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Geomorphological Survey and Mapping

Edited by

EUGENIUSZ DROZDOWSKI AND JAN SZUPRYCZYŃSKI

CONTENTS

PREFACE

This volume contains invited papers, mostly those which were read at the joint symposium of the IGU Working Group on Geomorphological Survey and Mapping and the IGU Working Group on River and Coastal Plains, organized by the Department of Lowland Geomorphology and Hydrology, Institute of Geography and Spatial Organization, Polish Academy of Sciences, and held at Ciechocinek near Toruń, 25–30 May 1987. The meeting was attended by 46 scientists, mainly geomorphologists and Quaternary geologists, among them 19 from foreign countries. The honourable guest of the symposium was Professor Mieczysław Klimaszewski, full member of the Polish Academy of Sciences, the former President of the IGU Subcommission on Geomorphological Mapping.

The purpose of the symposium was to review recent developments in geomorphological research and mapping, particularly on river and coastal plains, and the problems associated with related hazards and applied works.

The arrangement of the papers, with the exception of the first one, does not follow the symposium proceedings. The paper written by Mieczysław Klimaszewski is a summary and appraisal of what was done in detailed geomorphological mapping in various countries during the first period of international research co-ordinated by the International Geographical Union. Comparisons of various legends, reflecting different concepts in detailed geomorphological mapping are presented and discussed.

The following paper, written by Joop A.M. Ten Cate, Vice-President of the Working Group on River and Coastal Plains, deals with one of the most important geohazard problems of the present-day world, i.e. with rising sea level under the influence of climatic changes generated by man. Apart from this, the author presents briefly the Dutch legend for the Geomorphological Map of The Netherlands on the scale 1:50000, which seems to be particularly applicable for preparing various kinds of geohazard maps.

Problems of geomorphological mapping are also considered in the next paper submitted by Matthias Kuhle. It is actually a critical essay on the latest trends in geomorphological mapping. The author speaks against a reductionistic approach being pursued in the geomorphological mapping inasmuch as it may lead to the loss of the regional concept in geography. Geomorphological mapping should accentuate, according to the author, the inhomogeneous morphogenetic features that create the diversity in the landscape.

Edmund Falkowski proposes some new models of river valley evolution on the Polish lowlands. Worthy of note is his attempt to combine the old geomorphological schemes with new physical and mathematical models which could be applied in solving some engineering problems.

Criteria that should govern the choice of areas designed for nature protection in high-mountain environments are the subject considered in the next study of Christine Hamann. The author applied Farcher's method and came to the conclusion that this method is not successful for high-mountain environments. She suggests that a new solution to the problem is likely to lie in a combination of further research on information theory and traditional techniques.

The paper written by S.B. Basu and L. Ghatowar refers to sequential changes in the lower course of the river Lish in Darjeeling Himalayas, as documented from systematic hydrological research carried out since 1929. The authors conclude that the river quickly readjusts itself to the increasing loads supplied from numerous landslides at the upper reaches of the river.

The following paper of Lászlo Góczán and Denes Lóczy is a kind of expertise about the predicted environmental impact of the barrage system on the Danube which involves damming the river at Gabčikovo and at Nagymaros. Since this projects will affect lowland areas, the environmental changes envisaged are more serious than those connected with other barrage systems on the Danube which were built in gorges or narrow valley stretches.

The last but not less significant problem taken up in the papers is the mechanism of splash-processes. This topic is considered by Berthold Bauer in his study of soil splash as an important agent of erosion. Basing on field experiments, the author shows – in a quantitative way – the mechanism of raindrop splash and the variables which control the destructive phenomena involved in soil erosion.

We are grateful to the authors which contributed to this volume and to our colleagues of the Department of Lowland Geomorphology and Hydrology, Polish Academy of Sciences in Toruń, for their assistance at the meeting.

We would like also to acknowlege that the organization of the meeting has been made possible by the financial support received both from the local authorities of Toruń and Włocławek voivodships and from the international organizations: International Council of Scientific Unions and International Geographical Union.

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THIRTY YEARS OF DETAILED GEOMORPHOLOGICAL MAPPING

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A geomorphological map showing landforms of the study area and including a tentative explanation of their origin was proposed relatively recently, i.e. 75 years ago. Such a late concern with a geomorphological map was the result of intensive development of topography and topographic maps at various scales, with different accuracy and differing relevance to practical purposes, i.e. economic, military and scientific ones.

Topographic maps include information about the characteristics of landforms, i.e. of morphography and morphometry. From the data supplied on topographic maps by means of shading, hachuring, contour lines and on the basis of knowledge of the principles of geomorphology, inferences might be made as to the origin of the main landforms and some factors and processes which had affected their formation and appearance. However, the topographic maps did not include information about the age and origin of landforms, especially small ones. Therefore, a detailed geomorphological map which would provide a full picture of relief was in demand.

The first concepts of a geomorphological map were put forward by Passarge (1912, 1914, 1920) and Gehne (1912). They did not encourage most geographers who took up geomorphology to elaborate geomorphological maps on the basis of arduous fieldwork. Although words of encouragement came froms different countries (Poland, Germany, the Soviet Union), there was slight interest in geomorphological mapping. Geomorphological studies did not cover all landforms present in a given area but were confined to some selected forms such as terraces, landslides, glacial or karst landforms. Neither interrelationships between forms were discerned nor detailed classification of landforms was given. A verbal description could not substitute a cartographic representation.

Only after the Second World War the necessity arose to identify in greater detail relief features in respect of quality (in what manner, in what conditions and at what time particular landforms were produced) and quantity (distribution, size, frequency, density, inclination, rates of formation and growth). Thus, all landforms had to be recorded on topographic maps, thereby the method of geomorphological mapping had to be used. “A Detailed Geomorphological Map” at the scale of 1:25000 or 1:50000 has been the result.

The elaboration of detailed geoorphological maps was proposed by Boesch, Annaheim, Markov, Klimaszewski, Borisevich, Spiridonov and Tricart. In 1956 Annaheim and Klimaszewski presented two papers concerning the elaboration of detailed geomorphological maps at the 18th International Geographical Congress in Rio de Janeiro. In 1960 as many as eight papers on geomorhological mapping were presented by Bashenina, Galon, Gellert, Klimaszewski, Macar, Michel, Tada and Tricart at the 19th International Geographical Congress in Stockholm. Owing to the intensification of interest in geomorhological mapping, the Subcommission of Geomorphological Mapping was set up within the framework of the Commission for Applied Geomorphology. Klimaszewski became its chairman.

The purpose of this Subcommission was threefold:

(1) to introduce the method of geomorphological mapping to geomorphology, which resulted in "A Detailed Geomorphological Map",

(2) to work out a uniform method of detailed geomorphological map compilation and to establish its principles for comparative purposes,

(3) to provide the national economy with an accurate picture of relief as an important element of the geographical environment in the form of detailed geomorphological maps for the needs of rational utilization of the Earth's surface.

In order that the task might be completed, a lot of maps were compiled, many publications appeared and a few legends were created (cf. References). The meetings of the Subcommission were held in Poland (1962, 1966), France (1962, 1963), Great Britain (1964), Czechoslovakia (1965, 1967), Belgium (1966), the Soviet Union (1967) and India (1968). At the meetings

(i) various geomorphological maps were evaluated,

(ii) the scale of 1:50000 or 1:25000 was found to be the best,

(iii) it was admitted that a detailed geomorphological map should include information about morphography, morphometry, morphogenesis and morphochronology,

(iv) it was established that a detailed geomorphological map should be the result of geomorphological mapping carried out in the field with the use of air photos,

(v) it was indicated that a map should provide a full and dimensional picture of relief in terms of origin and chronology, which would enable the user to identify relief details, to reconstruct its past and to predict future developmental trends,

(vi) attempts were made to develop a uniform concept of detailed geomorphological maps and to work out methods of their compilation in order to achieve a comparability between maps of areas with different structure and under a different climate,

(vii) the contents of detailed geomorhological maps were adopted and their legend was suggested at the word-scale level.

These guidelines together with the legend were presented in a two-part study entitled "The unified key to the detailed geomorphological map of the world" (1:25000 – 1:50000). The legend containing 570 symbols for different landforms was compiled in English, Russian, French, German and Polish. The activity of the special working group under the chairmanship of Klimaszewski (Bashenina, Gellert, Joly, Scholz, Gilewska) was presented at the 21st International Geographical Congress in New Delhi in 1968. The authors asked for comments on, and amendments to, the proposed list. The Subcommision for Geomorphological Mapping fulfilled in this way its programme presented at the 19th International Geographical Congress in 1960. Afterwards the activities of the Commission for Geomorphological Mapping and next, those of the Working Group were confined to the compilation of the legend and 1:2 500000-scale maps. This did not call for field mapping as it was done at a desk.

PURPOSES

A geomorphological map should be compiled so that not only morphologic characteristics (morphography, morphometry) may be indentified but also successive stages of the geomorphological development may be reconstructed, as well as knowledge of the present state may be acquired and further developmental trends (morphogenesis, morphochronology) may be predicted. It should also include information about the distribution and present-day development of landforms suitable and unsuitable for particular spheres of human economy. A detailed geomorphological map may be difficult to read for users from other fields, e.g. land planners. Therefore, geomorphological-engineering derived maps may and should be compiled on the basis of the detailed geomorhological map. They illustrate the distribution of features unsuitable and suitable for different spheres of human economy. Such a way of compilation of detailed geomorphological maps on the basis of fieldwork is intended to support scientific interests and meet the needs of economic planning. This twofold purpose of a detailed geomorphological map in science and practice forces a geomorphologist who examines and maps a certain area to look at each form, process and phenomenon from the theoretical-scientific (when, in what way, under what conditions a given form was produced) and practical-economic (of what value it is, how useful it is for various spheres of economy, how it should be utilized) viewpoints. This twofold aspect of research is very helpful for the development of geomorphology and to geomorphologists. The same landforms may be somewhat differently assessed from the climatological, hydrographical and pedological viewpoints but complex physical-geographical maps should serve this purpose. Among others, Haase, Journaux and Kondracki proposed such maps. The concept of compilation of detailed geomorphological maps on the basis of geomorphological mapping carried out in the field and supplemented by air photos and satellite photographs has been accepted in many European countries, e.g. Belgium, Czechoslovakia, France, Holland, Yugoslavia, the Federal Republic of Germany, the German Democratic Republic, Norway, Poland, Sweden, Switzerland, Hungary, the Soviet Union and in non-European countries, e.g. Algeria, Brazil, Canada, China, Egypt, India, Indonesia, Israel, Japan, Nigeria, New Zealand.

TENTATIVE EVALUATION

Geomorphological maps compiled in the above countries differ a lot in contents and appearance. This study gives a listing of general and national legends and maps with regional legends. Their list is presented in the enclosed references. These are the following legends and maps:

(i) six general-world legends proposed to the authors of "Detailed Geomorphological Maps" by Klimaszewski (1963), Posea and Popescu (1964), Tricart (1963, 1965), Joly (1966). Bashenina, Gellert, Joly, Klimaszewski and Scholz (1968); they allow contents of maps areas with different structure and under a different climate to be compared,

(ii) seven national legends proposed by Annaheim (1956), Klimaszewski (1956), Bashenina et al. (1960), Demek (1964), Tada and Oya (1968), Leser and Stablein (1975, 1980),

(iii) seventeen maps with regional legends, compiled by Helbling (1952), Simonov (1957), Klimaszewski (1961), Galon (1962), Onge (1968), Tricart (1963), Taillefer et al. (1969), Starkel (1965), Kugler (1965), Lukniš (1973), Joly (1966), Ulfstedt (1976), Zuidam (1977), Kakembo (1980), Dorsser (1981), Möller and Stablein (1982), Klimaszewski (1985).

The legends consist mostly of five parts includings different data (Table 1). The contents of particular parts in various legends differ a lot and are often incomparable.

A: the first part includes information about the authors, countries, the year of publication, the study area, a scale of the map, a background, especially hypsometric one, and the legend character (general, national or regional).

B: the second part of the legend often contains lithological, hydrographic and structural-tectonic data. Lithological and hydrographic data included in some legends prevail in the geomorphological contents and change a geomorphological map into a physiographic one (Table 2).

C: the third part shows to what degree morphologic, morphometric, morphogenetic and morphochronologic data are supplied on the map.

D: the fourth part provides an inventory of forms labelled by 200 to 550 symbols which represent 15 genetic categories.

E: the last part includes information about the arrangement of the legend, especially the

TABLE 1. Characteristics of maps

A. General data	D. Landforms
1) author	20) neotectonic
2) state	21) volcanic
3) year	22) denudational
4) area	23) fluvial
5) scale	24) created by river erosion and slope denudation
6) background	25) fluvio-glacial
7) scope	26) subglacial
B. Detailed data	27) karstic
8) topographical	28) glacial
9) structural and tectonic	29 frost and nival
10) lithological	30) thermokarstic
11) hydrographical	31) aeolian
12) nival-glacial	32) marine
13) aeolian	33) biogenic
14) marine	34) man-made
15) morphogenic processes	E. Composition of legend
C. Content	35) quantity of signs
16) morphography	36) quantity of forms
17) morphometry	37) colours
18) morphogenesis	38 coloured area
19) morphochronology	39) signs
	40 symbols
	41) plasticity
	42) legibility

genetic one, the number of symbols on maps, the number of forms designated by symbols, the number of colours used on maps, colour surface symbols, linear and point symbols labelling definite forms of different origin, symbols indicative of the occurrence of a given microform or process in a given area. Symbols which resemble in shape the outline of a form present in an area are fairly often encountered. They indicate the distribution, dimensions, characteristics, origin and frequently age of landforms. There are also schematic or even token symbols like that for small valleys, which are not associated with the remaining relief.

Some legends and maps contain rather indefinite forms within geomorphological units, whereas distinctions made between landforms should represent the main contents of geomorphological maps. Symbols should resemble in outline the actual form rather than play a part of a sign which indicates the presence of a given form in a given region. Similar colours are used for some genetic categories of landforms in various legends. For instace, green and blue indicate forms of fluvial origin, yellow is used for forms of aeolian origin, purple for erosional glacial forms and black for anthropogenic forms. Owing to this, the map contents may be easily read and compared. This guideline should always be followed. The number of symbols varies a lot between geomorphological maps. Altogether, there are 200 to 560 symbols. The numer of symbols representing genetically definite landforms varies from 30 (Leser and Stäblein) to 540 (Klimaszewski). On some maps the age of landforms and the operation of certain morphogenetic processes which do not correspond with definite forms are indicated by letters, numerical symbols or plane figures. Symbols do not define the location of very small forms or minor phenomena but indicate them.

TABLE 2. Contents of some general, state and regional legends, antedating the landform list, included into the detailed geomorphological map (number of signs in brackets)

J. Tricart: *Légende des cartes géomorphologiques détaillées* (1963)	
Données lithologiques	(12)
Données structurales	(14)
Données hydrographiques	(21)
Données hydrologiques et biologiques	(12)
Processus	(13)
Formes	(198)
H. Kugler: Geomorphologische Karte 1:25 000. Das Hasselbachtal... (1965)	
I. Morphographie	
Haupt- und Halbhöhenlinien	(2)
Neigung	(6)
Wölbung	(6)
Spezielle Angaben zur Grösse	(10)
Gestein	(12)
Komplex typisierende Kennzeichnung relativ kleinerer Reliefeinheiten	(36)
II. Aktuelle geomorphologische Prozesse	(10)
III. Ergänzender Inhalt	(4)
F. Joly: *Legende des cartes géomorphologiques.* Centre National de la Recherches Scientiphiques (1966)	
I. Données morphomertriques et tectoniques	
A. Hypsometrie et clinometrie	(6)
B. Accidents tectoniques	(14)
II. Données hydrographiques et hydrologiques	
A. Ruissellement	(17)
B. Lacs	(4)
C. Neiges et glaces	(14)
D. Mers	(10)
E. Vent	(3)
III. Données lithologiques	
A. Lithologie du substratum	(21)
B. Lithologie des formations detritiques	(16)
Processus	(15)
IV. Formes et formations	(318)
A. Kakembo: *Vallee Central del Huerva, España* (1980)	
Geomorphological units	
Units of structural/denudational origin	(13)
Units of denudational origin	(11)
Units of fluvial origin	(5)
Lithological units	(7)
Geomorphological details (landforms)	(24)
H. Leser and G. Stäblein: GMK-Schwerpunktprogramm der DFG. GMK-25 (1980)	
A. Morphographie und Morphometrie	
1. Neigung	(9)
2. Wölbungslinien	(5)
3. Wölbung von Kuppen und Kesseln	(4)
4. Stufen und Kanten	(9)
5. Täler und Tiefenlinien	(11)
6. Kleinformen und Rauhheit	(26)
7. Formen- und Prozess-spuren	(7)
B. Substrat	
8. Lockersubstrate	(41)
9. Lagerung	(5)
10. Schichtigkeit und Mächtigkeit	(13)
11. Gestein	(14)
C. Morphodynamik und Morphogenese	
12. Geomorphologische Prozesse	(25)
13. Geomorphologische Prozess- und Strukturbereiche	(18)
14. Hydrographie	(29)
15. Ergänzungen und Situation	(19)

For the purpose of obtaining plasticity, well marked contour lines, shading and colour symbols should be used on a map. Some maps identify the location of definite forms but do not provide a plastic representation of the relief and do not distinguish between mountains, uplands or lowlands in a given territory.

As far as legibility is concerned, a map should be readily legible and should give a clear picture of the relief. Some geomorphological maps are poorly legible because of overlapping colour areas and a variety of surface grid, linear and point symbols. Their understanding requires a lot of time and effort.

LEGENDS AND GEOMORHOLOGICAL MAPS COMPILED IN THE FEDERAL REPUBLIC OF GERMANY (GMK – 25)

In 1972, i.e. after 12 years following the setting up of the Subcommission for Geomorphological Mapping of the IGU and after Professor Leser and Doctor Kugler had attended some of its meetings, a group of West German geomorphologists decided to compile a detailed geomorphological map of Germany at a scale of 1:25000 (GMK-25). The red, green and white legends were compiled by Professors Leser and Stablein in 1973, 1975 and 1980, respectively. The white legend contains 226 symbols, including 63 for lithology, 29 for hydrography and 19 for the "Supplement area". The other symbols identify morphometric characteristics (28) and include morphographic data on such things as the distribution of ski paths (26), imprints of processes (7) and areas affected by them (18). This legend is for a physiographic map rather than for a detailed geomorphological map unless other reasons justify such a name.

The essence and purposes of geomorphology are rather explicitly stated. According to Maull (1938), geomorphology is "*die Lehre von der Formung und den Formenschatz der festen Erdoberfläche*". Pitty (1971) sees it as "the study of landforms", while Louis (1979) considers it to be "*Lehre von den Formen des festen Erdoberfläche*". Thus, it is the study of landforms and the evolution of Earth's surface (Klimaszewski 1978). Therefore, landforms should be mainly shown on detailed geomorphological maps. Data on lithology or hydrography may only supplement the morphological contents. Should a sophisticated term "swelling" be used instead of a simple one "esker"? Should a colour indicate that it is of glacio-aqueous origin? Should familiar terms used in geomorphology for tens of years be forgotten?

The legend and a poorly legible non-plastic geomorphological map based on this legend give rise to some general thoughts: is there a science called geomorphology? is it worthy of study? may geomorphological maps serve as the basis of reconstruction of the morphological development that is so important from the scientific viewpoint? Maps GMK-25 may be useful for the planning of various economic spheres but do they need to be called Detailed Geomorphological Maps?

FINAL REMARKS

Over thirty years passed after the International Geographical Congress in Rio de Janeiro. Since then a lot has been done to make the concept of a fieldwork-based detailed geomorphological map popular. The method of geomorphological mapping was adopted in many European and non-European countries, especially over the 1956–1986 period. Yet, mapping methods, especially that of compilation of detailed geomorphological maps, still need to be made uniform. Such maps are intended to determine the development of geomorphology and, simultaneously, are of considerable value for rational economic planning purposes.

REFERENCES

Boesch H., 1945, Morphologische Karten, *Schweizer Geograph* 22, 55–65.

Borisevich D., 1950, Universalnaya legenda dla geomorfologicheskich kart, *Zemlevedeniye* 3, 1–43.

Gehne H., 1912, Geomorphologische Karte der Umgebung von Thale nach eine neue Methode auf Grund eigener Beobachtungen dargestellt, *Mitteilungen des Sächsisch-thüringischen Vereins für Erdkunde zu Halle a. S., Erdkunde* 36, 1–8.

Haase G., 1964, Landschaftsökologische Detailuntersuchung und Naturräumliche Gliederung, *Petermanns Geographische Mitteilungen* 108.

Journaux A., 1975, Légende pour la Carte des milieux physico-géographiques du bassin du Roubion et du Jabron.

Klimaszewski M., 1953, The problem of the geomorphological field mapping of Poland, *Przegląd Geograficzny* 25, 16–23.

Klimaszewski M., 1978, *Geomorfologia*, PWN, Warszawa.

Kondracki J., 1964, Problems of physical geography and physico-geographical regionalization of Poland, *Geographia Polonica* 1, 61–77.

Kugler H., 1965, Zur Aufgabe einer geomorphologischen Detailkarte der DDR, Leipzig (mimeo),

Louis H., Fischer K., 1979, *Allgemeine Geomorphologie*, W. de Gruyter, Berlin.

Markov K.K., 1948, Metodika sostavleniya geomorfologicheskich kart, in: *Problemy geomorfologii, Trudy Instituta Geografii*, Akademia Nauk SSSR 39, 278–290.

Maull O., 1938, Geomorphologie, in: *Enzyklopädie der Erdkunde*, Leipzig-Wien.

Passarge S., 1912, Über die Herausgabe eines physiologisch-geomorphologischen Atlas, *Verhandlungen des 18 Deutschen Geographentages zu Innsbruck vom 28 V–2 VI 1912*, G. Kollm, 236–247.

Passarge S., 1914, Morphologischer Atlas. Lieferung I: Morphologie des Messtischblattes Stadtremda, *Mitteilungen der Geographischen Gesellschaft in Hamburg*, 28.

Passarge S., 1920, Morphologischer Atlas. Lieferung II: Morphologie des Messtischbattes Saalfeld, *Mitteilungen der Geographischen Gesellschaft in Hamburg*, 43.

Pitty A.F., 1971, *Introduction to geomorphology*, Methuen, London.

Spiridonov A.A., 1952, *Geomorfologicheskoye kartografirovaniye*, Geografgiz, Moskva.

Tricart J., 1954, Un complement des cartes *géologiques – les cartes géomorphologiques, Bulletin de la Société Géologique de France* 6, 739–750.

GENERAL LEGENDS

Bashenina N.W., Gellert J., Joly F., Klimaszewski M., Scholz E., 1968, Project of the unified key to the Detailed Geomorphological Map of the World, *Folia Geographica, Series Geographica-Physica* 2.

Joly F., 1966, *Légende des cartes géomorphologiques détaillées*, CNRS..

Klimaszewski M., 1963, Landform list and signs used in the detailed geomorphological map, in: *Problems of geomorphological mapping, Gegraphical Studies* 46 (annex).

Posea G., Popescu N., 1964, Harta morfologica generala, *Anales Universitate Bucureşti*, vol. *Geologie-Geografie.*

Tricart J., 1965, *Principes et méthodes de la géomorphologie*, Masson, Paris.

Tricart J., Bourdiec F., Ottmann L., 1963, *Légende des cartes géomorphologiques détaillées (1:20000 – 1:25000)*, Centre Géographie Applique, Strasbourg.

STATE LEGENDS

Annaheim H., 1956, Zur Frage der geomorphologischen Kartierung, *Petermanns Geographische Mitteilungen* 100, 315–319.

Bashenina N.W., Leontiev O.K., Simonov J.G., Vyskrebentseva V.S., Zarutskaya I.P., 1960, *Legenda geomorfologicheskoy karty Sovetskogo Soyuza mashtaba 1:50000 – 1:25000*, Moskva.

Demek J., 1964, Legend for General Geomorphological Maps on 1:25000 – 1:50000, Brno (manuscript).

Klimaszewski M., 1956, The principles of the geomorphological survey of Poland. Table of geomorphological forms and signs used in the geomorphological map of Poland, *Przegląd Geograficzny* 28, Supplement, 32–40.

Leser H., Stäblein G., eds, 1975, Geomorphologische Kartierung. Richtlinien zur Herstellung geomorphologischer Karten 1:25000. 2. veränderte Auflage, *Berliner Geographische Abhandlungen, Sonderheft.*

Leser H., Stäblein G., 1980, Legende der Geomorphologischen Karte 1:25000. 3. Fassung im GMK-Schwerpunktprogramm, *Berliner Geographische Abhandlungen* 31, 91–100.

Tada F., Oya M., 1968, *A geomorphological survey map of the Kuzuryu River Basin indicating areas subject to flooding, 1:50000*, Science and Technology Agence, Tokyo.

REGIONAL LEGENDS

Dorsser H., van, 1981, A Geomorphological Map of the SW part of the Cantal, Massif Central, France, 1:50000 *Revue de Géomorphologie Dynamique*, Supplement.

Galon R., 1962, *Instruction to the detailed Geomorphological Map of the Polish Lowland*, Institute of Geography, Polish Academy of Sciences, Toruń.

Helbing E., 1952, Morphologie des Sernftales, *Geographia Helvetica* 7, 89–141.

Joly F., Bessac J., 1968, *Carte géomorphologique détaillée de la France, Mansle SO, 1:50000*, CNRS.

Kakembo A., 1980, *Geomorphological Map Design. Central Huerva Valley, Spain, 1:50000*, Cartographical Department ITC, Enschede.

Klimaszewski M., 1961, The problems of the geomorphological and hydrographic map on the example of the Upper Silesian Industrial District, in *Problems of applied geography, Geographical Studies* 25, Warszawa, 73–81.

Klimaszewski M., 1985, Geomorphological Map of the Polish Tatra Mts. 1:30000, in: *Atlas Tatrzańskiego Parku Narodowego*, WZK-art, Warszawa.

Kugler H., 1965, Das Hasselbachtal bei Naumburg. Geomorphologische Karte 1:25000, in: *Einheitliche Gestaltungsprinzipien und Generalisierungswege bei der Schaffung geomorphologischer Karten verschiedener Massstäbe, Petermanns Geographische Mitteilungen, Ergänzungsheft* 271 "*Landschaftsforschung*", 259–79.

Lukniš M., 1973, *Geomorphological map of the Vysoke Tatry (High Tatra Mts) and their Foreland, 1:50000*, Geologicky Ustav CSAV, Praha.

Möller K., Stäblein C., 1982, *Geomorphologische Karte 1:25000 der Bundesrepublik Deutschland, Blatt 17, Bad Sooden-Allenstein.*

Simonov J., 1957, *Geomorfologicheskaya karta chasti Sredne Sibirskogo Ploskogoria, 1:50000*, Geograficheskiy Fakultet Moskovskogo Universiteta.

Starkel L., 1965, Geomorphological development of the Polish Eastern Carpathians (upon the example of the Upper San Basin). Fragments of geomorphological map 1:50000, *Geographical Studies* 50, Warszawa (in Polish with English and Russian summary).

St. Onge D., 1968, *Lancer, Saskatchewan, geomorphology, 1:50000*, Canada. Geographical Branch, Department of Mines and Technological Surveys.

Taillefer F., Carcenac C., Coinçon R., 1969, Cart géomorphologique du Mas-d'Azil SE, *Revue Géographique des Pyrénées* 40, 329–51.

Tricart J., 1963, *Carte géomorphologique détaillée de France, Saverne, 1:50000.*

Ulfstedt A.-C., 1976, *Geomorphological maps 25E Grasvattnet and 25F Umfors*, Statens Naturvardsverk, SNV PM 731, Stockholm, 1–86.

Zuidam R.A., van, 1977, A geomorphological survey of the Zaragoza Region, Spain, *ITC Journal* 4, Enschede, 595–623.

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SEA-LEVEL RISE AND GEOMORPHOLOGICAL MAPPING

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1. INTRODUCTION

There is an internationally growing evidence that sea level rise, as a consequence of man-induced climatic changes, will affect our planet not only on a regional but also on a global scale and will create severe problems for society.

In this paper we summarize the effects of climatic changes in the past, indicate the different types of man-induced climatic changes and discuss the (potential) effects of these changes on the worldwide average sea-level. Thereafter a summary of the progress in geomorphological survey and mapping is presented with The Netherlands serving as an example. Finally some remarks are made on useful geomorphological data: survey and mapping can contribute in encountering the problems caused by sea-level rise on society in the next century.

2. CLIMATIC CHANGES

2.1. THE EFFECTS OF CLIMATIC CHANGES IN THE PAST

Worldwide climatic changes have been the dominating influence in shaping the geological and geomorphological features of our planet in the Quaternary which is the latest period in geological history extending to the present.

Although many theories have been proposed to explain these climatic changes, a growing body of evidence strongly supports one idea. It is the Milankovitch theory, called after Milutin Milankovic, a Yugoslav astronomer, who developed this theory in the first half of the 20th century. It asserts that orbital variations (small changes in the tilt of the Earth's axis and in the geometry of the Earth's orbit around the sun) change the climate by altering the amount of solar energy the Earth receives at different latitudes and in different seasons. For a review of the Milankovitch theory reference is made to Covey (1984).

Climatic changes have resulted in major worldwide processes and events, some of which are:

A. Extension of landice in high-latitude regions

In the northern hemisphere, a series of major glaciations, separated by interglacial periods, is recognized. Glacial erosion and deposition thoroughly changed the existing landscape in high and middle latitudes. In Southeast Asia, only the highest mountain peaks became glaciated, e.g. Mount Kinabalu in Sabah, Malaysia (Koopmans and Stauffer 1968) and Mount Wilhelm in Papua New Guinea (Hope and Peterson 1975).

B. Alternation of pluvial and interpluvial periods in low latitude regions

In low latitude zones (e.g. East Africa) wet phases (pluvials) alternating with drier ones (interpluvials) are recognized (Street 1981 and Bowen 1978). Pluvials were indicated by evidence of high lake levels. Closed lakes appear to be absent from humid equatorial lowlands and from Southeast Asia. Correlation between pluvial/interpluvial sequences with glacial/interglacial alternations on a worldwide basis is still not possible.

C. Latitudinal migration of the principle geographical zones

Due to differences in mean annual temperature between alternating cold and warm periods, the principal geographical zones shifted. In tropical areas shifts of vegetation zones are noticeable in higher elevated areas. At present, conclusive evidence for vegetational changes in the Southeast Asian lowlands is lacking. It has been suggested that drier conditions prevailed during periods of glaciation (e.g. Verstappen 1975; Street 1981; and De Dapper 1987).

D. Changes in sea-level

High sea-levels appear to have occurred in the Cretaceous. According to Bachelor (1979), very low sea-levels are recorded in the Miocene, after which the sea-level rose spasmodically up to the present level.

The growth of landice caps during glacial periods resulted in important lowerings of the water-level in seas and oceans. During these periods large parts of the shelf areas became dry land or coastal swamp e.g. the North Sea (between England and The Netherlands). In Southeast Asia large parts of the Sunda Shelf emerged, and flora and fauna could migrate from continental Asia to the islands of the Indonesian Archipelago.

On a worldwide scale five principal factors affect sea-level variation over time:

– Longterm tectonic changes. Variations in ocean basin volume (due to increased or decreased oceanic rifting and crustal subsidence or uplift of mid-oceanic ridges) is considered the most important long-term factor affecting relative sea-level. Of course, regional and local tectonic activity also influences the relative sea-level, especially in tectonic unstable areas in e.g. Indonesia, the Philippines and Papua New Guinea (e.g. Bloom et al., 1974).

– Glacial isostasy. Deformations due to loading and unloading of the Earth's crust by ice.

– Hydro-isostasy. The effect brought about by water loading and unloading the ocean floor (Chappell 1974)

– Geoidal changes. The present surface of the ocean is not level but uneven. Changes occur due to tides, and radiation and heating by the sun, and the stronger cooling down near the poles. The geoid is a kind of standard surface in case the present oceans would cover the whole Earth not being hampered by tides and thermal differences. Using satellites and laserbeams the height above the surface of the Earth can be calculated exactly. With that information the difference in height with regard to the geoid is also known. Geodetic sea-level (the equipotential surface of the geoid) is characterized by undulations of several meters amplitude. Past variations of the geoid may account for anomalous sea-levels. In a review of the relation between past sea-levels and possible changes in the geoid, Mörner (1976) shows how it may have changed with the changes in the glacial and interglacial configurations of the Earth. It follows that sea-level curves (Fig. 1) cannot be used worldwide. Geophysicists have developed a model of the geoid in the last 16000 years, depicting 6 zones of relative sea-level changes (Clark et al., 1978; Fig. 2).

– Glacial-eustatic movements due to alternating glaciation and deglaciation. In general terms glacial periods correspond with periods of low sea-level (huge amounts of water have been stored in icecaps), whereas interglacials show high sea-level stands. However, from the above it may be clear that many more factors than just glacial-eustatic changes are to be considered to understand the variations in sea-level throughout the Quaternary (Fig. 3).

E. Different erosion and deposition patterns

To mention an example, during glacial periods fluvial or eolian/fluvial processes and

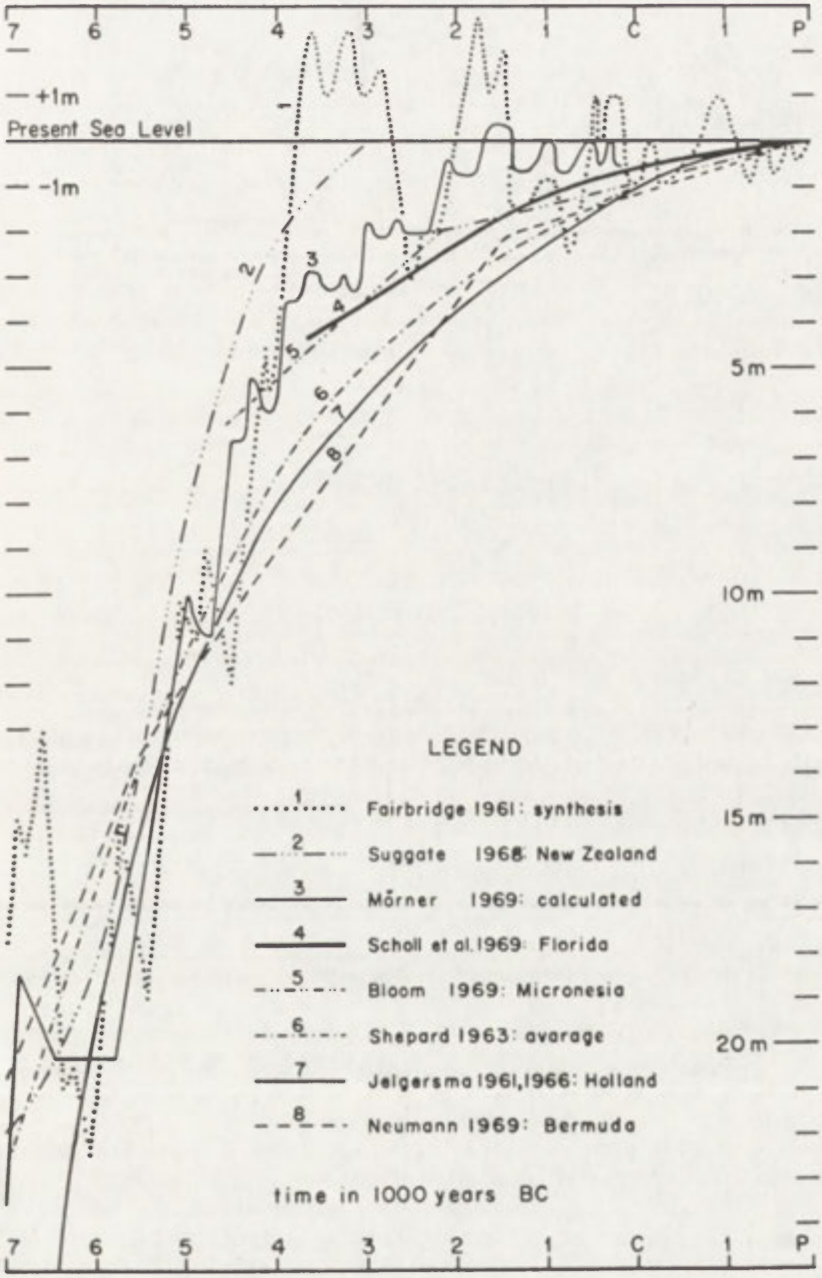


Fig. 1. Eight different "eustatic" sea-level curves (in Mörner, 1976)

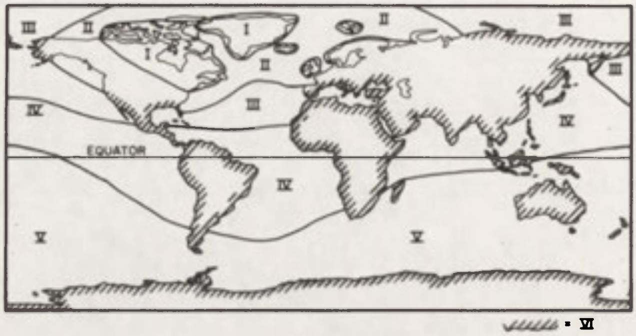


Fig. 2. Illustration of the six sea-level zones for the realistic melting case (emerged beaches are predicted for zones I, III, V and VI; localities in zones II and IV are submerged; in Clark et al., 1978)

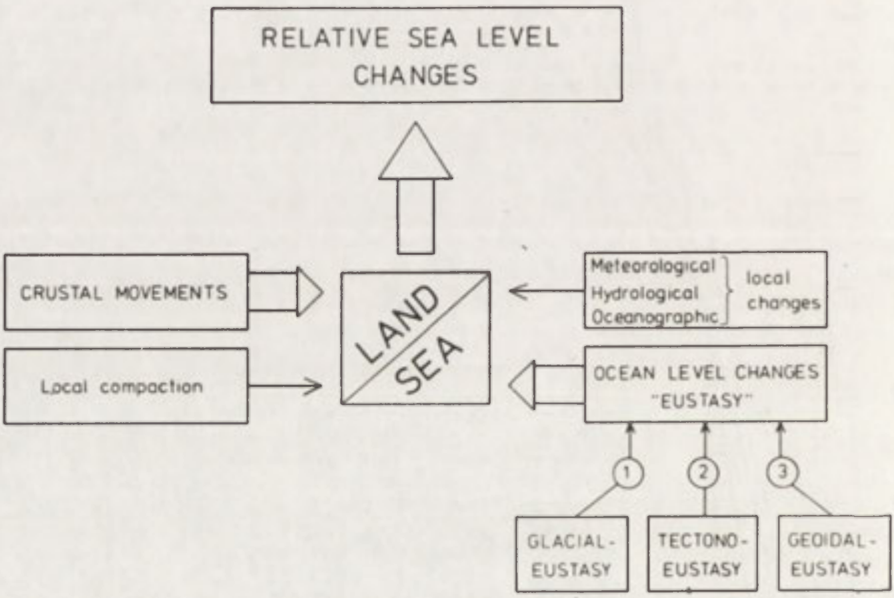


Fig. 3. The relative sea-level changes as the function of land/sea changes (in Morner, 1976)

sedimentation occurred in some shelf areas (e.g. Sunda shelf and North Sea shelf respectively); in interglacial periods, marine deposition dominated in shelf areas.

In addition to evidence from biological and geological sources, variations in the proportions of stable isotopes of hydrogen, carbon and oxygen in biogenetic carbonates, organic matter and ice can provide evidence of climatic changes (e.g. Dansgaard et al., 1971 and Shackleton and Opdyke, 1973). To determine the chronology of sea-level changes, the most useful methods utilised are C14 dating (maximum 70 000 years) and Uranium series disequilibrium dating (U238–U234–Th230–Ra226, with a maximum of about 300 000 years). Other methods are dendrochronology (at present with a maximum of 9000 years), amino acid racemization dating and palaeomagnetic studies. For recent developments in dating methods of young sediments reference is made to Hurford et al. (1986).

2.2. MAN-INDUCED CLIMATIC CHANGES

Current scientific opinion is that the world is at a climatic transition from a past climate dominated by natural fluctuations to a (future) climate dominated by the uncontrolled effects of man, causing the greenhouse effect.

Greenhouses get hot because of the rather peculiar optical properties of glass, letting through up to 90 per cent of the sun's visible radiation. If this was all that happened, a greenhouse would simply get hotter and hotter. However, a cooling mechanism is also involved, stabilizing the temperature inside the greenhouse at a reasonable level (though a temperature that is much higher than the air outside). This mechanism depends on the way in which the interior of a greenhouse radiates energy back into the atmoshere. Greenhouse glass absorbs about 90 per cent of radiation longer than 2000 μm.

The Earth's temperature is maintained by a similar, though much more complicated, mechanism, The greenhouse effect of the Earth is best explained by summarizing its heat balance (Fig. 4). The Earth radiates 115 units of long wave radiation (infrared), of which 106

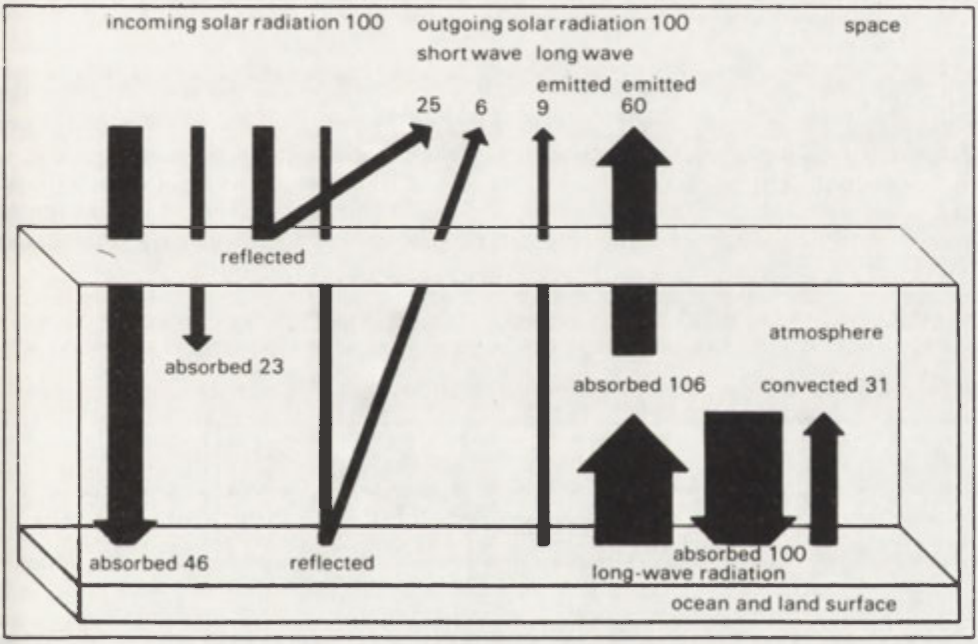


Fig. 4. The heat balance of the Earth (after UNEP/GEMS Environment Library, 1987)

are absorbed by the atmosphere. In its turn, the atmosphere radiates 60 units out into space. The difference, of 46 units, is caused by gases in the atmosphere that absorb radiation at these wavelengths. If concentrations of gases in the atmosphere would increase, less radiation would be emitted to space, and hence the atmosphere would warm up. This picture is more complicated by what would happen at the Earth's surface. The net result of increasing the greenhouse effect on the Earth is not only a warmer Earth but, overall, a drier soil and a wetter atmosphere. Greenhouse heating, in other words, effects our climate (UNEP/GEMS Environment Library, 1987).

Earth's climate depends on how much the concentrations of carbon dioxide and other trace gases are likely to increase in the future. Table 1 shows the concentrations of these

TABLE 1. Concentrations of trace gases in the atmosphere and the rates at which they are increasing (after UNEP/GEMS Environment Library, 1987)

Trace gases	Atmospheric concentration (ppbv)	Annual rate of increase (%)
Carbon dioxide	344000	0.4
Methane	1 650	1.0
Nitrous oxide	304	0.25
Methyl chloroform	0.13	7.0
Ozone	variable	–
CFC 11	0.23	5.0
CFC 12	0.4	5.0
Carbon tetrachloride	0.125	1.0
Carbon monoxide	variable	0–2

trace gases in the atmosphere in parts per billion by volume, and the rates at which they are increasing. These increases are ultimately caused by fact that Earth is becoming more populated, its industries more numerous and, in some cases, more noxious.

Before industrialization, during the first half of the 19th century, levels of carbon dioxide in the atmosphere are thought to have been about 270 parts per million by volume (ppmv). Figure 5 shows (through analyzing the air trapped within ice in glaciers) that carbon

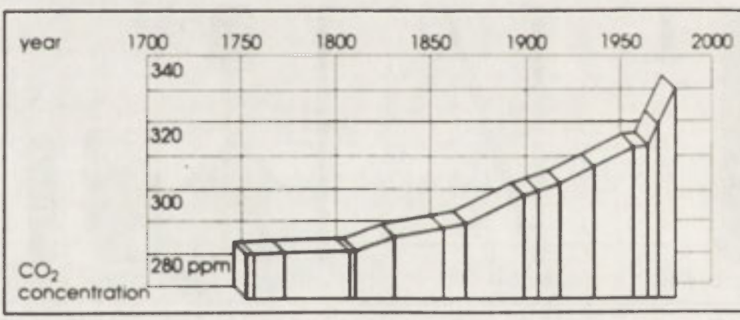


Fig. 5. The analysis of air trapped in ice preserved since the 18th century (after UNEP/GEMS Environment Library, 1987)

dioxide levels have steadily increased since the late 19th century (mainly through burning of fossil fuels and deforestation). Models of the global carbon cycle predicts that future carbon dioxide levels would reach between 367 and 531 ppmv by the year 2050.

As indicated in Table 1 concentrations of trace gases in the atmosphere are increasing. Of these trace gases ozone presents different problems compared to the other trace gases. Ozone concentrations appear to be increasing in the lower atmosphere, but higher up, about 25 km, ozone levels are beginning to decline. Whether these two opposing effects would balance one another out, or whether one would predominate, has still to be resolved. Some indications in the UNEP/GEMS Environment Library paper no. 1 (1987), on how climate will change between 1960 and 2030 (as a result of increased concentrations of the carbon dioxide and the other greenhouse gases) are given below (based on several models).

Temperature. Earth's average surface temperature would increase by some 4°C. For comparison, the average temperature during the most recent glacial period was probably about 15°C lower than it is now. About 5000–7000 years ago (sea-level in Southeast Asia about 3 m higher than presently according to Quaternary geological research including C14 datings), the average temperature was perhaps 1°C higher than it is at present. The climate was substantially different from today's; more rainfall in the tropics and sub-tropics (probably 50 to 100 per cent more in Africa and India), and the Sahara was probably not a desert but dry savanne. The 4°C warming would be most marked in the Northern hemisphere in the winter at high latitudes and in the Southern hemisphere the largest warming would occur in Antarctica.

Precipitation. Overall precipitation would increase by between 7 and 11 per cent with largest changes between 30°N and 30°S.

Soil moisture. Soils seems likely to get drier during the summer at middle and high latitudes in the Northern hemisphere.

Reflectance and cloudiness. A decrease in the Earth's reflectance and a general decrease in cloudiness would occur. However, some models suggest more low-level clouds at high latitudes and more high clouds in middle latitudes.

Some of the warming will, however, be delayed by thermal lag. The thermal lag of oceans is so large that probably only about half the predicted temperature increase would occur by 2030, the other half taking a few decades longer to manifest itself. As a result of this effect, warming of the Earth could be anything between 1.5 to 4.5°C. Records of temperatures in the Northern hemisphere indicate that the average temperature has risen by about 0.5°C over the past 120 years. According to Broecker (1987), there are strong indications that climates could change abruptly from one stable system to another stable system under certain conditions.

2.3. THE (POTENTIAL) EFFECTS OF MAN-INDUCED CLIMATIC CHANGES ON THE WORLDWIDE AVERAGE SEA-LEVEL

Society is more or less adapted to existing climates. Society will suffer when climate will change. Of course, the speed at which climatic change occurs is important. A fast change will be much harder to adapt than a slow one. If climate changes, there are likely to be effects on e.g. all bio-productive sytems (forests, croplands, fisheries etc.), demand and supply of water and energy, soil erosion, desertification, ecosystems, human health, the hydrological balance, and natural hazards like floods.

Gauge measurements during the last 100 years along parts of the European coast indicate a rise in sea-level by between 15 and 20 cm during this period. This rise is higher than that in the past. From Roman times to the present, the rise has been only 1 m, which indicates 5 cm per century. It is very probably that this current rise in sea-level is caused by the global warming of the Earth.

At the International conference on health and environmental effects of ozone modification and climate changes, organized by US Environmental Protection Agency (EPA) and UNEP in June 1986 at Chrystal City, USA, which included a workshop on sea-level rise (Goemans, 1986), the following conclusions on the causes of a future sea-level rise were stated:

— The projected global warming would accelerate the current rate of sea-level rise by expanding ocean water, melting alpine glaciers, and eventually, causing polar ice sheets to melt or slide into the oceans.

— Global average sea-level has risen 10 to 15 cm over the last century. Ocean, and glacial studies suggest that the rise is consistent with what models would project, given the 0.4°C warming of the past century. However, no direct cause-effect relationship has been conclusively demonstrated.

– Projected global warming could cause global average sea-level to rise 10 to 20 cm by 2025 and 50 to 200 cm by 2100.

– Desintegration of the West Antarctic Ice Sheet might raise sea-level an additional six metres over the next centuries.

– Local trends in subsidence and emergence must be added or substracted to estimate the rise at particular locations.

Reference is also made to a report of the project-planning session on "Impact of sea-level rise on society" (ISOS), organized by Delft Hydraulics Laboratory, The Netherlands (Wind, 1986). In this report a table is presented on estimates – based on several models – of future sea-level rise in the next 100 years (see Table 2).

TABLE 2. Estimates of future sea-level rise (cm). Sources: Hoffman et al., 1986: Meyer et al., 1985; Hoffman et al., 1983; Revelle, 1983, and Thomas, 1985, in: Titus, 1987.

	Thermal expansion	Alpine glaciers	Green-land	Antarctica		Total
Year 2100 by cause (2085 in the case of NAS 1983)						
NAS (1983)	30	12	12[a]	70		
EPA (1983)	28–115	*c*	*d*	56–345		
NAS (1985)[d]	–	10–30	10–30	–10–+100		50–200
Thomas (1985)	–	–	–	0–200		–
Hoffman et al. (1986)	28–83	12–37	6–27	12–220		57–368
Total rise in specific years[b]						
	2000	2025	2050	2075	2085	2100
NAS (1983)	–	–	–	70	–	–
EPA (1983)						
Low	4.8	13	23	38	–	56.0
Mid-range low	8.8	26	53	91	–	144.4
Mid-range high	13.2	39	79	137	–	216.6
High	17.1	55	117	212	–	345.0
Hoffman et al. (1986)						
Low	3.5	10	20	36	44	57
High	5.5	21	55	191	258	368

[a] Revelle (1983) attributes 16 cm to other factors. [b] Only EPA reports made year-by-year projections for the next century. [c] Hoffman et al. (1983) assumed that the glacial contribution would be one to two times the contribution of thermal expansion. [d] NAS (1985) estimate includes extrapolation of thermal expansion from Revelle (1983).

3. PROGRESS IN GEOMORPHOLOGICAL MAPPING

In the last twenty years considerable progress has been made in detailed geomorphological mapping in many countries all over the world and in producing a system of symbols and colours related to the portrayal of the evolution, the resultant forms and the age of the units of the geomorphological landscape, using map scales between 1:10000 and 1:25000. This is mainly due the work of the Commission on Geomorphological Survey and Mapping of the International Geographical Union (e.g. Demek, 1972; Demek and Embleton, 1976, and Embleton, 1984).

In The Netherlands, where the local relief nowhere exceeds 200 m, systematic surveys have been carried out since 1966 (Maarleveld et al., 1974). This led to the start of the publication of the Geomorphological Map of The Netherlands, scale 1: 50000. The legend for this map (Maarleveld et al., 1977, and Ten Cate and Maarleveld, 1977) was especially developed for the Dutch lowland. In other countries legends were developed for all kind of landscapes, varying from alpine mountains to coastal plains.

3.1. MAIN ELEMENTS OF THE 1: 50000 GEOMORPHOLOGICAL MAP OF THE NETHERLANDS

The basic criteria used as a framework for more specific representation of landforms are those of relief classes and form groups. Eight relief-classes are distinguished, defined by maximum angle of inclination and length of slopes. This primary division is combined with an independent classification of eighteen relief-subclasses (Table 3). Form groups are

TABLE 3. Classification of relief and landforms in The Netherlands

Relief

	Relief classes	Relief subclasses
	Areas with little relief	
I	Flat areas	1 and 2
II	Almost flat low areas	3 up to 6
III	Almost flat high areas	7 up to 9
	Areas with pronounced relief	
IV	Relief with short gentle slopes	10 and 11
V	Relief with very short steep slopes	12 and 13
VI	Relief with long gentle slopes	14 and 15
VII	Relief with moderately short steep slopes	16 and 17
VIII	Relief with long steep slopes	18

Landforms

	Form groups	Form units
A	Slopes	1 up to 3
B	Isolated high hills, ranges of high hills and high dike-like forms	1 up to 13
C	High hills and ranges of high hills with associated plains and lower areas	1 up to 4
D	Plateaus	1 up to 3
E	Terrace forms	1 up to 11
F	Plateau-like forms	1 up to 12
G	Fan-shaped forms	1 up to 7
H	Slightly inclined surfaces	1 up to 14
K	Isolated low hills, ranges of low hills, low ridges and low dike-like forms	1 up to 36
L	Low hills, ranges of low hills and low ridges with associated plains and lower areas	1 up to 22
M	Plains	1 up to 48
N	Closed depressions	1 up to 10
R	Shallow valleys	1 up tp 14
S	Moderately deep valleys	1 up to 7
T	Very deep valleys	1 up to 5

recognized on the basis of more qualitative definitions of relief geometry. They include plateaus, groups of hills, fan-shaped forms, plains etc. (Table 3). Each form group, in its turn, is subidivided into form units according to form and genetic considerations. Thus "Plains" are separated into 48 form units, e.g. "Group moraine plain, sometimes with rises, with a layer of coversand", "Plain formed by snow meltwater deposits", "Coversand plain", "Alluvial plain overlain by coversand", "Backswamp", "Tidal accumulation plain", "Marine abrasion plain", "Peat plain under cultivation, sometimes covered with clay or sand", and "Area disturbed by man".

The code of each mapping unit indicates relief subclass, form group and the genetic-morphological name of the unit. The mosaic of colours conveys the genetic classification. The symbols indicate certain form groups. The intensity of the colours and the boldness of the symbols are an expression of the relief.

The morphochronological dimension is considered with a specially constructed legend giving the ages of form units according to a simple five-fold division ranging from Pre-Quaternary to Recent. In the same way, a comprehensive morphogenetic classification according to a nine-fold division, such as aeolian, fluvial and biogenetic, is given (Fig. 6).

Information about the lithology of the landforms is represented in an indirect way. The

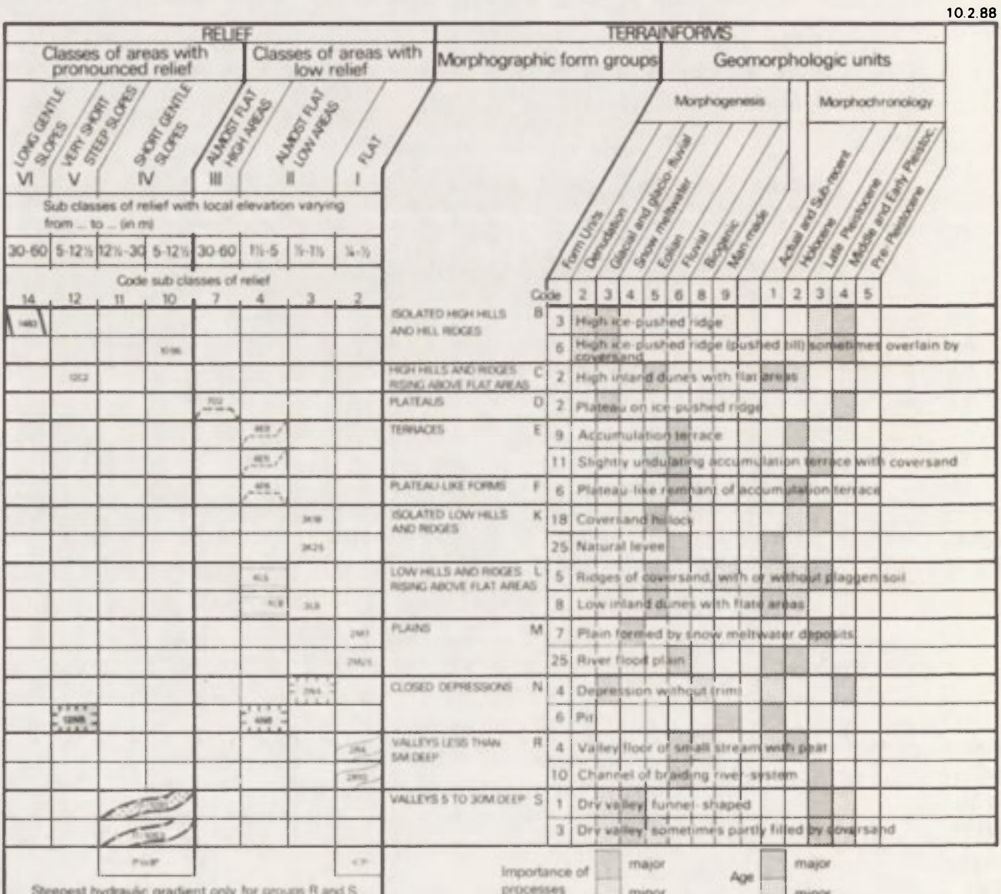


Fig. 6. Set-up of the legend of the Geomorphological Map of The Netherlands, scale 1:50000 (after Van Dorsser and Salome, 1983)

morphogenetic name quite often reveals the lithology, e.g. coversand ridge, tidal accumulation plain, peat plain, and ground moraine plain. Detailed lithological information can be found on the geological and soil maps of The Netherlands. Figure 7 shows the progress made in geomorphological, geological and soil mappings.

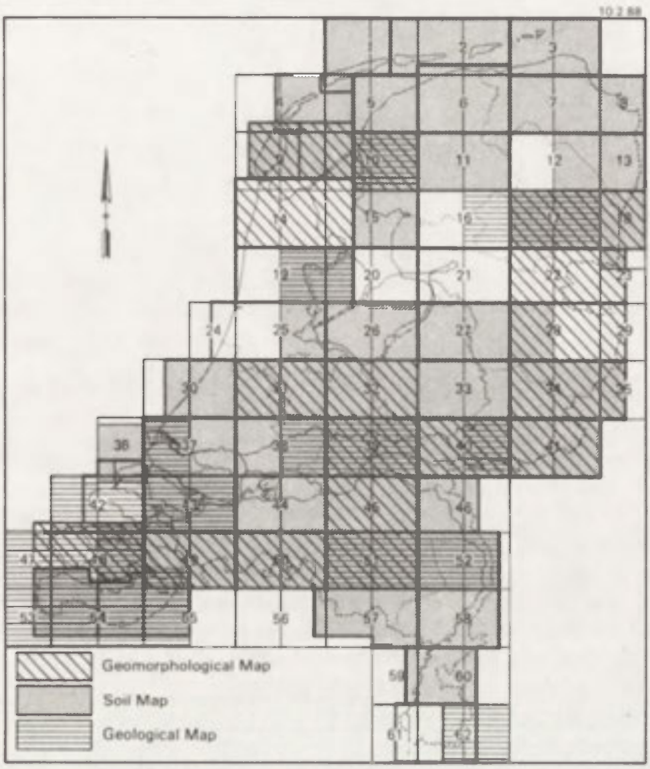


Fig. 7. The progress made in geomorphological, geological and soil mapping of The Netherlands, scale 1:50000 – sheets published up to 1988

3.2. NEW DEVELOPMENTS IN GEOMORHOLOGICAL MAPPING

In the last few decades geomorphological surveys and mapping gradually emerged from two rather different approaches: analytical (emphasizing morphogenetic, morphological, morphometrical and morphochronological aspects) and synthetic (encompassing also terrain parameters related to soils, vegetation, hydrology etc.). A third, pragmatic approach is opted nowadays by concentrating the data gathering on those types of information which are relevant to the purpose of the survey. A variety of applied maps has been compiled according to this pragmatic approach (Fig. 8, and Meijerink et al., 1983) e.g. geohazard maps.

Geohazards can be divided into those of endogenous origin (mainly earthquake and volcanic hazards), those of exogenous origin (floods, accelerated erosion, mass movements etc.), and those of anthropogenic origin or man-induced hazards (pollution, mass-movements, subsidence etc.).

Of all geohazards, floods are the most destructive. They are not so spectacular as

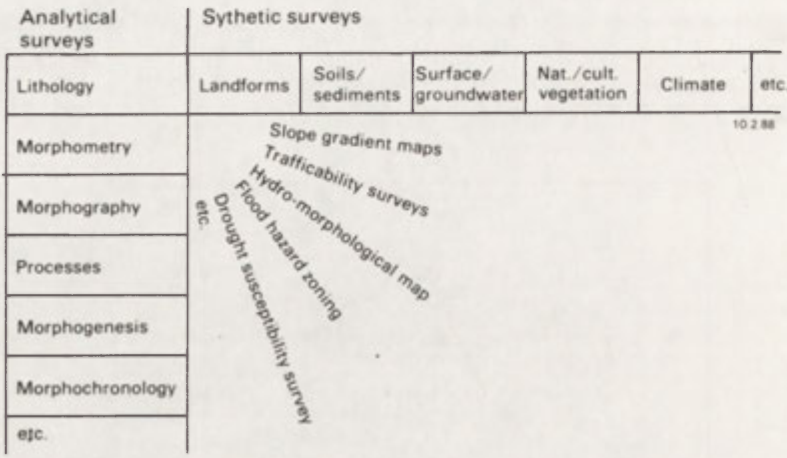


Fig. 8. Three main approaches to geomorphological surveying: Analytical, synthetic and pragmatic (after Meijerink et al., 1983)

volcanic eruptions or so cataclasmic as earthquakes, but they occur regularly, and generally where people live and work. Flood susceptibility surveys and flood hazard zoning have been developed particularly in the deltaic lowlands of East and Southeast Asia, where flooding is a major problem (e.g. Oya, 1973 and 1977; and Oya and Haruyama, 1987). The flood in The Netherlands in February 1953, with a water level 3–4 m above danger level, inundated 165 000 ha; 67 major and 495 minor dike bursts in the southwestern delta area were counted. The geohazard map of The Netherlands to be compiled in the next few years will indicate among others items on:

- seaward and landward displacement of the coast;
- the effects of a future sea-level rise;
- man-induced subsidence;
- pollution;
- erosion.

4. GEOMORPHOLOGICAL DATA AS CONTRIBUTION IN ENCOUNTERING PROBLEMS CAUSED BY SEA-LEVEL RISE IN THE NEXT CENTURY

Almost all the ancient cities in the world are situated along the banks of rivers or along the coast. The world's rural population is diminishing and the increasing trend towards urbanization in the world may be gauged from Table 4.

At this moment the most densely populated areas are the alluvial river and coastal plains, especially the delta areas. On the one hand these areas often form the most suitable regions for agriculture; on the other hand they are plagued by floods causing loss of live, disruption of human activities, damage to property and agricultural crops, and health hazards. Flood control aims to provide specific protection against floods by channel improvement such as the construction of levees and flood walls (dykes and embankments), diversions and by-passes, reservoirs, detention and retarding basins, and land reclamation works.

Table 5 provides some information on areas of major and some minor coastal plains of the world.

TABLE 4. The progress of urbanization in the world (after Framji and Garg, 1976).

Year	1960	1970	1975	1980	1985
Total population (× 1000)	2 981 621	3 635 184	4 028 548	4 467 334	4 948 263
Per cent urban	33	37	40	42	44

TABLE 5. Areas of major and some minor coastal plains of the world (after Colquhoun, 1968).

Geographical name	Area (x 1000 km^2; exclusive of continental shelf and landward portions of major drainage basins)
Africa	
Egyptian-North African (Egypt, Libya, Tunisia)	370
Niger	90
Mauritania, Spanish Sahara	300
Mozambique	130
Somali	110
Asia	
Bengal, Pakistan-India	220
Coromandel-Colconda, India	40
Irrawadyy, Burma	40
Kanto Plain, Japan	5
Karachi, Pakistan-India	370
Malbar-Konkan, India	25
Mekong, Vietnam-Cambodia	100
Ob-Khatanga-Lena-USSR	800
Persia, Saudi Arabia, Iraq	325
Sumatra, Indonesia	160
Yellow-Yangtze Plains, China	125
Australia	
Nullarbor	120
Europe	
Aquitaine, France	25
Baltic, Poland	6
Flandrian and Netherlands (Belgium, Holland, Germany)	150
Po, Italy	25
North America	
Arctic U.S.–Canada	130
Atlantic and Gulf Coastal Plain	940
Costa de Mosquitas, Nicaragua-Honduras	28
Los Angeles, U.S.	21
Yucatan–Tabasco–Tąmpeco, Mexico	125
South America	
Amazon, Brazil	245
Buenos Aires, Uruguay	270
Orinoco–Guyana (Venezuela, Guyana, Surinam, French Guyana)	120

As indicated in paragraph 2.3 estimates of the rise in sea-level in the next 100 years show a range from 0.5 to 2.0–3.5 metres. Such a rise will have an important impact on society. Most low lying coastal areas, especially deltas, are subject to tectonic subsidence which will increase the predicted sea-level rise if there is no balance between subsidence and sediment supply. In deltaic areas with a dense population and heavy industrial development, man-induced land subsidence due to overdrawing of groundwater is already a serious problem e.g. Bangkok and Jakarta. A further man-induced subsidence is caused by draining of land and making polders in these areas (subsidence due to compaction of unconsolidated sediments and oxidation of peat soils). The predicted sea-level rise will among other things:

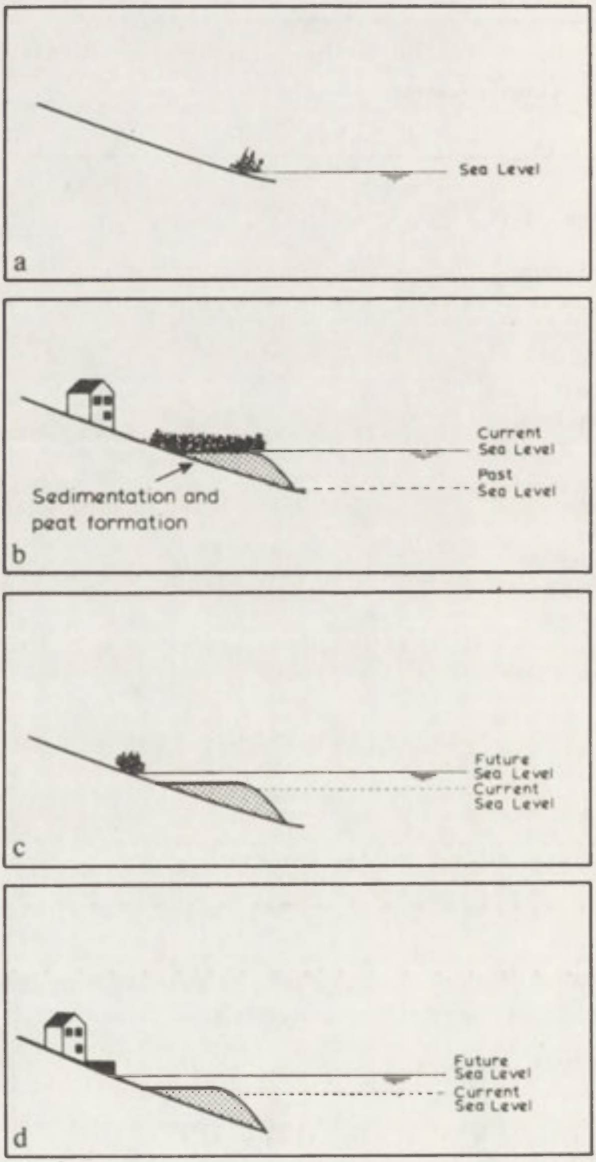


Fig. 9. Evolution of wetlands etc., as sea-level rises (in Titus, 1987): a – 5000 years ago, b – today, c – future, substantial wetland loss where there is vacant upland, and d – future, complete wetland loss where house is protected in response to sea-level rise

— *submerge coastal wetlands.* Wetlands account for most of the land less than 1 m above sea level and are unprotected areas. If sea-level is rising more rapidly than the wetland's ability to keep pace through sedimentation and peat formation, there will be a net loss of wetlands. A complete loss might occur if protection of developed areas prevents the inland formation of new wetlands (Fig. 9).

— *increase the risk of inundation, especially of reclaimed lowlands.* The risk of inundation of protected coastal areas less than 1 m above sea-level is increasing. This will also occur in areas up to several metres higher, particularly if sea-level rises at least one metre (Jelgersma, 1987 and Titus, 1987).

— *accelerate coastal erosion.* Because beach profiles are generally flatter than the portion of the beach just above sea-level, the "Bruun rule" (Bruun, 1962) generally implies that the erosion from a rise in sea-level is several times greater than the amount of land directly inundated (Fig. 10).

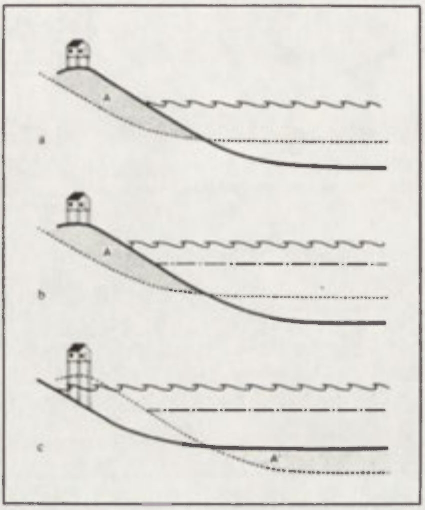


Fig. 10. The Bruun rule (in Titus, 1987): a — initial conditions, b — immediate inundation when sea-level rises, and c — subsequent erosion due to sea-level rise

— *increase the risk of flood disasters.*

— *increase salt water intrusion into aquifers, rivers, bays and farmland.* This will threaten drinking water supplies and disturb the ecological balance in coastal systems. Concerning rivers, due to a change in climate, a decreased runoff can cause important salt water intrusion in the upstream area and an increased runoff can provide problems for the embankments.

As a contribution in encountering the problems caused by sea-level rise in the next century, geomorphologists should focus their research on among other things:

— *the compilation of detailed geomorhological maps of the alluvial and coastal areas.* The basis of such a map should be a detailed topographical map with an interval of contourlines of at least 1 metre. Figure 11 represents several maps of The Netherlands with altitude of soils related to mean sea-level. Morphological, morphometrical, morphogenetical and morpholithological aspects should be indicated on geomorphological maps. Such maps could be used by Governments to encounter problems caused by the predicted sea-level rise. They also provide data on the occurrences of sand and gravel necessary for the construction of embankments, sea dikes and areas to be raised. Exploration of aggregates on sea close to

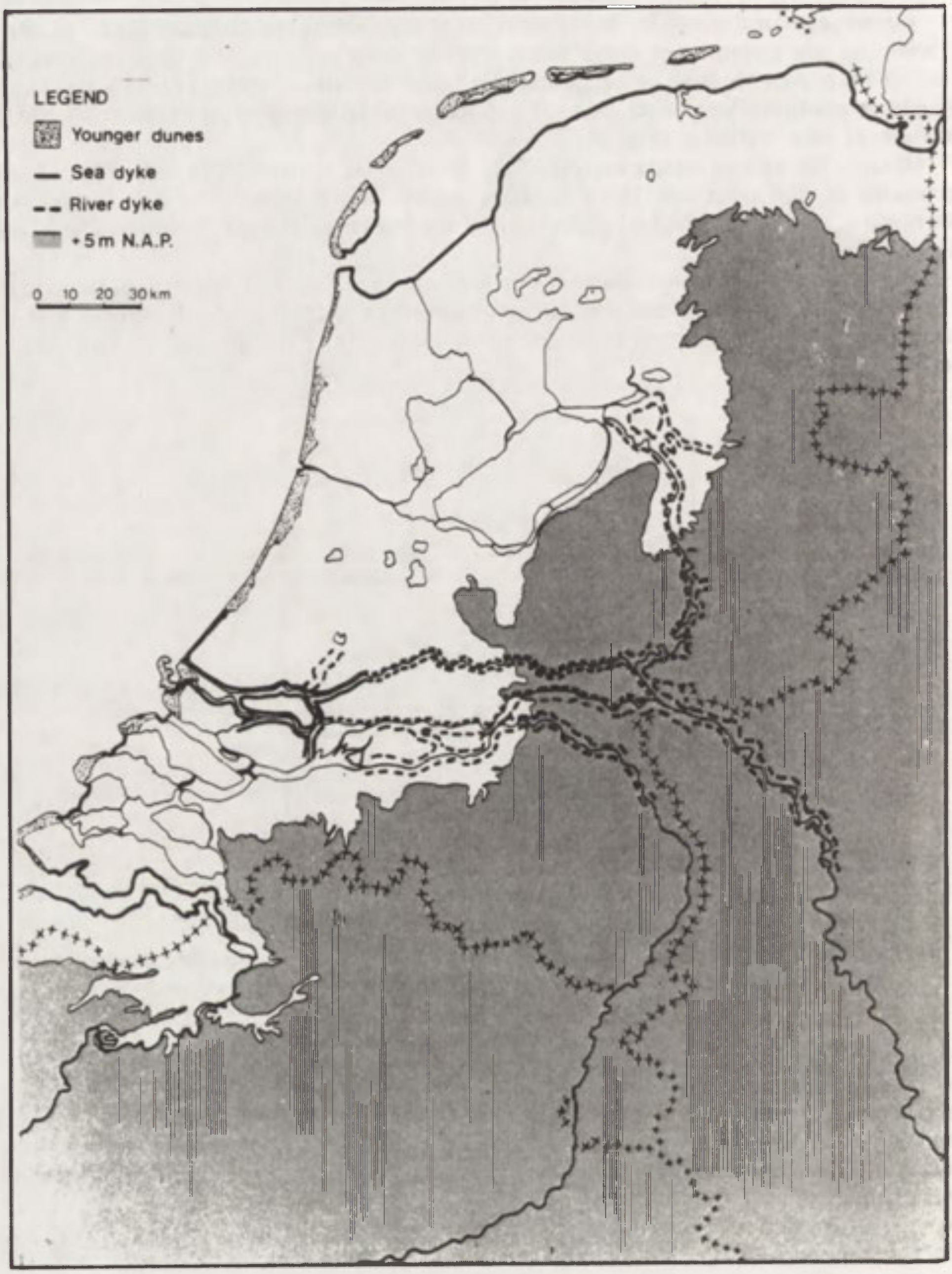
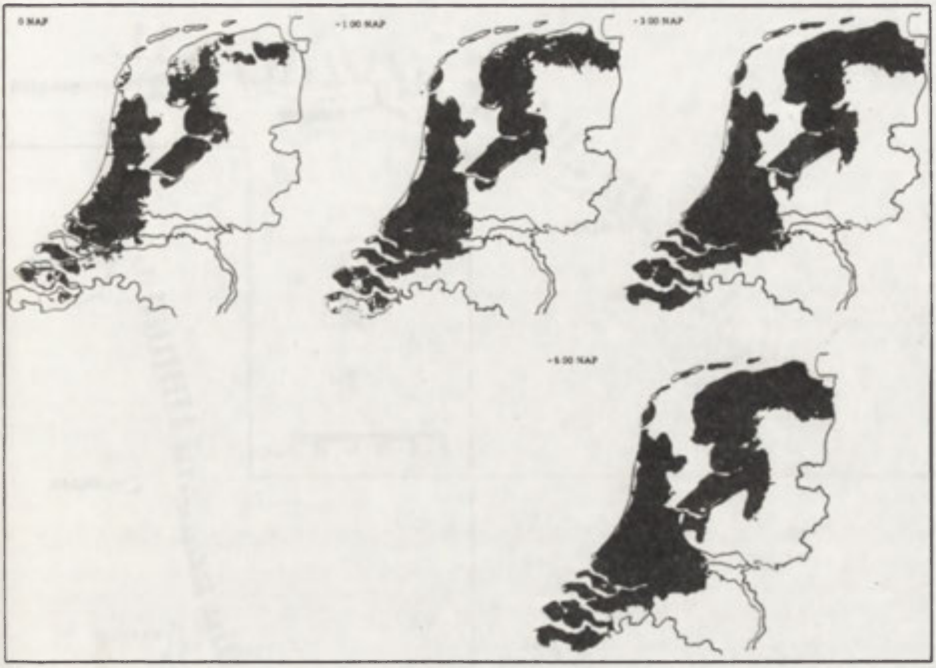


Fig. 11. Altitude of soils related to Mean Sea Level in The Netherlands (in Jelgersma, 1987).
11a – Defense system against flooding



11b — The four maps give an impression of the area which would be flooded, if there were no dunes and dikes to protect The Netherlands, given certain rises in sea-level

the coast will enlarge coastal erosion. In The Netherlands dredging is only permitted at a distance of at least 20 kilometres from the shore (Oele, 1987).

– *study of the coastal development and monitoring coastal erosion and aggradation.* Figure 12 and 13 represent examples of coastal evolution in the past based on fieldwork and the study of existing maps and aerial photographs. Monitoring of the coastal zone through remote sensing techniques in the next decades, will provide data on further coastal erosion and aggradation.

– *the compilation of geomorphological maps of the shoreface and adjacent part of the continental shelves.* Recently, the "Morphological Map of the Dutch Shoreface and Adjacent Part of the Continental Shelf" in colour, scale 1:250000, has been published (Rijkswaterstaat, 1988). This map is mainly based on interpretation of soundings and provides data on:

1. forms and slopes of large elements, such as seabottom (slope < 1:1000); coastal slope (two slope classes); bank or ridge (two slope classes); ebb delta (three slope classes) and terrace (slope < 1:1000).

2. medium elements, such as sandwaves (height > 6 m, 4–6 m and 2–4 m), bars (breakerbar, isolated bar, reef low bars), shoals (subtidal, tidal, high tidal) and ebb or flood channel.

3. various medium elements such as navigation channel, direction of flow, high and low points in metres with regard to present sea-level, depth contourlines and type of sea-defence (dike, dunes, groynes).

By monitoring the changes of the different forms, especially of the medium elements, data are provided on the morphodynamic and sedimentary consequences of sea-level rise.

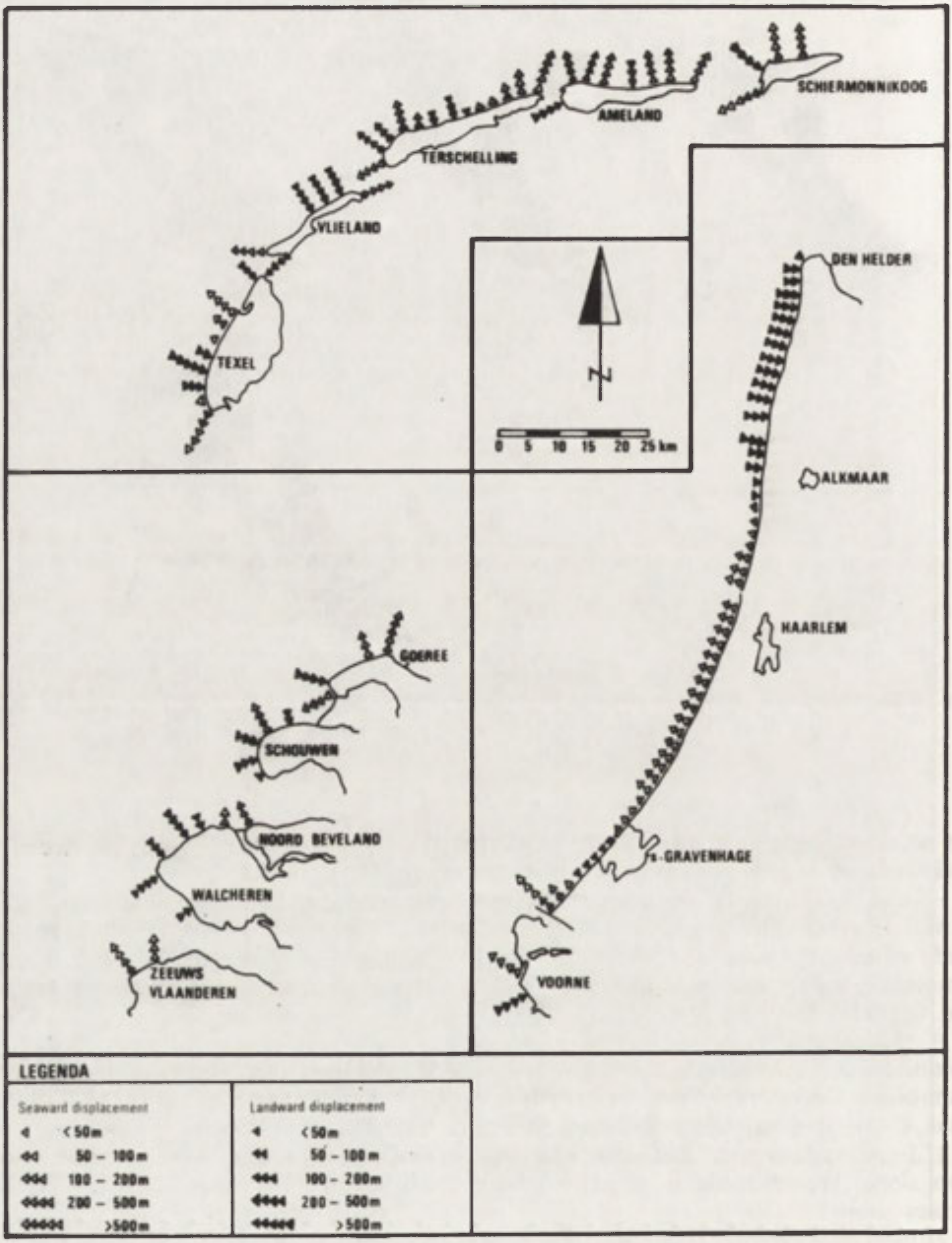


Fig. 12. Net shift in the dune-foot along the Dutch coast between 1850/1860 and 1960/1970 (after Bakker et al., 1979: black triangles indicate retreat and open triangles indicate seaward accretion)

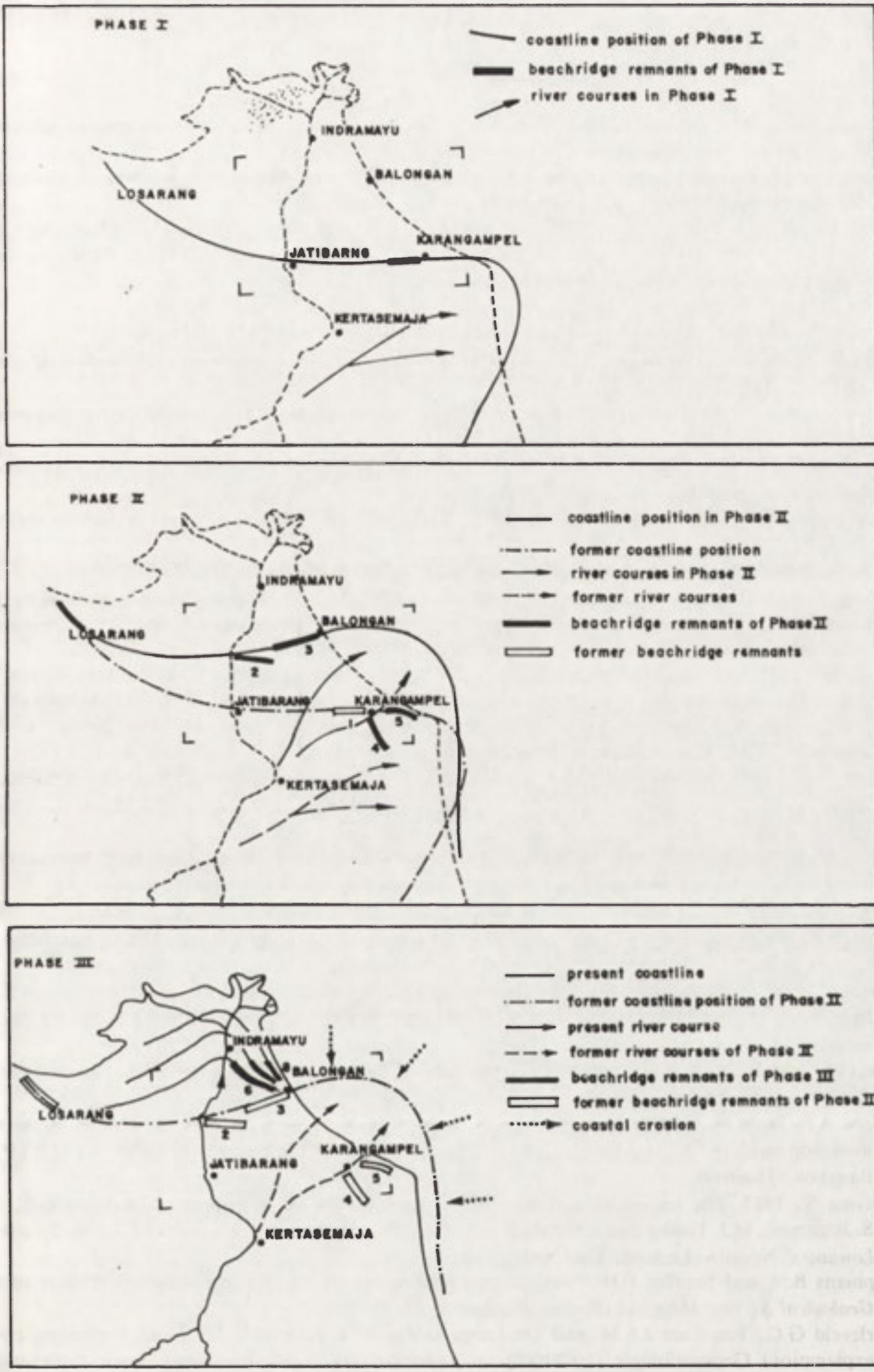


Fig. 13. Several phases in the development of the Cimanuk delta plain, Java, Indonesia (after Suparan et al., 1987)

REFERENCES

Bachelor B.C., 1979, Discontinuously rising Late Cenozoic eustatic sea-levels, with special references to Sundaland, Southeast Asia, *Geologie en Mijnbouw* 58, 1–20.

Bakker T.W.M., Klijn J.A., and van Zadelhoff F.J., 1979, *Duinen en duinvalleien: een landschapsecologische studie van het Nederlandse duingebied*, Pudoc, Wageningen.

Bloom A.L., Broecker W.S., Chappell J.M.A., Matthews R.K. and Mesolella K.J., 1974, Quaternary sea-level fluctuations on a tectonic coast: new Th–230/U–234 dates from the Huon Peninsula, New Guinea, *Quaternary Research* 4. 185–205.

Bowen D.Q., 1978, *Quaternary geology*, Pergamon Press, Oxford.

Broecker W.S., 1987, Unpleasant surprise in the greenhouse? *Nature* 328, 9 July.

Bruun P., 1962, Sea-level rise as a cause of shore erosion, *Journal of Waterways and Harbors Division*, ASCE, 1, 116–130.

Chappell J.M.A., 1974, Late Quaternary glacio- and hydro-isostasy on a layered earth. *Quaternary Research* 4, 405–428.

Clark J.A., Farrell W.E. and Peltier W.R., 1978, Global changes in postglacial sea-level: a numerical calculation, *Quaternary Research* 9, 265–287.

Colquhoun D.J., 1968, Coastal plains, in: R.W. Fairbridge, ed., *The Encyclopedia of Geomorphology*, 144–150.

Covey C., 1984, The Earth's orbit and the ice ages, *Scientific American* 250, 42–50.

Dansgaard W., Johnsen S.J., Clausen E.B., and Langway C.C., 1971, Climatic record revealed by the Camp Century ice core, in: K.K. Turekian, ed., *The Late Cenozoic Glacial Ages*, Yale University Press, New Haven, 37–56.

De Dapper M., 1987, Landform development during the Late Quaternary in the upland area of Peninsular Malaysia. in: F.W. Wezel and J.L. Rau, eds, *Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in East and Southeast Asia during the last decade"*, CCOP/TP18, Bangkok, Thailand, 109–140.

Demek J., ed., 1972, *Manual of detailed geomorhological mapping*. Czechoslovak Academy of Sciences, International Geographical Union, Commission Geomorphological Survey and Mapping, Academia, Prague.

Demek J. and Embleton C., eds, 1976, *Guide to medium-scale geomorphological mapping*. International Geographical Union, Commission Geomorphological Survey and Mapping, Brno.

Embleton C., ed., 1984, *Geomorphology of Europe*, Macmillan Reference Books, London.

Framji K.K. and Garg B.C., 1976, *Flood control in the world , a global review*, vol. 1. International Commission on Irrigation and Drainage, 78 Nyaya Marg., Chanakyapuri, New Delhi.

Goemans T., 1986, *The sea also rises, the ongoing dialogue of the Dutch with the sea. Workshop on Sea-level Rise*, UNEP/EPA International conference on health and environmental effects of ozone modification and climate changes, Chrystal City, Virginia, USA, June 16–20, 1986.

Hope G.S. and Peterson J.A., 1975, Glaciation and vegetation in the high New Guinea mountains, *Bulletin of the Research Society of New Zealand* 13, 155–162.

Hurford A.J., Jäger E. and Ten Cate J.A.M., eds, 1986, Dating young sediments, in: *Proceedings of the workshop held in Beijing*, People's Republic of China, September 10–20, 1985, CCOP/TP16, Bangkok, Thailand.

Jelgersma S., 1987, The impact of a future rise in sea-level on the European coastal lowlands, in: S. Jelgersma, M.J. Tooley and I. Shennan, eds, *The impacts of a future rise in sea-level on the European Lowlands*, Noordwijkerhout, The Netherlands.

Koopmans B.N. and Stauffer P.H., 1968, Glacial phenomena on Mt. Kinabalu, Sabah, *Bulletin of the Geological Survey Malaysia* (*Borneo Region*), 8, 25–35.

Maarleveld G.C., Ten Cate J.A.M. and De Lange G.W., 1974, Kaartblad III–1 met toelichting (with explanation) Geomorfologie (1:600000) en kaartblad III–2 met toelichting (with explanation) Geomorfologie: details (1:50000), in: *Atlas van Nederland*, Staatsuitgeverij, 's-Gravenhage, The Netherlands.

Maarleveld G.C., Ten Cate J.A.M. and De Lange G.W., 1977, *Geomorfologische kaart van Nederland, schaal 1:50000. Legenda*, Netherlands Soil Survey Institute (Wageningen) and Geological Survey of The Netherlands (Haarlem).

Meijerink A.M.J., Verstappen H.Th. and van Zuidam R.A., 1983, Developments in applied geomorphological survey and mapping, *Geologie en Mijnbouw* 62, 621—628.

Morner N.A., 1976, Eustasy and geoid changes, *Journal of Geology* 84, 123–151.

Oele E., 1987, The application of Quaternary Geology in offshore and coastal mangement, in: F.W. Wezel and J.L. Rau, eds. *Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in East and Southeast Asia during the last decade"*, CCOP/TP18, Bangkok, Thailand, 13–24.

Oya M., 1973, Relationship between geomorphology of alluvial plains and inundations, *Asian Profile* 1, 479–538.

Oya M., 1977, Comparative study of the fluvial plain based on the geomorphological land classification, *Geographical Review Japan* 50, 1–31.

Oya M. and Haruyama S., 1987, Flooding and urbanization in the lowlands of Tokyo and vicinity, *Natural Disaster Science* 9, 2, 1–21 also published in: M. Oya, ed., "*Report of Working Group on the Geomorphology of River and Coastal Plains, from January 1986 – March 1988*", vol. 6, International Geographical Union.

Rijkswaterstaat, 1988, *Geomorphological map of the Dutch coastal waters.* Ministry of Transport and Public Works, North Sea Directorate, Rijswijk, The Netherlands.

Shackleton N.J. and Opdyke N.D., 1973, Oxygen isotope and palaeomagnetic stratigraphy oequatorial Pacific core V 28—238: oxygen isotope temperatures and ice volumes on a 10^5 and 10^6 year scale, *Quaternary Research* 3, 39–55.

Street F.A., 1981, Tropical palaeo-environments, *Progress in Physical Geography* 5, 157–185.

Suparan P., Rimbaman, Janssen J.J.W. and Dam M.A.C., 1987, The Quaternary geological map of Jatibarang, West Java, Indonesia, in: F.W. Wezel and J.L. Rau, eds, *Proceedings of the CCOP Symposium on "Developments in Quaternary Geological Research in East and Southeast Asia during the last decade"*, CCOP/TP18, Bangkok, Thailand, 63–80.

Ten Cate J.A.M. and Maarleveld G.C., 1977, *Geomorfolgische kaart van Nederland, schaal 1:50000. Toelichting op de legenda*, Netherlands Soil Survey Institute (Wageningen) and Geological Survey of The Netherlands (Haarlem).

Titus J.G., 1987, The causes and effects of sea-level rise, in: H.G. Wind, ed., *Impact of sea-level rise on society*, Balkema, Rotterdam, 104–125.

UNEP/GEMS Environment library no. 1, 1987, *The greenhouse gases*, Nairobi, Kenya, UNEP.

UNEP/ICSU/WMO.1985, International conference on the assessment of the role of carbon dioxide and of other greenhouse gases in climate variations and associated impacts, Villach, Austria.

Van Dorsser H.J. and Salomé A.I., 1983, Mapping in physical geography; three maps of a formerly glaciated lowland, *Geologie en Mijnbouw* 62, 605–610.

Verstappen H.Th., 1975, On palaeo-climates and landform development in Malaysia, in: G. Bartstra and W.A. Casparie, eds, *Modern Quaternary research in South East Asia*, Balkema, Rotterdam, 3–35.

Wind H.G., 1987, *Impact of sea-level rise on society. A report of a project-planning session, Delft 27–29 August, 1986*, Balkema, Rotterdam.

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QUANTIFICATIONAL REDUCTIONISM AS A RISK IN GEOGRAPHY INSTANCED BY THE 1:25000 GEOMORPHOLOGICAL MAP OF THE FEDERAL REPUBLIC OF GERMANY

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"A speech that shows the learned lord you are
What you don't touch, is leagues afar;
What you can't grasp, is total loss for you,
What you can't reckon, seems to you untrue.
What you can't weigh, possesses then no weight,
What you can't win, must be invalidate".

Mephistopheles, Faust II, Act I
J. W. v. Goethe

1. THE CONCEPT OF THE GMM-25

"The Geomorphological Map (= GMM) aims to depict systematically the characteristics and phenomena of relief relevant for a geomorphological and ecological interpretation as well as for a practical evaluation of natural area potentials, in scale-specific spatial differentiaton and an analytically complex graphic representation in the form of an ontological regional description", (Stäblein, 1980).

The GMM is subdivided into eight levels of classification:

- topography;
- slope;
- steps, minor features, valleys, roughness elements;
- convexity (curvature lines);
- substrate, surface rock;
- processes (current);
- hydrography;
- process and structural areas.

The GMM's assembly system of legend units is new: all complex forms with a basis width of more than 100 m are resolved via quantificational symbols into their relief elements and relief characteristics (Leser and Stäblein, 1975). By disintegrating complex notions, which are not readily accessible to precise descriptive delimitation, into quantitatively detectable, homogeneous subsegments, the results and measurements of geomorphological field work can also be made available for EDP applications (Barsch and Stäblein, 1978:65). Thus, reduction is the underlying principle of the GMM legends. The risk inherent in reduction is that the disintegration of complex phenomena into their elements can be irreversible. The synthesis of the complex from a precise knowledge of the individual elements is therefore precluded. The question arising from this is whether it is still expedient, for the object of geomorphological research, to pursue the degree of reduction proposed in the GMM legend.

2. COMPLEXITY VERSUS EXACTNESS

Complexity is a basic characteristic of the object of geomorphological research. The form of the earth's surface is the result of highly variable interference upon different factor structures in time and space. The determination of similarities (Lorenz, 1974) opens the way to a causal analysis of empirical multiplexity and allows it to be classified into typological units. Starting with morphographic typologies of low predicative value one can finally arrive at a morphogenetic type at a high level of integration, embedded in a network of explanatory theories.

In principle, an empirical type is not derived from homogeneous elements but from polymorphous groups, i.e. phenomena with character-rich centres fading into gradual transitions at the edges (Riedl, 1987). On account of their complex genesis geomorphological types must provide for a high degree of random variability, a fact which restricts the possible sharpness of limiting criteria. Mathematical exactness of limiting criteria can, however, only be achieved by the reduction of complex phenomena to elements at the lowest level of integration.

In the GMM–25 landscape morphology is depicted on the basis of the above-mentioned levels of information. Relief elements with a base length exceeding 100 m (B > 100 m) have to be depicted split up into the prescribed criteria for a given information level. This means, for example, that a *roche moutonnée* with a base length < 100 m would appear as a "knob" or a "field of knobs", whereas one with a base length > 100 m as dipping patterns and convexities. Glaciated rock faces are also subsumed under features with B > 100 m. Their dipping patterns are, however, irresolvably linked to those of the valley flanks. An accompanying upper limit of glaciation of high genetic predictability will be retained mainly at point locations protected from erosion, such as cols or rocky ridges, and appears, if at all as a curvature line, as a broken one. Furthermore, no demarcation in respect of curvature lines of structural descent can be effected. This also goes to show that a quantitative delimitation of B > 100 m results in an arbitrary splitting of real, i.e. qualitative criteria. Dimensional data are of only secondary importance in geomorphology. Moreover, the resolution scale is determined by an examination of a given context. It is derived from matter in question. The reconstruction of maximum Pleistocene ice sheet thickness in the central Scandinavian Alps will concentrate on the symbol for "upper limit of glaciated rock faces" and will be able to ignore all other omnipresent phenomena of glacial erosion. On the western slopes of the Nanga Parbat Massif in the Indus Valley, however, some glacially scoured rock faces only a few square metres in area at heights below 1000 m above mean sea level would have to be indicated by their own map symbols.

Frequency and magnitude of phenomena either do not correlate at all or only negatively with their indicative or perceptive value. Evaluation of the relative importance of features can only be effected within or through the relevant relational field. Numerical tabulations without qualitative correlates to the intended subject matter are meaningless.

Dipping patterns and curvature lines are similarly questionable. Slope classifications are only interpretable in their essential aspects (erosion danger) in the light of an overriding context, as for example when the vegetation cover and climatic parameters are known. Both are absent here.

No genetic or process related answers are obtainable which could not also be derived from a study of the isohyptic lines. Profiles and dipping patterns are unsuitable for synthesis to a three-dimensional picture, such as can be realized unproblematically and to far finer definition by means of contour lines, In the GMM–25, however, topography has been degraded to a mere "service function" (Stäblein, 1978:8) and only sporadically is able to penetrate the seven superior (and overprinted) levels of information.

The arguments in favour of dipping patterns and curvature lines derive from aspects of anthropogenic utilization (engineering, road building and agriculture). The selective adoption of criteria unrelated to the discipline without the accompanying assumption of specifically relevant research insights is, however, a problematical approach whose consequences will be discussed later on.

The morphographic and morphometric symbols on the GMM–25 are genetically indifferent. The roughness of the surface relief elements could be interpreted, among others, as ripply, hummocky or stepped, whereby it remains an open matter whether stepped roughness refers to periglacial terracettes or 'sheep tracks' in the periglacial sector, and whether hummocky roughness designates limestone clints, hummocky moraine, hillocky meadows, slump, sand blown fields or frost hillocks of whatever age concerned. The accompanying substrate characteristics are indeterminate here, as there is, according to the "assembly system of legend units", only a coincidence but not a genetic correlation.

An exceptionally highly differentiated symbol key is provided for the substrate and subsurface (down to 100 cm beneath the soil level), having been derived from the standard of pedological mapping. From the geomorphological point of view such high resolution levels are not particularly meaningful. Whereas the predicative value of fine analyses in autochthonous substrate areas and in unstructured morainic fields is low, the unbroken ancestry of polygenetic, allochthonous substrates and their inclusion in large-scale formation cycles (geochronology) within apparently homogeneous substrate areas is of great interest. This type of substantial relational phenomena cannot on the contrary be adequately conveyed in the apt degree of differentiation by the GMM legend (Cf. section 8).

In conformity with the modular system each of the eight information levels represents a discrete unit. The individual parameters are theoretically neutral, abstractly defined (purely normative), measurable basic units, which are gathered across the whole representational plane. The relation between the information levels is provided by the coordinate axis. This is antithetical to an objective evaluation of the relative importance of landscape features. This has particularly fatal aspects, because "every interpretation of individual relief characteristics, relief elements or relief forms (...) (appears) against the background of a *process area*. However, for the surface area concerned, only *one* mainly complex process group is indicated – e.g., green (...) fluvial, i.e. formed by linear water run-off –, without differentiating between individual process components ..." (Barsch et al., 1978). In view of the polygenetic history of any given landscape element, this undifferentiated characterization of surface processes represents a cognitive regression which on the one hand suppresses the results of discriminative genetic research and on the other hand leads inevitably to a misinterpretation of polygenetic landscape elements.

If the map of the Würm (= Devensian/Wisconsin) Stage Inn-Chiemsee Glacier according to Troll (1924) were translated in terms of the small-scale legend of the GMM–25, the following would ensue:

– the representation of the end moraine areas of the five distinguishable stades, of the older morainic basement between the tongue-like basins, and the ground moraine areas would have to be executed with the aid of a sevenfold violet (glacial/nival) scale, because the legend does not provide symbols for crescentic end moraines (Cf. Barsch at al., 1978),

– attached glaciofluvial accretions would have to be interspersed into the morainic area by means of a sixfold ice green (glaciofluvial) scale,

– on account of their dimensions the characteristic drumlin swarms would be represented as domed surface roughness or similarly indifferent lines of convexity against the background of glaciofluvial process colours on the one hand and morainic on the other,

– differentiation between centrifugal and peripheral valley troughs, their stadial assignment as well as the representation of their partial coincidence with recent hydrography is not possible,

– periglacial moulding would have to be indicated by a purple (cryogenic) grid, e.g., superimposed on the sevenfold violet scale of the morainic complex,

– this colourful mosaic would in turn be overlain by the remaining information levels, including dipping patterns and profile lines. The latter would be particularly instrumental in breaking up the young moraine ramparts into uncharacteristic lineaments, which would tend to record the accidental postglacial dissection rather than the subsidial line of the former ice margin. A definitive and unambiguous recognition of landscape elements is rendered impossible here.

The actual cognitive achievement, which as gestalt perception signifies the selection of descriptive characteristics and their synthesis to a system on a higher level of integration (Lorenz, 1959), is therewith destroyed.

3. DICHOTOMY – AND THE PROBLEM OF FALSE ALTERNATIVES

"Since the strongest cartographic means of expression, area colouring, is employed to represent geomorphological processes, the whole complex geomorphological detailed map is given an unequivocally morphodynamic emphasis" (Barsch et al., 1978). To asses the significance of this process-group information content, which is obviously assigned an important role, it should be pointed out that the map symbols employed are of the most general nature. Thus the column "glacial or nival" (violet) can be equally applied to the Alpine fund of erosional forms, the Quaternary accumulations on the Alpine piedmont and of North West Germany. As a common denominator remains the criterion "produced by the action of ice or snow", which to the present state of geographical knowledge can only be considered trivial if not even partially false.

"The paramount problem of colour selection lies in the development of a systematic, logical and interpretation-enhancing conceptual typology of process groups" (Barsch et al., 1978). The result has been a dichotomous descending classification, the so called "decision ladder" (Barsch et al., 1978, Fig. 1).

Aristotle was an early ridiculer of logical dichotomy as a means of acquiring significant classifications. Biological sciences have meanwhile accumulated enough negative experience to substantiate the hazards of this approach. "In this method of logical division nothing is more important than the choice of differentiating characteristics" (Mayr, 1984:129). "Depending on the characteristics chosen in the initial stages of differentiation, one inevitably obtains entirely different classifications" (Mayr, 1984:130). The criteria which should lead to decisions being made between or within the five priority steps: (1. temporal, 2. natural or artificial, 3. genetic, 4. gravitational and medial, 5. aquatic) result from the analytically clearly defined medial categories, whose application is directly based on the evidence of topographical fieldwork (Barsch et al., 1978:10). Some examples: processes caused anthropogenically always signify an anthropogenically induced diversion or modification of natural processes or states. Thus the marine moulding along the North Sea coastline is modified by the current anthropogenic poldering, which differentiates it strongly from natural coastal shaping influences. The process group colours orange-red (present), grey (anthropogenic), blue (marine/littoral/lacustrine/limnic) are therefore indicated to cover the entire polder. By affirming the first proirity step "present" or the second "anthropogenic" one is precluded from arriving at the final or fifth step in which the question "marine" could be answered.

Ninety per cent of the terrain of the Federal Republic of Germany is anthropogenically influenced. When do we transgress the threshold of the "inessential" to arrive at priority step 3 "genetic"? In this step we are faced with the choice between "endogenous" and "exogenous". The basic prerequisites of exogenous processes are those of an endogenous nature. Starting with the spheroidal shape of the planet, the respective distribution of land masses and oceans, orogeny, through to local faulting and bedding structures, the exogenous processes constitute a superimposed system, not the fundamental one. In consideration of the time factor, the mutual interference of the two systems can produce a feedback mechanism (isostacy). But this does not even bring us to the "chicken/egg" conundrum but only, to sustain the mataphor, to the "chicken/chicken-hutch" problem, which is of course solved in favour of the hen. If logic were the criterion here, we would reach the premature end of the decision ladder at Bordeaux red (tectonic/magmatic) or reddish-brown (structural). The only admissible consideration is, however, that endogenous processes *alone* do not suffice to explain the morphology of the terrestrial surface.

4. EMERGENCE – THE LIMITS OF REDUCTION

This brings us to the problem of emergence (Weisskopf, 1977; Lorenz' fulguration, 1973), by which the interference of two independent system complexes gives rise to new properties, which can only be investigated on this integrative level and cannot be extrapolated theoretically from either of the isolated systems. The discovery of emergence in geography dates back to Alexander von Humboldt (1807), who recognized that the causes and laws governing hypsometric changes of morphology lay in the superimposition of specific variable factors.

The glacial paradigm comprises a host of emergences at various hierarchical levels: the properties of ice cannot be analysed either by considering water or sub zero temperatures alone but in the interaction of both effects. Mass balance and flow dynamics of glaciers is dependent on temperature, humidity, insolation and relief. The temporal and spatial configurations of glacial phenomena and the laws which govern them can only be comprehended by a study of their concrete expression and not by extrapolation from these basic partial elements. The interlinking of these laws governing glacial systems with the random interference of geotectonics and the astronomically varied radiation balance (Milankovitch radiation cycle, 1941) can at a higher hierarchical level lead to positive feedback systems, which manifest themselves in a cyclic recurrance of global glaciation phases (Kuhle, 1987).

Al the level of regional geomorphology these superimposed structures find their expression in individual morphological constellations, which take on historical dimensions through the agency tradition.

The circular relation between highly individual morphological situations and the superimposed systems is preserved in all events. The possibility of perceiving these relations depends, however, on the level of integration which in turn is related to the intended subject matter. The alternative endogenous/exogenous does not obtain because *both* components *always* act synergetically at the interface of the earth's surface. The decision as to which aspect of this interference complex is to be accorded greater significance rests on subjectively legitimized perception of contexts or perspective evaluation of the relative importance of individual features, and therefore is not per se "clearly definable". The question whether a mountain range is, for example, more strongly characterized by tectogenesis and its concomitant structures than by subsequent glacial moulding has to remain open. From the point of view of a geomorphologico-palaeoclimatological survey only the glaciogenetic aspect can be emphasized. On the other hand, particularly the differential consideration of interference between structural basements and forms of glacial erosion can supply the criteria for discriminating structurally conditioned types of glacial erosion and their convergence phenomena.[1]

Glacial moraine complexes in North West Germany can have been reworked postglacially by nival, periglacial, fluvial, aeolian, marine or tectonic processes in any number of permutations and intensities. If the emphasis of the enforced dichotomous decision is laid on the original source of the allochthonous material and a "predominatly determinative" (Barsch et al., 1978:12; where is the decisive criterion to be found? When is cryogenic moulding predominantly more determinative than subsequent fluvial dissection?) process of moulding (the combination of more than two colours not being possible), then the outcome is, e.g., glacial/cryogenic (violet/light purple). If one now compares such North-West German morainic complexes with the Recent or Sub-Recent Alpine Glacial/Periglacial region to which the same symbols have to be applied, one can recognize only a very remote, hardly still partial, rather definitorial than evident "homology", which is overlain with comparatively dramatic differences (it is no coincidence that the elucidation of the genetic parallels mentioned here has taken more than 100 years of systematic research.) On account of the genetic indifference of the symbols in the remaining seven information levels it is however impossible to reconstruct the foundations of this homology or the causes and nature of the phenomenological difference from a study of the map.

A hummocky glacial relief can be substantiated by *roches moutonnées* or moraines and can be angled by periglacial drift mantles or a covering of sand dunes into a false homology of accumulative genesis. The compulsion to make dichotomous decisions therfore amalgamates polygentically moulded terrains into apparently homologous units. Instead of representing morphogenetical complexes and the regional characteristics resulting from their spatial interference and temporal chronology (Principle of geographic change of morphological regions as the basis of regional geography according to Lautensach, 1952), we obtain a stereotypic grading of landscape structures with a great loss of information.

The foundation of this reductionistic approach is a formal orientation to an ideal of total predictability which only proved successful in classical physics. The reason for this is that it consists of a factor analysis at the lowest level of integration under experimentally controllable boundary conditions. The uncritical adoption of alien methods in biology (which is comparable to geomorphology by reason of its typological and historical approach) has frequently resulted in more handicaps than benefits (Mayr, 1984:50). One typical example from the field of geomorphology is the attempt to apply Markov chains.

5. MARKOV CHAINS IN REGIONAL GEOMORHOLOGY?

Markov chains describe the conditional probability of transition with stochastic distribution in closed systems. The transition probabilities are arranged in a matrix. According to Stäblein (1984:14) this model is applicable to numerous aspects of regional geomorphology: "By viewing the relief types as states in an otherwise invariant system, one can deduce probabilities from one state to the next of the various relief developments, and these can be arranged to a matrix of transition probabilities. Generally speaking, certain types of transition sequence will predominate. Thus the Markov property is achieved, i.e. the

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[1] The dichotomy between "endogenous" and "exogenous" led, especially in glacial geomorphology, to gross errors, so that only after decades had elapsed is it now possible to recognize the dependence of glaciogenic forms in proportion to the relief energy or the rate of lift, respectively, and the bedding conditions of the rock. For example, the far more extensive glaciation of Central Asian mountain ranges, whose features are glaciogenic V-shaped valley forms, has only become accessible in the past decade.

dependence of a state on the immediately preceding state." The latter statement is false by virtue of its triviality, since *every* subsequent state is dependent on its predecessor. But here the claim is made that the transition probability is exclusively determined by the immediately preceding state of the system, i.e., it must be "memory-free" (Ashby, 1964). This quality is seldom achieved in geomorphology, however, on account of the mechanistic/material fixation of morphological processes (e.g. in contrast to ethological structures). If one generates a matrix of random distribution of rockfall at the foot of a rockface, it results in an increased probability that a debris particle will be deflected to the periphery the greater the accumulation of debris in the direct line of fall. The direction of deflection and plane of deposition of a given particle are determined by the number and deposition location of its predecessors. As the talus cone increases in height the surface area and curvature radius of the scree cone mantle changes and with it, e.g. the number of debris particles that can lead to a change in the direction of deflection. This leads to a continuous change in the transition probability versus time. Feedback systems of this nature are typical of geomorphological processes, but they cannot, however, be correlated to Markovian processes. A suitable area of application is stochastic reaction patterns causing no material fixation or at best only very transitory fixation (without feedback), e.g. changing wind directions and the resultant wave motions on coastlines (Thornes and Brunsden, 1977:165). The conversion of such a transition probability matrix in terms of coastline modification is, however, also contingent upon mass-movement, i.e. a permanent change in the reference system, and again is not compliant with the Markov criterion.

How does this correlate with the different types od relief? Stäblein defines relief types as "states in an otherwise invariant system", which happens to be a *contradictio in adjecto*. An invariant system is for example the laws of optics or geometry, which remain self-identical throughout all realizations. They possess this quality by virtue of the specifically a-historical approach: a low level of integration coupled with a high level of abstraction. Conversely, a type results from the combination of polymorphic individuals to produce domains of similarity (Riedl, 1987). Variance within a given group increases proportionately with the level of integration. Types are never realized in abstract combinations of characteristics but in an individual state embedded in a historical situation. On account of the high complexity of relief states this variability is corresondingly great and the concomitant terms of reference can never be fully grasped. In oder to draw up a statistically watertight matrix of transition probabilities all the transition states would have to be reviewed several times under consistent terms of reference, which is an absurd demand in view of the protracted nature of morphological cycles in geological time. The change of state from the glacial to the periglacial process regime has often been established, but is nevertheless dependant on the climatic boundary conditions and not the process sequence itself, thus precluding the derivation of a statistical transition probability from it. This proves that Markov chains are unsuitable for apprehending either large-scale or local relief developments. Their formal recommendation (Stäblein, 1984) has no place at all in geomorphological empiricism.

The contention that Markov chains provide explanatory patterns in geomorphology is symptomatic of an urge to copy mathematically exact methods without considering that there is no field of application for them in this discipline. It reflects an indoctrination to an ideal which cannot always be reconciled with our field of research.

6. UTILITY VALUE OR ARROGATION OF COMPETENCE?

One of the underlying principles of the reductionist concept as applied to the GMM-25 legend was to develop a generally accepted descriptive relief catalogue and basic terminology which would be equally useful "to our geoscientific neighbours" as to automatic data processing (Barsch and Stablein, 1978:64 f.). A complex and theoretically circumscribed term such as *roche moutonnée* is therby transcribed into the easily comprehensible information fractions: slope $10^0/_0$; roughness: hummocky, hilly; surface rock: metamorphic; process: glacial/nival. The geomorphological layman should be in a position to extract the information he needs without difficulty and thus the maximun utility value is achieved for all practical evaluation purposes (Stäblein, 1978:8).

The prerequisite for this type of use is that the various information units are standardized among themselves and thus behave identically in the various fields of reference.[2]

Mäusbacher (1985) proposes a use catalogue for the GMM-25. Here we find, e.g. qualification matrices for calculating the use value of any desired terrain unit. The gross suitability qualification for the use category "agriculture" rests for instance on the criteria: climatic stage, insolation, cold air, useful field capacity, soil erosion, aeolian erosion, trafficability; for the use category "civil engineering" (location lines) the criteria: potential hazards through geomorphodynamics, bearing capacity, frost hazards, trafficability, steps and ledges (ibid., table 55 and 56).

.The requisite information is contained indirectly in the GMM and can be made available for evaluation by means of translation instructions: e.g. Table 21 (Mausbacher, 1985) suitability of steps in laying down location lines, calculated in proportion to step heights: step height < 1 m = moderately suitable; step height < 5 m = poorly suitable; step height > 5 m = very unsuitable.

It gives the appearance of being an objective valuation method due to its factual backing, but it makes the mistake of being *totally user oriented* to the exclusion of the overall environmental situation. Under prevailing social consensus such a one-sided view may well be sanctioned, but against the background of ecological network systems it represents a totally retrograde approach.

For assessment of the gross suitability for "waste disposal or storage of toxic wastes" the cataloque is based on the substrate properties of the surface layer which were secured by sporadic drillings down to a depth of 1 m. The geological basement is never considered, and groundwater only when its table is less than 1 m under the surface of the soil. Minor injuries to the topsoil, cased for instance by grading operations, would be sufficient to allow toxic leachate to penetrate porous underlying beds and thus pollute the groundwater. It is therefore extremely questionable to deal so superficially with this aspect under the heading of "gross suitability".

The utilization map entitled "recreation" evaluates areas with natural surface water as "very well suited" respecting provision of picnic places, trails, angling and hiking facilities (Mäusbacher, 1985:59, 65). This gives 'scientific sanction' to the touristic exploitation of the last remaining natural biotopes which have survived the encroachments of roadbuilding, agricuture and forestry. From the point of view of the utilization map for evaluation of "civil engineering" (location lines) the GMM can grant the rating "very well suited" in the case of a test circuit for an automobile concern. Form the ecological standpoint this can very well entail at the same the wholesale destruction of a meadow landscape with its residual fauna and flora.

Every form of utilization of a landscape element occasions interference in the natural order. This is not determined only by the factors listed in the GMM but intrinsically by the biotic factors as well. Land use evaluation can therefore only be made from a higher level of integration in consideration of the biotic aspect. To pronounce *gross suitability qualifications* of any kind whatsoever on the basis of the reduced information level provided by the

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[2] Fields of the inclination class $> 2° - 4°$ are homogenous from the point of view of "inclination" but can exhibit widely heterogenous properties in respect to erosin hazards, due to the different substrate properties in the overlying and underlying beds as well as the different plant cover and climatic conditions.

GMM-25 represents an inadmissible arrogation of competence, which paves the way to continued landscape abuse and environmental destruction.

The quantification of partial elements of landscape structure is no guarantee of qualitative homogeneity. "The bugbear of quantification ideology is the brainchild of scientistic reductionism. It rests on the shortcomings of our intuitive vision respecting the emergence (...) of the new qualities. The ideal that all is quantifiable finds additional support in a further inadequate adaptation of our inherited intuitive notions. This leads us to expect that we may extrapolate arbirarily from quantitative experience, without giving consideration to change in qualitative values" (Riedl, 1985:142). Seen in this light the utilization maps of the GMM represent an inadmissible extrapolation of qualities into a field of reference in which their declaratory value (their interpretation) becomes heterogeneous.

The explantion offered for this striving to produce "relevant statements" is the fear that otherwise "our geomorphology will be becalmed in the doldrums of an esoteric 'orchidology'" (Barsch and Stäblein, 1978:64).[3] Accordingly, in several passages the claim is made that the GMM contains important ecological or geo-ecological regional information (Stäblein, 1978; Mäusbacher, 1985; Riedel et al., 1987). Landscape ecology has been defined as the interplay of abiotic, biotic and anthropogenic dependences and interrelationships (*Lexikon der Geographie*, 1983, Vol. 3: 41). While endeavouring to attain a correct and clearly defined terminology (especially with the outsider in mind), it would have been advisable to restrict this complex term to that section of it which is actually addressed in the GMM-25, namely: the abiotic. As the very nature of reductionism avers, there can no longer be any question of ecology in such a narrow view. Riedel et al. (1987) provided a very revealing contribution to this problem in thier commentary on the "Bredstedt" sheet of the GMM-25. The ecological field of tension herewith mediates between the agricultural, silvicultural and military utilization of the environment and the flora and fauna threatened by it. Neither the existence nor the geographical distribution of these two opposing vectors can be deduced from a study of the map: the conflict is addressed only *verbally*. The only point of reference is the structure of the substrate as a factor determining the type and extent of agricultural land use. The amount of effort put into the soil survey was correspondingly great: a total of 3000 drillings, each to a depth of 1 to 5 m, covering the entire area. This represents a standard more in keeping with a pedological survey than a geomorphological mapping operation. It thus becomes evident, too, that the genetical landscape areas are by no means congruent with the substrate areas. For this reason it was expedient to append a supplementary map to the commentary since this (and not the GMM) supplies "the greatest possible differentiation among the ecologically significant categories" (Riedel et al., 1987:232).

Discussion of the ecological situation is therefore utterly detached from the special information contained in the GMM. All the more astonishing and at the same time symptomatic is the contrived conclusion, viz.: acquisition of data of ecological importance, assignment of land use areas and the analysis environmentally significant utilzation problems can all be effected by the GMM since it identifies the relevant information sytematically and comprehensively (Riedel et al., 1987:232).

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[3] A scientific discipline cannot be uplifted in its historical validity by any amount of donkey-work but it will be totally sapped by the lack of innovative impulses in basic research. Particularly in this respect the less "applied" Quaternary research and classical geomorphology – evidenced by the major successes in climatography and paleoclimatology during the past decade – need not hide their candle under a bushel. Anyway, it is often the orchidology-type sciences which have led to breakthroughs in cognition – a fact which any programme of science promotion, implying also the furtherance of culture in general, must take into account. After all, though Mendel's Laws were elaborated through peas, they could also have been discovered by a study of orchids.

7. ENTROPY VERSUS COGNITION

The GMM-25 has turned out to be a peculiar mixture of utilitarian and scientific information units. Morphography and morphometry are enlisted in the service of agronomy, civil engineering, waste disposal and recreation. Morphogenesis is relegated to a stereotype through the use of area-related colour coding and the dichotomous decision ladder that goes with it. The computer-oriented dissolution of complex landscape structures into normative, exactly defined and quantified elements is a condescension to electronic data processing (EDP). The necessary fundamental information is not presented cohesively enough for any of these utilitarian and scientific aspects. As the choice of map symbols has been influenced by the most heterogeneous claims, they cannot be correlated in any significant way. The intended interpretation can only result from a number of different specialist contexts. Nevertheless, the symbols of all the eight information levels are overprinted on a single map sheet.

In information theory entropy (in the sense of Brillouin, 1956) implies the increasingly homogeneous distribution of smallest units of information, the dissolution of ordered structures, loss of information and a transition to chaos. Knowledge is negentropy. It implies selective perception, judgement of priorities, discovery of structures – and hence of higher information contents – at various different levels of integration.

Overprinting of information from heterogeneous contexts results in an entropy increment in that those factors, which scientific cognition in the shape of gestalt perception (Lorenz, 1959), as type and natural order, had dissected out of the background of chance and irrelevancy, are again destructured, neutralized and intermingled with factors belonging to a different context – but now irreversibly so through the egalitarian filter of the map symbols. It is obvious that the headlong use of EDP is not going to elicit any more significant interpretations from such theoretically neutral, quantitatively homogeneous, yet qualitatively heterogeneous information units.[4] The actual object of geomorphological analysis largely

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[4] There is no doubt that EDP has a place in physical geography, namely in geology. In this case it is a useful tool in the indentification of layers for the purpose of information acquisition (retrieval), drawing up profile columns and cross sections as well as their spatial relationships (Vinken et al., 1978). This is effected by means of unambigous, substrate-governed criteria such as particle-size ranges, index fossils or absolute datings. Although geomorphology is able to make use of such bedding profiles (e.g. Quaternary ones), they are only a means to an end and are not self-evident. The true aim is to explain morphogenetical complexes, and in this respect there are *no* hard and fast criteria which are valid for any number of locations, but a necessary mutation in the hierarchy of characteristics by virtue of the respective higher-order macro-contexts. Plotted descriptions of linear relief facets for easy digestion by EDP as proposed by Barsch and Stablein (1978) are of absolutely no interest to geomorphology as no distinction is allowable between the typical and the coincidental in them. Practical applications are also ruled out since the biotic element has also been omitted. This is another instance of method borrowing without ascertainig whether the structures of the various areas of application are analogous.

The same applies to biology, where plants can be identified by means of their chemical substances, but where, however, genetical classification does not possess the same unambiguous indicators. "Objective" methods, such as numerical phenetic systemology, therefore also fail on grounds of the heterogeneity of phenotypical characters as indicators of genetic relationships (Mayr, 1984:181). Biology is at an advantage in having the individuum as a sharply defined unit uniting all the essential characters in itself (as a pendant to the geological layers). But the geomorphological "individuum" first has to be distilled out of a continuum as a genetic type or process element, constituting a relational phenomenon of an entirely different spatial order. Theoretically neutral, plotted descriptions of linear relief facets (Barsch and Stablein, 1978) possess the same cognitive value as an EDP-dedicated, histological microtome series, arbitrarily cut though the body of a chicken, would have for elucidating the phylogeny of the *Phasianidae*.

defies such procedures, since it will always be inaccessible to reductionist quantification by virtue of its high level of integration.

8. COORDINATION OR COMPULSION TO CONFORMITY?

"Our whole civilization is being reductionistically indoctrinated through the complacent self-assessment of the 'exact' sciences and the inadmissible arbitrary extrapolation of arbitrary abstractions resulting from a lack of education for an understanding of higher levels of complexity and of the value decisions that follow them. Our scientistic society has even reconciled itself to issuing actions against non-conformists or even resorting to open threats." (Riedl, 1987:149). In translating geomorphological reality in terms of the symbol code of the GMM legend, numerous editors expressed strong reservations. Grimmel and Schipull thereupon drew up an alternative, necessitated by the special morphological conditions prevailing in the North German lowlands with the early glacial relief of the Saale period and the Elbe urstromtal. The so-called GMM-Coordination Commission (Leser and Stablein, 1975) disallowed this non-conformist enterprise and refused to print it. Publication of the "Bleckede" map sheet was therefore executed within the framework of the *Hamburger Geographische Studien* (1983).

The map is distinguished by its considerably enhanced readability. The contents have been separated sensibly according to subject matter, i.e. partly printed at a reduced scale in the margin. The legend pursues a genetical chronology and is therefore consistent with lending rapid transparency to origins and structural relationships of landscape elements. The typography remains adequately legible although the characteristic morphology of the moraine landscape is emphasized by means of a special convexity index grid. In the commentary (Grimmel and Schipull, 1983) the deviations from the GMM legend are objectified and substantiated. An example of this is the probable influence upon glacial and glaciofluvial morphology by isostatic and diapiric movements, which is not, however, fully explained in its local effects. In view of the additional fluvial, periglacial and aeolian weathering the authors are not prepared to assign unilateral process group colours to such polygenetic landscape elements.

Another mapping venture which was started within the framework of the GMM-25 programme (Heine and Siebertz, 1980) and excluded from publication, to be included in the *Arbeiten zur Rheinischen Landeskunde* (Siebertz, 1980), is the "Kalkar" map sheet (Saale-contemporaneous push moraines and glacial outwash, Weichsel-contemporaneous loess deposits, holocene alluvial terraces of the Lower Rhineland plain). According to the present state of knowledge the map reveals an extremely high genetic resolution of substrate and process areas. By using area colouring to indicate temporal-genetic units a high information density, incompatible with the GMM legend, was achieved. In the GMM-25 the Rhineland lowlands would be coloured green (fluvial) whereas Siebertz makes use of an eightfold green brown colour gradation. Dipping patterns and profile lines, being of little significance in view of the presence of contour lines, are not represented. By rejecting egalitarian process group colours it allows a highly defferentiated expression of current knowledge of these landscape phenomena to be presented.

Wheareas the consistent application of the GMM-25's map symbols on the "Bleckede" sheet would lead to over-simplification and a false sense of scientific authenticity on the one hand and to a declarification of morphographic characteristics on the other, in the case of the "Kalkar" sheet the results would be an artificial supperession of current knowledge of the subject and the emphasis of inessential relief elements. Both maps provide an excellent basis for making ecologically relevant mappings of biotope areas.

An interesting comparison can be made on the basis of the "Bredstedt" map sheet (Saale-contemporaneous morainic complexes, Weichsel sandur, marshlands) which conforms to the

GMM-25 ideology and was mapped by Riedel and Schröder (1985; appendix to Riedel et al., 1987). In the "morphostructural" general map the whole complex of the Saale moraines is designated "periglacially overworked, Weichsel-contemporaneous." In the accompanying text (Riedel et al., 1987:231) it is furthermore maintained that the entire geest (lowland heath) area has been reworked by aeolian action. In the GMM-25 for the main complex of the Saale moraines the sole colour is "glacial", with sporadic, closely defined areas of blown sand. The periglacial body colour – described as "cryogenic-periglacial Weichsel-contemporaneous flushing plains" – only appears at crucial points on the outwash fields. Where it is printed on the peripheral areas of morainic deposits it is open to debate whether it refers to "flushing plains" or cryogenic overworking. Marine overworking (Eemian Sea) receives no mention at all. Weichsel-contemporaneous valley forms are simply defined as "fluvial" and therefore cannot be distinguished from recent fluviatile process areas. The broad zone of tripartite dyke construction is assigned to the process area "marine" without further differentiation, except for a grey overprinting of the dyke infrastructures, the embankments and mounds signifying their "anthropogenic" origins – just as if a polder had the same effects as a natural marine alluviation field. The complexity of the genetic-chronological landscape structure and the consequences of anthropogenic interference in natural evolutionary processes are unsatisfactorily and sometimes falsely depicted. In the interests of an unambiguous depiction of process areas, a random sample is stylized to an – unrealistic – principle, which cannot be justified out of the necessity to generalize.

It is therefore to be hoped that the alternatives to the GMM hitherto accomplished will find their way into future draught maps and that the application of the existing GMM legend will be terminated with the presentation of sample sheets.

9. CONSEQUENCES

The proposal made here is that in future mapping projects the legend should be draughted more on the lines of a clue key than as entrenched doctrine. Especially at the outset of legend development for the preparation of sample sheets considerable leeway should be allowed for exploration of a variety of different realization methods, so that the features of a landscape unit and the current state of knowledge concerning genetic relationships are comprehended in their true scale inductively and not normatively. Priority must be given to the isolation of complex subject matter, the presentation of typological differences and emergent properties, but above all to embedding the results in a higher hierarchical level of insight and a macroframework of relationships.[5]

At present the emphasis is placed on the data-technological rather than primarily scientific quantification of results and their usefulness in terms of electronic data processing. It is however evident that a meaningful extrapolation of quantities only obtains insofar as the underlying system of coordinates is not consciously departed from. The proper discovery and delimitation of such, of necessity qualitatively defined, reference systems and reference hierarchies can never result from the routines of electronic data processing as a mere tautological transformation, but is an achievement of human ratiomorphic gestalt perception (Lorenz, 1978; Riedl, 1981). Only the description, at a high level of integration, and the qualitative analysis of landscape structures can point to a meaningful approach towards a cautious quantitative registration and evaluation.[6] This opens up the pathway to a concept of regional geomorphological mapping.

[5] For example, comparative map sheets of Norh West Germany and the Alpine piedmont area should make it clear that they depict inland ice marginal areas and denticulate marginal areas of piedmot glaciation, respectively.

[6] This not only applies to geomorphological maps but also equally to mapping that is truly aimed to ecology and therefore necessarily based on a record of the vegetation cover.

REFERENCES

Ashby W.R., 1964, *An introduction to cybernetics*, Methuen, New York.
Barsch D. and Mäusbacher R., 1980, Auszugs- und Auswertungskarten als mögliche nutzungsorientierte Interpretation der geomorphologische Karte 1:25 000 (GMK 25), *Berliner Geographische Abhandlungen* 31, 31–48.
Barsch D. and Stäblein G., 1978, EDV-gerechter Symbolschlüssel für die geomorphologische Detailaufnahme, in: G. Stablein, ed., Geomorphologische Detailaufnahme, *Berliner Geographische Abhandlungen* 30, 63–78.
Barsch D., Fränzle O., Leser H., Liedtke H. and Stäblein G., 1978, Das GMK 25 Musterblatt für das Schwerpunktprogramm Geomorphologische Detailkartierung in der Bundersrepublik Deutschland, in: G. Stäblein, ed., Geomorphologische Detailaufnahme, *Berliner Geographische Abhandlungen* 30, 7–19.
Brillouin L., 1956, *Science and information theory*, Academic Press, New York.
Grimmel E. and Schipull K., 1983, Geomorphologische Karte 1:25000, Blatt 2730 Bleckede (mit Erläuterungen), *Hamburger Geographische Studien, Sonderheft.*
Heine K. and Siebertz H., 1980, Abriss der paläogeographischen Entwicklung des unteren Niederrheingebietes, *Arbeiten zur Rheinischen Landeskunde* 46, 1–13.
Humbolt A. von, 1807, *Ideen zu einer Geographie der Pflanzen nebst einem Naturgemälde der Tropenländer von Al. von Humboldt und A. Bonpland. Bearbeitet u. herausgegeben von dem ersten,* Tübingen u. Paris.
Kuhle M., 1987, Subtropical mountain- and highland-glaciation as Ice Age triggers and the waning of the glacial periods in the Pleistocene, *GeoJournal* 4, 393–421.
Lautensach H., 1952, Der geographische Formenwandel. Studien zur Landschaftssystematik, *Colloquium Geographicum* 3, Bonn.
Leser H. and Stäblein G., eds, 1975, Geomorphologische Kartierung. Richtlinien zur Herstellung geomorphologischer Karten 1:25 000, 2. veränderte Auflage, *Berliner Geographische Abhandlungen*, Sonderheft.
Leser H. and Stäblein G., 1978, Legende der Geomorphologischen Karte 1:25 000 (GMK 25). 3. Fassung im GMK-Schwerpunktprogramm, *Berliner Geographische Abhandlungen* 30, 79–90.
Lexikon der Geographie, 1983, Herausgegeben von W. Tietze im Westermann Verlag, Bd. 3 (Sonderausgabe, Zweiburgen Verlag),
Lorenz K., 1959, Gestaltwahrnehmung als Quelle wissenschaftlicher Erkenntnis, *Zeitschrift fur Experimentelle und Angewandte Psychologie* 4.
Lorenz K., 1973, *Die Rückseite des Spiegels*, Piper, München.
Lorenz K., 1974, Analogy as a source of knowledge. *Les Prix Nobel en 1973*, 185–195, The Nobel Foundation.
Lorenz K., 1978, *Vergleichende Verhaltensforschung. Grundlagen der Ethologie*, Springer, Wien — New York.
Mäusbacher R., 1985, Die Verwendbarkeit der geomorphologischen Karte 1:25 000 (GMK 25) der Bundesrepublik Deutschland für Nachbarwissenschaften und Planung, *Berliner Geographische Abhandlungen* 40.
Mayr E., 1984, *Die Entwicklung der biologischen Gedankenwelt*. Vielfalt, Evolution u. Vererbung, Springer, Berlin — New York (in English: *The growth of biological thought*, Harvard University Press, London 1982).
Milankovitch M., 1941, Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitproblem, *Serb. Akad. Wiss., Nat. Sekt.*, 33.
Riedel R., 1981, *Biologie der Erkenntnis. Die stammesgeschichtlichen Grundlagen der Vernunft*. 3. Aufl., Parey, Berlin — Hamburg.
Riedl R., 1985, *Die Spaltung des Weltbildes. Biologische Grundlagen des Erklärens und Verstehens*, Parey, Berlin — Hamburg.

Riedl R., 1987, *Bergriff und Welt. Biologische Grundlagen des Erkennens und Begreifens*, Parey, Berlin — Hamburg.

Riedel W., Müller C. and Stäblein G., 1987, Ökologische Struktur und Umweltfragen an der Westküste Schleswig-Holsteins aufgezeigt am Blatt Bredstedt der Geomorphologischen Karte 1:25000 (GMK 25), *Die Erde* 118, 227–240.

Siebertz H., 1980, Ausgewählte quartärmorphologische Probleme am unteren Niederrhein — Ergebnisse einer geomorphologischen Kartierung, dargestellt am Beispiel einer geomorphologischen Übersichtskarte vom Raum Kalkar, *Arbeiten zur Rheinischen Landeskude* 46, 37–46.

Stäblein G., 1978, Feldaufnahme zur geomorphologischen Detailkartierung. Beispiel aus dem Westhessischen Bergland (Wetschaft-Niederung), *Berliner Geographische Abhandlungen* 30, 21–31.

Stäblein G., 1980, Die Konzeption der Geomorphologischen Karten GMK 25 und GMK 100 im DFG-Schwerpunktprogramm, *Berliner Geographische Abhandlungen* 31, 13–30.

Stäblein G., 1984, Regionale Geomorphologie, *Berliner Geographische Arbieten* 36, 11–16.

Thornes J.B. and Brunsden, 1977, *Geomorphology and time*, Methuen, London.

Troll C., 1924, Der diluviale Inn-Chiemsee-Gletscher, *Forschungen zur deutschen Landes- und Volkskunde* 23, 1, 1–121, Stuttgart.

Vinken R., Barckhausen J. and Preuss H., 1978, Die automatische Datenverarbeitung in der geowissenschaftlichen Kartierung — dargestellt am Beispiel Geologie. *Berliner Geographische Abhandlungen* 30, 33–61.

Weisskopf V., 1977, The frontiers and limits of science, *American Scientist* 65, 405–411.

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MORPHOGENETIC CLASSIFICATION OF RIVER VALLEYS DEVELOPING IN FORMERLY GLACIATED AREAS FOR THE NEEDS OF MATHEMATICAL AND PHYSICAL MODELLING IN HYDROTECHNICAL PROJECTS

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This paper deals with proposals of natural models of river valley evolution useful for physical and mathematical modelling in hydrotechnical projects. Such models are known from investigations of numerous valley reaches of the Wisla (Vistula) River and the Odra (Oder) River drainage basins (Fig. 1). The proposed classification of model types forms an open system that can be supplemented with new types and subtypes, characteristic for other regions of the world.

It should be strongly underlined that the experience of author and his research team (Dr K. Krauzlis, Dr K. Laskowski, W. Granacki M.Sc., T. Falkowski M.Sc., J. Karabon M.Sc., R. Bieganowski) proves the usefulness of the morphogenetic approach in studying the river channels and valleys. Otherwise, wrong or non-precise conclusions can be drawn. Such approach is desirable either in basic research studies or in investigations for practical purposes, e.g. in hydrotechnics.

1. NATURAL MODELS OF RIVER VALLEYS

The first attempt of classification of river valleys was presented by E. Falkowski (1971: Fig. 1) with making use of the criterion based on the reaction of rivers on climatic-biologic changes (man impact inclusive) in a drainage basin. This classification reflects different phases of the channel pattern cycle "braided-meandering-braided river" (Fig. 2). Three principial types were distinguished.

Type I, young river. It comprises rivers without well defined valleys. Independently of the water regime in a drainage basin (the presence or absence of water level variations) and discharges, such rivers form their valleys mainly by erosion or deposition. They cannot form free meander or braided patterns. Due to a considerable variation of initial geomorphological conditions as well as different evolutionary stages of the valley, such rivers have been subdivided into several subtypes:

IA, young erosive river being characteristic, for example, for terminal moraine belts. It is presented by an erosive narrow valley; resistance of slopes and slope processes play here a very important role (Fig. 3).

IB, young river that flows in an inherited system of depressions. The latter may be created by a row of overflow lakes, filled lake depressions or tectonic basins. Ice marginal streamways are not considered here as the author, basing on his studies, doubts if they have ever existed. The subtype IB is very common and is represented by several valley reaches in the Polish Lowland.

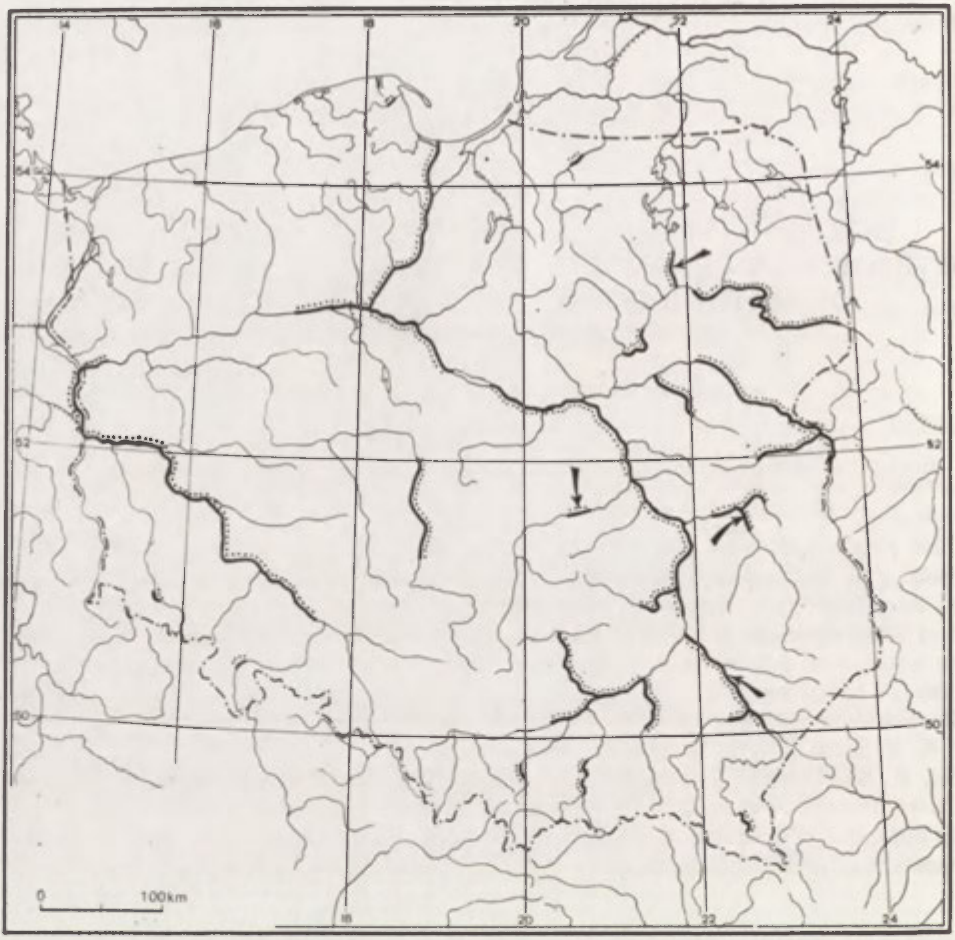


Fig. 1. Localization of tested river sections. Arrows denote river sections tested by A. Szumański (1986).

IB_1, young river that flows in inherited valleys and systems of overflow lakes, depositing channel sediments synchronically with lake deposition (Fig. 4). In consequence, lake sediments interfinger with alluvia of the channel facies. A system of ground waters is appropriate to this subtype. River waters usually do not contact directly with ground waters.

IB_2, young river that flows in inherited valleys, having a channel cut in lake sediments (Fig. 5). The contact is of erosive origin.

IB_3, young river with a channel of a "boggy" type, formed in marshes due to erosion of peats during freshets (Fig. 6). Channels are branched but one channel predominates. Changes of the main channel can occur during each freshet (a surge of floodwater).

IC, young river which is erosively stabilized on thresholds composed of resistant ground and has a braided pattern. The islands are a permanent morphological element of the river channel composed of resistant rocks or deposits (Fig. 7). The valley reaches of this type are particulary sensitive to ice jamming. Numerous reaches of the lower and some of the middle

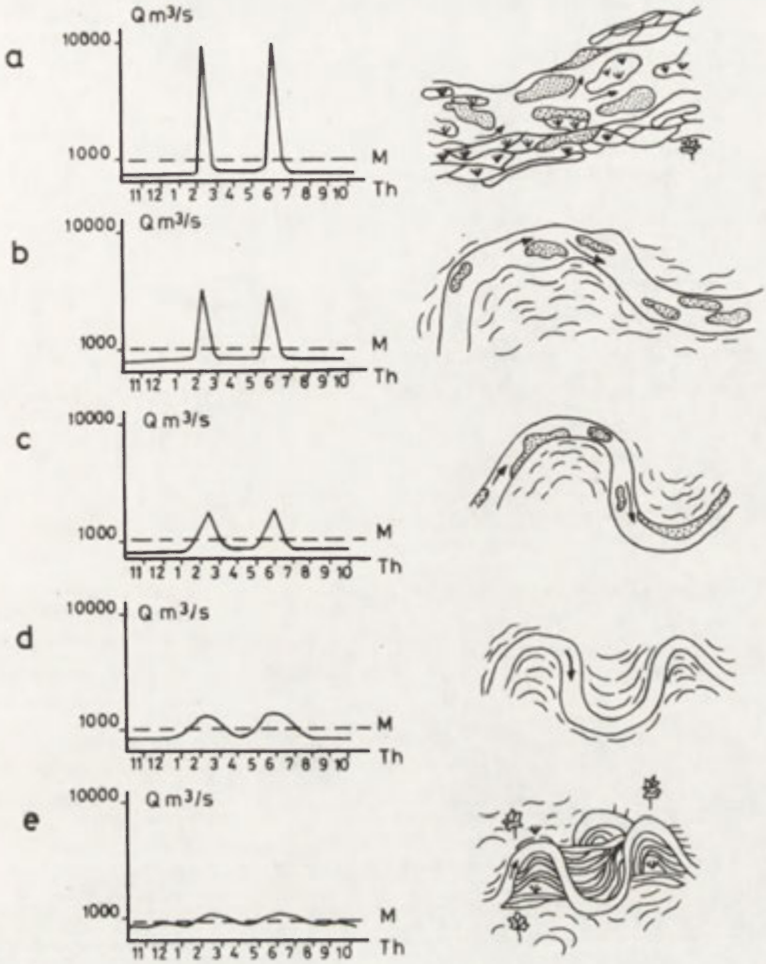


Fig. 2. Changes of hydrological regimes of rivers and corresponding phases (a-e) of river-bed development; Th – hydrological time (in years), M – average flow (during a year)

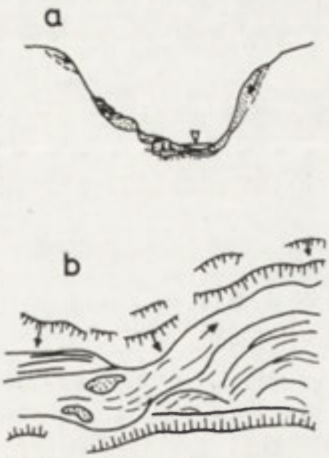


Fig. 3. Type IA – Young erosive river

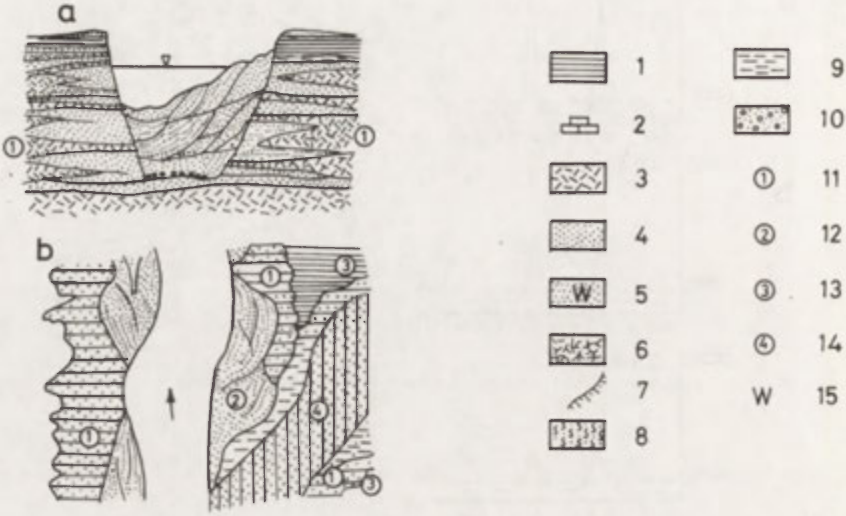
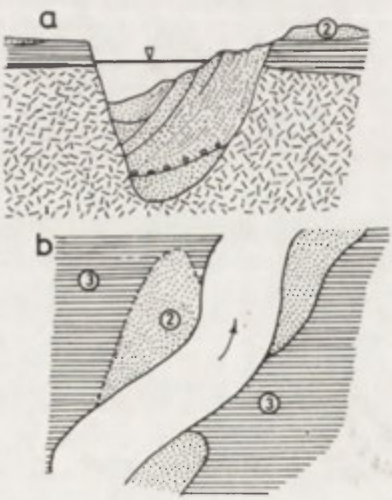


Fig. 4. Type IB_1 – Young river sedimenting in inherited valley–lake systems and river-bed dyke: 1 – mud, 2 – peat, 3 – gyttja, 4 – alluvial sand, 5 – aeolian sand, 6 – meadow ore, 7 – top of deposits resistant to erosion, 8 – till, 9 – clay, 10 – fluvioglacial sands, 11 – zone with interbedded sands, gyttja and mud, 12 – levees of recently braided rivers, 13 – mud, 14 – oxbow lakes with old sandy dikes, 15 – dunes



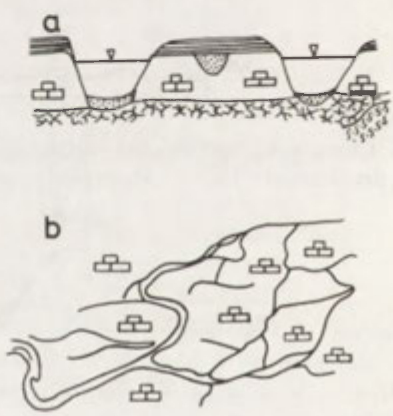


Fig. 5. Type IB_2 – Young river sedimenting in inherited valleys, alluvium dyke inbedded in lake sediments. For explanations see Fig. 4.

Fig. 6. Type IB_3 – Young river having a "swamp" type river bed formed by peat erosion. For explanations see Fig. 4

Wisła River (e.g. the reaches near Płock and Nieszawa) are good examples of this type.

Type II, mature free river. It comprises rivers or river reaches where the valley is already sufficiently wide for the development of the meanders, the size of which is related to flow and rate of the river discharge. A longitudinal profile of such river is smooth enough to fill the valley with alluvia (braided river) or to lower its bottom (meandering river) in

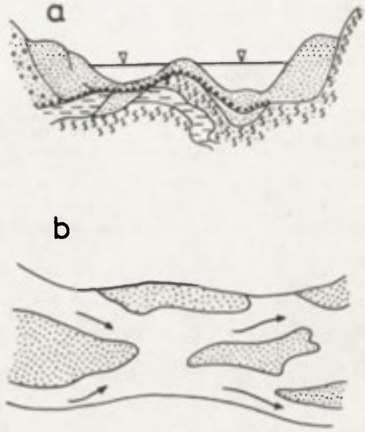
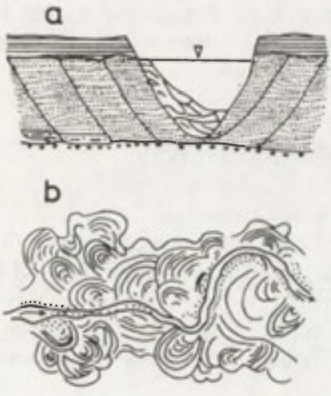


Fig. 7. Type IC – Young river with a constant erosion (stabilized) on erosion resistant ground braces. The river has braided character. For explanations see Fig. 4



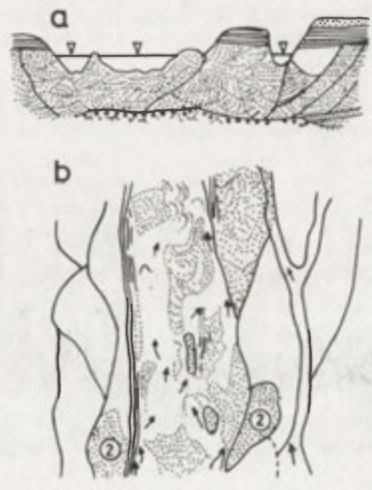
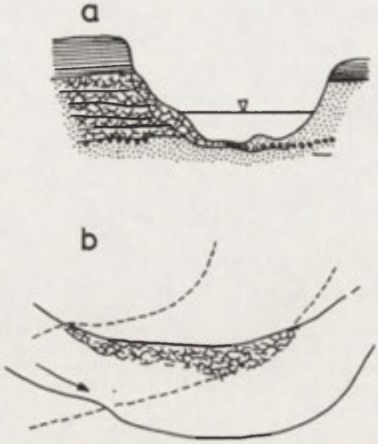


Fig. 8. Type IIA – Mature, freely meandering river. For explanations see Fig. 4
Fig. 9. Type IIB – Mature, freely braided river. For explanations see Fig. 4

favourable conditions. Changes of the channel pattern according to the full cycle "braided-meandering-braided river" (Fig.2) are also possible. Two subtypes have been distinguished: IIA, mature freely meandering river (Fig. 8), and IIB, mature freely braided river (Fig. 9).

Type III, mature constrained river. It is represented by valley reaches in which new influencing factors appeared, such as dunes, meadow ore, constructions etc., that completely or partly constrain the meandering. Such process can also result from river overloading, appearance of erosion-resistant deposits, damming of a stream, etc. When the constraining factors are removed, the river transforms again into a free mature one. On the basis of our investigations, the following subtypes are to be distinguished: IIIA, mature river which is contrained by meadow ore. It forms filled oxbows that are natural spits (Fig. 10), and IIIB,



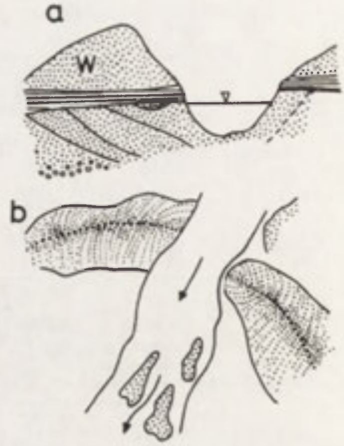


Fig. 10. Type IIIA — Mature river constrained by meadow ore. For explanations see Fig. 4
Fig. 11. Type IIIB — Mature river constrained by rock waste. For explanations see Fig. 4

mature river which is constrained by overload from washed dunes, coming from higher terraces (Fig. 11).

Wisła River provides good examples of such subtypes. A particular attention is to be paid on the Wisła reach of the IC type from Warsaw to Toruń which, due to thresholds composed of resistant deposits, is not so well developed in comparison with the reach from Zawichost to Warsaw.

2. TYPES OF MODELS OF MIDDLE AND LOWER WISŁA RIVER (FROM ZAWICHOST TO TORUŃ)

The middle Wisła River, as proved by several studies made since 1964 (Falkowski 1967, 1971), can be divided into reaches of three subtypes: IB_1 IC as well as IIA and IIB. Subtype IB_1 was noted only locally near Ciechocinek (Fig. 12). Both the latter types are to be referred to the present channel and the intra-dam zone. The subtype IC displays thresholds composed of material resistant to erosion (Fig. 7) and represents the so-called Warsaw

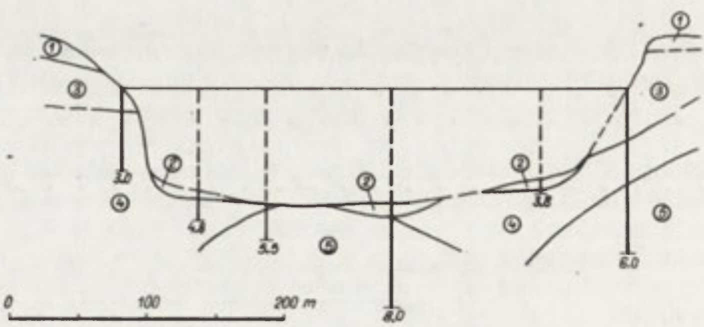


Fig. 12. Geological cross-section across Wisla River bed near Ciechocinek: 1 — sandy mud, 2 — alluvial sand of recent Wisla River, 3 — alluvial sand of Holocene Wisla River, 4 — lake deposits (gyttja, peat, organic mud), 5 — glaciofluvial gravels, sands with pebbles

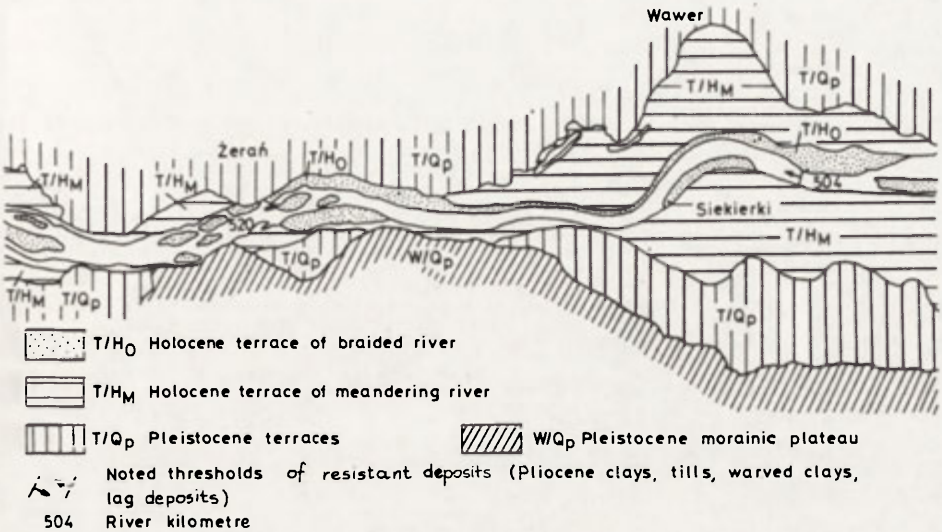


Fig. 13. Geomorphological sketch of Wisla valley (Warsaw area). Approximate scale 1:100000

corset (Fig. 13). It was found at the mouths of Wyżnica and Kamienna rivers, near Dęblin, Brzeźce–Piotrowice, Tarnów and Wilga, between the mouth of Czarna River and Góra Kalwaria, and at Gocław–Buraków. A threshold model is illustrated by a longitudinal section of the channel in the Warsaw reach of the Wisla River (Fig. 14).

In the case of the reach Warsaw–Toruń, the subtype IC predominates, in which the

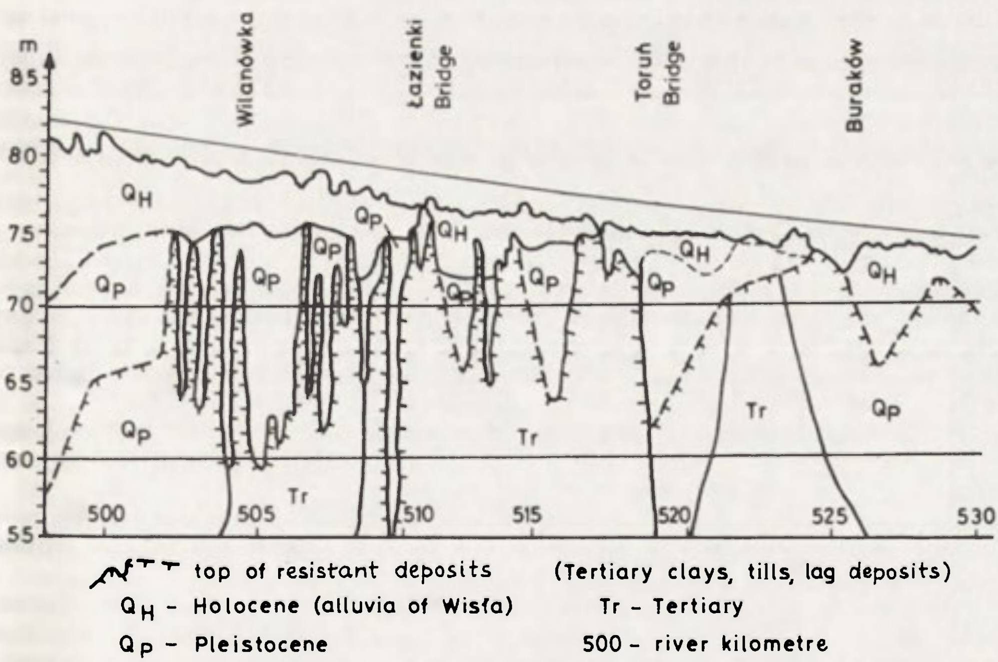


Fig. 14. Fragment of a longitudinal section of the Wisla channel in Warsaw area

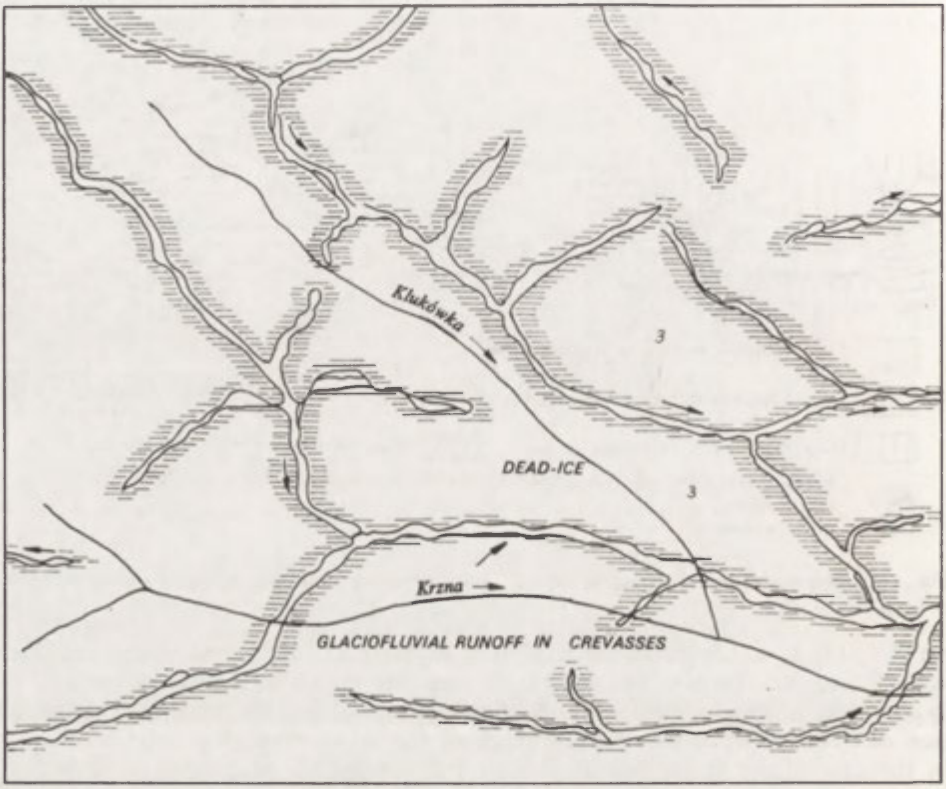


Fig. 15a. Scheme of areal deglaciation in a fragment of the Krzna drainage basin: 3 – dead ice

present river channel corresponds almost entirely with the borders of the Holocene valley. It was formed due to ice jamming that are easily formed on thresholds composed of rocks resistant to erosion. Such thresholds were noted in Warsaw area, near Zakroczym, Wychodźce, Czersk, Kępa Polska, Dobrzyków, Płock, Włocławek, Bobrowniki, Nieszawa, Toruń.

Type IB_1 (Fig. 4) was defined by boreholes in a reach, about 10 km long, near Ciechocinek and near Toruń (Silno). In the bottom and banks of the channel, there were lake sediments, organic muds and gyttja. In channel banks, lake sediments interfinger with alluvia, proving thus a syngenetic sedimentation of lake and fluvial deposits. Type of sediments and their continuous occurrence in the channel bank excludes their oxbow origin. They form the traces of the postglacial overflow channel lake that was used by the Wisła River. In this area, E.Wiśniewski (1976) described from Kępa Zielona abundant Holocene molluscs, ascribing their origin to the channel environment of the Wisła River.

Thresholds are frequently composed of pebbles and boulders. They have been exploited in the 1920th and earlier for building purposes. At present, the residual glacial deposits cannot be exploited as the resources are rather small.

Now, the Wisła River is strongly influenced by man. The influence is expressed by more frequent low water levels and the occurrences of freshets, and also by increased soil erosion and debris supply. This results in further braiding of the river.

In reaches of young erosively stabilized river (subtype IC), a correction of the channel should take into account the morphology of the top of resistant deposits. Usually, it is necessary to remodel the channel fragments in these reaches by digging of the channel.

An opposite characteristic is typical for the lower Wisła, particularly in the reaches

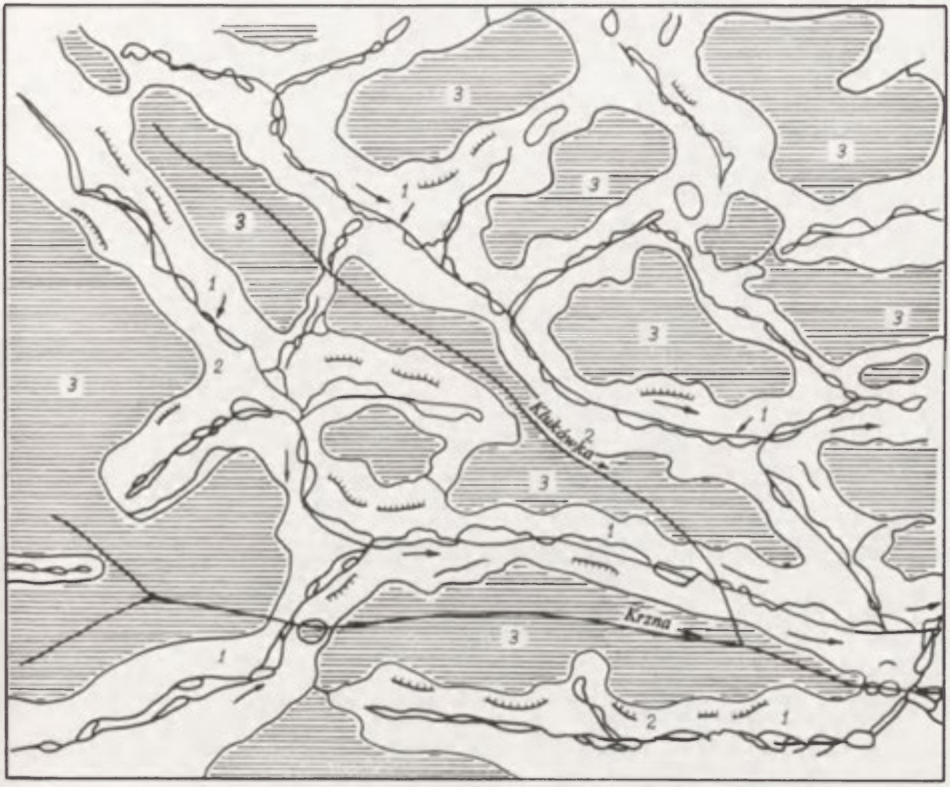


Fig. 15b. Formation of plain levels (steps) with meltwater floods amidst gradually widened crevasses. Deformed kames (cf Fig. 4) have been almost entirely buried: 1 – glaciofluvial pattern, 2 – initial plain levels, 3 – dead ice

Kazuń–Płock and near Ciechocinek. Subtype IC decidedly predominates there, displaying in places numerous thresholds composed of resistant deposits, commonly including glaciogenic pebbles and boulders. These thresholds were described in 1921 by R.Ingarden.

It should be emphasized here that geological and particularly geomorphological literature usually neglects the problem of varying morphology and shallow occurrences of resistant deposits in rivers. Frequently, we encounter a false interpretation of geological structure of the river bed or wrong evaluation of the phenomena proceeding in the channel. The paper of Z. Babiński (1979) is an example of such false interpretation of fluviodynamic phenomena. Curves of the main current, caused by material resistant to erosion in the floor of the type IC channel, were treated as a meandering phenomenon. There are also mistakes in interpretation of geological sections: sands with pebbles and boulders are considered as alluvia of the Wisła River, although the latter has never been able to transport such material in its lower and middle courses due to its smaller gradients.

In the opinion of the local inhabitants and some of the staff of water administration from the Ciechocinek and Toruń areas, the Ciechocinek–Toruń reach of the Wisła River is found to be well regulated. However, one should consider the fact that the Wisła River has a braided pattern. Such a regular braiding of the main river current should be ascribed, according to our studies, to a similar resistance of the channel banks but not to the regulation of the channel itself. This is just the illustration, how the lack of sufficient information about the morphogenesis and lithogenesis of the river channel and valley, results in unreasonable estimation of the effects of river activity. Hypotheses concerning

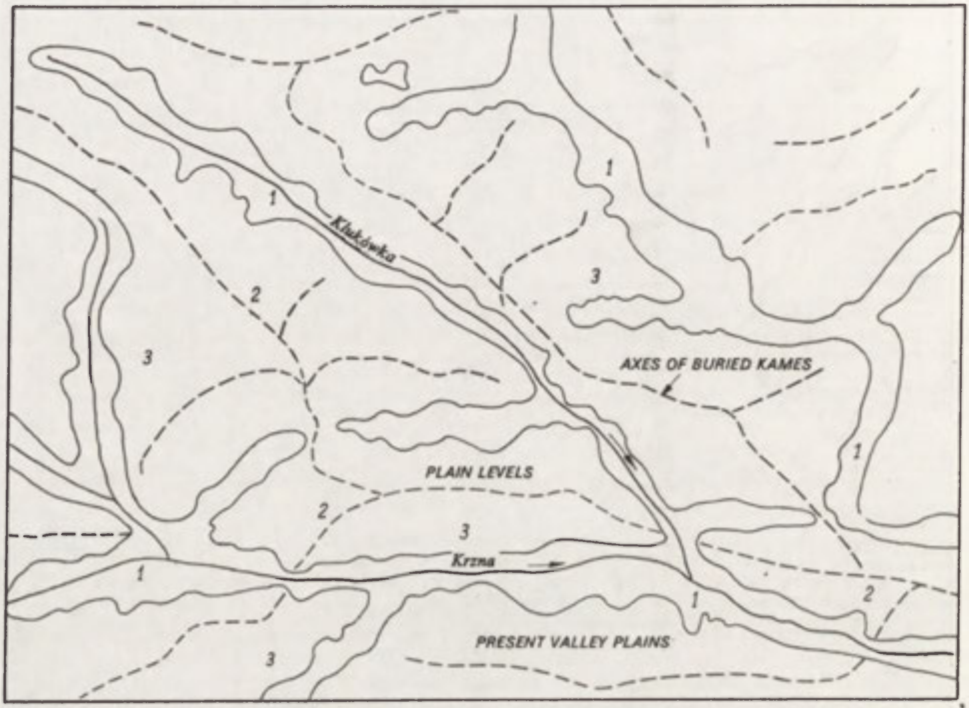


Fig. 15c. Shrinkage of dead ice up to borders of present depressions — valley plains (cf Fig. 15a,b and 16) 1 — outline of present valley plains, 2 — axes of buried kames, 3 — plain levels (outline of initial glaciofluvial pattern)

erosion valleys with numerous fluvial terraces seem to have been overestimated by numerous scientists.

Complex development of fluvial pattern on the present floodplain is presented in Figures 15 a-c and 16.

Detailed geological investigations carried out by the author and his team during 1979–1987 in a drainage basin of the Krzna River (tributary of the Bug River, Vistula catchment) indicated that the valley system is the youngest geomorphological element of this area. We noted here a distinct morphological inversion, expressed by the fact that the highest parts of the valley developed during areal deglaciation of this area. Valleys formed in that time include forms of the kame type and maintain in their fluvial patterns directions of former ice crevasses. Therefore, the present fluvial pattern frequently follows dead-ice depressions. The development of such pattern is illustrated in Figures 15a-c and 16.

A morphogenetic typology of the river valley reaches on the basis of maps, air photos and in the field seems to be very easy if the presented indications will be used. It should be underlined that the classification is open and may be supplemented with progressing investigations of the river valleys.

3. CONCLUSIONS

The results of the investigations carried out for many years by the author with his collaborators from the Institute of Hydrogeology and Engineering Geology, Warsaw University, on the origin and geological structure of numerous river valley reaches and on

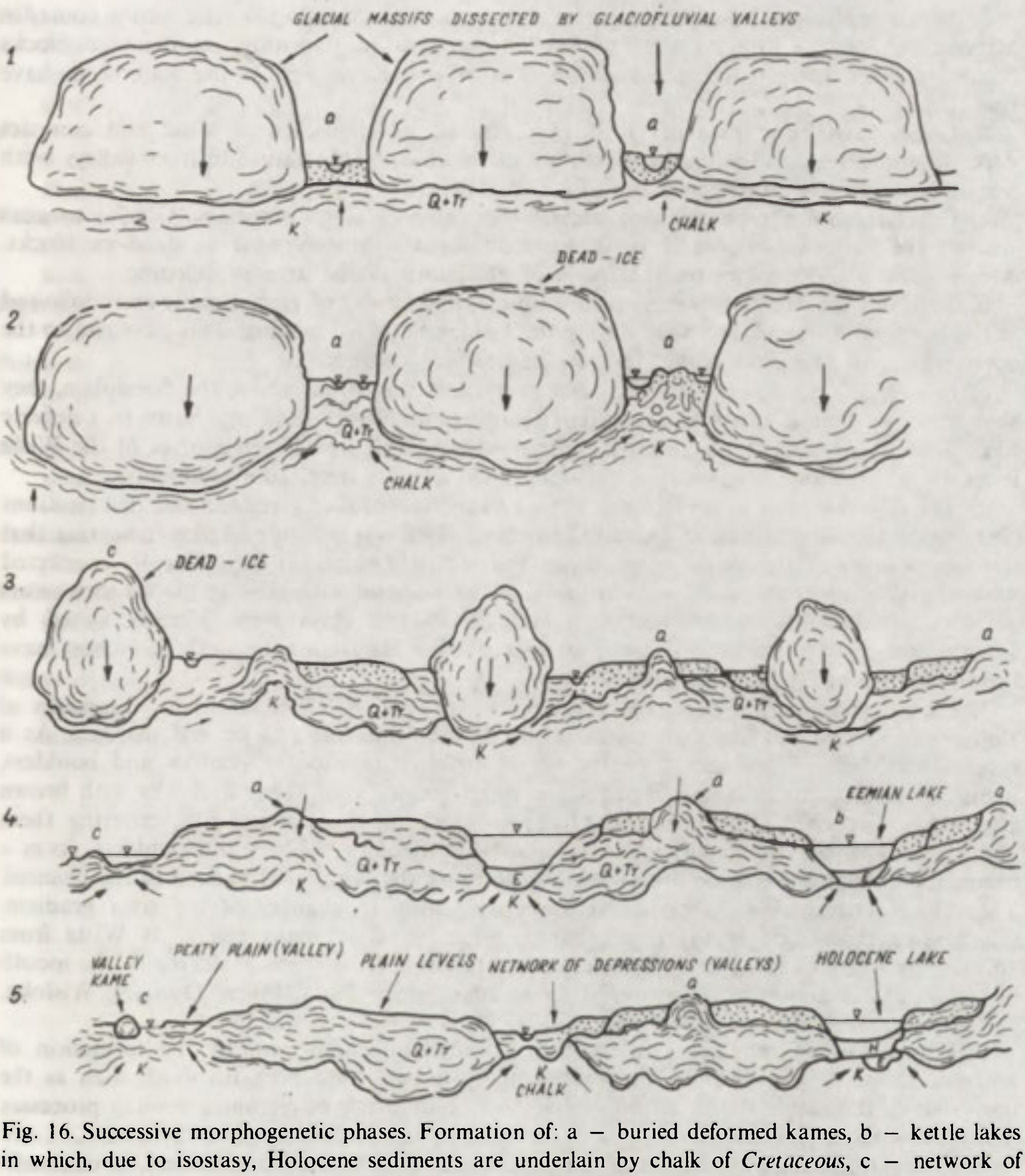


Fig. 16. Successive morphogenetic phases. Formation of: a – buried deformed kames, b – kettle lakes in which, due to isostasy, Holocene sediments are underlain by chalk of *Cretaceous*, c – network of depressions used by peat-filled valleys. Horizontal scale considerably reduced.
K – *Cretaceous* (chalk), Tr – Tertiary, Q – Quaternary, E – Eemian Interglacial, H – Holocene

the changes in horizontal and vertical river channel patterns (Fig. 2), allow to draw the following conclusions:

1. Fluvial erosion, being a process that detaches material from the valley bottom and transports it downstream, is not the most singnificant process in the modelling of the valley morphology.

2. In an area formely glaciated, glacial erosion and dead-ice melting should be considered as the main factor in the modelling of the valleys.

3. When analyzing the development of a river pattern, one should take into account, in agreement with S.Z.Różycki (1958), that during areal deglaciation, as dead-ice blocks became smaller and smaller, the location of river pattern as well as the watersheds have been changing.

4. Common deformations of layers in valley slopes composed of loose and compact deposits and also the lithological variability of the alluvia substratum in river valleys (with frequent outcrops of Tertiary materal) prove that:

a) Glacial erosion predominated amidst the valley-creating processes. Glacial tongues entered the valleys earlier and persisted there for the longest time as dead-ice blocks. A reference to older views on the mode of glaciation of the area is welcome.

b) Valleys were filled with masses of dead-ice, and runoff of glacial meltwaters followed at the borders of the future valley during the last phase of ice melting. This gave rise to the development of numerous kame terraces in dead-ice depressions.

c) In spite of hypsometric concordance of terraces that occur above the floodplain, they should not be bound into a single system denoting runoff from drainage basin in a definite time. This is particularly true for the valley of the middle and lower courses of the Wisła River in which kame terraces are also composed of proglacial lake sediments.

d) The occurrence of kame terraces as well as the presence of glaciotectonic deformations (Parchatka, Chodcza, Józefów, Dębno, Zawichost–Rybitwy) are an evidence indicating that the morphology of the Wisla gorge (from Puławy to Zawichost) is genetically connected with glacial erosion and deposition in proglacial lakes and with flowing glacial meltwaters (kames and lake sediments within a valley). Varved clays were already noted by J.Samsonowicz (1934), whereas traces of activity of a glacial tongue near Zawichost have been reported by W.Pożaryski (1953).

5. Fluvial erosion that corrected the systems of kettle-holes in numerous fragments of Polish rivers, resulted finally in washing out of the sediments rich in fine material. As a result, thresholds of resistant deposits were formed, composed of pebbles and boulders, mainly Scandinavian in origin. Besides, the rivers incised into sands and silts with brown coal (Miocene), clays (Pliocene) and Quaternary lake sediments and tills, covering them afterwards with the lag deposits. Such deposits, particulary pebbles and boulders, form a boundary for bottom erosion and, therefore, stabilize the horizontal pattern of the channel. These local erosion base (thresholds) result frequently in changes of the river gradient. Glaciogenic thresholds in the river channel were noted in many rivers, as Wisla from Józelow to Kezmark, Bug from Drohiczyn to Małkinia, Odra from Malczyce to the mouth of the Warta, Narew from Nowogród to Pułtusk, lower Nida, Pilica, Dunajec, Wisłoka, Wieprz, Krzna, Łyna and many others (Fig. 1).

6. Polygenesis of the river valleys is a common phenomenon. In the formation of different shapes of the river valley reaches many factors have been involved, such as the resistance of tne material, the action of glaciers, the influence of tectonics, aeolian processes (dunes and their influence).

7. Mountain streams of very large gradients (over $5^0/_0$) and all other rivers, in contradistinction to the discussed above river valleys, have a common trend to model a free valley, adequately to their sizes.

8. Studies of river evolution in Poland, carried out in the Institute of Hydrogeology and Engineering Geology, point to the significance of determination of the morphogenetic type of the river valley, either for research or for practical aims.

REFERENCES

Babiński Z., 1979, Wstępna charakterystyka utworów powierzchniowych koryta Wisły poniżej stopnia we Włocławku (Preliminary characterization of Vistula bed superficial formations downstream Włocławek dam), *Gospodarka Wodna* 1, 10–12.

Falkowski E., 1967, *Ewolucja holoceńskiej Wisły na odcinku Zawichost – Solec i inżyniersko-geologiczna prognoza jej dalszego rozwoju* (Evolution of the Holocene Vistula River at a reach Zawichost–Solec and an engineering-geological prognosis of its further development), Biuletyn Instytutu Geologicznego 198, Warszawa.

Falkowski E., 1971, Historia i prognoza rozwoju układu koryta wybranych odcinków rzek nizinnych Polski (History and prognosis for the development of bed configurations of selected sections of Polish lowland rivers), *Biuletyn Geologiczny* 12, 5–121.

Falkowski E., 1986, Engineering-geological teledetectopm for preliminary projects of hydrotechnic constructions, in: *Proceedings Fifth International IAEG Congress, 20–25 October 1986*, A. A. Balkema, Rotterdam/Boston, 1077–1083.

Ingarden R., 1921, *Rzeki i kanały w byłych trzech zaborach* (Rivers and canals in partitioned Poland), Warszawa.

Pożaryski W., 1953, *Plejstocen w przełomie Wisły przez Wyżyny Południowe* (The Pleistocene in the gorge of Vistula River across the Polish South Uplands), Prace Instytutu Geologicznego 9, Warszawa.

Różycki S. Z., 1958, Próba odtworzenia procesu formowania się rzeźby polodowcowej. Eksperyment geomorfologiczny (An experiment in geomorphology reconstructing the formation glacial relief), *Acta Geologica Polonica* 8, 1, 1–116.

Samsonowicz J., 1934, *Objaśnienia arkusza Opatów ogólnej mapy geologicznej Polski w skali 1:100000* (The explain to the geological map of Opatów sheet, 1:100 000 scale), PIG, Warszawa.

Szumański A., Postglacjalna ewolucja i mechanizm transformacji dna doliny Dolnego Sanu (Late glacial evolution and mechanism of transformation of a floor of a Lower San Valley), *Kwartalnik Akademii Górniczo-Hutniczej, Geologia* 12, 1.

Wiśniewski E., 1976, *Rozwój geomorfologiczny doliny Wisły pomiędzy Kotliną Płocką a Kotliną Toruńską* (Geomorphological devlopment of the Vistula Valley between the Płock Basin and the Toruń Basin), Prace Geograficzne IGiPZ PAN 119, Warszawa.

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PROBLEMS OF LANDSCAPE EVALUATION: A TEST OF A CONVENTIONAL TECHNIQUE IN THE OBERTAUERN AREA, AUSTRIAN ALPS

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INTRODUCTION

Recent decades have shown a growing interest in and awareness of the natural environment. There is concern about mounting economic pressures on the environment and over problems of pollution; it is also evident that recreational demands on the environment are increasing because people have more leisure time and easier access to the countryside. One particular type of landscape that is coming under greater pressure from tourism is the high-mountain or "alpine" environment, with the influxes of summer visitors, hikers and mountaineers, and with the enormous growth of the winter sports industry with all its associated problems of pollution, soil erosion and the visual intrusiveness of pylons, cableways, buildings and access roads.

In attempts to grapple with the problems created by greater demands from tourists and developers on the one hand, and the needs of conservation on the other, regional planners need to be able to identify areas under threat, including those subject to the most severe pressure and those where the landscape is particularly sensitive. The development of Notional Parks and Nature Reserves has been one way in which a measure of control may be exercised on the exploitaion of the landscape. Such Parks and other zones designated for nature conservation aim not only to provide access for visitors but also to protect the landscape, its flora and fauna. Another function is educational – to instruct the visitor about geology, the landforms, the vegetation and the wildlife, and to foster a sense of the need for conservation. But first it is necessary for the planners to make decisions about the selection and location of areas for Parks and their extent. In the case of Parks planned chiefly for tourism and recreation, what criteria should govern the choice of area? One important consideration is clearly the scenic quality and variety present in the landscape, and it is here that the geographer can make an important contribution. In a recent book, Appleton (1975) notes that "it has become, in many areas, a matter of urgent necessity, for planning purposes, to be able to indentify aesthetically satisfying landscapes". Scenic beauty or attractiveness is, however, in the eye of the beholder – it is not something that can immediately and simply be measured directly, though many have tried to do so. Landscape is something much more than the physical surface of the Earth; it involves not only the cultural imprint of Man but also the mental processes by which man sees and appreciates the landscape. Whereas the physical features of a landscape may be objectively described or measured using scientific techniques, its aesthetic qualities are much more difficult to evaluate since their appreciation depends on psychological processes collectively termed "perception". Because people differ widely in how they perceive landscape (because of upbringing, past experience, psychological outlook and so on), assessment of landscape quality involves far more than analysis of its physical components. We all know of landscapes that we instinctively like or dislike, yet our likes and dislikes will probably be very different from those of our neighbour; at the same time, we may find it wery difficult to give reasons for our preferences.

The history of scientific landscape evaluation is relatively short. One of the first geographers to embark on the scientific study of scenery was Vaughan Cornish in the 1930s (1930, 1934; see also Goudie 1972) who played an important part in developing early ideas of National Parks. He also argued that lowland scenery needed special care and conservation since it is more easily spoilt, visually, compared with the bolder highland scenery. Research in the next two to three decades was sporadic and tended to concentrate on attempts to base landscape evaluation on measurable landscape features. An example of this type of approach is that of Linton (1968). Linton claimed that scenic quality is the product of two features, landform and land use. He assigned scores to components of these two features on the basis of their supposed degree of scenic value. Landforms, for instance, were divided into six main types and scores arbitrarily allotted as follows:

Lowlands	+0
Low uplands	+2
Plateau uplands	+3
Hill country	+5
Bold hills	+6
Mountains	+8

Many criticisms may be levelled at this sort of approach. It assumes that landscape can be disaggregated into sets of components, and ignores possible interactions among these components. The choice of components and the scores allotted is arbitrary and dependent on personal judgement; why, for example, should mountains be rated more than twice as highly as plateau uplands? And are lowlands necessarily devoid of scenic beauty?

The 1960s and 1970s saw many other studies in which landscape was treated as an object which could be dissected and measured so as to be able to place a value on its scenic quality. The attractions of the method are clear: the measurements can usually be made from existing maps or documents, saving laborious field survey, and the results are susceptible to statistical analysis yielding definite answers. Unfortunately, the answers may be totally spurious, as Dearden (1980) notes!

One of the more ambitious attempts to calculate such indices of scenic quality is the subject of this paper. It is the method devised by Farcher (1971) which itself is largely based on an earlier attempt by Kiemstedt (1967), who developed the *Vielfältigkeitswert* index. This, however, was designed for use in areas of to moderate relief; Farcher's adaptation allows an index to be calculated for high mountain areas and is therefore adopted in this present study for a test area in the Austrian Alps, around Obertauern.

FARCHER'S INDEX OF LANDSCAPE VARIETY: THE *MANNIGFALTIGKEITSWERT*

The units of calculation are kilometre grid-squares in each of which four basic landscape components are measured: land-use, "edges" (i.e. the lengths of the borders of woodland or water areas), slopes and height.

(1) Land-use: in each grid square, the percentage area of each land use is measured. Each land use is subjectively weighted and a total land-use index is obtained by summing the results. The weighting proposed by Farcher had to be modified slightly for use in the Obertauern area because, for example, of local differences in vegetation and the need to include scree and debris slopes which were not considered by Farcher. Farcher used a

weighting of 12 for the land-use category "swamps", which, mainly useless to man and difficult to cross on foot, are not dissimilar to scree slopes in terms of land use. This relatively low weighting was therefore adopted for scree and debris slopes. The following list shows all the weightings adopted:

Lakes: % area weighted by a factor of	30
Bare rock:	22
Alpine meadow:	19
Forest:	17
Alder and pine scrub:	13
Scree and rock debris slopes:	12
Built-up areas and buildings are excluded.	

(2) Edges: (a) Water features. For lakes, the perimeter is measured; for rivers and streams, the total length of one bank (not both) in the grid square is measured. The total length of water edge is then divided into units of 125 m, and the number of units is weighted as follows:

Streams: by a factor of	31
River > 5 m wide:	63
Lakes:	78

Farcher further applies a reduction factor if the total length of water edge in any one grid square exceeds 1 km; this is found to be necessary because, otherwise, the water edge begins to dominate the scenic evaluation:

$$L_r = L_g^{-1 \cdot 3}$$

where L_r is the reduced length and L_g the measured length.

(b) Woodland edges. Farcher ignores woodland edges above the level of human habitation, arguing that they are here not sharply defined, in contrast to areas lower down where they are mainly man-made, abrupt, and therefore have a greater scenic effect. Although this contention may be questioned, it was decided to follow Farcher's ruling for the Obertauren study, and woodland edges were omitted from consideration because the whole area lies above the normal limits of permanent human habitation.

(3) Slopes: Farcher calculates the "mean maximum slope" for each grid square. In the part of each grid square that possesses the strongest relief, a straight line 1 km long is drawn orthogonal to the contours. Along this line, the height intervals between all crossing contours are summed, and the total height so obtained is expressed as a percentage of the 1 km length. This percentage represents a gradient which is then converted to give the mean maximum slope (M):

$$M = 45 \sqrt{\text{gradient } \%}$$

(4) Height: A height index (H) is calculated for each grid square as follows:

$$H = (Hn/10)^{1.5} \div 5$$

where Hn is the sum of the absolute heights of the lowest and highest points. The aim in introducing a measure of absolute altitude into the landscape assessment is to bring in elements of climate, vegetation and the "wildscape" (wilderness landscape), as well as the effects on scenic quality of the presence or absence of high ridges, summits, etc.

The four indices are then added and divided by 1000 to give a final score for each grid square. It will be noted that geomorphology (including relief and hydrology) makes a fundamental contribution to several of these components — in certain forms of land use (areas of scree and debris slopes, etc.), water features, slope and height.

FARCHER'S METHOD APPLIED TO THE OBERTAUERN AREA

The Obertauern area lies in the province of Salzburg, astride the main central ridge of the Alps. It was chosen for reasons mentioned at the beginning of the paper: it is an example of an alpine area that has been coming under increasing pressure from tourism, particularly winter sports activity. The relief is shown in the contour map (Fig 1). The rectangle includes 132 kilometre-grid squares for which the Farcher scores are grouped into seven categories (Fig. 2). The mean score is 4.08 (standard deviation 0.342); the maximum and minimum values are 5.222 and 3.271 respectively.

The resulting pattern is clearly not a random one. Distinct areas of above-average, average and below-average scores are apparent.

1) Above-average values occur mainly in the north-east and east, characterising the Seekarspitze area and extending north-east towards the Oberhüttensattel and south-east along the Gurpitscheckkamm. These areas broadly correspond to the Radstadter quartzite and quartz-phyllite series. Particularly high values are to be found in the area of small lakes

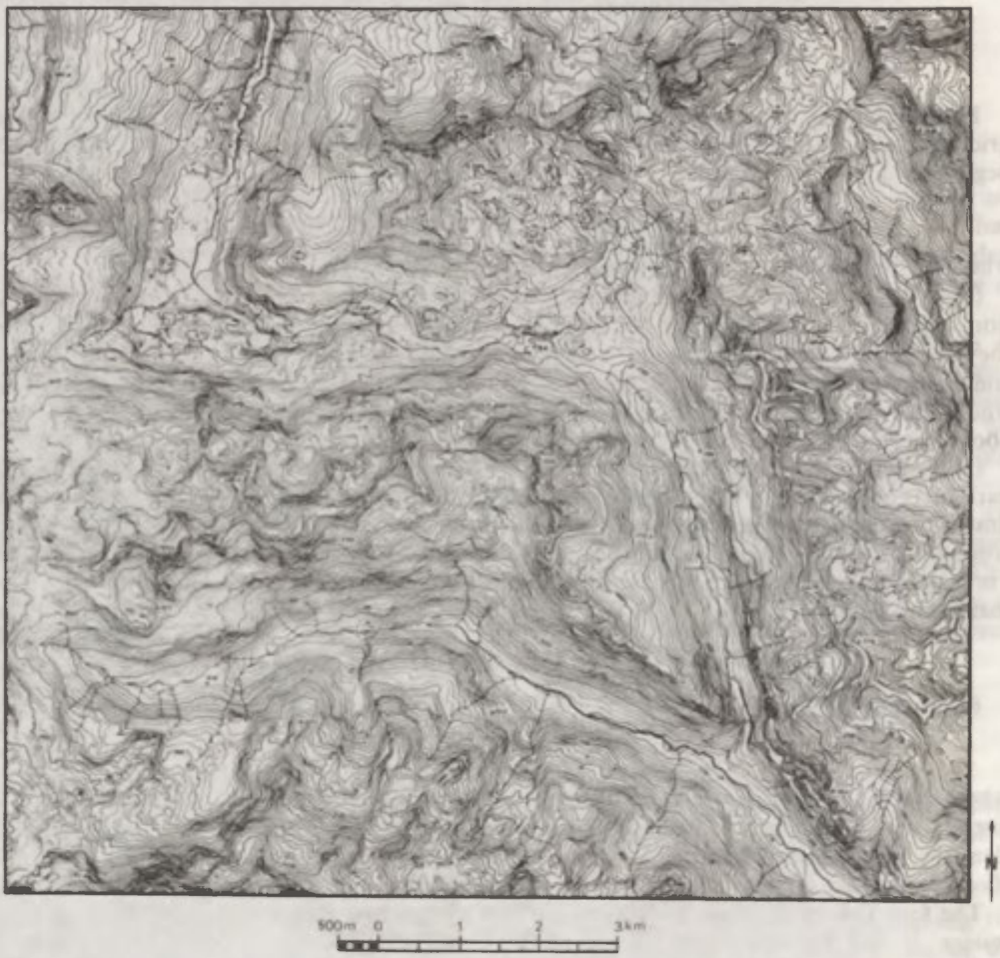

Fig. 1. The relief of the Obertauern area, Austria. (For placenames, see Fig. 2)

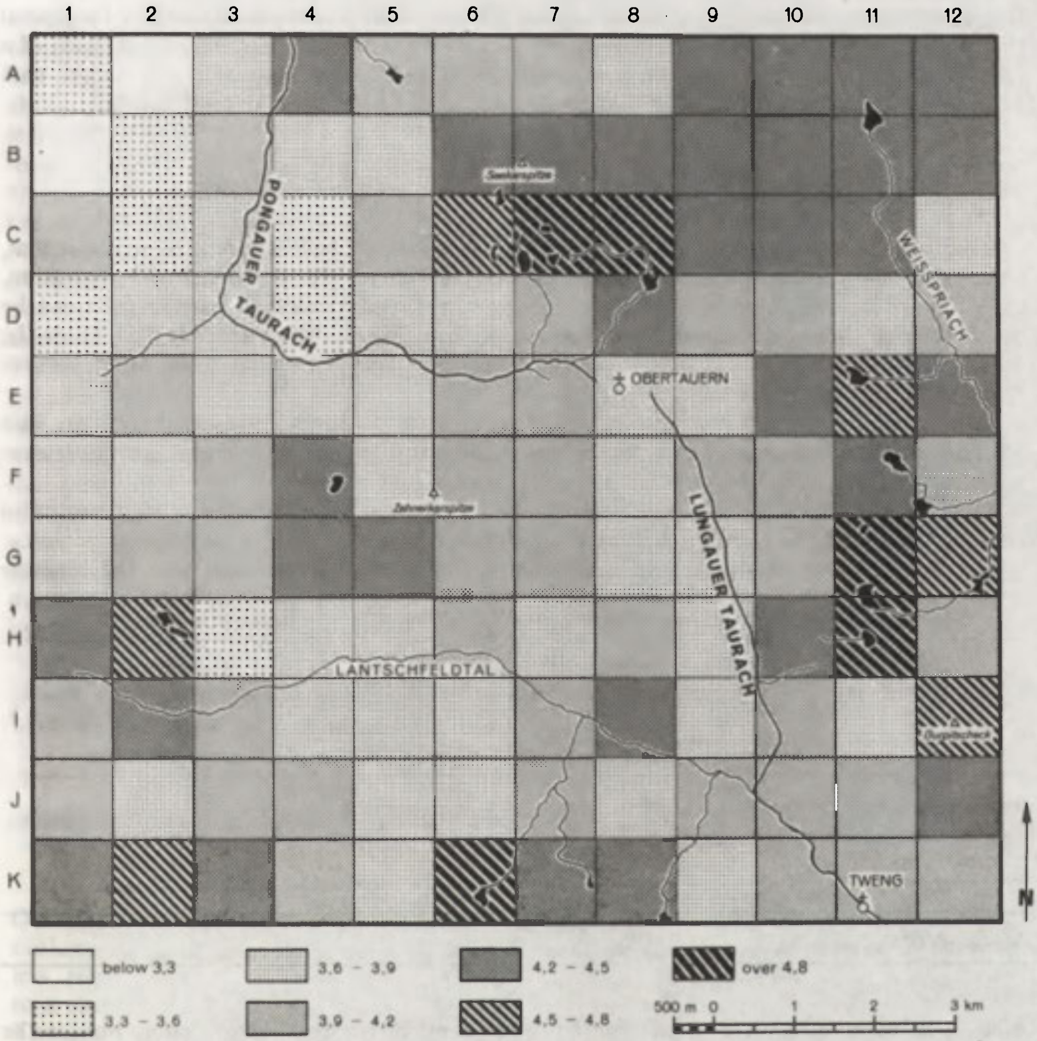

Fig. 2. Assessment of landscape quality in the area of Fig. 1, using D. Farcher's (1971) method. The scores are grouped into seven categories; the darker shadings indicate areas of supposed higher scenic quality

and coalescing cirque floors forming a shelf south of the Seekarspitze. Along the Gurpischeckkamm, the highest values lie east of the ridge and are related to the presence of a series of small cirque lakes. There are also some high values in a separate area along the south-east margin of the map, marking the Hochfeindzug ridge.

2) Average values are, in contrast, mainly associated with areas underlain by Triassic sediments (especially limestone) in the Pleißling mountain group. A small area corresponding to the highest ground on the Triassic limestone has scores slightly above average, whereas the margins of the outcrop, falling into the Taurach valleys and the Lantschfeldtal, have scores slightly below average.

3) Below-average values are to be found largely in the north-west of the map, represen-

ting the north-south section of the Pongauer Taurach valley and its side-slopes. In general this is the lowest part of the whole area. Its lack of attractiveness is a function mainly of a lack of distinctive relief features and a general forest cover; however, the factor that produces the low total scores in Farcher's method is simply low overall height.

EVALUATION OF FARCHER'S METHOD FOR THE OBERTAUERN AREA

How successful is this method of landscape assessment? The first point to make is that, although the Obertauern landscape shows quite marked contrasts in relief and vegetation, the range of values given in the Farcher scores is relatively small. In particular, it can be noted that the seven categories used on Fig. 2 each span a range of only 0.3. Secondly, there are two features of the landscape which strongly affect the scores, while other features make little difference, namely

a) lakes and rivers (marked in black on Fig. 2) — high values correspond to areas with abundant water features (mainly the relatively impermeable quartzites and phyllites: contrast the lower scores of the drier limestone areas; and

b) absolute height — the high watersheds, peaks and ridges produce high scores in contrast with the low-lying valley floors and lower slopes.

Table 1 helps to analyse these relationships further. It will be seen that the *land-use*

TABLE 1. Analysis of Farcher scores (x 1000) for the Obertauern area

Component	Mean scores of each component and their contribution (%) to the total mean score	Standard deviation	Percent of cases in which the score departs by more than 150 from the mean
Land use	1745 = 43	105	14
Edges	283 = 7	298	64
Slopes	985 = 24	141	29
Height	1035 = 26	187	45
Mean score	4048		

component accounts for the greater part (43 per cent) of the total mean value, but, at the same time, this component shows the smallest range of variation across all grid squares. Taking the individual elements that make up land use overall, "alder and pine scrub" is the only one that gives marked negative deviations; "areas of bare rock" provide the only positive deviations. These two elements are, in fact, the only ones that are capable of effecting any significant change in the land-use scores. "Lakes" have the highest weighting of any element (x 30). but unfortunately in the Obertauern area they are all small in size and therefore have only a minor effect on the total land-use scores. Another effect which tends to give a "grey" result rather than a clear "black-and-white"differentiation of land use across the map, is Farcher's omission of built-up areas. In theory this has the effect of lowering the scores for each grid-square where settlement exists and therefore detracting from the scenic value; in practice, built-up areas are too restricted to have any significant effect.

To improve on Farcher's method in terms of land-use differentiation, it is necessary to introduce a much more differentiated weighting system. In particular, the low weighting (x 12) given to areas of scree and debris may be questioned; many might consider, for example, that this component is not wholly adverse to scenic quality but actually adds special interest on its own account so long as it is not too extensive.

Edges contribute little (7%) to the total but are responsible for the greatest degree of differentiation (64%). The actual value for this component can be as low as zero for limestone areas lacking in drainage (and remember that woodland edges are not counted above the limits of settlement), but can rise to 700 or 800 in other areas rich in water features. There are therefore strong areal differences which have a pronounced effect on the total scores. It can be argued that the importance of edges in Farcher's scheme is over-emphasised, and that, despite the inclusion of a reduction factor for lengths greater than 1 km, this does not provide sufficient compensation.

Slope accounts for about one-quarter of the total score; at the same time it has a range of variation of about the same amount (29%). Of the four components of landscape, this one appears to be relatively well-balanced in its ability to help in the differentiation of scenic quality.

Height is a much more problematic component. As already noted, height is mainly responsible for the low total scores in the north-west corner of the map, an area which, coincidentally, is rather unattractive scenically. On the other hand, the Pleisslinggruppe would have scored much worse if the height component had not largely offset low scores in this limestone area from the general lack of "edges". The effects of the presence or absence of high ridges and summits (which undoubtedly needs somehow to be taken into account in scenic evaluation) are certainly incorporated by Farcher, but it is also the case that low-lying valley-floors and middle slopes are too under-valued. It is a mistake to attach so much importance to absolute altitude, and it leads to the absurd conclusion that, of two hypothetical identical landscapes lying at different elevations, the higher-altitude landscape is superior in quality to the lower one. The effects of the presence or absence of high ridges and summits in the scenery needs to be expressed in some way other than that devised by Farcher.

CONCLUSION

It is shown that Farcher's method of evaluating scenic quality is not successful in the Obertauern area. Farcher's technique is typical of the traditional methods of landscape evaluation commonly used in regional planning. These methods are all based on the more-or-less arbitrary selection and measurement of certain physical variables which, according to a chosen algorithm, are weighted and combined to give a set of scores for scenic quality. The problem is that the choice of variables, their relative weighting and their statistical manipulation are subjective, because of the lack of theory behind these methods. The results obtained are therefore highly questionable.

Elsewhere, the author has demonstrated (Hamann 1987) that the use of questionnaire techniques (both in the field and using photographic images) can provide a far superior method of landscape evaluation, especially because they are able to take account of people's preferences and perceptions of landscape. On the other hand, questionnaire techniques are costly and time-consuming to carry out, and for the needs of regional planning are therefore generally impracticable. Landscape evaluation in regional planning has in the end to fall back on a landscape-based approach, but the form of analysis adopted has to be chosen with extreme care if it is not to yield erroneous results.

An essential first step is to identify the visually important landscape elements — those which contribute fundamentally to the visual quality of a landscape — and to do this, a theoretical framework is necessary. This in turn must be based on perception theory. It is commonly agreed that the aim of perception is to gain new and/or more information; therefore, to consider a landscape in terms of the information that it provides is likely to assist in discovering what exactly underlies people's preferences. In this context, indentification of the important geomorphological elements in the landscape (Hamann 1988) has proved to be helpful.

There has been a great deal of recent research on information theory and on how it may be applied in the field of landscape evaluation (see, for example, Dearden 1977, 1980; Elsner and Smardon 1979; Eringis and Budriunas 1972; Geyer 1972; Jacobs 1975; Loidl 1981; Nohl 1980; Penning–Rowsell 1973, 1975), but it has not yet yielded any practicable method. The way forward seems likely to lie in a combination of further research in this field with analysis of, and experimentation with, traditional techniques. In this way, the cornerstone of new solution to the problem of landscape evaluation may be found.

REFERENCES

Appleton J., 1975, *The experience of landscape*, Wiley, London.

Cornish V., 1930, *National Parks and the heritage of scenery*, Sifton Praed, London.

Cornish V., 1934, The scenic amenity of Great Britain, *Geography* 19, 192–202.

Dearden P., 1977, Landscape aesthetics. An annotated bibliography. Monticello, III: Council of Planning Librarians, Exchange Bibliography 1220.

Dearden P., 1980, Landscape assessment: the last decade, *Canadian Geographer* 24, 316–25.

Elsner G.H. and Smardon R.C., Eds., 1979, Our national Landscape. Proceedings of a Conference on Applied Techniques for Analysis and Management of the Visual Resource, 23–25 April 1979, Incline Village, Nevada. (General Technical Report PSW–35, US Dept. of Agriculture, Pacific South-West Forest and Range Experimental Station).

Eringis K., and Budriunas A.R., 1972, Zur strukturell-ästhetischen Bewertung der Landschaften, *Archiv für Naturschutz und Landschaftsforschung* (*Berlin*), 12, 4, 315–24.

Farcher D., 1971, Landschaftsbewertung in Tiefenlagen und im Hochgebirge, *Das Gartenamt* 6, 260–71.

Geyer M., 1972, Eine Methode zur Bewertung der Landschaft als Informationsgegenstand, *Landschafts-architektur* (*Berlin: VEB Deutscher Landwirtschaftsverlag*), 2, 57–8.

Goudie A., 1972, Vaughan Cornish: geographer, *Transactions of the Institute of British Geographers* 55, 1–16.

Hamann C., 1987, Analyse des Landschaftsbildes von Obertauern, *Arbeitsbericht zum Projekt MAB 6–20-Karst-Wald-Obertauern.*

Hamann C., 1988, Geomorphologische Karten zur Beurteilung der optischen Qualität von Landschaften, *Zeitschrift für Geomorphologie* N.F., Supplementband 68, 125–42.

Jacobs P., 1975, The landscape image. Current approaches to the visual analysis of the landscape, *Town Planning Review* 46, 2, 127–50.

Kiemstedt H., 1967, *Zur Bewertung der Landschaft fur die Erholung* (Stuttgart).

Linton D.L., 1968, The assessment of scenery as a natural resource, *Scottish Geographical Magazine* 84, 219–38.

Loidl H.J., 1981, Landschaftsbildanalyse – Ästhetik in der Landschaftsgestaltung? *Landschaft und Stadt* 13, 1, 7–19.

Nohl W., 1980, Ermittlung der Gestalt- und Erlebnisqualität, in: K. Buchwald and W. Engelhardt eds, *Handbuch für Planung. Gestaltung und Schutz der Umwelt* (München, Wien, Zürich): BLV, vol. 3: Die Bewertung und Planung der Umwelt, 212–30.

Penning–Rowsell E. C., 1973, Alternative approaches to landscape appraisal and evaluation. *Middlesex Polytechnic Planning Research Group Report* No. 11 (Enfield, England).

Penning–Rowsell E. C., 1975, Alternative approaches to landscape appraisal and evaluation. *Middlesex Polytechnic Planning Research Group Report* No. 11, supplement.

THE IMPACT OF LANDSLIDES ON FLUVIAL PROCESSES IN THE LISH BASIN OF THE DARJEELING HIMALAYAS

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INTRODUCTION

The river Lish originating from Lalegaon (26°59'N and 88°33'E) at an altitude of 1 820 m traverses a distance of about 21.02 km to join the mighty river Tista at Shaugaon (26 49'N and 88°33'E). On the way, it receives at least 75 tributaries and the important among them are the Chun-Khola, the Phang-Khola, the Lish-Nadi, the Turung-Khola and the Rato-Khola. The total catchment of the river Lish is about 70 km^2.

Records since 1929 (Fig. 1 and Table 1) show a sharp acceleration in the rate of devastating slide occurrences (Total number of 135 covering an area of 1.5 km^2 which is about 2.15% of the total area of the Basin) along with lesser slips leading to great loss of life and heavy damage to land and property. The situation has deteriorated further in recent times, the last two decades having witnessed the worst landslides on hill-slopes (Total number 64 covering an area of 4.52 km^2, which is about 6.47% of the total area of the Basin).

Historically speaking, sliding was a minor physical phenomenon, a hundred and fifty years ago when the population on these hills was thin and the balance of nature was well held. But, thereafter, with the gradual establishment of a stable government, and with the increase of prosperity brought in by the people from the plains, the population increased by leaps and bounds with the consequent increase of pressure on land. A scramble resulted and in their anxiety to grab as much land as possible and as fast as possible, quite a large number of people and particularly those with some local influence, took possession of extensive areas including areas under forest cover. To offset such moves, the constitution of state reserve forests started in Darjeeling district then called British Sikkim – in the year 1866 (Banerjee 1980). The early development of the Darjeeling hills not having followed a plan drawn up in advance, the *status quo* had to be accepted when reservation started and the consequent position today is practically no forests exist on 63% of the total area of the Basin. Such deforested slopes, composed mainly of semi-crushed phyllites of Daling series, are quite susceptible to weathering. Selective weathering proceeding along the mica-rich bands disturbs the cohesiveness of the Daling rocks which thus become brittle. During monsoon, as soon as the moisture laden clouds are intercepted by the Nazzcokh-Samthar ridge bordering the NW part of area under study, most of the moisture is precipitated in the form of rain (average monsoonal rainfall 2994 mm). Slopes that were otherwise stable for moderate run-off become vulnerable and give rise to soil-erosion and soil-slides as soon as the shearing stress on the material beneath the slope becomes equal to shearing resistance.

Most of these slides have never been treated scientifically with proper protective measures and as such these are in the habit of expanding their territories during monsoon, adding more and more silts to the parent river, the Lish which is incapable of transporting

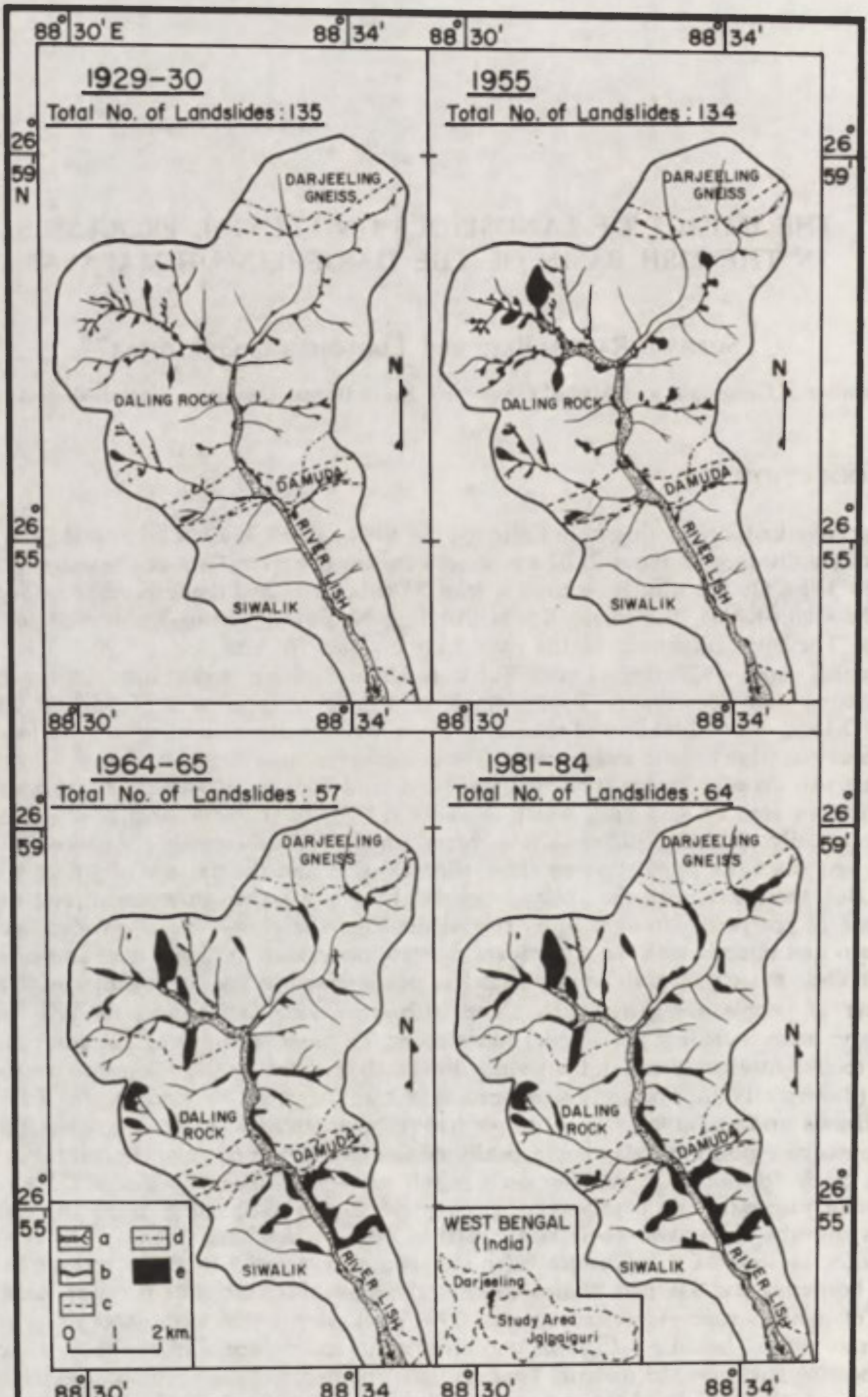

Fig. 1. Landslides of the Lish Basin: a – river with sediments, b – watershed boundary, c – geological boundary, d – forest boundary, e – landslides

TABLE 1. Areas and percentage of various geological formations together with landslides and land use of the Lish Basin in different years

Sl. No.	Gology	Total area (km^2)	Total area (%)	Total slided area in km^2 (No. of slides)	Total area (%)	Area under forest cover (km^2)	Total area (%)	Area under agri- culture settlements (km^2)	Total area (%)
				1929 – 1930					
1	Alluvium	17.91	25.59	–	–	1.23	6.86	7.00	39.08
2	Siwalik	12.44	17.77	0.0372(8)	0.30	12.35	99.27	–	–
3	Damuda	3.15	4.50	0.1212(10)	3.85	2.00	63.49	0.1203	3.82
4	Daling	31.52	45.03	1.3302(115)	4.22	12.36	39.21	4.4035	13.97
5	Darjeeling Gneiss	4.98	7.11	0.0153(2)	0.31	3.61	72.48	0.2020	4.05
6	Total	70.00	100.00	1.5039(135)	2.15	31.55	45.07	11.7258	16.75
				1955					
1	Alluvium	17.91	25.59	–	–	0.91	5.08	9.37	52.31
2	Siwalik	12.44	17.77	0.0487(8)	0.39	12.30	98.87	–	–
3	Damuda	3.15	4.50	0.1296(9)	4.11	1.57	49.84	0.1501	4.76
4	Daling	31.52	45.03	1.7107(115)	4.53	11.00	34.89	7.9315	25.16
5	Darjeeling Gneiss	4.98	7.11	0.0162(20)	0.33	3.25	65.26	0.2276	4.57
6	Total	70.00	100.00	1.9052(134)	2.72	29.03	41.47	17.6792	25.25
				1964 – 1965					
1	Alluvium	17.91	25.59	–	–	0.88	4.91	10.56	58.96
2	Siwalik	12.44	17.77	1.1400(10)	9.16	12.20	98.07	–	–
3	Damuda	3.15	4.50	0.1346(4)	4.27	1.27	40.31	0.1802	5.72
4	Daling	31.52	45.03	2.5623(41)	8.13	10.63	33.72	11.9230	37.82
5	Darjeeling Gneiss	4.98	7.11	0.0170(2)	0.34	3.13	62.85	0.2532	5.08
6	Total	70.00	100.00	3.8539(57)	5.50	28.11	40.15	22.9164	32.73
				1981 – 1984					
1	Alluvium	17.91	25.59	–	–	0.81	4.52	12.32	68.78
2	Siwalik	12.44	17.77	1.4123(16)	11.35	11.78	94.69	0.32	2.57
3	Damuda	3.15	4.50	0.1431(4)	4.54	1.13	35.87	0.1950	6.19
4	Daling	31.52	45.03	2.9530(41)	9.37	9.86	31.28	13.6741	43.38
5	Darjeeling Gneiss	4.98	7.11	0.0182(3)	0.37	3.00	60.24	0.2788	5.59
6	Total	70.00	100.00	4.5266(64)	6.47	26.58	37.97	26.7879	38.26

(Data collected from field works and various other sources have been processed and compiled in the above form by the authors).

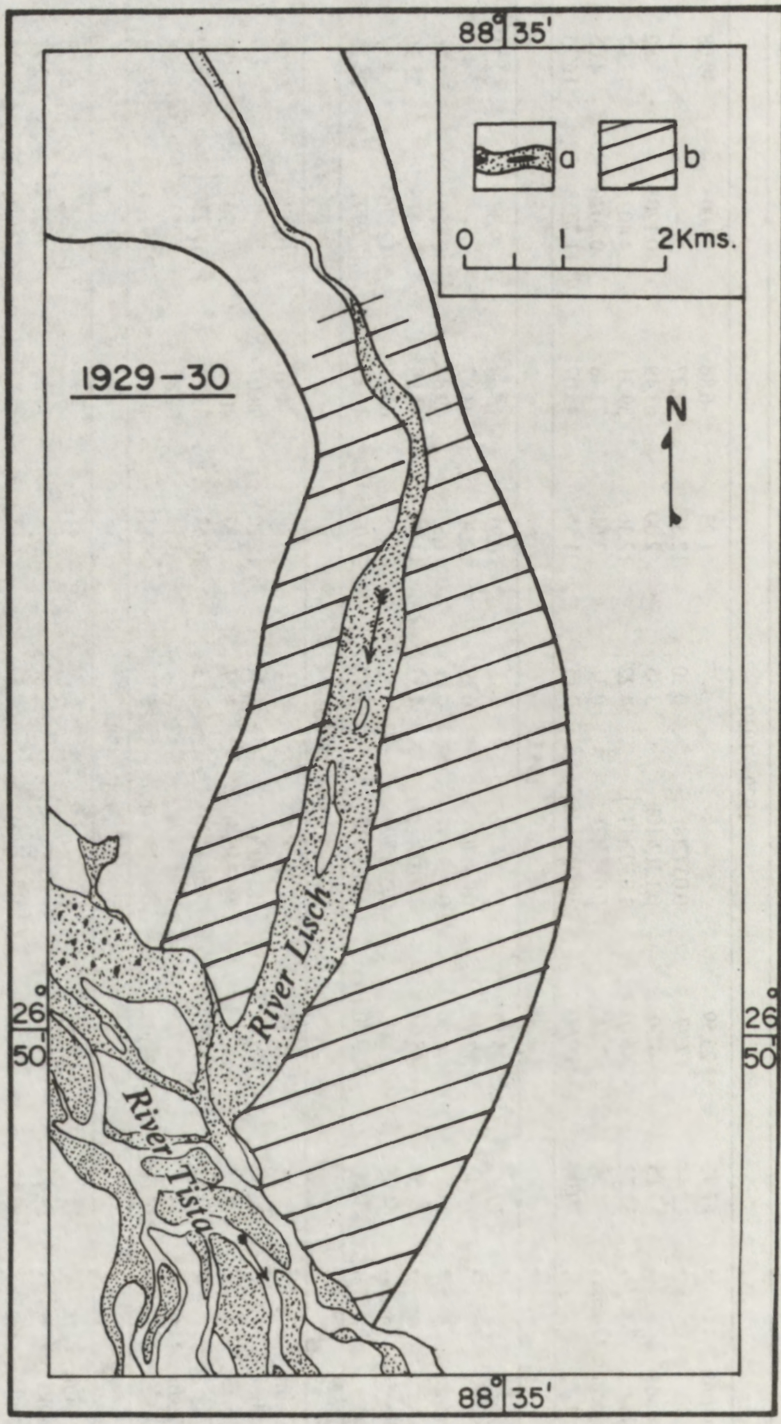

Fig. 2A. Lower course of the Lish River, 1929–1930: a – river with sediments, b – area under floods

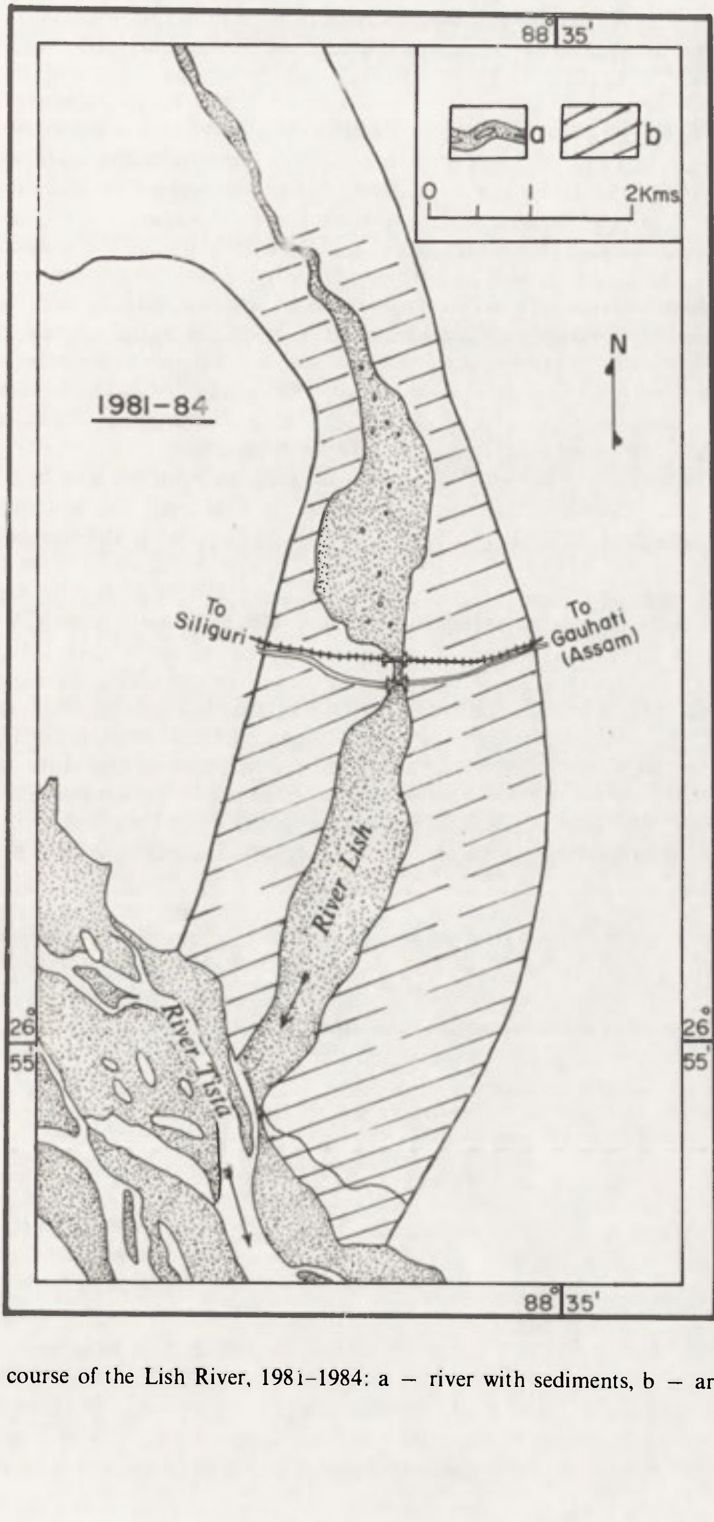

Fig. 2B. Lower course of the Lish River, 1981–1984: a – river with sediments, b – area under floods the bed-loads efficiently under existing hydrological conditions, especially in its lower reaches. During summer, the observed increment of the size of bars and shoals downstream to Bagrakot (26 53′N and 88 34′E) proves such contention (Fig. 2A and B). In order to avoid such numerous islands in midst of the channel, the river, in its lower reaches, thus attains the significant physical characteristic of braiding and this has better be attributed to both incompetency and incapacity of the river. That is, the stream can transport neither the total amount of debris (approx. 100 million m^3) nor the size of debris that is supplied to it as bed-load. As a result, the bed of the river is rising at some sections resulting in the lessening of cross-sectional areas which being incapable of arresting the unusual monsoonal discharges, allow the water to spill causing floods (Dutta 1955). Moreover, the narrow road and railway-bridges spanning this river at the foot of the hills as well as the pillars supporting these, are always considered to be barriers interrupting the natural load-movement behaviour of the stream causing more and more deposition at the bottom of the bridges and thereby narrowing the outlets of the river gradually. Such deposits (sometimes more due to the entanglement of uprooted trees) to the voluminous flows of flood often multiply its effects manifold damaging the bridges themselves.

During the devastating flood of 1968, the Lish road and rail bridges had been washed away by the swirling flood-water which also partially destroyed the settlements and tea-gardens of Bagrakot and Washabari (26 52′N and 88 33′E). During 1954, about 1.98 million m^3 of materials came hurtling down the slope from the Yangnakun slide (26 56′N and 88 31′E) to form about a 14 m high natural-dam across the river Lish. The mighty pressure created by the water-charged debris loosened from the Pabringtar slide (26°57′20″N and 88 31′30″E), might have burst it open on a later date. The release of such a huge volume of water charged with sediments, caused devastating floods in the plains damaging two spans of the Lish road-bridge while the arches of the bridge had almost been filled up with debris. The spans had ultimately been dismantled and replaced by a new bridge (Dutta 1955).

Thus, it can be well concluded that the natural equilibrium of the slope of hills of the Lish Basin has been so seriously disturbed that during heavy rains innumerable landslides are caused transporting huge amount of sediments to the river Lish, not only reducing the channel but also causing devastating floods and thereby endangering the fate of the local inhabitants.

Being alive to such a commanding role of the river Lish in regulating the overall economy of the area of study, the authors have outlined some of the interesting results of their investigations on the physical and hydraulic characteristics of the lower course (approx. below 200 m) of the river Lish. The ultimate aim is to depict the sequential changes in the lower course of the river Lish in combating with the increasing loads supplied from numerous landslides situated in the upper course of the river.

PROGRESSIVE CHANGES IN THE CROSS-SECTIONAL AREAS

To study the progressive changes in the cross-sectional areas of the river Lish in recent years, the cross-sections drawn twice (during rains and winter) during each of the years from 1981 to 1984, have been consulted. From these two sets of cross-sections, cross-sectional areas have been worked out subsequently for these years and tabulated (Table 2) and mapped (Fig. 3) for comparison.

The following conclusions can be made about the changes in cross-sectional areas:

(i) From the changes in the cross-sectional areas between any two consecutive years, it would be evident that the process of scouring and silting usually alternate not only at a particular section point, but also from station to station, as we proceed downstream from the foot-hill, resulting in the formations of pools and riffles along the long-profiles of the rivers under study.

TABELA 2. Cross-sectional area (in m²) of the river Lish in the rainy and winter seasons during 1981 – 1984

Stations	Distance from the source (in km)	1981	1982	1983	1984	Range of variation
Lish (Rainy)						
A – A′	20.27	1023.75	495.00	1050.31	520.30	555.31
B – B′	19.17	908.00	720.00	972.42	680.21	292.21
C – C′	15.17	972.15	318.99	798.99	578.79	653.16
D – D′	14.63	820.25	288.61	680.51	432.11	531.64
E – E′	14.23	416.20	276.46	488.09	407.09	211.63
F – F′	13.83	513.41	294.68	467.85	382.85	218.73
G – G′	13.43	431.39	297.72	425.32	374.52	133.67
Lish (Winter)						
A – A′	–	–	–	–	–	–
B – B′	–	–	–	–	–	–
C – C′	15.17	2.70	2.10	3.00	2.10	9.90
D – D′	14.63	2.40	2.40	3.00	1.95	1.05
E – E′	14.23	2.85	2.41	3.30	2.40	0,90
F – F′	13.83	2.40	3.00	2.20	1.25	1.75
G – G′	13.43	1.80	2.42	2.10	2.10	0.62

(ii) At any particular section-point, the changes in the cross-sectional areas from year to year usually alternate and in some sections three years might elapse before the process is completely reversed.

(iii) No definite conclusion could be made out about the progressive improvement or deterioration of the channels during these years except that the changes are small and nullified in the very next year by the reversal of the process (silting alternating with scouring), thereby indicating the remarkable adjusting capacity of the river to its varying discharges and loads.

PROGRESSIVE CHANGES IN WETTED-PERIMETER

A separate table (Table 3) showing the wetted-perimeters of various cross-sections for the years 1981–1984, has been worked out to study the progressive changes, if any, of the river Lish. In the adjoining figure (Fig. 3) these changes have also been shown graphically. The following points emerge from the study, regarding the progressive changes:

(i) At all the sections the wetted-perimeters do not change in the same way or to the same extent from year to year.

(ii) At any particular section point the changes in wetted-perimeter from year to year usually alternate and three years might elapse before the process is completely reversed.

(iii) There appear to be a few section points (D,E,F and G) with very little changes in wetted-perimeters during all these years compared to the other section points. These might be regarded as the more stable sections.

(iv) As we proceed from upland to lowland there is a tendency for the wetted-perimeter of

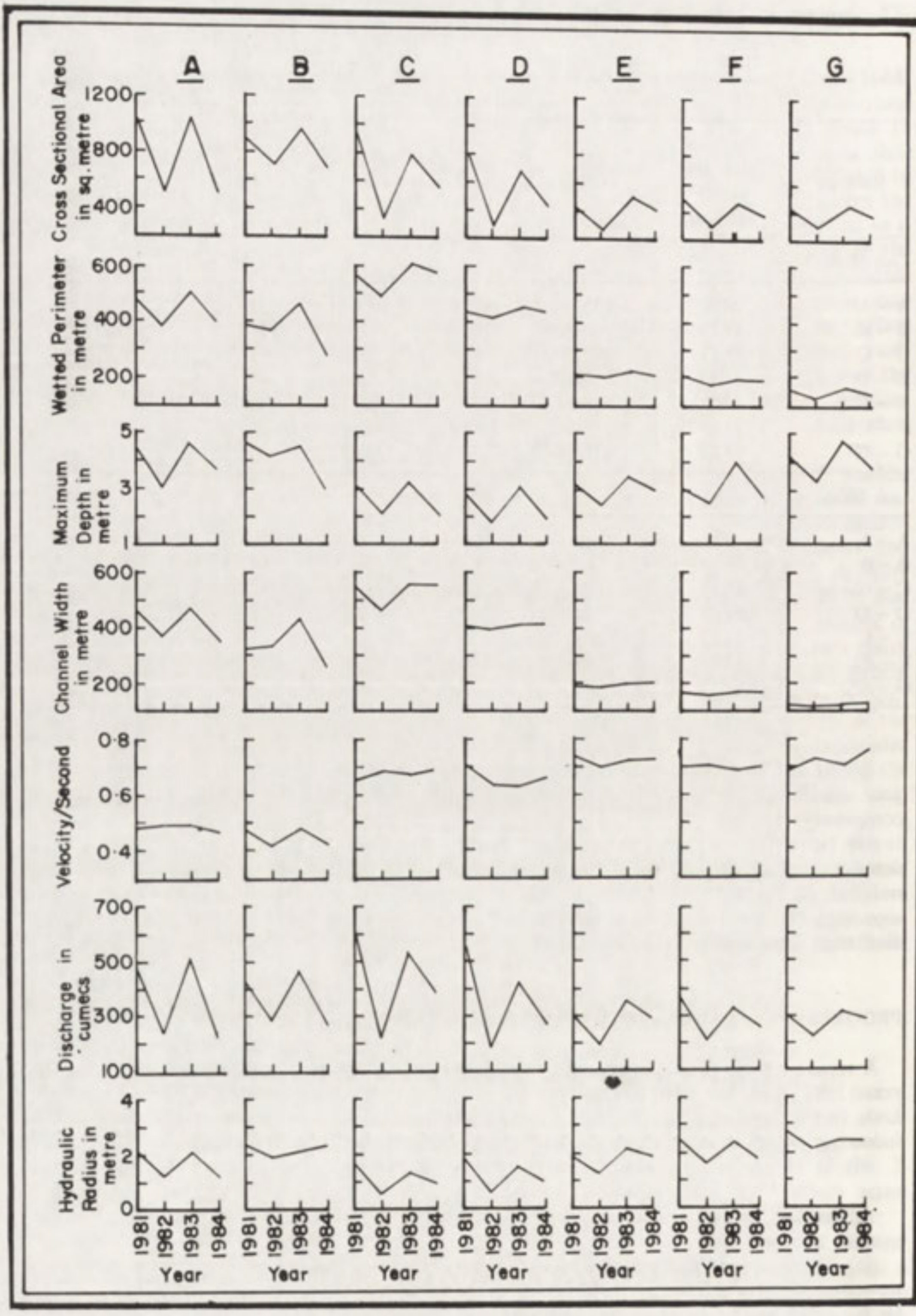

Fig. 3. Various drainage parametres of the River Lish at different stations during rainy seasons of 1981–1984, A–G – stations

TABLE 3. Wetted perimeter (in m) of the river Lish in the rainy and winter seasons during 1981–1984

Stations	Distance from the source (in km)	1981	1982	1983	1984	Range of variation
Lish (Rainy)						
A – A′	20.27	475.00	382.50	502.50	400.00	120.00
B – B′	19.67	380.00	370.00	464.00	290.00	174.00
C – C′	15.17	570.00	496.00	600.00	570.00	104.00
D – D′	14.63	435.00	420.00	450.00	433.50	30.00
E – E′	14.23	217.50	210.00	226.00	217.50	16.00
F – F′	13.83	202.50	180.00	195.00	193.50	22.50
G – G′	13.43	157.50	135.00	172.00	151.50	37.00
Lish (Winter)						
A – A′	–	–	–	–	–	–
B – B′	–	–	–	–	–	–
C – C′	19.67	15.00	18.00	19.50	19.50	4.50
D – D′	15.17	13.80	12.00	13.00	14.00	2.00
E – E′	14.63	18.00	18.00	15.00	13.00	7.00
F – F′	13.83	14.25	13.00	13.00	10.50	5.75
G – G′	13.43	11.25	11.60	12.50	10.60	1.90

the channels to get increased being fed by more and more run-off from the surroundings and the departure from the norm at stations A and B is due to the diversion of water through canal to tea-gardens at the section C.

(v) No definite law or trend in variation of the wetted-perimeters from station to station and from year to year could be made except that at some sections changes do occur and these soon get readjusted as the river tries to get its level back to its original position by means of either lateral or vertical corrasion.

PROGRESSIVE CHANGES IN DISCHARGE

To study the progressive changes in discharge of the river in recent years, the cross-sectional area of each section point has been multiplied by its respective velocity (averaged from a number of observations) and the data obtained for rainy and winter seasons have been tabulated (Table 4) and mapped (Fig.3) for comparison.

The following important conclusions can be made about the changes in discharge data:

(i) The discharges of the rivers, generally increase being away from the foot-hills and gradually reach the maximum near the confluence.

(ii) From the changes in discharges between any two consecutive years, it would be evident that the process of scouring and silting usually alternate and three years might elapse before the process is reversed.

(iii) There is a wide difference between the rainy and the winter discharges of the river and during summer the lower sections (A and B) of the river Lish remain totally dry as the water is being diverted illegally to tea-gardens through canals.

(iv) The variations in discharges in the river over years are more or less due to the fluctuations in rainfalls in the catchment.

TABLE 4. Discharge (in cumecs) of the river Lish in the rainy and winter seasons during 1981–1984

Stations	Distance from the source (in km)	1981	1982	1983	1984	Range of variation
Lish (Rainy						
A – A′	20.27	491.40	242.55	514.65	244.54	272.10
B – B′	19.67	426.76	295.20	466.76	285.68	181.08
C – C′	15.17	631.89	220.10	535.32	393.58	411.79
D – D′	14.63	582.38	184.71	428.72	285.19	397.67
E – E′	14.23	307.99	193.52	351.42	297.18	157.90
F – F′	13.83	359.39	209.22	322.81	267.99	150.17
G – G′	13.43	297.66	217.34	301.98	284.64	84.64
Lish (Winter)						
A – A′	–	–	–	–	–	–
B – B′	–	–	–	–	–	–
C – C′	15.17	1.38	1.18	1.26	1.05	0.33
D – D′	14.63	1.18	1.22	1.23	0.96	0.27
E – E′	14.23	1.43	1.18	1.58	1.06	0.52
F – F′	13.83	1.15	1.50	1.01	0.60	0.90
G – G′	13.43	1.01	1.16	1.02	0.86	0.30

(v) Whether the discharge of the river is increasing or depleting in recent years, can never be categorically proved as the deteriorating condition of one year readily compensated in the very next year.

PROGRESSIVE CHANGES IN HYDRAULIC RADII

A separate table (Table 5) showing the hydraulic radii of the various cross-sections for the years 1981–1984, has been compiled to study the progressive changes, if any, in the river Lish. In the adjoining figure (Fig. 3) these changes have also been shown graphically.

The following conclusions may be made out regarding the progressive changes:

(i) All the sections do not change in the same way or to the same extent from year to year.

(ii) There appear to be a few section points (F and G) with very little changes in hydraulic radius during all these years compared to the other section points. These might be regarded as the more stable sections.

(iii) Again, at any particular section point, the change in the hydraulic radius from year to year usually alternate due to the alteration of the process of scouring and silting.

(iv) The variation of the hydraulic radius at any section point across the river Lish do not conform to or appear to be influenced by changes in the immediately preceding or succeeding section points.

(v) The data of hydraulic radius of a particular section change from year to year but after the end of three years this (as evident from the value of the hydraulic radius) tends to come back to its original level, the hydraulic radius in 1981 being nearly the same as in 1984.

TABLE 5. Hydraulic-radius (in m) of the river Lish in the rainy and winter seasons during 1981–1984

Stations	Distance from the source (in km)	1981	1982	1983	1984	Range of variation
Lish (Rainy						
A – A′	20.27	2.16	1.29	2.09	1.30	0.86
B – B′	19.67	2.39	1.95	2.10	2.34	0.44
C – C′	15.17	1.71	0.64	1.33	1.02	1.07
D – D′	14.63	1.89	0.69	1.51	1.00	1.20
E – E′	14.23	1.91	1.32	2.15	1.87	0.83
F – F′	13.83	2.54	1.64	2.39	1.98	0.90
G – G′	13.43	2.74	2.21	2.47	2.47	0.53
Lish (Winter)						
A – A′	–	–	–	–	–	–
B – B′	–	–	–	–	–	–
C – C′	15.17	0.18	0.12	0.15	0.12	0.06
D – D′	14.63	0.17	0.20	0.23	0.14	0.09
E – E′	14.23	0.16	0.13	0.13	0.10	0.06
F – F′	13.83	0.17	0.23	0.17	0.12	0.11
G – G′	13.43	0.16	0.21	0.17	0.20	0.05

CONCLUSIONS

To summarise briefly, it may be stated that,

(a) the cross-sectional areas of the river Lish change very little from year to year and when such changes do occur, however small in amount, the river quickly readjusts itself by means of either erosion or deposition;

(b) no definite law or trend in variation of the wetted-perimeters from station to station and from year to year could be made except that at some sections changes do occur and these soon get readjusted as the river tries to get its level back to its original position by either lateral or vertical corrasion;

(c) whether the discharge of the river is progressively increasing or decreasing in recent years, can never be categorically proved as the deteriorating condition of one year is readily compensated in the very next year by means of higher rainfall;

(d) the hydraulic radii of the Lish tend to change in a small degree in conformity with a small change in cross-sectional areas, but these soon get readjusted as the river tends to come back to its original position.

Thus, it is evident that the river Lish is continuously struggling against the vagaries of nature for its existence and is passing through successive phases of deterioration and improvement in its course, thereby pointing to its remarkable adjusting capacity.

REFERENCES

Banerjee A. K. et al., 1980, Gazette of India, Darjeeling, p. 47.

Dutta G. N., 1955, Landslides and soil erosion in the Kalimpong sub-division, Darjeeling district and their bearing of North Bengal Flood, *Bulletins of the Geological Survey of India*, Ser. B, No. 15, part 1, 62–69.

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THE SLOVAK-HUNGARIAN BARRAGE SYSTEM ON THE DANUBE RIVER AND ITS ENVIRONMENTAL PROBLEMS

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INTRODUCTION

Exploiting the facilities provided by major rivers, economic and cultural relations and through these peaceful coexistence of nations can be fostered. Not all European rivers are, however, exploited to the same extent. Although the Danube is shared between eight countries, it does not as yet function as internationally outstanding waterway, comparable, for instance, to the Rhine. No real compensation is provided by the fact that disastrous pollution events like the release of poisonous material into the Rhine from the Sandoz AG, Basel, Switzerland, have been avoided on the Danube until now. The agglomeration of industry along the Danube is significant and the requirements for large-scale transportation are ever increasing. The growing trade links between western and eastern European countries also call for fuller exploitation of the Danube as a major artery. The largest river systems of Europe are meant to be connected through the Rhine-Main-Danube Canal joining the Danube at Kelheim above Regensburg (Ihrig 1970; Nagy 1980).

To improve navigation, a series of barrages are projected on the West German and Austrian sections of the river and at the confluences of major tributaries. Thirteen of these barrages had been built and an additional one was constructed on the Lower Danube in the Iron Gate (Portile de Fier-Derdap) in 1972 in a joint Yugoslavian-Romanian venture.

Ultimately, these and any other improvements in navigability must depend upon a higher degree of international cooperation, most particularly because for 1037 km of its 2860 km length the Danube is a border river.

All the barrages completed to date were built in gorges or in narrow valley sections and, therefore, their immediate environmental effects are limited to a narrow strip along the river. In the vicinity of the gap, however, where the river enters the Carpathian basin at Devin (Dévény), the damming in the section of Gabčikovo (Bös) will affect lowland areas under intensive agricultural cultivation. As a consequence, more serious environmental problems are envisaged.

The present paper is meant to outline the predictable environmental impact of the construction and operation of the barrage system. It should be emphasized that there have been no lowland dams and storage lakes constructed on the Danube until now and, thus, no experience on the precise nature of consequences of building a dam at Gabčikovo is available. From the academic side, both existing environmental data should be re-evaluated and some additional research be made.

THE PHYSICAL BACKGROUND TO THE BARRAGES

1. THE BRATISLAVA (POZSONY)-KOMÁROM STRETCH OF THE DANUBE

Where the Danube crosses the Little Plain (Ádám and Marosi 1974), it runs across a spindle-shaped vast alluvial fan (Fig. 1). The river continues to deposit in this area and braids into two main channels: the leftbank Malý Dunaj (Csallóközi-Duna) embraces the Žitný Ostrov (Csallóköz) and on the right bank the Mosoni-Duna surrounds the Szigetköz. The surfaces of these regions are shaped in Holocene alluvial fine sand and sandy silt deposited on sandy gravel beds. Soils are fertile calcareous alluvial and meadow soils and, in minor patches, meadow chernozems. Stream slope decreases from 30 cm/km to 20 cm/km along this stretch and the maximum grain size of bedload is from 5–7 cm to 2–3 cm (Pécsi 1959).

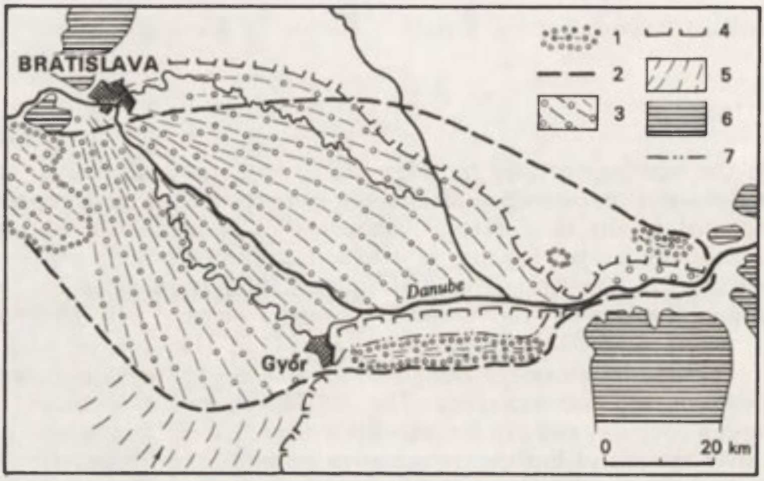


Fig. 1. Sketch of the old and young alluvial fan in the Little Plain (after M. Pécsi): 1 – remnants of older alluvial fan of the Danube, 2 – extension of early Pleistocene fan, 3 – Middle Pleistocene fan, 4 – recent fan, 5 – young fans of tributaries, 6 – mountain blocks, 7 – terraces

The residence time of floods was substantially reduced by the last-century river regulation whereby the Mosoni-Duna, which meanders along its 125 km length, was closed by a lock above Rajka and discharge in this channel was limited between the minimum of 64 m^3/s and the maximum of 120 m^3/s (Göcsei 1979 – cf. the figure for the projected discharge of the Old Danube mentioned later). The storage of groundwater in aquifers of great thickness in the alluvial fan (Rónai 1960) is due to their high void ratios, closely related to the discharge patterns of the Danube (Ubell 1959). Throughflow is considerable and near parallel to the surface in response to zero hydraulic gradient and results in uniform water quality throughout the region (Erdélyi 1983).

2. THE DANUBE BEND (FROM ESZTERGOM TO VÁC)

The shrinking of the Pannonian inland sea and the latest Pliocene – early Pleistocene crustal movements made the Danube gradually shift eastward to its present course (Pécsi 1959). The Visegrád gap was initially a shallow valley between Tertiary andesitic mountains with a large caldera. Recent uplift turned it into a gorge cutting through the caldera remnants and having steep walls bordering a narrow floodplain. The floodplain has two embayments at Esztergom and Pilismarot, but sandy alluvial soils only maintain low-level agriculture. The main potential of the region lies in recreational endowments. Therefore, the predictable ecological impact is of much lesser dimensions here than in the case of the Gabcikovo barrage.

SLOVAK-HUNGARIAN COOPERATION IN CONSTRUCTION

The scheme of this barrage system (Fig. 2) arose as an idea more than thirty years ago and acquired its final form in the early 1970s.

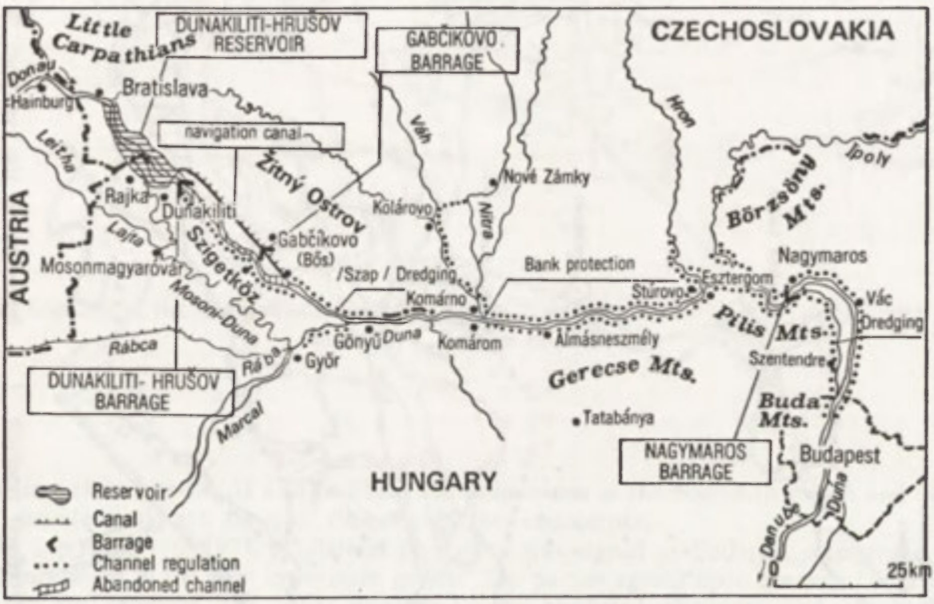


Fig. 2. The projected Gabcikovo (Bös) – Nagymaros Barrage System on the Danube

The more recently projected Slovak-Austrian barrage at Hainburg would have satisfied the demands of navigation, energy production and flood control. Austrian "green" environmentalists, however, argued against the scheme mentioning potential adverse influences on agricultural conditions and their protest made the Austrian government repeal the agreement concerning the barrage construction. As a result of this reversal, the project in the Szigetköz section of the Danube came into consideration again, first of all, by Slovak authorities.

The first unit of the Slovak-Hungarian barrage system (Nagy 1985) comprises the Dunakiliti Hrušov (Dunakörtvélyes) reservoir at the 1842 river kilometre (with 243 million m^3 total storage capacity and 60 million m^3 useful storage capacity). The reservoir would cover an area of 60 km^2 at 131 m above sea level behind the Dunakiliti dam (Fig. 3). Attached establishments would include seven free navigation passes (24 m wide) in the dam, a diversion canal (25.2 km long with a discharge of 4000 m^3/s), a hydropower plant of 720 MW (formerly this was emphasised as of primary importance), and a twin-lock of twice 34×275 m useful area. The Nagymaros barrage (Fig. 4) would dam up a resevoir of 170 million m^3 storage capacity and 68 km^2 area, a hydro-power plant of 160 MW to produce

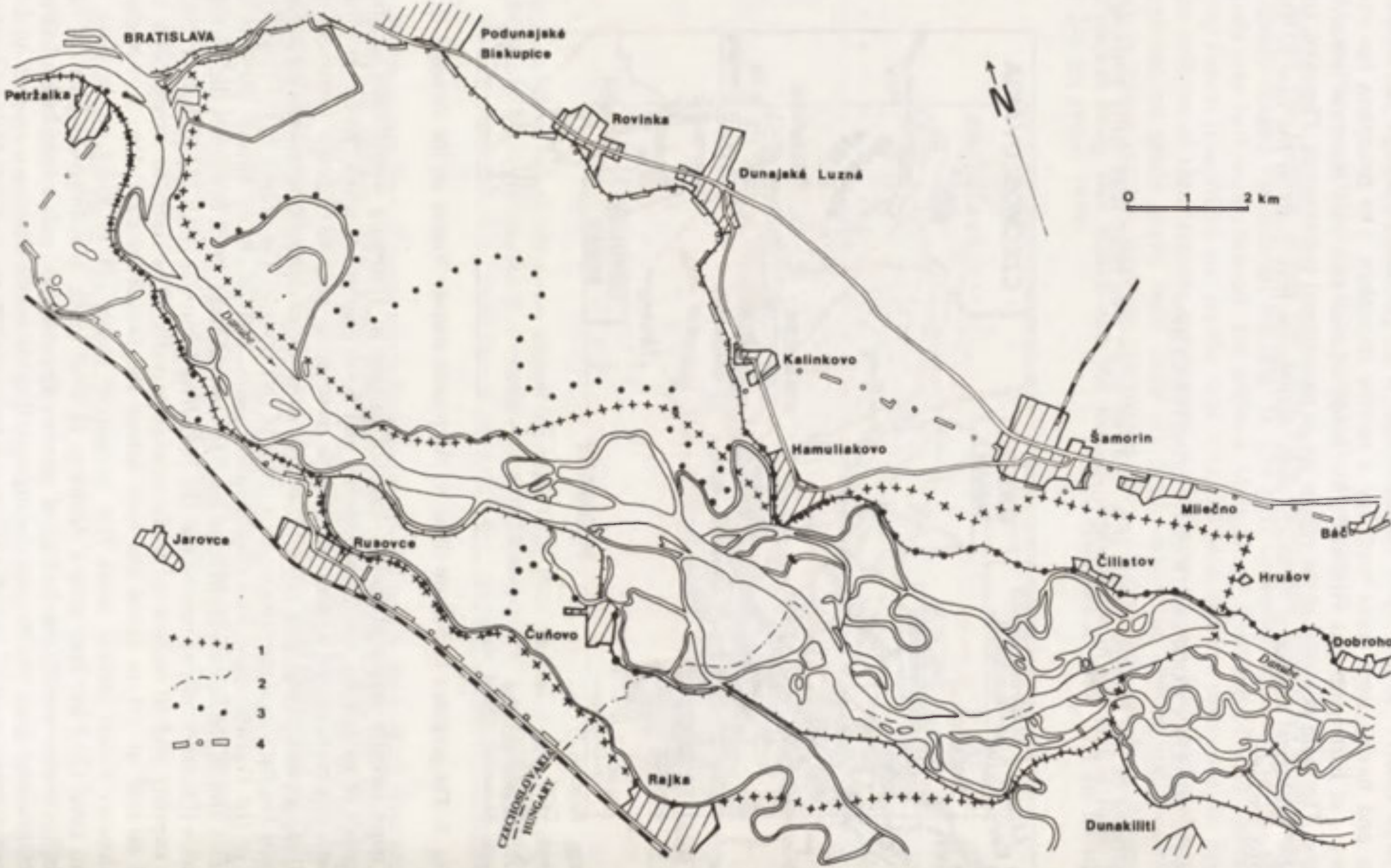


Fig. 3. The Dunakiliti – Hrušov (Dunakortvelyes) reservoir: 1 – boundary of the reservoir, 2 – national border, 3 – boundary of preserved landscape region, 4 – protected zone of preserved landscape region (after Slovenska Kartografia, 1973)

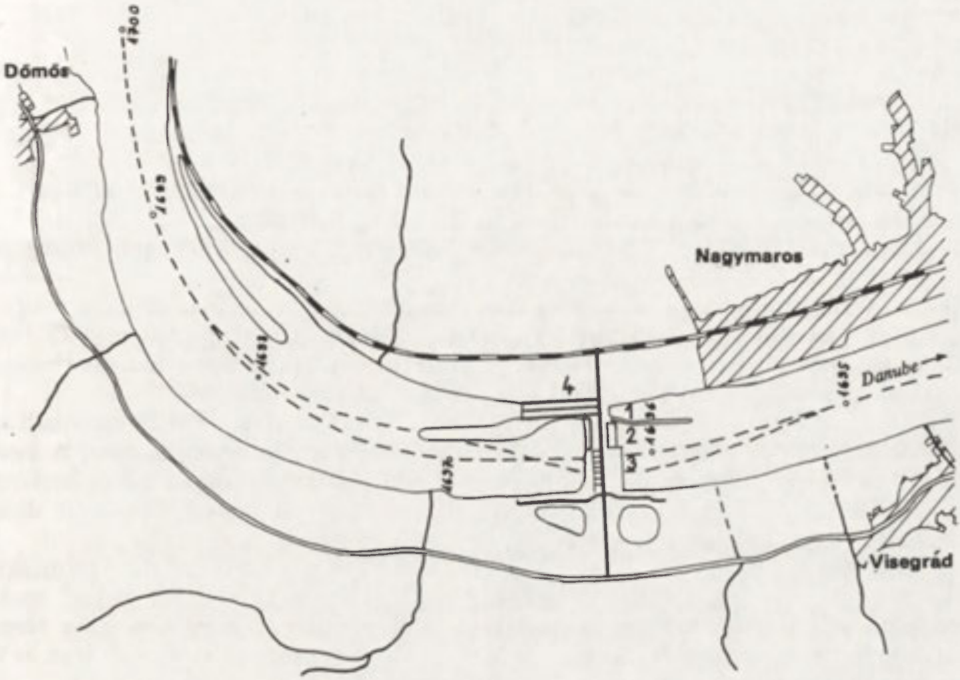


Fig. 4. Location of the Nagymaros barrage: 1 – lock, 2 – hydroelectric plant, 3 – dam with free passes, 4 – facilities on bank

peak-time electricity would also be built. The dimensions of the Nagymaros dam and twin-lock are identical with those of their Gabčikovo counterparts.

On September 16, 1977, a bilateral agreement was signed in Budapest concerning the implementation of the joint investment project. The parties agreed upon the equal contribution to the expenses, the equal division of the produced electricity and the mutual exploitation of other benefits. According to the original schedule, the completion of the Gabčikovo hydroelectric station was set at 1986 and of the Nagymaros one at 1990. Construcion began in 1978 with large-scale dredging in Czechoslovakia. The economic crisis of the early 1980s, which affected both countries, involved the necessity of re-scheduling and it was agreed upon in the supplementary protocol signed by the prime ministers of the two countries in Prague on October 10, 1983. The start of electricity production at Gabčikovo is contemplated now for 1990 and the Nagymaros station would begin to operate in 1993. In 1984, in the area of Dunakiliti dam large-scale activity was commenced by Hungarian enterprises. In 1986 the Hungarian government commissioned the Austrian company, Donaukraftwerke Gmbh, to undertake 80 per cent of all tasks involved by the implementation of the hydroelectric plants on the Hungarian side.

Since the agreement did not consider probable environmental impacts for the period of operation, both parties commissioned various institutions to prepare reports on foreseeable ecological consequences. Preliminary investigations by Hungarian experts have indentified several problems in the conservation of the environment and this compelled the National Council for Environmental Protection to initiate the preparation of a comprehensive study on environmental impacts (Dosztányi 1985).

MAJOR PREDICTABLE ENVIRONMENTAL IMPACTS IN HUNGARY AND RELATED RESEARCH

Among the likely impacts, four essential fields of ecological damage are highlighted in the report:

1. Problems of water quality and drinking water supply,
2. Sewage disposal of the municipalities involved (primarily of the town of Győr),
3. Destruction of poplar stands grown in the active floodplain,
4. Decline of agriculture in the Szigetköz as a result of groundwater table sinking into the gravel beds of the alluvial fan.

1. Damming reduces current velocity and, as a consequence, selfpurification capacity in the stream decreases. Increased primary production results in eutrophication (Tóth 1983). This is a potential hazard to the drinking water supply of Budapest and its thorough investigation would necessitate several years of hydrological experimentation.

Another issue here is the swamping and siltation of the Old Danube of 28 km length and 50 m^3/s discharge no longer active after the establishment of the diversion canal. A means to avoid it would be bottom sills, which proved to be a successful device along the Upper Rhône River (Bognár 1981). In the plan reducing environmental damage, this device should have been included as an alternative.

A serious problem of water quality is the potential contamination of the vast drinking water reserves stored in the gravel beds of the Little Plain alluvial fan (5 km^3 on the Hungarian side and 8 km^3 on the Slovakian side – Erdélyi 1979). This water reserve would be badly needed for developing industries and urbanizing settlements as soon as the barrage system begins to operate.

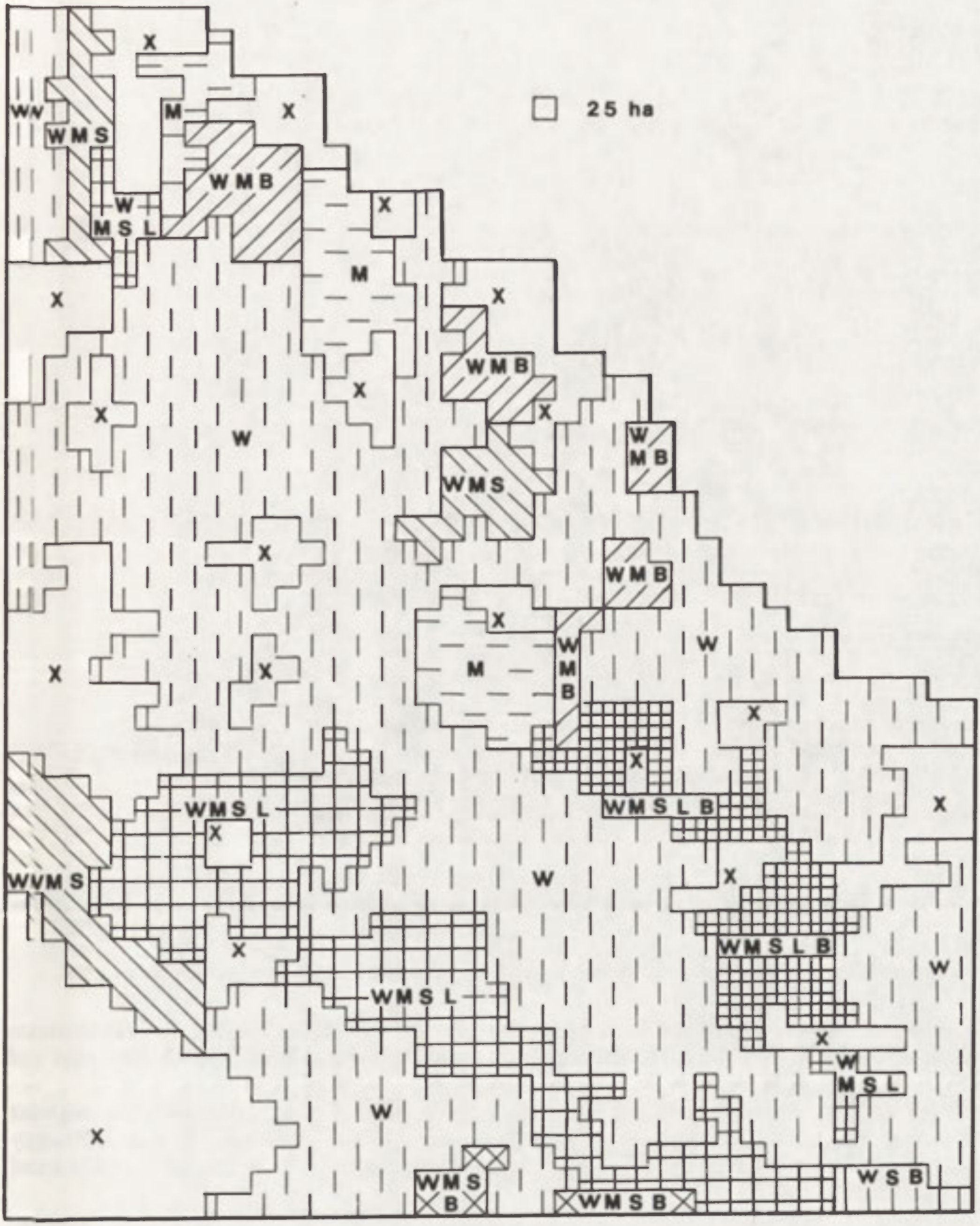
2. Sewage disposal problems seem to be solved by ensuring adequate financial support under a separate project.

3. To save the poplar stands on the active floodplain, important for cellulose production, feasible solutions were contrived. By-channels should be inundated repeatedly and the soils of the forests in the active floodplain inundated in the periods of the growing season when it is required by poplars.

4. The most complicated issue is the preservation of conditions suitable for agriculture. In the alluvial terrain between the Old Danube and the by-channels water is readily available in the rooting zone through capillary rise during the critical period of water demand, i.e. during summer droughts (Góczán 1984). As a result, crop yields are outstanding in national comparison. In mapping the environmental potentials of the counties of Hungary for the cultivation of major crops, we evaluated land use (Lóczy 1988) and the range of crops profitably grown in Győr-Sopron county (Fig. 5–6). The tracts of the Szigetköz along the Mosoni-Duna excel in this respect.

With the operation of the barrage system this situation would change. Groundwater table would fall and water would cease to be available for plants. It is intended that groundwater be recharged by an infiltration canal running on top of the alluvial fan. This device is, however, not only too expensive but the outcome is also doubtful. The mapping project of alluvial landforms in the Szigetköz (Fig. 7) revealed an intricate network of filled meanders of various depths (Balogh and Lóczy 1987). The water seeping from upward laterally would concentrate in these filled meanders and former channels and, thus, they would become waterlogged with the simultaneous drying-out of higher-lying terrain. In addition, the costs of operating this system would have to be born by local farms, thus placing an extra burden on economic units engaged in agricultural activities of low profitability.

The environmental impact statement prepared in the cooperation of 16 institutions was approved by the Hungarian governnment on its session of August 15, 1985. The communique asserts that the implementation of the barrage system according to the plans



Figig. 5. Detail of the map assessing environmental potential for cultivation, N-Szigetkoz (after L. . Goczan et al.): Initials denote crops most profitably produced in the 25 ha units: W – wheat, M – maize, S – sunflower, B – sugar-beet, L – lucerne, X – settlement or forest

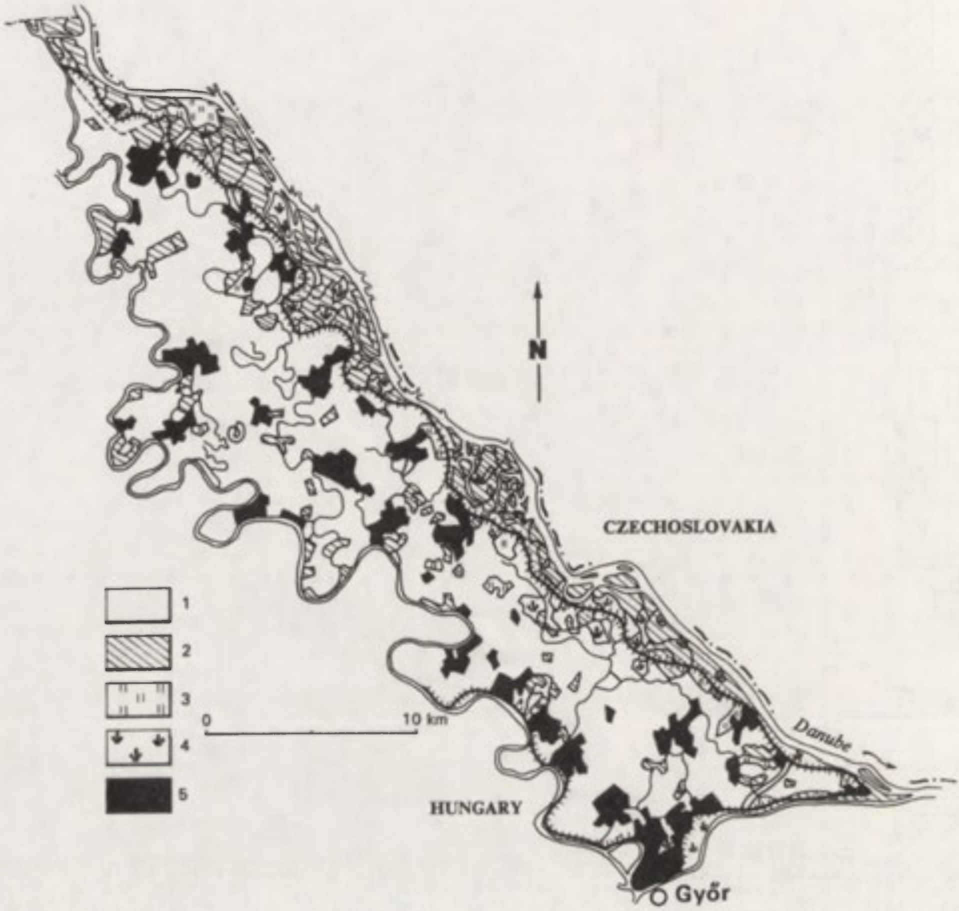
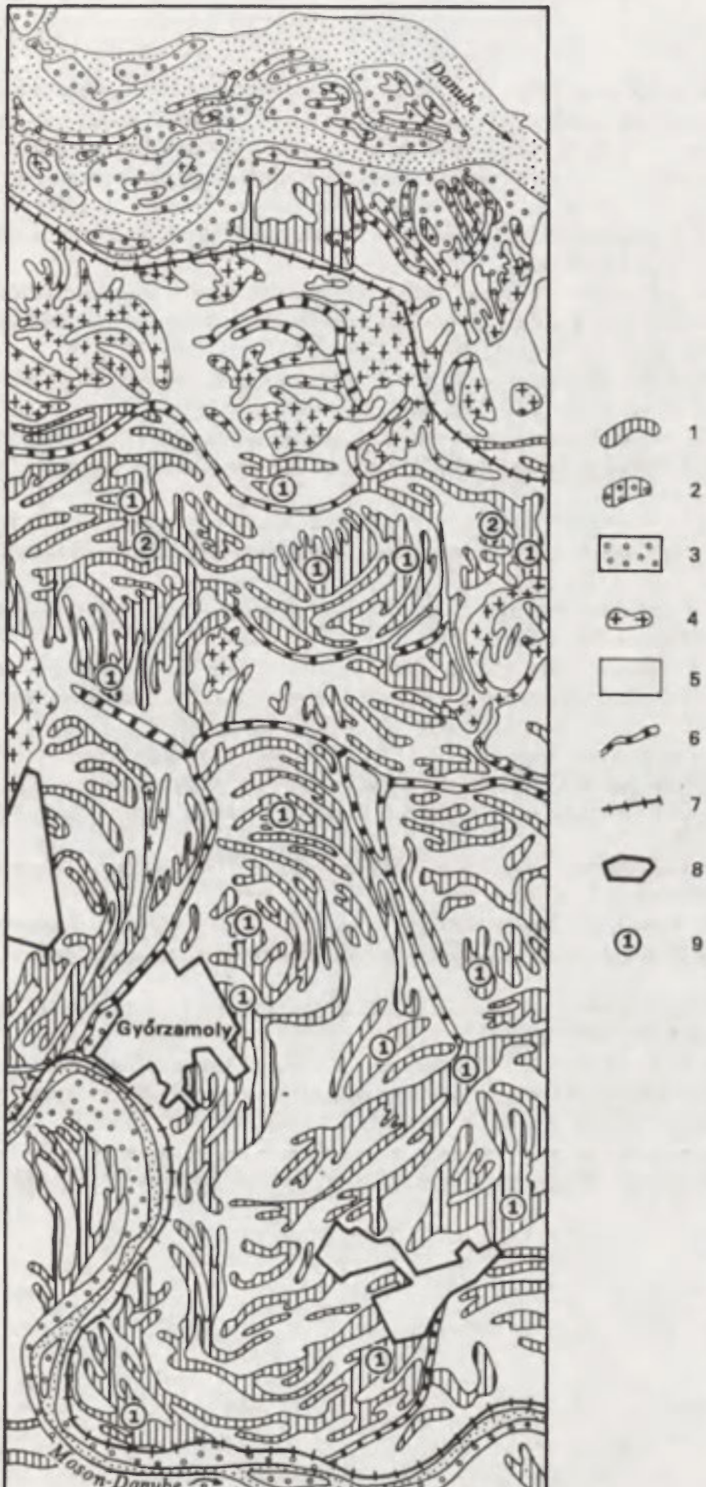


Fig. 6. Land use map of the Szigetkoz (by D. Loczy, revised from satellite image): 1 – arable land, 2 – forest, 3 – meadow and pasture, 4 – wetland, 5 – built-up area, garden and orchard

allows the rational use of the Danube, the preservation of water quality, the elimination of adverse human influences and the conservation of the natural landscape. (A large part of the floodplain on the Slovak side is now declared a preserved landscape).

Neither the demand for electricty, nor the requirements of navigation justify the neglect of environmental considerations. It is an important diplomatic task to find mutually beneficial solutions to avoid possible irrevocable damage to the populations of Slovakia and Hungary.

Fig. 7. Detail from the map of geomorphological facies in the Szigetkoz (collective of authors led by M. Pécsi, the map surveyed and drawn by J. Balogh, original scale 1:50000): 1 – remnant of cut-off meander, cultivated, 2 – remnant of cut-off meander in forest, 3 – low flood-plain forest, 4 – remnant of cut-off meander, seasonally waterlogged, 5 – point bars on high flood-plain, cultivated, 6 – canalized meander remnant, 7 – flood control dyke, 8 – built-up area, 9 – ①, ② – depth of meander: 1 – 0–1 m, 2 – 1–2 m


Danube
Győrzamoly
Moson-Danube
1
2
3
4
5
6
7
8
9

REFERENCES

Ádám L. and Marosi S. eds, 1974, *A Kisalfold és a Nyugat-magyarorszaagi peremvidek* (The Little Plain and the West-Hungarian Borderland), Akademiai Kiado, Budapest. (Magyarország tajfoldrajza 3).

Balogh J. and Lóczy D., 1987, Arteri formak és hasznosításuk táverzekeleses vizsgálata a Szigetkoz egy jellemzö szelvenyeben (Remote sensing of flood- plain features and their use in a characteristic transect of the Szigetköz), in: *Táverzekeléses alkalmazások*, Bekescsaba, 170–177.

Bognár Gy. 1981, A Peage-de-Rousillon vízlepcsö a Rhone-on (The Peage-de-Roussillon barrage on the Rhone), *Vízügyi Kozlemények* 1, 163–168.

Dosztanyi I., 1985, Komplex környezeti hatásvizsgálatok tükreben a Bös(Gabčikovo) – Nagymaros Vízlépcsörendszer (The Gabčikovo – Nagymaros Barrage System in the light of comprehensive environmental impact statement), *Búvár* 5, 204–207.

Erdelyi M., 1979, A Kisalfold hidrogeologiaja és hidrodinamikaja (Hydrogeology and hydrodynamics of the Little Plain), *Hidrológiai Kozlony* 59, 290–301.

Erdelyi M., 1983, A Györi-medence termeszeti-gazdasági ertekei és a tervezett vízlepcsö (Natural resources and economic values of the Gyor basin and the projected barrage), *Foldrajzi Ertesít26* 32, 3–4, 475–490.

Góczán L., 1984, A Szigetkoz "fedöreteg" vastagsaga és talajainak vízháztartási típusai (Thickness of "cover beds" and water budget types of soils in the Szigetköz). Geogr. Research Inst., Budapest (typescript).

Gocseli I., 1979, *A Szigetkoz természetfoldrajza* (Physical geography of the Szigetkoz), Akadémiai Kiado, Budapest. (Földrajzi Tanulmányok 16).

Ihrig D., 1970, Az osztrak Duna-szakasz ottensheimi vízlépcsöje mint a Rajna-Majna-Duna hajóut egy eleme (The Ottensheim barrage on the Austrian Danube section as an element of the Rhine-Main-Danube waterway), *Vízügyi Kozlemények* 52, 391–395.

Lóczy D., 1988, Cultural landscape histories: two case studies in Hungary, in: *The cultural landscape: past, present and future*, Cambridge University Press, Cambridge (in press).

Nagy L., 1980, Duna-Majna-Rajna csatorna (The Danube-Main-Rhine Canal), *Magyar Vízgazdálkodás* 3. p. 31.

Nagy L., 1985, A Gabčíkovo – Nagymarosi Vízlepcsörendszer (The Gabčíkovo – Nagymaros Barrage System), *Dunakanyar* 1, p. 3.

Pécsi M., 1959, *A magyaroszági Duna-völgy kialakulása és felszínalaktana* (Development and geomorphology of the Hungarian Danube valley), Akadémiai Kiado, Budapest. (Foldrajzi Monogrfiak 3).

Rónai A., 1960, Vízföldtani tanulmány a Kisalföldröl (Hydrogeological study of the Little Plain). *Hidrológiai Kozlony* 40, 470–484.

Toth J., 1983, A Bös–Nagymarosi Vízlépcsörenszer környezeti hatásairol és néhany varható okologiai problémájárol (On the environmental impact and some predictale ecological problems of the Bös–Nagymaros Barrage System), *Foldrajzi Küzlemények* 31 (107), 1, 1–11.

Ubell K., 1959, A Kisalfold déli, Magyarország területére esö reszének talajvízviszonyai (Groundwater conditions of the southern, Hungarian portion of the Little Plain), *Hidrologial Közlöny* 39, 165–175.

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SOIL SPLASH AS AN IMPORTANT AGENT OF EROSION

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As specified in the title I am dealing with water as the erosive agent. Wind erosion is excluded. Under the term of soil erosion we usually understand the motion of soil particles from higher locations to deeper ones, due to the higher potential energy of the higher position in comparison to the deeper one.

The energy of the system is contributed by gravity. The agent is water, water in different ways though:

(1) water in the of superficially running water (overland flow),

(2) water in the form of raindrops producing "splash" which is the detachment and transport of soil particles through the air by the impact of raindrops on the soil.

Which input leads to running water on the surface? The normal case is rainfall as an input. By this, water may collect on the surface if the infiltration capacity of the soil is exceeded. On slopes the surface-waterfilm is able to move downslope if the inner (cohesion of water molecules) and outer friction (water-soil boundary) is exceeded. This running water has the kinetic energy to transport soil-particles – if e.g. *splash-processes* procure such particles. If the running water has still more kinetic energy, soil particles may be picked out (plucked out) of the soil formation by the force of the water-flow itself.

As can be shown by experiments, an important part of the general land-denudation is due to the influence of raindrop splash.This influence may be either:

(1) a direct one = saltation of soil particles, or

(2) an indirect one = by disturbance of the surface water film (change of laminar flow to turbulent flow), destruction of soil aggregates and washing in of fine substance in the pores by compression etc.

Especially in the usual case of these laminar flows with low speed (and therefore low kinetic energy) a raindrop hit will change the flow to a turbulance and will bring about a short-time energy increase at that point. By this a threshold is exceeded and soil particles may be taken up by the water film and transported further. This may be seen in the field when it is raining and runoff is hit by raindrops. The runoff is clear water and only at the point of raindrop- impact one experiences a turbidity where soil particles are taken up in the transport medium, but after a short stretch of transport the particles may be dropped again (sedimented) when the water power (mainly speed) is not high enough.

To get to know to which percentage this indirect effect of splash contributes to the "general" soil erosion a of lot new experiments would have to be set up. One would have to generate undisturbed runoff (without raindrop impact) and compare it with disturbed runoff at the same test sites. At this point I should like to try and give some evidence for the direct effect of splash, i.e. displacement of soil particles by raindrop impact, and compare it to "overall soil erosion by water".

EXPERIMENT SETUP

In order to make statements about the correlation of precipitation, infiltration, runoff, soil erosion and splash one needs *experiments*. These may be carried out in the laboratory (where one has more control over most of the parameters) or in the field. Since I was also interested in the influence of vegetation only field experiments were possible. From literature one knows that soil properties, slope, land use (vegetation), and precipitation characteristics are the most important factors for soil erosion. For that reason the test plots and the experiments should present a variation of above factors. Considering all the factors would have broken my experiments financially as well as timewise. It was necessary to limit cases as well as to eliminate some factors (by equalling them).

SOIL PROPERTIES

I have tried to find soil types that are well represented in the eastern part of Austria. Two test plots are in the area of *Östliches Waldviertel*, where the lithology is Tertiary sediments. By river action and erosion a quick change of sand and clay strata form the today surface which in some places are covered by thicker or thinner loess deposits (Fig. 1).

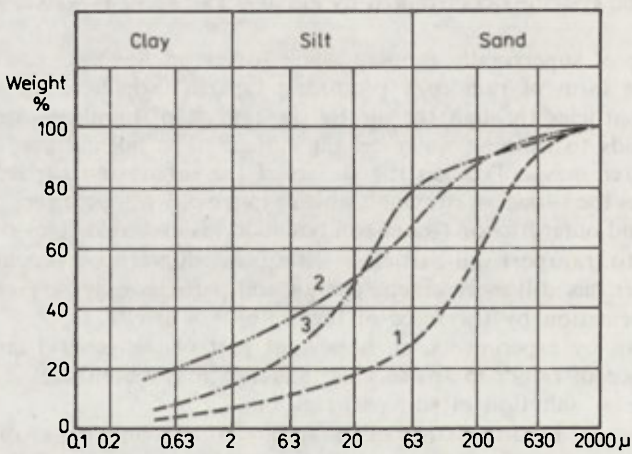

Fig. 1. Soil texture: 1 — Riedenthal-Nord, 2 — Riedenthal-Süd, 3 — Wagram

	Clay Silt Sand
D_{50} = 163µ	7/5/6/10/30/32/10 %
D_{50} = 20µ	28/8/14/18/20/7/5 %
D_{50} = 23µ	15/10/23/32/9/5/6 %

Riedenthal North is a soil of a south facing slope of a small tributary of the river Russbach. It is a calcareous Rhegosol, low in humus content, loosely structured and sandy with low aggregate stability.

The opposite slope. *Riedenthal South*, is a soil on a lower slope with a quick change of clay and sand of Tertiary age. The soil type is chernozem.

Test site *Wagram* is situated at the eastern slope of *Dunkelsteiner Wald*, where thick deposits of loess cover Pleistocene terrace gravel or the bedrock. The soil type is a chernozem or a degraded chernozem.

The test plots were 5 m long and 6 m wide, delimited by plastic strips on three sides while at the bottom tin profiles were used to seal the soil surface and lead the runoff into a trough and from that to a barrel. The barrel was metered by a gauge where a 2 mm-exact reading was possible representing a waterfilm for the whole test-plot of 0.033 mm (Fig. 2). This method enabled a time resolution of 2 / 5 / 10 / 15 / 20 / 25 minutes. At these intervals

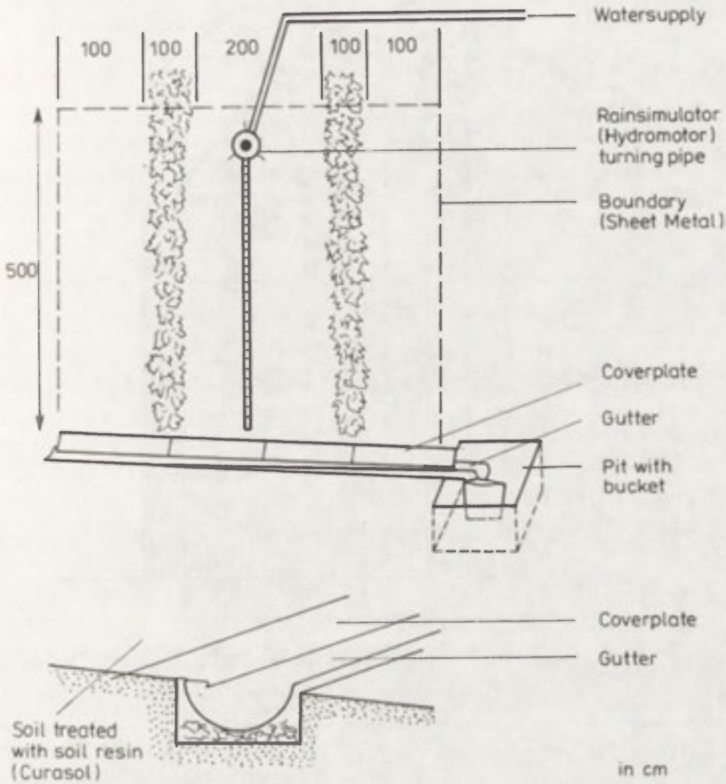

Fig. 2. Experiment setup

samples of runoff were taken in bottles and the gauge was read. Therefore I knew the runoff (liter/m^2) and by the sediment concentration (gramms/liter) also the soil erosion (gramms/m^2).

Splash was measured by two setups. Overall splash was measured by splash cups. Cylindric splash cups were set in the soil nearly even with the top rim. Above the filter paper, which rested on a sieve, the soil particles were collected, dried and weighed.

To find out the net splash downhill it was necessary to use another method. A splash board was constructed (1 m sides) and set in the soil vertically and parallel to the contour. At the bottom end it had a small trough, at the downhill-side as well as at the uphill side. By splash action soil particles are thrown on the board and at the end of the experiments the board is cautiously rinsed and the soil particles are collected in the trough and bottles at their end. More material is being splashed downhill than uphill, which is a function of slope. Therefore by substracting the amount of the uphill splashed material from the downhill splashed one gets the net splash downhill for 1 m slope width.

As mentioned, the input for generating soil erosion in the natural process-system is rain. Soil erosion processes may be studied by watching the natural phenomenon "rain on a soil

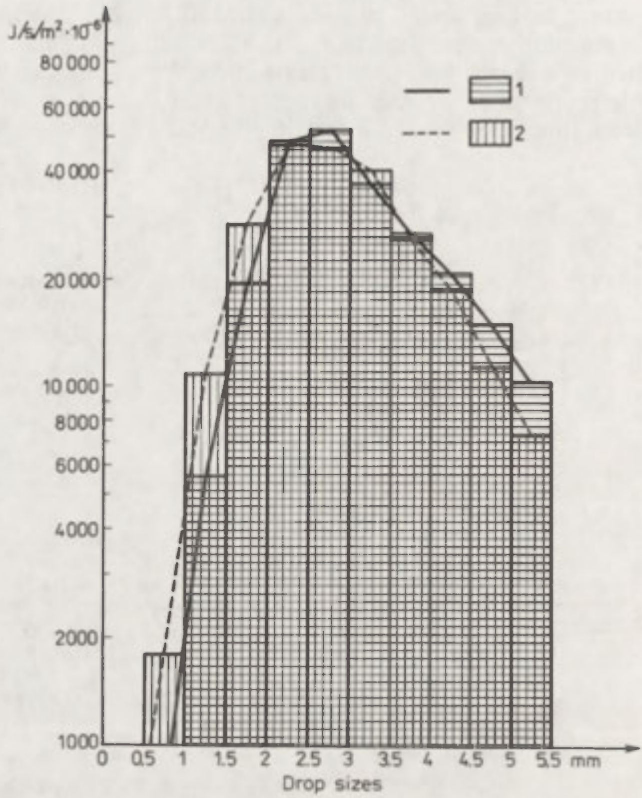

Fig. 3. Mechanical energy pro area (Energy/s/m^2); (J/s/m^2); I = 40 mm/h: 1 – Bauer rain simulator, 2 – natural rain (1950)

surface". Alternatively, the precipitation may be produced artificially. Then we talk about rain simulation. This additional complication is necessary because otherwise the study of soil erosion becomes very time-consuming. Installations in the field like test plots, containers, gauges etc. have to be watched and this also takes a lot of time, even if it does not rain for a long time and you do not get any data. But personnel becomes the most expensive factor of today. Time, location, rain characteristics (as amount, duration, intensity, drop-size etc.) may be chosen (in certain limits).

I have used a jet-type rain simulator and by many experiments I have reached a drop spectrum which is very similar to the natural spectrum in our environment. I used two different intensities: 0.66 mm/min (40 mm/h), and 1.5 mm (90 mm/h). Not only the drop sizes have to be simulated correctly but also the kinetic energy of the drops hitting the ground. Therefore one should reach end-velocity of free fall for them. As can be seen by Figs 3 and 4 I have succeeded in that pretty well, too. This part of research today is only directed to results on bare soil, of course. It is clear, though, that the formerly discussed processes of overland flow and splash are drastically changed by vegetation.

SPLASH PROCESS

By raindrop impact, soil particles either primary particles or aggregates are displaced and thrown outward in a splash corona. The angle of the trajectory is around 30° when the soil

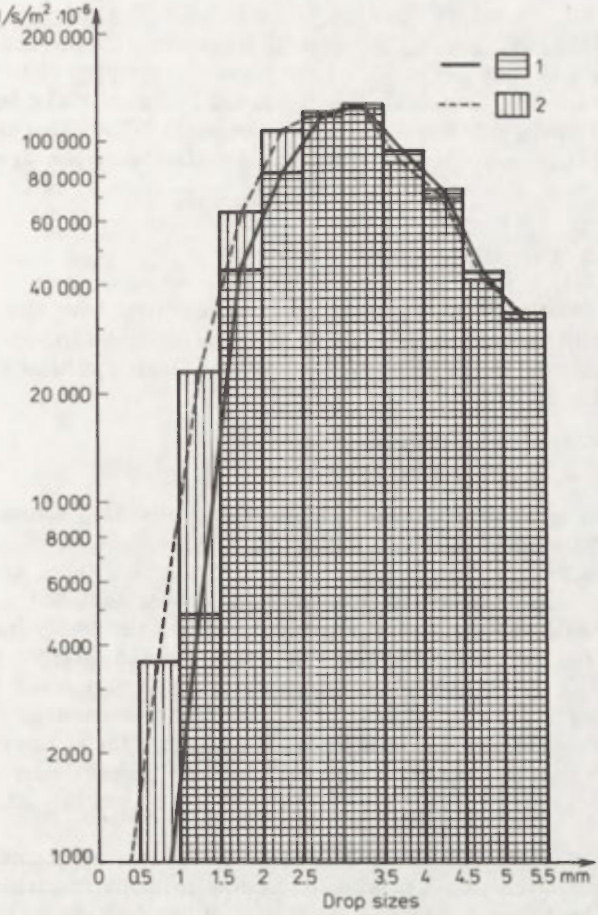

Fig. 4. Mechanical energy pro area (Energy/s/m^2); (J/s/m^2); I = 40 mm/h

is dry or has a very water film. When the water film becomes thicker (> 1/10 mm) the angle increases rapidly to 60°–80°.

THE INFLUENCE OF SOIL PROPERTIES ON SPLASH

TEXTURE

All experiments have resulted in the statement that sediments with median particle sizes around 100 μm will have the highest splash amounts. Coarser sediments have lower splash amounts due to the higher weight of the particles and the sediments with finer texture offer higher resistance to the detachment of soil due to their cohesion forces.

SOIL MOISTURE

Soil moisture is also an important factor for the splash amount. Assuming dry soil the raindrops are being absorbed very well into the pores of the sediment. The soil suction is very high and therefore the splash rates are not very high. The energy uptake of the soil is still high because of the flexibility of the soil particles (pores are still filled with air). As soon as the soil surface is uniformly wetted – not all pores are completly filled with water yet – a situation of high stability is reached. The resistance to water intake becomes higher and therefore the droplet bursts and forms the water corona. It follows that the splash rates will increase from dry situation to wetted situation and shall decrease again at liquification stage.

EXPERIMENT DATA AND DISCUSSION

Looking at the three different types of soils at one time, the soil Riedenthal North (sands) stands out with the highest splash amounts (and therefore the lowest force necessary for 1 g of soil detached). Approximately 3 g soil per Joule mechanical energy are being moved by splash process.

Riedenthal South = 1.7 g/J

Wagram = 1.1 g/J

Though the two last mentioned types of soil have the same D_{50} values (20/23) the splash amount for Riedenthal South is much higher

(1) due to the higher percentage in the texture range 63–200μm, and

(2) because of the higher aggregate stability (net sieving analyses).

The sandy soil of Riedenthal South has its modal value in the sandy fraction and has low aggregate stability. The increase of the fine sand fraction in the splashed material is eminent already at the beginnig of the rain while it does not increase very much later on. While the other two soils show a greater increase in the fine sand fraction in the splash process. I should like to explain this by the occurrence of soil aggregates in the two soils and their destruction during raindrop impact. A soil with mainly primary particles (as Riedenthal North) will bring about splash material mainly in the size classes (63–200μm) right from the start.

Soils with a lot of aggregates react differently. First, also aggregates next to primary particles are included in the splash process. According to many researchers, soil aggregates consist of finer material than the matrix of the soil. When fractioning the splash amounts, these aggregates are being reduced to their primary particles and therefore the increase in the fine sand fraction cannot be observed clearly. Only later, when the processes of aggregate destruction offer a wide matrix for the splash process, the preference of the size class 63–200μm can be clearly observed again.

SEDIMENT DISCHARGE BY OVERLAND FLOW – VERSUS NET DOWNSLOPE SPLASH

Observing the amounts of sediment discharge by overland flow soil erosion by water and comparing this to the measurements of downslope splash one can easily see that at the beginning of each rain, and sometimes during its whole occurrence, splash is the only soil moving process (Figs 5 and 6). Many rains do not exceed innitration capacity and therefore no overland flow is generated, while splash acts right from the start with the falling of each raindrop. But even after the overland flow sets in splash rates are still higher during the first minutes than the sediment discharge by water. Only later the relation is reversed.

In Riedenthal North at a slope of 10° at 0.66 mm/min precipitation splash offers higher downslope soil erosion rates than sediment discharge by water until 10 min of rain duration. In Wagram the net splashdown at a duration of 10 min is about 1/3 of the sediment discharge. At a duration of 20 min the reversal is very obvious. Riedenthal North downslope splash is only 1/4 of the sediment discharge, and Wagram about 1/15th.

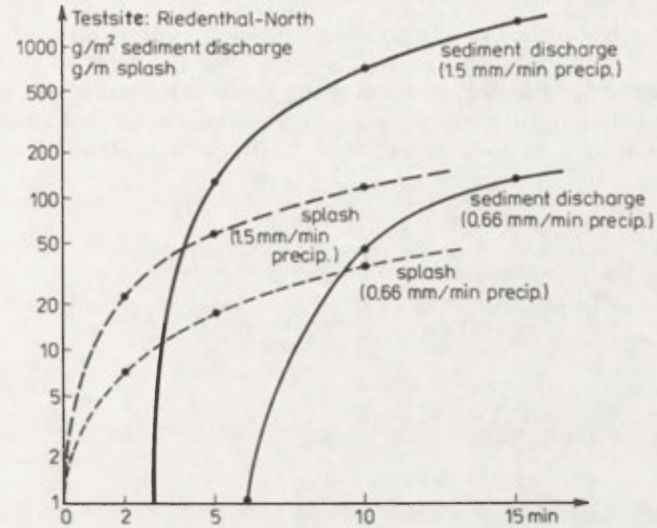
Testsite: Riedenthal-North
g/m² sediment discharge
g/m splash
1000
500
200
100
50
20
10
5
2
1
0
2
5
10
15 min
sediment discharge
(1.5 mm/min precip.)
splash
(1.5 mm/min
precip.)
sediment discharge
(0.66 mm/min precip.)
splash
(0.66 mm/min precip.)

Fig. 5.

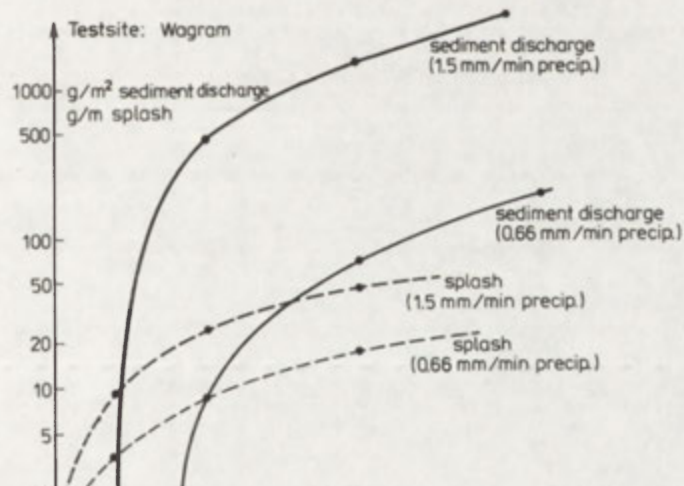
Testsite: Wagram
g/m² sediment discharge
g/m splash
1000
500
100
50
20
10
5
2
1
0
2
5
10
15 min
sediment discharge
(1.5 mm/min precip.)
sediment discharge
(0.66 mm/min precip.)
splash
(1.5 mm/min precip.)
splash
(0.66 mm/min precip.)

Fig. 6.

CONCLUSION

The higher the D_{50}-values of the soil are, the more splash action takes part in the downward motion of soil. The better a soil is sorted and the more silty a soil is, the more sediment discharge by overland flow takes place. Since many rains in Central Europe do not generate overland flow (too little intensity, too short duration) but splash sets in already at the first drop impact we must regard it as an important denudational process.

Please insert this List of References into "Geographia Polonica", 57, 1989 (B.Cori, Towards a new geography..., p.52).

REFERENCES

Becattini G. and G.Bianchi, 1982, Sulla multiregionalità dello sviluppo economico italiano, Note Econ., 5-6.
Bianchi G., 1983, Centri periferici e periferie centrali, Banca Toscana. Studi e Informaz., 6, 97-102.
Biondi G., 1984, Mezzogiorno produttivo. Il modello solofrano, Ediz.Scient.Ital., Naples.
Cassese S. and G.Graziosi, 1980, Quale futuro per il sistema degli incentivi?, L'Industria, 3.
CENSIS, 1982, Gli anni del cambiamento, F.Angeli, Milan.
CENSIS, 1984, Dal sommerso al post-industriale, F.Angeli, Milan.
Cori B, 1979, Le piccole e medie industrie in Italia: aspetti territoriali e settoriali, Quad.Fondaz.Agnelli, 34.
Del Monte A., 1982, Dualismo e sviluppo economico in una economia periferica: il caso italiano, in: S.Goglio, ed., Italia: centri e periferie, F.Angeli, Milan, 44-83.
Dematteis G., 1983, Deconcentrazione metropolitana, crescita periferica e ripopolamento di aree marginali: il caso dell'Italia, in: C.Cencini, G.Dematteis and U.Leone, eds, L'Italia emergente, F.Angeli, Milan, 105-142.
Dematteis G., 1985, Le metafore della Terra, Feltrinelli, Milan.
Frattali L., 1979, Situazione e prospettive dell'attività di sub-fornitura nel Mezzogiorno con particolare riferimento all'industria meccanica, in: R.Varaldo, ed., op.cit., 209-240.
Fua G. and C.Zacchia, eds, 1983, Industrializzazione senza fratture, II Mulino, Bologna.
Garofoli G., ed., 1978, Ristrutturazione industriale e territorio, F.Angeli, Milan.
Garofoli G., 1983, Aree di specializzazione produttiva a piccole imprese in Europa, Economia Marche, 2, 1, 3-46.
Garofoli G., 1986, I sistemi produttivi locali in Lombardia: meccanismi di funzionamento e politiche di intervento, in: U.Leone, ed., La rivalorizzazione territoriale in Italia, F.Angeli, Milan, 83-110.
Latella F., 1982, Mezzogiorno: modalità di eviluppo, categorie analitiche e politiche di intervento, in: S.Goglio, ed., op.cit., 265-295.
Macaluso F. 1986, Le aree di innovazione mobiliera nel Veneto, in: U.Leone, ed., op.cit., 327-343.
Marchi L. 1985, Aspetti caratteristici dei sistemi informativo e decisionale nelle imprese produttrici di mobili, Economia Marche, 4, 1, 111-128.
Mura P.M., 1986, Le vicende recenti dell'industria in Calabria e le transformazioni del territorio, in: U.Leone, ed., op.cit., 263-281.
UNIONCAMERE and CENSIS, 1983, II delta del localismo italiano, F.Angeli, Milan.
Varaldo R., ed., 1979, Ristrutturazioni industriali e rapporti fra imprese, F.Angeli, Milan.

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