EARTH-SCIENCE CONSERVATION: NO SCIENCE WITHOUT CONSERVATION

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ABSTRACT

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The first call for the conservation of geologically important sites in The Netherlands was made by Van Baren in 1908. In the decade that followed, some reserves were established, mainly through the efforts of interested individuals as no lead was given by the professional societies and only a few scientists chose to play an active role. Further, those conservation societies which were in existence and in receipt of support from numbers of professional scientists, had interests which were largely confined to biological features. It was not until 1969, when the Gea working group was inaugurated, that systematic governmental involvement in earth-science conservation began.

Descriptive inventories of sites of scientific and/or educational value are produced province by province; in addition special reports dealing with individual sites threatened with destruction are also prepared. Some case histories in geological conservation are outlined in this paper.

INTRODUCTION

Earth-science conservation aims to preserve landforms and exposures for two reasons. Firstly, there is a clear scientific need to preserve and maintain those type areas and type localities which serve as standards. Secondly it is equally in the public interest to ensure that landforms and sections through sediments, whether natural or artificial, should remain available for both educational and recreational use. Both these aims were fulfilled when the Schokland Geological Park (Gesteentetuin) was opened earlier this year for here the State Forest Service (Staatsbosbeheer), in close collaboration with interested laymen (Jonge Onderzoekers), amateur and professional geologists and the Lake IJssel Polder Development Authority (Rijksdienst IJsselmeerpolders), has set aside part of one of their forests as a specially designed educational area. After years of preparation, this park now demonstrates erratic boulders of Scandinavian origin arranged according to their petrography, artificial exposures specially cut in boulder clay and also natural surfaces of lag-deposits, consisting of cobbles washed out by the waves of the former Zuiderzee. In addition an attractive information centre has been provided. The unflagging enthusiasm of Mr. W. Tj. Hellinga and Mr. G. D. van der Heide and the generosity of the State Forest Service (the owners of the park), have produced a geological educational facility unequalled in The Netherlands.

The new development at Schokland was not solely planned to display and explain its intrinsic geological merit. Close to the park lies the P. van der Lijn Geological Reserve, established in 1954. The scientific value of the reserve has been so seriously and adversely affected by hammering and collecting by visitors that it had to be closed to the general public, allowing access only to specialist groups under expert guidance. The Schokland Geological Park is much less vulnerable to over-use by visitors than the Van der Lijn Reserve.

The conservation movement in The Netherlands dates from the close of the nineteenth century and initially received only moderate scientific support. The first reserve, the Naardermeer, was established in 1906 by the Society for the Preservation of Nature Reserves in The Netherlands, shortly the Society (Vereniging tot Behoud van Natuurmonumenten in Nederland).

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Fig. 1
Specific earth-science reserves and monuments in The Netherlands. 1 = Koudum (ice-pushed Pleistocene sediments); 2 = Roode Klif (disappeared by re-allotment); 3 = Oude Mirdumerklif (fossil cliff in boulder clay); 4 = Mildam (pingo remnant); 5 = Gieten forestry (pingo remnant); 6 = Exloo-Odoorn forestry (pingo remnant); 7 = Finsterwolde (ice-pushed Pleistocene sediments); 8 = Urkerbos, Geological Reserve P. van der Lijn (abrasion platform in boulder clay); 9 = Schokland, Geological Garden (abrasion platform in boulder clay); 10 = Emmeloord (Holocene Almere Member); 11 = Kuinderbos (landscape of filled-up erosion holes in peat); 12 = Zwolse Vaart (Eemian peat); 13 = Hattem (ice-pushed Pleistocene sediments); 14 = Huizen (ice-pushed Pleistocene sediments); 15 = Blaricum (ice-pushed Pleistocene sediments and coversand); 16 = Kaapse Bossen (collection of erratics); 17 = Usselo (type locality of the Usselo layer); 18 = Losser Staringmonument (Cretaceous Losser sandstone); 19 = Zuid Weihoek (fossil creek); 20 = Nieuw Namen (Pliocene coastal sediments); 21 = Vessem (cryoturbated coversands); 22 = Uden (Peelrand faultstep); 23 = Tegelen (type locality of the Tiglian); 24 = Brunssum (Feldbiss fault); 25 = Voerendaal (Kunrader chalk); 26 = Kosberg (Maas sediments in the Kosberg level); 27 = Epen, Geological Monument Heimansgroeve (Carboniferous sediments); 28 = Cottessen (Carboniferous sediments); 29 = Platte Bosschen (Tiglian humic clay and pseudo-gley profile); 30 = Vijlener Bosch (collection of Tertiary cemented sandstone boulders).

• = protected site; ○ = protection in preparation; * = inventoried province ⋆ = inventory in preparation.

Governmental involvement in conservation commenced in 1908, when the Muy Lake on Texel was established as a reserve by the State Forest Service. In the same year, the inland-dune area of Kootwijkerzand was also set aside as a conservation area because of its geological interest. Subsequently, voluntary conservation organisations were established – for example the provincial societies for nature preservation, the first of which appeared in 1927.

In 1968, the Nature Conservation Act came into effect and provided a formal statutory basis whereby conservation considerations could influence the decision-making process. Still, voluntary and official interest continued to be directed mainly towards the conservation of flora and fauna. The conservation of features of earth-science interest was properly organised only in the following year, when Dr. F. de Soet of the Research Institute for Nature Management (Rijksinstituut voor Natuurbeheer) organised the Gea working group in which various organisations with interests in conservation and in the earth sciences were represented.

EARTH-SCIENCE CONSERVATION

The aim of the Society, as formulated in 1905, is the conservation of the natural flora and fauna and the conservation of geologically important features. The geologist and mining engineer Professor G. A. F. Molengraaff sat in the Board of this Society from its foundation until 1943 and the geologists Professor J. A. van Baren and Dr. P. Tesch (Director of The Netherlands Geological Survey, (Rijks Geologische Dienst) acted as advisors.

Despite the promise inherent in the aim of the Society, and the distinction of the geological representatives on its Board, few nature reserves were established primarily for their significance to the earth sciences (Fig. 1). Many of the reserves which were established admittedly possessed geological interest, but it was only rarely that such interest was seen as the principal argument for their conservation. There are several reasons for the poor representation of geology among the nature reserves established at this time: many small pits and quarries of geological interest were exploited by hand and the slow rate of extraction in such artificial exposures kept their interest available for education and research for a long time – there was thus no urgent necessity to preserve large and rapidly changing exposures. Similarly, small-scale exploitation operating at a leisurely pace did not seriously damage landforms. Moreover professional geologists were often indirectly involved in mineral extraction and this may have served to reduce their interest in conservation. Other geologists may well have thought that Dutch geological localities were not spectacular enough to merit conservation. VAN BAREN, (1908) in a pioneer paper, pointed out that a number of features, although not spectacular, did in fact possess sufficient significance to deserve protection on scientific grounds and cited the terpen (artificial mounds), the ice-pushed ridges near Steenwijk, the peat moors, the coversand dunes (at that time interpreted as eskers and kames) in the Drenthe and Overijssel provinces and the landscapes between Delden and Haaksbergen and near Eindhoven.

All these were already seriously threatened in Van Baren's time. Little response, however, was forthcoming to his call for

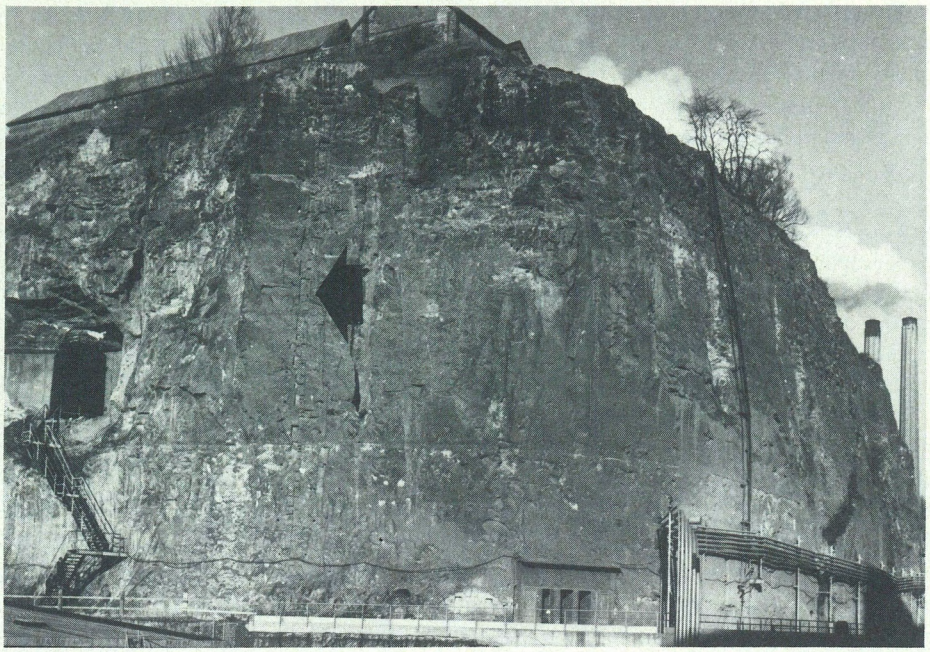

Fig. 2*
Type section of the Maastrichtian in the E.N.C.I. quarry near Maastricht (Zuid-Limburg). Left from the centre the vertical lined sample holes are visible. Photograph: Rijks Geologische Dienst, L. F. Funcken, 1961.

conservation. The journal of the Royal Netherlands Geographic Society (Koninklijk Nederlands Aardrijkskundig Genootschap), in which he published his paper, never became a mouth-piece for conservation, nor did the journal of the Royal Geological and Mining Society of The Netherlands (Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap), which first appeared in 1912.

Professional geologists, such as Kruizinga, Van Baren, Steenhuis, Waterschoot van der Gracht, Jongmans and Van Rummelen, and amateur geologists such as Heimans, Bernink and Van der Lijn wrote papers about Dutch geology intended for the general reader; these were published in journals which specialised in natural history, especially biology. Most were purely informative; they included accounts of regional geology and descriptions of interesting localities and finds. STEENHUIS (1921-1923), for instance, published a series on short-lived, temporary exposures but did not suggest that these should be kept available for science nor gave any indication of how they could be preserved.

HEIMANS (1911) was an author to press for the protection of regions of geological interest. His book *'Ons Krijtland'* closes with an expression of his hope that the area around Epen would become a national park. In 1911 and 1912 Heimans attempted to preserve a concentration of large erratics in the Crailo sandpit, between Hilversum and Bussum. The owners, Stad en Lande van Gooiland (the common land commission), did not appreciate his initiative and made every attempt to reclaim the area at the earliest opportunity. VAN DER LIJN (1916) met with more success when he approached the Town Council of Amersfoort and suggested that a pit excavated in boulder clay close to the town should be preserved. This exposure was preserved for some years as a 'curious relic from the Ice Age' (VAN DIJK, 1980).

After Van Baren, TESCH (1920) was the first professional geologist to publish his concern about the need to preserve geologically valuable areas. He described how the dunes, which he knew well through his geological work, were becoming deformed and disturbed by human interference. Soon afterwards, important areas of the Dutch coastal dunes were given reserve status, mostly as a result of governmental decisions. However, this initiative by the Director of the Geological Survey could not prevent building, sand extraction and the digging of infiltration canals for water supply in large stretches of the supposedly protected dunes. Moreover, heavy pumping of subterranean water for domestic consumption dried up the dune areas. In 1923, VAN DER SLEEN made a plea for the conservation of the St. Pietersberg, near Maastricht. This famous chalk hill is the type locality of *Mosasaurus* and of hundreds of other, less spectacular but no less important, fossils; it is also the stratotype of the Maastrichtian stage (Fig. 2). Its rocks had long been subject to quarrying and further extension of mineral extraction now threatened their complete removal. In the event, however, neither Van der Sleen's paper nor the many biological pleas for conservation could avert the decision to proceed with further quarrying.

Although this case was lost, others succeeded. Reports published by the Society (VERENIGING) on the Rheden Heath (1910), the Kootwijk inland dunes (1920) and the Wolfheze

forest (1939/40) make it abundantly clear that the need to conserve the earth-science interests of these reserves was not only understood but also appreciated. The Society followed the advice of Professor Van Baren and approached the Town Council of Arnhem and the military authorities to seek conservation of the fossil course of the brook known as the Heelsumse Beek.

In 1917, the Board of the Society agreed with the Directors of the State Railway Company (Nederlandse Spoorwegen) to transfer some large erratics from the railway's sandpit at Maarn to a site near the station where, in the following year, an educational geological park was set up. In 1927, an interesting exposure of boulder clay in a cliff (known as the Oude Mirdumerklif) facing the then-open Zuiderzee in south-western Friesland was purchased. The closing of the Zuiderzee in 1932 led to a rapid degradation of the exposure, which soon became colonised with vegetation; subsequent artificial changes in water levels led to further deterioration. The Mirnser Klif, a similar locality, was acquired by the provincial association for conservation 'It Fryske Gea' in 1941 but has now become completely overgrown. For some years after 1943, It Fryske Gea protected a sand pit in the Roode Klif, a nearby hill, where boulder clay overlies fluvial sand. This section was later lost in a re-arrangement of land use.

In the southern Netherlands, HEIMANS (1911) drew wide attention to the country around Epen, the only part of The Netherlands where Carboniferous rocks are exposed. Scientific research by Jongmans and Van Rummelen led to the setting up of an excursion route known as the 'Carboniferous Promenade' in which the last-visited exposure was specially excavated. (JONGMANS, 1937). The project was supported financially by various societies and organisations and, through their help, a section, more than 100 m in length, was cut in Carboniferous shales and sandstones. Since 1937, the rent of this geological monument, known as the Heimans Quarry, has been paid by the provincial foundation for conservation 'Het Limburgs Landschap'.

Also in 1937, JONGMANS & VAN RUMMELEN presented the results of the first systematic regional survey of features of value to the earth scientist. Their account covers Southern Limburg and includes an inventory of forty localities which, in the opinion of the authors, should be protected.

Intensive mapping of the region of large rivers in the central Netherlands led to the recognition of the so-called 'donken' – isolated sand hills which emerge from beneath the fluvial clays. These are now interpreted as river dunes of late Pleistocene or early Holocene age. EDELMAN & VINK considered the desirability of protecting these river dunes and reported their findings to the Society (1941). In their report, published in 1946, the authors state that 'the donken are last vestiges of a geological past that could not be reconstructed without these hills and which, if the hills were levelled, would become unintelligible to posterity'. Edelman and Vink noted that several donken had already been levelled and suggested that a better source of sand lay in the silted-up old river courses. Their report, however, did not lead to a cessation of sand extraction and the levelling of the river dunes (LEEUWIS, 1953).

In 1944, the amateur geologist VAN DER LIJN, who had become well-known through his many popular presentations of geology to lay readers, wrote a paper on a 'first-rate geological monument near Urk'. This area, as mentioned above, contains fresh exposures of boulder clay which became visible after the Noordoostpolder was reclaimed; these exposures were the subject of intensive studies by DE WAARD (1949). In 1954, parts of this boulder-strewn outcrop – four hectares out of a total of fifteen – were fenced off as a geological reserve, now named after Van der Lijn. The State Forest Service, as owners of the site, have made great efforts to prevent the growth of vegetation over the fertile surface.

Other exposures in whose conservation Van der Lijn was involved include the boulder clay pit near Amersfoort (mentioned above), a second boulder-clay pit between Hilversum and Bussum and the occurrences of cemented fluvial sands in the Bikbergen Forest near Huizen. The second and third lie within properties owned by the Goois Natuurreservaat, a regional conservation foundation.

A more recent attempt at earth-science conservation by a single individual is to be found in FELDER's (1962) description of the dolines of the Vijlen Forest in the southernmost part of the province of Limburg whose scientific interest is endangered by refuse dumping. In 1964 the same author prepared a guide to this area – a good example of educational usage co-ordinated with conservation.

In 1966, it became known that the city of Nijmegen intended to build over a Late-Pleistocene braided-river system to the west of the town. This plan aroused fierce opposition led by TEUNISSEN (1966), a geologist teaching at Nijmegen University, who prepared a petition to the City Council which explained the importance and interest of the area to earth scientists. Although, for the first time, many prominent Dutch earth scientists gave their support, the effort nevertheless failed to achieve its objective. Similar development had earlier threatened the Losserse Es, a hill adjoining the village of Losser. This hill is the only structurally determined landform in the eastern Netherlands; it consists of lowermost Cretaceous sandstones and is the type locality for a variety of fossil mollusca. In 1964, ANDERSON (1968) in association with other amateur geologists, argued that part of the hill should remain accessible for geological research and instruction. They explained their views to the authorities and, four years later, an artificial exposure was opened in part of the hill which had been excluded from the built-up area. This geological monument was named after Staring, the doyen of Dutch geology, who had undertaken investigations into the use of Losser sandstone as a building material 125 years previously.

The strong upsurge of interest in conservation in the 60's is reflected in the appearance of a number of multi-disciplinary reports. One example is a special issue of the Limburg Natural History Journal (Natuurhistorisch Genootschap in Limburg) in which KUYL (1967) highlighted the geological history of the

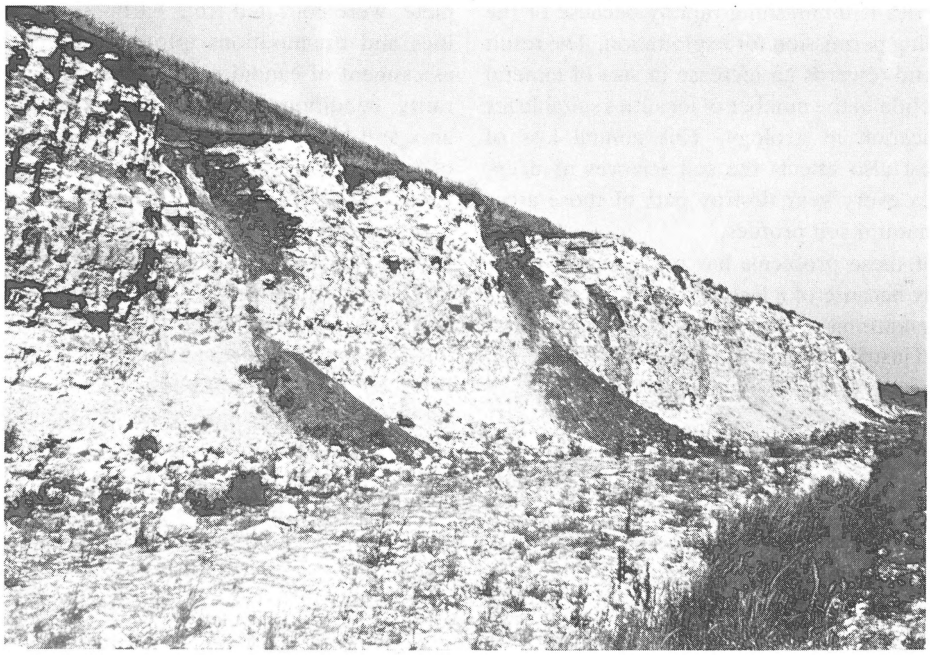

Fig. 3
Kunrade chalk exposed along the State Highway A 76 near Heerlen (Zuid-Limburg). This part of the wall is not finished because of its geological value.

Brunssum Heath and emphasized the geological importance of its complicated structure. KUYL & FELDER (both from the Geological Survey Branch Office in Heerlen) published a paper in the same journal a year later (1968) on some geological localities in the southernmost part of Limburg which they considered to be well worthy of protection. Another example, showing an integrated approach, is the extensive volume recording a study made on the Dinkel Valley. The work was co-ordinated by VAN DER HAMMEN & WYMSTRA (1971) who provided a summary of the localities of geological and biological interest. The exposures along the Dinkel River in the Lutterzand dune area are considered to be of international importance.

The publication by a Working Group (WERKGROEP) in 1972 of *'De Kleuren Van Zuidwest Nederland'* (The Colours of the Southwestern Netherlands) a volume in which an attempt was made to map and to evaluate various environmental factors, was a landmark in the development of conservation strategy. For the first time, an attempt was made to devise a quantitative approach which could be used to determine the influence conservation should have on general planning considerations. The earth sciences, however, were not taken into account in this report, and they were also ignored in a number of later, similar studies. The first work in which the earth sciences received full consideration was the geomorphological inventory and valuation prepared by MAARLEVELD & DE LANGE (1972) for inclusion in the report on the forelands along the great Dutch rivers which was edited by DE SOET (1976). Another planning report in which geomorphology was taken into account is that concerned with the Veluwe (TEN HOUTE DE LANGE, 1977).

THE GEA PROJECT

Problems

In The Netherlands, as in so many other countries, the population has approximately doubled since the beginning of the present century. Urbanisation and technical development have reduced the open rural space while the pace of exploitation of mineral resources has increased rapidly. Ice-pushed ridges, river terraces, coversand ridges and dunes have been worked to provide sand and gravel; forelands and Cainozoic deposits have produced clay; the Triassic and Cretaceous strata found in Limburg and in the easternmost parts of Gelderland have been quarried for limestone and the once extensive peat deposits have nearly all been dug away to provide fuel. At the same time, land which was formerly waste has been developed and rivers canalised. All these activities have served to degrade the geomorphological features of The Netherlands.

In the course of development many temporary exposures of value to geological research have been produced and outcrops in railway cuttings and along highways (Fig. 3) have yielded valuable information. Similarly sand-pits, clay-pits and quarries, although they often scarred the landscape, have played an invaluable role in geological studies. However, the small-scale pits and quarries, which traditionally have been important for education and research in geology, are now largely closed as further extraction has not been permitted. At the same time, the faces of large excavations have been covered with overburden or are used as refuse dumps. The number of

new pits and quarries is diminishing rapidly because of the difficulty in obtaining permission for exploitation. The result of this modern trend towards an increase in size of mineral workings is a reduction in the number of localities suitable for research and education in geology. This annual loss of localities of interest also affects the soil sciences as deep-ploughing practices every year destroy part of those areas which still retain natural soil profiles.

The existence of these problems has received scanty recognition, probably because of a lack of interest in the earth sciences by conservationists. Further, professional earth scientists have paid insufficient attention to the pressing need to protect the sources from which they derive their own research material.

Aims

Until 1969, the protection of sites of earth-science interest in The Netherlands was largely the result of private initiative, as Government Conservation Agencies had shown little interest in this field. In 1969, however, the Head of the Geography Division of the Research Institute for Nature Management, Dr. F. de Soet, considered that protection for earth-science interest was as necessary as the protection given to biological, cultural and archaeological interests. He therefore convened the Gea working group on which the Research Institute for Nature Management, the Dutch Geological Society (Nederlandse Geologische Vereniging) (an amateur body), the Netherlands Geological Survey, the Soil Survey Institute (Stichting voor Bodemkartering) and the Laboratory of Physical Geography and Soil Science (Fysisch-geografisch en Bodemkundig Laboratorium) of the University of Amsterdam were represented. The working group was later joined by representatives from the Netherlands National Museum of Geology and Mineralogy (Rijksmuseum van Geologie en Mineralogie) and from the State Forest Service (Staatsbosbeheer). This working group was convened specifically to carry out the aims of the so-called 'Gea Project', i.e. to assess the value and to make an inventory of all sites of interest to the earth sciences and to undertake research into the management and conservation of such sites. The work would be largely scientific and educational in character and would have ethical and aesthetic aspects. With the setting up of the working group, a start could be made to achieving the aims already voiced by VAN RIJSINGE (1953) in 1945.

Methods

Although the working group first considered the possibility of undertaking a study of a limited number of important sites, it soon came to the conclusion that a systematically prepared inventory of all sites of value was required. The work was to be carried out largely by the first author, Secretary of the working group.

From May 1970 to 1971, data, admittedly somewhat incomplete, were collected from earth-science institutes, universities and organisations interested in conservation. In the assessment of candidate localities, five criteria were used – rarity, condition, scientific importance, educational importance and 'representativity'. Finally, in some cases, the range of variation in geological features is used as an additional criterion in site selection. It had to be borne in mind that exposures of the soft rocks which form most of The Netherlands are easily damaged and that such damage is not repaired by nature. Many surface features have been produced by processes which no longer operate – for example Tertiary karst, ice-pushed ridges and periglacial phenomena cannot be replaced – and renewal and recovery can take place only in those areas where appropriate geological processes are currently active (e.g. dunes and tidal regions). More often than not, however, the natural forces on which the processes depend have suffered from human interference so that the features they would produce would not be identical to those originally present.

After localities have been selected for conservation, their interest is described and the relevant information is collected and collated into provincial reports which are sent to conservation organisations and to bodies concerned with planning and development. Their contents comprise short descriptions of each site, conclusions concerning its conservation, bibliographic references and maps (Fig. 4). In addition to these systematic inventories, prepared on the basis of single provinces, attention is also paid to individual sites which are urgently in need of protection. For these, reports are prepared which deal with the nature of the site, its scientific value, the damage that may result from proposed or likely development and other aspects of site preservation and management.

Protection

Dutch legislation currently in force gives opportunities for conservation both by public and private organisations. The community can conserve sites through the planning system, through financial arrangements to preserve natural features, through designation as natural monuments and by purchase. The individual and the voluntary organisation can protect sites by purchase, rent, ground rent and management agreements. The method chosen is always the result of the compromise of a number of factors – the wishes of the owner, the financial means available and the management that is required.

Management

For most sites protection alone is not sufficient – management to protect specific aspects of the geological interest is also required. The management needed to conserve geological interest may be in conflict with that required to conserve the biological interest and compromises must be devised whereby both needs can be satisfied.

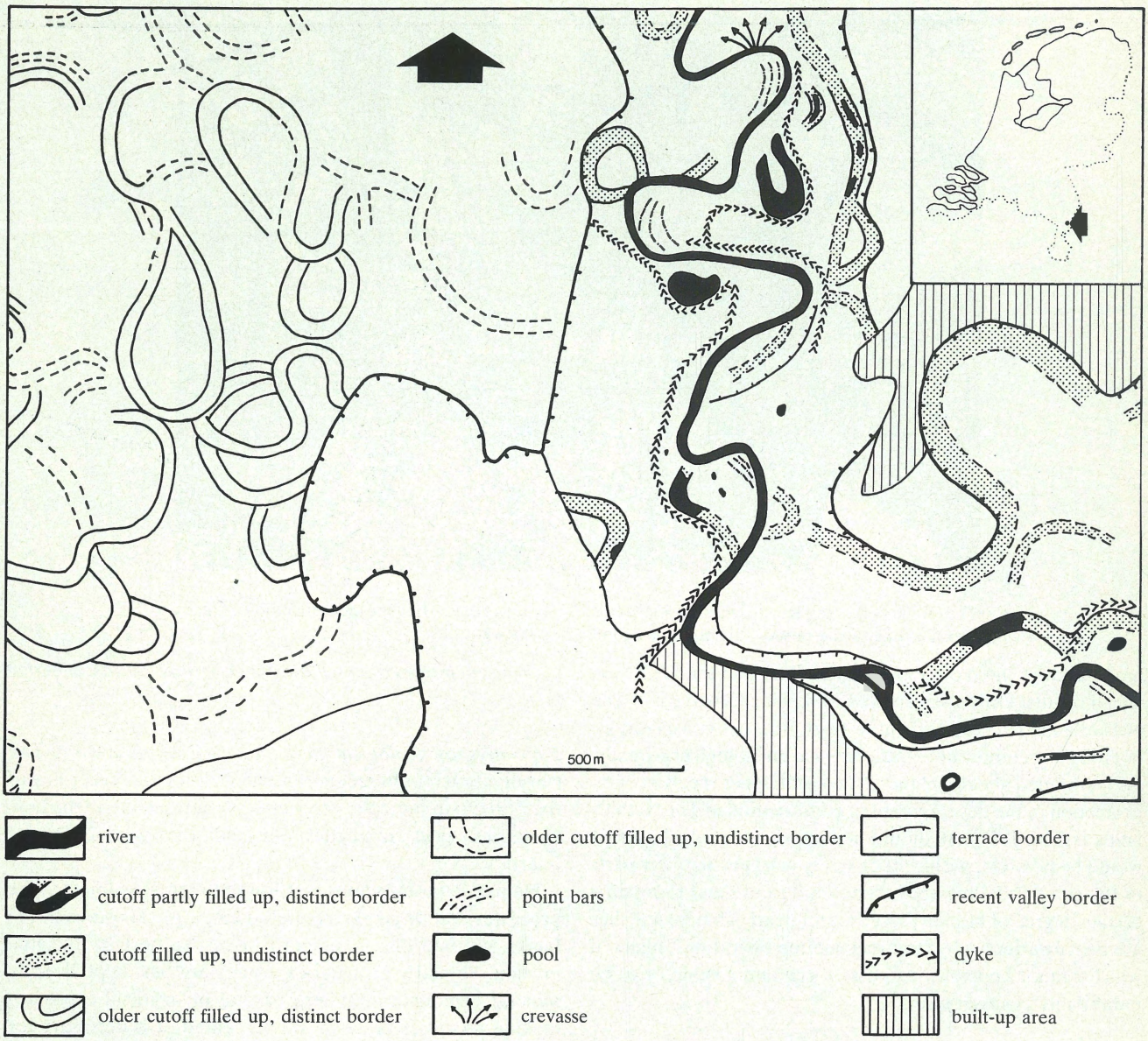

Fig. 4
Detail of a preliminary aerial photo-interpretation map, in aid of nature-conservation purposes within the framework of re-allotment activities.

Three main types of earth-science sites can be distinguished through their management requirements.

Geomorphologically important sites – Such sites must be managed so that their structure and the morphology of their landforms are kept intact. Where such sites are the property of a conservation organisation, this presents no problem; where such sites are in outside ownership, conservation can be effected through appropriate management agreements. Protection of sites of this type is especially important in the Low Countries, where there is little topographic relief. For instance, in the part of Holland floored by Holocene deposits, a large number of fossil marsh-creek systems, near or at the surface, are currently being destroyed through meadows being turned into arable fields. At present, such conversion from cattle grazing to arable farming is having adverse effects on the Wassenaarsche Polder in the province of Zuid-Holland. The dry creeks in the reclaimed mudflats of Goeree-Overflakkee Island now end abruptly at the boundaries of farms where clandestine levelling has taken place. Through entering into management agreements, it is hoped that the loss of this particular scientific phenomenon can be prevented in the future.

Geomorphological conservation involves more than the preservation of landforms – it is of course necessary to maintain the natural processes that have led to their creation. A case in point is provided by the small brooks and rivers, most of which have been canalised in the past; THIJSSE (1933, 1934)

Fig. 5
The Dutch part of the Ruenberger beek (Overijssel) is one of the few free meandering brooks. On the German side of the border this brook is completely canalized.

has already pointed out the impoverishment of the landscape which results. Only a few intact brook systems survive in The Netherlands (Fig. 5) and these warrant strict conservation, not only on geomorphological, but also on biological grounds. As mentioned above, inland and coastal dunes received early protection in the development of conservation in The Netherlands (TESCH, 1920). It should now be considered whether it would be possible, within strict safety margins, to allow parts of the coast (tidal marshes, dunes and sand flats) to retain a certain degree of mobility. At present nearly all tidal marshes are heavily affected by land-reclamation operations, many of which cannot be shown to possess economic value or to be indubitably necessary.

Buried features of importance to geology and soil science – In certain areas artificial exposures have to be made and maintained, or sampling by auger must be possible for education or research. The land surface itself does not need any special management, other than to protect it against any form of development which might prevent access to the deposits beneath. A good example of the problems affecting such a site can be seen at the type locality of the Usselo Layer (Late Pleistocene Interstadial). The researches of HIJSZELER ET AL. (1941) and VAN DER HAMMEN (1951) earned this locality international significance. A renewal of research interest led to a section being re-opened in 1975 (GONGGRIJP, 1975-a). The locality now has legal protection because of its archaeological and stratigraphical importance but, as the area is not owned by any conservation organisation, this has proved ineffective. In the past the land above has been used as a motor-cross circuit and at present it is part of a garden. A site of such recognised international importance surely merits a better fate!

Exposures of geological or pedological importance – The conservation requirements of such localities vary according to their origin; in some the exposures are natural but, in the Low Countries, most are artificial and take the form of pits and quarries.

Natural exposures must be allowed to remain subject to the processes that originally created them, e.g. exposures in the banks and bed of a river must be left subject to fluviatile erosion. Similarly artificial exposures are best kept clear by mineral exploitation. Where natural or artificial exposure-making processes cease or are prevented, it is necessary for human conservation agencies to intervene and ensure that the exposures remain visible. How this is best achieved depends largely on the nature of the exposure concerned.

Large exposures, which display phenomena of considerable horizontal extent and where there is no objection to the face retreating, can be preserved by periodic cleaning of its surface. The conservation of smaller exposures which cannot be cleaned at intervals is much more complicated. Such exposures must be sheltered from wind, rain, groundwater, capillary water, frost and undesirable biological influences (e.g. overgrowth by vegetation and burrowing by animals) by the erection of protective shields, the covering over of exposures, the installation of drainage behind the face, the cladding of the exposure with plastic mats, the grading and terracing of the face and the enclosure of the outcrop. Such measures only tend to delay damage to the exposure rather than eliminate it completely. In sandpits, impregnation of the face with water-

glass, lacquer or plastic compounds can be an effective means of protection. A considerable disadvantage, however, is that research on faces fixed in this way is severely restricted. This handicap can be lessened either by the encouragement of intensive scientific research before impregnation takes place or by treating only part of the exposure, the remainder remaining in an untreated state. The employment of impregnation techniques is costly and therefore must be restricted to exposures that are of high educational value.

Impregnation methods were employed in an attempt to conserve an artificial outcrop in a sandpit on Brunssum Heath (see also KUYL, 1967, and GONGGRIJP, 1978), which showed the major Feldbiss Fault. A first attempt to preserve the section by impregnation with waterglass failed. Further attempts employing a solution of lacquer in acetone will be made in a renewed attempt to keep the fault permanently exposed.

It is essential that the educational interest and scientific significance of earth-science sites should be explained to visitors. This can be done, either by making leaflets available, or by erecting suitably worded signs and displays. Local museums, town halls and visitor centres may be of great help – for example the Staring Quarry in Losser is the subject of an exhibit in the town hall, a visitor centre interprets the Schokland Geological Park and the preserved type locality of the Tiglian in Tegelen is presented in the botanical garden and museum of Jochum's Hof at Steyl.

Results

The work of the Gea Project has already raised interest in the preservation and conservation of earth-science sites. The appearance of finalised inventories of such sites for the provinces of Overijssel, Zuid-Holland, Noord-Holland, Groningen and Utrecht and of provisional inventories covering the provinces of Drenthe, Gelderland, Noord-Brabant and southernmost Limburg has certainly contributed to this increased attention. It remains to be seen, however, how much influence these reports will eventually exert on planning authorities such as municipalities and the provincial and state planning services. So far reactions have been slow and sporadic.

Different circumstances prevail when a report is presented dealing with a single site currently under threat. Reactions quickly become available from persons with a direct interest in the site and from conservation agencies which lead to consultations among all parties over the possibilities of preserving and managing the site and solving any accompanying financial problems. Final decisions can take months, or even years, to reach, depending on the urgency of the case in question.

Although the work under the Gea Project has so far yielded few tangible results, it can be confidently expected that in the years to come the earth sciences will achieve parity with their biological counterparts in nature conservation in The Netherlands. At the same time it is expected that the number of nature reserves specifically declared for geological reasons will increase considerably in the near future. Four typical case histories are outlined in the following section of this paper.

CASE HISTORIES

Fault Escarpment near Uden

Between Uden and Bedaf, the Peelrandbreuk, a NW-SE trending fault separates the Peel Horst on the north-east from the Central Graben on the south-west. Movement still takes place along this fault: in 1932 an earthquake, with an epicentre near Uden, occurred and recent levellings near Gemert and Bakel show that movement has continued (WAALEWIJN, 1961, 1966). The fault scarp is seen at a number of places, including Bakel and Meyel, but is best seen at Uden where it is about 3 m high.

The presence of Tiglian Clay close to the surface on the Peel Horst has led to a situation of considerable hydrological interest. Movement on the fault has caused the clay locally to occupy the fault plane and to obstruct the flow of groundwater from the horst to the graben. The groundwater is rich in dissolved iron and, where it enters well-aerated sands in the graben, iron hydroxides are precipitated. Long continuation of this process has built up a vertical barrier of bog iron ore along the fault plane which acts as a weir and causes groundwater seepages. Repeated attempts to improve the circulation of the groundwater have all failed because any gaps made in the bog iron ore weir are rapidly repaired by the natural weir-forming process.

On the northeastern side of the fault escarpment, a bog and a related soil, the Wijstgrond, have developed. Bogs of this type are uncommon in The Netherlands and the associated soil is of extreme rarity over a much wider area. Further, the locality is one of the very few places in The Netherlands where a fault escarpment of any sort can be demonstrated.

This important site was threatened by changes in land ownership and usage and by the route proposed for State Highway 75. The Netherlands Geological Survey brought the scientific value of the locality to the attention of the Gea working group and they passed on this information to the State Forest Service. This body then took the matter up with the local committee for the re-allocation of land. The Institute for Environmental Education (Instituut voor Natuurbeschermingseducatie) presented a report on the geological, pedological and biological aspects of this site. As a result of these representations, ownership of part of the area was transferred in 1978 to the State Forest Service. Although this has done much to secure the conservation of this geologically restless area, a diversion of the proposed route for State Highway 75 still remains to be secured before the unique scientific interest can be considered free from threat.

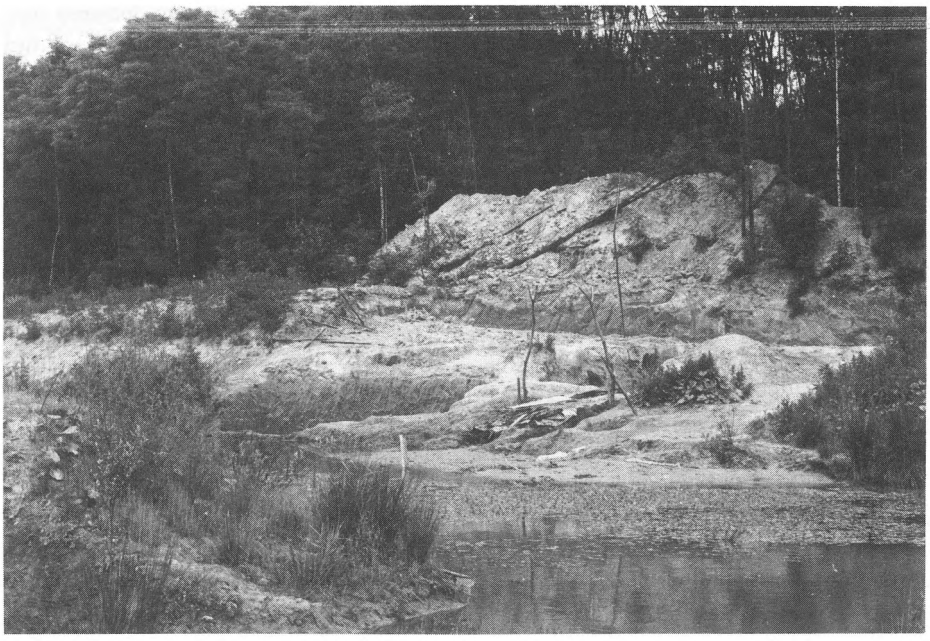

Fig. 6
The protected Tegelen type locality (Limburg) during scientific investigations in the river-bed deposits carried out by The Netherlands' National Museum of Geology and Mineralogy.

Stratotype of the Tiglian

A number of clay pits lie to the east of the village of Tegelen. These pits have a long history – the Romans obtained the raw material for their tegulae here while, in recent times, their main product has been roofing tiles. They also have a long history of scientific investigation – Professor Dubois studied their fossil mammals, the Reids investigated the seeds from the clays and Schreuder and Bernsen later continued Dubois' work. During the Second World War, Van der Vlerk and Florschütz commenced their stratigraphic and palaeontological investigations into the clay at Tegelen and presented their results as a number of fundamental papers on Pleistocene stratigraphy. Most of the research was done in the Canoy-Herfkens Pit and this would logically have become the type locality of the Tegelen Clay and the stratotype of the Tiglian. This locality, however, became inaccessible and ZAGWIJN (1963) selected the Russel-Tiglia-Egypte Pit, which had also been the subject of extensive geological and palaeontological studies) as the new stratotype on the grounds that it showed the most complex and complete section in the Tegelen Clay.

For some years this pit was not in use, with a brief exception in 1970. No arrangements existed to ensure the security of this type locality, although in 1966 the Netherlands Geological Survey had undertaken to protect the exposure and the unworked ground behind the face. When the Netherlands Geological Survey informed the Gea working group of the locality's interest, the latter, in co-operation with the scientific workers active in the Tegelen area, produced a report which demonstrated the unique geological significance of the site (GONGGRIJP, 1975-b). It was presented to the State Forest Service and, after some hesitation, acceptance of the value of the site as a geological 'archive' led in 1976 to the purchase of the Jammerdaal Heath in which the pit lies. This action only just averted the possible destruction of the pit by a developer who was acquiring interests in the area at the time.

The management of the pit as a geological reserve then had to be established. In this the State Forest Service acted jointly with the Netherlands National Museum of Geology and Mineralogy where much of the research into the Tegelen Clay had been done. The Jochum's Hof botanical garden at Steyl lies close to Tegelen and is now the site of a special open-air exhibit which features a re-construction of the Tegelen flora and an exhibition building where a small permanent indoors display of fossil material from the former pits is exhibited and explained. Although this most important locality (Fig. 6) now has the status of a nature reserve, it cannot be regarded as completely safeguarded from all future threats. Current proposals for a new highway across the Jammerdaal Heath pose a serious threat to the continued existence of the site.

Holocene Almere Deposits near Emmeloord

During the digging of ditches in the newly-reclaimed Noordoostpolder, a silty deposit containing many interesting sedimentological structures was discovered. WIGGERS (1955) named these Holocene sediments the Almere Deposits; within them he could distinguish seven different beds of varying grain size and humic content. The deposits were laid down in a fresh to slightly brackish lagoon which developed in the Zuiderzee between the first and the fifteenth century. The deposits show disturbances in the finely laminated sequences,

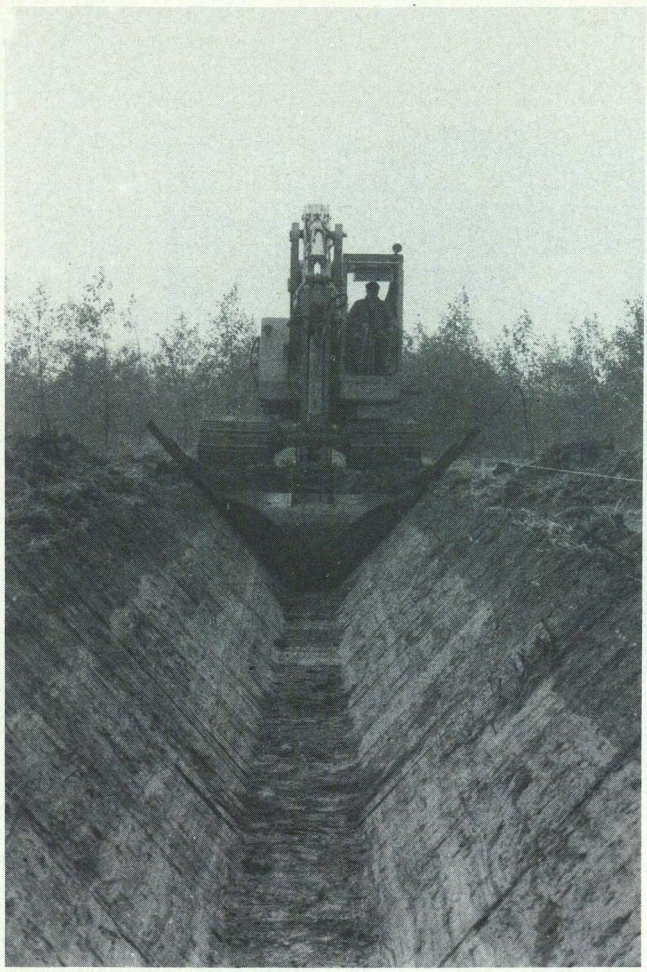

Fig. 7
Digging a ditch in the Holocene lagoonal Almere Member for scientific and educational purposes near the traffic circuit of the State Highways 50 and 338 in October 1979 in the Noordoostpolder (Overijssel).

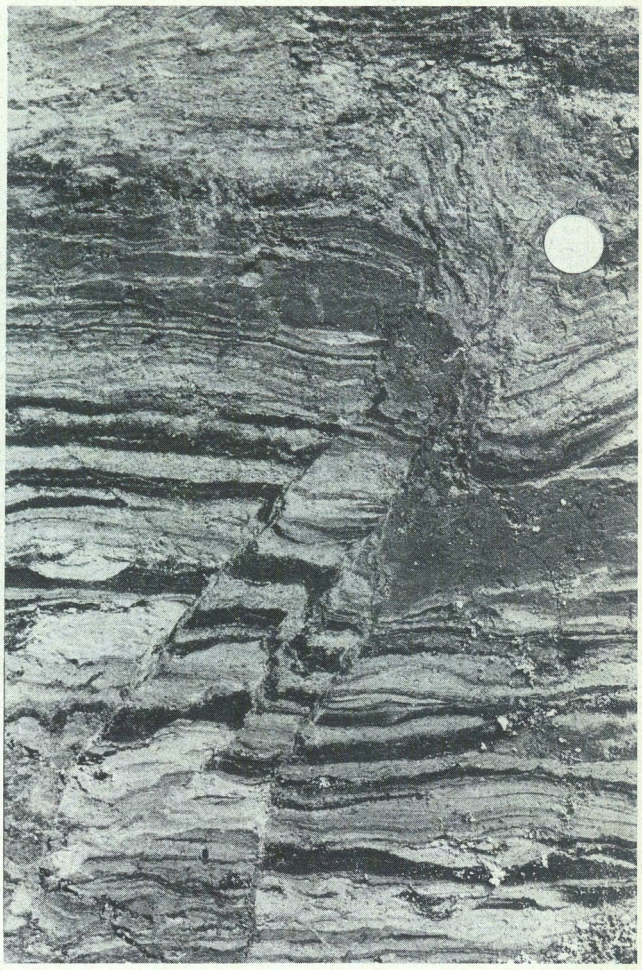

Fig. 8
Metasedimentary faulted blocks with small faults and plastic deformation phenomena (cf. Van Loon & Wiggers, 1976) in the right top, exposed in the side of a ditch, excavated in the Almere sediments.

such as slumping, convolute lamination and flow structures. Small-scale faulting also occurs as do erosion surfaces, scour-and-fill structures and rocking holes.

Van Loon & Wiggers resumed research on the Almere Deposits which they called the Almere Member of the Groningen Formation, and the results of this work have been published (e.g. 1975-a, b, 1976). The beds are found only over part of the extent of the former Zuiderzee, but a complete section occurs in the vicinity of Emmeloord. In their distribution and sedimentary structures, the deposits are unique and for this reason Wiggers and Van Loon in 1975 asked the Research Institute for Nature Management to try to preserve the type section. In the same year a report was issued (GONGGRIJP 1975-c); in 1978 consultation with the Zuyder Zee Project Authority (Directie Zuiderzeewerken) on the possible conservation of the locality commenced. It was found that it would not be feasible to open and maintain a section at the type locality but that, through co-operation with the State Forest Service, an exposure could be opened close to the roundabout on State Highways 50 and 338. This new exposure was made with a dragline (Fig. 7) in 1979 and ever since has shown a section showing a variety of sedimentological features of interest (Fig. 8). It has proved necessary to clean the section annually to keep it in a condition suitable for educational and research use.

Mulder Sand Pit, Finsterwolde

The small Mulder Sand Pit, between Beerta and Finsterwolde, has been cut in a knoll belonging to a group of low hills in the eastern part of Groningen province. The origin of these hills has been a subject of discussion for many years – EDELMAN & MAARLEVELD (1958) and FABER (1960) support an earlier interpretation which regards the hills as drumlins, TER WEE

Fig. 9
Sandpit Mulder near Finsterwolde (Groningen) with the light-coloured Pliocene river sands, the dark Elsterian meltwater clays ('potklei') and a toplayer of 'tilloid' material with erratics. The top side of the huge granitic erratic is glacially flattened and striated.

(1962) maintains that they are remnants of an ice-pushed ridge while ZONNEVELD (1975) considers them to be drumlins which originated from the overthrusting of ice over an ice-pushed ridge.

When visiting the little-known Mulder Sand Pit, the second author learned that it was to be filled in and afforested as a result of proposed changes in the land-use of the area. This information was passed to the Research Institute of Nature Management and it was discovered that the pit and its surroundings were to be allocated for recreational use. Following the advice of the State Forest Service, a report on the geological significance of the pit exposures was prepared as a first step to conservation (GONGGRIJP, 1980). This report describes the regional geology and landscape morphogenesis of a broad area in which the sand pit is the only exposure. On the strength of the information gathered during the survey for this report, the first author has come to support ZONNEVELD'S (1975) opinion – the occurrence of 'drumlinised' remnants of a glacially overthrust ice-pushed ridge is a phenomenon of great rarity in The Netherlands.

The exposure shows coarse white fluvial deposits of Pliocene age overlain by the so-called Potklei (= Potter's Clay). The Potklei is a meltwater deposit of Elsterian age formed in depressions left by retreating ice. Both the sand and the clay are ice-pushed and are overlain by a clay deposit containing many erratics (Fig. 9). Whether this is a till or a mixture of the clay with remnants of a moraine produced by local cryoturbation is not yet clear. At the base of the tilloid deposit there occurs a huge erratic which shows exceptionally fine glacial striations. It is hoped that the conservation of this site for further research and education will be secured shortly.

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