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UTILIZATION OF COMPUTING TECHNOLOGY IN SOLVING SELECTED GEOGRAPHICAL TASKS

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SUMMARY

The author of the present paper mentions the possibilities of utilizing non-traditional ways of data processing in geographical research. He deals above all with two spheres of the possible utilization of computing technology in geography. The first are the requirements, formation and technical assertion of information systems. That part is completed by the autor's own examples and experience of the research carried out in the region of Rosice—Oslavany. He deals with the utilization of computers for the calculation of selected morphometrical characteristics and the application of mathematical and cartographical modelling in calculations and space interpretation of the values of potential and anthropogenically influenced soil erosion. On the basis of the information obtained he carries out the regionalization of the intensity of anthoropogenic effects on the relief by means of the computer. He draws the attention to the possibility of some statistical calculations (correlations).

The second part is devoted to the problems of computer cartography and its utilization in geographical research and the sphere of accepting geographical solutions. The paper is completed by 6 specimens of computer maps.

1. INTRODUCTION

The utilization of computing technology in geography is a reflection of increasing introduction of mathematical methods and approaches into solving complicated geographical tasks. While in the recent past we met mathematics only in the quantification of simple relations between two, seldom more, geographical phenomena, at present mathematical methods are utilized also for the study of complicated territorial relations in the landscape. Geographical research and collecting geographical data, organically connected with it, are objectively and subjectively complicated procedures within the individual geographical branches as well as in the interpretation of the results of the synthesis of information of several geographical events. In either case a creative cooperation of geography with mathematics starts to play an important role. Mathematics enables the study of geographical phenomena and regularities independently on their essence and contents, starting from the deductions on the axiomatic basis. According to L. I. Vasilevskij and Ju. V. Medvedkov (1976) geographers are motivated in their relation to mathematics by the following facts: a) the possibility of creating methods resulting in a better substantiation, reliability and accuracy of conclusions; b) a precisioned and generalized interpretation of the theory with a stress on the clarification of the generality or a homology of structures in externally and subjectively different phenomena; c) the possibility of heuristically fruitful intellectual contacts with other branches by means of formulating conclusions in a generally scientific language of mathematics. The importance of mathematics in geography begins to make itself conspicously felt in connection with the utilization of computers in geographical research. As a member of the research team of our department I verified some possibilities in connection with the establishment of the information system as a part of the state research project called "The Territorial System of the Region of Rosice-Oslavany and its Potential" which I participated in solving.

2. COMPUTERS AND GEOGRAPHICAL RESEARCH

According to Ju. G. Simonov (1975) every geographical research is divided into four stages: 1. Formulation of the task and selection of information indices, 2. Measurement of the parameters of the objects studied, 3. Processing, 4. Accepting geographical solutions. As early as in formulating the task and information indices mathematical methods enable a new interpretation and modification of traditional tasks. They concern the precisioning and defining of the tasks themselves and they look for the answer, solution, from the point of view of new tasks standing before geography. Measuring the parameters of the objects to be studied requires to create new quantitative measures and together with including computing technology also possiblities for processing and registering the measured characteristics in rational time. The sphere of processing geographical data includes not only the technical assertion of the calculation, but often also the elaboration of general algorithms for solving the individual, types of geographical tasks. Accepting geographical solution then completes the whole research, since it applies the information obtained in a creative way both in science and in practice.

The utilization of computers in geographical research has been evoked by several reasons. The first is a frequent extent and complication of geographical systems whose research is connected with collecting, preserving and processing a great amount of information. Further, the solution of geographical tasks requires a great extent of procession work, and, finally, the study of geographical systems is also possible by means of modelling their functional relations and the overall development. In such cases we speak about computer modelling.

2.1 TYPES OF SOLVED GEOGRAPHICAL TASKS

In geographical research there are a number of operations that can be executed advantageously by using computing technology. A. D. Armand (1973) summarizes the views of P. Hagget (1969) and P. Gould (1969), delimiting the following four directions of research connected with the introduction of computing technology:

1. Different methods of variation statistics employed in solving tasks of classification and regionalization. Here belongs the verification of hypotheses with the aid of statistical criteria, the analysis of variations, simple correlations and linear regressions which P. Gould considers the most valuable methods of geographical analysis. The above methods are on a higher level completed by set regression, factor and multidimensional discriminating analysis and canonic correlations.

2. Tasks connected with the analysis of trend surfaces. By means of this method regional and local trends in geographical phenomena are divided, comparison of regions is carried out according to general charactristics of subordinate trends in periodical and rhythmical phenomena.

3. A complex of activities leading to making geographical maps. It includes the collection of primary data, logical and arithmetical operations with it, its transfer into space expression and finally the graphical drawing itself. A great hope is put in this connection into processing information obtained from the materials of the remote sensing of the Earth.

4. Modelling processes developing in time. As an example there are quoted calculations of diffusion, development of geomorphological processes, etc. The Monte-Carlo method is successfully used. Many geographical phenomena can be studied by means of simulation on computers.

The above list must be, in our opinion, completed by the formation of information systems about the territores which enable on the one hand carrying out the above specified tasks, on the other hand they are a higher system enabling storing, preservation, renewal and processing the results of geographical research for the needs of practice.

2.2. SOME NEW APPROACHES TO THE SOLUTION

Utilizing computers in geography does not consist solely in the formulation of the type of tasks solved, but above all in the readiness of the solvers to understand and utilize another "mathematical way" of thinking. In the actual realization of the solved tasks geographers must manage the mathematical apparatus and the utilization of automation of the most frequent operations by means of an established library of programs. As examples may serve relatively simple programs for the calculations of mean elevations, relative mean angles of slope gradient, or, on a higher level, the calculations of the values of potential and anthropogenically influenced erosion. Carrying out the operations and above all the interpretation of the results by means of computer maps enriches the proper geographical thinking and habits in solving geographical tasks. An example of a scheme enabling the realization of the operations mentioned is also the geographical information system described below.

It is certainly very difficult to list in an exhaustive way all tasks that can be solved by means of a computer. As was stated above, computers are used in mapping, as well as in the analysis and the synthesis of the material collected. Our research in the sphere of utilizing computers has been aimed at the following spheres:

1. Collecting, storing, and processing geographical information
2. Computer cartography

Though dealing with them separately, I understand both spheres inseparably connected and independent on each other.

3. INFORMATION SYSTEM OF A TERRITORY

For meeting the growing requirements of institutions and organizations of all degrees to a sufficient amount of topical information on processes and phenomena in a landscape information systems of a territory are formed. According to B. Langeforse (1966) I consider an information system to be such a system as contains components for the collection, storage, procession and issue of information. A particular aspect of geographical information is its space-time character. Space information documents the distribution of elements of certain properties and enables the study of their mutual relations in time.

3.1. Practical requirements of the user of the information system about a territory

In building schemes of the information system about the territory in the district of Rosice-Oslavany and the prepared system in the Brno conurbation which are not connected to other information systems in Czechoslovakia (such as those built by Terplan) I considered above all the following requirements:

1. Collecting and storing of all established geographical data (physical and economic-geographical) about the territory.
2. Processing data according to the requirements of the user who is acquainted with only the fundamentals of computing technology.
3. Flexibility of the system to react to changes in the requirements of the users in processing.
4. An easy output of the characteristics selected from the computer in a digital form and above all in the map form, which will enable to obtain a space survey of the occurrence of phenomena in the given territory or in a part of it.
5. The possibility of anticipating the development of natural and socio-economic processes and phenomena and/or their integrated effect in the territory under investigation.
6. Making the information system an open system with a possibility of extending it, if necessary, by the user himself, even by a user without special knowledge in the sphere of programming.

The above requirements are fulfilled by the information system programmed in the Fortran language and processed with the computer EC 1033, property of the Institute of Computing Technology, J. E. Purkyně University, Brno.

Besides the realization of the above requirements there was a purposeful utilization of data stored in our information system in mathematical cartographic modelling. The assertion of the mathematical cartographical modelling is connected with a broader and broader utilization of nontraditional ways of processing information in geography. By mathematical cartographical models is understood a system connection of mathematical and cartographical models in making new maps and broadening their use for research purposes (V. T. Žukov et al., 1980). By combining mathematical and cartographical models some of their negative properties were suppressed and positive properties were connected and strengthened. Mathematical models, applied in geographical tasks, did not always yield the best results, above all because of the intricacy of introduction and formalization of territorial aspects which belong to the most important ones in geography. In the mathematical cartographical modelling different trends of research were formed. All of them have kept certain general features of both mathematic and cartographical modelling. The modelling proper, in dependence on the intricacy of the modelled phenomenon, consists of a number of links, each of which is constituted by a cartographical and a mathematical model (map). Mathematical and cartographical modelling enables composing different purposeful variants of resulting maps with different quantitative scales, making it possible to find the most suitable solution of the given problem. It can be very advantageously applied in solving different tasks based on data bases.

3.2. Technical assertion

In forming and constituting the information system of the studied territory we worked with the 3rd generation computer EC 1033. That is a universal computer currently used for the needs of teaching and research at universities. The computer is not equipped with special programming means for the needs of the geographical and cartographical research. It includes several magnetic disc units (each with the capcity of N = 29 MByte), further magnetic tape units, readers of punch cards and tapes. The output of data from the computer system can be carried out in printing equipment by means of the punch tape or cards or also by means of the digigraph which enables the drawing of graphical figures.

From the other computing systems used in this country it is possible to draw attention to the properties of computers of the SMEP series that enable a direct (interactive) approach of the user to the computer by means of the terminal. Besides, computers of this series can be provided with digigraphs and chiefly by special terminals for drawing graphical figures and making paper copies of figures from the screen. Computing means of the EC and SMEP series are sufficiently powerful tools for the needs of integrated research with a stress on the formation of information systems about a territory and the graphical interpretation of the results of the research.

In the world some firms concentrate on the production of specialized computing systems for the needs of individual geographical branches and computer cartography. For hitherto needs as well as for the near perspective of our research the technology of the SMEP and EC series is sufficient.

3.3. THE CONTENTS AND UTILIZATION OF THE GEOGRAPHICAL INFORMATION SYSTEM ABOUT A TERRITORY

The formation and composition of the information system from the region of Rosice—Oslavany with a prospect of building an information system in the Brno conurbation consists of three basic stages which are as follows: 1. Collection of data, 2. Punching of data according to the project of research, and 3. Utilization of the conversion program.

Collection of data is carried out by each of the partial solvers on the one hand for the conclusions of their own branch, on the other hand for the needs of the complex evaluation of natural and social and economic relations.

Punching of data was carried out with the help of the technical workers of the Department of Geography, students and the individual solvers of the project using the punching machine Soemtron.

By means of the conversion program the punched data was recorded on an external memory of the computer EC 1033. A set of data from every geographical branch was and/or can be put in the memory. Since all data is related to a discrete hexagonal network, the set of data of each branch is also provided with the coordinates of the respective hexagon. In that way an extensive database was formed which an individual solver would set up only with difficulties; it would also be difficult to find relations among its individual elements. All data of the database is stored according to predefined "sizes". By means of simple programs the data can be taken out and basic mathematical and logical operations, such as penetration, union, correlation and others can be carried out with it. The results of these operations can be plotted directly by means of a special program into the hexagonal network. This operation makes it possible to find interactive bonds of arbitrary geographical characteristics related to the basic hexagons. Further it is possible to study different bonds of elements of environment via the possibility of communication of more solvers at the same time, which, besides others, deepens the team work in solving tasks. The individual operations can be applied repeatedly with the characteristics of the territory under investigation; this makes it possible to follow relations between bonds of different characteristics of the system under consideration. Thus, geographical characteristics put in the information system about the territory can be followed individually, in pairs, sets of three, bonds of pairs and sets of three (in the case of six characteristics). An important condition for the assertion of different combinations is, of course, the problem of the sense of their performance.

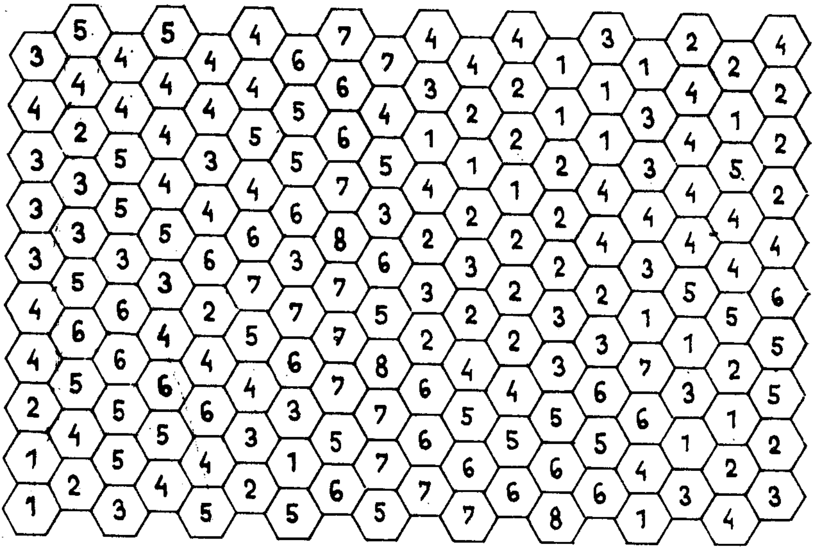

Fig.1: A specimen of a computer map of relative heights of the relief of a part of the territory studied

Explanation:

Value (m):	0—10	10—15	15—20	20—25	25—30	30—40	40—50	50—70	> 70
Printed symbol:	1	2	3	4	5	6	7	8	9

An actual and relatively simple example of the above statements was the employment of the third generation computer Tesla 200 in solving the Dyje Pass. The program by means of which the application was carried out, had been set up in the language Fortran, the memory capacity was 120 KByte. Data was obtained by research in the field, on the basis of which thematic maps were made of the area under investigation. Individual data concerning the natural components was printed into discrete hexagonal network part by part (according to the individual elements) or in a combination of these elements. The result was a computer map, which realistically and in scale expressed qualitative data about the territory with the prospect of its quantitative procession (Hynek A., Konečný M., Rais K., 1978).

The information geographical system from the region of Rosice—Oslavany with the prospect of being used in the Brno conurbation, which is being formed,

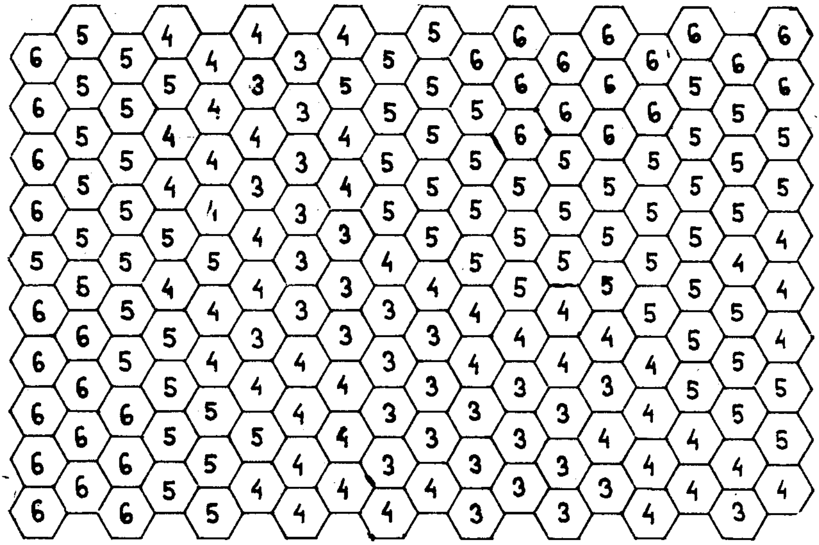

Fig. 2: A specimen of a computer map of average elevations of a part of the territory studied

Explanation:

Value (m):	< 350	350 — 400	400 — 450	450 — 470	470 — 500	500 — 530	530 — 560	560 — 600	> 600
Printed symbol	1	2	3	4	5	6	7	8	9

can be provided with a number of data from the spheres of physical and economic geography. Thus it contains data on geomorphological, climatical, hydrological, pedological and biogeographical conditions of the territory, further data on the density of population, natural increment, age structure, retail turnover, industrial production, power consumption, etc. Both primary characteristics and those calculated from them were put in the information system into the computer memory. In this paper I should like to describe some operations in the part of the information system devoted to geomorphology and cartography. The calculations were carried out by operations (subprograms) of the main system program. In the calculations as well as in the interpretation of the results I employed the individual stages of the mathematical cartographical modelling. Mathematical modelling

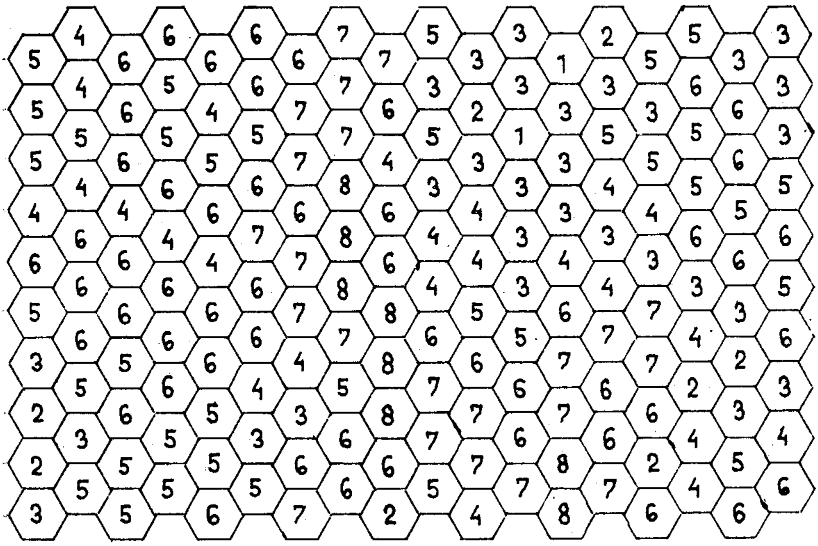

Fig. 3: A specimen of a computer map of mean angles of slope in a part of the territory studied

Explanation:

Value (degrees):	0—1	1—2	2—3	3—4	4—5	5—7	7—10	10—15	> 15
Printed symbol:	1	2	3	4	5	6	7	8	9

(if we accept the view that every mathematical calculation is a specific form of mathematical modelling) was primarily employed in the calculation of morphometric data, such as relative heights (Fig. 1), mean elevations (Fig. 2) and mean angles of slope, which were calculated in two variants: for the needs of geomorphological mapping (Fig. 3) according to the scale suggested by the Committee of Geomorphological Mapping of the IGU (Demek et al., 1972) and for the needs of further calculations (like the values of soil erosion). All this data was calculated from the values of elevations by means of a simple arithmetic calculation from previously punched characteristics of peaks and centres of the individual fields of the hexagonal network.

Further morphometric characteristics from the territory under investigation — the density of valley network and slope lengths — were found out by traditional cartographic methods and their values were directly stored into the data bank.

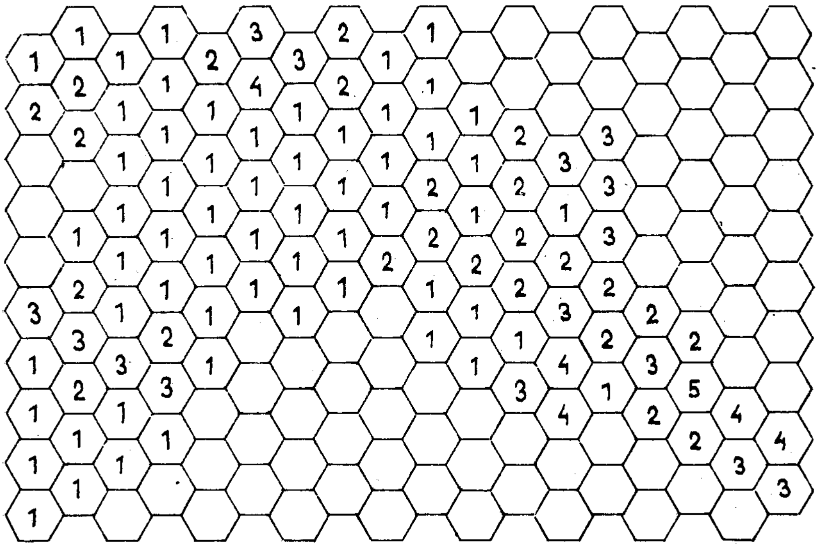

Fig. 4: A specimen of a computer map of potential soil erosion in a part of the territory studied

Explanation:

Value (mm . year^{-1}):	0,0—0,5	0,5—1,0	1,0—1,5	1,5—2,5	2,5—5,0	> 5,0
Printed symbol:	1	2	3	4	5	6

Some operation in the information system will be characterized in finding out anthropogenic transformation of the relief. For that purpose some data concerning individual anthorpogenic shapes of the relief and some components of the environment of the region under investigation which by their properties influence the course of present-day geomorphological properties was stored in the bank. That data was found from thematic maps (cartographical models) — climatical, pedological and geological, made on the basis of field investigation and utilization of available literature (Hynek A. et al., 1980). Cartographical modelling with the aid of computers enables a new interpretation of these results, either in the digital or in the graphical form by means of computer maps — cartograms.

The mathematical tool can be applied to both primary and newly created or found data, thus obtaining new qualitative and quantitative characteristics. In our information system this approach was employed in calculating potential and anthropogenically influenced soil erosions according to the methods of O. Stehlík

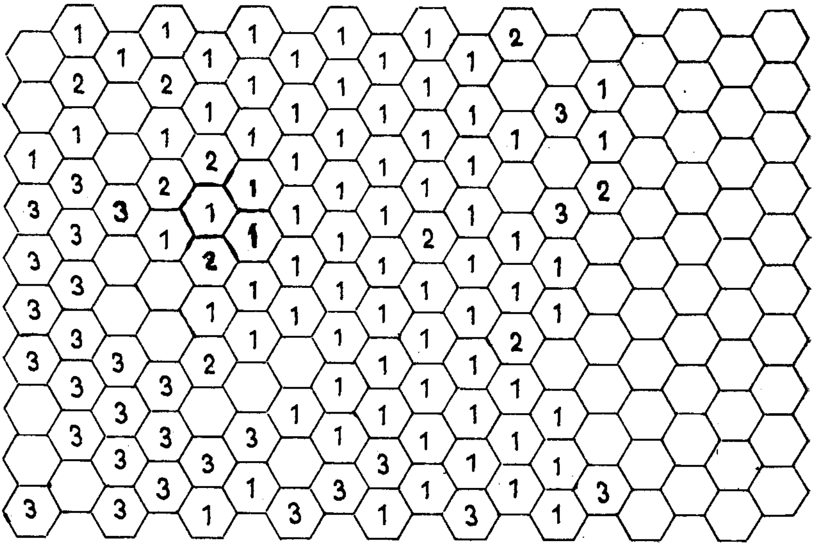

Fig. 5: A specimen of a computer map of the distribution of forest covered areas in 1825 and in 1980

Explanation:

Year of occurrence:	in 1825 and also 1980	only in 1980	only in 1825
Printed symbol:	1	2	3

(1970, 1971). In interpreting the results of calculations I employed the mathematical cartographical modelling which advantageously combines the performed operations. The results of partial calculations of different characteristics or their combinations are specially expressed by means of computer maps (Fig. 4). This approach not only enables a graphic interpretation acceptable for practice, but also a statistical evaluation of dependences and occurrence of the phenomena studied.

In the described information system the following operations was actually verified. On the basis of simple logical criteria I determined parts of the territory with characteristics chosen in advance, necessary for practice from the data calculated the computer (suitability for agrotechnical methods, purposeful utilization of soil). Further I compared some data in a long time interval by means of the computer, such as the extent of urbanized areas and their changes in 1825 and 1980 (Fig. 5).

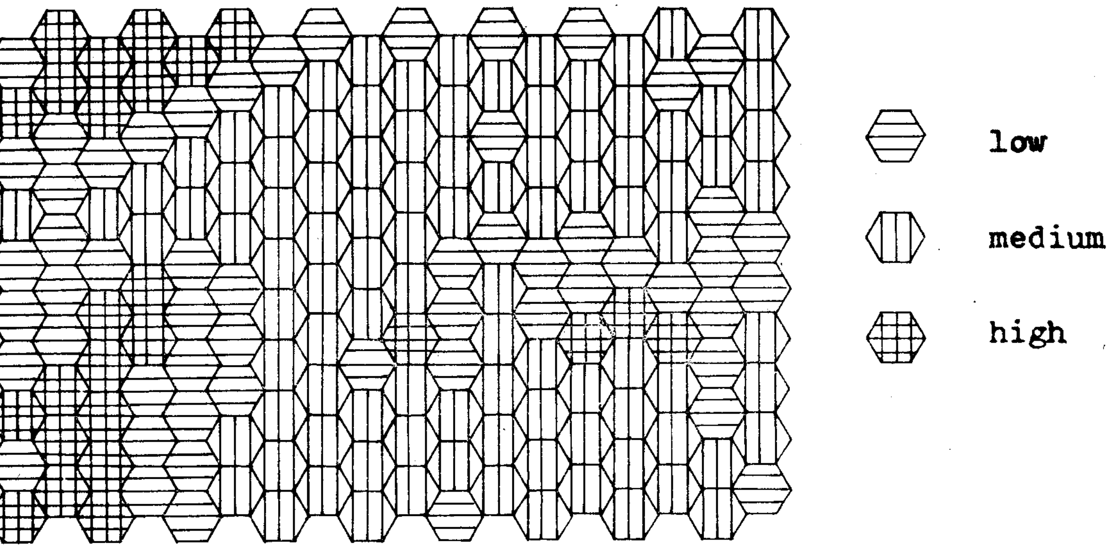

Fig. 6: A specimen of a computer of the regionalization of anthropogenic transformations of the relief in a part of the territory studied

The described information system about the territory makes it further possible to find out correlations between the individual characteristics, such as between potential erosion and individual factors influencing it.

Besides the above operations the described information system enables carrying out also the regionalization of the territory on the basis of selected parameters. This possibility was also utilized in the classification of the territory according to the degree of anthropogenic influence on the relief (Konečný M., 1980). The method was as follows: In the memory of the computer data is stored concerning the occurrence of one or more anthropogenic relief shapes according to the units of the discrete hexagonal network. Anthropogenic shapes were divided into groups according to their weight in the anthropogenic transformation of their surroundings. Maximum influence was thus ascribed to urban shapes and areas, tips, dumps, stone quarries, etc. A similar approach was employed in the scale of calculated data of the total erosion affected anthropogenically. These two data items, considered to be standard in determining anthropogene influence on the relief, were processed by the program which is a part of the program equipment of the system. The output of the program was a qualitative division of the studied territory according to the degree of anthropogene influence (Fig. 6).

Another advantage of the above system are the possibilities of completing it by means of a periodical collection of data on all characteristics followed in the course of a preselected time interval (5, 10, and more years). Such retrospective studies can then be utilized in forming prognoses of physical and socioeconomic processes and phenomena in the given territory based on the knowledge of the hitherto and the assumed anthropogene pressures. A periodic collection of data can on the other hand verify the prognoses formed on the basis of computer modelling based on theoretical assumptions.

One of the basic fulfilled requirements on the system is the simplicity of the access to the formation of geographical and cartographical models not only for specialists, but also for current users from practice.

The present state of procession of geographic data by means of computing technology was achieved in cooperation with the workers of the Institute of Computer Technology, J. E. Purkyně University, Dr. V. Račanský, Ing. K. Rais, and M. Drášil to whom I should like to thank.

4. COMPUTER CARTOGRAPHY

In the first part of the present paper mention was made of the fact that the department of information systems was only a contract institution, since both components are closely connected in our research and their activities percolate.

Computer cartography is a relatively new trend in cartography, which has had its rapid development in the last twenty-five years. Computer cartography is an effective tool of the information management. It makes it possible to map and process extensive amounts of space data. It thus becomes a means of analysis and interpretation of information for different types of theoretical as well as practical applications. Unlike traditional cartography, where the making and above all the production of a map takes a lot of time, the production of computer maps is very quick, immediately continuing the information stored in the computer memory. Computer maps have in essence taken over the advantages of computer units, enabling us to quickly process a great amount of data as well as its graphical presentation. The research worker and the computer form a kind of "symbiosis" in the processing, he takes his orientation according to graphical networks contained in the maps, without which he would be unable to interpret the results correctly.

The first assumption for the utilization and work with computer maps is the formation of the cartographical data base. That contains at least the x—y coordinates describing the shape of the studied territory and/or parts In our case the data base is related to the system of hexagons covering a territory of irregular shape.

Another part of the data base is, as a rule, constituted by conventinal thematical and statistical data. Those parts of the data base are considered to be independent entities existing side by side.

The computer mapping system consists of three components:

1. Collecting data
2. Processing data
3. Information display

The first two points have been dealt with above, where the possibility of printing the individual data items has been mentioned according to the units of the discrete network. In further research a transition to more advantageous recorders and digigraphs is prepared which are connected with special terminals enabling putting down graphs and figures by means of multicolour pens and accuracy of tenths and hundredths of millimetres.

5. CONCLUSION

Generally it can be said that great possibilities of the present computing systems in geographical research have not been utilized fully so far. The reserves consist both in the technical improvement of the abilities of the individual solvers to be employed in above all synthetical and complex studies with the aid of computing technology, and in the sphere of technical equipment. As has been stated above, special terminals of computers of the SMEP series are not yet utilized for a quick procession and printing of information, as well as coordinate recorders for the making of maps and the graphical interpretation of the results obtained.

The author of this paper sees here a broad sphere of possibilities for the utilization of geographical results by means of computer maps or formation of information systems. The formation of the information system about a territory is a realistic attempt at utilizing computing technology in geography as a mathematically non-traditional sphere. Hitherto experience and approaches, as well as trends in the world geographical and cartographical sciences hint at a further deepening in the utilization of computer technology not only in theory, but also in practice.

REFERENCES

Armand A. D. (1973): Geografia i EVM. Izv. AN SSSR, serija geografičeskaja, č. 4: 126—130.

Berljant A. M. (1980): Geografičeskaja kartografija, jejo razvitije i novyje zadači. Izd. MU. Moskva.

Demek J., ed., (1972): Manual of Detailed Geomorphological Mapping. 344.

Demek J. (1978): Teorie a metodologie současné geografie. Studia Geographica 65. 137.

Gould P. (1969): Computer and Spatial Analysis: Extensions of Geographic Research. Geoforum, 1.

Hagget P. (1969): On Geographical Research in a Computer Environment. The Geographical Journal, 135, 1—4.

Hynek A. a kol. (1980): Teritoriální systém Rosicka—Oslavanska a jeho potenciál. Závěrečná zpráva DÚ II-5-4-1.

Hynek A., Konečný M., Rais K. (1978): Počítačový kartogram dyjské soutěsky. ISOFGK. Brno.

Konečný M. (1978): K vyjádření antropogenních vlivů na reliéf v geomorfologických mapách. Scripta Fac. Sci. Nat. UJEP Brunensis. Geographia I, 9: 27—34.

Konečný M. (1980): Anthropogenic Geomorphology: Questions, Problems, Tasks. Sb. ČSGS, 1; 21—28.

Konečný M. (1981): Využití matematicko-kartografického modelování při řešení vybraných geomorfologických úkolů. Sb. XV. sjezdu ČSGS. Brno.

Langefors B. (1966): Theoretical Analysis of Information Systems.

Simonov Ju. G. (1975): Někotoryje mysli ob avtomatizacii geografičeskich issledovanij. Vest. MGU, 4: 36—42.

Stehlík O. (1970): Geografická rajonizace eroze půdy; metodika zpracování. Studia Geographica, 13. 44.

Stehlík O. (1971): Eroze půdy proudící vodou na území okresu Bruntál. Studia Geographica, 22: 103—118.

Tomlinson R. F. a kol. (1976): Computer Handling of Geographical Data. The UNESCO Press. 214.
Vasilevskij L. I., Medvedkov Ju. V. (1976): Perspektivy matematičeskich metodov v geografii. Voprosy geografii 100: 93—108.
Žukov V. T. a kol. (1980): Matematiko-kartografičeskoje modelirovanijə v geografii. Izd. Mysl. Moskva. 223.