Ingenieurs Geologische Kring
Netherlands Section of Engineering Geology
Secretaris: Dr. J.J.A. Hartevelt
Postbus 63, 2260 AB Leidschendam (the Netherlands)
Postgiro: 3342108, t.n.v. Penningmeester Ingeokring Delft

INGEOKRING

EEG91

NIEUWSBRIEF

EEG91

EEG91

Autumn 1991

CONTENTS

EEG '91 European Engineering Geology Special Issue

Foreword from the Editor

This issue of the Ingeokring Nieuwsbrief has been specially prepared for the EEG'91 European Engineering Geology event, which takes place from 8 to 14 September. It is very pleasing that quite a large number of English engineering geologists will visit our part of Europe to gain an impression of the way the geotechnical profession operates over here.

We in Holland feel very much attached to the engineering geologists from the British Isles. Engineering geologists in The Netherlands have either studied in England, or received their training in Delft from David Price. David is certainly the father of engineering geology in The Netherlands, but also one of the few who were at the cradle of the blossoming engineering geology profession in the UK. When David arrived in The Netherlands nobody over here seemed to have even heard of engineering geology. Now more than 60 Dutch engineering geologists have been educated by David. Since about 1989 engineering geologists are working for all our large engineering consultancy firms and contractors. David's students are pervading the whole country, working for small consultancy firms or local town geotechnical departments, literally from Groningen to Maastricht and The Hague to Enschede.

My colleague, Pieter Michiel Maurenbrecher, although Dutch by nationality, is considered by myself not to have lost any of his typical English-type gentleman characteristics. His mannerism may be considered at times a little bit strange over here, but from what I have seen in England would be perfectly normal over there. His main hobby is golf. And he was playing golf in Holland already at those times when people in Holland called a golf club a golf stick (probably because the main sport at the time in Holland was hockey). He is tremendously active to promote our profession in Holland. His continuous drive to organize yearly symposia and congresses and also to stimulate the regular appearance of our newsletter is greatly appreciated.

This newsletter normally appears quarterly. The majority of the work to prepare the publication is done by students. In this issue you will find information on engineering geology in The Netherlands. Enjoy your reading. And the participants of the EEG'91 study tour are wished a pleasant stay in Holland.

Peter Verhoef

EEG '91 Netherlands Visit Monday 9th September, 1991:
Programme for Bus A and for Bus B

Bus A Programme

7:45-8:20 Coffee at TU Delft Faculty of Mining & Petroleum Engineering, Geological Museum

8:30-11:15 Visit to Delft Geotechnics

> 8:30-8:45 Welcome by Dr. J. Nieuwenhuis Director Research, Delft Geotechnics
>
> 8:45-9:15 Dutch cone penetration test, new developments. Environmental projects. Ir. W.J. Heijnen, retired Director
>
> 9:15-9:30 coffee break
>
> 9:30-9:45 The new Delft Geotechnics centrifuge. Ing. H.A.M. Nelissen
>
> 9:45-10:45 Tour of Delft Geotechnics

11:15-12:15 Travel to Nieuwegein, your guides are Floris Schokking and Pieter Maurenbrecher

12:15-13:15 Visit KIWA, Nieuwegein on Hydrogeology of East Brabant

> 12:15 Reception in the water buffer storage basement
>
> 12:15-13:15
> Short introduction by P.R. Nowee,
> Present research by Mr. Straatman
> Geology and geochemical research by F. Schokking

13:15-14:45 Travel via Arnhem to Vierlingsbeek

14:45-15:30 Water Supply Company East-Brabant Vierlingsbeek Pumping Station

> Demonstration on taking of samples and explanation on mini-filter well.

15:30-16:30 Travel to Valkenburg Hoorensberg Mine

16:30-17:45 Visit mine under guidance Prof. David Price and drink in the Fairy Tale Restaurant.

17:45-18.30 Travel to Liège

18:30 Liège Holiday Inn

Bus B Programme

7:45-8:20 Coffee at TU Delft Faculty of Mining & Petroleum Engineering, Geological Museum

8:20 -9:00 Travel to Fugro Leidschendam under guidance of ir. Walter Zigterman of ITC (Internation Institute for Aerospace Surveying and Earth Sciences)

9:00-12:00
Reception and word of welcome by Ir. G.J Kramer, President FCI, Fugro Consultants International BV.

Visit of Fugro BV and Fugro-McClelland BV facilities: onshore and offshore equipment, laboratories and engineering offices.

12:00-13:30 Travel to 's-Hertogenbosch under guidance of Walter Zigterman and Joris Lap (Fugro)

13:30-14:30 In-situ soil sanitization project at 's-Hertogenbosh (Den Bosch on road signs)

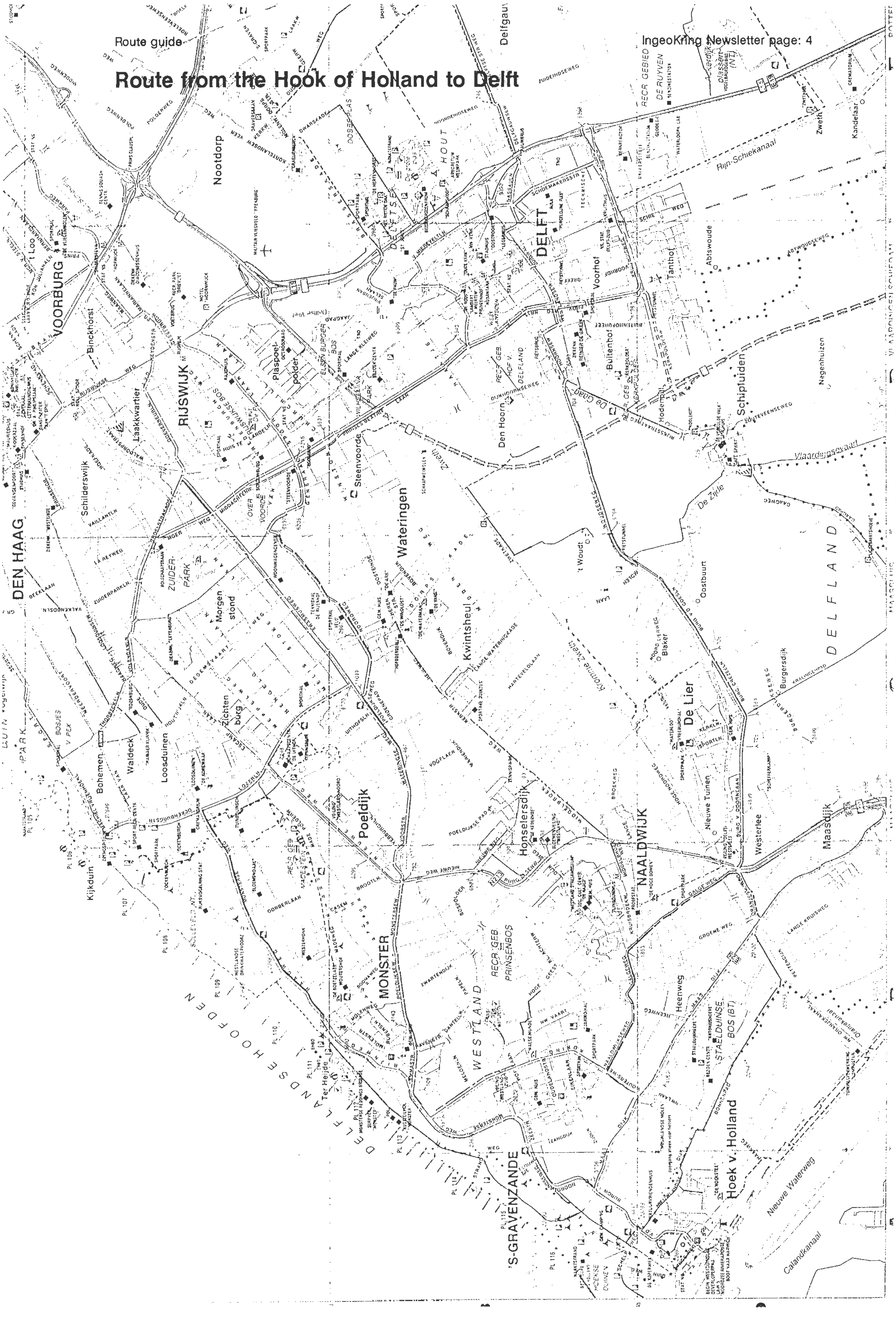
14:30-15:00 travel to site 2 in the Grote Peel district.

15:00-16:00 Geological factors effecting local geohydrology.

16:00 Depart for Liège

17:30 Arrive at Holiday Inn, Liège

Route from the Hook of Holland to Delft



Engineering Geology Setting in The Netherlands

by P.M. Maurenbrecher

This article covers a few themes not covered by the article written for the EEG '91 symposium to be held in Brussels on Friday, 13th September 1991 in Brussels. These themes would, with the article for Brussels give a more comprehensive picture on Engineering Geology in the Netherlands.

Evolution of engineering geology in the Netherlands

Geologists in The Netherlands are their own worst enemy. Geology does not really exist in the Netherlands (except for a few who think the Quaternary has to do with geology) and therefore they spend most of their field work training in mountainous areas such as the Alps, the Apennines and the Pyrenees. They now go further a field to places such as Rhodes and Crete. Little wonder that Dutch industry does not know what to do with a geologist and most geologists do not know what to do with Dutch industry. Few find much employ in their field of study. Despite the significant contribution of mineral resources in the Netherlands from groundwater, salt, coal and early indications of hydro-carbons the State Geological Survey almost disappeared through lack of appreciation in the 1930's as an economising measure by the then Dutch government. The Netherlands does not have any mountains thus it does not have any geology and so what do we need geologists for? This view is still prevalent and as long as our geological training takes place in mountainous regions can one blame the rest of the professional Dutch for taking this view?

The lack of appreciation from the government remains as strong as ever (ref: Prof. Zwart opening Coastal Lowlands conference 1987) so that closures of geological museums (Leiden 1991) and university departments (Leiden 1979) and Amsterdam (UvA) 1988 are not only present day threats but also fact. The government advisors, usually "grocery" accountants have little or no sympathy for the earth sciences and are apparently blind towards the enormous wealth they contribute towards the Netherlands. These advisors argue for centralisation of facilities which is more akin to out-dated Soviet economic politics then to encouraging competition between universities.

The small percentage that do find employ work largely for one oil company: Royal Dutch Shell, for the state geological survey (RGD: Rijks Geologische Dienst) and for teaching geology at Delft, Utrecht, Wageningen (Agriculture University), the Free University, Amsterdam and to foreign students at ITC: Institute for Aerospace Survey and Earth Sciences (ITC originally stood for International Training Centre). Only at Utrecht and the Free University can one graduate as a geologist, with specialisations akin to engineering geology such as geophysics and applied hydrogeology (before geology graduates were also from Leiden, Groningen and Amsterdam Universities). At Delft one graduates as a Mine Engineer specialised in Engineering Geology or in Geophysics, amongst others (Petroleum, Raw Materials Processing and Ore Extraction).

Time and place: meeting of geology and civil engineering

After scrambling for years around the mountains to the south in recent years the less real geology of the Dutch delta started to slowly interest a few geologists. The impetus came partly from protection of the coast against flooding from the sea and from the great boost of hydro-carbon activity in the North Sea and on land in the 1960's and 1970's.

Dutch geology and civil engineering finally met as a result of the North Sea activity through geophysical investigation for pipeline routes and for foundations of oil jacket platforms and for jack-up rigs. So The Netherlands had geology after all? They were not easy times for hard rock mountain geologists to relate to soft ground civil and soil mechanics engineers. This state of affairs is reflected in the record of events from the Geotechnical Section of the Royal Institution of Engineers. The section was founded in 1949. The first meeting using the term "geology" was in 1953, coincident with the year of the devastating floods in the province of Zeeland. The meeting was on "subsea sliding and turbidity currents as geological processes". Four meetings were held with regard to soil mechanics problem in mining: 1955 (twice), 1958 & 1968 (Aberfan). Numerous meetings were held with regard to groundwater and pore water pressures, which is understandable, as any slight change in ground water level in the Netherlands can either cause flooding or large settlements. Much pioneering work has been done in the thirties by the founder of soil mechanics in the Netherlands, A.S. Keverling Buisman on long term secondary settlement in clays. Even Arnold Verruijt, present professor of the Geotechnical Department at the Faculty of Civil Engineering and chairman of the KIvI Geotechnical Section reflects this combination having published two books, his first deals with groundwater flow and his second on soil mechanics.

Engineering geology appears on the agenda in 1972: "Soil mechanics and geology: one unity". In 1975, one year after the founding of the Ingenieurs-geologische Kring "IngeoKring" (Engineering Geological Circle) a course was jointly set up by the Geotechnical Section with IngeoKring and the University of Technology, Delft to present lectures on engineering geology by "foreign specialists" suggesting such specialists were then not resident in the Netherlands. The specialists were John Knill soon followed that year by David Price, who was appointed to the newly established chair in Engineering Geology at the Department of Mining at the university.

Educating the Dutch to become engineering geologists

The period 1970 to 1975 was significant in a number of respects for engineering geology. The last coal mine of DSM (De Staats Mijnen) closed in 1973. (DSM chemical industries now occupy the site). The increase use of geologists on North Sea investigation and the closure of the mines in Limburg gave cause for the then professor of geology, Jacques Dozy, of the Department of Mining at Delft to search for new possibilities in the geology and mining curricula. Furthermore a number of geology students from Leiden University were specialising in Engineering Geology by attending the Engineering Geology course at Imperial College. (1973: Eric de Boer, Ben Degen and Bert Schuchman). (The first Dutch engineering geologists appeared in the late sixties Niek Rengers geology Leiden University and rock mechanics Karlsruhe University, Pieter Maurenbrecher civil engineering University College London and engineering geology Imperial College London).

Niek Rengers subsequently founded the engineering geology course at ITC and helped establish IngeoKring. Eric de Boer and Bert Schuchman spent their early career working abroad in geohydrology under the auspices of foreign aid programmes. Ben Degen joined the then Fugro-Cesco site investigation company and was soon involved in numerous off-shore site investigations ranging from the Norwegian Sea to the Persian Gulf as well as working for the Fugro offices abroad in Hong Kong, Dubai, Saudi Arabia and Iraq. Pieter Maurenbrecher joined Fugro-Cesco in 1977 after having worked remote from the Netherlands the previous 7 years in South Africa and the United Kingdom. Much of the Fugro work was again on projects abroad and so the first qualified engineering geologists, despite 50% based in the Netherlands were only gaining experience abroad and not in their own country despite working for a Dutch Company.

The attitude at Fugro was very much then that the experts in geology were more suited for projects abroad as "ground conditions were more akin to geology then ground conditions in the Netherlands!" to quote a senior geotechnical engineer in Fugro. Geology, presumably, still was understood to mean mountainous rocky ground conditions. Conversely the Dutch geotechnical engineers and geo-hydrologists are sufficiently knowledgeable about ground conditions in the Netherlands that, like it or not, to a large extent they are latent engineering geologists. The attitude is further re-inforced by the distinction made in the Netherlands between the engineering science graduate an "Ir." and the pure science graduate, the "Drs.". If the engineering geologist was a pure science graduate (Leiden or Utrecht) it is often assumed that he is incapable of carrying out work involving calculations such as pile bearing capacity determinations. This certainly is not the case with students from Utrecht who attend the engineering geology course at TU Delft.

Another contemporary of the Leiden contingent, Floris Schokking meanwhile attended the course at Imperial in 1979 followed by Ger de Lange who went to Durham in 1980. A third student went that year to Leeds. Unlike Floris Schokking or Ger de Lange, he decided to enter into the banking business in Geneva, presumably the financial rewards were greater and, after all, there are mountains.

Meanwhile mining students were attending the first lectures given by David Price and assisted by Mr. Bosma. Students from Leiden and Utrecht were also attending the course so that engineering geologists were graduating as either mining engineers or as geologists. The first student to graduate was Chris Dykstra who then promptly emigrated to Canada and works for Beaver Dredging in Alberta, a subsidiary of Bos Kalis Westminster. A listing of students who subsequently graduated is given in this issue, including the titles of their final year theses.

The number of graduates fluctuates considerably and depends on the fluctuation of annual intake of students to study at the faculty and the success of persuading the students to study engineering geology in favour of more lucrative specialisation such as petroleum engineering, geophysics or process technology. To date, possibly because the number of graduates remains relatively small in the Netherlands and because industry is finally realising there is another type of geologist now who can relate with engineering, little difficulty is experienced finding employment for graduates.

The market

Graduates do not find difficulty in employment. The listing of graduates and members of the Netherlands branch of the IAEG are given with the addresses of the organisations they work for in this issue of the Newsletter. Two important observations with regard to this table: The organisations are quite diverse, and there is still potential for further diversification, especially with employment in companies involved in construction materials (gravels quarrying and the cement industry.) A number of major contractors and consulting organisations still have to employ their first engineering geologist; those that do not have them are quite willing to try.

The second significant observation is that graduates are finding work in the Netherlands and carrying out projects in the Netherlands. Many also find employment much the same way as the first generation: working for Dutch companies and organisations internationally. (Its also used in the sales talk to attract students: if you want to travel become an engineering geologist and the boss will pay). Married life can be difficult as travel often disrupts family life, more so then with other "travelling professions" as travel is irregular and for indeterminate periods. Often three days offshore can involve three weeks offshore, or three weeks can extend up to three months.

Thirdly the market: the last decade in the Netherlands has seen a huge rise in environmental projects. Stricter controls and huge government founding for cleaning polluted ground and groundwater (through the VROM- "Volkshuisvesting, Ruimtelijke Ordening en Milieu" Ministry of Housing, Planning and the Environment) have caused this market to expand enormously. Engineering geology is diverse enough to be able to manage such projects. The first pioneering graduates in this field are hammering at the door asking for more graduates.

Fourthly new developments in connection with durability of natural materials and abrasion of mechanical excavators and hydraulic pipe transport of dredged materials now form a significant branch of engineering geology largely through research work carried out by Peter Verhoef at Delft. Also significant, especially for the dredging industry, are information systems/ stochastic modelling to help them determine potential profitability of a dredging project often priced on relatively sparse geological information. Rock mechanics, despite the lack of mountains, is of increasing significance: mine subsidence in the south east (the discontinued coal mines of Limburg from the Carboniferous and the building stone mines of the Cretaceous), feasibility study underground pump storage scheme, OPAC in the Carboniferous sandstones and underground storage studies of radioactive and chemical waste. Much of this work has been carried out under the guidance and initiatives of David Price. Initiatives are now under way to establish a European underground space centre to encourage more use of underground space. At Delft a conference is being held on this subject ICUSESS 92 (6th International Conference on Underground Space and Earth Sheltered Structures), as part of the 150th foundation year of Delft University of Technology, to highlight this aspect of engineering geology jointly with Civil Engineers and Architects.

A final aspect, which gives the Dutch engineering geology a head start over his contemporaries in the other European countries, is that his knowledge of languages is usually greater. This is due to two factors: emphasis on languages in secondary schools and television from Germany, Belgium (Flemish and French), France and the UK beamed into about every Dutch household. With the opening of eastern Europe good communication will be perquisite to being able to operate in this potential market place, in places, less then a days drive from the Dutch border.

Commercial side of engineering geology

Grondmechanica Delft, until recently known as LGM (Laboratorium Grondmechanica) was the first organisation to have an Engineering Geology section and have been actively using geologists, geophysicist and engineering geologists on projects such as the Maarkerwaard polder study, subsidence in Maracaibo oil fields, harbour works in India and engineering geological mapping (together with the R.G.D.) of urban areas. They now employ three graduates from the engineering geology section two of which have been working there for over six years.

Fugro, and now Fugro-McClelland has been employing geologists at first by default when Fugro joined with CESCO back in 1972. They employ presently five engineering geology graduates, four are relatively recent graduates from TU Delft. Projects are mostly concerned with marine structure for the oil industry, though through support of their extensive overseas offices many land-based site investigations involve the engineering geologists.

GeoCom Consultants was set up six years ago by two ex-Fugro engineering geologists, Ben Degen and Pieter Maurenbrecher. GeoCom has the distinction of employing the one of the first woman engineering geologists in the Netherlands. Their projects are as extensive as the subject allows varying from marine investigation to route surveys in the Andes. With the assistance of a new partner, also an Engineering Geology graduate from Delft, the firm is expanding into computer information and mapping services.

Other site investigation companies employ engineering geologists, but do not have engineering geology sections such as Joustra Geomet, IGN (Instituut Geotechniek Nederland), Intron, GeoFox and SeaTeam. A number of site investigation companies still have to employ their first engineering geologist.

The main contractors such as the HBG-Group, Ballast Nedam and Royal Bos Kalis also employ engineering geologists but, as yet, a very small number in terms of the size and turn-over of these companies.

Municipal engineering department at Amsterdam, the Hague and Rotterdam are starting to employ engineering geologist. Often the work is not dissimilar to that performed by their geotechnical engineers.

The RGD employs one engineering geology graduate, Floris Schokking, though a number of geologists are graduates from the applied geology course at the Free University, Amsterdam.

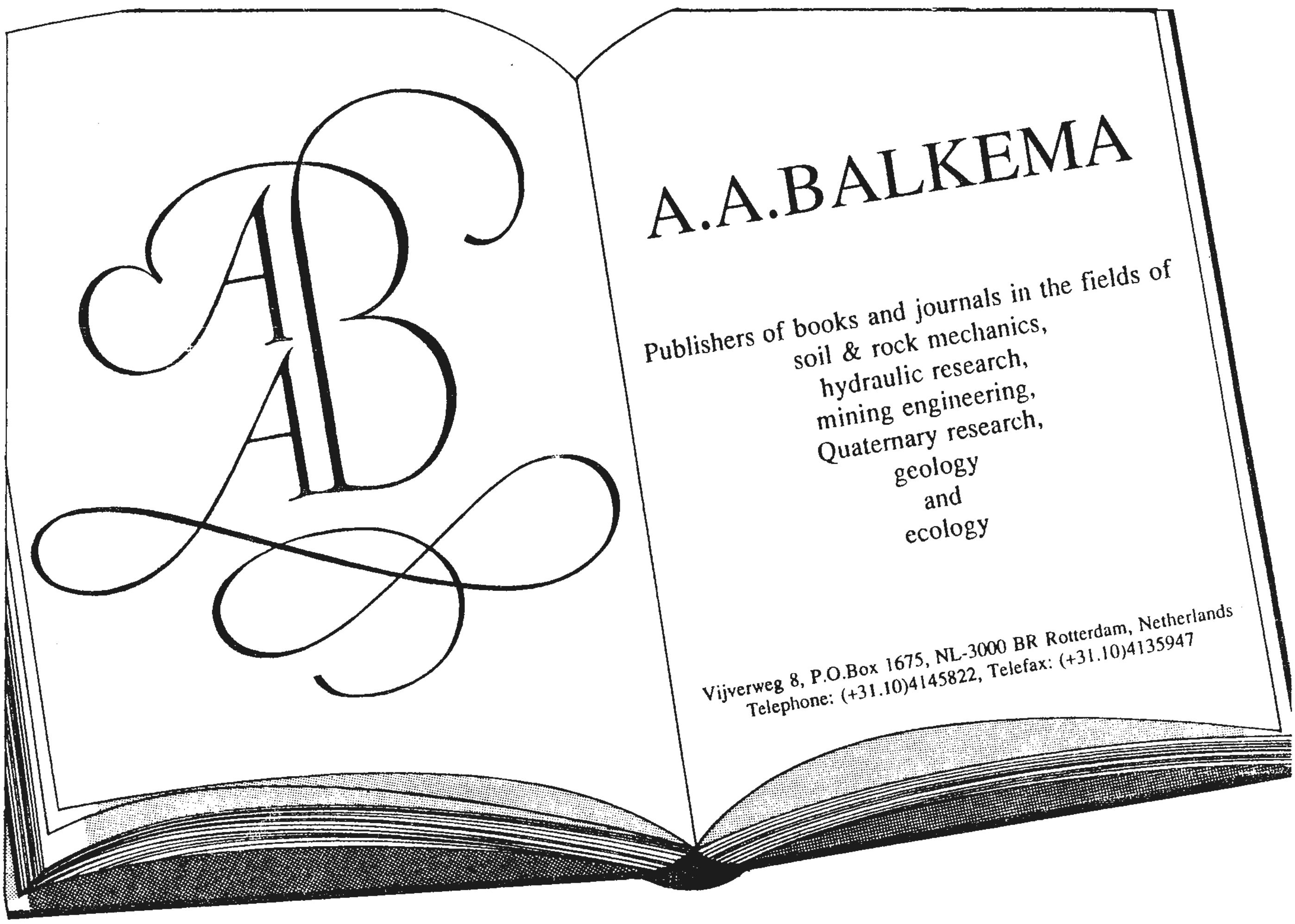
Present and Future

Like the UK the Dutch governemnt is very much concerned with balancing their books. Recent economic evaluation bodes a difficult future. This has resulted from welfare laws which were instituted in the late sixties. Unlike the time these laws came into being the proportion of effective working population in the Netherlands has dropped dramatically (2.5 million for a population near 16 million). The result is that the tax and social security premium burden is now disproportionately high compared to other European countries. This has been met by increasing productivity per person. The result is now the Netherlands working person produces the highest productivity in the world (!) anbd the economic growth is zero. The population that is supported by the 2.5 million working persons are minors, old age pensioners and un-employed of which the latter a large per centage has qualified for permanent sick leave or early pension resulting from stress related reasons. The vicious circle is that high productivity means the working person is increasingly opting out on a redundancy payment due to the increasing stress the person is working under with the knowledge that after taxes the sick-leave or early pension income is not much less then they would get if employed. Much of the electorate now consists of welfare recipients so that the government has been too timid to revise the welfare laws to reverse the trend.

To try and avoid increasing taxes or social security premiums the government has been balancing its budget by cutting back in education. Despite the fact that engineering geologists to date have found employment in the Netherlands, in their vocation, does not secure education in engineering geology. Universities seem to be embarked in self-destruction through implosion as various departments haggle over a smaller subsidies made available to research and education .

Normal economic logic would dictate that we must invest in our future. A government which is too afraid to face an electorate which makes no contribution financially and a government which further can only think solely in terms of accountancy without any form of entrepreneurship has not only created an implosion situation in education but also for the country as a whole.

The bright side is that we will soon witness a collapse of the present government which hopefully by then has at least come face to face with and recognized the Catch-22 spiral The Netherlands has found itself in.


A.A.BALKEMA
Publishers of books and journals in the fields of
soil & rock mechanics,
hydraulic research,
mining engineering,
Quaternary research,
geology
and
ecology
Vijverweg 8, P.O.Box 1675, NL-3000 BR Rotterdam, Netherlands
Telephone: (+31.10)4145822, Telefax: (+31.10)4135947

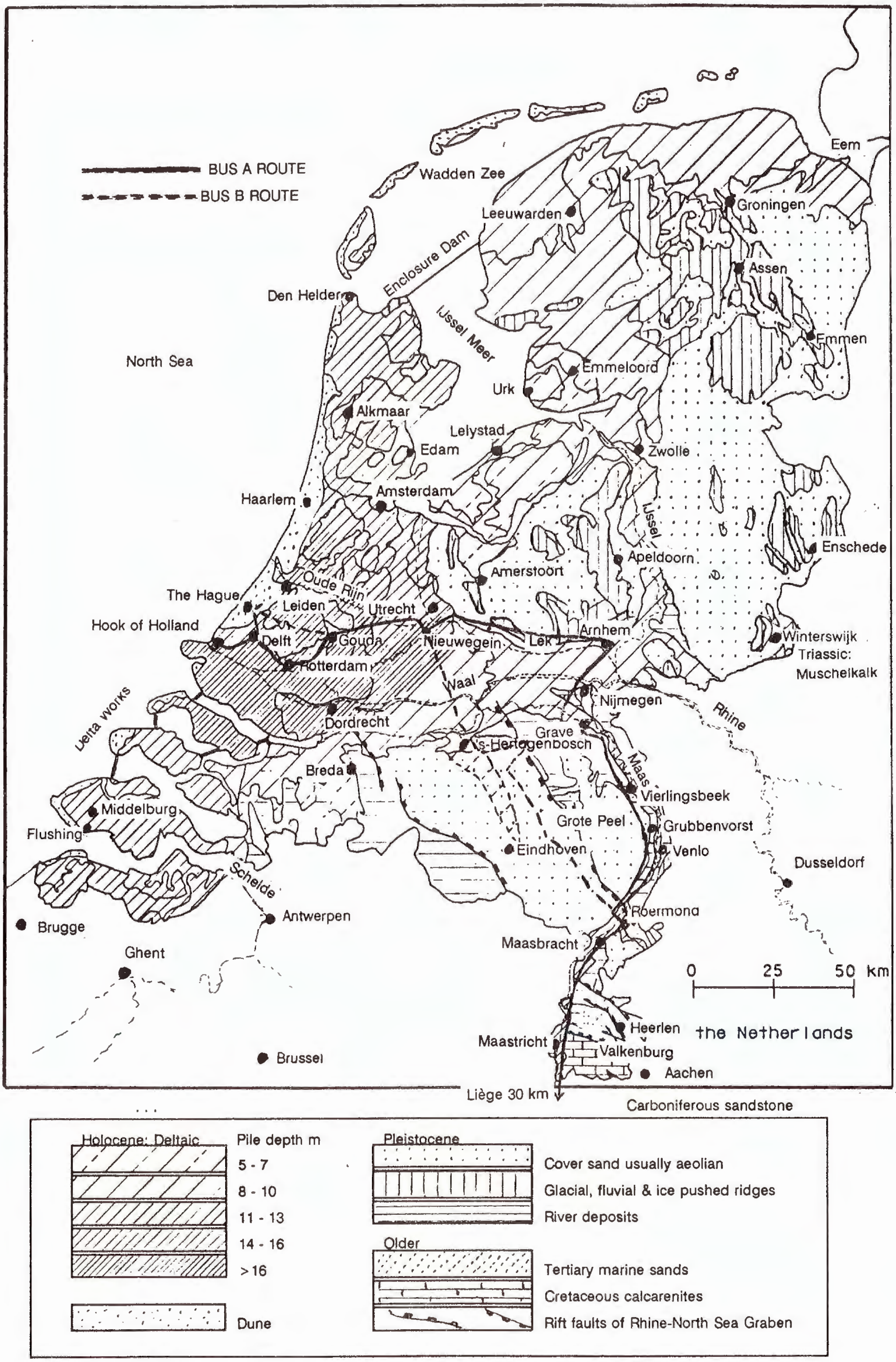


Figure 1 Geology Map with route Bus A and route Bus B through the Netherlands
(based on Heijnen, 1885 and van Staalduinen et al 1979)

Engineering Geological Routes in the Netherlands:
Cross-section of Geological History: The E25 (E9), The Benelux Route

by P.M. Maurenbrecher

Two routes are described in this special "early" autumn issue of the IngeoKring Newsletter. Up to now routes were described from last year's IAEG post-conference tour through the Netherlands. In this issue two routes are described. Route one, the shorter route initially follows the same route up to Utrecht/ Nieuwegein, the E8 from The Hague area (i.e. Leidschendam and Delft). After Utrecht the first route continues east to Arnhem and then south towards Limburg and Belgium. The second route goes south from Utrecht to 's-Hertogenbosch, Eindhoven and then Limburg and Belgium. The routes are superimposed on the geology map (specially drawn for the EEG symposium, Friday 13th) in **figure 1**. Much of the route description has been taken from the route description "Winding into history along the A2 (E2), from the present to 60 million years in the past" which is the motorway the "Fugro" bus B joins at Utrecht to head south for their rendezvous somewhere in the "Peel" district. The "Delft" bus A continues east after a short diversion to Nieuwegein and from that point travellers on the Delft bus must turn over a few pages to the guide written by Floris Schokking.

The Silver Triangle: Westland

Initially you were today relatively safe. Much of Hoek of Holland and the coastal strip towards the north is above sea level: the littoral sand dunes, deposits situated at the top of the geological table: young, Holocene and Recent. The Romans, when they were here must have seen them differently. They stretch in a slight arc northwards from the Hoek towards Den Helder. Much of it is a recreational belt: cycle paths, beaches, wild life sanctuary, three links golf courses on which the second at Noordwijk this year held the Dutch Open, and fresh water infiltration reservoirs. The latter, one area north of the Hague and the other just south of Haarlem supplies most of the Randstad with drinking water. The Randstad (literally *Edge-city*) meaning the cities and towns between and including Rotterdam and Amsterdam (Delft, The Hague, Leiden, Haarlem) water originated from pumping stations on the banks of the Rhine and Maas. The water receives treatment before infiltration, after entering the ground water is filtered by natural infiltration, is stored as groundwater and before it is again extracted it also serves to depress the fresh/salt -water interface (see **figure 1 in Floris Schokking's article**).

You travelled along the E36 if the motorway route was chosen to Delft. This follows the Nieuwe Waterweg, the main arterial canal from the coast to the vast Rotterdam Harbour which serves as a major transhipment point for the hinterland of Europe. Like the waterway it parallels, the E36 connects with the heart of industrial Germany, the Ruhr. The waterway is now the only estuary of the Rhine that is open to the sea. All other estuaries have barriers to protect the hinterland from surge tidal flooding. This will soon end: the first piles are being driven for the construction of a storm surge barrier containing gates eight storeys in height. The gates are to be situated between the Hoek and the next town of Maassluis (**figure 2**).

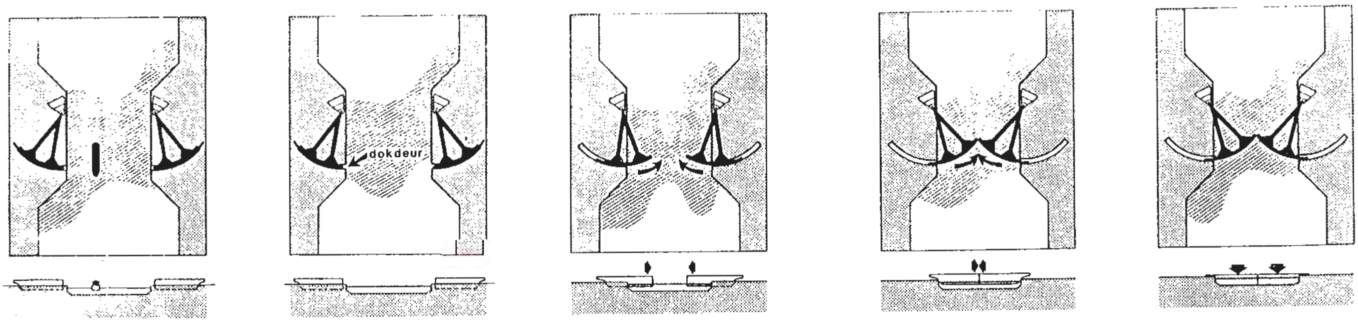


Figure 2. Gate closing procedure for Nieuwe Waterweg storm tidal barrier. The gates can under all water current situations be closed. The design is based on compression loading as a tension loaded gate had negative consequences for the hinge design. (from van Oorschot, 1990)

Maassluis? Translated: The sluices of the Maas. The water is mostly Rhine water flowing past, but at this point the River Maas (you will see quite a lot of this river today) has done a lot of mixing with the Rhine. A Franco-Germanic mix as the two great rivers have been courting nearly all the way from Nijmegen in the east of the Netherlands through tributaries and man made canals. Dredgers allow navigation of up to 300 000 tonne tankers; the mostly Franco-Germanic ooze with a good dose from Switzerland, Belgium and The Netherlands which is dredged from the Nieuw Waterweg is so toxic with strange names like PCBs that it has to be deposited for safe-keeping in large lagoon repositories built on reclaimed land in the Slufter area located in the outer reaches of Europoort; the harbour south of the waterway.

The dunes quickly make way for the flatlands of polder country. These flatlands will remain for Bus B all the way to past 's-Hertogenbosch. For Bus A some relief is promised! After the stop at Nieuwengein near Utrecht. (see **figure 2 of Floris Schokking's article** showing schematized west - east crossection).

Both buses may have not followed the waterway into Rotterdam but instead have opted for the more direct route to Delft (half the distance). This area could be regarded as Holland's silver triangle, The Westland. Satellite pictures show a silvery patchwork area which consists of plantations of glass-houses. Tomatoes are the main crops, but other vegetables are also grown in great profusion. The area is also polder country; below see level and hence drained artificially by a local drainage authority known as Delfland. The drainage authorities gave birth to the democratic tradition in the Netherlands. Known as *Waterschappen* these bodies were cooperatives established by landowners in the middle ages to set up windmills to drain the land. Officials were elected by those who payed for the drainage to run the authorities. It is still an honour in the Netherlands to serve on the committees. The chairman receives the title of *Dijkgraaf*, a Dike Count (Dike Reeve). Their meeting places consist of buildings not unlike those of the London guilds. Much of the deposits are sands: flattened remnants of dunes that have moved farther west, marine sands and estuarine silts and peats. Entering Delft the sands give way to peat deposits whose type location is known as Dunkirk. Strange... though in France it is a Flemish name Duinkerke meaning Dune -church. Its nothing to do with the lithology but with the stratigraphy. The deposits are still very young and they are sensitive to water level changes as too much drainage will cause too much settlement. You may have noticed: the water levels of the drainage ditches in the sandier parts of a polder are usually allowed lower relative to the land then in the peat areas or clay areas. Hence watch those water levels; its says something about the geology.

Delft is an ancient Dutch market town with traces to Roman times; the main navigation canal, the Delfsevaart was built by the Romans and connects the Rhine estuary (now a minor tributary known as the Oude Rijn; *Old Rhine*) to the North near Leiden with the Maas estuary to the south near Schiedam, Rotterdam. Have a close look at the church towers. The "Old Church" leans. The tower dates from the 15th century and is reputedly built on cow-hides for foundation. As you near the University part of Delft, you cross the Roman built canal, the Delfsevaart. Hopefully you were still feeling sufficiently fit especially after the buses' suspension must have been tested on differentially settled roads to cope with a cup of coffee.

Bus A would then drive further into the polder south of Delft containing the mostly rehoused faculties, the result of building spree in the sixties and seventies to Delft Geotechnics. The road at present is quite level; it had settled much but recently been elevated and levelled.

Bus B would have continued to Leidschendam following the Roman canal north along the levelled remnants of dune deposits on which satellite towns of The Hague, Rijswijk, Voorburg and Leidschendam are founded. The Hague itself is situated both on remnants and on actual dunes, parts are in fact quite hilly towards the sea side resort area of The Hague with the tongue-twister name of Scheveningen. Older buildings are often founded on spread footings rather than piled foundations. The main roads in The Hague follow a grid pattern based on the older dune ridge lineations which trend NE-SW slightly skew to the present coast (NNE-SSW). One of the Province of South Holland's provincial deputies, with the appropriate name of Mr. R.E. Waterman, is the principal champion for re-aligning the coast between Scheveningen and the Hook to create more land for recreation and urbanization. He gave an excellent presentation last year for the occassion of a seminar organised to celebrate the first five years of the students' chapter of engineering geology at Delft "DIG" meaning *Dispuut Ingenieurs Geologie* and GeoCom a Dutch engineering geology consultancy started by two Herbert Lapworth Club members who also celebrated five years of survival (from the sea, of course).

The Hague area to Utrecht: The Wetlands

Travelling east especially from Leidschendam one is almost abruptly into the polders of Holland consisting mostly out of peats and clays. The route could follow two motorways to Gouda. Bus A will

probably head for Rotterdam then turn east. Bus B will probably head straight east from The Hague. The Rotterdam route is of interest in that more suspension tests will be experience as the bus rides over some of the worst soil conditions that can be found in the Netherlands. Deep deposits of very soft clays and peats extending up to 15 to 20 m before a sand layer is found to support a pile foundation. At the main junction just before entering Rotterdam look at the terraced houses on the right. These often are illustrated in articles and textbooks as a good example of differential settlement.
For the next five kilometres the road is elevated. Piers and pile foundations have kept settlements at bay. Once back into the flatlands its back to polder country and further suspension trials. The depressions in the paving are attributed to two possible causes:

Differential settlement as a result of

1. infilled channels

2. drainage culverts.

The locations are easy to spot on aerial photographs as the vehicles usually spill leakage oil droplets from the sudden upward or downward acceleration.

Bus B also heads straight into the polder. Lakes have been formed recently (one on the left). These are borrow areas for sand used for elevating much of the motorway complex at the outskirts of The Hague. Then hills! appear. These are refuse disposal dumps landscaped and wooded. They now function as recreation area (a golf course) and a sound screen for the satellite town of Zoetermeer. On the right a large is area is being prepared for a large exhibition "The Floriade" to show-off horticultural products (as well as industrial).

Once past the urban and industrial areas of Zoetermeer and east Rotterdam more traditional polder landscape appear; long rectangular fields separated by straight linear drainage ditches instead of wire fences or hedges. The symmetry and regularity of the pattern suggest a modern development. In fact they usually date from medieval times. The cows in the field, usually always of Frisian stock produce the local cheese; Gouda. Where the motorway from Rotterdam joins the motorway from The Hague it passes beneath the Gouwe canal viaduct. The canal connects the river Amstel (Amsterdam's namesake river) with the Rotterdam Rhine tributary "Hollandse IJssel". Your lunch packet should contain one Gouda cheese sandwich which you can now enjoy as we pass Gouda on our right. Gouda is situated in an area which contain thick peat deposits. These have been excavated over extensive areas of Holland to supply fuel before the coal fields of Limburg took over. The excavations left many scars in the form of lakes and ponds. Now these "scars" are recreation areas and nature reserves. They have risen to the level of national monuments because of their unique landscape. Will the scars we create today follow the same path? No one seems to think so. The Reeuwijkse plassen ("plassen" means anything from puddles to lakes as well as the verb "to pee" in Dutch) are such a recreation area. It has been exploited further for its sand. Hence in places they reach 40 to 50 m depth. The motorway continues east now alongside the Old Rhine just to the north towards Utrecht. The deposits are mostly fluvial in origin consisting of sands and clays, though beneath are often peats. One can only recommend along this slightly monotonous stretch to eat a ham sandwich and do a bit of drainage ditch water level spotting to determine what type of soil type is being drained.

Utrecht to Brabant: Rivers & Rifting

Just before Utrecht we turn south onto the A2. The A12 or E36 continues east as Bus A route described henceforth; Floris Schokking takes over the route description. The A12 (Bus B route henceforth except for a short diversion of Bus A into Nieuwengein) continues over the Dunkirk fluvial/deltaic sediments laid down by the tributaries of the Rhine. Just beyond Nieuwegein we encounter our first main Rhine tributary, the Lek River. The other principal tributaries are the IJssel (not the Hollandse IJssel; its all part of the confusion river wrought on deltas) which branches off towards the northwest skirting the ice-pushed ridges along their northern flank flows into IJssel Lake, the old Zuider Zee (South Sea) and the Waal the largest tributary which we cross after another 25 km further along the A2. The geology remains Dunkirkian. The area is known as the Betuwe which is known for its fruit orchards. A second east-west road, the A15 we cross before crossing the Waal onto the island of Bommelerwaard. It is an island as after only another 10 km we meet yet again another major river. This time It is not a Rhine tributary but the Maas River which started of as the Meuse in France, flows as the Meuse through Belgium until it reaches the southeastern extremity of the Netherlands at Maastricht. There-after it becomes the Maas and for a short length also forms the border with Belgium. For that part of Belgium it is also known as the Maas as the Walloon (French speaking) and Flemish (Dutch speaking) border in Belgium meets the Netherlands at the same point where the Meuse/Maas enters the Netherlands.

About 10 km east of the bridge a short channel connects the two great rivers. Further down stream the major confluence occurs in a wild marshland area known as the Biesbosch; hence the island of Bommelerwaard.

The young deposits and rivers congregating in this area can be mainly attributed to the fact that the whole route we are following to Limburg follows a basin which is subsiding along the graben of a major rift fault system. Two routes are postulated from 's-Hertogenbosch ("Den Bosch" on the road signs). The first route probably is the one you would approximately take. They were written for the IAEG excursion last year which in the end followed the second route, shorter route, despite no hold ups. The first route as we pass 's-Hertogenbosch (pronounced *sairtochenbos* the *ch* as in the Scottish pronunciation of *loch*) provincial capital of Brabant. 's-Hertogenbosch is near the centre line of the rift graben so that Pleistocene deposits extend to 200 metres depth and the underlying Tertiary sediments extend beyond 500 metres depth (see crossection **figure 6 from Floris Schokking's article**).

The first route is to view the still active Peelrand fault. The fault forms the first fault of many on the north eastern flank of the graben. Evidence for the fault can be seen at Uden. To reach this we drive east to Oss along the A50 then at the Oss by-pass we drive down country roads for 10 km to Uden. At Uden we follow the road to Veghel which first by-passes Uden to the east. Along the turn-off to Volkel and the military cemetery on the left is where the Peelrand fault forks to the northwest into two faults. It runs parallel to the road up to the railway track, where after it trends south east as the road makes a wide bend to the east. At Uden the oldest Pleistocene formation (Tegelen) on the north eastern side is faulted against the youngest (Twente) on the south western downthrow side. To the east are fluvial deposits of the Veghel formation and the general low lying area of the Peel which has inland peat deposits from the Eemian interstadial of 70 000 years ago.

We head then along the road to the town of Veghel from which the name of the above formation is taken. There we turn left along the Zuid-Willemsvaart the main navigation route from 's-Hertogenbosch to the Belgium canal which connects the Maas further upstream with the port of Antwerpen. The land now rises towards a watershed that approximately follows the Belgian-Dutch border to the south. The rise in land is the result of glacial wind blown sands piling up against the rise of the Brabant-London Massif which has not been effected by the rifting skirting its eastern flank. The sands blew in from the north picked up by arctic winds as they passed over the glacial deposits derived from the high ground east of Utrecht. The nutrient of the ground is less than in the fluvial flat lands and hence much of it is forested.

Brabant to Limburg: Heathland

If there was too little time to visit Uden the bus would have continued along the A2 (N2) from 's-Hertogenbosch to Eindhoven. The geology again is the same as described above along the Zuid-Willemsvaart canal. The terrain passes a ridge of dune sand which trends SW-NE to the north of Eindhoven and can be found on normal route maps "Lieshoutse*heide*" near the Zuid-Willemsvaart and "Sonse *Heide*" east of Best along the N2 to Eindhoven. "*Heide*" means heath and suggests high sandy ground covered with heather. Much of this terrain persists round Eindhoven "Oirschotse*heide*", and further SW Oostelbeerse *Heide* etc all the way into Belgium. Further parallel ridges exist towards Tilburg as well as to the south of Eindhoven though the SW-NE trends seem less obvious as stream erosion dominate the landform in this area. Eindhoven is a company town. Philips has their headquarters here; it also started here 100 years ago and supplied electric lamps then to light up the Winter Palace of the Czar of Russia. The football club of Eindhoven is called PSV: Philips Sport Vereniging and it supplies players to the Dutch national team.

Limburg: Uplands

The sands continue up to and past Weert where the Zuid Willemsvaartroute joins the A2. The road approaches a large power station the Claus Centrale, which derives its cooling water from the River Maas. The River Maas has followed a circular bend of radius 50 km with Eindhoven at its centre and so now it is tangential to the SE radius flowing towards the NE in a large broad valley whereas at 's-Hertogenbosch it was tangential to the northern radius flowing west. The Maas has been considerably widened caused by gravel exploitation from the gravels the river has transported from its source quartz and granite rock in the Ardennes and the Vosges.

Crossing the bridge the A2 follows the Maas upstream which unbends almost into a straight line south. The terrain remains slightly undulating, all the way to the Sittart junction. On the right can be seen the dyke which contains the elevated Juliana canal; the navigation channel of the Maas /along this stretch which rejoins the river just north of Maastricht, "the Juliana Haven". The ground cover is becoming less sandy as distance has sorted the glacial sand winds from the north so that finer sands and silts make up the soil cover. This soil offers more nutrient and in this area is ideal for asparagus cultivation. Asparagus features locally on every menu during May and June. The Quaternary here does not dominate as it did up to now, monopolising only the narrow (7 to 15 km wide) isthmus of Dutch land that extends from the Belgium border along the Maas in the west and to the border with Germany on higher ground in the east. The higher ground becomes Tertiary sands of the Miocene famous for the huge open pit brown coal mines further east.

Shortly we reach the Van Der Valk hotel with its large incongruous Toucan bird sign. We have travelled up to thirty million years. Here we stayed with last year's IAEG conference tour. A further ten minutes drive you rise into the Cretaceous limestone plateau landscape of south Limburg. Across the road is the northern end of a large chemical complex of the DSM. DSM has its origins in geology; *De Staats Mijnen* meaning The State Mines. Part of the complex exists over the now discontinued Maurits Mine. The mines obtained Carboniferous coal which had replaced peat as the main energy source in the Netherlands during the nineteenth century. In 1973 the last mine was closed; coal by that time had been replaced by a cheaper cleaner source of energy: the vast natural gas fields of Slochteren in the northern extremity of the Netherlands. The Staats Mijnen had been diversifying into chemicals. Less labour intensive then the mines the miners had to find work elsewhere. Many were employed in the then fledgling automobile industry of the DAF car factory at Born situated just to the north at the narrowest section of the isthmus. Since 1976 the DAFs became Volvos.

The higher ground to the west is the Belgian Limburgseheide underlain by Miocene sands and the very ancient pre-Cambrian quartzites of the London-Brabant massif.

Just a kilometre to the north is the Heerlerheide fault, part of south western flank of the graben extending up to and past 's-Hertogenbosch. The fault system forms part of a rift complex extending well into the northern limits of the North Sea, passes through the Netherlands, winds its way along the Rhine towards Switzerland, then through France along the Rhone valley and into the Mediterranean through Sardinia and the Sicilian Channel ending up beyond the Gulf of Sirte in the desert wastes of the eastern Sahara. (see **figure 3**).

The A2 is also European Route E9. This continues to Luik (Liège) and onwards through the Ardennes along the north-south border between Luxembourg and Belgium towards France. The geology not only becomes much older, it also holds some hidden surprises. The surprises were for the foundations of the piers of the viaduct which bridges the roads and the River Amblève at Remouchamps. Remouchamps is renown for the underground Devonian limestone caves and subterranean rivers.

The next junction is the E39 (in this part of The Netherlands roads have a more European significance) which connects Aachen -the road signs use the Dutch spelling of "Aken"-, (the centre of civilization in western Europe during the Holy Roman Empire, where Charlemagne was born and had his palace, Aix-la-Chapelle) just across the border to the East with the port of Antwerpen to the West. Antwerpen is Belgium's great port and on the river Schelde. The Schelde is the last main river to make up the delta of the Netherlands as its estuary in the south western extremity of the Netherlands. Together with the Maas it drains the whole of Belgium.

At the Van der Valk hotel we were very near to our 60 million year goal. The Heerlerheide fault upthrows the Cretaceous close to the surface near the Hotel. The road now gradually climbs up the Cretaceous plateau passing up through increasing older terraces of the Maas. At the top is the airport of Beek, which is better known for keeping flight paths in control as the skies above are one of Europe's highest density airliner cross roads. Beek occupies much of the northwestern part of the south Limburg's plateau; they want to occupy more for a second runway.

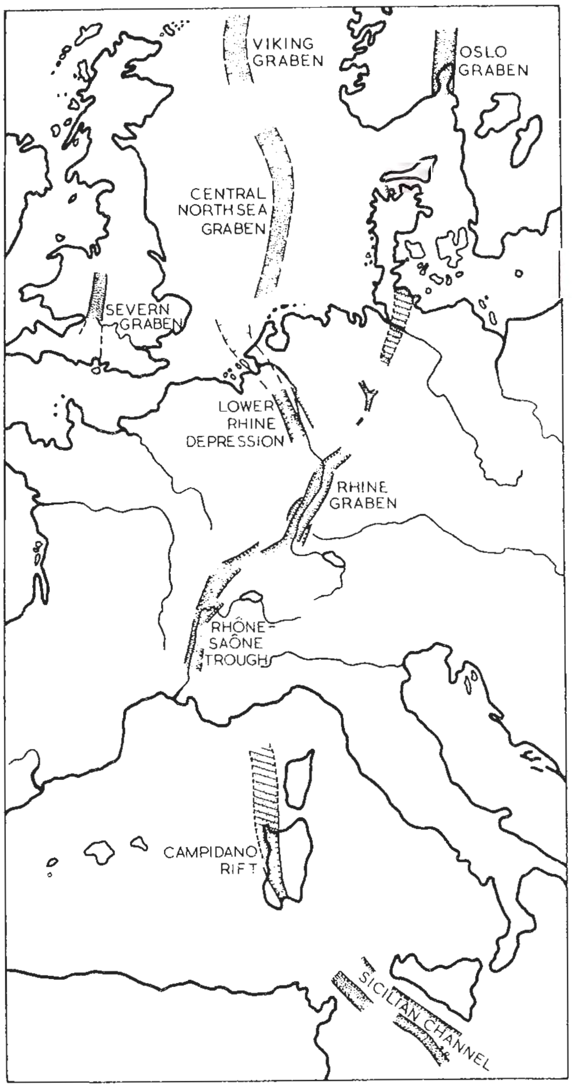


Figure 3 The rift system of western Europe (taken from Ager 1980 attributed to P. Wallace)

The A2 now drops down a steep gradient back towards the Maas valley where it joins the valley of the Geul. We pass Maastricht to our right, We continue following the Maas upstream along its east bank and see to our right the remnants of the Cretaceous plateau in this remaining corner of the Netherlands. Just before the border, a few hundred meters to the south of the Maas locks and the large cut for the Albert Canal which takes river transport to Antwerp are thee ENCI cement works and its large quarry in the Cretaceous calcarenites (Upper Chalk; Maastrichtian) the St. Pietersberg (see **figure 4** crossection through the Maas valley and the St. Pietersberg).

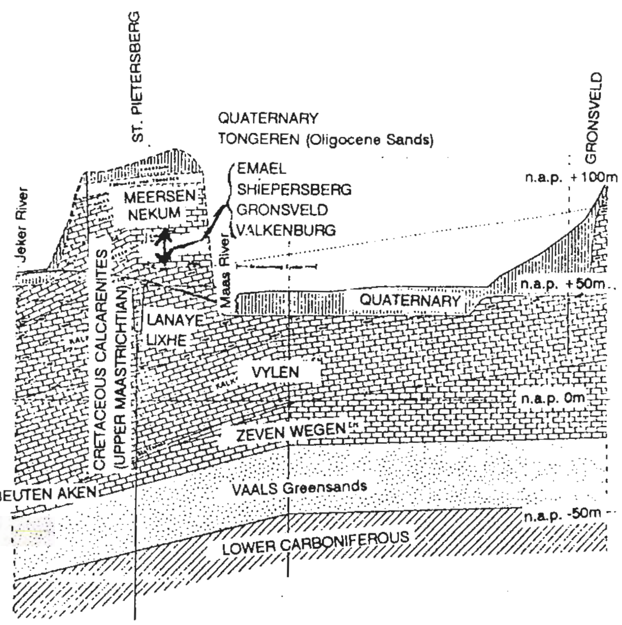


Figure 4 West to East geological crossection of the Maas valley at the St. Pietersburg. **from west to east: Jeker valley, St. Pietersburg/ENCI, Maas and Gronsveld Cretaceous plateau scarp.(from RGD report)**

Quarry and mine-lands: The ENCI

The ENCI: means Eerste (First) Nederlandse Cement Industrie was established in 1926. It is owned by Belgian and Swiss holding companies specialized in cement. It also supplies nearly 80% of all cement needs for The Netherlands. This guide will refrain from divulging too many statistics, that pleasure we leave to our hosts at the ENCI. Behind the ENCI is a vast quarry. It has exposed the Maastrichtian, the local Maastricht formation and its underlying upper section of the Gulpen formation. More of the Gulpen will be soon exposed as the ENCI has received a concession to excavate deeper to ensure The Netherlands retains its first (and almost only) cement industry. Environmental concern has though made greater stipulations; the ENCI must determine the effects on the aquifers surrounding the quarry as they are also digging still deeper below original groundwater levels. Groundwater in Limburg is the principal drinkwater resource, especially the groundwater from the Cretaceous limestone aquifers.

This is no easy job. The limestones appear to be uniform calcarenites. They are certainly more uniform than other sediments. When it comes to predicting groundwater flow and aquifer parameters such as permeability, transmissibility and storage, simple sand aquifer modelling we are used to in the dune areas of the coast of Holland do not apply.

Plans have been made to increase the mining depth to 5 metres above sea level. Presently, the hydrogeological consequence of these plans in and around the quarry is a subject of investigation. As yet, only a minor increase of groundwater inrush due to a deepening of the excavation level is anticipated. It is only in zones of major fractures or faults that an important additional inflow of groundwater appears to occur.

Engineering geological studies were also carried out previously to examine the strength and deformation properties of the calcarenites. Professor David Price will be only to willing to describe this work he carried out during students field work early in the 1980s.

Other significant incidental aspects of the ENCI of interest to engineering geological are properties of the calcarenite with respect to making of cement. Of concern to the ENCI is not only the carbonate content of the calcarenite (it drops with depth) but also the water content. The low permeability means water is retained requiring more fuel to dry the rock before processing. The flintstones are very numerous with depth, though their number reduces as the ENCI penetrates beyond the Lixhe formation. The flintstone, locally known as "silex" is used to grind the cement clinker in the rotary kiln. It's otherwise run to spoil and used in the quarry as a temporary paving for access roads.

The final aspect is the reinstatement of the quarry once a section of it and eventually the entire quarry when the concession runs out. Much of the reinstatement has already been achieved in which the ENCI prides itself for receiving in 1988 a high European commendation. It is the southern area known as the "Observant" because of its fine views over the Maas. Fine views? In winter possibly as the trees are so numerous. Its on a spoil dump. One would hardly notice it was man made and that the ENCI complex was so near.

Building stone mines and the St. Pietersberg

Floris Schokking in his article mentions Napoleon's army floundering in the melt ice. Despite the occupation of the Netherlands, obstensibly to give the Dutch a bit of culture, Napoleon's army is the butt of Dutch military anecdotes. Very extensive buiding stone mining has taken place in the Cretaceous of southern Limburg since about Roman times. The French army lay siege to the St. Pietersburg Fort. The army filled the mines underneath with gunpowder kegs for an attempt "undermine" the fort in this way. The high bulking factor of the calcarenite rock ensured after the explosion no subsidence took place.

Oldest mine in The Netherlands? Rijkholt:

We then pass Rijkholt to our right where old flintstone mines were discovered; attributed to the Neolithic period. Peter Bosch, from the Netherlands Geological Survey in Limburg, published an article in Scientific American (1979) on these mines.

The border with Belgium is reached and we continue south towards Liège. It will probably be dusk by now. The Meuse, as the Maas is now called continues south then divert to the southwest after Liège. The geology is still Cretaceous though the river cuts down to the Carboniferous lying unconformably beneath after a geological hiatus. Much of the towns in this part of Belgium have a mining history; iron ore, coal as well as numerous slate and limestone quarries make the area a geological paradise. Drive on the the A2, or more in the European context now that we are climbing past Liège towards the Ardennes: the E25 (if you persist it takes you all the way to Genoa via Luxembourg, Metz, Strasbourg, Basel, Bern, Geneva, the Mont Blanc Tunnel and Turin). Older maps show it as the E9 except that the E9 starts in Amsterdam and the E25 (hold your breath), Hoek of Holland.
This most "EEG" (in Dutch it means *Europese Economische Gemenschap* i.e. Dutch for EEC!) of routes can be found an engineering geology article (Waltham et al. 1986) on the foundations of its viaduct at Remouchamps only a short distance south. By that time the rock is Devonian limestone. We wish you an interesting stay in Belgium and your guides who are not adverse to Belgium geology (real relief) would not be adverse towards a Belgian beer or two.

Bibliography

Ager, D.V. (1980) The geology of Europe. McGraw-Hill, London 554pp

Bosch, P.W. (1979) A Neolithic Flint Mine. Scientific American, June, 98-105

Heijnen, W.J. (1985) Design of foundations and earthworks. in The Netherlands Commemorative Volume for the 50th anniversary of the ISSM&FE, editor: E.H. de Leeuw, published by Netherlands Member Society, p53-70.

Oorschot, J.H. van, (1990) Circelvormige sectordeuren beschermen Zuid-Holland. (*Circular shaped sector doors protect South Holland*). Land + Water, Jan/Feb 86-90

Staalduinen, C.J. van, H.A. van Adrichem Boogaert, M.J.M. Bless, J.W. Chr. Doppert, H.M. Harsveldt, H.M. Montfrans, E. Oele, R.A. Wermuth and W.H. Zagwijn (1979) The Geology of The Netherlands. Mededelingen Rijks Geologische Dienst Vol. 31-2 49pp

Waltham, A.C., G. Vandenven, and C.M. Ek (1986) Site investigations on cavernous limestone for the Remouchamps Viaduct, Belgium. Ground Engineering Nov. 16-18

First announcement / **Call for papers**

ICUSESS '92

5th International Conference on Underground Space & Earth Sheltered Structures
2nd to 7th August 1992 Delft University of Technology, The Netherlands

The Netherlands National Research Centre for Innovative Use of Underground Spaces, the NOVA TERRA Foundation, invites authors to submit papers for the 5th International Conference on Underground Space and Earth Sheltered Structures. The conference will be held at Delft University of Technology from 2nd to and including 7th August 1992. The conference will be held in the English language. All abstracts and papers must be submitted in English. There will be no translation facilities at the conference.The aim of the conference is to develop discussion and exchange knowledge and opinion about all factors relating to the development and use of underground spaces and earth sheltered structures for living, working, recreation, infrastructure, industry and storage and as an aid to the environmental protection of the surface. The conference is open to all with interest in the use of underground space and it is expected that delegates will come from the fields of civil engineering, architecture, geology, planning, economics, politics, law, medicine and environmental science.

The proceedings of the conference will fall under five main themes. These are:

1. **Planning** The use of underground space and earth sheltered structures within urban, national and environmental development planning.

2. **Design and use** Architectural and social design of underground space with regard to function, safety, natural light, comfort, health and utilisation, in accordance to specific uses and possibilities of underground space.

3. **Construction** General problems relevant to the construction of new underground spaces and the use of existing underground space and earth sheltered structures. Environmental impact of the construction process.

4. **Economy** The economy, marketing and financing of the use and development of underground space and earth sheltered structures, in particular in contrast to the continuing exploitation of surface space. The economy of mining/quarrying with a view to creating underground space.

5. **Law and politics** The present situation and developments in national and international law, standards and political opinion with regard to the use of underground space and earth sheltered structures. The use of underground space and earth sheltered structures as a factor in the development of policies for environmental protection.

Case histories relevant to one or a combination of the themes listed will be particularly welcome.

Submission of abstracts

Authors are invited to submit 5 copies of the abstracts (of not more than 300 words) of their intended papers as soon as possible, and no later than 30th. September 1991, to the Conference Bureau. Abstracts will be reviewed by qualified professionals engaged in the field covered by the conference under the supervision of the Scientific Committee. Authors of abstracts accepted will be informed by the Scientific Committee as soon as possible and not later than the 1st December 1991, of acceptance and sent instructions for the required typographical form of their paper. The arrival deadline for the submission in a camera-ready form is the 1st May 1992. All papers will be refereed.

Proceedings

The proceedings will be available during the conference. They will be edited by Prof.Dr.Lester L.Boyer of the Texas A & M University, USA. The proceedings will be officially published.

Reply Card

Please use typewriter or CAPITAL LETTERS

Surname...

First Names..

Affiliation...

Address..

Postal Code/ City...

Province/Country...

Tel:...Fax:..

I estimate my chance of attending the Conference as __100% __50% __ 0

__ I will attend with ___ accompanying person(s)
__ I intend to submit an abstract
__ I would like to follow the post congress excursion__ I will prepare __ poster(s) for the poster sessions
__ I would like to be kept informed on developments

Organisation of the conference

Sunday 2 August 1992

Registration and excursion.

Monday 3 August to Friday 7 August

Plenary sessions of the Conference. A half day technical excursion will be held on Wednesday 5th August 1992.

Keynote speakers will be invited to give "State of the Art" lectures relevant to each of the main themes. It is intended to allow selected authors to present their papers. All authors may present their papers as "posters"; poster sessions will be held at which authors will have the opportunity to discuss their papers with other delegates. There will also be time for questions and discussions within the plenary sessions.

Saturday 8 August

The Organising Committee intends to organise a post congress excursion for about 7 to 10 days to visit underground space sites throughout Western Europe. Those who would wish to participate in such an excursion should complete the box on the reply card.

Accompanying persons

There will be a touristic programme for accompanying persons.

General information

All correspondence should be sent to the Conference Bureau which is: Congress Office ASD, P.O. Box 54, 2640 AB Pijnacker, The Netherlands, Tel. 31 1736 95356; Fax 31 1736 92242. Per 6th May 1991: P.O.Box 40, 2600 AA Delft, The Netherlands; Tel. 31 15 120234; Fax 31 15 120250.

- -

please return to:

Congress Office ASD
P.O. Box 40
2600 AA Delft
The Netherlands

Date

August 2 - 7, 1992.

Location of conference

Delft University of Technology, Aula Building, Mekelweg 5, Delft, The Netherlands.

Registration fee

- if received before June 1, 1992
  Dfl. 1.150,--; ± $ 680,--.
- if received after June 1, 1992
  Dfl. 1.300,--; ± $ 770,--.

Hotel accommodation

Hotel accommodation will be available in The Hague and at prices ranging from Dfl. 260,-- for a double room and Dfl. 195,-- for a single room per day.

Second announcement

The Congress Second Announcement will be issued in October 1991, and will include full details and registration forms.

Authors - please note these important dates

Abstracts received after 30th September, 1991 will not be accepted. Authors will be notified of the decision of the Scientific Committee not later than 1st December, 1991. Complete camera ready papers should be submitted by 1st May, 1992.

ICUSESS '92 occurs during the 150th anniversary year of the University of Technology, Delft. The University is the principal sponsor for the conference through the faculties of:

* Architecture, Housing and Urban Planning
* Civil Engineering
* Mining and Petroleum Engineering

Please note:

The Nova Terra Foundation intend to establish through the European Community a European Underground Space Centre (E.U.S.C.). 1992 has, after all, been earmarked by the Community as the year to further their ideal of unity between member nations by creating on European customs union and hence allowing unrestricted movement of goods and people across members' borders. Hence in the spirit of 1992 an effort is made by the Nova Terra Foundation to establish a the E.U.S.C. to encourage more use of underground space for the whole of Europe.

We would be pleased if you would return the reply form even if you are unable to participate in the conference. We can then keep you informed of any new developments with regard to the European Underground Space Centre and provide you with relevant information.

Engineering Geological Routes in the Netherlands:

Netherlands in relief: Part 2 / bus A: East by southeast, Nieuwegein, Arnhem, Grave, Vierlingsbeek, Maasbracht

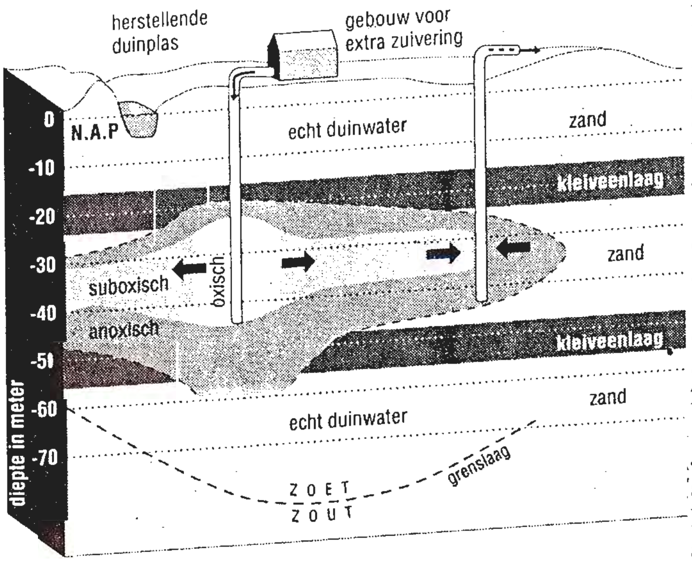
by F. Schokking

After reading the first part of the journey through flatlands and wetlands you will be pleased to know that Bus A passengers will shortly find relief from the monotony and they can all feel sorry for Bus B passengers who will have to wait until the late afternoon before they two will be relieved by relief. Probably they would have resorted to special Dutch gin brewed with waters taken from the peat bogs of the Peel district to drive away the flatness. We will know once in Liège tonight. Floris Schokking takes over as your guide from Nieuwegein to give you some relief from Pieter Maurenbrecher who hopefully got the bus (and lunches!) as far as Nieuwegein. Please note that he refrained from using the map given in the EEG '91 poster.

About the flatness of Nieuwegein..

From Nieuwegein we drive to the South to cross the river Lek, the name for the river Rhine in this area, and then to return to the North near Vianen to see some interesting civil engineering works.

Close to the office of KIWA the intake is situated for Rhine water used for the surface infiltration in the coastal dunes SW and NW of Amsterdam. This water is used to recharge the fresh water bell from which water is abstracted for use as drinking water for the city of Amsterdam and other large cities in the Province of North-Holland. At the intake the water is cleaned for 40 to 50% from heavy metals, partly from phosphate and from silt and clay.
Ecological instability of the dunes as a result of the "area alien" water and the gradual draw down of the regional water table necessitate the future use of deep infiltration methods of the water (**Fig. 1**).



GLOSSARY **herstellende duinplas:** recovering dune pond, **bebouw voor extra zuivering:** building for extra treatment, **echt duinwater:** original dune wate, **kleiveenlaag:** clay-peat layer, **(sub), (an)oxisch:** (sub) (an) aerobic **zoet/zout:** sweet/salt **grenslaag:**boundary layer

Fig. 1 Deep infiltration of Rhine water in dunes

East of the bridge, which brings us back to the North of the Lek, one can see the weir complex at Hagestein, consisting of a weir and a lock. This is one of the several weir complexes in the river Rhine that regulate the water level in the river to keep the river also navigable in times of low run off. Near Arnhem in we will see a similar weir near Doorwerth. In the middle one of the three piers of the weir at Hagestein a 1 MW turbine is installed; the first hydroelectric power station in The Netherlands!!

Just East of Nieuwegein runs the Amsterdam-Rhine Canal, made several centuries ago to ship cargo from the transit harbour of Amsterdam to the Eastern Netherlands and Germany. It connects with the river Lek near Wijk bij Duurstede (one of the earliest settlements in The Netherlands dating back from pre-Roman times *the first Englishman to pronounce **Wijk bij Duurstede** correctly wins a bottle of Genever, courtesy Floris Schokking*) and with the river Waal near Tiel.
A branch of the canal connects at Vreeswijk with the Lek where in 1894 the Koninginne (Queens) lock was built, which made the canal navigable for ships up to 1200 t. In 1931 it was decided to construct a waterway from Amsterdam to the Upper Rhine which was navigable for ships up to 4000 t. This route only became operational in 1952. Since that time further enlargements of the canal to allow push-tow navigation have been accomplished including widening of the canal to 100 to 120 m and deepening to 5 m and construction of push-tow locks along existing locks at Wijk bij Duurstede and Tiel with dimensions 260x24 m (ANON, 1985).

Just after turning East on the motorway we can see on our right hand side the Fort Vechten. In Roman times it was a naval base called Vechio and was situated on the Kromme Rijn (Curved Rhine), a now mostly abandoned Rhine tributary running through the city of Utrecht and entering the North Sea near the city of Leiden (see Geological Map).
Fort Vechten formed part of the fort girdle defending the city of Utrecht and was positioned at the eastern boundary of the Nieuwe Hollandse

waterlinie (approx. 1880).
The waterlinie (water defense line) was a barrier existing of a stretch of inundated low lying areas, which protected Holland against invasions over land. It could be formed by breaching water retaining structures. This was done successfully in 1672 when Louis XIV of France tried to conquer Holland.
During the French revolutionary wars in 1795 marshal Pischegru thought he could eliminate the effect of waterlinie by waiting for frost. During his first successful advance over the frozen water he had to retreat as a result of a sudden thaw, suffering heavy losses. The next year he was more successful

Relief of glacial proportions! (for the Netherlands): Utrechtse heuvelrug and Gelderse Vallei

Driving to the East on the motorway to Arnhem, we gradually leave the peat-rich floodbasin deposits and the sandy Pleistocene layers are nearing the surface **(Fig. 2)**. Near Maarn we reach the Utrechtse heuvelrug (Utrecht hill ridge), sandy ice-pushed ridges surrounding glacial basins, dating from the Saalien period.

Several of these glacial basins are situated at the southern extent of the Saalien land ice sheet **(Fig. 3)**. The basin we are passing is filled in the southern part with syn- and postglacial sediments as meltwater sediments, stagnant water sediments, slope deposits and eolian sediments, mainly composed of fine sands and silts and peat.

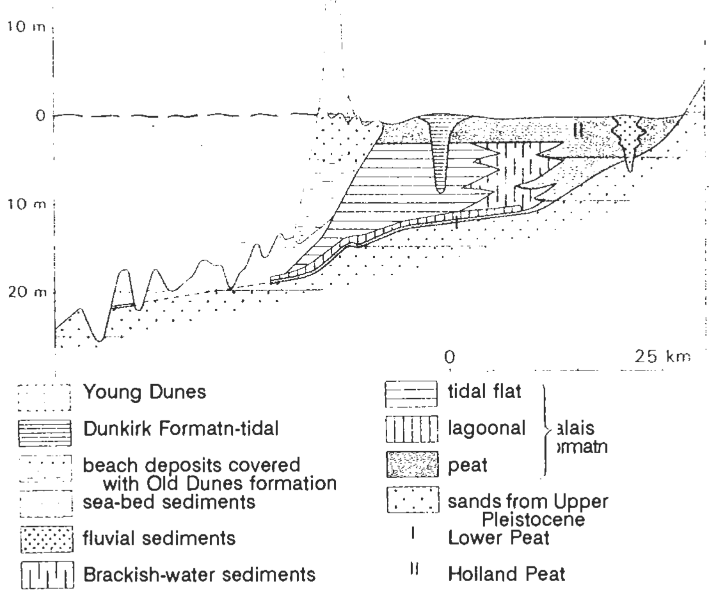


Fig. 2 Schematized W - E cross section through the Holocene deposits in the western part of The Netherlands (after Stichting Wetenschappelijke Atlas van Nederland, 1985).

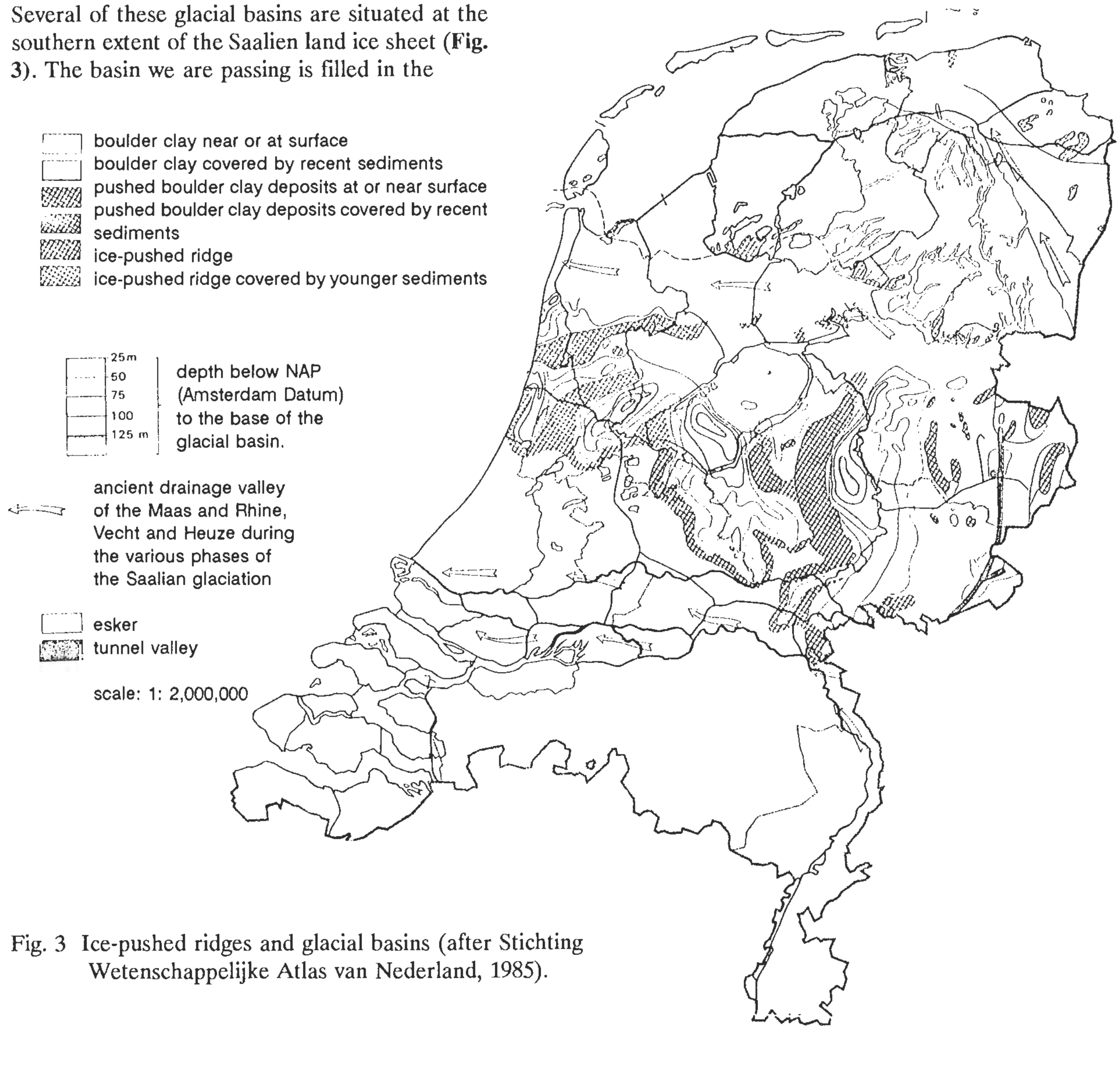


Fig. 3 Ice-pushed ridges and glacial basins (after Stichting Wetenschappelijke Atlas van Nederland, 1985).

At the outside of the ice-pushed ridges coarse grained meltwater sediments dating from the time of ultimate ice extent are laid down. These we can see in the area NW of Arnhem.
Several large groundwater abstractions for drinking water are situated within the ice-pushed ridges.

We pass to the North of the city of Wageningen, with the Landbouw Universiteit (Agriculture University). In this city , in Hotel "De Wereld", the cease fire agreement with the Germans was signed in may 1945.

At the start of the war in May 1940 the Grebbelinie, a small waterlinie was established in the Gelderse vallei (Gelder Valley) by inundating the area through the Grift canal, which connects with the river Rhine . The Germans were held up here for one and a half day.

In the area east of Wageningen and West of Arnhem near to the end of the war heavy fighting between trapped British para-troopers and an unexpected German panzer division. The para-troops were dropped to try and capture the Northern head of the bridge near Arnhem just before the winter, after the successful crossing of the river Waal near Nijmegen. It appeared "a bridge too far" and Holland had to wait a "hungry" and cold winter before the allied could cross the Rhine near Wezel in Germany.

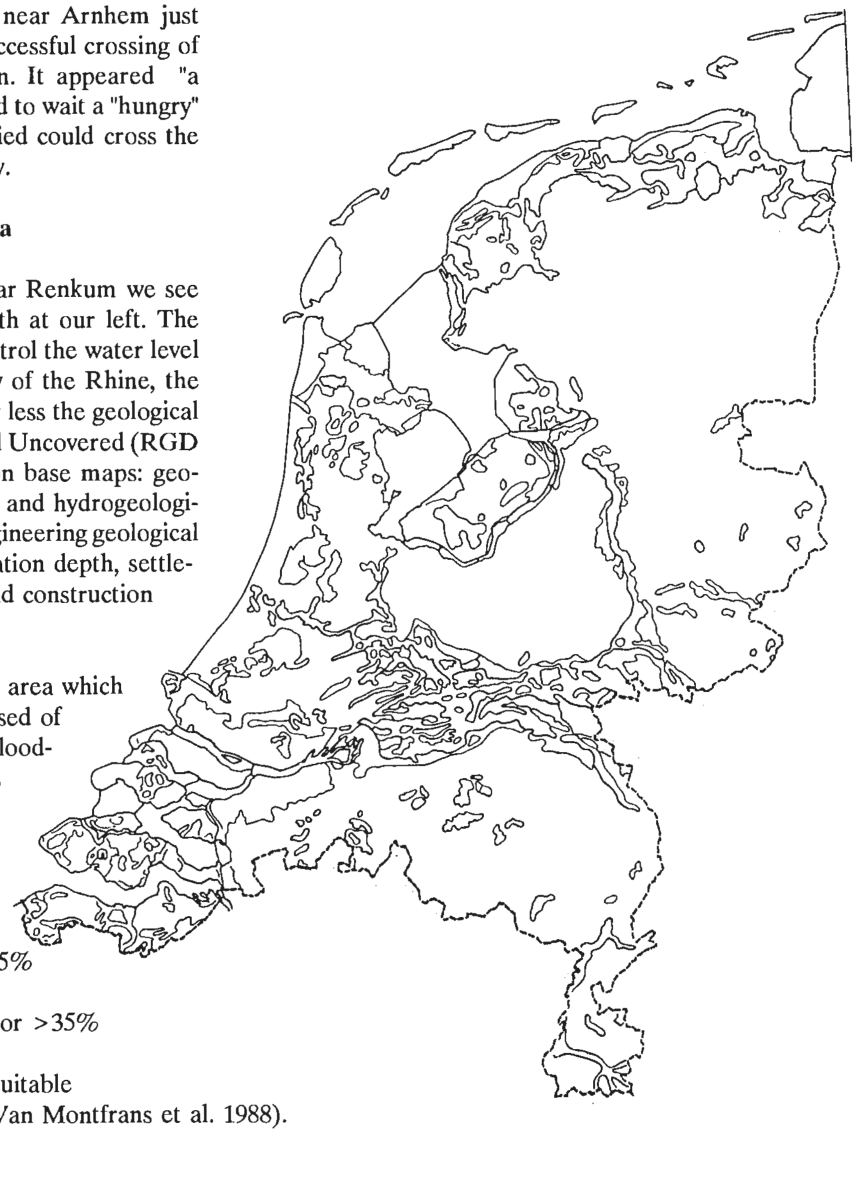
Central Netherlands river area

Crossing the Lower Rhine near Renkum we see the weir complex of Doorwerth at our left. The main goal of this weir is to control the water level in the North running tributary of the Rhine, the river IJssel. We follow more or less the geological profile A-B as shown in Subsoil Uncovered (RGD et al., 1984). In this publication base maps: geological, soil, geomorphological and hydrogeological maps are found, besides engineering geological thematic maps, such as foundation depth, settlement, ground improvement and construction material maps.

The Central Netherlands river area which we are crossing now is composed of Holocene river channels and floodbasin deposits. In the West, as in the area of Nieuwegein, the floodbasins consist mainly of peat, in the East they are predominantly clayey. The Holocene deposits are underlain by generally coarse grained river sands originating from the rivers Rhine and Meuse. The Pleistocene river dunes, forming relatively high locations in the area, date from the time of deposition of the river sands.

Foundation conditions vary widely in this area and are influenced by the, often "foundated", sand filled river channels and the sand dunes, which allow pad or shallow pile foundations. Old settlements and also more recent villages are often found situated on these locations. In the floodbasin areas pile foundations in the Pleistocene sands up to 15 m depth may be required.

In the large river area both clay and sand are extensively borrowed for use as construction materials. Already many centuries the Holocene floodbasin clays from this area are used for the fabrication of bricks and roof tiles. Although this area holds the major part of the brick producing factories, also in other parts of the country these are found in areas with suitable clay occurrences with fraction <2 um between 17,5 and 35 % (**Fig. 4**).



clay fraction 17.5 to 35%

clay fraction <17.5% or >35%

Fig. 4 Clays near the surface suitable for borrowing (after Van Montfrans et al. 1988).

Sand for both mortar and concrete production and use as fill material, are found in the Holocene channels and in the deeper Pleistocene deposits. **Fig. 5** shows that this is the most western area of the country where onshore sand for mortar and concrete production can be quarried.

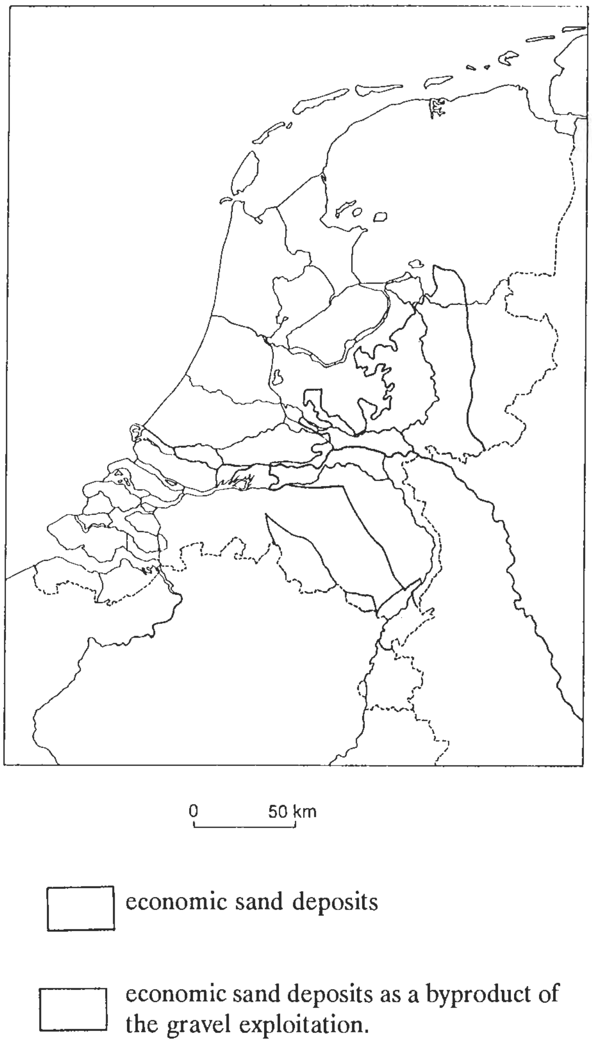


Fig. 5 Sand near the surface for mortar and concrete production (after Van Montfrans et al. 1988).

Peel area

After crossing the river Meuse and driving on its west bank we enter the Peel area. This name is also connected to the Peel Horst, situated adjacent to the large Central Graben (nowadays called Roerdal Graben, **Fig. 6**).

This still subsiding graben system (approx. 4 cm/century) has been the flow area of the rivers Rhine and Meuse during many periods of the Pleistocene (**Fig. 7**) and a huge sequence of sediments, up to approx. 250 m, has accumulated since the end of the Tertiary.

The fault system forming the graben and horst structure has the same strike direction as generally NW-SE striking faults which allow already since the Carboniferous vertical movements to occur (**Fig 8**).

The Venlo Graben adjacent to the Peel Horst forms the present valley of the river Meuse.
Near Vierlingsbeek, the Pleistocene river sands are by marine fine sands, silts and clays of Late Tertiary age.

Near Grave is one of the weir complexes in the river Meuse of which the lock was renewed and widened in the seventies, as was the case with several other weir complexes, to increase the navigability of the river. During the investigations of the influence of the dewatering of the open excavation on the water levels in the surrounding area it appeared that there was a distinct difference in the recharging capacity of the part of the river above the weir and that below it. The upper part was in fact "plastered" with fine particles and had almost no recharging effect; the water table became draw down below it, and the other side of the Meuse was effected (Schokking, 1972)
The lower part showed an opposite effect

Past Grubbenvorst, where we will have tea and a nice view over the Meuse valley the area starts where there is gravel borrowing in the river.

References

ANON, 1988 , The Netherlands commemorative volume for the 50th anniversary of the ISSMFE, 11th Int. Conf. on Soil Mech. and Found. Eng., San Francisco , 1985, Ed. E.H. de Leeuw.
Heybroek, 1974, Explanation of Tectonic Maps of The Netherlands. Geologie en Mijnbouw, 53.
Van Montfrans, H.M., L.W.S. de Graaff, J.M. van Mourik, W.H. Zagwijn, 1988, Delfstoffen en Samenleving, Reeks Geologie van Nederland, Rijks Geologische Dienst, Haarlem
RGD, DGV/TNO, StiBoKa, 1984, Subsoil Uncovered
Schokking, F., 1972, RID Report on geohydrological research for the dewatering of the new lock near Grave, Doctoraal thesis, Leiden University.
Schokking, F., 1990, Geologie en natuurlijke bodemdaling in Nederland. Symposiumverslag Bodemdaling in Nederland, TU Delft, november 1990.
Stichting Wetenschappelijke Atlas van Nederland, 1985, Atlas van Nederland, Deel 13, Geologie, Staatsuitgeverij

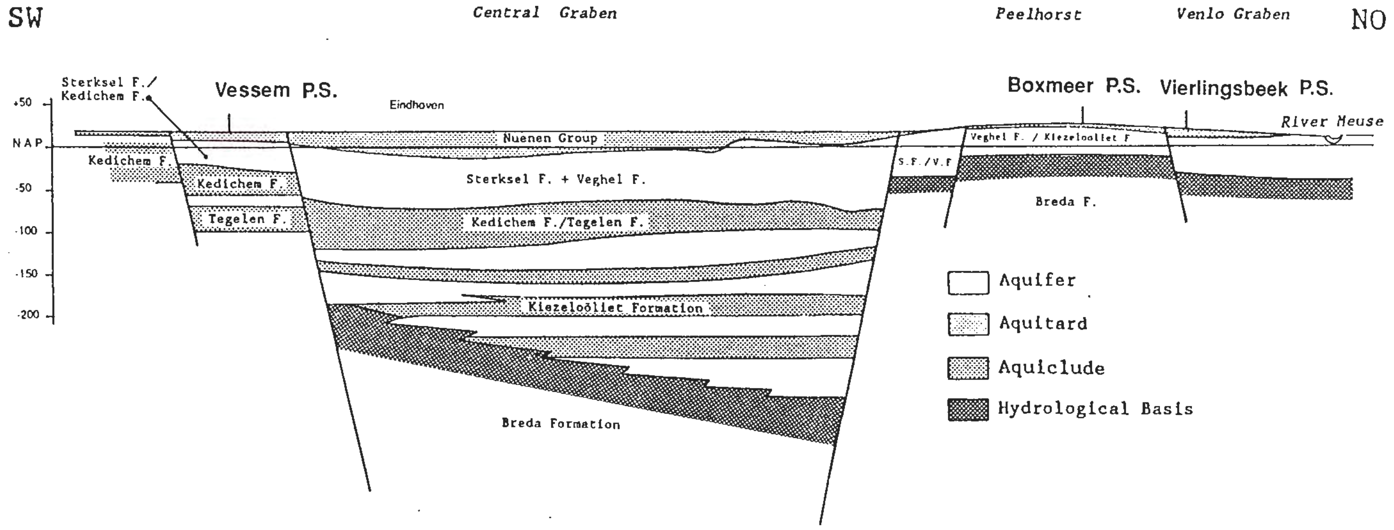


Fig. 6 Central graben system (modified after Schokking, 1990).

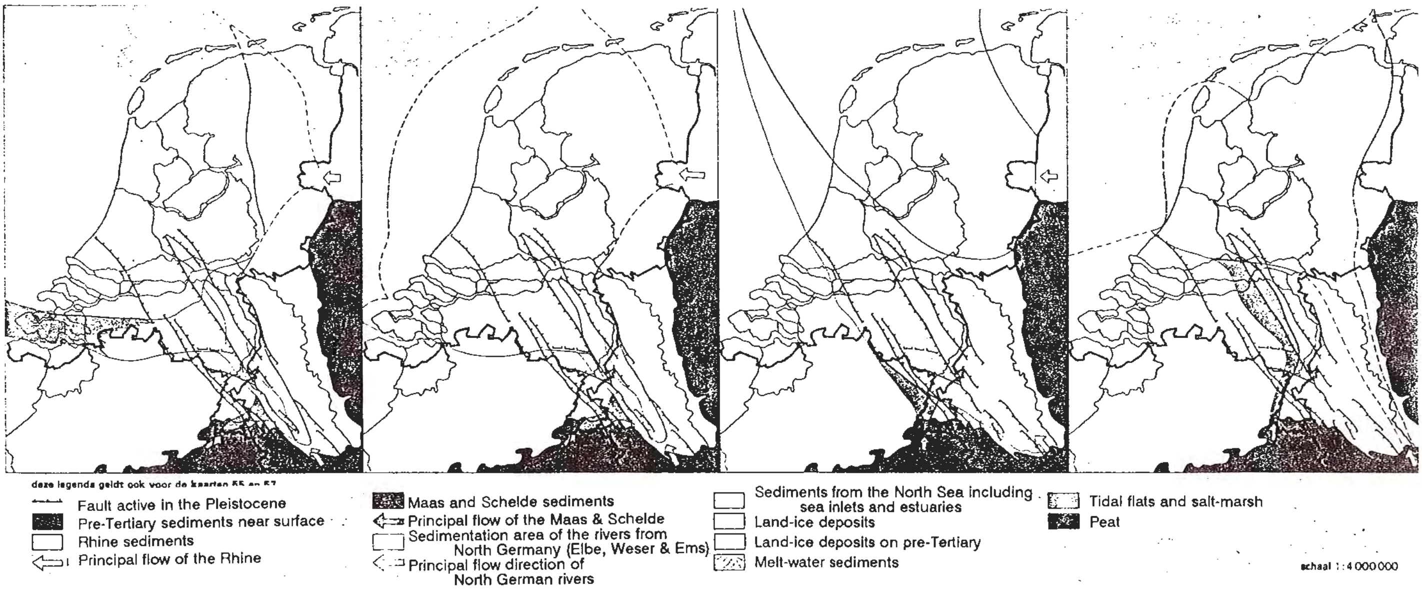


Fig. 7 Sedimentation stages during the Pleistocene, palaeogeography: a. Tiglian, b. Late Tiglian, c. Early Cromerian Interglacial d. Late Cromerian Interglacial (after Stichting Wetenschappelijke Atlas van Nederland, 1985)

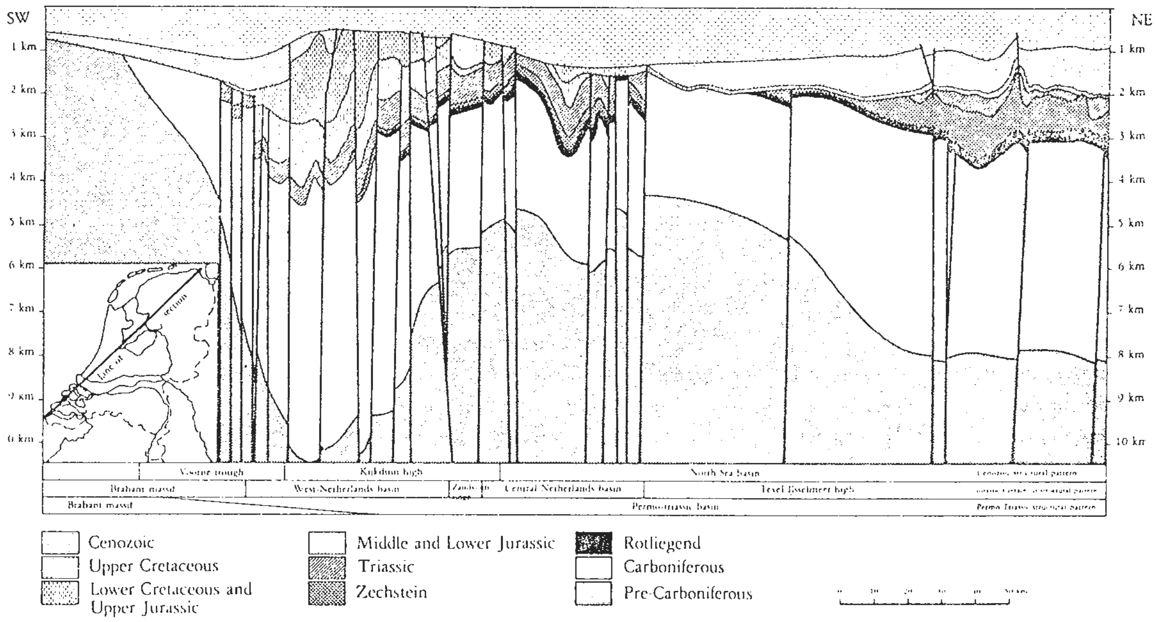


Fig. 8 SW-NE geological section through The Netherlands (after Heybroek, 1974)


Route in East Brabant/ North-Central Limburg The Peel
Route guide
Oss
Grave
Cuijk
Goch
Heesch
Rosmalen
Gennep
Uden
Boxmeer
Kevelaer
Berlicum
St. Michiels-gestel
Vught
Veghel
Schijndel
Boxtel
St.Oedenrode
Gemert
Venray
DE PEEL
Son en Breugel
Best
Oirschot
Helmond
Deurne
Horst
Nuenen
EINDHOVEN
Mierlo
Geldrop
Asten
Veldhoven
Someren
Waalre
Heeze
Valkenswaard
Eersel
Blerick
Venlo
Tegelen
Sevenum
Baarlo
Belfeld
Reuver
Meijel
Panningen
Maasbree
Arcen
Natuurpark
Brachter

Visit to the Hoorensberg Mine, Valkenburg.

by Prof. Eur. Ing. D.G. Price

The Hoorensberg Mine is part of the "Sprookjesbos" park. *Sprookjesbos* means **fairy-tale woods** and hence displays from fairy tale stories can be seen. One would therefore expect the seven dwarfs to be at work in the mine and Snow White serving at the bar in the restaurant.

Snow White and the Seven Dwarfs?

From route A1 we make a short diversion up the Geul valley to the resort town of Valkenburg-on-the-Geul. The small town lies in a river valley cut into the Maastrichtian limestone plateau by the Geul river. The south side of the valley many entrances can be found to underground limestone building stone mines some dating from Roman times. The purpose of the diversion is to visit one of these mines, **the Hoorensberg Mine**. The visit to the mine is followed by a drink in the Sprookjesbos (Fairy Tale Woods) Restaurant on top of the entrance to the mine. Notice the antropogeneous rock-type exposed. Please do not whack it with your hammer, unforeseen effects may take hold of you!

Lithology

The Maastrichtian rocks of the Upper Cretaceous of the Province of Limburg consist of calcarenites and calcilutites with bands of flint and "hard ground". Apart from the thin layers of "hard ground" the rocks are weak and highly porous and particular layers are generally free of joints and have almost imperceptible bedding. These layers have been worked for very many years (the earliest workings are believed to be Roman) as a source of building stone. The extraction has been by underground mining using a room and pillar technique. The rocks have been sawn out using steel saws, chisels and wedges to give large blocks, which were cut into smaller building stone sizes on the surface. Table 1 gives the horizons that were worked and some rock mechanics properties of the rocks.

Areal extend and stability

The abandoned mines are present under quite large areas of Limburg, mostly in the vicinity of the cities of Maastricht and Valkenburg. In both areas the abandoned mines have been used for shelter in times of war, for mushroom growing and are now mostly used as tourist attractions. Many of the mines are decorated with paintings and sculptures. The mines are generally stable but there have been instances of partial or total collapse. Research is being undertaken by the section Engineering Geology of Delft University of Technology to establish a means of evaluating mine stability. Some details of this are given in the paper by Bekendam and Dirks (1990) presented in theme 5.3 in the Proceedings of the IAEG Congress.

The Hoorensberg mine is one of the mines which has been surveyed in the course of this work. A stratigraphical column showing the strata within which the mine has been excavated and a plan showing the results of a mine survey is given in fig. 1 and 2 respectively.

The general problems of mine surveying and assessing stability will be described in the course of the visit.

The mine to be visited links with another much larger mine in which it is quite easy to get lost so participants are asked to keep close to the guide. Safety helmets will be provided and must be worn during the visit.

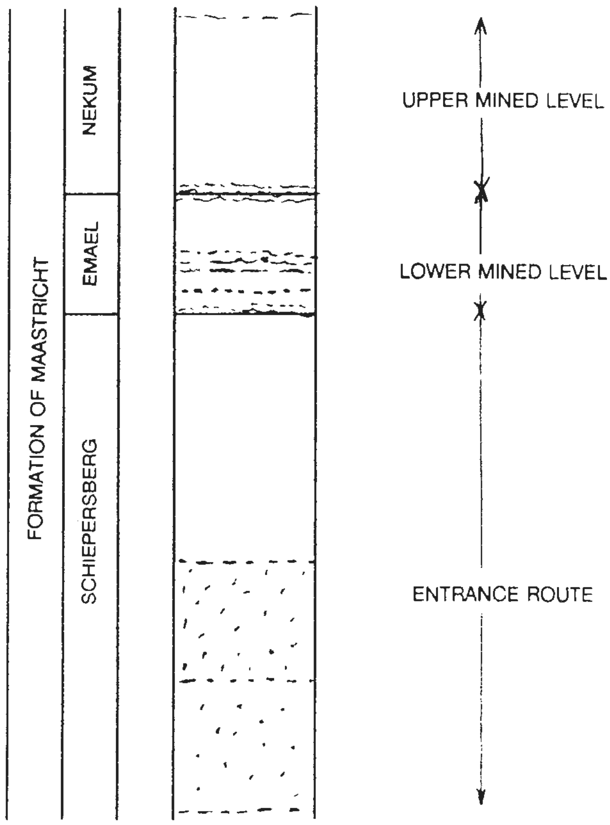


Figure 1 The stratigraphy of the Hoorensberg mine

Stratigraphic unit	Lithology	Geotech-zone	Mine Zone	Dry Unit Weight (kN/m^3)	Porosity (%)	Unconfined Compressive Strength (MPa)		
						Dry	Sat.	Nat.
Meersen		A	■	13.2	46-50	2.6-2.8	1.7-1.9	1.3-1.9
		B	■	12.9	46-50	1.5-2.5	1.3-1.7	1.2-1.7
Nekum		C	■	12.6	47-51	1.9-2.5	1.0-1.6	1.3-1.9
Emael		D	■	12.8	45-51	1.5-1.7	0.5-0.9	0.5-0.7
		E	■	12.8	49	2.7	2.1	2.3
Schiepers-berg		F		13.5	49	4.2	2.0	2.3
Gronsveld		G		<---------- Not Tested ---------->				
Valken-burg		H		14.8	32-36	4.0-8.0	2.0-2.8	2.7-3.3

Approx. scale 0 ⌊⌋ 4m ---------Hardground ·········Flint Sat.= saturated, Nat.= at natural moisture content

Table 1 Some geotechnical properties of the stratigraphical units of the Maastrichtian

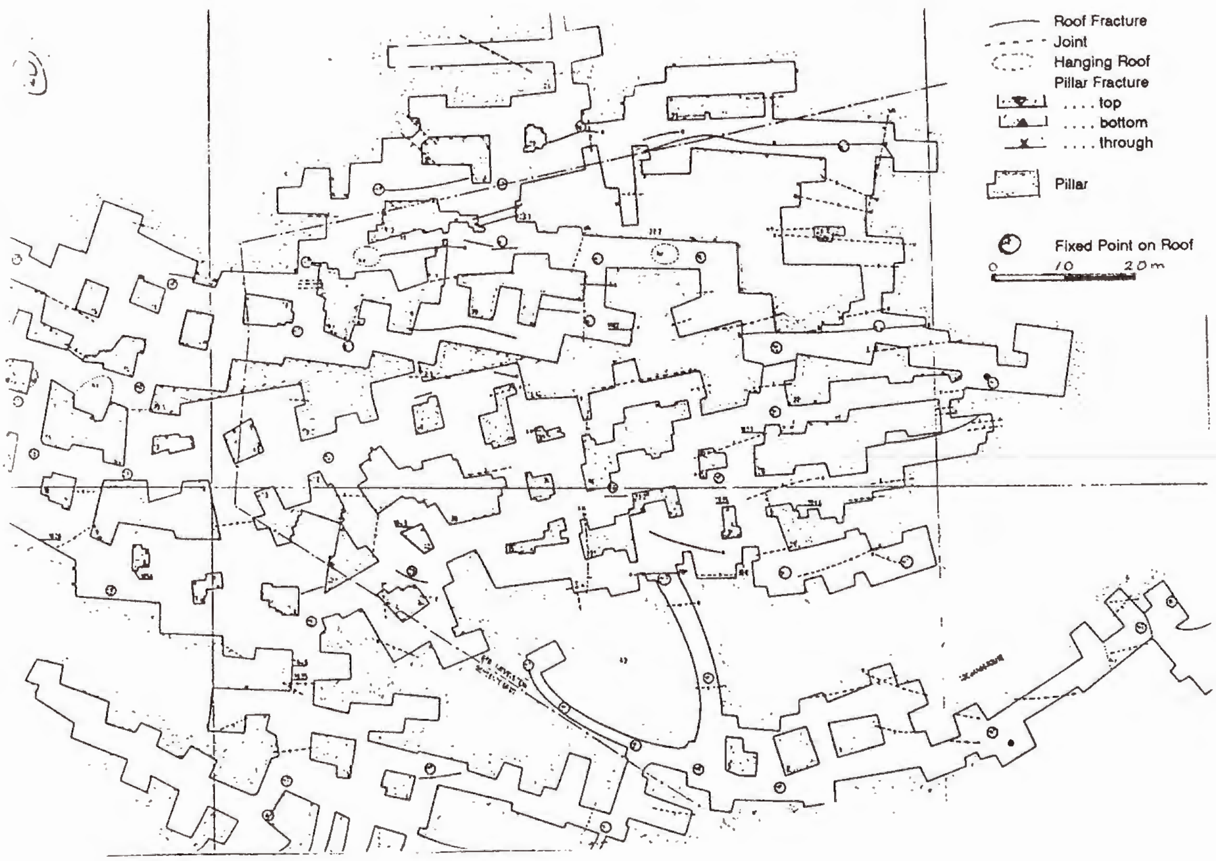


Figure 2 Plan of the Hoorensberg Mine at the "Sprookjesbos", Valkenburg

Bibliography

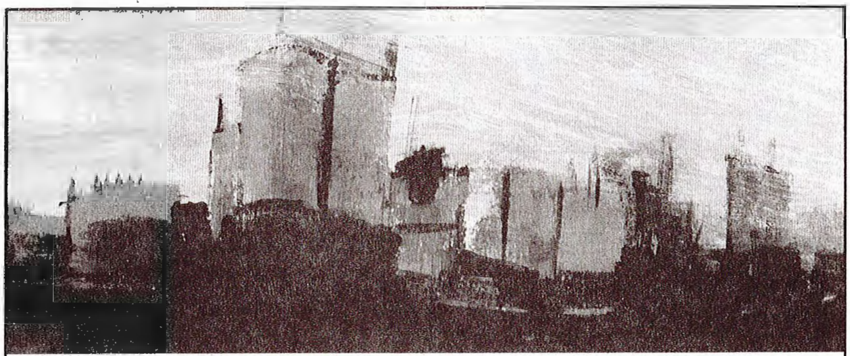
Bekendam, R.F. and W.G. Dirks (1990) Stability assessment of the Hoorensberg room and pillar mine, Southern Limburg, using separate shape factors for intact and cracked pillars. Proceedings of the 6th International Congress IAEG, Balkema, Rotterdam, v 4, 2627-2636.

R.R. Kronieger (1989) - Geotechnical profile of the Maastrichtian Chalk. "Chalk", Proceedings of the International Chalk Symposium, Brighton, 4-7 September, Thomas Telford, London.

Rijks Geologische Dienst (1989) - Geologische kaart van zuid-Limburg en omgeving. *Afzettingen van de Maas*. Rijks Geologische dienst, Haarlem.

Rijks Geologische Dienst (1988) - Geologische kaart van zuid-Limburg en omgeving. *Oppervlaktekaart*. Rijks Geologische Dienst, Haarlem.

Rijks Geologische Dienst (1984) - Geologische kaart van zuid-Limburg en omgeving. *Pre-Kwartair*. Rijks Geologische Dienst, Haarlem.



TU DELFT ENGINEERING GEOLOGY :

Centre for Engineering Geology in The Netherlnads

The origins

In 1975 engineering geology was as good as unknown in the Netherlands amongst earth scientists. A few geology students from Leiden University had attended a course in engineering geology at Imperial College the previous year. In fact, up to then, the number of Dutchmen who had completed a course up to M.Sc. level in engineering geology numbered four. Professor David Price was invited to TU Delft, Faculty of Mining Engineering, that year to build up an engineering geology section in the Faculty.

By 1979 the first graduate from the Faculty of Mining and Petroleum Engineering, a **mijnbouwer**, graduated with specialization in Engineering Geology. Graduates soon followed not only as **mijnbouwers** but also geology graduates from Leiden, Utrecht and both of Amsterdam's universities who chose engineering geology as their specialization. Paradoxically the recession which started in the early eighties increased interest in The Netherlands in engineering geology. Not only did geologists look for employment opportunities in this field but industry was forced through increased competition to work to narrower profit margins. In the dredging industry, for example, this meant that careful attention had to be paid to predicting seabed conditions with increasing confidence.

The market

Today over sixty graduates are working for a variety of employers, the oil industry, the oil service industry, mining, dredging, contracting, civil and geotechnical consultants, geotechnical and geophysical site investigation companies, environmental consultants, municipalities and, more recently, in computer systems engineering.

This reflects the unique character the engineering geologist has established for him- and herself. The education the student receives is from staff who have accumulated a wide experience working on numerous projects associated with a wide spectrum of industry all over the world. The result is a very broad outlook and experience which is passed on to the student. Often the student before graduation already reflects this experience by having done practical work in areas ranging from California to Australia and from northern tundra of Sweden to the tropical rain forests of the Cameroons.

The Student

Since 1985 a students chapter in engineering geology was set up called appropriately DIG, **Dispuut Ingenieursgeologie**, which has since become active in organising visits, meetings and symposia. The latter covered current topics such as **Computer use in the earth technologies, Environment and earth technology** and this year, appropriately after the hurricane force storms of this winter to celebrate their first five years, **Coastal engineering geology.** As a result of the great interest and attendance of the Computer symposium an earth science computer users group was established in The Netherlands called **CompuTerra**. Old students and staff form the committee for this group. The DIG plays a large role by introducing engineering geology to industry by paying regular visits to different institutions and companies. They also organise four times each year the newsletter for the Dutch national group of the International Association of Engineering Geologists, the Ingeokring.

The study

At TU Delft the student first attends a common course for the the first two years. In the third year he or she is asked to choose a specific direction which can be, besides engineering geology, also mining and mineral process technology, petroleum and reservoir engineering or geophysical engineering. Many of the lectures remain common as, for example, parts of reservoir engineering in petroleum are applicable to hydrogeology. The student can also choose to combine two specialisations such as geophysics and engineering geology. Unlike the other specialisations the engineering geologist also attends courses outside his own faculty at civil engineering. In addition to lectures there are practicals, field excursions, field work (In France for geological mapping and the last two years in Spain for engineering geology field work) and a final year project.

Joint venture

If this is not enough to broaden the student's outlook, the engineering geology third and four year course is run together with that of ITC's (International Institute for Aerospace Survey and Earth Sciences) engineering geology diploma and M.Sc. course. Here students from mostly Africa, Asia and South America, usually B.Sc. graduates in either geology or civil engineering are given scholarships from the Ministry of Foreign Affairs to study for the diploma course and some continue their studies for the M.Sc. in engineering geology. In fact, this year, the first student to receive his doctorate from TU Delft in engineering geology was Joseph Olusola Akinyede from Nigeria; his promoters were both from TU Delft and ITC.

The staff

The close cooperation with ITC means that the combined full-time staff numbers six lecturing staff, three from TU Delft and three from ITC. The TU Delft staff are Professor David Price, Drs. Peter Verhoef and Pieter Michiel Maurenbrecher M.Sc. and from ITC: Dr. Niek Rengers, ir. Wolter Zigterman and Drs. Robert Hack. Two are civil engineers specialised in engineering geology or geotechnics and three are Chartered Engineers (two of which were originally geology graduates!).

The numbers are supported by Ing. Willem Verwaal who runs the laboratory and is assisted by Arno Mulder. Two further lecturing staff associated with the section are Ir. Christiaan Maugenest who lectures part time on Environmental Engineering Geology and Prof. Dr. Adrian Richards who is honorary professor lecturing on Marine Engineering Geology. Heleen van Yssel-Hage is the section's part time secretary and will answer your enquiry on most mornings during the week. Not to be out done ITC also have an engineering geology secretary, Tara McNally who joined the staff last year. TU Delft engineering geology also employ two research staff through external funding: Drs. Wilfried Pieters and Ir. Jan-Reinout Deketh.

Research

The research effort has seen a significant rise as in the last three years the section has had two doctorate students Drs. Rene Kronieger and Drs. Roland Bekendam involved with mapping the geotechnical and material properties of South Limburg soils with emphasis on loess and investigating the stability of disused underground building calcarenite-stone mines respectively. The staff is also involved in research work. Wear on excavation tools used in dredging, hydrogeology of Cretaceous calcarenites in South Limburg, information handling and storage, subsidence due to underground mining and fluid extraction, construction materials, dangerous waste underground storage to underground pump-storage feasibility are a few examples of recent and current research studies.

Funding

Recent developments in government policy towards research and education has meant that the staff increasingly have to spend more time marketing to obtain projects and finance. The loss to engineering geology will be in research and development work where the benefits are only obvious in the long term. Governments today who are answerable to periodic elections and hence do not consider the longer term is in their interest; industry who is answerable to their shareholders and financiers even less so. The quick profit or early profitability is the key to economic thinking today. The price for this economic thinking is all to apparent: the heavy toll it has taken in polluting and destroying our environment. It is a very stiff price to pay today for the blindness of yesterday for which the present the government has to pay dearly; not just in terms of money, but money that has to be diverted from research and education to finance the clean up. The policy engenders a cynicism which cannot be helped; that engineering geologists are in a good position to profit from past environmental mismanagement which makes up for the downturn in investments in education and research. Today's government is blind towards education and research; the results may be more catastrophic than yesterday's environmental lapse.

Despite the difficulties funds are provided by the STW (Stichting Technische Wetenschappen-Technical Sciences Foundation), the Rijks Waterstaat (State Public Works) and Province of Limburg. Additional funds are obtained on a project basis where speciallist expertise of the staff are required. The funds have been allocated for research into wear and abrasion of digging tools especially those used in the dredging industry, the durability of dike protection rip-rap and for engineering geological mapping.

The future

Engineering Geology has come a long way in The Netherlands. It still has a long way to go; much will be spent on rectifying past environmental mismanagement, but also in developing better environmental and resources management for the Such efforts are being channelled into information technology. This technology is for information about the geology on which the Netherlands depends on its wealth. The wealth is its water, fuel and building material resources but also its land use in agriculture, recreation, nature reserves and urbanization. The geology needs too be inventoried to ensure best economical use both in financial terms but also in environmental terms. New innovative technologies are required to counter by far our worst environmental damage; the ever increasing spread of industrial and housing urbanisation at the expense of what little landscape is left. This can be achieved by developing alternative spaces underground out of sight and saving enormous amounts of energy by requiring less heating in winter and less cooling in summer. In the Netherlands nearly every structure is plugged underneath the subsurface with up to a depth of five floors or more of piles. Why not use this space for storage, utilities, shopping, factories or offices using buoyant basements? Too costly? Short term, yes, financial economics, yes, environmental economics......? The latter part of the question needs answering. The answer lies in research. Research needs funding. The question, increasingly, is from where?

Research and reports

01. **Dijkstra, C.,** 1979, Engineering geological feasibility of rehabilitating Buhisan Reservoir (Cebu Island, Philippines),
02. **Hoogebrugge, W. et al,** 1980, Reports on an engineering geological fieldwork at Slochd Beag, Scotland.
03. **Hoogebrugge, W.,** 1980, The influence of discontinuities the excavation of rock by disc bottom cutter dredging
04. **Goeje, C.H. de,** 1980, The development of a mini point load tester.
05. **Pool, M.,** 1980, Rebound methods of assessing rock properties in field and laboratory
06. **Winkoop, A. van,** 1981, De WH:10, een compact lichtgewicht sondeerapparaat
07. **Winkoop, A. van,** 1981, Ingenieursgeologische atlas van Venray.
08. **Dierx, H.A.L.,** 1982, De Lugeon proef onder de loupe genomen.
09. **Hack, H.R.G.K.,** 1982, Seismic methods in engineering geology.
10. **Maris, P.,** 1982, On the assessment of relative density by the measurement of longitudinal wave velocity. 11. **Blomer, F. et al,** 1982, Engineering geological investigation of Markle Mains Quarry, Haddington, East Lothian, Scotland
12. **Berg, L. van den et al,** 1982, Engineering geological investigation of Orrock Quarry, Burntisland
13. **Nooy van der Kolff, A.H.,** 1982, Slochd Beag. A visual presentation of the results of an engineering geological field work.
14. **Nooy van der Kolff, A.H.,** 1982, The choice of possible area for the construction of underground pumped hydro-electric storage in the Netherlands based consolidated bedrock geology
15. **Onstenk, H.J.C.M.,** 1982, Stacking problems in a swamp area
16. **Onstenk, H.J.C.M.,** 1982, Slochd Beag. A visual presentation of the results of an engineering geological field work (continuation)
17. **Blomer, F.,** 1983, Engineering geological aspects of the laterite as a road construction struction material

18. **Bruijn, R.G.M. de,** 1983, Solution phenomena in the Chalk of SE-England, SW-Belgium The Netherlands
19. **Maugenest,Chr.,** 1983, Investigations into the applicability of the Slake Durability Test to predict the nature of weathering of hard rocks.
20. **Taselaar, F.,** 1983, Engineering geological data for dry earth moving
21. **Price, D.G. (Editor), H Grabandt, H Klumpen, J Leo, O Lussenburg, T de Ruyter,** 1983, Engineering geological properties of Maastrichtian Chalk, ENCI Quarry Maastricht, (Fieldwork 1982)
22. **Price, D.G. (Editor), H Grabandt, H Klumpen, J Leo, O Lussenburg, T de Ruyter,** 1983, Voorlopig rapport. Ingenieursgeologisch veldwerk. (ENCI Groeve, Maastricht) : Veldwerk 1982
23. **Berg, L.v.d.,** 1984, Landslides in de Argille Scarliose, een onderzoek naar helling instabiliteitsproblemen in de Marechia Vallei
24. **Beek et al, MV, F vd Bos, R Cost, M v Groningen, KH Schothorst,** 1984, Engineering geological properties of Maastrichtian Chalk, ENCI Quarry, Maastricht, Phase 2, (Fieldwork 1983)
25. **Onstenk, H.J.C.M., D.G. Price,** 1984, Ingenieursgeologische Aspekten bij lokatiebepaling voor de OPAC
26. **Amerika, A., C v Bergen Henegouw, I de Bruyn, R Goedjaar, M Philippart,** 1985, Engineering Geological Properties of Maastrichtian Chalk, ENCI Quarry, Maastricht, Phase 3, (Fieldwork 1984)
27. **Beek, M. van,** 1985, Stabiliteit van verlaten mijnen. Computer evaluatie en modelproeven (St. Pietersberg, Maastricht)
28. **Venmans, A.,** 1985, Instability in the St.Pietersberg room and pillar workings. Model tests on a newly developed base friction machine.
29. **Price, D.G.,** 1985, OPAC - Description of and result of tests on cores from Kastanjelaan 2 and Heugem 1a boreholes
30. **Cost, R.,** 1985, Fracture toughness and rock durability
31. **Ruyter, de T.F.M.,** 1985, The influence of discontinuities on rock blasting operations. A comparison of existing equations.
32. **Berkhout, T.,** 1985, Model tests to assess the deformational characteristics of jointed rock foundations
33. **Price, DG, PNW Verhoef & W Verwaal,** 1985, OPAC Engineering Geological Aspects
34. **Groeningen, van M.R.,** 1986, Toepassing van grondradar in de ing.geologie (Delft LGM terrein, Delftgauw en Sibbe grotte, Z. Limburg)
35. **Grabandt, L.J.,** 1985, Some aspects of large scale engineering geological mapping (Aberdaldy, Scotland and Trooz -SE Liège, Belgium)
36. **Leo, J.B.P.M.,** 1986, Load transfer of socketed pile foundations in karstic limestone
37. **Lussenberg, O.J.,** 1986, A study to recent tectonic displacements in South Limburg (NL), (EM 34-3 surveys fault detection, Heerlen Kunrade Fault)
38. **Bold, van den H.J.,** 1987, De abrasieve slijtage van snijwerktuigen door gesteenten,
39. **Price D.G., P.N.W. Verhoef,, R.R. Kroniger, W. Verwaal & M. Th. van Staveren,** 1987, OPAC-GEVERIK: **1** *General Report on eng. geol. aspects OPAC borehole*, **2** *Borehole record*, **3** *Laboratory Test Results*, **4** *Discontinuity Survey*
40. **Staveren, M.T.,** 1987, Discontinuity studies for the OPAC project.
41g. **Steveninck, R. van; Griendt, v.d. M.; ITC: Kushkush,** 1986, Engineering Geology of Borger quarries, Brunssum (Fieldwork 1986 Group7)
41a. **Deibel, I.K.; Dierendonck, M.G.D. van; Nienhuis, H. & Zuidberg, J.,** 1987, Stability analysis of part of Geulhemmer Mine, (Berg en Terblijt) (Fieldwork 1986 Group 1, seismic testing).
41b. **Leo, J.M.J.; Rösingh, J.W. and Wit,de R.,** 1987, Group 2: Quarry Nekam 't Rooth), Cadier en Keer
41c. **Vreugendenhil,R.; Vermeer, J. and Mchihyo,E. ITC,** 1987, Engineering Geology of Quarry Curfs, Meerssen (Geulhem)
41d. **Baeten,M.H.M.; Niese,M. and Giorgis-ITC,** 1987, Engineering Geology of Quarry Blom, Berg en Terblijt (Fieldwork 1986, Group 4)
41e. **Berghuis,R.; Man, de Y. & ITC: Osama Shady,** 1987, Engineering Geology of Quarry Belvedere, Maastricht (Fieldwork 1986, Group 5)
41f. **Plasman,S.J.; Bik,M.L.; Goedemoed,S.,** 1987, Engineering Geology of Quarry Bruls, Schinnen (Nagelbeek) Miocene Sand s (Fieldwork 1986 Group 6) Draft.

42. **Eijk, F.C.A.A. van,** 1987, Exploration & exploitation aspects of large armourstone blocks, qualit y designation for large rockblocks
43. **Schothorst, K.H.,** 1986, Application of the piezocone with reference to permeability measure- ments
44. **Nitzsche, M.,** 1987, Submarine slope stability Banda Sea using overlay techniques
45. **Oorthuys, G.J.,** 1987, The automation of the production of engineering geological maps (Amste rdam Mapping Project Ingeokaart)
46. **Oorthuys, G.J.,** 1987, Memoir Engineering Geology Map of Quadrant A1, Amsterdam, Amerika Haven
47. **Lap, J.M.J.,** 1987, Liquifaction hazard SE Netherlands (Midden Limburg/ Oost Brabandt)
48. **Steveninck, R. van,** 1987, Past mining in the Maastrichtian Limestone
49. **Swart, P.D.,** 1987, An engineering geological classification of limestone materials (Limestones from UK, Belgium and the S. Limburg (NL)
50. **Berghuis, R.,** 1987, Engineering geological map from oblique aerial Photographs using the Stereochord; (S. Limburg Map of Quarry Curfs, Berg en Terblijt)
51. **Rösingh, J.W.,** 1987, Use of photogrammetry in engineering geology mapping of steep slopes (Quarries Curfs -Berg en Terblijt & -'t-Rooth, Z. Limburg)
52. **Jager, W.,** 1988, An investigation on the abrasive capacity of rock
53. **Kooter, B.,** 1988, The egis project: partial implementation of Engng Geological Information System
54. **Nienhuis, H.,** 1988, The scale effect with regard to deformability of calcarenite
55. **Riet, P.A.L. van; Vlasblom, E.,** 1988, Engineering geological map of Villaller - Pont de Suert and Castarnes - Llesp (Spain)
56. **Leonora, R.,** 1988, Slope stability applications to natural slopes
57. **Dierendonck, M.G. van,** 1988, The Methylene Blue Test: An Index Test for Swelling Materials?
58. **Man, Y.H.H. de,** 1988, Surface near Douvergnehout and in the Eastern Mining District South Limburg, The Netherlands
59. **Schrier, J.S. van der,** 1988, A comparison between the statically and dynamically determined mechani cal properties of rock: A case study.
60. **Goedemoed, S.,** 1988, De berekening van spanningsvelden en veiligheidsfactorvelden in een ge steentemassa met lineair elastisch transversaal isotroop gesteente materiaal
61. **Vreugdenhil, R.,** 1988, The influence of natural discontinuities and material strength on the safety of calcarenite mine pillars
62. **Deibel, I.,** 1988, Solution pipe phenomena, effects, location and remedies in South Limburg, The Netherlands
63. **Touw, K.v.d.,** 1988, Een studie naar de aspecten en mogelijkheden van niet-verwerkbare chemische afvalstoffen in de diepe ondergrond van Nederland
64. **Wit, R. de,** 1988, Grondwaterstroming in het kalksteenpakket in Zuid-Limburg.
65. **Niese, M.,** 1988, Classification of large armourstone blocks using an acoustic velocity analysis method
66. **Griendt, M.A. v.d.,** 1988, De classificatie van grind in de groeves Belvedere, Curffs en Steenber g afgraving in Zuid Limburg voor toepassing in beton, asfalt en wegfunderingen
67. **Zuidlberg, J.M.,** 1988, The influence of dolomitisation on the engineering geological properti es of limestones
68. **Bik, M.L.,** 1988, Het ontstaan en de geohydrologie van een droogdal
69. **Plasman,S.J.,** 1989, Engineering Geological Properties of the Loess in South Limburg
70 **Kam, M.,** 1989, Engineering geological properties of glauconitic sediments of the Vaals and Tongeren Formations, South Limburg, NL
71. **Vermeer,T.W.M.,** 1989, Investigations on the abrasive- and erosive wear capacity of rock rela ted to rock- cuttig tools
72. **Smits, E.P.T.,** 1989, Determination of joint shear stiffness with the portable rock shearbox .
73. **Diem, A. van,** 1989, De inventarisatie van de bodem van het Ketelmeer
74. **Klumpen, H.J.C.,** 1989, Geoline Manual: data management system used for the OPAC Geverik 1 and Kastanjelaan boreholes
75. **Reinking, M.,** 1989, Linear cutting test in artificial sandclay mixtures to study the influ ence of brittleness on abrasive wear of cutting tools

76. **Erren, H.**, 1989, Introduction to engineering geophysics (2nd edition)

77. **Herbschleb, J.**, 1990, IngeoBase Design and Implementation of an engineering geological database (for quadrant D5 of Amsterdam.)

78. **Kootstra, J.**, 1990, Engineering geology of the sandstones of the Heksenberg Formation in south Limburg area, The Netherlands

79. **Dirks, W.G.**, 1990, The influence of pillar geometry on calculating pillar stren ght; using the "Hornsberg Groeve" as a case study.

80. **Clements, S.** 1990, Schade inventarisatie rond Grou

81. **Bisschop, R.** 1990, The analysis of a laboratory cutting and abrasion test to be applied in rock cutting dredging

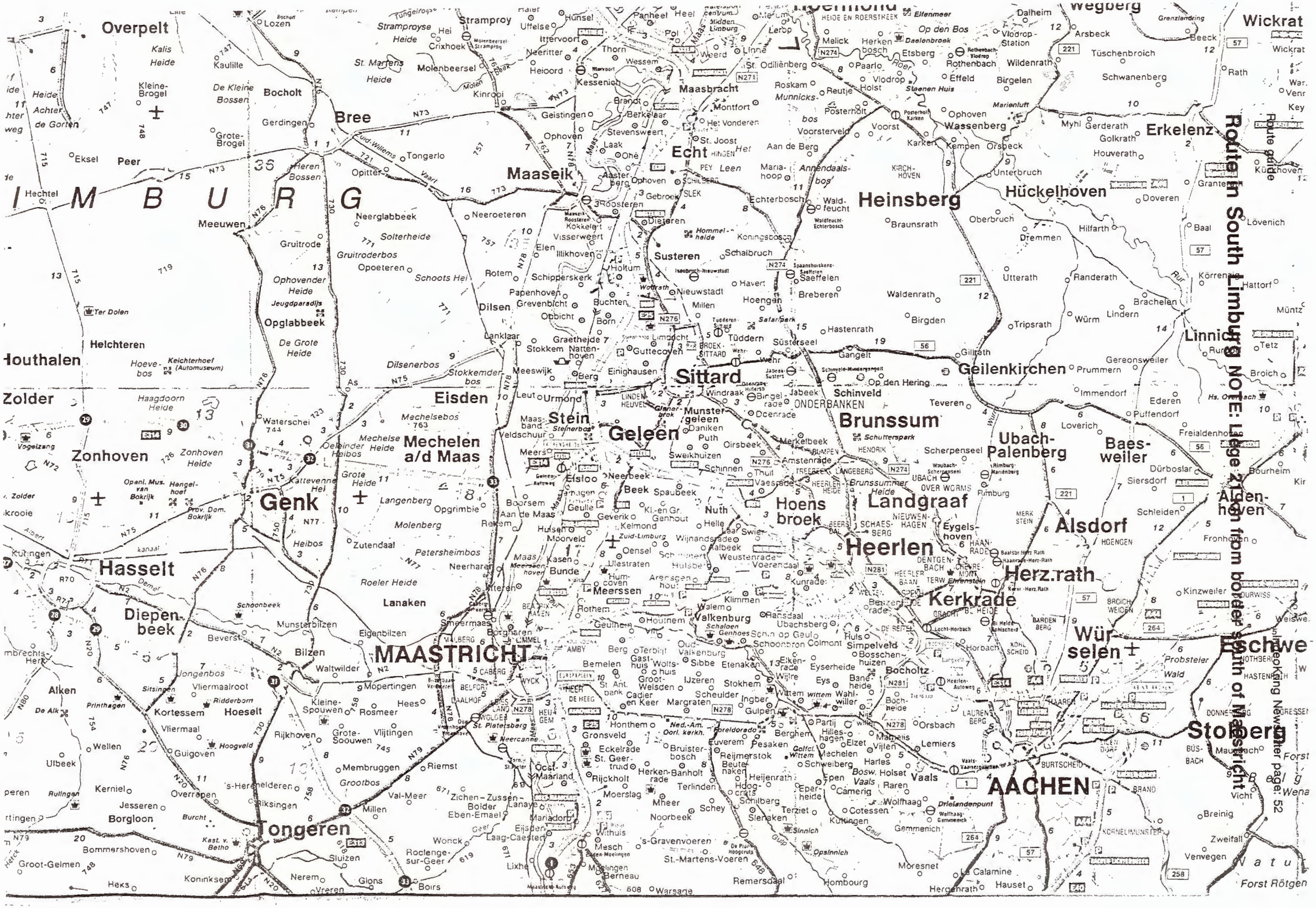
82. **Waverijn, C.G.**, 1990, De hydrologische evaluatie van het kalksteenpakket in de ENCI groeve

83. **Molendijk, W.O.**, 1990, Towards an automated detection of grain parameters and reservoir characteristics from thin sections of sandstone

84. **Breukink, C.H.**, 1991, An alternative procedure to sample gravel deposits

85. **Deketh, J.R.**, 1991, Determination of optimum conditions for the modified pin-on-disc test

86. **Boor, N.J.H. van der**, 1991, Het gebruik van een mengsel van löss en bentoniet als afschijdingslaag bij de mogelijke aanleg van vuilstortplaats in Zuid Limburg



Route in South Limburg NOTE: Liege 21km from border south of Maastricht
Route guide
LIMBURG
Overpelt
Bree
Maaseik
Echt
Heinsberg
Hückelhoven
Erkelenz
Wickrat
Wegberg
Roermond
Maasbracht
Susteren
Sittard
Geilenkirchen
Linnich
Genk
Hasselt
Zonhoven
Houthalen
Zolder
Diepenbeek
Bilzen
Tongeren
Eisden
Mechelen a/d Maas
Stein
Geleen
Brunssum
Landgraaf
Heerlen
Hoensbroek
Kerkrade
Herzogenrath
Alsdorf
Baesweiler
Ubach-Palenberg
Würselen
Eschweiler
Stolberg
AACHEN
Vaals
MAASTRICHT
Meerssen
Valkenburg
Gulpen
Lanaken
Kinrooi
Meeuwen
Peer
Dilsen
Opglabbeek

Laboratory examination of geomaterials for construction

by Peter N.W. Verhoef, Delft University of Technology

This paper forms part of a lecture to be presented at the post-graduate course "Essentials of Engineering Geology", to be held in October 1991 for the Foundation for Postgraduate Studies in Civil and Structural Engineering, University of Technology, Delft. The course is given in the English Language. Details about postgraduate courses can be obtained from the Course Secretary, P.O. Box 5048, 2600 GA Delft, Telephone: 31 (0)15 784618, Fax. 31 (0)15 784619.

Introduction

The geological materials commonly used in civil engineering construction are mainly natural soil aggregates (sand, gravel, boulders) and crushed rock or rock blocks. These granular materials are the subject of this paper. Other geological materials used in construction, like clay, asphalt or groundwater are not considered. The main theme of this chapter is to emphasize the special nature of rock and soil materials. Rocks and soils are composed of minerals. These could be single minerals, mineral aggregates, or minerals cemented together to form rock.

The distinction between soil and rock is that soil is considered here as an aggregate of loose mineral (or mineral and rock) particles and rock as a mineral aggregate which is cemented (like in sedimentary rocks), or crystalline (igneous rocks or metamorphic rocks). Rocks have, due to the cementation or crystallinity, a certain tensile strength. The magnitude of the tensile strength is dependent on the nature of the bond between the mineral particles. Generally the tensile strength of rocks is in the order of MPa; much higher than that of cohesive (fine grained) soils (chapter 3).

The rocks or the soil grains often have pore spaces in between the mineral grains, or very fine hairline cracks along the grain boundaries. The microscopic structure, just like the internal structure of other materials such as steel or concrete, is determining to a large extent the mechanical behaviour of the geological materials. Like concrete, rock is strong in compression but weak in tension. The mechanical properties have relevance for the application they are used for. The aggregate type, for example, determines to a large extent the strength properties of concrete. The shape, size and material properties of rock blocks determine to a large extent the strength (or better: the design) of a breakwater structure. Dynamic or static loading of structures may have detrimental effects on the rock/soil materials. If so, they are considered to be not *durable* in the engineering environment they are used in.

A mineral is a crystalline structure with a specific chemical composition. Minerals are in fact chemical compounds. As each chemical compound minerals, which are not in chemical equilibrium, may react with other minerals, or with chemical substances carried in water or air, to form a compound with a chemical composition which is stable in the present environment. Rocks, or soils, are not generally thought of as chemically active. May be only earth scientists think about it. Most earth scientists have the idea that, due to the slow kinetics of most geochemical reactions, such reactions are so slow that they take "geological time" to perform. Very commonly this is indeed the case. But in some instances such reactions occur within "engineering time" (the lifetime of an engineering construction). For example, alkali-aggregate reactions in concrete, or the dissolution of gypsum rock can take place in short time spans. But a feature relating to this which has a very great impact on the engineering behaviour of rock is that due to the (very slow) geochemical weathering reactions that take place near the earth surface, nearly every rock, even those considered "fresh" or unweathered in engineering rock classifications, could contain secondary minerals. The reaction products of weathering reactions could be clay minerals or ironhydroxides. Such secondary minerals could have detrimental effects, even when present in minute amounts (less than one volume percent of the rock). If we take rocks, sands or gravels from a certain location we want to know whether reactions could take place in the engineering environment or whether secondary minerals may have detrimental effects. This is a second aspect relating to *durability*.

Durability is defined as the ability of a geological material to keep its mechanical properties during engineering time in the engineering environment.

What the civil engineer commonly wants to know is:
1. What are the properties of the rocks that I need to know for the purpose I want to use it for?
2. How are these properties measured?
3. Is the material durable?

The present state-of-the-art of aggregate investigation is not very sophisticated. Concerning all above questions much debate is going on. Over the years so-called standard tests have been developed. Commonly such tests were developed to simulate as accurately as possible the conditions that would occur in practice. This has appeared a very difficult undertaking and most tests are known to relate only in a remote, qualitative, way to practice. Much effort has been undertaken in the past two decades to select those standard tests which have relevance to applications in road, hydraulic or construction engineering. In Europe this exercise is currently repeated to make European (EN) standards and norms. But there is still a large gap between the parameters that a design engineer would like to use for his design and the rock or soil properties expressed as index values from standard tests he receives from the engineering geologist.

The problem with rocks and soils is the large variability of properties (Table 1) that these natural materials have. This variability occurs on all scales. This is the major difference with wholly engineered materials such as steel or -to a large extent- concrete.

Table 1. Variability in strength of rock (Roxborough, 1987)

Variability in compressive strength		
all sedimentary rocks	(112)	: 21.7%
sandstones	(40)	: 19.8%
limestones	(16)	: 22.0%
all igneous rocks	(15)	: 19.5%
all metamorphic rocks	(10)	: 15.3%
Variability in tensile strength		
all sedimentary rocks	(38)	: 21.7%
sandstones	(17)	: 26.8%

coefficient of variability = standard deviation expressed as percentage of the mean

When new materials are being developed and used for construction, the materials engineer plays a large role in its development, quality control and research. It is not more than logical that for geological materials, if we want to understand their engineering behaviour, we should make use of rock material scientists. The petrographer is a scientist trained in the materials characterisation of minerals and rocks. A petrographer with sufficient knowledge of the civil engineering requirements could do the job. Such people are scarce and have become knowledgable in the field due to their own personal career background. No training into this specialisation is given in universities. But it is agreed in most literature on the subject that a petrographic characterisation is the essential core of a proper investigation into a study on the suitability of geological materials. The importance of petrography is illustrated by Table 2, showing the dependence of mechanical properties of aggregates on petrographic parameters.

Table 2. Main petrographical features affecting engineering test results (Fookes et al. 1988)

Aggregate petrography/ engineering test	Specific gravity	Mineralogy	Compactness	Porosity	Hardness	Texture	Shape	Moisture content	Anisotropy	SM content	Micro fractures	Cleavage	Grain size
Water absorption			×	×						×	×		
Specific gravity	×	×	×	×						×	×		
Compressive strength			×		×	×		×	×	×	×	×	
Tensile strength			×			×		×	×	×	×	×	
SHV		×	×	×	×			×			×		
Slake durability	×			×	×	×		×		×			
Washington degradation test	×	×	×	×			×		×				
Wetting–drying				×		×				×	×		
Freeze–thaw			×	×		×		×			×		
Sulphate soundness			×	×			×		×	×	×		
Rapid abrasion test	×		×		×	×	×	×			×		×
Los Angeles abrasion	×		×		×		×				×		×
AAV			×		×	×	×				×		×
ACV		×	×	×	×					×	×		
10% fines			×		×	×	×				×	×	×
PSV		×			×	×				×		×	×
Aggregate shrinkage		×		×				×		×			
Sonic velocity			×	×				×			×		
M.AIV	×		×	×	×	×	×	×		×	×		
Ultrasonic cavitation			×		×	×				×	×	×	

× = significant to test result.

Current methods of durability assessment

Current practice in construction requires that materials testing is performed as much as possible using test methods that are used in official standards (NEN, DIN, ISO, BS, ASTM). In Europe new European standards (EN) are developed which will be used commonly in the near future. Regarding these tests one would like to know the relationship of the test results with the real behaviour in practice. Case histories and monitoring studies or generally "practical experience" have given some idea of boundary values for test results. For specific purposes generally lists of requirements are made. Very often this is a listing of standard tests with limiting requirements. Especially with marginal materials discussions may occur. Sometimes materials known to be suitable in practice fail some test requirements and are not allowed to be used. The opposite may be worse. The fact that materials pass through the required standard tests but do not fulfil their function shows the weakness of the present methods of suitability assessment. In the following common indicators of suitability for some applications are given. In the Appendix reference to common standard tests is given.

Road stone

Table 3. Tentative limits for road stone (adapted from Collis and Fox, 1985; after Shergold, 1948)

Type of construction	UCS (MPa) (min.)	LAA(% fines) (max.)	ACV (% fines) (max.)
Waterbound			
light traffic	100	35	30
medium traffic	170	25	23
heavy traffic	275	13	13
Concrete			
normal traffic, body of road	70	50	40
surface of road	85	40	35
heavy traffic, body of road	85	40	35
surface of road	100	35	30
Bituminous			
normal traffic, body of road	85	35	30
surface of road	170	25	23
heavy traffic, body of road	85	35	30
surface of road	200	17	17

UCS = unconfined compressive strength of rock specimen
LAA = Los Angeles Abrasion test
ACV = Aggregate crushing value

Table 4. UK specifications for airfield pavements (Collis and Fox, 1985)

	I_F (%, max.)	ACV (%, max.)	WA (%, max.)	Soundness[2] (%, max.)
Surfacing material, general (Marshall asphalt, Marshall DTS, rolled asphalt wearing course, macadam base course, dense tar surfacing)	30	30,25[1]	2	18[2]
Friction Course	25[3]	16[3]	1.5	18[2]

[1] first number: crushed rock or slag; second number gravel
[2] overall percentage mass loss based on the mass losses of the various size fractions tested from one supply source
[3] crushed rock only of specified rock types
I_F = flakiness index; ACV = aggregate crushing value; WA = water absorption (all tests BS 812); Soundness = magnesium sulphate soundness (ASTM C88)

Armourstone

Table 5. Suggested rock quality parameters for marine structures (draft CIRIA/CUR manual on coastal protection structures, Laan et al. 1990)

Index test	Facings or Armour	Underlayers	Core/Fill
Weathering grade (ISRM[1])	I - II	I - II	I - III
Discontinuity spacing (ISRM)	> 1m	> 0.5m > 0.2m	
RQD (%) (ISRM)	70 - 100	70 - 100	50 - 100
Porosity (%)	0 - 10	0 - 15	0 - 15
Water Absorption (%)	< 2.0	< 2.5	< 3.0
UCS (MPa)	> 100	> 100	> 50
Density (Mg/m^3)	> 2.5	> 2.0	> 2.0
AIV (% fines)	< 30	< 30	< 30
10 % fines (kN)	> 100	> 100	> 100

[1] ISRM: see Brown (1981); RQD=Rock Quality Designation, see Brown (1981); AIV=Aggregate Impact Value (BS 812)

Table 6. Guide to rock durability from test results (draft CIRIA/CUR manual on coastal protection structures, Laan et al. 1990)

Index test	excellent	good	marginal	poor	remarks
dry density (Mg/m^3)	> 2.9	2.6-2.9	2.3-2.6	< 2.3	(1)
Water Absorption (%)	< 0.5	0.5-2.0	2.0-6.0	> 6.0	(1)
$MgSO_4$ Soundness (%)	< 2	2-12	12-30	> 30	(2)
Freeze-Thaw (%)	< 0.1	0.1-0.5	0.5-2.0	> 2.0	(3)
Methylene Blue Adsorption (MBA) (g/100g)	< 0.4	0.4-0.7	0.7-1.0	> 1.0	(4)
Fracture Toughness K_{ic} ($MPa.m^{1/2}$)	> 2.5	1.4-2.5	0.8-1.4	< 0.8	(5)
Point Load Index (MPa)	> 8.0	4.0-8.0	1.5-4.0	< 1.5	ISRM 1985
AIV (% fines)	< 10.0	10-20	20-30	> 30	BS 812
Mill abrasion resistance K_s	<0.001	.001-.003	.003-.01	> .01	(6)
Normalised velocity index I	< 1.25	1.25-2.0	> 2.0		(7)
Rock durability indicator; static RDI_s	> 2.5	2.5 - -1	-1 - -3	< -3	(8)
dynamic RDI_d	< 0.5	0.5-2.0	2.0-4.0	> 4.0	(8)

(1) density and water absorption have been found to be useful indicators of material quality. WA is the single most important indicator of resistance against degradation and also a good indicator of weathering resistance. WA can be mis-leading for porous limestones with large free draining pores.
(2) indicates resistance to weathering and salt crystallisation growth. important test for porous sedimentary rocks in hot dry climates.
(3) freeze-thaw and magnesium sulphate soundness both correlate with WA test
(4) this test is very useful to indicate the presence of swelling clay minerals in rock and soil and can be used in combination with petrographic examination (Stapel and Verhoef, 1989; Verhoef, 1990)
(5) this test is a fundamental indicator of tensile strength of rock specimens. correlates with abrasion resistance. (ISRM, 1988)
(6) simulation test for abrasion of rock armouring stone (Latham, 1991)
(7) a method to predict possible breakage of large armourstone blocks, in research stage (Niese et al.1990; Houwink & Verhoef, 1991)
(8) these indicators are treated in the section on rock deterioration in engineering time (Fookes et al. 1988)

Concrete

Table 7. BS 882:1983 Mechanical property requirements for coarse aggregate

Type of concrete	10% value value (kN);	AIV (%) (alternative)
heavy duty concrete floor finishes	> 150	< 25
pavement wearing surfaces	> 100	< 30
others	> 50	< 45

Table 8. Wet strength and wet/dry strength variation (10% fines test; McNally et al. 1990)

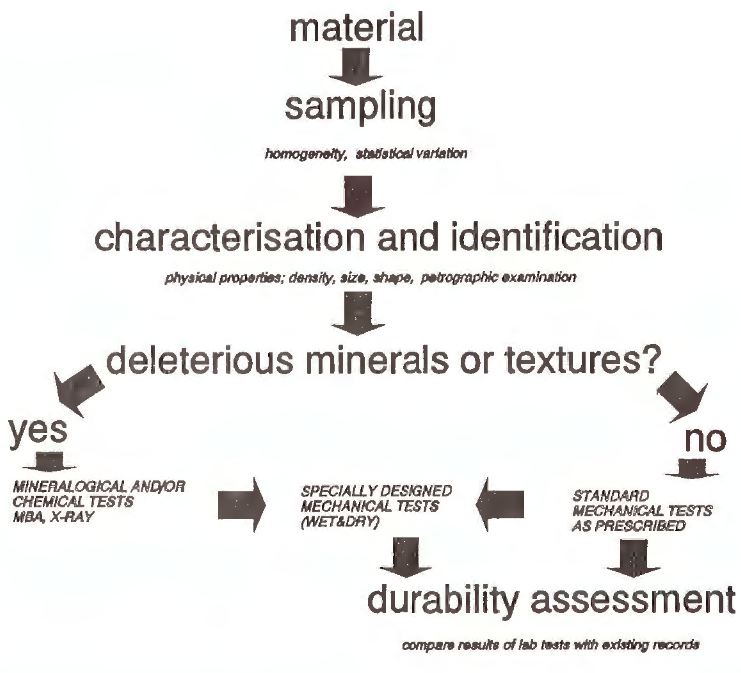
Concrete exposure classification	Min. 10% fines wet strength(kN)	Max. wet/dry strength variation (%)
severe	100	25
moderate	80	35
protected	50	45

The design of a laboratory investigation of construction geomaterials

The guidelines for rock quality given in the above paragraph give only an indication. In fact, from the lists it is clear that apparently a single test is not sufficient to indicate suitability. Evaluation of several test results is necessary. The point stressed here is whether the combination of tests that has been chosen is adequate for the purpose. Secondly, one should be sure that no hidden defect is present in the rock. Important in this respect is the presence of deleterious minerals and structures.

There may be several reasons for testing rock or aggregate:- to assess the usefulness and quality of a new source of aggregate
- to compare quality of rock from different sources
- to assess sample variability
- to predict performance in service
- to predict durability

The test programme to be designed depends on the purpose, but also on the material to be tested. For most applications of granular geomaterials there are specific requirements regarding size and shape. Especially for large armourstone blocks, much of the information on potential size and shape of blocks that can be obtained from a quarry comes from special field studies. After adequate and representative sampling -which is a subject in its own right (Gy, 1979)-, the work should start with a proper characterisation of the material. Apart from geometry (size, shape, flakiness index, angularity) and physical properties (specific gravity, water absorption, porosity) this is done using petrographic examination by micro-scopic techniques. The following flow diagram gives the course of investigation proposed.



The diagram emphasises that before mechanical testing of aggregate is started the mineralogical composition should be known. Most minerals can be determined using the petrographic polarising microscope. Fine grained clay minerals cannot be determined this way. Traditionally clay minerals are determined using X-ray diffraction techniques and differential thermal analysis. In engineering geology one is not necessarily interested in the correct determination of a clay mineral. The point is whether such minerals are swelling when wetted and shrink when dried. Even if very small amounts of swelling clays are present in rock, when moisture conditions vary swelling clays start to act as small pumps from which cracks can grow leading to degradation of the rock. Wetting and drying can, of course, occur when rock is used as coastal protection rip-rap, but a less obvious example is the moisture variation that can take place within road base aggregate by dynamic loading of traffic. Examples are known of argillaceous aggregate developing a thin clay layer by this process between subbase and pavement leading to failure of the road surface (Collis and

Fox, 1985). Only minor amounts of swelling clay could give problems. The simple method of staining the thin sections used for microscopic study with methylene blue, and titrating ground rock or soil with a methylene blue solution, is sufficient to identify and establish the swelling potential of clays (Stapel & Verhoef, 1989; Verhoef, 1990). Since even "fresh" rock could contain some clay the MBA test is carried out in a standard way when performing a petrographic examination.

After the characterisation phase of the investigation, the testing programme is designed. If no special petrographic problems have arisen, standard tests as normally required for a certain application may be performed. If deleterious features are observed, however, the programme should be adapted to try to find out whether this feature really has detrimental effect. For example, if a rock is transected by partially cemented cracks, one could use the magnesium sulphate soundness test, to see whether salt crystallisation may lead to degradation. If clays are present, it is advisable to have mechanical tests carried out both wet and dry. For example the 10% fines test could be carried out wet and dry. The difference of the wet and dry results then gives an indication of the degradation due to hydraulic pumping (or other effects) of clay minerals.

This type of setting up a laboratory investigation does not comply with a rigid use of test result requirements, such as listed in the previous section. More and more it is recognised that also for geomaterials used in constructions another approach should be taken. In stead of using a suite of standard tests to assess the material, for each purpose an analysis of the *system* that completely describes the engineering environment should be made, which would describe as accurately as possible the stresses, loadings and environmental agents that would operate on the rock material. Then the testing programme would address specifically these features. This is akin to the systems approach used now in tribological (wear and lubrication) engineering (Uetz, 1986; Zum Gahr, 1987). Table 9 gives an indication of the type of wearing and degrading processes that occur in various structures.

Table 9. Degrading mechanisms acting on geomaterials in particular engineering structures (Fookes, 1991)

Engineering structure	Type of structure	Main degradation mechanism: Abrasion	Impact	Crushing	Salt crystallization	Freeze–thaw	Polishing	Wetting–drying
Unbound road base	D			×		×		
Road wearing course	D	×	×	×	(×)	×	×	×
Riprap/ cut slopes	S	(×)	(×)		(×)	×		×
Filter media	S	(×)				(×)		×
Railway ballast	S + D	(×)	×	×		×		×
Breakwater armour	S + D	×	(×)		×			×

×, important; (×), may be of importance; S, static; D, dynamic.

Rock deterioration in engineering time
(Fookes et al. 1988)

It has been stated already that most degradation processes that take place in engineering time are the result of the interaction of the new engineering environment with deleterious minerals or microscopic structures *already present in the rock due to weathering processes that have taken place in the natural environment where the rock comes from.*

Table 10 gives an idea of the forces that can be exerted by clay minerals or crystals growing in pore spaces of rock.

Table 10. Comparison of typical pressures exerted by physical weathering processes on rock (Fookes et al. 1988).

freezing (max. at -20°C)	200 MPa
crystallization of salts	2 - 20 MPa
hydration of salts	100 MPa
clay expansion	2 MPa

Examination of Table 11, where data are assembled on rock deterioration leading to failure of engineering works, shows that especially basalt-type rocks are involved. This is not so surprising. Especially the minerals building up basalt rock weather towards swelling-type clay minerals. The rock may seem sound in hand specimen and perform well in simple standard aggregate tests. Especially when the source quarry occurs in a dry environment and the application is under wet conditions dramatic failures may occur. But, as is also indicated in the table, swelling clay minerals or other detrimental features can occur in any rock.

Fookes et al. (1988), after analyzing many aggregate tests, concluded that only combinations of tests could give an indication of durability. They proposed tentative durability indicators, one for static conditions (foundations of structures, cut slope faces, dam or highway embankments) and one for dynamic conditions.

$$RDI_s = \frac{PLS - 0.1(SST + 5WA)}{SG_{ssd}}$$

$$RDI_d = \frac{[MAIV + 5(WA)]}{SG_{ssd}}$$

PLS = average dry and saturated point load strength (ISRM, 1985)
SST = magnesium sulphate soundness test (Hosking & Tubey, 1969)
WA = water absorption (BS 812)
SG_{ssd} = specific gravity saturated and surface dried (BS 812)
MAIV = modified aggregate impact value (Hosking & Tubey, 1969)

This attempt to evaluate the potential durability of rock using a combination of tests that relates to the engineering use and to the petrographic properties of the rock (Table 2) is a useful start towards the system analysis approach that hopefully can take place in the near future.

Table 11. Reported case histories of in-service deterioration of rock aggregate with presumed cause (numbered ones: see Table 9 of Fookes et al. 1988 for references)

Rock Type	Structure	Age of failure	Weathering state original rock	Cause
1. basalt NW USA	roads	< 5 years	altered	secondary minerals
2. basalt Washington	roads	3 months	altered	idem + production plastic fines
3. basalt Idaho	roads			sec. min.s + change particle size
4. claystone Auckland, NZ	motorway			production moisture sensitive fines
5. basic igneous; Mauritius	runway	18 months	weathered	secondary minerals
6. olivine basalt; UK	road		weathered	in-situ weathering
7. olivine dolerite, UK	road		weathered	in-situ weathering
8. basalt Victoria, Aus.	concrete		altered	secondary minerals
9. granite Santa Mateo, USA	rip rap		weathered	sec. min.s expanded due to moisture
10. basalt Glenbrook, New Zealand	roads		altered	action of moisture on alteration products products highly active plastic slurries
11. dolerite SW England	roads	< 1 year	weathered	physical degradation
12. basalt gravels Ethiopia	roads	< 5 years	altered	physical degradation
limestone Lake Tunis	rip rap	few months	slightly weathered	30 % completely deteriorated due to presence of swelling clay

Conclusion

Evaluation of suitability of geomaterials for construction should be based on
- an analysis of the function of the material in the construction and the expected static and dynamic loadings and environmental conditions imposed (system analysis)
- professional field survey of potential sources.
- laboratory investigation of representative samples, centred around petrographic examination
- a purposely designed testing programme

Recommended literature

Collis, L. and Fox, R.A. (1985): "Sand, gravel and crushed rock aggregates for construction purposes". The Geological Society of London, Engineering Group, Spec. Publ., No. 1, 220 pp. (new edition in preparation)

Literature

British Standard Institution. BS 812: 1975, 1985. "Testing aggregates"
Brown E.T. (ed.) (1981): "Rock characterisation, testing and monitoring. ISRM suggested methods. Permagon press, Oxford, pp 201.
Dolar-Mantuani, L. (1983): "Handbook of concrete aggregates". Noyes Publications, Park Ridge, N.J., USA.
Fookes, P.G., Gourley, C.S., Ohikere, C. (1988): "Rock weathering in engineering time". Quarterly J. of Engng. Geol., 21, 33-57.
Fookes, P.G. (1991): "Geomaterials". Quarterly J. of Engng. Geol., 24, 3-15.
French, W.J. (1991): "Concrete petrography: a review". Quarterly J. of Engng. Geol., 24, 17-48.
Gy, P.M. (1979): "Sampling of particulate materials; theory and practice". Elsevier, Amsterdam, 431 pp.
Hosking, J.R. and Tubey, L.W. (1969): "Research on low grade and unsound aggregates". Report LR 293, Road Research Laboratory, Crowthorne (UK).
Houwink, H. and Verhoef, P.N.W. (1991): "Detectie verborgen scheuren in waterbouwsteen". Internal report Delft University. Memoirs of the Centre of Engng. Geol., 88, geomat.01, 130 pp.
ISRM: see Brown, E.T. (1981)
ISRM (1985): "Suggested methods for determining point load strength". Int.J.Rock Mechs.Min.Sci.& Geomech.Abstr., 22, 51-60.
ISRM (1988): "Suggested methods for determining the fracture toughness of rock". Int.J.Rock Mechs.Min.Sci.& Geomech.Abstr., 24, 71-96
Jones, F.E., Tarleton, R.D. (1958): "Experience with some forms of rapid and accelerated tests for alkali-aggregate reactivity". in: Recommended test procedures, part VI: Alkali-aggregate interaction, Her Majesty's Stationary Office, London, National Building Studies Research paper 25.
Laan, G.J., Latham, J-P., Pilarczyk, K.W., Poole, A.B., Yelland, D. (1990): Manual on the use of rock in shoreline and coastal engineering". Draft report. CUR-CIRIA.
Latham, J-P. (1991): "Degradation model for rock armour in coastal engineering". Quarterly J. of Engng. Geol., 24, 101-118.
Latham, J.P., Poole, A.B., Laan, G.J. and Verhoef, P.N.W. (1990): "Geological constraints on the use of quarried rock in coastal structures". Proceedings 6th International Congress IAEG, August 1990; Symposia volume, Symposium III: Coastal protection and erosion., Balkema, Rotterdam, 217 - 227.
LCPC (1989): "Les Enrochements". Laboratoire des Ponts et Chaussées, Paris, ISBN 2-7208-6200-2, 107 pp.
LCPC (1990): "Essai au blue de méthylène". Bull. de liaison des laboratoires des ponts et chausées, Paris, 159-164, 80 pp.
McNally, G., Williams, W., Stewart, I. (1990): "Soil & Rock Construction Materials". Key Centre of Mines Short Course, 27-29 November, University of New South Wales, Kensington, NSW, Australia, 400 pp.
Niese, M.S.J., Van Eijk, F.C.A.A., Laan, G.J. and Verhoef, P.N.W. (1990): "Quality assessment of large armourstone using an acoustic velocity analysis method". Bull. IAEG, vol. 42, 55 - 65.
Poole, A.B. (1991): "Rock quality in coastal engineering". Quarterly J. of Engng. Geol., 24, 85-90.
Rilem Technical Committee 26-GM "Granular Materials" (1982): "Aggregates". Materiaux et Construction, 15, 205-258.
Stapel, E.E. and Verhoef, P.N.W. (1989): "The use of the methylene blue adsorption test in assessing the quality of basaltic tuff rock aggregate" Engineering Geology, 26, 233-246.
Uetz, H. (1986): "Abrasion und Erosion". Carl Hansen Verlag, München. pp. 829.
Verhoef, P.N.W. (1990): "The methylene blue adsorption test (spot method)". Test description. Internal report, TU Delft, Faculty of Mining, Section Engineering Geology, 4 pp.
Tourenq, C., Denis, A. (1982): "Les essais de granulats". Rapport de recherche LPC No. 114, Laboratoire des Ponts et Chaussées, Paris, 88 pp.
Zum Gahr, K.H. (1987): "Microstructure and wear of materials". Elsevier, 560 pp.

Logisterion brengt

ARC/INFO

ARC/INFO, het meest gebruikte **Geografisch Informatie Systeem,** integreert (topo)-grafische en administratieve gegevens in een topologische en relationele datastructuur. Hierdoor kan ARC/INFO voor een breed scala van toepassingen worden ingezet. ARC/INFO is nu verkrijgbaar op de volgende hardware platforms:

PC'S

IBM AT
IBM PS/2

WORKSTATIONS

DEC VAXstation, Tektronix, HP, SUN, IBM RT, Apollo, Data General

MINICOMPUTERS

Prime, DEC, IBM, Data General

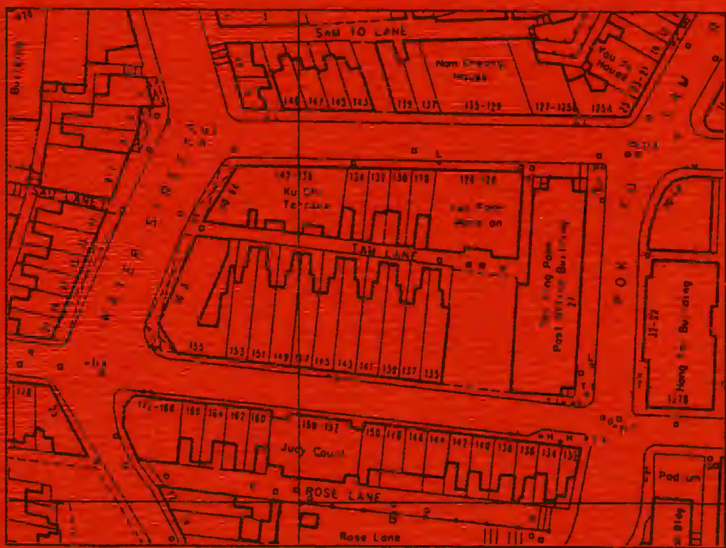
MAINFRAMES

IBM

TOEPASSINGEN

ARC/INFO kan toegepast worden in de volgende gebieden: planning, beheer, waterhuishouding, vastgoedinformatie, kartografie, bosbouw, landbouw, milieurapportering, ruilverkaveling, demografie, verkeer, 3-D analyse, expeditie, hydrologie.

3-D analyse



vastgoedinformatie

Het ARC/INFO systeem is een produkt van Environmental Systems Research Institute, Inc., Redlands, USA.

Logisterion b.v.
Automatisering

Stationsplein 45 Postbus 29 080 3001 GB Rotterdam
Telefoon 010 - 411 88 55 Telex: 23688

15595