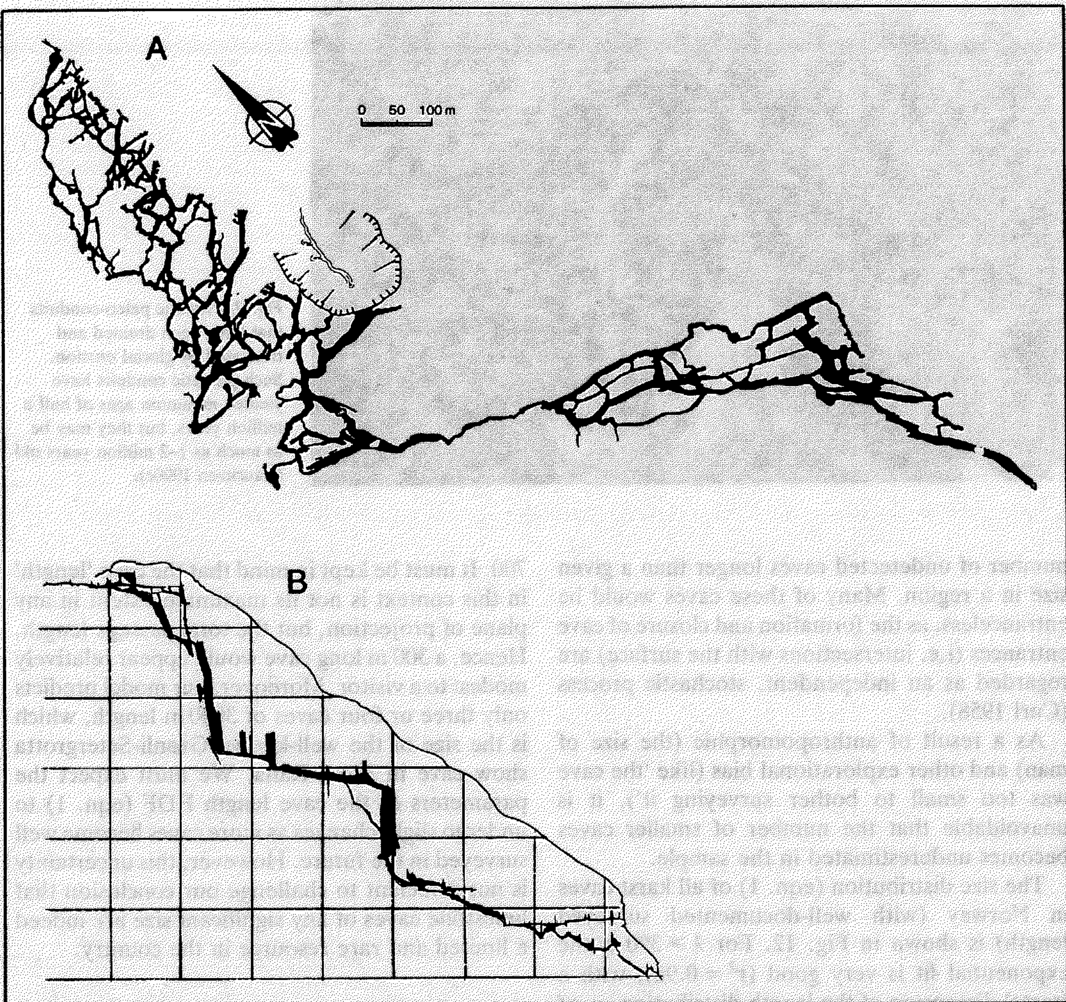


Fig. 8. The longest and the deepest caves in Norway. (a) Plan survey of Okshola, Nordland (total length 11 000 m). (b) Vertical projection of Råggejavriraigi, Nordland (580 m vertical range). The two caves are drawn to the same scale.

Caves as a measure of karst. – The rank-size distribution of many natural phenomena can be adequately described by exponential models (Rowlands & Sampey 1977), which also hold true for karst landforms (White 1988, Ford & Williams 1989). Curl (1966) suggested that the size distribution of caves in a region may provide a meaningful measure of karst. Later, Curl (1986) related cave length distribution to the equation,

$$N(\lambda) = N(\lambda_0)\left[\frac{\lambda}{\lambda_0}\right]^{-\nu} \qquad (1)$$

where $N(\lambda)$ is the fraction of the cave population with length greater than λ, and λ_0 is the shortest or cutoff length for the distribution. The exponent, ν, is the fractal dimension of the cave length population in the sense used by Mandelbrot (1983). In other words, cave lengths and other various elements that make up caves are self-similar in that their dimensions and other parameters depend upon the scale used for their measurement.

If a distribution can be parametrized as fractal, the function may be extrapolated beyond the observed data range. In terms of the distribution of cave lengths, we may then estimate the total

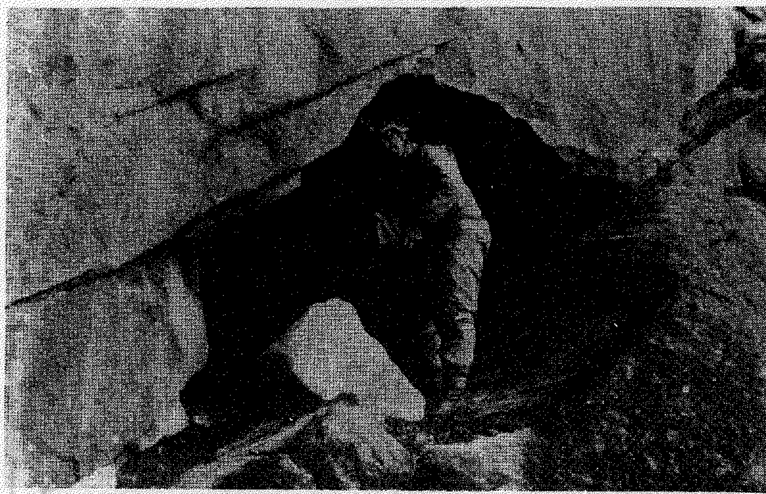


Fig. 9. Phreatic paleo-conduits that have been drained and truncated by glacial erosion. Such phreatic conduits have yielded minimum ages of half a million years, but they may be as much as 1–2 million years old (Lauritzen 1990c).

number of undetected caves longer than a given size in a region. Many of these caves would be entranceless, as the formation and closure of cave entrances (i.e. intersections with the surface) are regarded as an independent, stochastic process (Curl 1958).

As a result of anthropomorphic (the size of man) and other explorational bias (like 'the cave was too small to bother surveying it'), it is unavoidable that the number of smaller caves becomes underestimated in the sample.

The size distribution (eqn. 1) of all karst caves in Norway (with well-documented surveyed length) is shown in Fig. 12. For $\lambda \geqslant 390$ m the exponential fit is very good ($r^2 = 0.98$), with a fractal dimension of the length distribution, ν, of 1.4 ± 0.04. This is very similar to other sites, like the Pennsylvania caves ($\nu = 1.4$; Curl 1986), and is encouraging to further discussion.

Under the assumptions mentioned above, the total number of caves of particular size classes in Norway can be estimated (see Table 1). For instance, there are probably 340 000 caves of 1 m or longer in Norway. Most of them are small and they have neither entrances nor location. The concept of cave lengths of 1–5 m is obviously artificial for our purpose, as this would also include shafts and large grikes, which are known to occur by the thousand and will never be surveyed.

More interesting is the estimate of roughly 400 caves within the size class of 100–200 m length. The total number of caves in Norway of a length greater than 100 m is probably not more than 600–700. It must be kept in mind that the cave 'length' in this context is not its maximum extent in any plane of projection, but the total passage length. Hence, a 300 m long cave would appear relatively modest to a visitor. Moreover, our model predicts only three or four caves of 3000 m length, which is the size of the well-known Grønli-Setergrotta show cave in Mo i Rana. We must expect the parameters of the cave length EDF (eqn. 1) to undergo slight changes as more caves become well surveyed in the future. However, this uncertainty is not sufficient to challenge our conclusion that limestone caves of any significant size are indeed a limited and rare resource in the country.

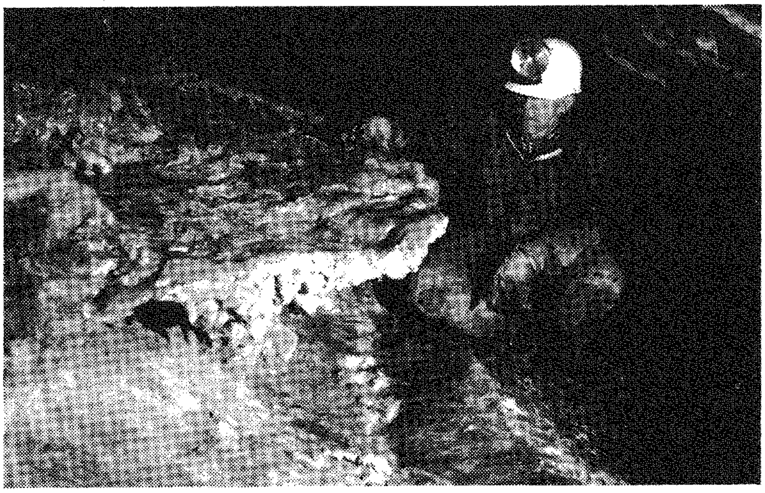
Climatic and topographic karst types

Most of the karst that is situated above the tree line is of the glacio-nival type. An appreciable part of the karst extends into the high alpine zone, where frost processes compete with karstification and produce karst drainage underneath a felsenmeer blanket.

Below the tree line well developed grike and doline karst with heavy deciduous or coniferous vegetation can be found. Limestone may provide nutrition for rare and specialized plants, which has opened the way for a cooperation between botanical and geological conservation interests. In particular, a well-karstified area (in South Norway) of pine forests which supports certain orchids (*Dactylorhiza fuchsi*), which are relatively rare elsewhere, is now under temporary pro-

(a)

Fig. 10. Examples of cave deposits that provide unique scientific information. (a) Speleothems (stalagmites) provide possibilities of accurately dating climatic events through the Pleistocene by using U-series dating techniques and the stable isotope composition of the calcite and water inclusions. These are unusually large specimens for Norway. (b) A glacifluvial gravel deposit overlain by a corroded stalagmite plate which was deposited prior to 350 ka BP. Amino acid racemization in the stalagmite suggests an age of about half a million years, which by far makes this deposit the oldest quaternary sediment known on the Norwegian mainland. (c) Wolf skeleton embedded in a levee deposit that was laid down by a cave stream during the Holocene. The bones were dated to 1200 years BP (^{14}C). Brown bear (*Ursus arctos*) remains in Norwegian caves may be up to 7000 years old (Lauritzen & Østbye in prep.). Such deposits, which may be extremely abundant in certain caves, provide new insight into the faunal history of the country.



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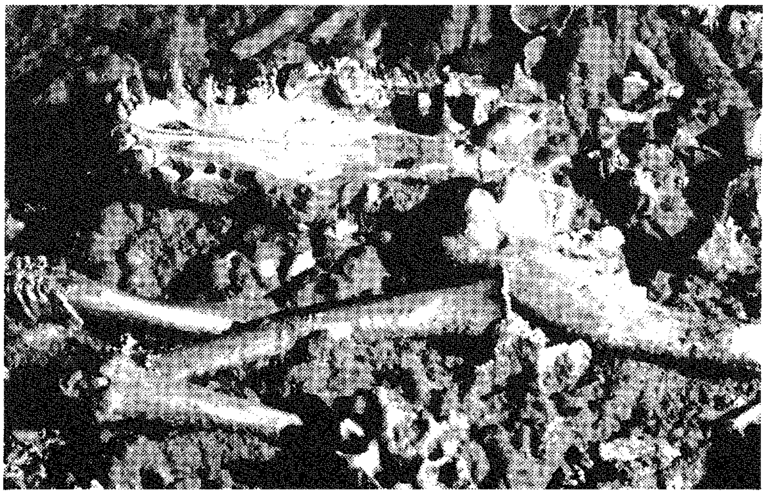

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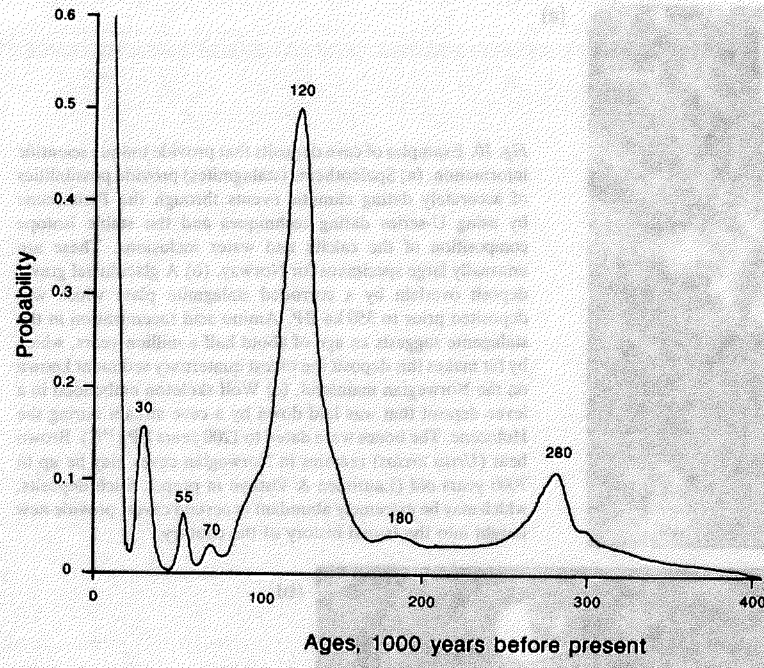


Fig. 11. Probability frequency diagram of 100 speleothem dates from Norway. Maxima represent warm periods of enhanced speleothem growth during the last 350 ka (1 ka, 'kiloannum' = 1000 years). The strong signals from the Holocene (0–10 ka) have been omitted for clarity. The strongest signal is the last interglacial at 120 ka (Eemian), but warm events occurred during the Weichselian at 30, 55 and 70 ka. Remote interglacials exist at around 200 and 300 ka. Above 300 ka ages cannot be distinguished from infinity. However, by adopting other dating methods, three remote interglacials have also been identified at about 500 ka (Lauritzen et al. 1990).

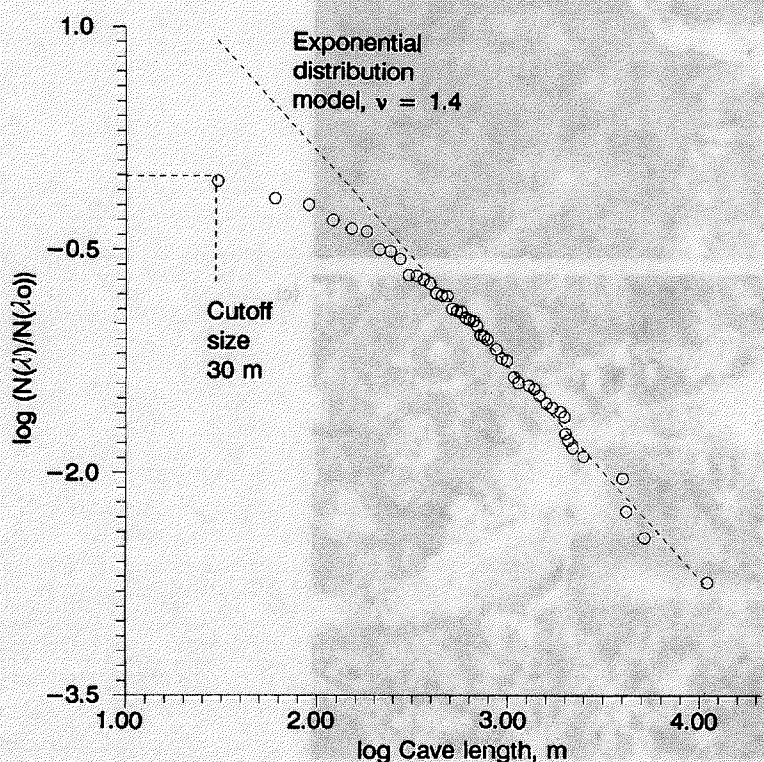


Fig. 12. Size distribution of 498 well-documented Norwegian karst caves. The cutoff size (λ_0) shown here is arbitrarily set at 30 m. For $\lambda > 390$ m, the exponential model, eqn (1) fits the data quite well ($r^2 = 0.99$) with exponent $\nu = 1.44 \pm 0.02$. The gaps between the curve and the observed data (circles) represent unknown caves, but many of them would be entranceless. See text for further discussion.

Table 1. Estimates of the total number of caves in Norway. Number of caves longer than a given length.

Size (m)	Model estimate	Observed
1	344 100	605
5	37 600	529
10	14 400	466
30	3 200	348
50	1 580	271
100	608	182
200	234	111
300	134	77
1000	26	24
2000	10	10
5000	3	3
10 000	1	1

tection for its combined botanical and speleological value.

Cave ecosystems

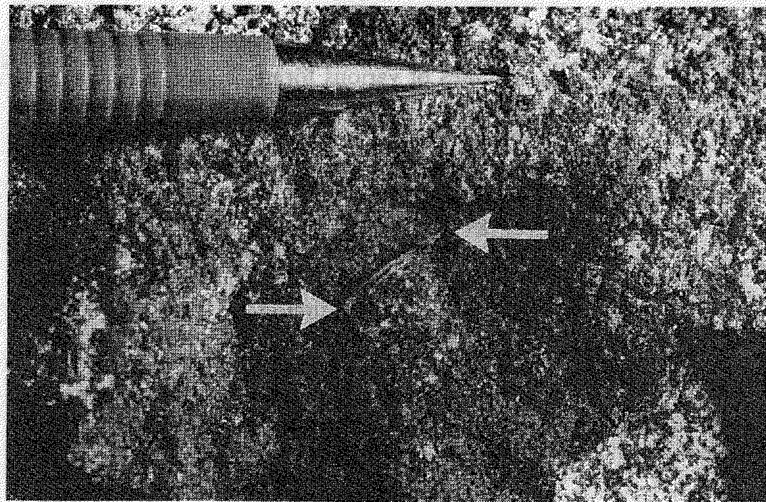
The constraints of a stable microclimate and limited energy supply to the cave ecosystems provide a natural laboratory condition that is hardly satisfied elsewhere (Culver 1982). This property has been studied in many countries with long traditions in karst science, examples are the research activities of the Postojna Karst Institute in Yugoslavia and the 'Laboratoire Souterrain du CNRS' in the French Pyrenees. At higher latitudes, the time available for evolution and invasion becomes a constraint, as the terrestrial cave ecosystems would only have had the post-glacial time available since the caves were last flooded. Consequently, cave ecosystems of the northern latitudes should offer interesing conditions for testing various hypotheses in ecology. The aquatic fauna of Castleguard cave, situated underneath the Columbia Icefield, BC, Canada (Holsinger et al. 1983) provides a very important example of how aquatic fauna components can survive under subglacial conditions.

Cave faunas in northern Europe are reported from well-documented sites in the British Isles (Jefferson 1976, Cubbon 1976). Moreover, fauna and flora are known from Swedish caves (Odell 1979, Engh 1980). During the last decade, faunas and ecosystems of the Norwegian caves have also been described (Østbye et al. 1987, Hippa & Koponen 1988, Dolmen & Arnekleiv 1990). In addition to documenting cave faunas regionally, we have made a detailed study of the Bevergrotta cave in South Norway. This has yielded a well-defined, stable cave ecosystem with isolated communities of various forms, Like the fungus gnat *Speolepta leptogaster* and the collembole *Onichiurus schoetti* (Østbye et al. 1987) (Fig. 13a).

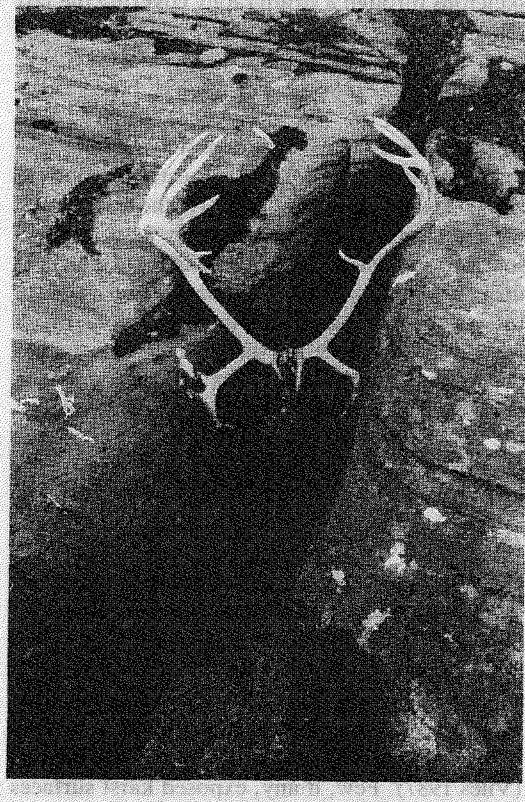
Dry cave galleries may often serve as habitats for scavenging and for hibernating mammals, like badgers, fox, wolverines and bears. Vertical shafts may become efficient, deadly pitfall traps which may sample the contemporary surface fauna over longer timespans (Fig. 13b). Hence, Norwegian caves have yielded more than 30 skeletons of the brown bear (Ursus arctos), varying in ^{14}C ages from a few hundred years to some 6500 years BP (Lauritzen & Østbye in prep). Moreover, Elgsjakta, a pitfall shaft in Sirijordgrotta, Vefsn, Nordland, has yielded about 10 000 bone fragments and complete vertebrate skeletons through a stratigraphy covering the last 7500 years (Lauritzen et al. in prep). Deposits from Skjonghelleren (a marine abrasion cave, Larsen et al. 1988) have yielded fauna components from the last interstadial, at 30 ka BP. Needless to say, such rich deposits are rare, and immensely valuable for the reconstruction of the faunal history of the country. At the same time, their exciting nature makes them vulnerable to souvenir collection by casual visitors, which in turn may be fatal for the interpretation value of the deposit. It would be highly prefereable if such remains were stored in one place, for example the Rana Museum, which has dedicated itself to speleological science and already keeps most of the Norwegian cave material in its collections (Lauritzen 1985).

Biokarst

Karst is a surface phenomenon and is therefore an inevitable part of the biosphere. Karstification is indeed governed by biological processes, the main source of H_3O^+ ions for carbonate dissolution is provided by CO_2 from soil respiration. Endolithic algae make out a true microscopic corrosion front underneath the limestone surfaces (Viles 1987). Few, if any, exposed karst surfaces on earth seem to escape infection by rock-eating micro-organisms. In Norway we find them, for instance, on bare alpine karst surfaces (Fig. 14). On the metre and decimetre scale, a whole series of biokarst morphotypes have been identified (Viles 1988). They are best developed in tropical rainforest and marine karsts, like the Sarawak



(a)



(b)

Fig. 13. (a) Recent cave fauna. Larva of the fungus gnat, *Speolepta leptogaster*, in Bevergrotta, Skrimfjell in South Norway (from Østbye et al. 1989). (b) Reindeer killed in grike, Glomfjell karst, Svartisen. Snow-covered karst grikes may be as deadly as glacier crevasses. These sites have a periodically active carrion fauna, and they serve as pit-fall traps which have sampled the contemporary vertebrate fauna up through most of the post-glacial period.

cave phytokarst of Bull & Laverty (1982) and the island phytokarst pinnacles of Folk et al. (1973). However, small but excellent examples of this karst type are also known from Norway. Corrosion pits filled with organic mud are numerous along the shores of karst lakes, good examples are found in the lakes of Glomfjell, Svartisen (Lauritzen 1982, Haugane 1985) (Fig. 15). The spectacular littoral karst of Lake Reingardslivatn, Rana, was already noted by Horn (1947), while

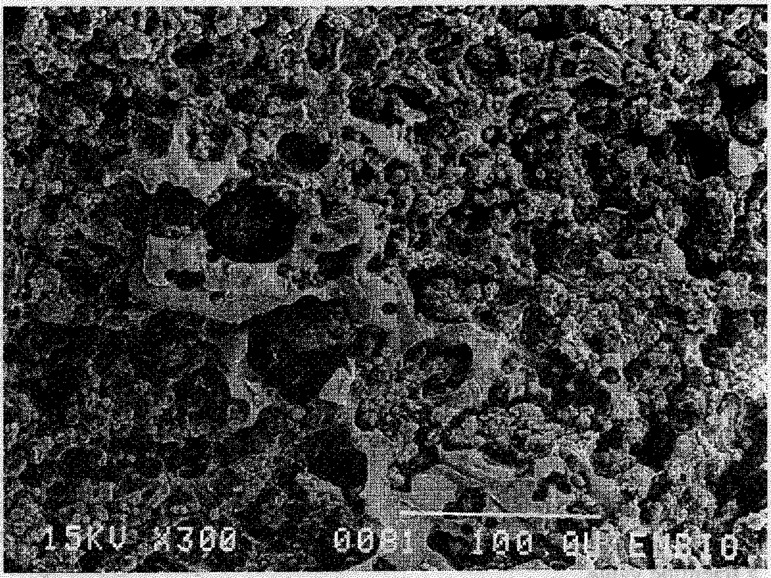


Fig. 14. Scanning electron micrograph of endolithic algae on an alpine karst surface, Pikhågan, Svartisen. The organisms are situated inside corrosion cavities that may penetrate several hundred µm into the marble crystals. The picture is taken from a horizontal Ausgleichsflache where much evaporation takes place. Scale bar: 100 µm (from Lauritzen in prep.).

Fig. 15. Corrosion pits in the littoral zone of lake Fiskvatn, Glomfjell. The egg-cup sized hollows have a paraboloid shape and are arranged in linear arrays along microfractures. They are commonly half-filled with organic mud.

Moe & Johannessen (1980) and Holbye (1990) reported marine bio-erosion forms from the Bodø area.

Biokarst forms also include depositional forms, like tufa that is precipitated from rivers or seepage water. In the northern karsts of Norway, we have not yet encountered any significant tufa deposits, but they are well known in South Norway. These tufas have mainly attracted the attention of botanists, who have described subfossil plant material from them (Nordhagen 1921). All tufas so far known are thought to be of Holocene age.

Evaluation of the karst landforms

Thanks to the foresight and pioneering work of Dr Gunnar Horn (see Horn 1947), *caves as a phenomenon* (i.e. all caves, known or unknown at the time) on the state-owned land in Rana district, northern Norway, were protected in 1931. Later, in 1967, seven caves on private ground in Rana were also protected. Due to extensive hydroelectric projects and the planning of the national park, a major inventory of karst in the Saltfjellet–Svartisen area, in the Arctic Circle, was carried out in the period 1970–1980 (Holbye 1974, 1975, Lauritzen 1977, 1982).

Systematic karst assessment on a national scale was undertaken in 1984 and finished in 1990 (Lauritzen 1991b). The work was supported by the Royal Ministry of Environment and by the Directorate of Nature Management, as a part of the national programme for registration of conservation sites and areas with geological significance (Erikstad 1984). Similar projects have been carried out in other countries (see for instance Mylroie 1981, Waltham 1983, Wright & Price 1990).

Value categories

The assessment has mainly focused on the following values (Lauritzen 1988) (see Fig. 16):

1. *Scientific research and teaching value.* – Objects which display certain processes, highlight certain problems or contain pertinent information (which need not be readily available at present) represent a scientific value.

2. *Aesthetic recreational value.* – Objects which display beauty and perfection of shape and/or arrangement will appeal to non-professional visitors and form the basis for organized tourism in karst.

3. *Physical recreational value.* – Objects which represent a challenge to physical activities, but which are not necessarily aesthetic, fit under this classification. Muddy, crawling passages are very challenging for cavers, but hardly aesthetic!

These main classes of properties may be further differentiated by:

(a) The degree of morphological perfection and density of forms.
(b) The combination of forms (diversity)
(c) The untouched condition of vulnerable morphology and setting.
(d) The occurrence of 'unique' objects or processes.

Physical recreational values may be judged from the severity of sporting challenge (depth of vertical shafts, amount of water, aperture of squeezing passages) and by contrasts in passage appearance (from muddy crawls into clean-washed streamways). Severity and danger are criteria for the general public management of sites, which of course must be sensibly judged against accessibility and number of visitors. Several, non-fatal, cave accidents have occurred

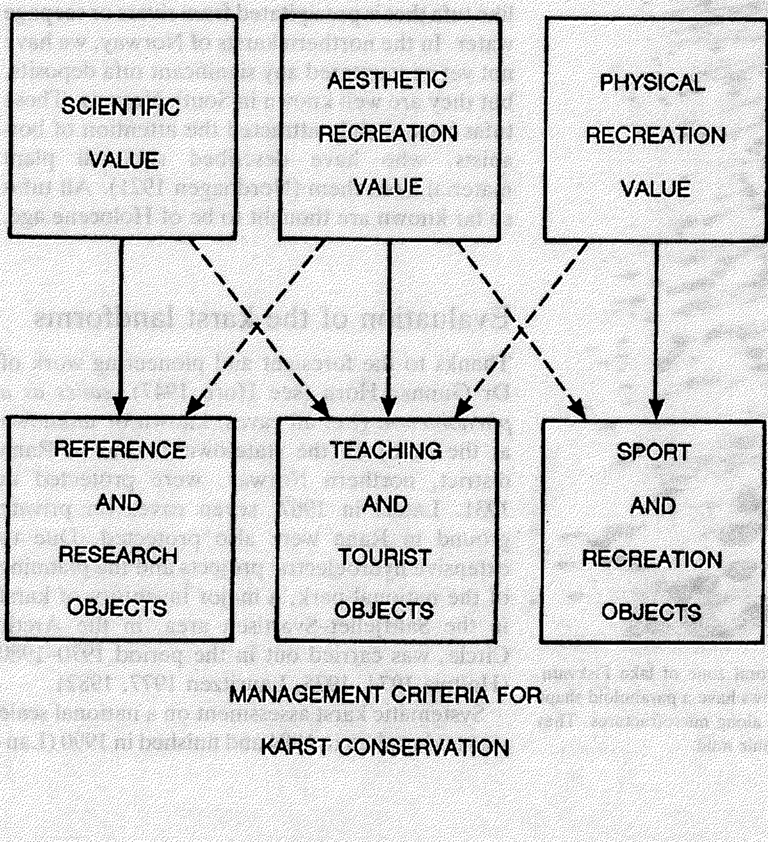


Fig. 16. Categories of conservation values and the consequent classification of objects (from Lauritzen 1988).

in Norway during the last decade, in which the Norwegian Cave Rescue Group has proven to be a vital factor in the successful recovery of victims.

Based on whatever values dominate each object, they may be subdivided according to Fig. 16 and managed accordingly. The three criteria may of course cause conflicting user interests where they occur together.

Vulnerability

When seen from a geological perspective, karst landforms (caves) are among the oldest and most resistant quaternary landforms of an area. Despite this, they can easily be spoiled and destructed by man – in a surprisingly short time (Ford 1990).

Karst is basically threatened in two ways, by acute events and by long-term processes (see also a recent discussion on British sites by Wright & Price 1990). Among the acute events are development projects of various kinds. Karst objects may be demolished by blasting, they may become submerged in hydroelectrical reservoirs, water may be drained away from active caves, or they may become covered by landfills. Over time, however, man himself on the individual level becomes the most significant demolisher. Speleothems (cave dripstones) are most vulnerable to impact and they are extremely rare in Norway. Unfortunately, some of them have been vandalized. The more general wear and tear, grafitti and littering have been encountered in most of the easily accessible sites, of up to about half an hour's walking distance from the nearest road. At greater distances, we may still find the occasional cave that has hardly been entered before. It is therefore evident that the pristine condition of the Norwegian karst is largely a result of remoteness and a low profile of interest in the general public. Hence, increased access and interest, like road-building and tourist developments, are very likely to cause damage and disturbances of surface and subsurface karst environments. Some examples of actual and potential threats may illustrate this.

1. *Show caves and the tourist industry*. – Only one show cave has been in regular use in the country, i.e. Grønligrotta, Rana. The cave has electric lighting and walkways, and receives around 15 000 visitors per year. Recently, another part of the Grønli cave complex, Setergrotta, was used commercially for 'wild caving' trips. The large number of visitors in the Grønli system is somewhat artificial as the cave is part of the general marketing of the main attraction, the Svartisen Glacier. The cave is located only a short distance off the road to the glacier. In earlier times, a more remote cave, Løvstadgrotta, in Beiarn, was used as a show cave, but with little success.

Bearing this in mind, as well as the fact that the Norwegian caves are few and small (Fig. 12), we must realize that the potential for a cave tourist industry in Norway is not promising. Caves in Norway and in southern Europe are quite different in size, beauty and number. The previously remote karst area of Jordhulefjell, Grane, Nordland, has recently become accessible from a highway. A great number of caves have been documented, some of them with a high scientific value. Politicians have expressed that 'the cave discoveries came like a gift from heaven for the tourist industry' (Engen 1983). This is clearly a gross misjudgement, but modest use of one or two dedicated caves by local enthusiasts would probably do little harm. The greatest conservation problem with organized guiding does not necessarily occur during the conducted tours. The real risk of accidental damage occurs when enthusiastic but inexperienced visitors decide to return on their own. This consequence is also the responsibility of the developers, and the economic benefits of showing people sites must be weighted against such risks.

2. *Marble quarries and the cement industry*. – The marble and limestone industries also find karst outcrops attractive. A very interesting karst area of Kjøpsvik, Tysfjord, is quarried for the production of cement. The fossil, phreatic caves described by Skundberg (1959) are now gone, but another larger cave was intersected in the quarry. This cave contains large amounts of sediments and displays the largest paragenetic roof retreat so far known in the country (see explanations of the phenomenon in Ford & Williams 1989). Although the long-term fate of the cave is still uncertain, the managers of the quarry and cement factory have been careful and cooperative. More serious and unpredictive is the potential impact of the recent flourishment of small marble quarries that may be profitable for only a few years, leaving permanent damage to limestone outcrops.

3. *The Saltfjellet–Svartisen National Park*. – The

large-scale hydroelectric projects that are planned for the Svartisen area have indeed affected the karst and its conservation. First, the strange shape of the borders around the new Svartisen National Park represents a compromise between conservation needs and the hydroelectric projects. In the planning stages, caves and karst were highlighted as one of the special qualities of the national park. Clearly, this has only been sufficient to secure a minor fraction of the karst in the region. Almost 90% of all caves in the Saltfjellet–Svartisen area are still outside the park and cannot therefore benefit from protection by the Park Codes (see Fig. 17).

4. *Conflicting interests with hydroelectric projects*. – Two karst areas of special interest bordering the national park are the Glomdal karst and the Glomfjell karst plateau (Fig. 17). The two areas have been excluded from the park because of hydroelectric plans and they will both suffer damage as a result of the constructions and the secondary impact of increased traffic and access.

Conservation, why and how?

Nature conservation means protecting nature or parts of it in an intact or unaltered state for the

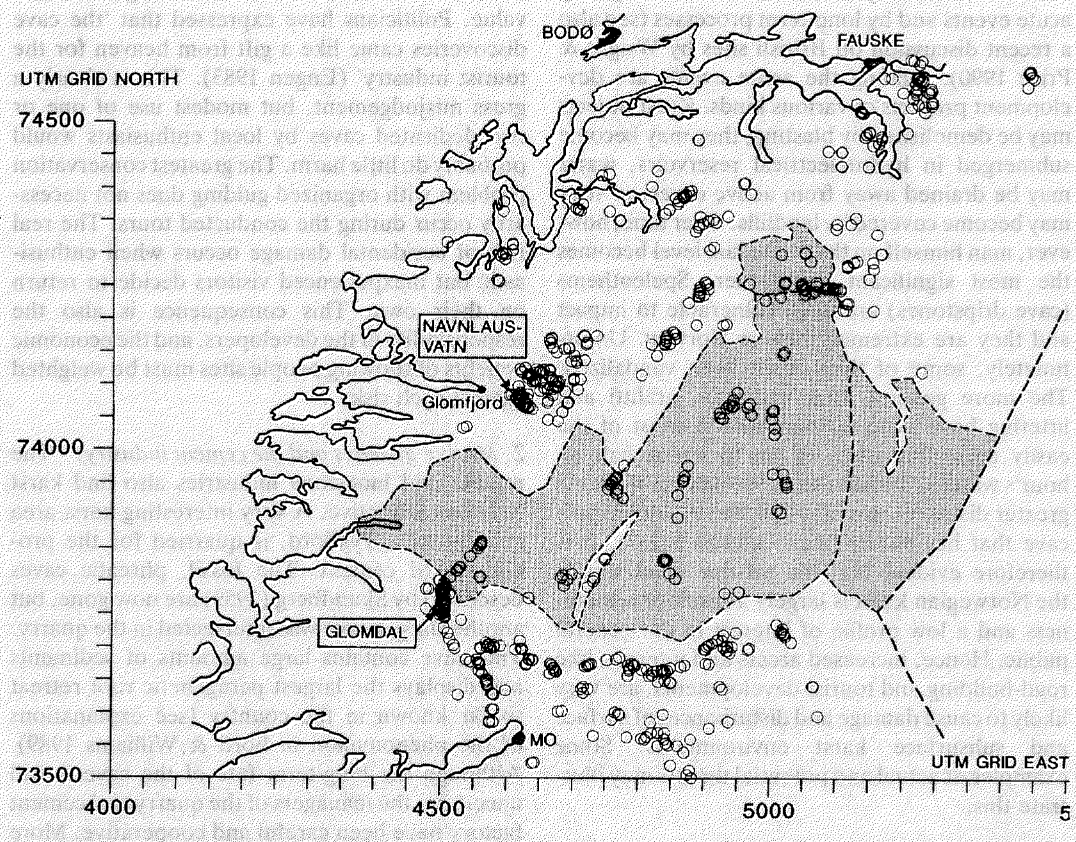


Fig. 17. Caves in the vicinity of the Saltfjell–Svartisen National Park. The map covers all registered karst objects between UTM Zone 33, North 73500 to 74500 and East 4000 to 5500, a total of 393 objects. Only a minor fraction of the caves and other karst objects fall within the park limits, hence the park and adjoining areas offer insufficient protection to the karst phenomena of the region. This is particularly serious for the Glomdalen karst and for the large autogenic karst plateau at Navnlausvatn. There is an urgent need for protecting these two and the other high density areas shown on the map, either by expanding the park areas or by making them into natural reserves. The irregular shape of the park border is due to compromises with hydroelectric development interests in the area.

future. Conservation is based upon the view that man's activities are excessive and, in part, 'unnatural', thereby threatening the existence of objects and the equilibrium states of the geo-ecological systems they are a part of. Consequently, the *system* view is essential; protecting a few objects without considering them as part of a wider 'geoecosystem' would in many cases become useless. For instance, a scenic streamway cave cannot be adequately preserved unless the hydrological catchment is taken into consideration. The purpose of conservation may vary, ranging from the desire to save something for the consumption of 'future generations' or because the existence of untouched nature is valuable in itself, regardless of man. These views are subject to taste and political debate and therefore quite variable over time. However, regardless of where we may belong in this spectrum, we will have to admit that, among all the geological phenomena we know of, karst features are the most vulnerable. Karst is a rare phenomenon in Norway and the kind of karst in the country (stripe karst in marble) is also of a globally rare type. Norway's karstlands are pristine, generally remote and uninhabited, particularly when seen in relation to the rest of Europe. The only comparable areas in the northern hemisphere with respect to climatic and topographic setting are the North American and Canadian oceanic arctic-alpine karst areas. Like them, we still possess areas which have suffered a minor impact of man, and even sites where *no human being has yet been*. Accepting this as a 'value', it is quite clear that it is threatened by various kinds of development, like the tourist industry and the large-scale hydroelectric and quarrying projects.

The purpose of cave conservation is, at least in my opinion, to secure that the interests of both the scientist and the layman do not become reduced in the future. The scientist must be able to obtain at least the same amount and quality of information, and the layman must be allowed to experience the same atmosphere of untouchedness and beauty a hundred years from now as they can both do in the caves today. This will in most cases imply that the surroundings of the caves are also kept intact.

With respect to the scientific values of certain karst forms, we have to face the enigma that – although to a vastly lesser extent than limestone quarrying or hydrological regulations – the extraction of scientific information also implies some inevitable impact on the cave environment. We may view this as an analogue to the Heisenberg uncertainty principle, which states that it is impossible to gain information about any physical system without affecting it. It is therefore necessary to employ modesty not only with respect to sporting caving and tourism, but also with respect to scientific exploitation. Ideally, a few of our best cave sites should become sealed off (with concrete) for some 100 years in order to provide future scientists with untouched material. We may safely assume that future methods of scientific investigation will become more sophisticated than those of today. The kind of information that can be extracted is apt to change as is the environmental impact of investigations. Maybe large-scale excavations will become unnecessary? When seen on this background, it is of paramount importance that scientists be allowed access to cave sites which might have become opened by quarrying operations, *before* they become erased or rendered useless for science.

Management

Protecting caves and karst as a phenomenon

As shown above, the unique scientific or aesthetic values of certain karst sites are beyond any doubt. Since only a fraction of the most valuable objects are presently protected by law (i.e. the Rana Caves and those within the national park), it is necessary to find ways of protecting the remainder of them. A list of the, say, 'top 20' most valuable caves and karst areas is under preparation. This is a necessary start for a management plan, but not sufficient to catch new, valuable objects that might yet be found. Although an established list has been approved for legal protection, the inherent inertia of the bureaucracy makes it rather unlikely that new objects will be given protection in due time. The discovery of previously unknown objects in areas of controversy would also become very vulnerable to tactical arguments from those who may want to develop the area at the cost of the object.

A simple and efficient way of handling this problem is to protect caves as a phenomenon, like animal species or archaeological sites. This approach is quite reasonable, as caves and some other karst objects resemble archaeological sites by the kind of information they contain. In fact, many of the classic archaeological and hominid sites in the world are indeed located in caves. Hence, the approach involves only an extension of our concept of what pertinent information we want; the archaeologist considers information about early humankind, the Norwegian quaternary geologist considers unique information about temperature, fauna and flora of remote interglacial and glacial periods.

With respect to archaeology, *all* burial or settlement mounds are protected until we know what they contain. With respect to karst, it must be kept in mind that this is how some caves in Norway are already protected (i.e. those on parts of the state-owned land in Rana, see above). Therefore, it is not only logical to protect caves like a species, the Norwegian conservation authorities have also a *tradition* of doing so. Hence, we may suggest the following:

1. All caves in the country become protected against specified damage by reason of the *potential* pertinent information they contain.

2. Any kinds of development in the surrounding areas that would cause damage to the caves should be viewed as contracting. In cases of land development of various kinds, or requests to utilize the cave for tourism, permission may be given providing that the cave has been investigated by specialists. If the site does not reveal significant information of the kind shown in Fig. 16, it may then be released from protection. Otherwise, if the site does satisfy the criteria featured in Fig. 16, then it must either remain protected (i.e. highly valuable), or it must be sufficiently documented (perhaps excavated) before being sacrificed, at the expense of the contractor. In the case of caves and karst, such rescue documentation is rarely very costly, and it would be extremely useful where sites are affected by quarrying or flooding by water reservoirs. In the case of tourist developments, a previous investigation by scientists may indeed increase the display value of the cave.

There are between 100 000–200 000 burial mounds or other visible archaeological sites in the country (Hagen 1967) which are protected. Therefore, protecting and managing all our significant caves, which would probably never exceed 700 in number, would appear to be a minor task (see Fig. 12 and Table 1).

Outstanding sites and objects

The fraction of the objects mentioned above that satisfies the criterion of 'highly valuable', should be protected against future damage, depending on what kind of pertinent information is contained therein. When anonymity and remoteness no longer offer an efficient instrument for protection, areas of outstanding diversity and quality must be protected as nature reserves. Unfortunately, experience has shown that the only efficient way of protecting a cave and its interior is by gating (Fig. 18). This is of course an unpleasant experi-

Fig. 18. The cave gates may seem quite provocative and of little aesthetic value to most visitors. However, experience demonstrates that gating is the only efficient means of protecting vulnerable features of the cave interior from vandalism. From Hammarnesgrotta, Rana, Nordland.

ence for all serious cavers, for whom the feeling of entering an unknown and untouched site is an essential part of the caving experience. Others may feel that a gate represents a violation of individual freedom, which in Norway is strongly associated with the right of everyone to have access to all areas that are not utilized for growing crops or keeping animal herds. Since gates have a provocating effect, they would have to be of an extremely solid construction (see for instance the ideas of Hunt & Stitt 1975). An outstanding example is the protection of a small cave in the French Pyrenees, containing masses of snow-like hydromagnesite and aragonite deposits on the walls. Only a limited number of people are given access to the cave per year, which is closed by a series of three independent gates, one of them a steel safe door (Fig. 19).

The practice of cave-gating in Norway is not new, as a series of protected caves in Rana county were gated in the 1960s (Hjorthen 1968). The gates were of a relatively simple design which did not prove durable enough to withstand vandalism up through the 1970s when most of the caves were broken into. Based on visits in 1983 and 1985, there is evidence to show that speleothems have been smashed in one of them. This case story is by no means unique; for the archaeological

(a)

(b)

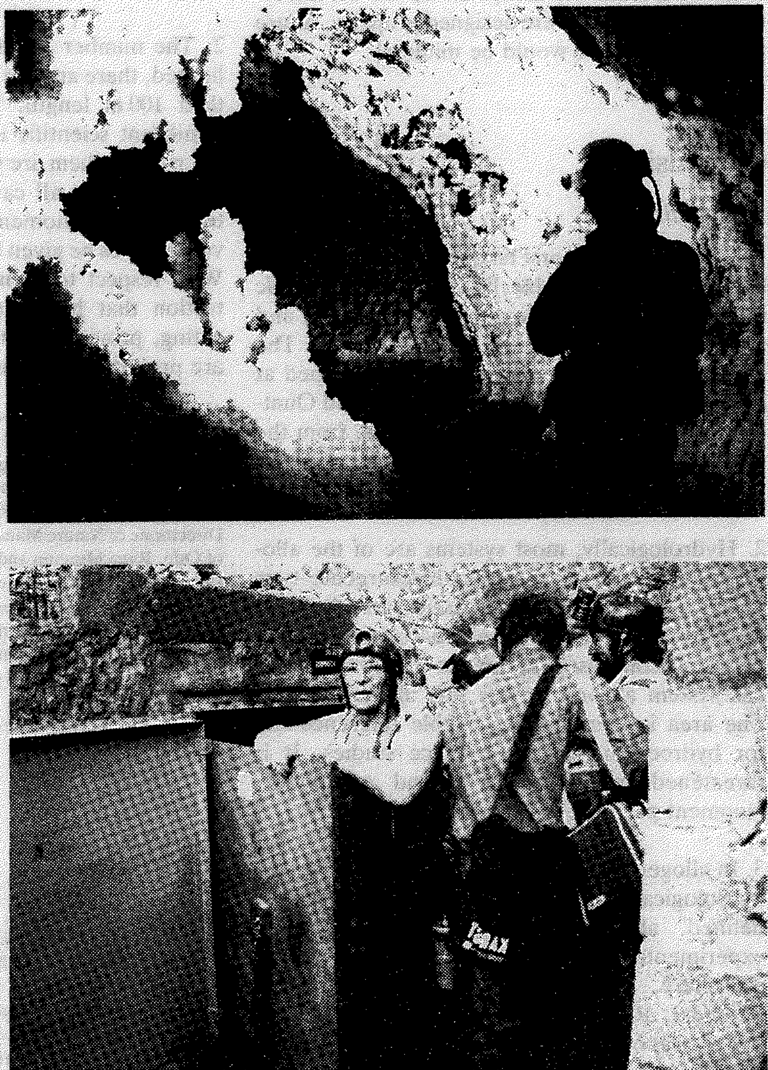


Fig. 19. (a) Fragile deposits of hydromagnesite and aragonite in a Pyrenean cave, France. (b) The cave is accessed by three gates, one of them a steel safe door.

scientist it may seem more the rule than the exception, as in the classic sites of Egypt (Fagan 1975). In 1990 the nature conservation authorities in Rana county started re-locking the gates, but it is questionable whether the old design will withstand the test of time. In addition, two more caves, one in the Svartisen area and the other at Skrimfjell, South Norway were gated. It is of paramount importance that all the future cave gates in Norway are of a standardized and sufficiently durable design, and that the gating is carried out by a few persons who could gain and utilize experience from site to site. Judging from the present knowledge of vulnerable sites, we would need to gate another 15–20 caves. This could be a relatively inexpensive, one-off undertaking. If the gates were designed properly, future maintenance costs would be minimal.

Conclusions

A. Qualities

1. The Norwegian karst landforms are dominated by metamorphic marble lithology and allogenic runoff. Marble stripe karst is globally rare, and may be said to be the *Norwegian karst* type. The karst display forms that may have developed at different times during the late Tertiary and Quaternary periods, ranging in size and age from the paleic mega-forms to conventional post-glacial karren types.

2. Hydrologically, most systems are of the allogenic point recharge types with resurgence-type springs. A few, totally autogenic karst drainage basins exist. The Glomfjell marble plateau at Svartisen comprises the largest autogenic drainage system above the tree line in the country. The area is therefore a valuable reference site for hydrochemical mass balance studies. It is threatened by hydroelectric and other development projects.

3. In allogenic stripe karst systems, lithologic and hydrological boundary conditions are often well defined, allowing exceptional conditions for experimental work that is not easily encountered elsewhere. The underground outlet of Lake Glomdal, Rana, is a unique, full-scale natural flume laboratory through totally phreatic conduits.

4. Cave deposits are presently the oldest dateable deposits of the continental Pleistocene in Norway. Caves are depositories for unique information about past climate, biology, geomorphology, and ice extents.

B. Vulnerability and conservation

1. Most types of karst landforms and their contents are vulnerable to direct human impact and to impact from industrial constructions. Most encroachments would be damaging and irreversible for the future. Most sites have until now been protected by remoteness and a low profile of public interest. This is rapidly changing with various road constructions and publicity.

2. The number of karst caves in the country is limited, there are less than 600–700 caves of more than 100 m length. The number of sites with significant scientific information may be fewer, but most of them are yet unknown. It is therefore suggested that all caves in the country be protected as a phenomenon, and that permission for various uses be given *after* scientific investigation. With respect to vulnerable sites, the only protection that has proven efficient over time is gating, provided that the gates are durable and are properly maintained.

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Recent changes in the landscape of the marine clays, Østfold, southeast Norway

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Erikstad, L. 1992. Recent changes in the landscape of the marine clays, Østfold, southeast Norway. *Norsk geogr. Tidsskr.* Vol. 46, 19–28. Oslo. ISSN 0029-1951.

Grading of gullies for agricultural purposes was heavily subsidized in Norway during the period 1971–1987. Grading activity was very high and has significantly contributed to the recent changes in the rural landscape of Østfold. Interpretation of aerial photographs indicated that at least one-third of the marine clay areas contained significant grading and similar encroachments. Detailed studies of three test areas revealed that between 60 and 80% of the total length of the observed gullies from the 1950s and 1960s had disappeared. Today it is almost impossible to find large intact gully systems that are not affected by grading. The few gully systems which are still reasonably untouched have therefore a high conservation value.

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This investigation is a part of a larger project with the aim of registering objects of quaternary conservation value in the county of Østfold (Erikstad 1991). This county comprises the southeastern part of the widespread marine clays of southeastern Norway (Fig. 1), and has a distinctive cultural landscape resulting from, among other things, a long agricultural history. Modern agricultural practices, including increased mechanization, have further introduced important changes to this landscape, particularly the grading activity during the last 20–30 years. The aim of this investigation has been to discover how extensive these encroachments have been, and how many of the gullies are still left.

Østfold consists mainly of Precambrian rocks: different gneisses in the inner and northern parts and granites in the southwestern parts (Sigmond et al. 1984). The rocks have strong lineaments from both faults and the folding structures in the gneisses, which are significantly reflected in the landscape. About three-quarters of the land area is bare rock, partly with a thin and discontinuous cover of till and organic deposits. The rest has more or less continuous cover of surficial deposits. The Ra-moraine traverses the county from northwest to southeast. Of the surficial deposits, however, the marine clays and silts dominate. The most important accumulations of clay and silt are found in the broad depression of the Glomma watercourse, outside the Ra-moraine and along the Haldenvassdraget watercourse (Fig. 2). The clays along the Glomma watercourse have the character of a wide plain heavily intersected by gullies and to a lesser extent slide depressions. In the southwestern parts of the county and along the Halden watercourse the clay is thinner and its surface therefore undulates more according to the bedrock topography. In the many fissure valleys below the marine limit, the valley floors are normally filled with clay.

Almost all the land surface of Østfold is below 300 m a.s.l. The climate is temperate with an annual precipitation of some 700 mm and the yearly runoff varies from about 12 to 16 l/s km^2 (Norwegian Water Resources and Energy Administration 1987a). The hydrology of the coastal regime is dominated by summer low flows and high runoff in autumn and winter, gradually shifting to a transition regime further inland, with low flows in both summer and winter and high flows during spring melt and autumn rains (Norwegian Water Resources and Energy Administration 1987b).

Methods of analysis

This investigation is based on a study of infrared aerial photographs in the scale 1:50 000 taken in 1987 (Series 9389 from Norsk luftfoto A/S). Older photographs were also used to study the situation in selected areas before grading had taken place (Series 296, 516, 1430 and 1515).

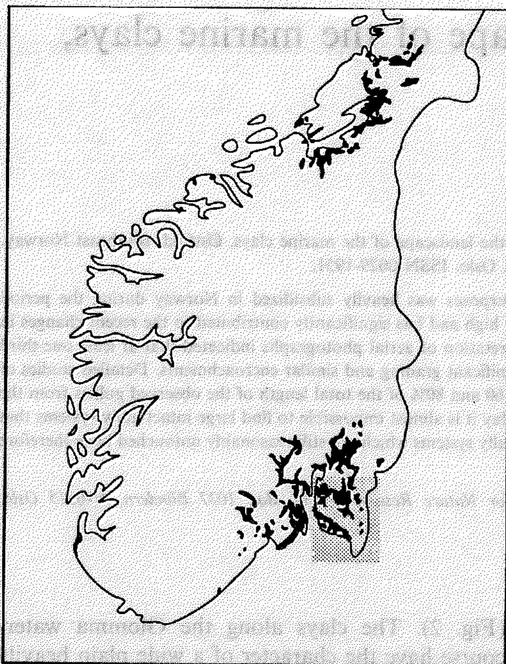


Fig. 1. The distribution of marine deposits in South Norway simplified after Thoresen (1990). The accumulation of clay in southeastern Norway and in Trøndelag, both shown on the map, comprising the two dominating clay areas in Norway. The area of investigation is indicated by a grey square.

Quaternary maps (Kjærnes 1984, Kjærnes 1986, Nordahl-Olsen 1990), as well as ordinary topographical maps were also used.

Grading is the extensive redistribution of surficial deposits to smoothen the terrain, thereby increasing the access for mechanized agricultural practices. These encroachments can be observed on aerial photographs using the following criteria: existing gully systems stop abruptly; the fields may end in a sharp dump towards the gully; a height difference of 1–3 m may occur between the field surface and the terrain bordering the field; residual parts of the former gully system occur (Fig. 7).

Other encroachments such as major canalizations and closing of creeks are also included in the investigation, the main reason being that they are difficult to distinguish from grading when small-scale aerial photographs are used. In addition, these encroachments have the same character as grading, since they also change the fluvial drainage pattern and processes as well as the landscape.

The gully systems and their genesis

Several authors have discussed the quaternary geology of Østfold. The description which follows refers mainly to Sørensen (1983). The glaciomarine deposits are linked with several glacial stages marking the retreat of the glacier from about 12 000 BP to 10 000 BP (Fig. 2). The most important of these is the Ra-moraine dating from 11 000 to 10 700. BP (Sørensen 1983) and which belong to the system of Younger Dryas moraines all around Scandinavia. Most parts of the Ra-moraine in Østfold are below the marine limit. Marine shore deposits normally cover the boundary to the marine clays distally.

The outer major clay accumulation is outside the Ra-moraine, but inside the Hvaler stage (12 000 BP (Sørensen 1983)). The large clay accumulation along the Glomma depression downstream from Lake Øyern is just outside the Ski-stage (10 000 BP (Sørensen 1983)), but inside the Ra-moraine. The particle sizes in the glaciomarine sediments are fine grained with alternating layers of clay and silt. The proportion of clay and silt varies from some 20% clay and 80% silt to some 60% clay and 40% silt (Nordahl-Olsen 1990).

The formation of the gullies can be summed up as follows. Immediately after deglaciation the clays were deposited on the sea-bed. The postglacial land upheaval exposed the clay for erosion. The uplift in this area has been significant and the marine limit varies from approximately 165 m a.s.l. (theoretically) in the outer parts, to some 200 m a.s.l. in the inner parts (Kjenstad 1984). The uplift was highest just after deglaciation (Fig. 3), in the order of some 100 mm/year during the first 1000 years (Sørensen 1979). The recent land uplift is currently about 2 to 3 mm/year (Sørensen et al. 1987). From this, most of the large gully systems have theoretically been subjected to a time of erosion of near 10 000 years for altitudes near the marine limit in the northern parts of the county, and about 6000 years for gullies in an altitude of some 50 m a.s.l. outside the Ra-moraine.

The first part of the erosional history started with the action of marine beach processes. The clay was washed away from the hills into the depressions. The gully erosion can be described in three phases. The first phase was dominated by the land uplift and subsequent lowering of the erosional base. This represents a period of some

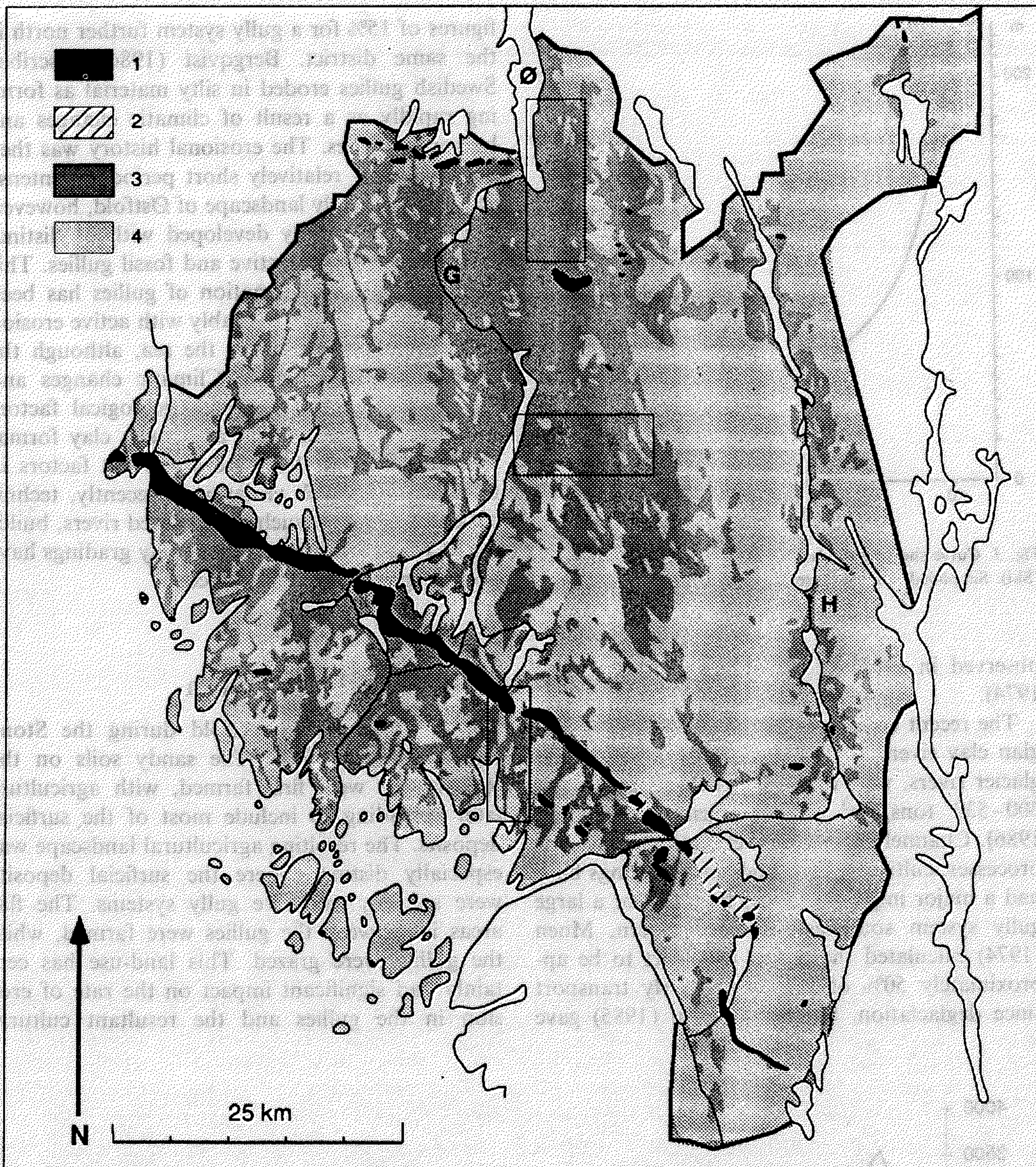


Fig. 2. The quaternary geology of Østfold. (1) Marginal deposits and major isolated fluvioglacial deposits. (2) Marginal moraine zone without distinct forms. (3) Surficial deposits, mainly marine clay and silt. (4) Bedrock and bedrock with a thin or discontinuous cover of surficial deposits. The map is based on quaternary maps from NGU together with own observations. The three test areas are indicated by squares.

1000–2000 years for watersheds with altitude ranges of about 100 m. The rate of erosion was probably very high, but has not been specified. After the establishing of a permanent erosional base, a second phase of adjustment to this new base started. The intensity and duration depended on the magnitude of erosion of the previous phase. The third and last phase started, or starts, when the main river reaches a stage of quasi-equilibrium. The erosion then is far less than during the first two phases, although it is still significant. Such a quasi-equilibrium can be

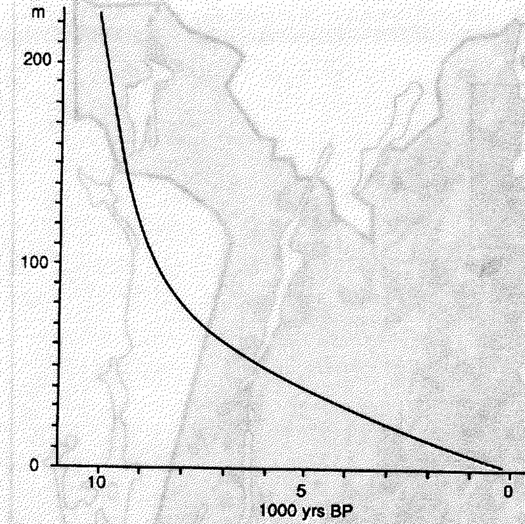


Fig. 3. Curve showing the land uplift for inner parts of Østfold (Ski). Simplified after Sørensen (1979).

observed in some of the systems today (Moen 1974).

The recent erosion in the southeastern Norwegian clay rivers is at the level of that of several glacier rivers, with measured erosion rates up to 300–530 tons/km^2 year (Bogen & Nordseth 1986). Channel erosion as well as different slope processes, cultivation methods and gradings have had a major impact on these figures. For a large gully system southeast of Lake Øyern, Moen (1974) calculated the recent transport to be approximately 50% of the mean yearly transport since deglaciation. Similarly, Loftu (1985) gave figures of 15% for a gully system further north in the same district. Bergqvist (1986) described Swedish gullies eroded in silty material as forming rapidly as a result of climatic changes and human activities. The erosional history was then dominated by relatively short periods of intense erosion. The gully landscape of Østfold, however, has been extensively developed without distinct differences between active and fossil gullies. This indicates that the formation of gullies has been governed regionally, probably with active erosion since the clay rose above the sea, although the erosion rate has varied. Climatic changes and human impact together with geological factors such as stability changes and quick clay formation (Rosenqvist 1960) are important factors in understanding such variations. Recently, technical encroachments such as regulated rivers, building of roads, bridges and especially gradings have been of particular importance.

Results and discussion

Agriculture came to Østfold during the Stone Age (Johansen 1978). The sandy soils on the Ra-moraine were first farmed, with agriculture later spreading to include most of the surficial deposits. The resulting agricultural landscape was especially distinct where the surficial deposits were split by extensive gully systems. The flat areas in between the gullies were farmed, while the gullies were grazed. This land-use has certainly had significant impact on the rate of erosion in the gullies and the resultant cultural

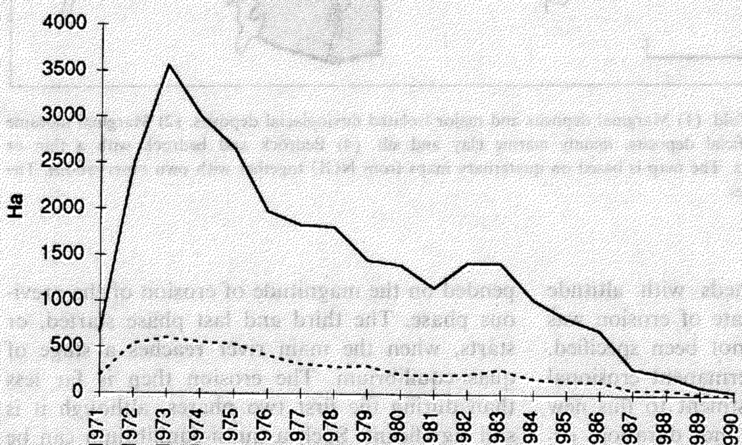
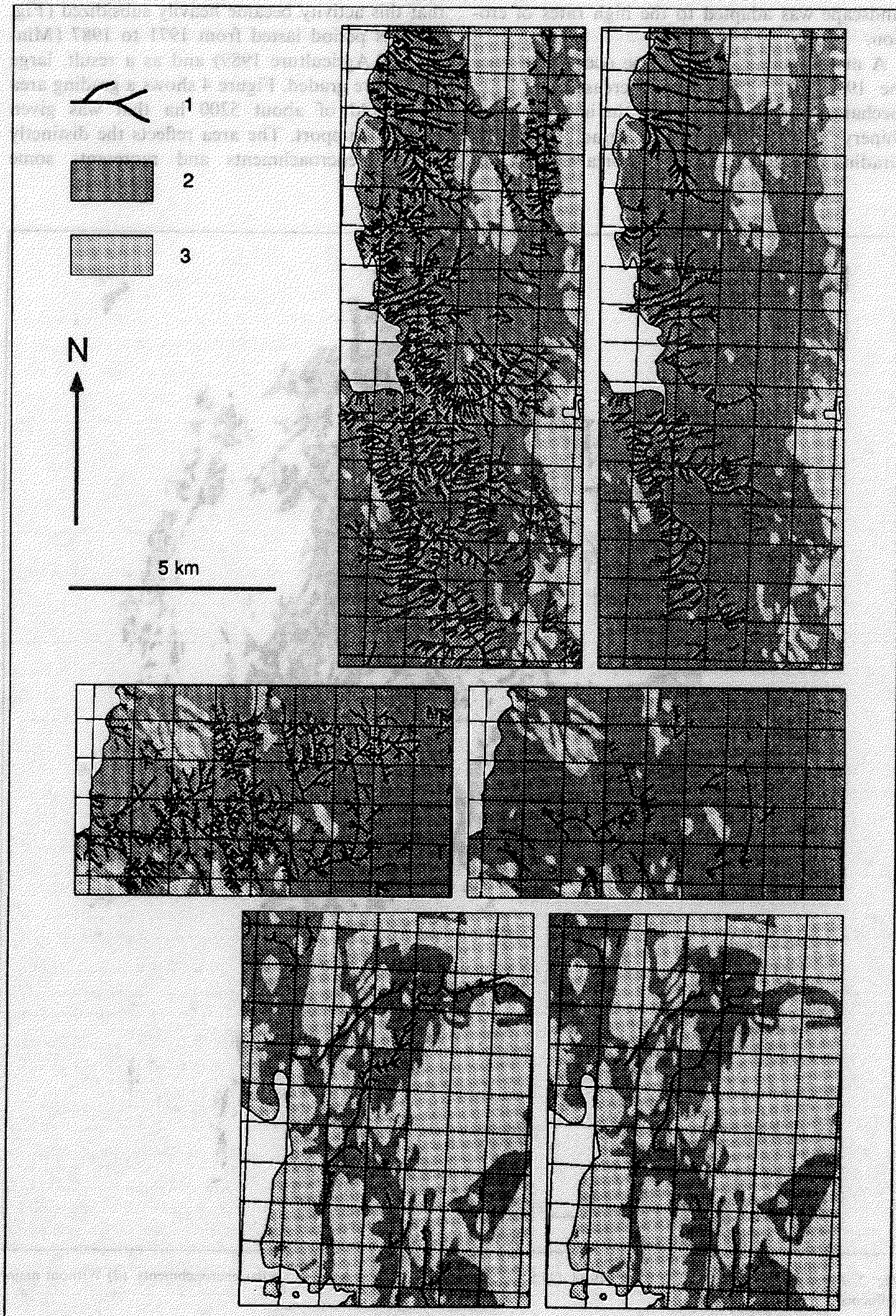


Fig. 4. Grading given financial support in Østfold compared (dotted) with the total for the whole country (solid line). Source: Central Bureau of Statistics, Oslo, Norway.

landscape was adapted to the high rates of erosion.

A major change in landscape occurred during the 1970s and 1980s. The increased need for mechanized farming as well as the improved machinery led to an increase in grading activity. Grading was regarded as so important and useful that this activity became heavily subsidized (Fig. 4). This period lasted from 1971 to 1987 (Ministry of Agriculture 1989) and as a result, large areas were graded. Figure 4 shows a grading area in Østfold of about 5200 ha that was given financial support. The area reflects the distinctly physical encroachments and represents some

Fig. 5. Areas of marine silt and clay in Østfold. (1) Strongly influenced by grading and similar encroachments. (2) Without major influence of grading.


1
2
3
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6.7% of the total area of ploughed fields, in 1979 77 729 ha. (Central Bureau of Statistics Oslo-Norway 1983). The grading in Østfold represents 18.5% of all subsidized gradings in Norway. Grading outside already ploughed fields is not included in these figures and, in addition, some grading activity has occurred without financial support. The Ministry of Agriculture (1989) calculated that the total area of grading (27 984 ha) for the country as a whole therefore represents a total of some 35 000–40 000 ha. Assuming the same ratio holds for Østfold, the graded area is then about 7000 ha.

The analysis of the aerial photographs (Fig. 5) illustrates the situation in 1987. Extensive areas were then influenced by grading. Calculations based on this inventory indicate that nearly 40 000 ha out of a total of some 100 000 ha (about one-third of the total clay area) was strongly influenced by grading and similar encroachments. Urban developments on marine deposits were not included. The investigation has a regional character and possible inaccuracies have been introduced mainly because of details being overlooked and misinterpretations occurring for example in the distinction between clays and moraine surfaces especially in dense spruce forest. These inaccuracies are, however, of minor importance in the regional analysis.

The figures that derive from this analysis are not comparable with the official figures quoted above. First, the total area registered is much larger than the area of ploughed fields. Woodlands, grazed land, light settlements, roads and the like, are included. Secondly, the graded area is much higher. This is partly the result of an analysis based on geomorphological understanding of the problem. This means that no attempt has been made to register the accurate borderline of the physical encroachment. Fields with former intersecting gullies, but which are now graded, were listed as strongly influenced by grading even though areas of flat terrain without technical encroachments are included. This makes sense in a geomorphological assessment, but may seem somewhat unfair from a farmer's point of view.

Other agricultural encroachments included in the inventory also partly affect the figures. This will be especially significant in terrain with a low relief such as outside the Ra-moraine and in the fissure valleys. Figure 5 shows extensive encroachments in this area because of the closing of creeks and the smaller redistribution of topsoils. Concentrating strictly on grading alone, these results will be overemphasized. From a geomorphological viewpoint, however, these encroachments are relevant and of the same character as grading.

Three different areas were selected for a detailed analysis to check whether the general pattern and degree of encroachments indicated in Fig. 5 were correct. The test areas (Fig. 2) were selected to include different degrees of present gully density. The three areas also form a N–S gradient along the axis of deglaciation and land uplift. Aerial photographs from the 1950s and 1960s were studied and compared with the registrations from the 1987 photographs. The analysis showed that changes from the mid-1950s to the mid-1960s were small and mainly connected with road-buildings and similar encroachments. In the Skjeberg area (Fig. 6) only a minor part of the area was covered by marine clay and silt. The relief of the clay surface was modest. In the mid-1950s roads and railways occupied larger parts of the clay surface than in the other two test areas. Other encroachments such as the closing of creeks and minor redistribution of soil were also indicated, but not studied in detail.

The result of the detailed analysis (Fig. 6) confirms the impression of a dramatic change in the landscape as a result of grading. Measured by the length of existing gullies, only 33% of the gullies survived the period of extensive grading in the Øyern area, 20% in the Rakkestad area and 42% in the Skjeberg area. As discussed already, this relatively high figure in the Skjeberg area may be due to the loss of some gullies prior to the 1950s. The Øyern area belongs to the part of Østfold where most of the natural gully terrain remains and the difference between this area and the Rakkestad area seems reasonable.

Fig. 6. Detailed map for the three test areas: at Lake Øyern (top), Rakkestad (in the middle) and Skjeberg (below). (1) Gullies. (2) Marine clay and silt. (3) Mainly bedrock. The maps to the left show the situation before major grading started (1964, 1956 and 1965). To the right the situation after the major grading period is shown (1978). Variations in scale and quality on the aerial photographs may give minor differences referring to the interpretation and not grading. The grid refers to the kilometre grid on the ordinary 1:50 000 topographical maps. The location of the test areas is shown in Fig. 2. Central UTM reference points: (32V) PM290150, PL310910, PL270630.

The real change is even greater, since short gully segments isolated from the gully system (Fig. 7) as well as central gullies with all tributary gullies graded, count as much as gully systems not affected by grading. In addition, a great number of small gradings do not show up on the map scales used, although their importance in comparatively untouched systems is quite significant (Fig. 8).

In addition to the visual change in the landscape, gradings also affect the geomorphological processes within the systems. The gully and creek gradients are changed and the surface water channelled. Depending on how well the artificial drainage system works, this will result in a significant increase in the erosion potential. Highly increased erosion caused by grading was observed in the years following the encroachment (Loftu 1985, Sandersen 1980). Graded gullies will normally tend to gain greater stability after some time. Particularly severe erosion problems can occur, however, as a result of the combined effects of grading, newly ploughed fields and mild snow-free winters. This was clearly illustrated in the winters of 1988–1989 and 1989–1990, with new gully formation in the gradings as well as extensive tunnel erosion along the drainage systems (Rognerud 1990).

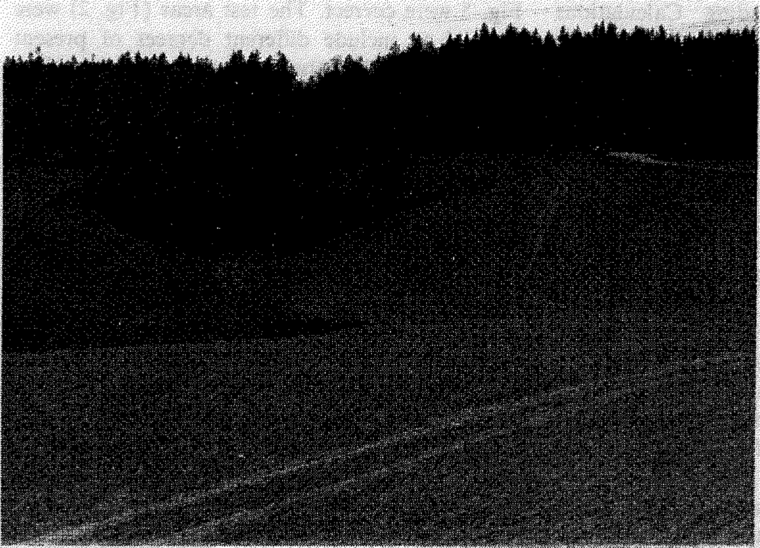

Fig. 7. An isolated gully remnant in a graded area. Solbergfoss, west of River Glomma.

Fig. 8. Undisturbed gully in the background. A relatively small grading crossing the gully in front. From Lund east of Lake Øyern.

Gullies in marine clay are landforms characteristic of areas with glaciations and glacial isotasy. In this respect Norwegian and Swedish clay areas are important on a world scale (Bergqvist 1990), and these countries therefore have a responsibility to manage these landscapes. In spite of heavy grading, there are still several areas with well-developed gully landscapes in Østfold (Fig. 9). Using the criterion 'naturalness' in assessing the value of these areas, it can be shown however, that hardly one single system is totally free of grading or similar encroachment. Naturalness if therefore a criterion which can only be used on parts of the systems.

Figure 9 shows the seven relatively intact gully systems in Østfold selected for nature conserva-

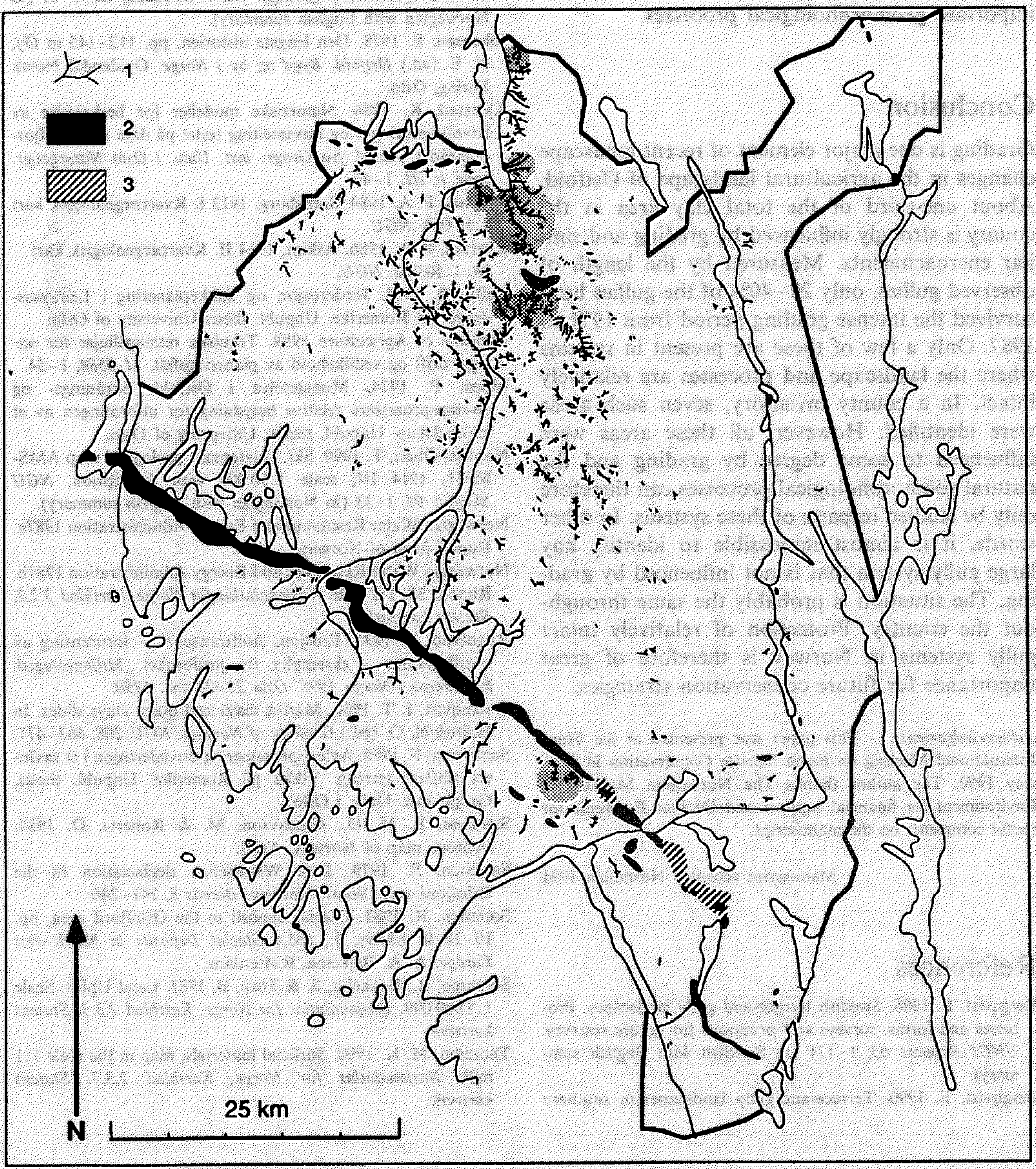

Fig. 9. The remaining gullies in Østfold. (1) Gullies. (2) Marginal deposits and major isolated fluvioglacial deposits. (3) Marginal moraine zone without distinct forms. The seven areas selected for nature conservation are shown as grey circles.

tion (Erikstad 1991). All of them are unfortunately to a greater or lesser degree affected by grading. The fact that these areas do not fully comply with the criterion of naturalness does not mean that they are of less value. Large relatively untouched gully systems have become rare and their value is increasing. In addition, these systems normally provide intact subsystems which are potential reference systems for the study of important geomorphological processes.

Conclusion

Grading is one major element of recent landscape changes in the agricultural landscape of Østfold. About one-third of the total clay area in the county is strongly influenced by grading and similar encroachments. Measured by the length of observed gullies, only 20–40% of the gullies have survived the intense grading period from 1971 to 1987. Only a few of these are present in systems where the landscape and processes are relatively intact. In a county inventory, seven such areas were identified. However, all these areas were influenced to some degree by grading and the natural geomorphological processes can therefore only be studied in parts of these systems. In other words, it is almost impossible to identify any large gully system that is not influenced by grading. The situation is probably the same throughout the country. Protection of relatively intact gully systems in Norway is therefore of great importance for future conservation strategies.

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