THE QUANTITATIVE METHODS OF PALAEOGEOGRAPHICAL RECONSTRUCTION

(Methodological guidelines for the IUGS–RDP Project "Neogene palaeogeographical maps of Central and Eastern Europe")

by

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INTRODUCTION

A modern and pragmatic palaeogeographical reconstruction of dynamic views is assumed to have been based on large numbers of standard data. It is also plain that all the pertaining qualitative definitions should be supported by due quantitative determinations.

This demand, however, cannot be invariably met everywhere, at all times and on every scale given. In our experience, it is most problematical to standardize basic data recorded during some decades. As for this, it can be foretold that differences in qualification, sphere of interest and perceiving power of the recorders, moreover the changing technical conditions (grade of efficiency in recovering drill cores, the extent and quality of laboratory works etc) might arouse difficulties. So it was felt necessary to settle the optimum sphere of data, which can be produced consistently, even if the quality of the constituent basic data is unlike. After due consideration it was decided to include megascopical observations relating to the examination of surface exposures and borehole logging, along with the lithological data selected from the instrumental measurements provided by borehole sounding. Out of the laboratory tests and analyses, the results of the commonest or "routine" ones are to be dealt with. For the interpretation of data, a frequency statistical approach based upon mean values has been chosen, regarding it as the simplest and most economic in cost and time.

Beyond its simplicity, the concerned method has also other advantages. In the first place, a large number of data is secured thereby, with no need for special pre-qualification to gain them. Moreover, data yielded by individual examinations of high scientific value and those provided by serial tests can be synthesized. The arrays of data produced are practicable for any level or phase of geological investigation, and they are convertible in many ways. Missing arrays of data can be retrieved upon interpretation, or substituted. Another benefit concerning the feasible graphic representations (in profiles, in space and time, on maps) allows the unknown parts to be predicted.

Nevertheless, a decisive advantage of the quantitative interpretation, as compared with the former methods of palaeogeological reconstruction, should be emphasized. Namely, all the former methods are closely bound up with the study of single beds or outcrops, even if on a high level of examination, enabling only to draw up the pertaining snapshot-like pictures of geological development. At the same time, the quantitative method will provide the understanding of a full sequence of events of any time span (including geohistorical times) and in any space, with the pertinent and complete characterization on a possibly exact basis of major geological units of regional extent and with a thickness of some thousand metres. Consequently, the general tectonic setting, the energy and directions of debris transportation, the variations of facies pattern, and all the palaeogeographical picture will be better reconstructed than by any former method.

With the introduction of this method, the scope of characterization of formations, areas etc can be expanded and parameters of the forthcoming (and more expensive) investigations outlined, including the possibilities of computer processing and self-development, too.

1. DATA COLLECTING SYSTEM

1.1. PREPARATORY WORKS

The first thing to embark on this work is the preparation of the contents of borehole logs, exposure descriptions and field geological note-books. This is the most important point of decision-making, since in regard with this material, only mechanical evaluations and hardly feasible corrections can be made during the subsequent steps of elaboration; this fact also is in favour of the computer processing. Moreover, these primary documents are assumed to involve the possibility of mass interpretation, for the results of laboratory analyses are attached only to several sections..

1.1.1. Separation of lithological units

Geological boundaries should be taken into consideration according to the original descriptions. Exception is to be made for the case when a more detailed quantifiable definition is derivable from the original log (e.g. "Sandbed ranging from 65.0 m to 75.5 m with pebbles contained in the uppermost 2 m". After revision, this statement will be modified as follows: "65.0 m–67.0 m: Pebbly sand; 67.0 m–75.5 m: Sand"). An additional specification is feasible upon the differences in such features as grain-size, colour, texture, apparent sedimentological peculiarities, appearance and disappearance of fossils according to bedding etc.

On the other hand, data may be drawn together e.g. when the description of samples from a borehole is joined with the cored intervals or it is done mechanically from metre to metre, and no boundary but only the depth in metres is to be recorded. Stratification by itself cannot be taken for geological boundary, however, units of unlike bedding of the one and the same rock type are to be distinguished. In this phase of work the statistical evaluation is aimed at the outlining of changes as suggested by differences. To represent bed thicknesses by numerals marked together with the concerned bed, an accuracy of 0.1 m is required.

Micro- and mesocycles should be marked to scale with their transgressive or regressive character denoted. When allowed by the borehole logs being at disposal, lithostratigraphical (formation) and chronostratigraphical boundaries should also be marked.

1.1.2. Denomination of rocks

Beds are petrographically classified according to the prevailing particle size: pebble, sand, silt, clay (with claymarl), limestone (with calcareous marl), coal and volcanics.

In the case of more than one lithological attributes, the name of the prevailing rock is to be chosen. Thus "fine-sandy, micaceous and silty clay" should be classified as "clay". If "volcanics" constitute an independent formation, their further subdivision can be readily done: units such as lava, agglomerate, tuff (or tuffite) will be distinguished.

Distinction should be made between syngenetic and reworked volcanic products. In this phase of work, out of the category of volcanics only the syngenetic volcanic rocks that are assumed to have been formed as separate strata, are taken into account. "Tuffaceous" or "biotitic" strata or rocks containing basically reworked volcanic material, are only classified according to the predominant size of their particles, e.g. as "sand". It is understood that the presence of "pure" limestone or evaporite etc may also involve the setting up of proper genetic systems of classification.

Since the convenient lower limit to a lithological division seems to be as low as 0.1 m, the case of a rock composed of alternating bands of clay and sand be exemplified here. In regard with this, the twofold lithological character will appear statistically by half-and-half quantities of the components, or, if determinable, by their actual shares. Accordingly, a 6-metre-thick sandbanded clay bed will represent 3 m for clay and 3 m for sand. If we know that the concerned bed consists of 0.05-m-thick clay streaks alternating with 0.2-m-thick sandbands, then in the statistics it can be put by 1.2 m and 4.8 m for clay and sand, respectively.

Simultaneously with the qualification of beds, other tasks can also be performed, namely:

– Colour statistics, dealing simply with colours by themselves or with colours in combination with beds (e.g. the colour of a formation established statistically upon colours of the different composing beds or the colour of sands only, likewise according to the colour statistics of the composing sandbeds);

– A refined specification of "pebbles" upon dealing with rock quality, particle size, roundness etc, given in percentage of frequency, weight or areal extent.

When data from laboratory treatment are registered in the drilling documentation, a further specification is feasible:

– Sands (particle size, heavy minerals content etc);

– Volcanics (microscopical features, chemical analyses etc);

– Mineral raw materials (e.g. classification of coals according to heating value, constituents etc).

1.1.3. Specific sedimentological features

The preparation of the drilling documentation to be scrutinized continues by enhancing additional important data therein (with the use of underlining or symbols). If possible, a full sphere of sedimentary features be examined as required by the sedimentary facies type concerned. Observations relating with the one-time dynamic conditions of sedimentation are particularly important as regarding gradation, stratification (laminite, microstratification, streakybanded stratification); traces of mud flow, bioturbation, intercalations or lenses (pebbles, carbonate, reworked volcanics); facies-indicating sediments (anhydrite, gypsum, coal etc) and concretions etc, together with their accurate position, extent and repetition.

1.1.4. Specific fossil contents

References to biological features likewise should be marked, expediently by other colour (root remnants, coalified or silicified plant remains; strings, bands or beds of coal; diatomaceous interbeddings; defined and undefined sole markings, lumachelle banks, biogenic limestones, special and rare fossil material (vertebrate bones, fish scales etc).

The level of appearance/disappearance of various facies index fossils, which are often found in borehole sections, is also to be stressed (Lithothamnium, pteropods, corals, Pectens, larger foraminifers etc).

1.1.5. Preparations for graphic data interpretation

The borehole log checked up according to the viewpoints described above, is to be represented by columnar section drawn to a proper scale. A key must be provided indicating the different beds (formations) as defined previously. Micro- and mesocycles, formations, boundaries and dimensions of chronostratigraphical units be indicated on a numerical basis. The other side of the column will display marks showing the specific sedimentological features and the accurate position of the fossils found. (These be put up first, since the indication of cycles might much depend thereon.)

Results of laboratory tests and analyses, if any, will be presented diagrammatically on the right of the columnar section: petrological composition, carbonate content, megaflora/microflora, megafauna/microfauna, number of taxons by beds, moreover: geophysical borehole log etc.

After completing the processing of data, the textual and graphic documentation should be supervised mutually, with the necessary corrections to be made.

The prepared borehole sections should be put along lengthwise and cross profile directions set up across the sedimentary basin outlined in a first approach. Now the position of boreholes will be marked upon the profile line at unit paces, however, with the statistical evaluation done, the topographical correction of the borehole sites as putting them on the right places must be carried out.

Dashed line is used to show the boundaries of meso- and megacycles, formations and chronostratigraphical units.

1.2. METHODS OF DATA COLLECTING

Data are collected as original or calculated ones on Data Sheets I, II, III and IV. They are registered to constitute a basis for the graphic interpretation to be done. Data processing is executed in a gradual way, with a progress from individual data towards generalizations, giving syntheses of geological-palaeontological, faciological, palaeogeographical and structure geological facts upon quantitative determinations and making the demonstrated scientific regularities so as proved on an exact basis, too.

1.2.1. Data Sheet I is devoted to the collection of the bed-statistical data of individual borehole sections (Table 1).

Name, serial number and symbol of borehole: Garáb 1 (G. 1)
Formation: Garáb Schlier Formation
Thickness: 400 m
e.g. thickness of Cycle 2=100 m (mesocycle)

Part 1: Data of cycle

Rock composition (in the columns, bed thickness is to be marked with an accuracy of 0.1 m)

e.g. Sedimentary Cycle 2 (mesocycle)	Pebbles	Sand	Silt	Clay
Data for beds (metres), thickness of the separate rocks	0,3 2,1 0,2 1,2 1,2	3,0 6,5 3,5 2,0	14,2 6,8 9,0 8,5 1,5 10,0	7,3 8,7 4,0 4,5 5,5
Sum total (metres)	5,0	15,0	50,0	30,0
The same given in % (in the case of a cycle 100 m thich) =rock composition	5,0	15	50	30
Thickness or stratification of rocks e.g. pebbles, sum of metres, number of pebbly beds	$\frac{5}{5}$=1.0 m	$\frac{15}{4}$=3.7 m	$\frac{50}{6}$=8.3 m	$\frac{30}{5}$=6.0 m
Average stratification of Cycle 2	$\frac{\text{total thickness of cycle}}{\text{number of beds}} : \frac{100}{20} = 5.0$ m			

Part 3: Formation data

Beds of the Garáb Schlier Formation in borehole Garáb 1, in cycles 1+2+3 . . . in total (metres)	10	70	220	100
Rock composition of the Garáb Schlier Formation in Borehole Garáb 1: total pebble, sand etc. contents (m), given in % in proportion to the formation thickness	2.5	17.5	55.0	25.0
Average thickness (or stratification) of the Garáb Schlier Formation in borehole Garáb 1: cycles 1, 2, 3 . . . total pebble, sands etc/the number of beds	$\frac{10}{8}$= 1.2 m	$\frac{70}{16}$=4.3 m	$\frac{220}{72}$=3.0 m	$\frac{100}{23}$=4.3 m
Average bedding of the Garáb Schlier Formation in borehole Garáb 1	total formation thickness/total number of beds = $\frac{400}{119}$=3.3 m			

for each borehole *Table 1*

Part 2: Other quantitative data for each sedimentary cycle (mesocycle)

e.g. type, number and thickness of microcycles belonging to the Cycle 2

transgressive (number)	regressive (number)	total (number)	thicknesses (m) (rocks get younger from below upwards)		total thickness of Cycle 2 (m)
			transgressive	regressive	
2	1	3	25.5 52.0	 22.5	100.0

Frequency of the specific sedimentological features belonging to the Cycle 2 (number)

laminite	mud movement	bioturbation	gravel string	carbonate peak	reworked volcanics	total
3	1	0	1	0	2	7

Frequency of the biofacies elements in the Cycle 2

Brissopsis zone	Coral zone	Pteropoda zone	number of mega-fauna taxons	number of Forami-nifera taxons	number of Forami-nifera cycles	number of micro-flora cycles	other	total (taxon with-out number)
2	0	0	7	23	3	2	–	7

Frequency of the Earth-historical events (number of events): (in the Cycle 2) $\frac{\text{lithological}}{\text{biofacies}} = \frac{7}{7}$, in total = 14

Part 4: Other quantitative data for each formation

e.g. type, number and thickness of mesocycles of the Garáb Schlier Formation

transgressive (number)	regressive (number)	total (number)	thickness (m) (rocks get younger from below upwards)		Garáb Schlier Formation (m)
			transgressive	regressive	
2	1	3	240.0 100.0	60.0	400.0
consisting of 6 micro-cycles	consisting of 2 micro-cycles	8 microcycles in total			

Frequency of specific sedimentological features in the Garáb Schlier Formation

Columns corresponding to those of the mesocycles
Data for mesocycles 1+2+3=Σ

Frequency of the specific biofacies elements in the Garáb Schlier Formation

Columns corresponding to those of the mesocycles
Data for mesocycles 1+2+3=Σ

Number of Earth-historical events of the Garáb Schlier Formation (event number)	$\frac{\text{lithological=22}}{\text{biofacies=15}}$ Σ=37

This Data Sheet should collect data from the individual points of observations (outcrops, boreholes) so as to show well documented and interpreted informations for the local sphere of recording. Vertical changes are indicated to describe geohistorical events which are attested to by rocks and ancient life, with due parameters showing dimension and frequency.

Contents of the Data Sheet: parts 1 and 2 have a bearing on lithological, sedimentological and biofacial data of Parts 3 and 4 should show lithological, sedimentological and biofacial data of formations made up of mesocycles.

The Data Sheet will be used (a) to forthcoming synoptic Data Sheets, (b) at the time of corrections of the borehole sections drawn, (c) and when correlations of lithologies, cycles, formations, biofacies and geofacies of the borehole sections set in profile lines are to be done.

1.2.2. **Data Sheet II serves as a summarizing areal register of bed-statistical data** (Table 2).

The goal of this Data Sheet is that the local reference spheres of point-observations be developed into major units such as (using examples taken from Hungary), full or partial sedimentary basins (Garáb "Basin"), facies zones (Zagyva Trough) or geographical land unit (Börzsöny-Cserhát-Mátra-Nógrád).

An additional purpose is to characterize areal units according to vertical changes (changes in time), with summarization of the local geohistorical events.

The Data Sheet will be used (a) to forthcoming synoptic Data Sheets, (b) at the time of preparing documentation regarding the textual characterization of lithostratigraphical systems, (c) during the geodynamic comparative studies of the individual areal units and (d) when plotting lithological maps with key.

1.2.3. **Data Sheet III is devoted to the summarization of bed-statistical data according to chronostratigraphical units** (Table 3)

The goal of filling in this Data Sheet is that the geohistorical events of a greater time span be summarized and vertical (timely) changes proved on an exact basis. Correlation and even a further reconnaissance of interrelated geostructural (in case, global) events, the course of megacyclic sedimentation, life evolution and litho-bio-chronostratigraphy. The possibility of the screening out of data dependent upon local or facial conditions, and the suitability for graphic representations should be secured. Contents: Means of lithological, sedimentological, biofacial data for major areas and time units on the basis of the processing of all basic data collected.

The Data Sheet will be used

– when preparing quantitative diagrams showing changes in time in regard with the chronostratigraphical units given,

– when elaborating the generalized stratigraphic columnar section, litho-bio-chronostratigraphic and tectonic scales of an area given, and

– during stratigraphical, facies and palaeogeographical interpretations.

Table 2

Data Sheet II: Areal summary
(Checked similarly to Data Sheet I)

Part 1: Areal summarization of cycles (for area, a sedimentary basin, a facies pattern area or a geological land unit may be taken)

	Pebble	Sand	Silt	Clay
1.1 e.g. total thickness in metres for each rock of Cycle 2 as observed in . . . boreholes				
1.2 The same for Cycle 2 in metre %				
1.3 Average thickness (or bedding) of the formation of Cycle 2 e.g.: total thickness of pebbles/number of pebbly beds				
1.4 Average stratification of Cycle 2 in the area	Total thickness (m) of Cycle 2 drilled in . . . holes/total number of beds penetrated=metre			

Part 2: Areal formation summary (for area, a sedimentary basin, a facies pattern area or a geological land unit may be taken)

	Pebble	Sand	Silt	Clay
2.1 e.g. total thickness in metres for each rock of the Garäb Schlier Formation as observed in . . . boreholes				
2.2 The same for the formation in metre %				
2.3 Average thickness (or bedding) of the Garäb Schlier Formation e.g. total thickness of pebbles/number of pebbly beds				
2.4 Average stratification of Garäb Schlier Formation in the area	Total thickness (m) of the Garäb Schlier Formation drilled in . . . holes/total number of beds penetrated=metre			

Table 3

Serial number 1.				Egyházas-gerge Formation	Garáb Schlier Formation			Fót Formation
1	**Data Sheet III:**							
2	**Summarization of chronostratigraphical units (e.g. variations in time of cycles belonging to Karpatian time)**			Mesocycle 1	Mesocycle 2	Mesocycle 3	Mesocycle 4	Mesocycle 5
3			Borehole tested	Nb.317.327 T.35.39.40 Sh.16. Kt.483. Mb.79.122 NSz. 3. — —	Nb.317.327 T.35.39.40 Sh.16. Kt.483. Mb.79.122 Nsz. 3. G. 1. —	Nb.317.327 T.35.39.40 Sh.16. Kt.483. Mv.79.122 NSz. 3. G. 1. Li. 17.	Nb.317.327 T.35.39.40 Sh.16. Kt.483. Mv.122. — G. 1. Li. 17.	Nb.317.327 T.35.39.40 Sh.16. — Mv.122. — G. 1. Li. 17.
	2.	3.		4.	5.	6.	7.	8.
4	Average thickness of cycle			92	120	97	128	81
5	Average thickness of formation			13.4	23.6	26.0	25.8	7.6
6	Microcycles	trans-gressive	average number per borehole	2	2	1	3	1
7			average thickness (m)	44	56	46	54	56
8		re-gressive	average number per borehole	0	1	1	0	2
9			average tchickness (m)	0	30	45	0	26
10		Frequency of the carbonate interbeddings		7	9	11	8	9

Table 3 (continuation)

1.	2.	3.	4.	5.	6.	7.	8.
11	Rock composition %	pebble	0	0	0	0	0
12		sand	58.1	11.5	15.6	7.8	23.4
13		pebble + sand	58.1	11.5	15.6	7.8	23.4
14		silt	38.5	66.1	58.3	61.1	47.4
15		sand + silt	96.6	77.6	73.9	68.9	70.8
16		clay (including limestone)	3.2	22.2	26.0	31.0	29.0
17	Frequency of the specific sedi-mentological features	pebble interbedding	10	1	2	0	2
18		laminite	12	20	13	12	5
19		mud movement	3	11	24	10	15
20		tuff, reworked tuff, bentonite	3	3	3	17	20
21		bioturbation	9	14	11	9	2
22	Number of lithological events	maximum	12	11	17	20	17
23		minimum	4	4	4	3	3
24		average	7	8	7	9	8
25	Average per borehole of the	number of megafauna species	1	13	18	22	5
26		number of Foraminifera species	20	33	38	38	17
27		number of Foraminifera cycles	2	2	4	3	2
28	Frequency of characteristic fossils	Brissopsis	2	5	12	10	4
29		Coral	0	1	3	4	1
30		Nautilus	1	0	4	2	1
31		Pteropoda	1	2	5	6	0
32		Pecten	6	1	1	3	0
33		suspension feeder	9	14	11	9	2
34	Number of bioevents characteristic fossils	maximum	5	8	9	13	8
35		minimum	1	2	1	1	1
36		average	3.4	3.7	5.0	4.5	3.3

Entries into Data Sheet III (according to serial numbers on the left-hand side margin)

1 Denomination of the lithostratigraphical formations that build up the chronostratigraphical unit chosen.

2 Serial number for the mesocycle building up the lithostratigraphical unit.

3 Symbol and serial number of borehole penetrating the mesocycle.

4 Total thickness of mesocycles measured in every borehole, divided with the number of boreholes.

5 Sum of beddings upon averages for each borehole divided by the number of boreholes.

6 The number of all transgressive microcycles that build up mesocycles as observed in all boreholes, divided with the number of boreholes.

7 Total thickness of transgressive microcycles in all boreholes, divided with the number of transgressive microcycles.

8 See 6, for regressive microcycle.

9 See 7, for regressive microcycle.

10 Total number of carbonate intercalations in all boreholes penetrating the mesocycle.

11, 12, 14, 16 Total thickness of pebble, sand, silt and clay added in all boreholes for the mesocycle, expressed as a percentage proportion to the sum of drilled intervals (e.g. in 10 holes 100 m was drilled with 52 m of sand; this equals 52%).

13 Pebble%+sand%.

15 Sand%+silt%.

17, 18, 19, 20, 21 Total number of laminites and tuff intercalations etc in all boreholes penetrating the mesocycle.

22 Filled in according to the borehole section testifying to the maximum number of lithological events, out of those holes which penetrated the mesocycle (event number=number of microcycles+number of specific sedimentological features).

23 Filled in according to the borehole section testifying to the minimum number of lithological events, out of those holes which penetrated the mesocycle.

24 Total number of lithological events (=number of microcycles+number of specific sedimentological features) observed in all boreholes penetrating the mesocycle, divided with the number of boreholes (rounded off by 0.5).

25, 26 Sum of megafauna and microfauna taxons determined for every borehole divided with the total number of boreholes [e.g. Cycle 5 is penetrated by 3 holes (1, 2, 3) with 32, 20 and 9 species collected respectively; it makes 61; 61:3=20].

27 Total number of Foraminifera cycles in all boreholes penetrating the mesocycle, divided with the number of sections.

28, 29, 30, 31, 32, 33 Number of specific fossils in a horizon as observed in all boreholes penetrating the mesocycle.

34 Filled in according to the borehole section testifying to the maximum number of biological events, out of the holes which have penetrated the mesocycle (event number=number of Foraminifera cycles+number of specific fossiliferous horizons).

35 Filled in according to the borehole section testifying to the minimum number of biological events, out of the holes penetrating the mesocycle.

36 Total number of biological events (=number of Foraminifera cycles+number of specific fossiliferous horizons) observed in all boreholes, divided with the number of boreholes.

1.2.4. **Data Sheet IV, for the lateral facies belts to be summarized** (Table 4)

The goal of starting to keep this kind of blank is to deal comprehensively with all data registered on Data Sheets I to III. These vertically collected and evaluated data now have to be made interpretable in horizontal extension i.e. in space, too. Besides the characterization of the lateral facies belts in terms of distance from coastline, there are other joint tasks to be performed. Firstly, an exact and provable definition of the lithological, sedimentological and biological changes is to be given. Then it comes to decide how the structure, morphology and rocks of the sedimentary basin, and the distribution of the former animal and plant life are interrelated. Finally, significant facies data are assumed to have been made suitable for diagrammatic representation and proper evaluation. The interpretation in space is, naturally, connected with time units i.e. with longer and shorter time intervals.

As for the contents, a large number of basic data bearing on extensive areas and time units should be incorporated. These are assumed to have been grouped upon the averaging of all relevant lithological, sedimentological and biofacial data.

This Data Sheet can be put to use when plotting the following drafts

– diagrams to show on a quantitative basis the constitution and variation in space of the lithological, lithostratigraphical or chronostratigraphical units involved,

– palaeogeographical and facies maps,

– lithological maps,

– space/time geodynamic charts.

Entries into Data Sheet IV (according to serial numbers on the left-hand side margin)

Here the lateral facies variations of the individual litho- and chronostratigraphical units are documented.

1 Denomination of lateral facies belts in terms of their distance from the coastline.

2 Coast-distance ratio: calculated for each borehole on the basis of Data Sheet I; the total drilled thickness of a unit (mesocycle, formation, stage) divided with the average bedding. (Example: Karpatian beds are as thick as 400 m in borehole Tar 39; the average bedding represents 5.8 m; 400/5.8=68.9. So the borehole site falls in the facies belt bounded by the ratios 50 and 75. The zonation based on the coast-distance ratios can be characterized by the following notions:

– In the case of a transgressive geological megacycle, betwen the theoretical limiting values of 100 (=basin edge) and 0 (=basin centre) the following zonation is made: 100–75: littoral, 70–50: sublittoral forespace depression, 50–25: sublittoral and below 25 the presence of an open marine facies is verifiable.

– In the case of a regressive geological megacycle, the ratio appears reversely: 0=basin edge, 100=basin centre (theoretical values). Note: For non-marine sedimentary environments, the coast--distance ratio has an identical interpretation.

3 Symbol and serial number of the boreholes penetrating the facies belt.

4 Metres drilled in total as penetrating the unit in the facies belt, divided with the total number of beds intersected (rounded off by 0.5).

5, 7 In the case of transgressive geological megacycles, the most characteristic microcycle number (e.g. if it is 3 for 5 holes and 4 for 2 holes, then the most frequent microcycle number is 3), observed in boreholes set in the facies belts. In the case of regressive geological megacycle, the average number of microcycles is taken (e.g. if it is 15 for 4 holes, the mean value is 15:4=3.7=4). (Geological megacycles should be differentiated, since the advancing transgression of a transgressive geological megacycle sets down deposits above one another with an increasingly open marine character.)

Table 4

Data Sheet IV: Summarization of facies units e.g. the variation in space of the Karpatian sedimentary cycles (summarized data)

Serial number 1.				Facies belts			
1				littoral	forespace depression	sublittoral	pelagic
				coast-distance ratio			
2				>75	>50	>25	<25
3			Borehole tested	Kt. 483. Mv. 122.	Sh. 416. Nb. 327.	T. 35. T. 40. Nb. 317. G. 1.	NSz. 3. T. 39. Li. 17. Mv. 79.
	2.	3.		4.	5.	6.	7.
4	Average formation thickness			5.7	12.0	14.7	17.6
5	Microcycles	trans-gressive	average number per borehole	1	2	2	5
6			average thickness (m)	53	64	47	46
7		reg-ressive	average number per borehole	1	1	1	1
8			average thickness (m)	33	29	31	40
9	Frequency of carbonate interbedding			12	1	7	11
10	Rock composition %	pebble		0	0	0	0
11		sand		41.3	27.2	32.8	35.9
12		pebble+sand		41.3	27.2	32.8	35.9
13		silt		50.2	56.0	45.8	26.8
14		sand+silt		91.5	83.2	78.6	62.7
15		clay (including limestone)		8.8	16.6	21.1	37.2

Table 4 (continuation)

1.	2.	3.	4.	5.	6.	7.
16	Frequency of the specific sedimentological features	pebble interbedding	3	3	3	4
17		laminite	18	10	15	6
18		mud movement	12	17	15	3
19		tuff, reworked tuff, bentonite	6	10	12	7
20		bioturbation	6	16	8	7
21	Number of lithological events	maximum	41	32	39	19
22		minimum	16	25	21	11
23		average	28	28	31	15
24	Average per borehole of the	number of megafauna species	24	?	12	12
25		number of Foraminifera species	58	?	36	31
26		number of Foraminifera cycles	12	?	9	7
27	Frequency of characteristic fossils	Brissopsis	13	8	5	12
28		Coral	3	2	0	3
29		Nautilus	1	0	4	2
30		Pteropoda	5	6	0	2
31		Pecten	4	1	0	3
32		suspension feeder	6	16	8	7
33	Number of bioevents	maximum	25	12	27	28
34		minimum	12	4	12	1
35		average	18	8	20	17
36	Average thickness	Maximum thickness of mesocycle 1 for each facies belt	X	C	117	X
37		Maximum thickness of mesocycle 2 for each facies belt	X	165	X	X
38		Maximum thickness of mesocycle 3 for each facies belt	126	X	X	X
39		Maximum thickness of mesocycle 4 for each facies belt	X	X	X	157
40		Maximum thickness of mesocycle 5 for each facies belt	165	X	X	X
41		Total thickness for each facies belt	483	627	520	486

6, 8 Thickness of the transgressive plus regressive microcycles divided with the joint number of transgressive/regressive microcycles, according the boreholes set in each facies belt.

9 Total number of the carbonate intercalations in borehole sections representing the facies belt.

10, 11, 13, 15 Per cent rock composition averages in drilled sections representing the facies belt (e.g. 60% sand in Borehole 1, 48% sand in Borehole 2 give 108/2=54% for the average sand content). Columns 10+11+13+15 make 100% (±0.1–0.2%).

12 Per cent values of Columns 10 and 11 as added.

14 Per cent values of Columns 11 and 13 as added.

16, 17, 18, 19, 20 Total number of laminite and mud flow etc records in boreholes representing the facies belt.

21 Maximum number of specific sedimentological features once recorded in a borehole chosen out of those sunk in the facies belt (see Columns 16–20 of the Data Sheet).

22 Minimum number of specific sedimentological features once recorded in a borehole chosen out of those sunk in the facies belt (see Columns 16–20 of the Data Sheet).

23 The average of Columns 21 and 22.

24, 25 Total number of megafauna and microfauna taxons recorded in each borehole sunk in the facies belt, divided with the number of sections examined.

26 Total number of Foraminifera cycles recorded in each borehole sunk in the facies belt, divided with the number of sections (numerals rounded).

27, 28, 29, 30, 31, 32 Total number of fossils characteristic of horizon recorded in each borehole sunk in the facies belt.

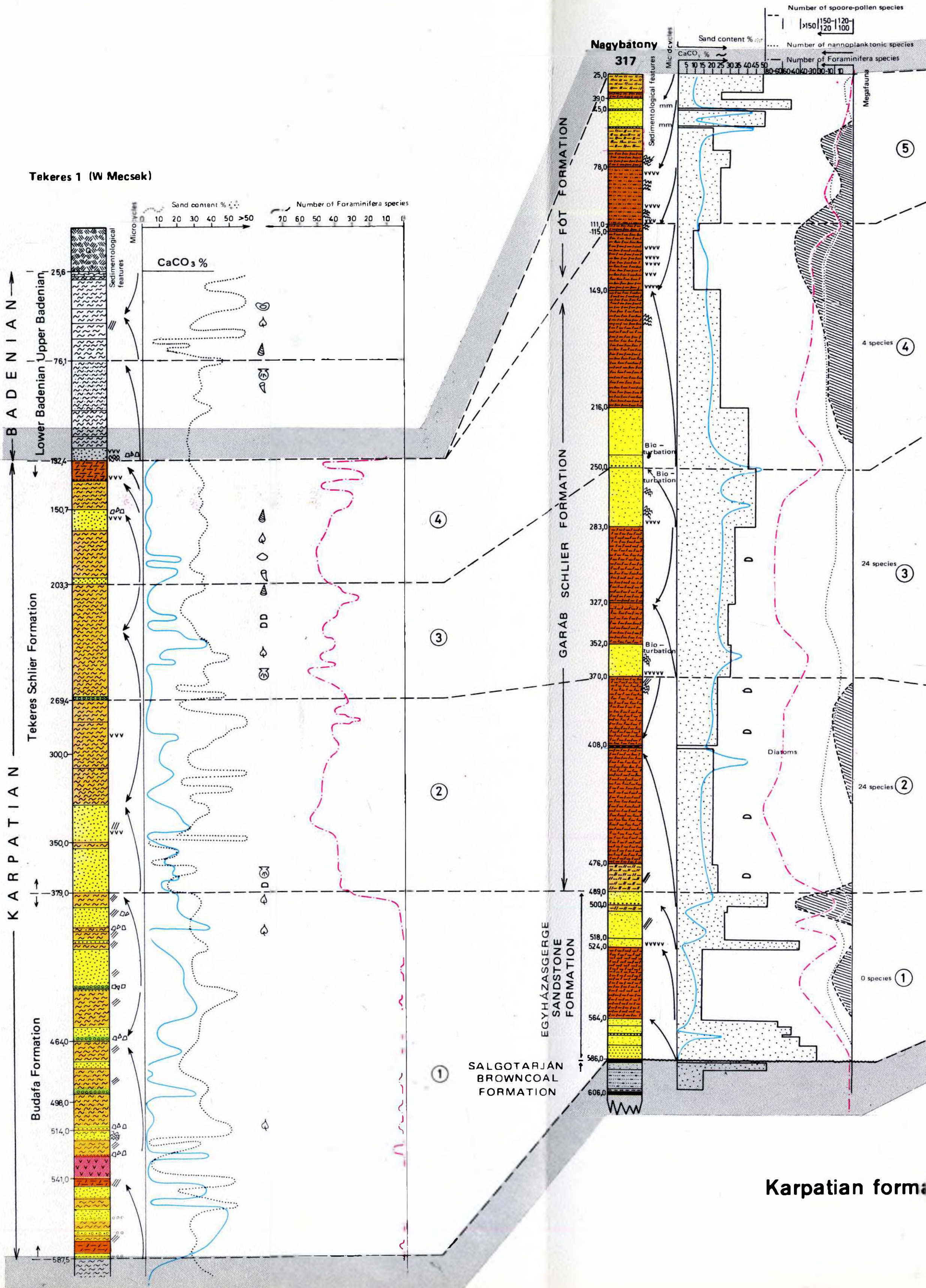
33 Maximum number of fossils characteristic of horizon as recorded in one borehole chosen out of those sunk in the facies belt plus the joint number of Foraminifera cycles.

34 Minimum number of fossils characteristic of horizon as recorded in one borehole chosen out of those sunk in the facies belt.

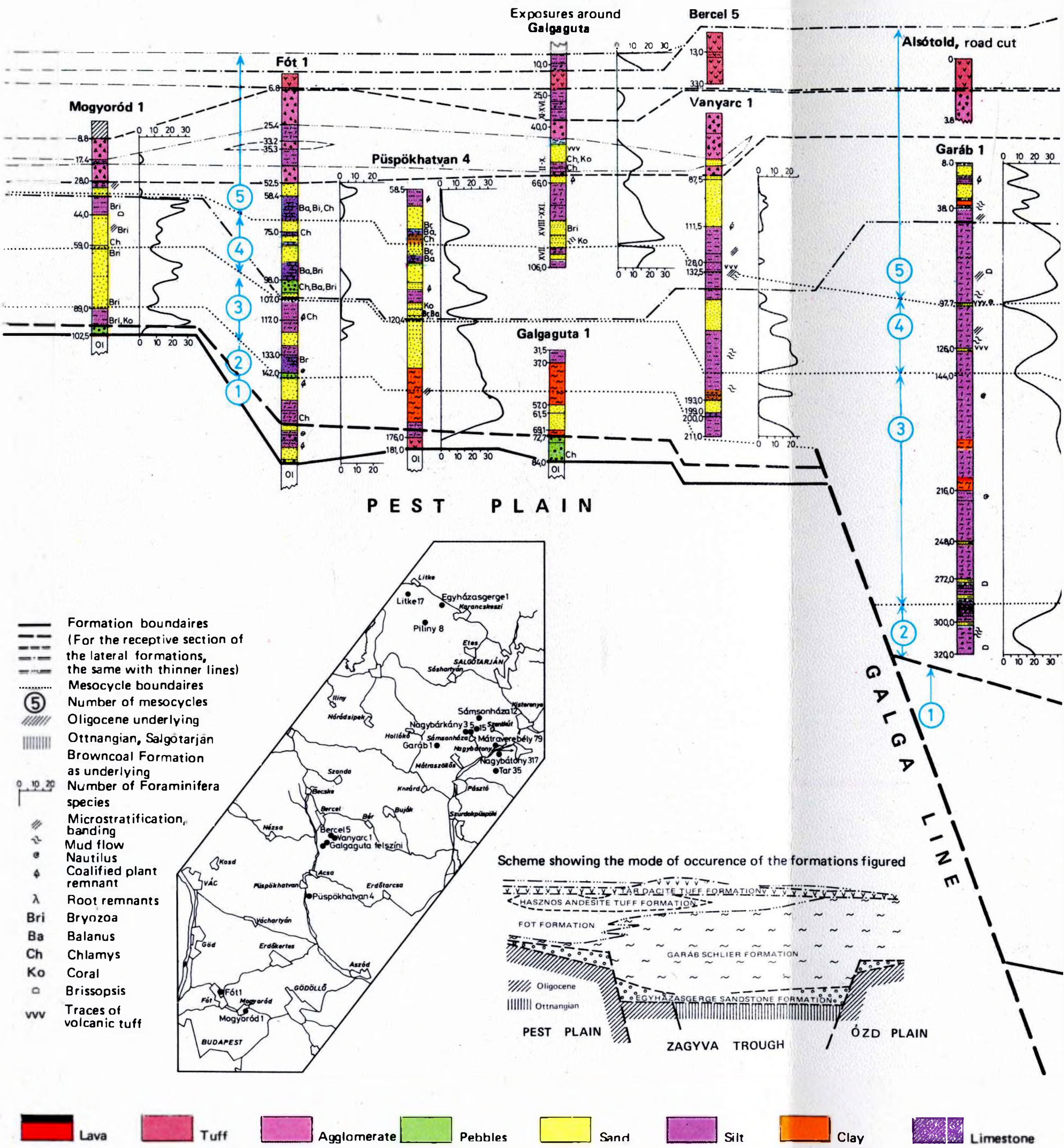
35 The average of Columns 33 and 34.

36, 37, 38, 39, 40 From the borehole sections representing the facies belt, the thicknesses of the individual mesocycles are added up and then divided with the number of boreholes. Into the corresponding place of the Table, the largest thickness of the formation is to be put.

41 From the borehole sections representing the facies belt, the thicknesses of the individual chrono-stratigraphical units are added up and divided with the number of boreholes.


Tekeres 1 (W Mecsek)
Microcycles
Sedimentological features
Sand content %
CaCO₃ %
Number of Foraminifera species
BADENIAN
Upper Badenian
Lower Badenian
KARPATIAN
Tekeres Schlier Formation
Budafa Formation
Nagybátony 317
Number of spoore-pollen species
Number of nannoplanktonic species
Megafauna
FÓT FORMATION
GARÁB SCHLIER FORMATION
EGYHÁZASGERGE SANDSTONE FORMATION
SALGOTARJÁN BROWNCOAL FORMATION
Bioturbation
Diatoms
4 species
24 species
0 species
Karpatian forma

Lithologies and sedimentary cycles of the Kar



2. THE GRAPHIC SYSTEM OF INTERPRETATION OF THE METHOD

2.1. GRAPHIC SUPPLEMENTS

The graphic supplements necessary for an on-the-way interpretation and correlation have already been mentioned above. Here two types and their aims are described.

2.1.1. Correlation charts (Fig. 1)

Correlation charts are prepared to document the descriptive logs of boreholes. To focus attention on the correlation of drilled sections, in the first place the cored holes belonging to the so-called key profiles are to be dealt with. These charts contain megascopical informations as restricted to the basic formations. In addition, sedimentological and palaeontological observations made in the field, moreover all laboratory data represented by diagrams–but, at least, the variation of per cent sand and $CaCO_3$ contents and the number of foraminiferal, nannoplanktonic and spore-pollen taxons should be shown according to formations.

This section type will secure the faculty of making reliable borehole sections (basic grid) easily adequate for the designation of correlable events (rhythmic and cyclic character of sedimentation, biological events etc) on the grounds of a maximum number of information.

After a manifold mutual control and correction of written documents, charts and quantitative statistical data, distinctions and determinations can be made in relation with the following essential features: microcycles and their character, the extent and character of mesocycles and the boundaries of lithostratigraphical formations. Between the individual key sections correlation can be made, using also the biostratigraphical data that exist.

2.1.2. Trend charts

Trend charts can be plotted along longitudinal and transversal directions chosen in accordance with the determining palaeogeographical situation. Only the vertical scale should be kept invariable. Thereby a picture of the geological makeup and lithostratigraphical structure of the chronostratigraphical unit can be sketched out. On the basis of trend charts it is possible to record approximately linear changes in the lithofacies, geofacies and biofacies, with the use of data and even quantitative data as far as possible.

2.1.2.1. For *the plotting of lithofacies sections* (Fig. 2), geological borehole logs are already used, even if they are not documented or examined in full. These logs may be important because of their site, decisive role in the solution of some detail questions, or as testifying simply to the thickness/depth conditions. Lithological data with sedimentological events indicated, moreover microfauna (mostly Foraminifera) cycles should be figured together with the following information: mesocycles, denomination and extent of the formations, the geological megacycles and the quality of bedrocks.

The aim of plotting lithofacies sections is to demonstrate variations in rock frequency and thickness. From this, parts of unlike mobility and bedrock morphology of the basement can be outlined. Furthermore, the possibility of "remote correlation" of the lithostratigraphical units and auxiliary documents for the correlation of the chronostratigraphical units should be supplied thereby.

From the lithofacies section, sections of bio- and geofacies can be derived (on the same scale, so as suitably drawn on a foil covering).

2.1.2.2. The biofacies section (Fig. 3) includes the quantitative information yielded by frequency statistics, which have been collected on Data Sheet for each borehole, and sporadic data. Along a section line the time of the appearance/disappearance, the position in space and zonation of the characteristic micro/megafauna (flora) associations, which had lived during the times represented by the chronostratigraphical unit given, are delineated. Decisive data are given here for the geofacies definition.

2.1.2.3. The geofacies section (Fig. 4) is plotted to show the position and movements in time of the single lateral facies belts, by a combined use of colours and hachures. Note in both section type the system, frequency and position of the interfingering facies.

When we put together the three section types in question, the following facts take shape:

– The constitution and the variation in space of lithostratigraphical formations;

– Site, temporal activities, syngenetic movements etc of the faults in the buried basement rocks;

– The basic data system for the maps of facies, palaeo-transportation and palaeogeography to be plotted later.

2.1.3. Synoptic sections

The object of this plotting is to generalize and synthesize in a graphic way the geohistorical events of each major zone (facies pattern, geological land unit) according to one or more chronostratigraphical units. As for this, besides outlining these geohistorical events in time, the extent in space of their consequences should be indicated for the area concerned.

Additionally, synoptic sections will provide a basis for the plotting of map variants. Their further application will be readily appreciated by a character of incorporating quantitative data bearing on geotectonics, volcanic activity, sedimentation and biofacies with regularities in their interrelation.

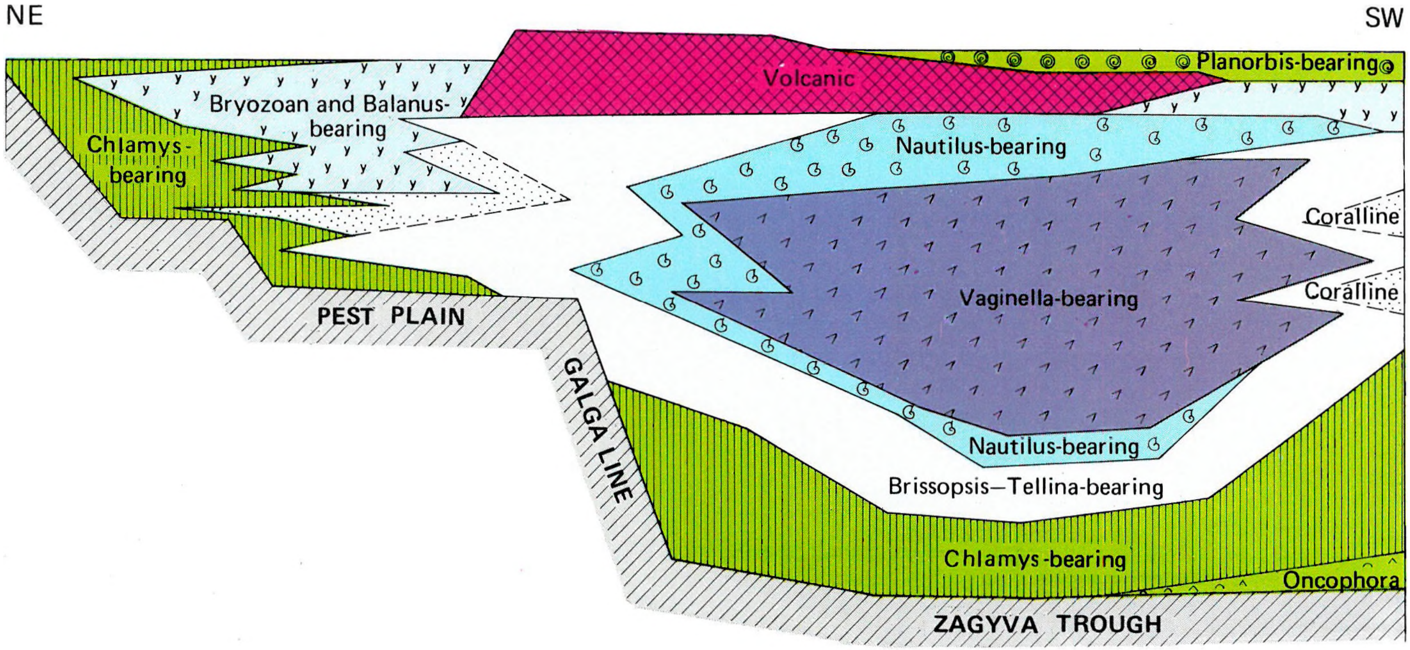


Fig. 3. Biofacies of the Karpatian formations in the Nógrád–Cserhát area (plotted by G. HÁMOR, 1979)

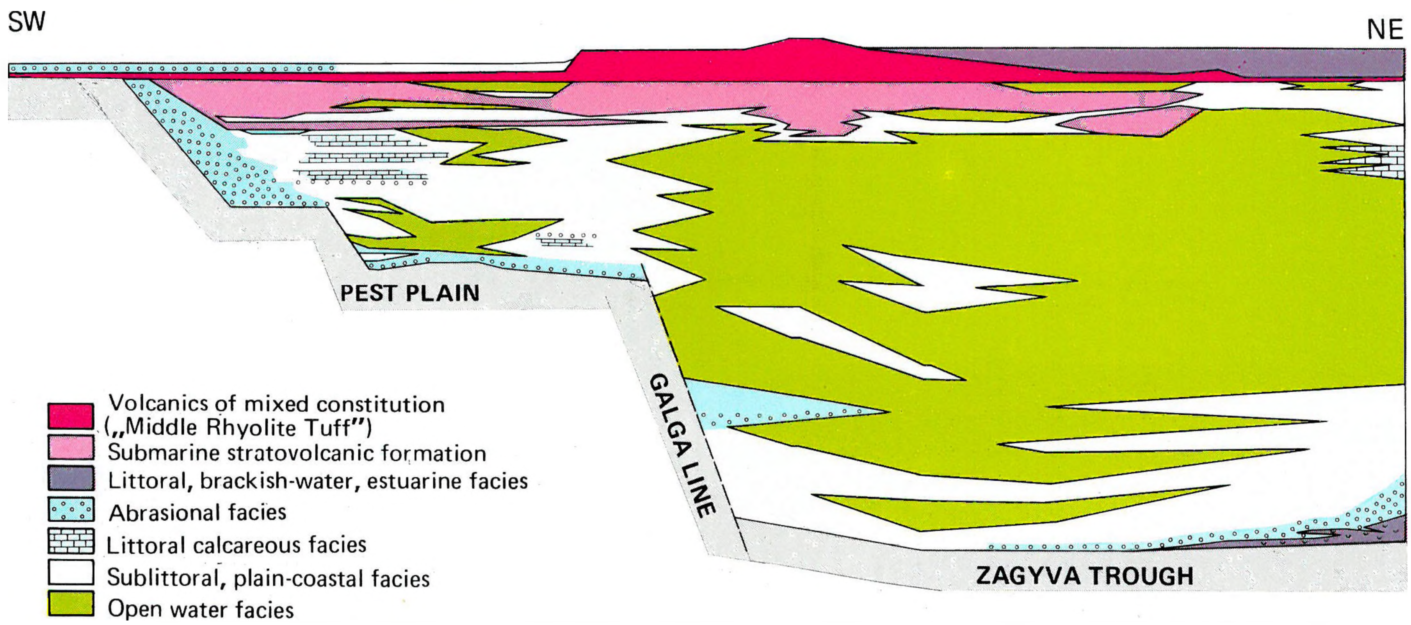


Fig. 4. Facies conditions of the Karpatian formations in the Nógrád–Cserhát area (plotted by G. HÁMOR, 1978)

Variation in time of the Karpatian sedimentary cycle (according to mesocycles, upon quantitative determinations)

(plotted by G. HÁMOR, 1978)

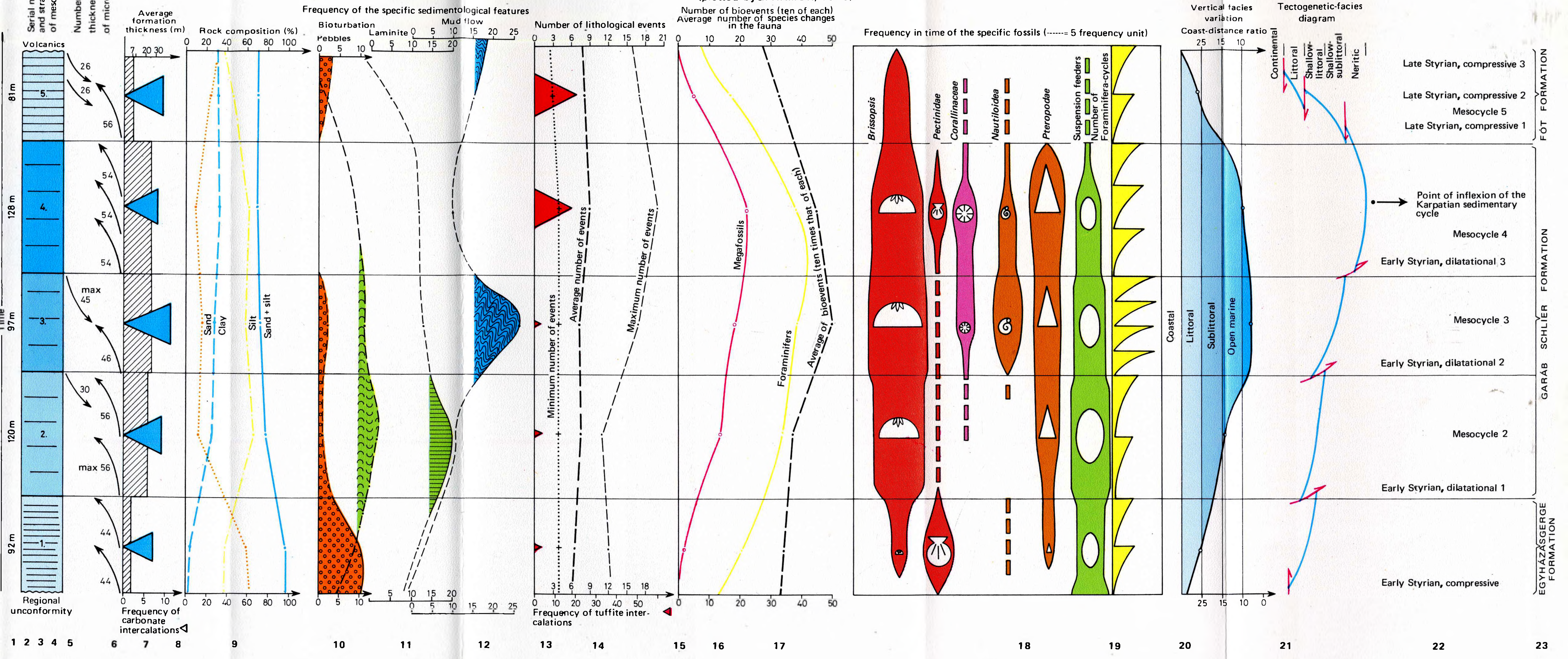
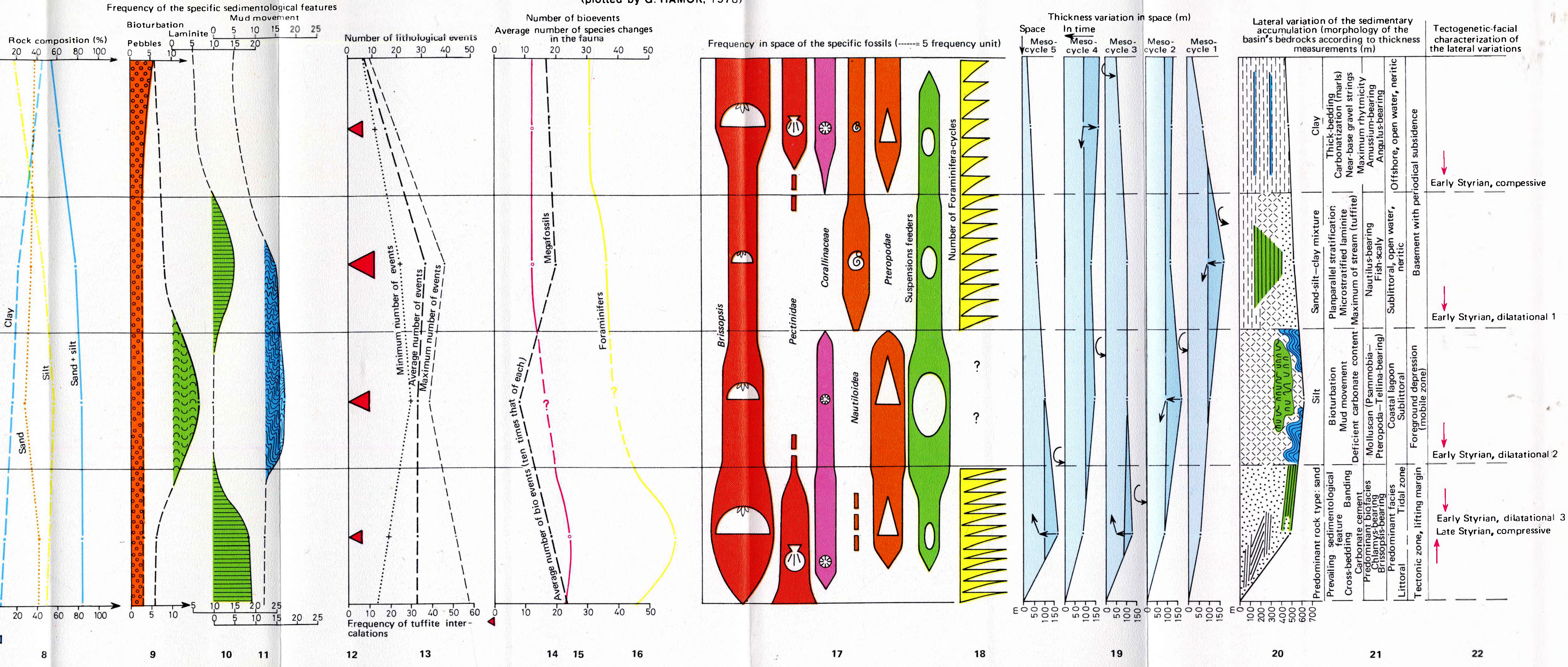


Fig. 5.

Fig. 6.

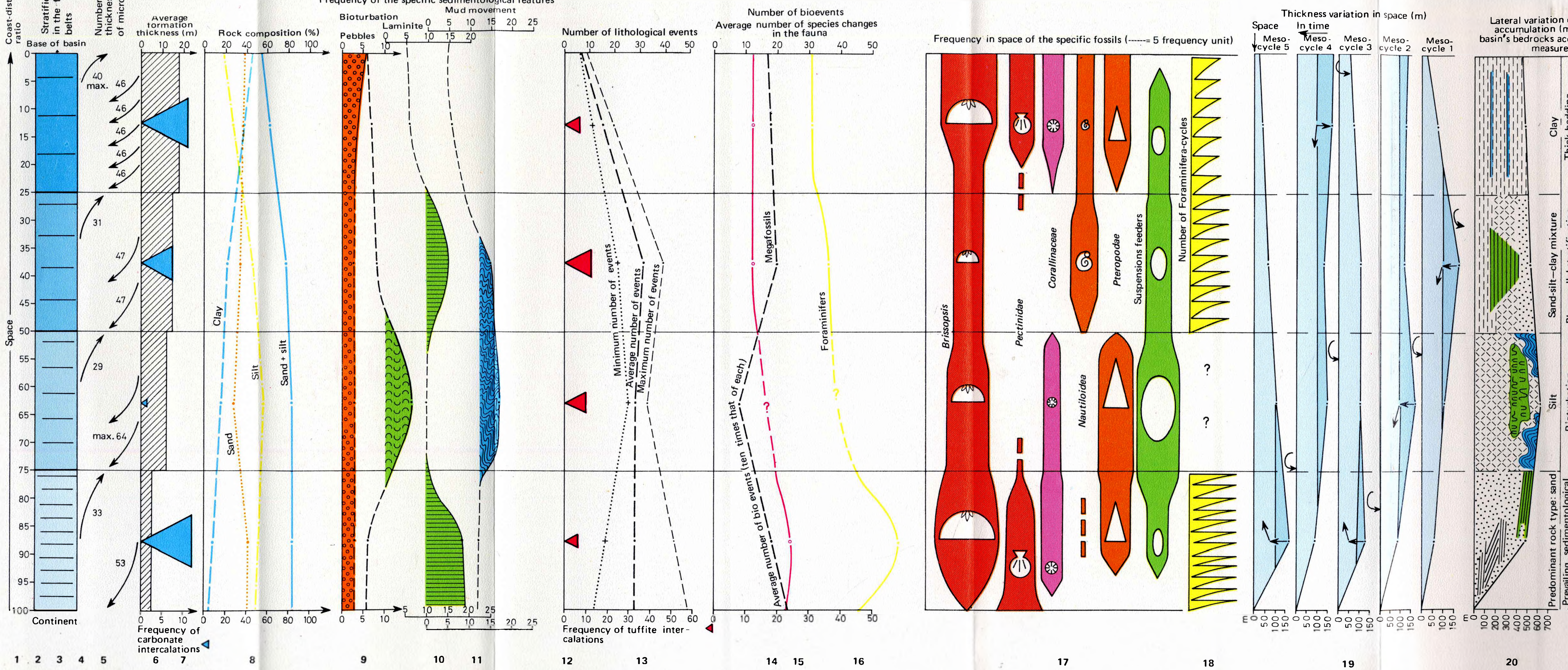
Variation in space of the Karpatian sedimentary cycle (according to lateral facies belts, upon quantitative determinations)

(plotted by G. HÁMOR, 1978)



Variation in space of the Karpatian sedimentary cycle (according to lateral facies belts, upon quantitative determinations)

(plotted by G. HÁMOR, 1978)



12 Frequency of the syngenetic (or reworked) volcanic intercalations: the number of pieces equals the height and base of the isosceles triangle.

13 Number of the lithological events peculiar to the facies belt (minimum, maximum and average), given according to the upper scale of the diagram.

14 Average of the biological events for the facies belt, measured out so as required by the scale (e.g. ×10).

15, 16 Number of the megafauna and Foraminifera taxons averaged for the facies belt.

17 Frequency number of fossils specific to the facies belt, figured to scale.

18 Number of all Foraminifera cycles of the facies belt, characterized by the number and height of the "teeth".

On the basis of data discussed above, some notable relations can be outlined:

- From the margin towards the inside of basin a continuous increase is experienced regarding
  - the average formation thickness,
  - the frequency of pebbly intercalations (phenomenon of turbation),
  - the clay contents and
  - the total number of microcycles.
- From the margin towards the inside of basin a continuous decrease is experienced regarding
  - the amount of sand plus silt,
  - the number of megafauna taxons, and
  - the number of Foraminifera taxons.
- Subordinately to bottom morphology (stream conditions), a variation can be experienced regarding
  - the thickness of microcycles,
  - the sand/silt proportion,
  - the carbonate contents,
  - the frequency of specific sedimentological features, and
  - the frequency of specific fossils.

19 This part of the diagram can be associated with the vertical synoptic section type of the synoptic sections (see 2.1.3.1.). It demonstrates the facies belt in which the thickest deposition took place through the passage of time, as related e.g. to mesocycles 1, 2, 3 . . . (parts with a thickness larger than 100 m are coloured darker). Interpretation: the deepest point of the basin, obviously formed tectonically, was wandering towards the edge of the depositional basin all along mesocycles 1, 2 and 3. Thereafter, following the oscillations of mesocycle 4, the closing mesocycle 5 was most intensive in the depression to the coastal forespace. Conclusions: the development of transgression, oscillation and regression should be determined tectono-genetically. Consequently, the facies belts are moving above one another, in space and time. Thus the question in which facies belt and when was most intensive the basement motion, can be decided.

20 It can be seen the lateral changes of sedimentation during the time of the whole chronostratigraphical unit, in terms of the total thickness. (For this, the Middle Miocene Karpatian stage is exemplified.)

21 A textual briefing is given here to characterize facies belts upon the following data: predominant rock type, sedimentological features, biofacies, an other facies/geofacies, according to bathymetric facies and tectonic peculiarities of the facies belt.

22 In this Column the peculiar processes of the basement of a sedimentary basin and the development and wandering in space of the facies belts are demonstrated concerning the determining factor (which orogenic cycle, when). As to this, Column 19 should also be involved.

Upon the joint use of the time/space charts, attention may be called to some additional combinations. Without striving for completeness, we mention, for instance, the case when a certain amount of sediments, together with peculiar slope conditions

– part of a sedimentary basin,
– an areal facies pattern,
– a geological land unit and
– a region.

2.2.1. Interpretation of a constituent area

Topographical situation. The model demonstrates the marginal part of a molasse-type sedimentary accumulation (Zagyva Trough).

Chronostratigraphical situation. Here a basal formation to the Karpatian sequence (Tertiary, Neogene, Middle Miocene) is represented.

The unit concerned is the Egyházasgerge Sandstone Formation, underlain by the Ottnangian Salgótarján Browncoal Formation and overlain by the Garáb Schlier Formation of Karpatian age.

Member: Kozár Sandstone Member.

Bed: "Oncophora beds".

Facies conditions. From the margins toward the interior of basin facies are observable according to the following order: estuary i.e. the mouth of a river (Congeria-bearing biofacies), plain-coastal brackish water facies, shallow lagoonal (Oncophora) Rhezakia-bearing environment, littoral zone of waving with the formation of drifts (Chlamys-bearing biofacies), sublittoral open marine facies (Tellina–Nucula biofacies).

Palaeogeographical situation. The formation figured is connected with the first mesocycle of the geological megacycle belonging to the SW-NE directed transgression. The Ottnangian sedimentation was interrupted by the Early Styrian orogenic phase of the transition from Ottnangian to Karpatian times, however, no complete uplift of the area resulting in a continental stage took place: on the basement tilt over, the Karpatian basal beds lie with erosional and angular unconformity and more extensively. The formation is covered by younger beds formed during the advancing transgression with oscillations involved.

2.2.1.1. The scheme of the *lithological interpretation* is presented by the uncoloured part of Fig. 7. To plot the section, data of some well-cored and examined boreholes were used. The important beds are marked by colours, with the specific sedimentological features and fossils indicated. As for the correlation, the presence of "Oncophora beds" and the formation boundaries are stressed. Since the examined unit consists of sands almost entirely, no lithofacies section is to be attached here.

The evaluation of fossil associations is made on the same section sheet so as expressed by colours (coloured parts of Fig. 7).

2.2.1.2. In order to *biofacies interpretation* (Fig. 8), borehole sections (with depths) should be ordered along the linear pattern, paying attention to the biofacial conditions and interfingering structures. To this, all superficial and drilling data, maybe deficient, are used, if at least minor details are enlightened thereby (e.g. a record by 152.0 m: "Oncophora fragments").

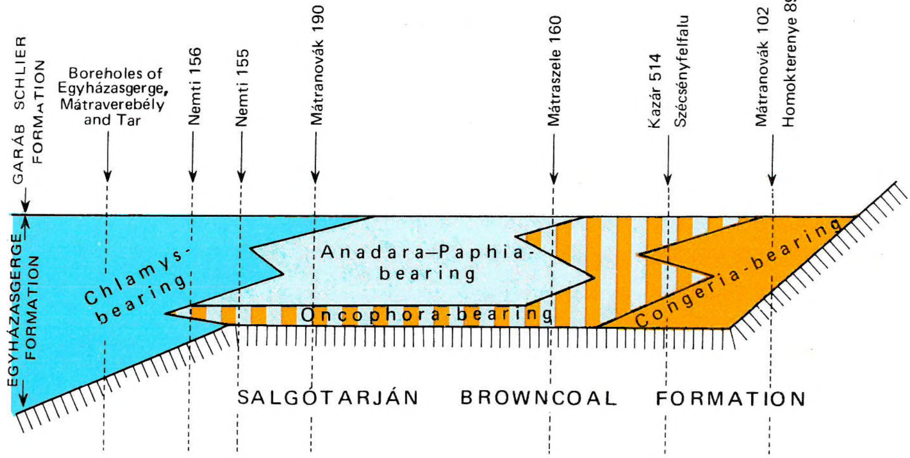


Fig. 8. Biofacies of the Egyházasgerge Formation and theirs interrelation

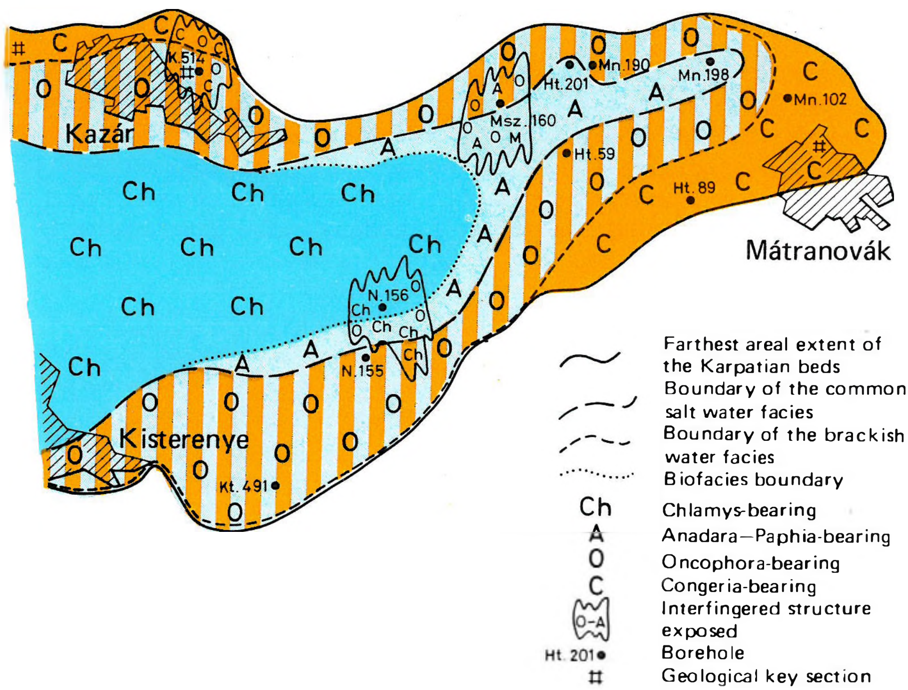


Fig. 9. Palaeogeographical and facies conditions at the beginning of the Karpatian sedimentary cycle (basal beds)

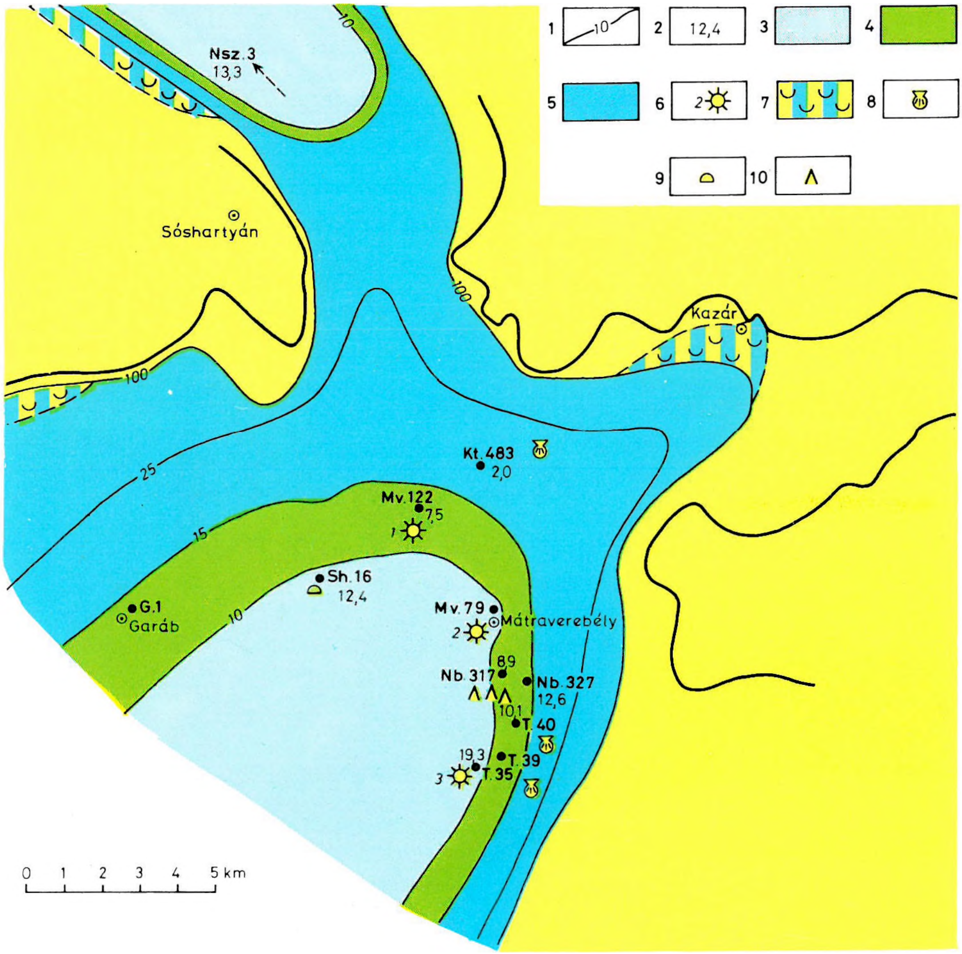


Fig. 10. Lithological and biofacies map of the Karpatian Mesocycle 1

1. Isolines showing distances from the coastline upon the coast-distance ratio (100 = coastline at the time of the cyclic sedimentation; continental zones are coloured in yellow), *2.* average formation thickness in metres, *3.* sand/clay proportion 10:1, *4.* sand/clay proportion 100:1, *5.* sand/clay proportion >100:1, *6.* number of Foraminifera cycles, *7.* Oncophora biofacies, *8.* Chlamys biofacies, *9.* Brissopsis biofacies, *10.* Pteropoda biofacies

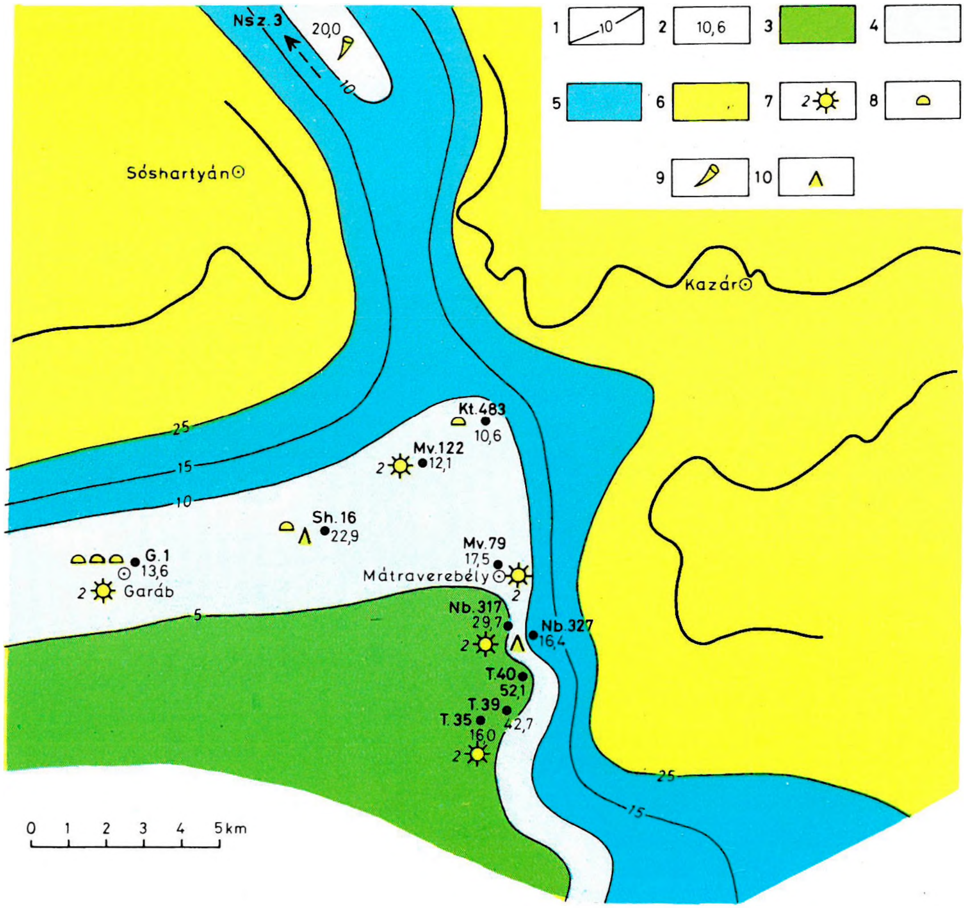


Fig. 11. Lithological and biofacies map of the Karpatian Mesocycle 2

1. Isolines showing distances from the coastline upon the coast-distance ratio, *2.* average thickness in metres, *3.* sand/clay proportion 100:1, *4.* sand/clay proportion 1:1, *5.* sand/clay proportion >100:1, *6.* continent, *7.* number of Foraminifera cycles, *8.* Brissopsis biofacies, *9.* coralline biofacies, *10.* Pteropoda biofacies

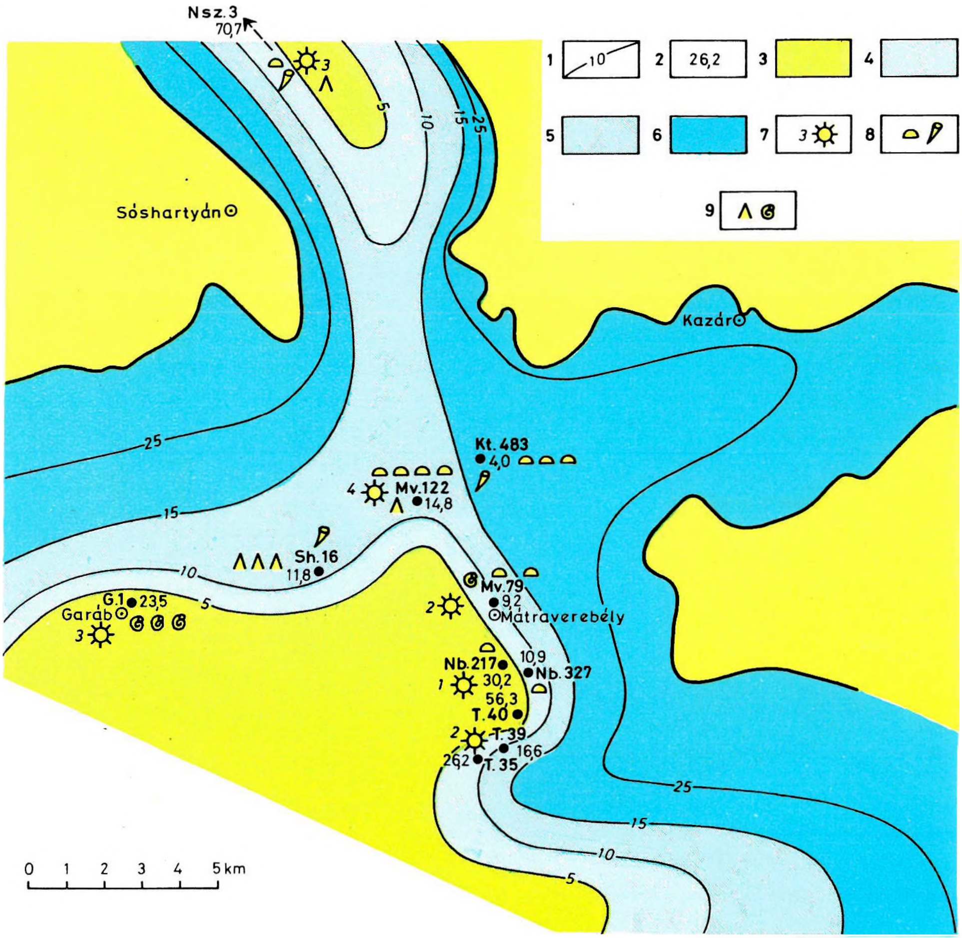


Fig. 12. Lithological and biofacies map of the Karpatian Mesocycle 3

1. Contour lines showing distances from the coastline upon the coast-distance ratio (continental zones are coloured in yellow), *2.* average formation thickness in metres, *3.* sand/clay proportion 1:1, *4.* sand/clay proportion 3:1, *5.* sand/clay proportion 11:1, *6.* sand/clay proportion >100:1, *7.* number of Foraminifera cycles, *8.* Brissopsis-bearing and coralline biofacies, *9.* Pteropoda-Nautilus biofacies

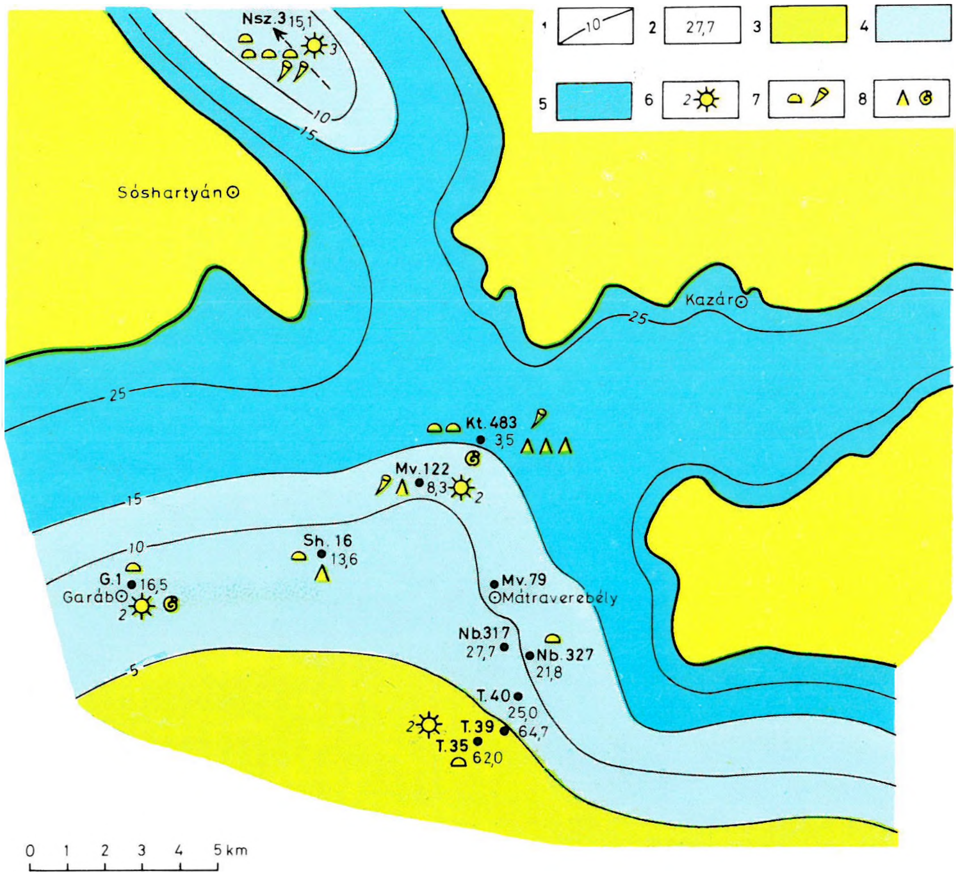


Fig. 13. Lithological and biofacies map of the Karpatian Mesocycle 4

1. Isolines according to the coast-distance ratio (continental zones are coloured in yellow), *2.* average formation thickness in metres, *3.* sand/clay proportion 1:1, *4.* sand/clay proportion 4:1, *5.* sand/clay proportion >100:1, *6.* number of Foraminifera cycles, *7.* Brissopsis-bearing and coralline biofacies, *8.* Pteropoda-Nautilus biofacies

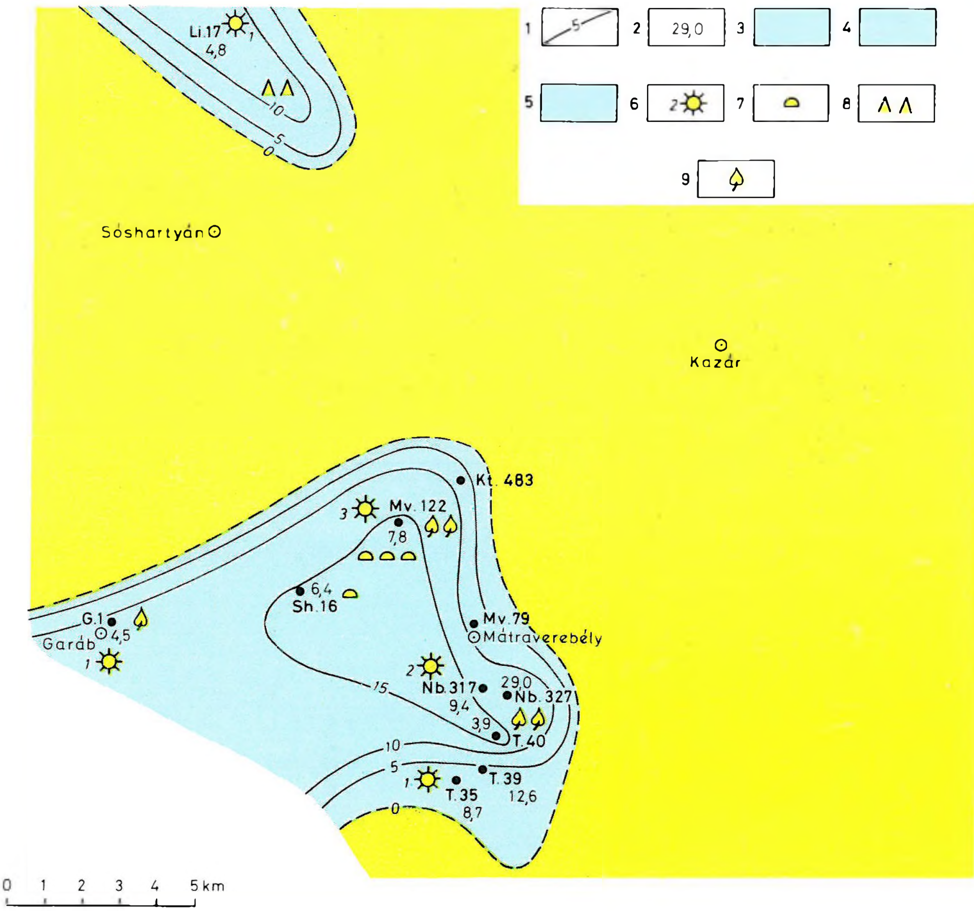


Fig. 14. Lithological and biofacies map of the Karpatian Mesocycle 5

1. Isolines according to the coast-distance ratio (0 = coastline at the time of the cyclic sedimentation; continental zones are coloured in yellow), *2.* average formation thickness in metres, *3.* sand/clay proportion 3:1, *4.* sand/clay proportion 4:1, *5.* sand/clay proportion 2:1, *6.* number of Foraminifera cycles, *7.* Brissopsis-bearing and coralline biofacies, *8.* Pteropoda-Nautilus biofacies, *9.* megaflora

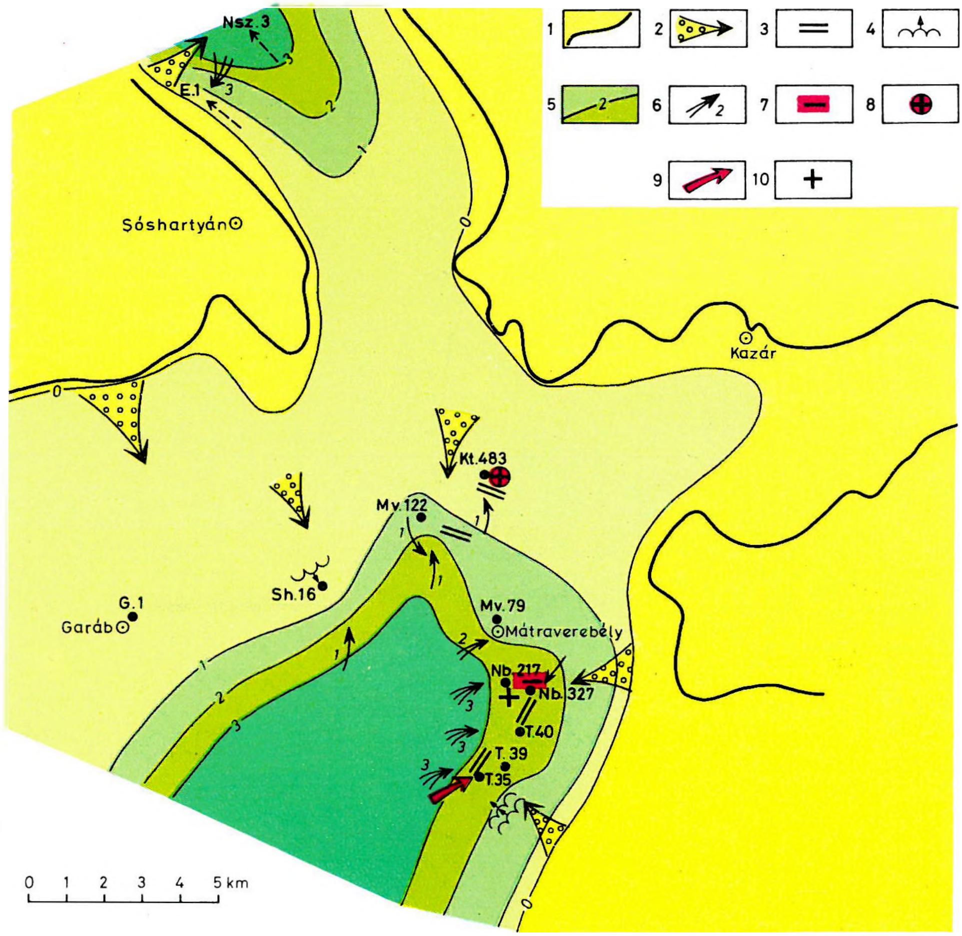


Fig. 15. Palaeogeographical map of the Karpatian Mesocycle 1

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* pebbly interbedding, *3.* amount of laminite, *4.* frequency of mud flow, *5.* isolines showing identical rhythmicity (0 = farthest extent of cycle; degrees marked by different colours), *6.* number of transgressive/regressive microcycles, *7.* maximum thickness of the complex, *8.* minimum thickness of the complex, *9.* maximum number of events, *10.* maximum number of Foraminifera species

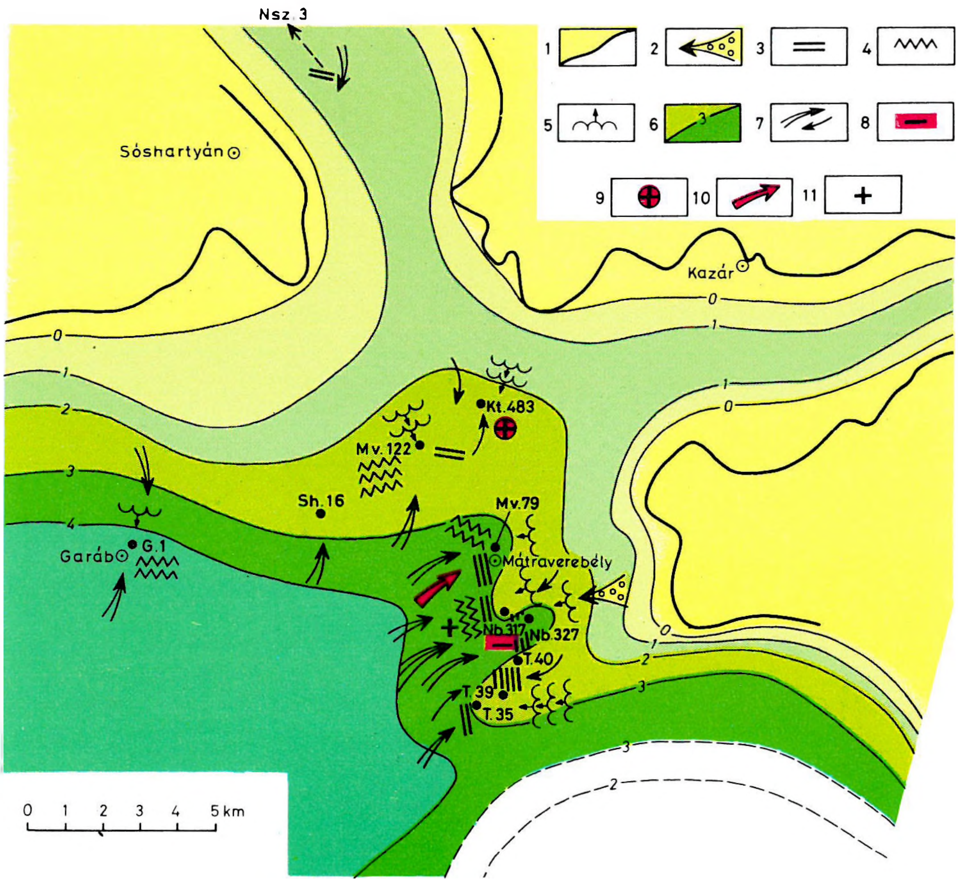


Fig. 16. Palaeogeographical map of the Karpatian Mesocycle 2

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* pebbly interbedding, *3.* amount of laminite, *4.* amount of limy interbeddings, *5.* frequency of mud flow, *6.* isolines showing identical rhythmicity (0 = farthest extent of cycle, with degrees marked by different colours, *7.* number of transgressive/regressive microcycles, *8.* maximum thickness of the complex, *9.* minimum thickness of the complex, *10.* maximum number of events, *11.* maximum number of Foraminifera species

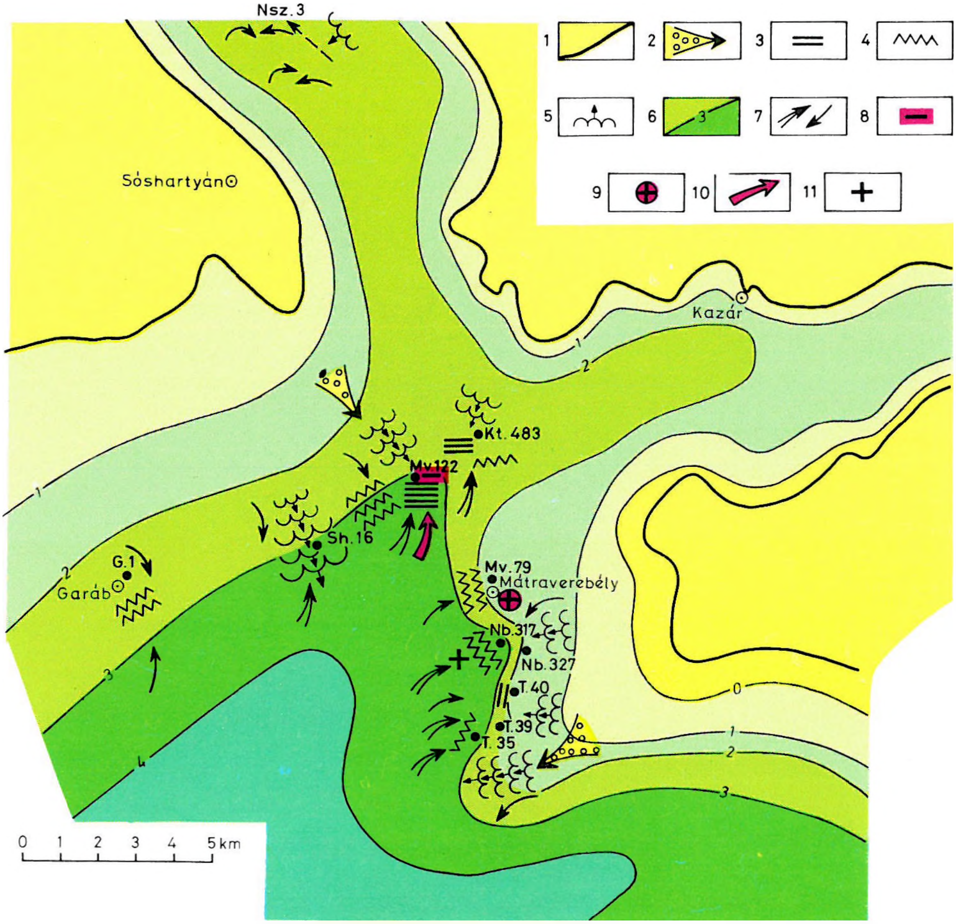


Fig. 17. Palaeogeographical map of the Karpatian Mesocycle 3

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* pebbly interbedding, *3.* amount of laminite, *4.* amount of limy interbeddings, *5.* frequency of mud flow, *6.* isolines showing identical rhythmicity (0 = farthest extent of cycle; degrees marked by different colours), *7.* number of transgressive/regressive microcycles, *8.* maximum thickness of the complex, *9.* minimum thickness of the complex, *10.* maximum number of events, *11.* maximum number of Foraminifera species

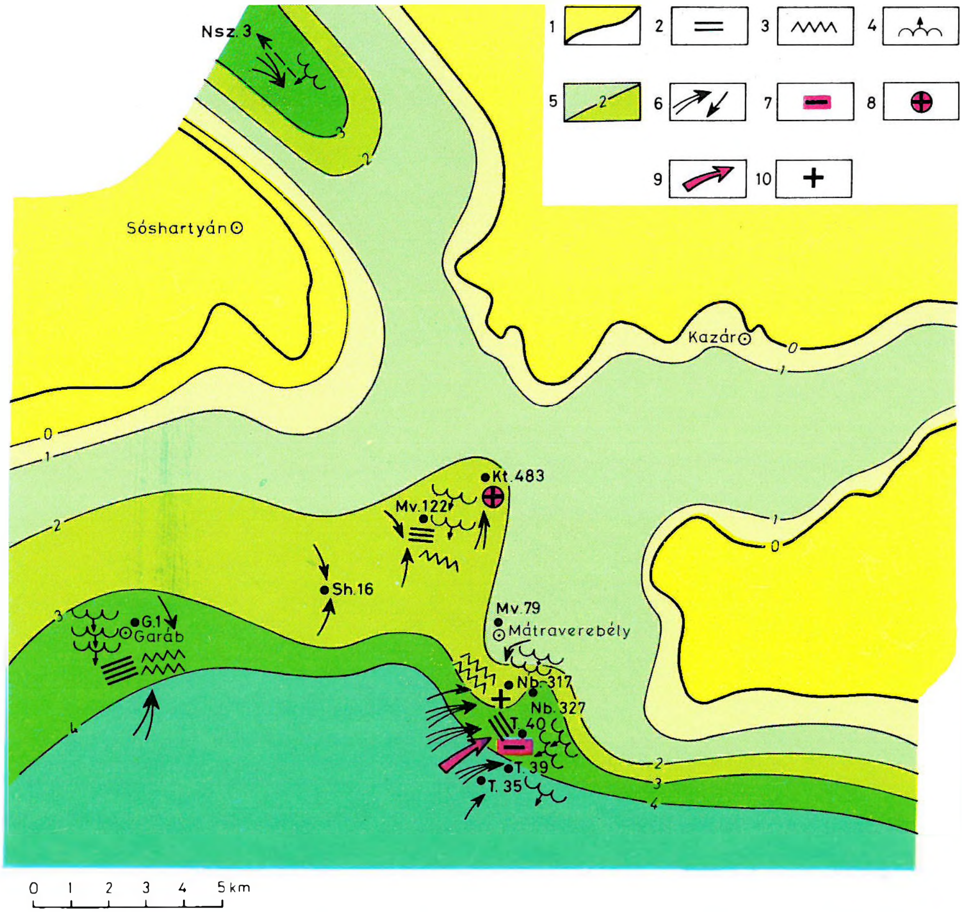


Fig. 18. Palaeogeographical map of the Karpatian Mesocycle 4

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* amount of laminite, *3.* amount of limy interbeddings, *4.* frequency of mud flow, *5.* isolines showing identiçal rhythmicity (0 = farthest extent of cycle; degrees marked by different colours), *6.* number of transgressive/regressive microcycles, *7.* maximum thickness of the complex, *8.* minimum thickness of the complex, *9.* maximum number of events, *10.* maximum number of Foraminifera species

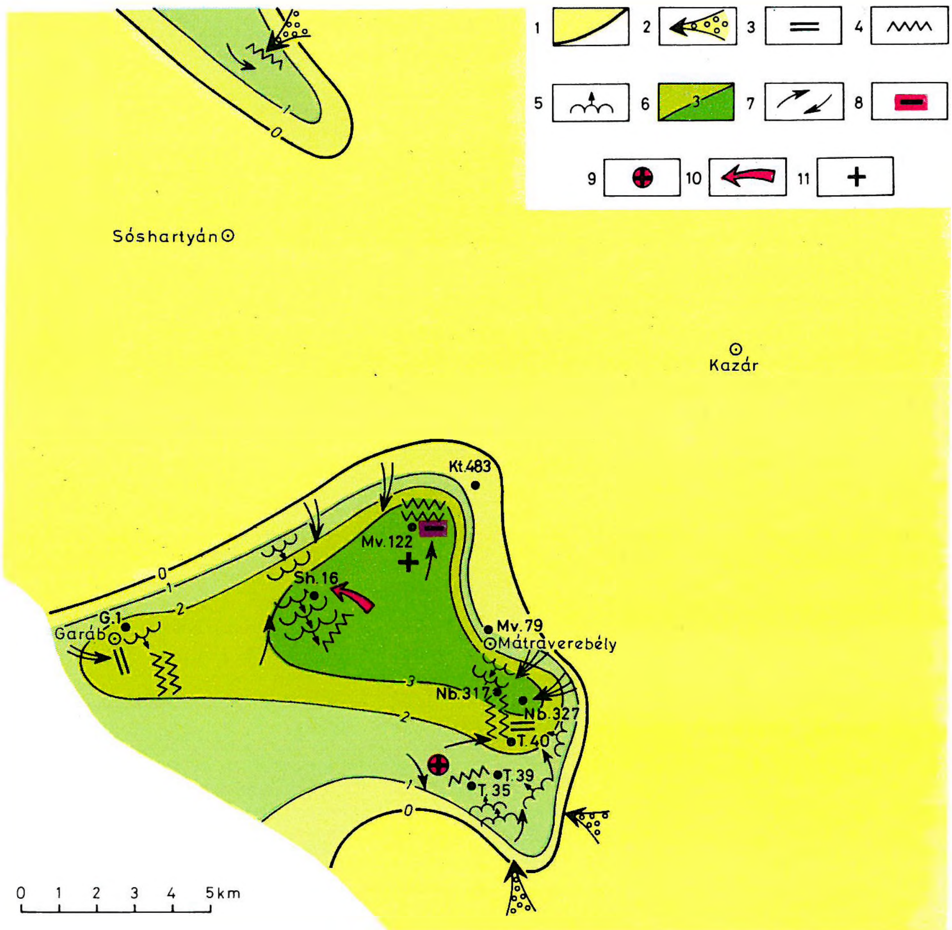


Fig. 19. Palaeogeographical map of the Karpatian Mesocycle 5

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* pebbly interbeddings, *3.* amount of laminite, *4.* amount of limy interbeddings, *5.* frequency of mud flow, *6.* isolines showing identical rhythmicity (0 = farthest extent of cycle; degrees marked by different colours), *7.* number of transgressive/regressive microcycles, *8.* maximum thickness of the complex, *9.* minimum thickness of the complex, *10.* maximum number of events, *11.* maximum number of Foraminifera species

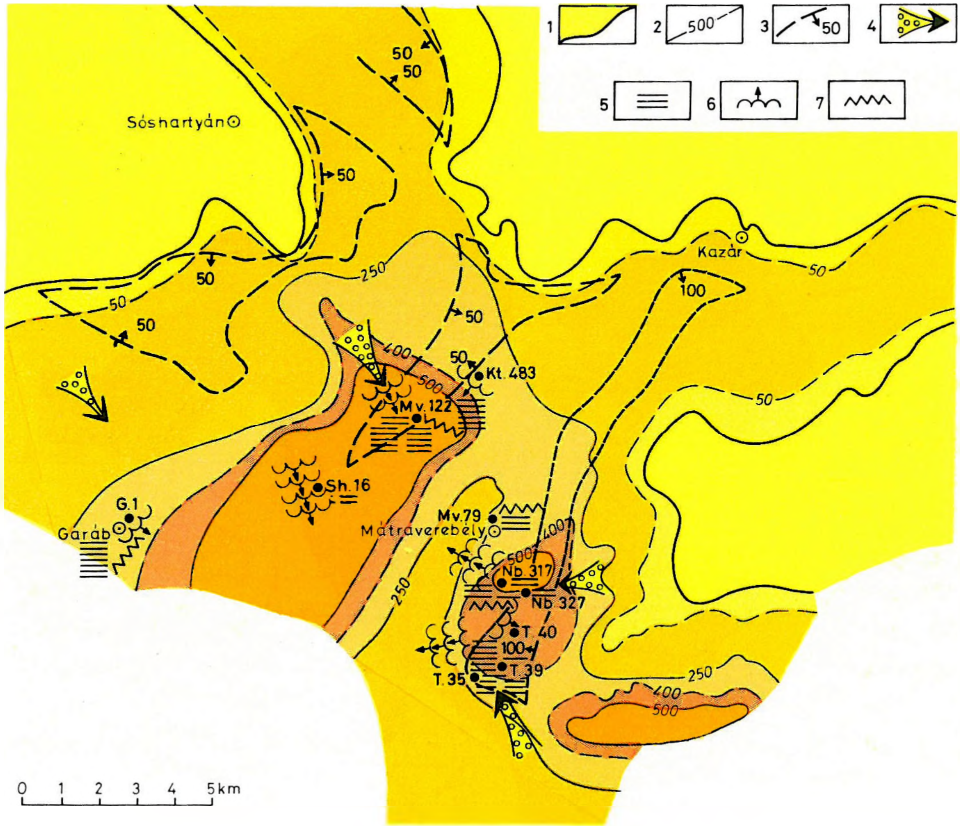


Fig. 20. Sedimentological and thickness conditions of the Karpatian sedimentary cycle

1. Coastline of the Karpatian sedimentary basin (continental zones are yellow), *2.* thickness of the Garáb Schlier Formation; with degrees marked by different colours, *3.* thickness of the Egyházasgerge Sandstone Formation, *4.* direction and extent of pebble-transporting streams, *5.* site and frequency of the laminite formation, *6.* site and frequency of mud movements, *7.* carbonate deposition

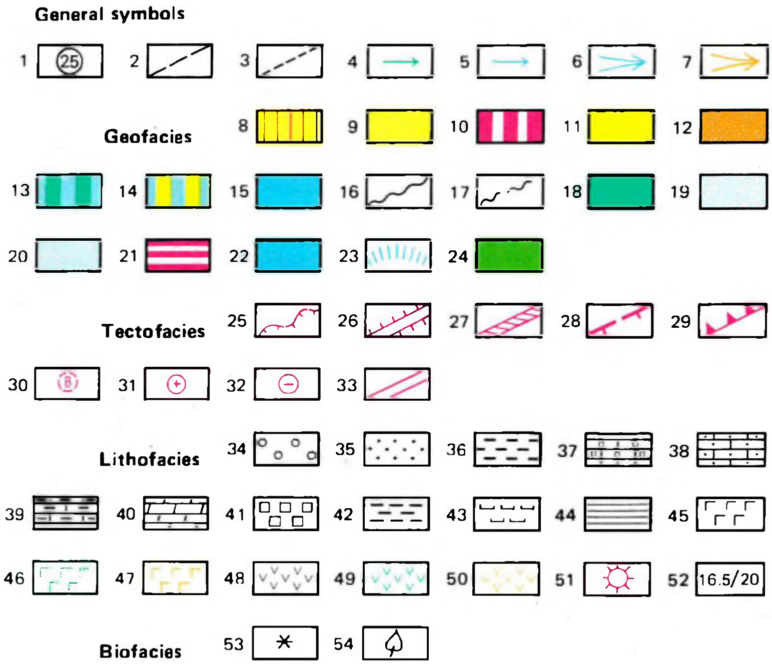


Fig. 22. Project on the compilation of the Palaeogeographic Map Series of the Neogene in Central and Eastern Europe on scale of 1:1 000 000 (IUGS–RDP). Legend for the map versions

General symbols: 1. Total thickness of the formations belonging to the represented time interval (in meters), *2.* geofacies boundaries, *3.* lithofacies boundaries, *4.* direction of terrestrial transport, *5.* direction of marine transport, *6.* direction of transgression.–*Geofacies: 7.* direction of regression, *8.* land being affected by heavy erosion, *9.* peneplain land, *10.* terrestrial volcanism, *11.* fluviatile, *12.* desert, *13.* brackish-water (sedimentary basin of reduced salinity), *14.* lacustrine-paludal, *15.* deltaic, *16.* shoreline (distinct)-visible or suggested by the closure of facies zones, *17.* shoreline (supposed), *18.* lagoon, *19.* littoral, *20.* near-shore, *21.* submarine volcanism, *22.* offshore (distant from the coast), *23.* reef, *24.* turbidite.–*Tectofacies: 25.* area uplifted, folded as a result of compression, *26.* tensional graben structure, *27.* line of contemporaneous extension of the Carpathian-Alpine range, *28.* active syngenetic fault, *29.* active overthrust, *30.* basin structure, *31.* uplifting platform, *32.* subsiding platform, *33.* volcanic fissures.–*Lithofacies:* Clastic sediments (to be shown when more than 33 %): *34.* psephites, *35.* psammites, *36.* pelites.–Carbonate and chemical deposits (to be shown when more than 50 %): *37.* calcirudites, *38.* calcarenites, *39.* calcilutites, *40.* dolomites, *41.* evaporites (inclusive salt, gypsum, anhydrite).–Biogenic deposits (to be shown when more than 50 %): *42.* caustobiolites (peat, lignite, coal), *43.* diatomites, *44.* siliceous rocks.–Volcanic rocks (to be shown when more than 50 %). Lavas: *45.* basic, *46.* intermediate, *47.* acid.–Pyroclastics: *48.* basic, *49.* intermediate, *50.* acid, *51.* volcanic centers, *52.* M.y. (volume of the radiometric measurements).–*Biofacies: 53.* faunal remnants, *54.* floral remnants.

2.2.1.3. Palaeogeographical interpretation (Fig. 9) can be made using data regarding the coastline and the separate facies belts, together with the marking of the first facies belt below the covering as available by borehole data. Areas or zones where the interfingering of different geofacies or biofacies is evidenced, are delimited.

The map is not completely "read" until all biofacies belts have been evaluated and marked with colours in accordance with the colouring of the sections. The same procedure might be done for geofacies too with the necessary quantitative information taken into stock (see Facies conditions).

2.2.2. Interpretation of facies pattern

Topographical situation. A sedimentary zone (North Hungary, Nógrád-Cserhát land unit, Zagyva Trough) with molasse-type deposition in tectonically preformed NE-SW/NW-SE-derected deeps is taken for example.

Chronostratigrafical situation. Rock sequence (zone NN 4) of the Karpatian stage (Tertiary, Neogene, Middle Miocene) is modelled here. The sequence is made up of the following formations, from olders to youngers: Egyházasgerge Sandstone Formation (Mesocycle 1), Garáb Schlier Formation (Mesocycles 2, 3 and 4), Fót Formation (Mesocycle 5). The series is overlain by volcanics of Karpatian age (Hasznos Andesite Formation and Tar Dacite Tuff Formation, showing at places an interfingering structure).

Facies conditions. Marine facies with such as open water offshore, open water littoral zone, littoral and coastal ("onshore") belt is observable. On the margins of the sedimentary basin and in a restricted areal extent, brackish water lagoonal beds of the backdeep lagoon are found so as showing evidences of intermittent contacts with the open water.

Palaeogeographical situation. The involved rocks were laid down by the SW-NE directed Karpatian transgression. Through the passage of time and in the frame of the full geological megacycle, elongated deeps provoked by trough faults attributable to the Early Styrian orogenic episode were getting to pass into basinal structure. After the peak of the transgression (the point of inflexion of the cycle), the cycle was finished by a gradual and then complete uplift due to the Late Styrian orogenic phase.

The mesocycles of the megacyclic makeup are well correlable with the repeated phases of the orogenic cycles of different type (compressive, dilatational).

With reference to the lithofacies, geofacies and biofacies sections (treated under 2.1.2.), here only the auxiliary documents for a palaeogeographical interpretation are depicted.

As being pressed for space in plotting every datum on the one and the same map, it seems expedient to execute a palaeo-environmental reconstruction on two maps, upon our experiences obtained in an empirical way.

Some factors such as lithological composition (with the sand plus silt/clay proportion), average formation thickness, biofacies conditions (faunal associations) or the so-called coast-distance ratio, are closely interrelated. They depend on facies, so they are interpreted in the form of an integrated lithological and biofacies map (facies maps).

A similar relationship is evidenced in respect with the regional geohistorical events that are more or less independent of facies conditions. They are pre-determined by or even attributable to the tectono-genetic conditions (e.g. peculiarities of the rhythmic and cyclic sedimentation, formation thickness, sedimentological events). These data can be plotted on palaeogeographical maps showing conditions of dynamic isocyclicity, palaeotransport, with the inclusion of the so-called event maps.

The two map types provide a plastic picture of the palaeogeographical and facies conditons of a given time interval (e.g. that of a mesocycle) as being complementary with one another. It is an essential element of this method that the process is shown on a series map. This (*a*) raises the documentary value of the illustration, then (*b*) enables the reconstruction of the events by means of the result of small but joint deviations, and (*c*) makes the results verifiable. Some trends are revealed, too, thus the otherwise undocumentable events turn to be documentable and usable for other aims (e.g. forecast works).

2.2.2.1. Facies maps (Fig. 10, 11, 12, 13 and 14). This map plotting requires data evaluated per borehole and per sedimentological mesocycle. Observations made on coastline, moreover the site, symbol and serial number of the borehole involved are to be figured on the map, together with the average thickness of the mesocycle concerned (with an accuracy of 0.1 m, according to Data Sheet I). Thereafter it comes the coast-distance ratio i.e. total mesocycle thickness drilled/average formation thickness ratio calculated for the mesocycle recovered in a borehole given to be calculated and completed with the isodistance contours plotted through a graphic interpolation. The coloration of these isolines is to be made by taking into account the sand plus silt/clay proportion as found for the mesocycle, according to proportion equalities (1:1) or to orders (1:2, 3, 4 . . .; 1:10; 1:100; >1:1000). The biofacies within the sphere of boreholes is marked by conventional symbols i.e. by the joint use of a symbol and a number of frequency showing the frequency of the specific elements (see Data Sheet I). The symbols showing the number of Foraminifera are joined with Arabic numerals showing the number of cycles found in each borehole. This illustration can evidently be adapted also for the registration of the prevailing Foraminifera taxons. If necessary, faunal associations can also be separated with dotted line (possibly on a foil covering), however, this picture will evidently be less rich in details than that of the coast-distance isolines. It is to be noted that in the case of transgressive cycles the index numbers of the coast-distance ratio decrease towards the interior of the basin, contrary to the regressive cycles, since the formation thickness is larger inside the basin and in the marginal zone, respectively.

2.2.2.2. Palaeogeographical maps (Figs. 15 to 20). The plotting of this map requires data evaluated per borehole and per sedimentological mesocycle (see Data Sheet II). Observations made on coastline, moreover the site, symbol and serial number of the involved boreholes are to be figured on the map. Beside them, the frequency of the specific sedimentological features at the given point is marked with a conventional symbol together with numerals showing frequency. Then data such as the character of the mesocycles (transgressive, microcycle with a direction tending towards the coast and regressive microcycle directed towards the interior of basin), the number of microcycles (one, two, three or more connected direction-arrows), moreover the frequency of mud flow, laminite formation, carbonate accumulation and pebbly interbedding given with attached numerals, are added.

Now the plotting of isolines showing identical rhythmicity has its turn. These contour lines enclose areal parts of identical mobility, for the microcycles are observed to show gradual extinction towards the coast i.e. in the direction of transgression; the greatest mobility is found in the "deep basin".

The maximum/minimum thickness of the given mesocycle is also to be marked on the map. Peak numbers of the events (lithoevents plus bioevents) and the maximum number of the Foraminifera species found will also appear thereon.

The maximum/minimum frequencies of the events and of the Foraminifera species are well correlable with the maximum/minimum of the microcycles and formation thicknesses.

On putting together the two map variants discussed, the following tasks can be performed upon *observable regularities:*

(1) The direction and the phases of a transgression can be recorded.

(2) The extension of the sedimentary basin, furthermore its changes with particular regard to the commence, culmination and regressive side of the geological megacycle, can be outlined.

(3) In terms of the distance from coastline, lateral facies belts can be identified and correlated by and large, together with the depositional zones of indentical motion controlled by an identical energy environment.

(4) On the consideration of all essential lithological and biological elements, it can be reconstructed the basement morphology of the depositional basin, with .approximate data for the depth of water. The most important data are given by such phenomena as mud slumping, mud flow and mud sinking. Buried slopes steeper than 8° are responsible for these movements; nonetheless, their repetition may be traced back to tectonic reasons.

(5) The structural development of the depositional basin can be monitored. The most significant bases to this are given by the recognition of the first or initial subsidence and of the basin-structural development tending towards the edges. Moreover, the consequences and relative heights of the backspace uplift and basement subsidence can be distinguished. Likewise it is possible to separate the forms of appearance of the power impulses released during an orogenic cycle referring to compressive (elevation-forming) and dilatational or tensile (subsidence-provoking) movements. Inactive time intervals are marked by the formation of laminite and carbonate.

The pre-existent pulsing character of the basement mobility, with differences on the right-hand or left-hand flanks in relation to the basin axis, can be verified. (This is most markedly shown by the red arrow representing the frequency peak of events and the minus sign of the maximum thickness of the complex. During the Karpatian megacycle exemplified above, a fivefold variation of the centre of gravity of the sedimentary accumulation taking place towards the right-hand side and left-hand side wings is verifiable to occur like the swing of a scale-cock).

Concerning the map variants treated, they are well complementary to the vertical and lateral synoptic sections showing an accordance with the variations recorded and figured thereon.

On the basis of these charts, synoptic maps can be plotted. For instance, a formation map holding together some mesocycles and another one recapitulating the palaeogeographical picture of a chronostratigraphical unit (e.g. Karpatian stage) with several formations, can be prepared. The latter will provide relevant information about the position and morphology of the basin by means of the formation thicknesses recorded.

It is noteworthy that the cycle-introducing formations are thickest around the basin axis and on the extreme flanks, whereas the cycle-closing formation displays the same feature around the basin axis.

2.2.3. **Interpretation of the geological land unit** (Fig. 21a, b)

Topographical situation. The model area implies rocks deposited in deeps preformed by NE-SW-trending faults, with molasse-type and epicontinental beds in the north and in the south, respectively. The Nógrád-Cserhát geological land unit is situated in northern Hungary as being a region with fault-bounded blocks and rift valleys. The latter represent depositional troughs too, which queue from the north southward under the following names: Etes Trough (NW-SE), Zagyva Trough (NE-SW) with the parallelly formed Ipoly Basin, followed by the Pest plain adjoining from SW.

Chronostratigraphical situation. A rock complex formed during Karpatian time (Mid-Miocene, Neogene) is involved. The palaeogeographical annex maps show the culmination and final stage of the regression finishing the Karpatian geological megacycle. For the latter, K/Ar method yielded 16.4±0.8 m.y. for the rock of a regional dacite tuff explosion.

Facies conditions. The land unit referred to comprises several facies developed in the following order (from the margins inward the basin):

The initial part of the cycle is constituted by brackish water lagoonal beds, abrasional and plain-coastal deposits and offshore-open water basin sediments.

The finishing part of the cycle displays the following peculiarities: uplifted basement; remnants of areas with freshwater sedimentation; volcanic and volcano-sedimentary rocks formed along marginal faults; coastal-plain littoral and sublittoral-shallow marine deposits; sediments of evaporating lagoons.

Palaeogeographical situation. On a surface pre-determined by the Early Styrian orogeny, molasse-type sedimentary rocks were deposited by a NE-trending transgression, which opened new relations towards SE. The compressive subphase of the Late Styrian orogenic phase brought about a backdeep uplift at the end of the cycle, along with the elevation above sea level of some formerly inundated areas. At the same time, in the zones of sedimentary accumulation left behind, the amount of terrigenous material with gypsum was increased, together with the impoverishment of the faunal assemblage. It took also place a continental to submarine andesite volcanic explosion, at first locally then in a regional extension, followed by the eruption of rhyodacitic tuffs.

For the plotting of the map, data collected on the surface and by drilling activity, are to be figured. So the observed and inferred trace of the coastline can be drawn with the aid of outlining the "closing" of facies and biofacies belts. To outline facies belts there are two methods at disposal: either we take for a basis the superficial boundaries of a facies belt or we can deal, when drilling, with the quantitatively prevailing lithofacies and biofacies penetrated by a borehole and relatable to the time interval to be considered. Facies belts can be markedly illustrated by the joint use of symbol and colour, and the application of fauna symbols is also appropriate when e.g. the coastline can be traced only upon the "closing" of the biofacies zones.

2.2.4. Palaeogeographical interpretation of a region

Topographical situation. For pattern area, a region extending from northern Hungary to southern Slovakia has been chosen. Accordingly, the region situated between the sub-Carpathian tectonic units (Veporidae, Gemeridae) and the Hungarian "Middle Mass" (the Mid-Hungarian Ridge) has to be taken into consideration. In a geological sense, it is a forespace depression of mobile basement, whose NE-SW directed sedimentary basin intersected by cross-faults is enfocussed. This region is immediately contacted palaeogeographically with the Mediterranean Basin in a south-westward direction.

Facies situation. Terrestrial, lagoonal, littoral, sublittoral and open marine beds are found.

Chronostratigraphical situation. A complex of Neogene (Middle Miocene) Karpatian to Early Badenian age is demonstrated. The time interval referred to has been chosen because it corresponds to the full time span of the Styrian orogenic cycles, including the Early and Late Styrian ones. Notes:

– During this time no significant geostructural development influencing the palaeogeographical picture is evidenced to have taken place.

– Through the time represented by the two orogenic cycles no lateral displacement is evidenced to have taken place to the extent of that having spoiled the possibilities of a joint evaluation enabled by the actual scale used.

– Anyhow, the biofacial variations are still presentable by palaeontological symbols.

– The picture which have been produced by the events that took place under the given palaeogeographical and large-scale tectonic conditions, is generalizable so as it be suitable for graphic representation.

It should be noted that the time intervals represented by the concerned map variants can also be reduced to a "snapshot-like" picture. To do this, it is enough to take into account the date at which a megafauna or microfauna zone rised, the palaeographical picture as recordable by the products of the first fallout forming a regional tuff blanket, or the palaeogeographical picture of a point of time determined radiometrically etc, provided an adequate amount of regionally correlated biostratigraphical data is at disposal.

The method of map plotting is by and large the same as described under 2.2.3. Because of some influencing factors given by the area to be figured, by the scale and the standardization of the degree of knowledge, some regular differences turn up. They are described here in an order of importance as follows:

(a) Structural elements determining the palaeogeographical conditions i.e. all the tectonic events to be figured for the time unit given, have a greater role. The thickness of the formations and chronostratigraphical units are to be given, at least by their order, even if recorded only geophysically.

(b) The lack of knowledge or the outlining of some presumably pre-existent sedimentary complexes eroded off require a very biased judgement which may involve many sources of error.

(c) Generalizations involve the omission of some local factors, good, spectacular or well-documented as they may be. At the same time, phenomena of a regional value have to be illustrated characteristically even if at places they be recorded as less striking or not so much scrutinized for the spot.

(d) Here no variants but only one map is needed, however, showing geofacies (colour, boundaries), moreover lithofacies (hachures and symbols with boundaries drawn only as evidenced) and biofacies (point marks). It is important to illustrate quantitative data, too, during standardization. Thus lithofacies be figured according to proper mass proportions (Fig. 22).

Rules for the illustration:

– Orange "tuff colour' will be used for the representation of a volcanic series with acid pyroclastics surpassing 50% therein, even if the amount of intermediate lava is so much as e.g. 38%.

– It is the same with carbonates i.e. chemical or biogenic deposits amounting beyond the empirical limit of 50%.

– In the case of clastic deposits, a limit by 33% has turned out to be adequate. The pertinent lithological symbol will be that of the rock with an amount exceeding 33% in the same series.

– When all lithogenetic group are found in the one and the same rock series, the symbol of the lithofacies represented by the highest mass p.c. is to be used according to the procedure described above.

In the case of equal rock proportions, which is very rare indeed, a combination of symbols is admissible. Nevertheless, this should be done without fading the picture of the facies belt zonation (e.g. with alternating marks set perpendicularly to those of the latter).

(e) The determination and illustration of the predominant geofacies can similarly be solved.

(f) Additional marks for data otherwise necessary for the interpretation of the palaeogeographical map can be figured expediently on supplementary exracts of map plotted on diverse but suitable scales. Such auxiliary drafts may embrace e.g. the following subjects: palaeogeology, palaeomorphology, palaeoclimatology, bioprovinces, sketches showing farther palaeogeographical relations; moreover maps indicating conditions of palaeotransport and streams, worm's eye maps showing irrelevant (younger) overlying sequences and forecast maps for the genesis and accumulation of mineral deposits, may be attached.

It is expedient to draw on the map margin columnar sections showing generalized stratigraphical sequences or facies conditions for zones or sub-zones.

There are zones which "suggest" the idea of plotting palinspatic maps too. Their principles and survey-methodological basing, with the task of their rendering, might be performed in the forthcoming years.

3. THE USE OF THE METHOD FOR STRATIGRAPHICAL INTERPRETATION

The name and place (in this summarizing study) of this chapter is not accidental. This choice is intended to suggest that the final stratigraphical interpretation shall be based on detailed quantitative observations evaluated and reconfirmed on the same basis, in space and time. Nonetheless, the actual practice is still somewhat different. Now stratotypes and parastratotypes are mostly overseen by deduction, being their point-bound examination as thorough as it is. Consequently, our present-day palaeogeographical reconstruction is restricted to the time of some isolated series of events or, in a worser case, to that of a single event e.g. the rise of Praeorbulinae.

To prove the fact how uncertain the result of this procedure is, we may mention the well-known difficulties in rising to the emergency when correlating marine, brackish water and continental fomations. Many times the mutual correlation of marine megafaunal, benthonic foraminiferal and planktonic foraminiferal–nannoplanktonic zonations is entirely difficult.

It seems more purposeful or, at least, worth trying to introduce an "*event-stratigraphy*" with the involvement on a correspondence in value of lithostratigraphical, biostratigraphical and chronostratigraphical methods, along with the clarification of events on a cause/effect basis and the spatial extension of qualitative and quantitative statements–a task to be tried and accomplished necessarily. We are convinced that a full synthesis of the vertical event-history and of the distribution in space of the events would mean a progress by itself. As a minimum requirement it should be set that "general" be separated from "particular", with the elimination of the virtual or ostensible contradictions so that further investigations be inspired. Two additonal advantages are promising by the fact that an equal firmness of the statements might be brought into being. Accordingly, in case we can decide whether some statement is based on a consistently executed series of examinations or on the (maybe very detailed) study of a single section, we can also establish the real sphere of influence of the statement in question, and in a topographical sense, too.

In summary, after gathering together all data with the subsequent interpretation and supervision of them (changes in space and time along profiles, representations on map, tectonic supervision, palaeogeographical reconstruction), it should be taken the final position expressed in the stratigraphical synthesis.

A methodological approach to the execution of the task is demonstrated by Fig. 23.

The diagram is divided in five main parts shared by lithostratigraphy, biostratigraphy, tectonic facies, geofacies, chronostratigraphy and geochronology.

Lithostratigraphy is dealt with by the application of the generalized stratigraphical column plotted, however, on statistical average figures giving the following information: lithological symbol of the most characteristic formation, average formation thicknesses drawn to scale, lithostratigraphical denomination of the divisions (formation, member, bed) and the rock composition of the individual formations, on an average for the area referred to.

Biostratigraphy is based on the number of taxons (mega- and microfauna, mega- and microflora) averaged for the single formations and also for areas, according to the expedient grouping of fossils collected from the formation. In an adjacent column the new fauna species of each formation are figured proportionally. The two columns are complementary to one another: the diagrams of the first column well coincide with the behaviour of the geological megacycles. It can be put the question whether the impoverishment recordable here is completely attributable to volcanic activity, or not? The second column concerned testifies to a "faunal break" indeed, with the existence and order of the rising new associations.

The next column shows the appearance in time and the distribution of the most important megafaunal and microfaunal elements, with a grouping upon provinces of distribution in time. Amounts are involved only as permitted by the evaluation concentrated on areas and formations, with a large number of determination and a full processing of data found in literature. Thereupon "cosmopolitan" taxons with great time-span can be screened out, whereas e.g. Pectinida zones turn out to be correlable with planktonic Foraminifera zones, and bioprovincia variations become demonstrable. The last column of the biostratigraphical part shows biozones which are accurately identifiable in the area.

The documentation of the *tectonic facies* begins by showing K/Ar radiometric dates to enable the comparisons with biozones. The date should be marked precisely at the point indicated by arrow on the section examined.

Data of Fig. 23 bearing on some single formations represent averages of at least 8–12, generally 20–30 measurements with the pertinent accuracy involved. The type and serial number of mesocycles are marked, together with the behaviour of geological megacycles, the serial number and character of the tectonic phases (orogenic cycles, episodes) and the time interval of the orogenic cycles.

All who say this method a "rigid diastrophism", can receive an unambiguous answer here and in the biostratigraphical part: the dynamic and continuous structural development is well correlable with the event history, however, it may precede the latter i.e. the limits of the orogenic phases do not coincide with the chronostratigraphical boundaries. Thus it is out of the question that Stille's theses on the existence of stiffly separated phases be renewed. On the contrary, we call attention to the pulsing but continuous development in space and time of these very phases.

The part dealing with *geofacies* presents determining types of the sedimentation: molasse, epicontinental etc the sites of deposition of the individual formations according to lateral facies belt, the character and mode of occurence of the volcanic formations.

The part on *chronostratigraphy* presents the scale established or proposed (substage, stage, age).

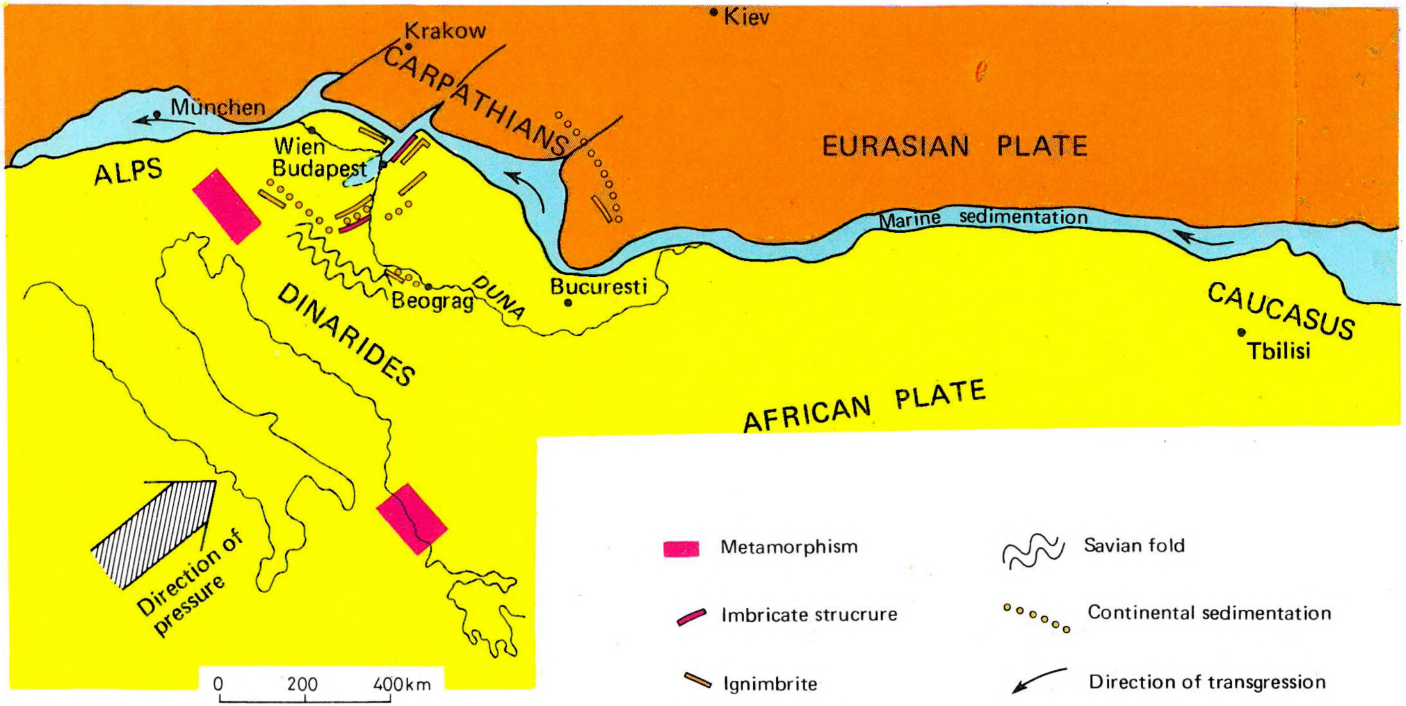


Fig. 24. Geotectonic pre-determination of the Neogene regions of sedimentation in the time of the Savian orogenic cycle (Eggenburgian–Ottnangian)

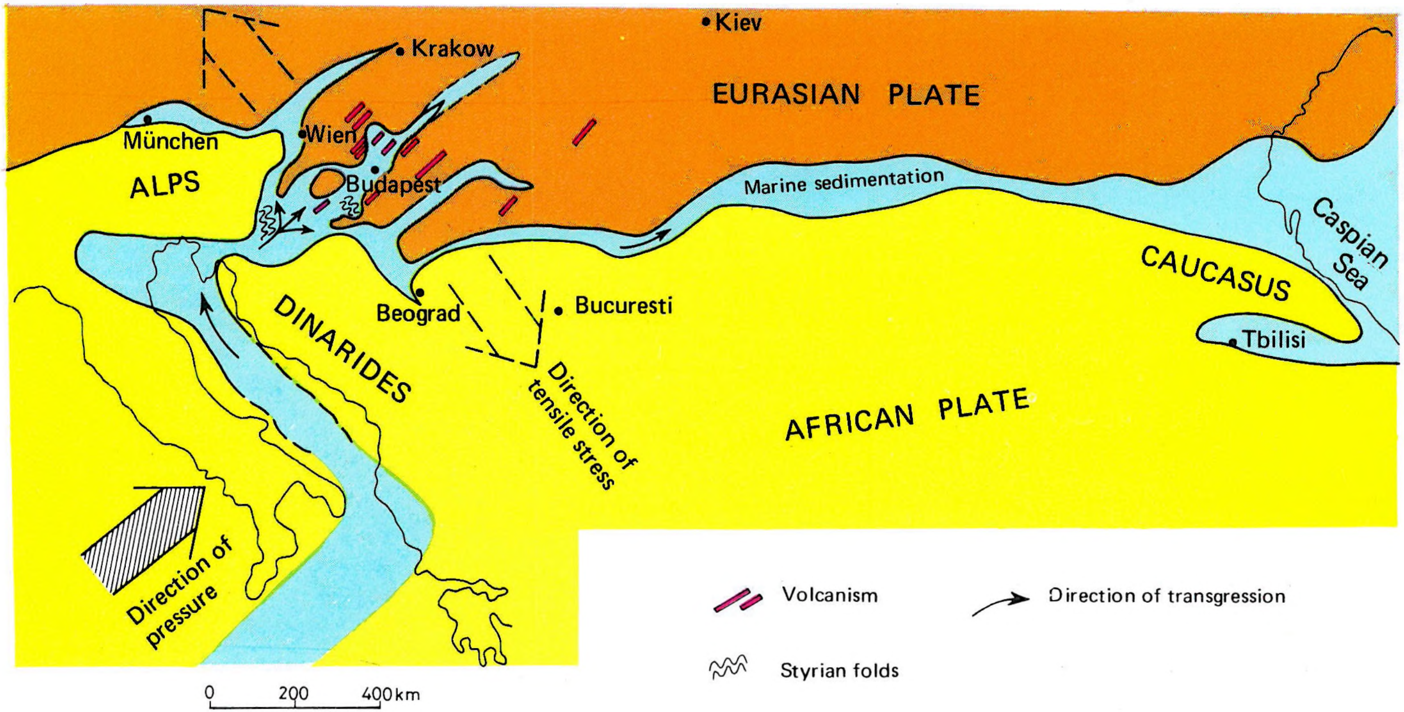


Fig. 25. Geotectonic pre-determination of the Neogene regions of sedimentation in the time of the Styrian orogenic cycle (Karpatian–Early Badenian)

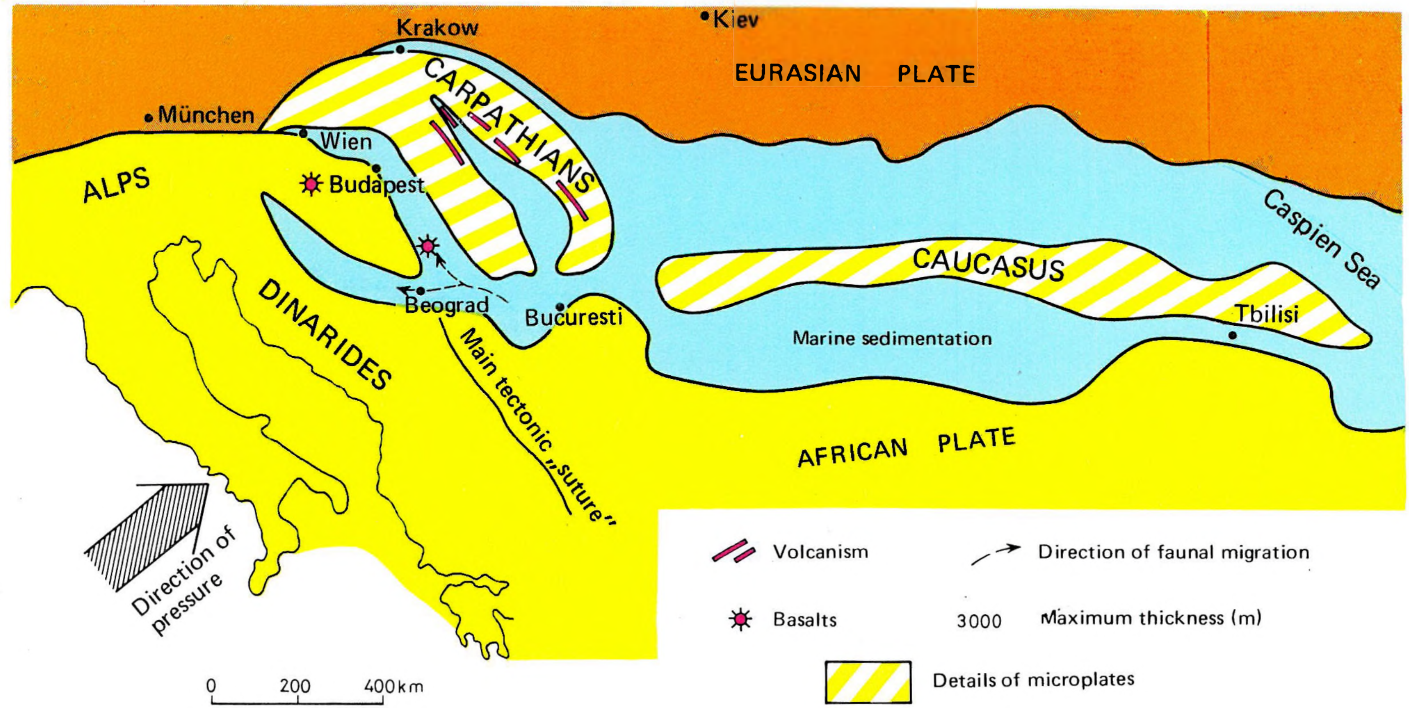


Fig. 26. Geotectonic pre-determination of the Neogene regions of sedimentation in the time of the Leithaian orogenic cycle (Late Badenian–Sarmatian–Pannonian)

4. REGULARITIES FOUND OR PROVED BY THE QUANTITATIVE METHOD

4.1. GENERAL RELATIONS BETWEEN TECTONISM AND SEDIMENTATION

4.1.1. Dynamics of the orogenic cycles in time

Stratum-statistical examinations enable to say that "orogenic phases" are not a series of cataclysms separated by considerably long periods of quiet. Their existence cannot be joined with some "discriminated points of time" verified stratigraphically, after which it comes a long period of tectonic inactivity with a sedimentation determined only by morphological and biofacial conditions and by the energy environment.

(a) *Orogenic phases belong to the dynamic and continuous life phenomena of the Earth's crust* and even of the mantle below it, with an unbroken series of movements filling up all the geohistorical time frame. Its course, however, is characterizable by the different behaviour of the subphases.

(b) Accordingly, we adopt here *the term "orogenic cycle"* as composed of *compressive* and *dilatational i.e. tensile phases.* The culmination of the cycle coincides with or, in time, is very close to *the point of inflexion* of the two effects of power.

Phases consist of subphases representing evidences for the pulsing power effects. The compressive phase developed continuously and got stronger through pulsation, and came to the point of inflexion in the 1st, 2nd, 3rd . . . etc subphases. Then the accumulating tension was released through tectonic displacements. (Looking in a static way at "orogenic phases", it was intended to determine the age of the "phase" with the time of these structural forms as coming into existence, however, it is more correct to deal with the age of the point of inflexion instead). Thereafter, the dilatational phase also passed off through 1, 2, 3 or more subphases provoked by gradually weakening tensile effects: It was followed by the first subphase of the compressive phase of a rising orogenic cycle.

Problems in determining the bounds of an orogenic cycle can be partly attributed to the fact that deposits accumulated during the former subphases may disappear, in extreme cases, owing to the rapid uplifting (erosion) or sudden sinking (transgression-abrasion) of the subsequent compressive phase.

In summary, an "orogenic phase" as defined by former interpretations cannot be called "compressive" or "dilatational". The orogenic cycle has to be a significant geological event, which can be characterized and interpreted in a complex manner of describing completely the pertaining space/time evolution history with the concomitant form-stock.

(c) *The age of an orogenic cycle* can expediently be given by the time of its full course. Referring to the contents of Fig. 23, the Savian orogenic cycle began with the first compressive phase in Egerian time of the Oligocene, and came to an end with the third dilatational phase of the latest Ottnangian (Miocene). In a lucky case, the starting and terminal points can also be determined by K/Ar radiometric dates. For the example taken above, the point of inflexion of the orogenic cycle is that can be dated by a rhyolite tuff explosion which took place in the 2nd subphase of the dilatational phase of the cycle (19.6±1.4 m.y.). Thus the age of the orogenic cycle referred to is late Egerian-Eggenburgian-Ottnangian, the date of its point of inflexion is 21 to 22 m.y. and its time interval represents about 6 million years (24–18=6).

(d) *Evolution history of the orogenic cycles* is closely related to that of the geological megacycles.

Sticking to the former example, the 1st and 2nd compressive phases of the early Savian orogeny had resulted in a general uplift. In consequence, water in the sedimentary basin became shallower with the appearance of swamps, and in the marginal zones a complete elevation took place. Actually, an increased amount and particle size of the terrigenous deposits is evidenced with regressive mesocycles and faunal extinctions. The formation of the regressive flank of the Oligocene geological megacycle is bound to that time and to such a way.

The 3rd and 4th compressive phases of cycle cause backdeep elevation and basement subsidence. The amount and particle size of the terrigenous sedimentary rocks decrease, transgressive mesocycles prevail and a new fauna appears. The point of inflexion of the cycle involves folding and imbrication in the backdeep, and the basin ceases to subside. Grabens now are separated from the imbricate-structural backdeep by tensile faults. They constitute a zone to which coarse terrigenous detritus is supplied rapidly from the higher parts of a rough terrain, with the consequence of a quick filling up. Then open water facies passes into a deltaic-fluviatile one (1st dilatational phase). Later on, in the 2nd dilatational phase the marginal faults to grabens pass into open cracks through which acid and viscous welded tuff invades the surface. Thus in the 3rd dilatational phase the smoothened swamp terrain becomes subject to a gradual subsidence resulting in the reappearance of the sea in the sedimentary basin of an invariably graben-type structure. The subsequent uplift has been evidenced for the next (Early Styrian) orogenic cycle's first compressive phase. So the elimination of the last third part of the Miocene Geological Megacycle I seems attributable to the transgression launched by the Early Styrian orogenic cycle.

Summary: The evolution history of the geological megacycles and the character and frequency of mesocycles are controlled by the orogenic cycles. This can be stated upon a cause/effect monitoring of event-stratigraphical views, instead of diastrophism. Only with lithostratigraphical facts at hand, no relations, be as simple as they are, can be found. On the contrary, in possession of all relevant data evaluated quantitatively as far as possible, the job will be done. An additional evidence is offered by the observation regarding the initial and terminal points of the orogenic cycles having been found not to coincide consistently with the chronostratigraphical boundaries. The points of inflexion of the orogenic cycles and geological megacycles appear somewhat systematically but at different times. Boundaries are surely correlable when the tectono-genetic, lithological and biological events are jointly interpreted for the one and the same system, and conformable conculsions can be drawn therefrom.

Nevertheless, the possibility of the correlation in time of the orogenic cycles has its own limits even if done on this very basis outlined above. That it to say, the sphere of statements is restricted to the involved major structural system such as that of the

Alps-Carpathians-Dinarides. The trend and sign of the orogenic cycles reflected by the behaviour of the connected geological megacycles are identical inside the same system. Other kind of system is e.g. the Russian Table; the trend and sign of the events may be reverse (regional compression in one system may simultaneously appear as tensile in another).

4.1.2. Dynamics of the orogenic cycles in space

Examining the behaviour of the orogenic cycles in space, similar identities and differences are found.

(a) According to a space model, in the sites (zones) of the most intensive power effects a conspicuous development in the structural makeup is brought about: elevation, folding, formation of imbricate structures and nappe systems with, maybe, regional metamorphism. Moving off the power impulse direction, continental elevations with foredeep and then basinal structure are assumed to have been formed. The basement to these tectonic zones is mobile, pressures are compressive and the space reductions considerable. Farther away grabens accompanied by fault-bounded blocks appear with tabular structures of eustatic movement. Here the basement is rigid, and tensile forms prevail.

As far as the example of 4.1.1. (c) is concerned, the Savian orogenic cycle was most intensive in the Hohe Tauern zone around 25 m.y. Here in the Pennine Window region an extensive metamorphism with a subsequent considerable uplift in the whole eastern Alpine region, took place.

On the continental elevation, folds ("Sava folds") with superimposed detrital accumulations at the foots and terrestrial-fluvioclastic freshwater molasses were formed (N Alps, E Alpine foredeep, region, lying W of the Danube in Hungary). Forespace depressions are filled with thick marine molasse (Austria, W Slovakia, N Hungary) with outwardly adjoining basin sediments of schlier facies. Along the faults of the tensile structure acid rhyolitic ignimbrites are found as outlining the deeper parts of the grabens. Table margins are characterizable by the appearance of limestone and paralic-limnic coal deposits.

It is noteworthy that the same space pattern is also identifiable in the E foreland of the Eastern Carpathians as assignable to the Savian orogenic cycle. Differences are given merely by the tectonic development of the "intensive zone" (nappes only) and by a table-marginal emplacement of evaporites.

Giving a summary of that treated above, it may be stated that there are conspicuous differences in the intensity and form-stock of the orogenic cycles.

(b) Pulsation i.e. intensity variations of the orogenic cycles lead to the displacement of tectonic zones, which may overlap one another in time. A shining instance for this is shown by the Alpine-Carpathian system where foredeep marine molasse, schlier successions of basin facies and epicontinental calcareous platform-series are ranging, somewhere with repetitions, on top of terrestrial molasse beds resting on the Neogene continental elevation.

In Hungary, the alternation of Triassic or Jurassic molasse sequences (German-type detrital formations) with basin-facies rocks (calcilutite) and platform series (Alpine-type carbonates), is likely to come under the same judgement. So these changes can be explained as pre-determined tectonically due to the wandering in space of the orogenic cycles, instead of general palaeogeographical or local facies variations.

(c) Similar displacement in time is evidenced for the magmatic rock-forming initiated by each orogenic cycle. The beginning, the end and the point of inflexion (volcanic paroxysm) of the magmatic cycles are, however, different from those of the orogenic cycles or geological sedimentary megacycles. Though the Carpathian Basin is abounding in neovolcanics, five Neogene orogenic cycles are associated only with two complete magmatic cycles (acid, intermediate and basic series). A dynamic layout pattern cannot yet be sketched out for these.

4.1.3. A plate-tectonic interpretation of orogenic cycles

It has been intended to give here the explanation of a succession of events in a given time (Neogen) and in a region (Alps-Carpathians-Dinarides system) likewise given, on the very basis of plate tectonics. For this, the principle "when and what as provable" is stressed.

This region falls in a space of contact between the African and Eurasian Plates. Neogene sedimentary basins with the thickest accumulation of deposits are assumed to have formed in the mobile belts situated over the renewed "sutures" of the plates, which had once been brought about and even "cicatrized" prior to Neogene time. Renewal of the Neogene orogenic cycles is attributable to the repeated breaking up of "sutures" and collision of the plates according to the pulsing movement of them as drawing near and then moving off again.

The intensity of the orogenic cycle and the areal layout of its depositional zones are controlled by the distance from the concerned "sutures".

For the spatial-geomechanical interpretation of the model, four remarks are to be mentioned in advance:

– During Neogene time, no subduction, obduction or long-range plate displacement took place. Portions of the plates had come to their corresponding place previously.

– Former plate-tectonic events are detectable by their aftermaths.

– The direction of plate movement controlling that of the tectonic movements varied by orogenic cycles.

– The Carpathian Arch had developed independently of the Alps, along with the peculiar formation of its nappe system. Consequently, the above-mentioned "sutures" were repeated according to a coulisse-like system even in the same orogenic cycle but with a conspicuous spatial displacement during the strongest cycles (Savian, Styrian and Leithaian).

The Neogene plate-tectonic scheme of the system can be outlined as follows below:

(a) During Savian orogeny, it was the last metamorphism of the Alps that took place in the margins of the uplifting African Plate moving towards NE, whereas the inward-situated Tertiary deposits were subjected to intense folding ("Sava folds"). In the foredeep to the Alps, deeps of continental deposition (Graz Basin, Mura Basin, Drava Basin, W Hungary), farther on Late Oligocene and Early Miocene deep marine basins were formed. (Sedimentary zones as well as W and S Slovakia, N Hungary, the northern Trans-Tisa region in Hungary and Transylvania (Erdély) are mentionable here.

Their situation is parallel to plate margin, and it is E-W trending north of the Alps i.e. NW-SE trending from the Vienna Basin on.) A depositional basin parallel to the latter was formed between the E foreland of the Carpathians and the Russian Table. The last two are asymmetrical, displaying an abruptly deepened basement in the forespace of the zones being elevated at that time. From there onwards, a moderately ascending basement is observable together with an expansive depositional space whose origin must have been related to the cycle-terminating plate separation. The coulisse-like repetition is presumably attributable to the "ice-floe effect" by moving microplates (Fig. 24). In a dip-cross direction acid ignimbrite masses are found in all three mobile zones. Their lack in the north Alpine forespace may be ascribable to a superior compression. According to thickness conditions, for the "main suture" it can be taken the middle one.

(b) The behaviour of the Styrian (Early and Late Styrian) cycles can be reproduced by two alternatives:

– African Plate took a direction towards N-NNW provoking tensile fractures at the edge of Eurasian Plate, or, and more probably,

– tensile power effects trending NW and SE perpendicularly to a steady NE pressure direction caused parallel fractures (similarly to the Rhine Graben System).

Depositional basins of sedimentation, belonging to the Styrian orogenic cycles, striking SW-NE deviate by 90° from the former system. The Karpatian-Early Badenian sedimentary basins of the intra-Carpathian region were connected directly with the Mediterranean Adria Basin as forming two sedimentary basin troughs in those times. Out of them, the northern trough was striking along the line marked now by the following zones: Styrian Basin–Bakony Mountains–Budapest–Cserhát Mts–Nógrád and Ózd Basins–Eastern Slovakia, with a bifurcation towards the Little Hungarian Plain–Ipoly Valley–S Slovakia in the north. The southern basin trough actually takes the direction S Tuzla–Drava and Sava Depression–S Hungarian Békés Depression, with a bifurcation towards Bácska–Banat–S Transylvania.

It is noteworthy that the existence of a NE-SW trending "backside" intermediate andesitic emplacement enables a nearly southward subduction of the Eurasian Plate below the African Plate to be presumed (Fig. 25). It is interesting that the cycle-initiating compression produced a dacite tuff blanket through heavy fallout, whereas the dilatational subphase formed intermediate stratovolcanics on a NE-SW fracture system.

The margins of both depositional basin troughs display volcanic garlands as well as the Banská Štiavnica (Selmec)–Kremnica (Körmöc)–Krupina–Börzsöny Mts–Dunazug Mts (Danube Bend)–Cserhát Mts–Mátra Mts–Eperjes-Tokaj Mts range for the northern unit and the Burgenland–S Lake Balaton–Middle Hungary range as bordering the southern trough. In the sedimentary basin lying farthest towards the north, volcanics are absent; this also may be ascribed to superior compressive forces then prevailing in the northern foreland of the Carpathians.

(c) The Leithaian orogenic cycle reflects again the initial situation, however, by displaced positions. With a moderately NE-tending motion of the African Plate the picture sketched out when dealing with the Savian orogenic cycle turned to be renewed, though with some small but regular differences; near the point of collision the folding was repeated. (Middle Miocene folds in Styria i.e. Steiermark.) Upon NW-SE trends the existence of three additional mobile zones is verifiable as corresponding largely to the Upper Badenian to Pontian deep basins of sedimentation. During the same time a maximum mobility was peculiar to some zones, namely: Mura-Drava Graben (Alpine basement); "Vardar Graben" and its parts in Hungary by the deeps Makó, Hódmező-vásárhely and Zagyva (foreland to the Alpine basement); graben in the eastern foreland of the Carpathians. The last two show an asymmetrical makeup, with foredeep deepening abruptly in the forezone of the uplifting parts and, farther off, with flatly ascending basement. The end of the cycle testifies to an expansion of the depositional space, which is attributable to plate separation. The "Vardar Graben" is considered to represent the main "suture", with deposits as thick as 2000–6000 m (Fig. 26).

An invariable feature of the volcanic activity is given by the fact that in the backside zone of the Vardar Graben large masses of acid to intermediate volcanics were extruded (Tokaj Mts, Tisa Ridge, Vihorlat-Gutin Mts and Baia Mare (Nagybánya), mainly in Sarmatian time. In the external zone volcanic products are invariably absent because of strong compressive forces (as it is attested to by correlable nappes in the eastern Carpathians). It means a difference the phenomenon of Basalt volcanism acting in both sides of the inner depositional zone. A plate-tectonic interpretation of basalts found in various zones remains a forthcoming task (Balaton Highland and Little Hungarian Plain, moreover the Graz Basin constituting the eastern and western flanks, respectively, of the Drava Graben; Kecel in the Danube-Tisa Interfluve on the western side of the Vardar Graben).

(d) The Rhodanian orogenic phase, which culminates near the Pannonian-Pontian boundary, does not show signs of plate movement. It was then and just then that the continuous mountain system of the Dinarides-Eastern Alps-Carpathians emerged parallelly with the "sinking in" and regional subsidence of the basement of the Pannonian Basin. This region, commonly cited as "Pannonian Basin" can be called "basin" from as early as the beginning of this orogenic cycle, when areas of greater extent became inundated by water. As a matter of course, then also the island mountains emerged only over the sea level. These are identifiable with the higher parts of the present-day mid-mountainous range.

Part of the island mountains moved not only isostatically. According to the particular trends, Neogene rocks older than Pontian were folded, however, not in a regional extent. Folds later developed into imbricate structure (e.g. in the Mecsek Mountains, S Hungary, where Pannonian beds got to be overridden by Mesozoic formations). A plate-tectonic interpretation is still required for the Pontian-Pleistocene basalt volcanism of the basin (N Hungary, Bár) and also for the Late Pleistocene acid rhyolite volcanic activity (Hargita, Aszód).

Summary: The evolution history of the Alpine-Carpathian mountain system together with the orogenic cycles of the adjoining foredeeps and basins, can well be understood on the basis of plate tectonics. For the "suture" between the African and Eurasian Plates two separations with subsequent collisions are verifiable to take place from the end of Oligocene time till the end of the Neogene.

The *first collision* is joined with the Savian orogenic cycle. The existence in that time of a "continental bridge" is provable by the inmigration of African Vertebrata faunal elements (Early Miocene early proboscideans). Owing to a separation of plates at the end of the cycle, depositional basins of sedimentation were formed in the foreland of the transcontinental mountain chain as opened up towards E, allowing the invasion of the Indo-Pacific fauna (Eggenburgian and Ottnangian Mollusca).

Through the time of passage of the Styrian orogenic cycles the separation continued. The depositional basin opened up more and more towards the west, giving way for the invasion of Atlantic faunae through the Mediterranean Sea Basin (Karpatian-Early Badenian whales, Mediterranean Mollusca, boreal Oncophora).

The *second collision* in Neogene time took place during the Leithaian orogenic cycle. Because of the "continental bridge", African main mammals (Primates, Dryopithecus, Rudopithecus) appeared on the Eurasian Table. In Central Europe, orographical conditions similar to those of our days came to existence. The development of the Late Badenian-Sarmatian-Pannonian deposition turned to be separated from that of the Mediterranean Sea basins by the Dinarides (persistent Mediterranean forms). At the same time, Indo-Pacific elements migrated towards the west through a series of foredeeps (Crustaceae, Decapodae) along with the appearance of characteristic East European Mollusca associations ("Konka" fauna, Ervilia, Nubecularia etc).

Then the collision was gaining strength by the Rhodanian orogenic cycle so that a regional uplift was launched ("Messinian salinity crisis" in the Mediterranean Sea Basin; "Pannonian faunal endemism" of isolated Pliocene sedimentary basins). In continental areas, Hipparions wandered towards the west.

Being as moderate as it may have been, the picture drawn on the movement of the plates (maybe, microplates) is verifiable by the following features to be considered:

– Folded Neogene structural forms as getting younger in an outward direction (Savian, Styrian and SW Hungarian folds).

– The moving character of the development of formation thickness in mobile zones.

– The extremely thin Earth's crust in the Carpathian Basin with the relevant heat flux and geothermal energy conditions.

– The reconstruction of palaeogeographical i.e. palaeofacies conditions in various sub-regions.

It is worth mentioning that e.g. in the territory of Hungary most of the Neogene hydrocarbon accumulations (Drava-Mura Graben, Vardar Graben) and the base-metal-bearing neovolcanics (Börzsöny, Mátra, Tokaj) are related to these mobile zones.

4.2. POSSIBILITIES FOR A TECTONIC INTERPRETATION OF THE SEDIMENTOLOGY EXAMINED ON A STATISTICAL BASIS

In former chapters the consequences of Earth-crustal events (major tectonics) were outlined. Stratum-statistical studies enable us to draw a generalized picture based upon elementary data, thus the sphere of their validity can be expanded. Without entirety, some examples of this inductive method are presented here.

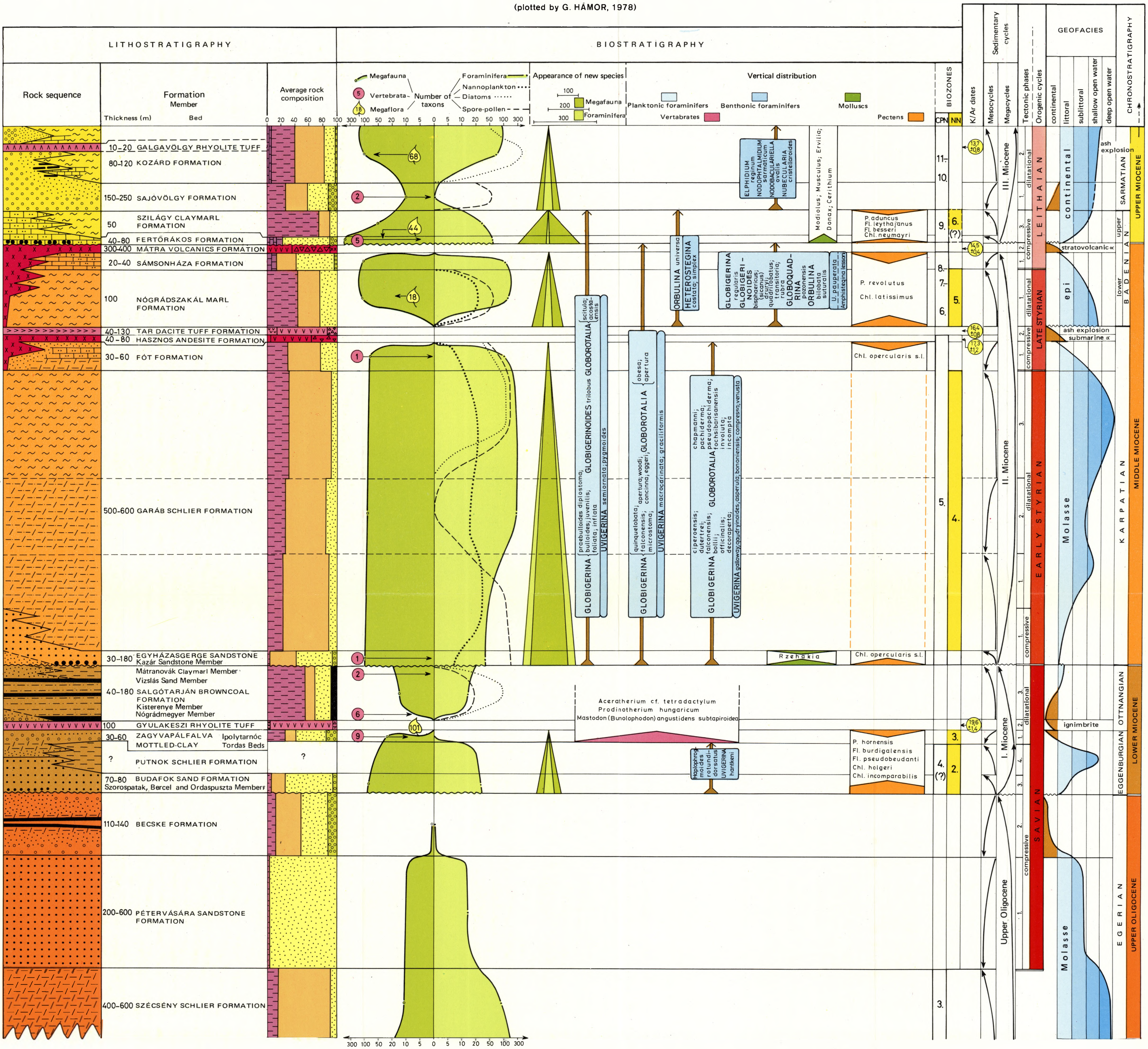
4.2.1. The basement of depositional basins as regarded from a tectonic angle

The main sedimentary basin types of the Neogene (continental, epicontinental and molasse) are clearly distinguished on a statistical basis. In this, the recognition according

Fig. 23.

Miocene formations and evolution history of the Nógrád–Cserhát region

(plotted by G. HÁMOR, 1978)



to which the character of sedimentation is determined by basement mobility, is instrumental. It has been evidenced that the continental and epicontinental sedimentary basins are related to graben-type structures, whereas the molasse sedimentation is joined with genuine basins.

Depositional zones for the first two types are mostly formed by a single subsidence, which is followed by isostatic vertical oscillation controlling the alternation of transgressions and regressions with the pertaining sedimentation. Molasse-type sedimentary basins are formed over the mobile parts of the Earth's crust where the sinking is continuous, and the basin development progresses in both (vertical and horizontal) directions. That is to say, on the basement the "rolling" undulatory movement of the crust is controlling the formation of the deepest basin zones, the direction and velocity of the transgression, the stream conditions etc.

It is common that molasse formations include epicontinental ones, meanwhile the basement remains, in principle, unchanged (e.g. Palaeozoic-Mesozoic table). The present method enables to detect the intervals of the Neogene orogenic phases that were connected with a mobile behaviour of the basement, and to define the pertinent power effects. It is provable that afterwards the same basement zone takes part in the movements as a rigid substance. Thereby it is possible to make proper definitions (active plate margin, consolidated state after collision, repeated dilatation).

4.2.2. Chronology of the geotectonic events

The geostatistical method of examination enables to distinguish facies-controlled (quasi local) phenomena from those independent of facies. Out of the latter, be mentioned here e.g. the events pre-determined by tectonic movements. Accordingly, the number, the behaviour and the phase intensities of geological megacycles and mesocycles are identical, independently of the type of the depositional environment. A sedimentary cycle produced by any phase (compressive or tensile) of the given orogenic cycle can be invariably reconstructed upon examining fluviatile, lacustrine, swamp or marine sedimentary deposits formed during the same time. The three phenomena mentioned above can be recorded identically for all facies belts of the sedimentary basin. As far as other factors such as rhythmicity, biofacies, thickness, environmental impacts are concerned, a great many differences are expectable to turn up.

The sphere of identities can be extended to greater regions and continental dimensions, however, not to a global extension. Consequently, the method is considered suitable for the purposes of geochronology and for promoting the correlation of continental and marine chronostratigraphical systems with the involvement of the event-stratigraphical systems to be developed.

4.2.3. Detection of the buried structures

During stratum-statistical studies, special attention was paid to the interpretation of isochronous facies. By so doing, evidence was found of a certain arrangement in space of the frequency of interfingering and transition shown by lateral facies types. Through detail examinations it was found that the linear arrangement of the above phenomena is indicative of buried structure lines or of their adjacent zones. With regard to this, two reasons are mentionable, namely

– the original level displacement by faulting and
– renewed (though small) displacements along the fault surface.

On the age dating of the formations i.e. isochronous facies resting on the buried structure, it was specified the

– syngenetic character of the motion and deposition and
– the age of displacement.

For this, a remarkably good example is presented in Figs. 2, 3, and 4 showing the "Galga line" situated below the zone where the Nógrád-Cserhát formation unit (N Hungary) contacts that of the "Pest Table".

In the figures, the makeup and the mutual interfingering of only two formations of Karpatian age are demonstrated. Nevertheless, upon sections plotted in a similar way for the same zone, showing older (Egerian, Eggenburgian, Ottnangian) and younger (Early Badenian, Late Badenian and Sarmatian) facies, it can be stated that the "Galga line" had appeared as early as the beginning of the Savian orogenic cycle and became active several times through the passage of the Styrian and Leithaian cycles.

In regard with the reconstruction of buried structures, the method as exemplified here might be extended to the monitoring of major tectonics or simple structure elements, too.

Sedimentary rock sequences of a palaeogeographical unit can be characterized by fundamental deviations detectable throughout periods, epochs and ages, whereas in the case of geological land units it is enough to deal with the deviation of one or two sedimentary cycles. Facies pattern areas, at the same time, can be described by differences between various parts of the cycle, and belts, zones by those recorded in dealing with some factors (particle size, fossil content).

4.2.4. Considerations on geodynamics

To answer fundamental questions emerged from a geodynamic consideration of our subject, the space/time quantitative interpretation yields some relevant evidences. For example, when interpreting the events of a sedimentary cycle, it is not all the same to know the conditions under which the sedimentation took place, regarding

– intense backdeep uplift,
– intense basement subsidence or
– the state of dynamic equilibrium of the former two.

Their order and variation in time, is another question. It has been found that an intense backdeep elevation is associated with the increase of the clastic depositional thickness towards the basin edge, whereas the intense basement subsidence involves the increasing frequency of coarse detritus towards the basin's interior as joined with the increasing average thickness of argillaceous rocks in the same direction. To the state of equilibrium, laminite formation and the equality of the (sand+silt): clay mass proportion, are peculiar.

Evidence for the geodynamic pre-determination of sedimentary cycles is found by the following observations:

– Through the time of passage of a cycle, the space reduction (decrease of coast distance, negative coastline displacement) as mass action appears prior to cycle culmination (point of inflexion).

– There is a linear relationship between the strength of the orogenic cycle and the number and average formation thickness of the mesocycles.

4.3. SEDIMENTOLOGICAL REGULARITIES

4.3.1. Cyclicity examinations

4.3.1.1. Variation in time of the cyclicity. These examinations have a decisive role in determining the transgressive or regressive character of the geological megacycles or the transgressive or regressive wings of them. The pertinent calculations are based upon microcycles (marking out, dimension, character).

(a) In the statistical mass proportion of the transgressive geological megacycle, the total thickness of the transgressive geological microcycles exceeds that of the regressive microcycles.

Taking again the Karpatian geological megacycle for example, from a total thickness of 5286.7 m drilled in 12 boreholes, the total thicknesses of the transgressive and regressive microcycles are 4153.6 m and 1133.1 m, respectively, giving a proportion of 4:1. In the case of a regressive geological megacycle this proportion is 1:1, or the number of regressive microcycles is larger.

(b) To define the character of the geological megacycles, the average thickness of the two microcycle types does not come to a crucial importance, since it has been claimed that in the case of both transgressive or regressive geological megacycles, a larger average thickness for the transgressive microcycles can be recorded. At the same time, the average thickness of both microcycles is increasing through the passage of the cycle, even if with oscillation, independently of their ascending or descending parts.

(c) Transgressive and regressive wings or flanks of a geological megacycle can be established upon the examination of the mesocyclic components. An intensity index can be gained by dividing the areal average thickness of mesocycle-making microcycles with the areal average thickness of the regressive microcycles to the same mesocycle. This index will be higher than 1.0 for transgessive mesocycles and below 1.0 for regressive mesocycles. As for a geological megacycle, the lowest intensity index will be found generally at about the cycle's point of inflexion.

(d) A similar conclusion can be drawn from the checking of the number of microcycles which are building up a mesocycle selected for an area. For the transgressive part, the frequency of transgressive microcycles is 9–7–5–2.5-times greater than that of the regressive microcycles and, for the regressive part, the number of regressive microcycles is 5-to-7-times exceeding that of the other. The point of inflexion of the geological megacycle is marked by more or less equal proportions (1 : 1).

4.3.1.2. Variation in space of the cyclicity. By means of these examinations, it is possible to reconstruct the geography of a depositional region, at some particular period in the past. Reverting to the example of the Karpatian geological megacycle, its microcyclic data calculated each as a function of the distance from coastline, appear in Table 5.

Table 5

	Transgressive microcycles		Regressive microcycles		Intensity index
	Average thickness (m)	Frequency	Average thickness (m)	Frequency	
Open water	46.6 ↓	23 ↓	39.8 ↑	6 ↓	1.17 ↓
Sublittoral	47.2	29	31.0	15	1.52
Littoral	59.0	29	30.5	14	1.93

Upon the data presented above, the following statements have been made:

(a) The number of both transgressive and regressive microcycles is likewise decreasing steadily in a direction from the basin edge towards the basin interior, by 20% and 50%, respectively.

Accordingly, a more marked appearance i.e. preservation of the events is expectable in marginal zones. At the same time, the same direction is characterizable by a 2–3–4-times increased proportion of the transgressive/regressive microcycles. For a regressive geological megacycle, the proportion is 1:1, or it takes a turn to 2–2.5 in favour of the regressive microcycles.

(b) The thickness of transgressive microcycles diminishes by about 20% inwards the basin. Contrary to this, the thickness of regressive microcycles increases by about 30% in the same direction.

This phenomenon reflects the proportions of deposits moving to and fro during oscillation.

(c) The Karpatian geological megacycle exemplified here is of transgressive character. It is easy to understand that the pertaining intensity index is highest for the coastal zone and is decreasing inwardly. In the case of a regressive geological megacycle, the situation is inverse with the index being highest in the centre of basin.

4.3.2. Sedimentary rock examinations

4.3.2.1. Depositional changes in time

(a) When being taken as a function of orogenic cycle intensity, some features of the geological megacycles are changing accordingly:

– the cycle thickness,
– the thickness of mesocycles,
– the average formation thickness, and
– the rock composition.

For this, see data taken from the Neogene of N Hungary (Table 6).

Table 6

	Thickness (m)	Average thickness of mesocycles (m)	Average formation thickness (m)	Psammite % in basinal facies
Savian orogenic cycle	1060	120.0	8.0	84.9
Styrian orogenic cycle	980	92.5	4.8	76.0
Leithaian orogenic cycle	700	40.6	3.3	56.7

(**b**) In a geological megacycle,

– the psammite percentage

is highest in the initial and terminal parts of the cycle. Near the point of inflexion, the following ingredients come to a maximum:

– average mesocycle thickness,
– average formation thickness,
– pelitic rock percentage and
– mega/microfaunal taxons,

as accompanied by a minimum of the

– psammitic rock percentage.

4.3.2.2. Variation in space of the sedimentation

(**a**) Upon a stratum-statistical basis, a coast-distance ratio has been introduced as a ratio between the thickness drilled in a hole given and the average thickness of the unit given.

As it has already been referred to, in the case of a geological megacycle the coastline is represented by 100, and the theoretical centre of basin by 0. However, it seems expedient to apply a division by 25, so that the scale of the coast-distance ratio be representative of the following categories: lower than 25, 25–50, 50–75 and higher than 75. These index values are, nonetheless, of a relative character, as having been fitted to the coastline presumed to be known. As for a regressive geological megacycle, the position of the values 100 and 0 are inverse (100=theoretical centre of basin, 0=coastline).

(**b**) Inside the depositional basin the following lateral variations are outlined:

– The thickness of formations or mesocycles depends on the basement mobility and morphology instead of the distance from coastline. The maximum thicknesses of mesocycles are "rolling" in space according to the direction of transgression or regression.

– From the basin edge in an inward direction, a continuous increase is shown by

– the average formation thickness, (when transgressive, with a basement subsiding),
– the frequency of pebbly interbeddings (turbidite),
– the argillaceous rock content %, and the
– number of all microcycles.

– From the basin edge in an inward direction, a steady decrease is shown by

– the average formation thickness (when regressive, with a basement uplifting),
– the psammitic rock percentage,

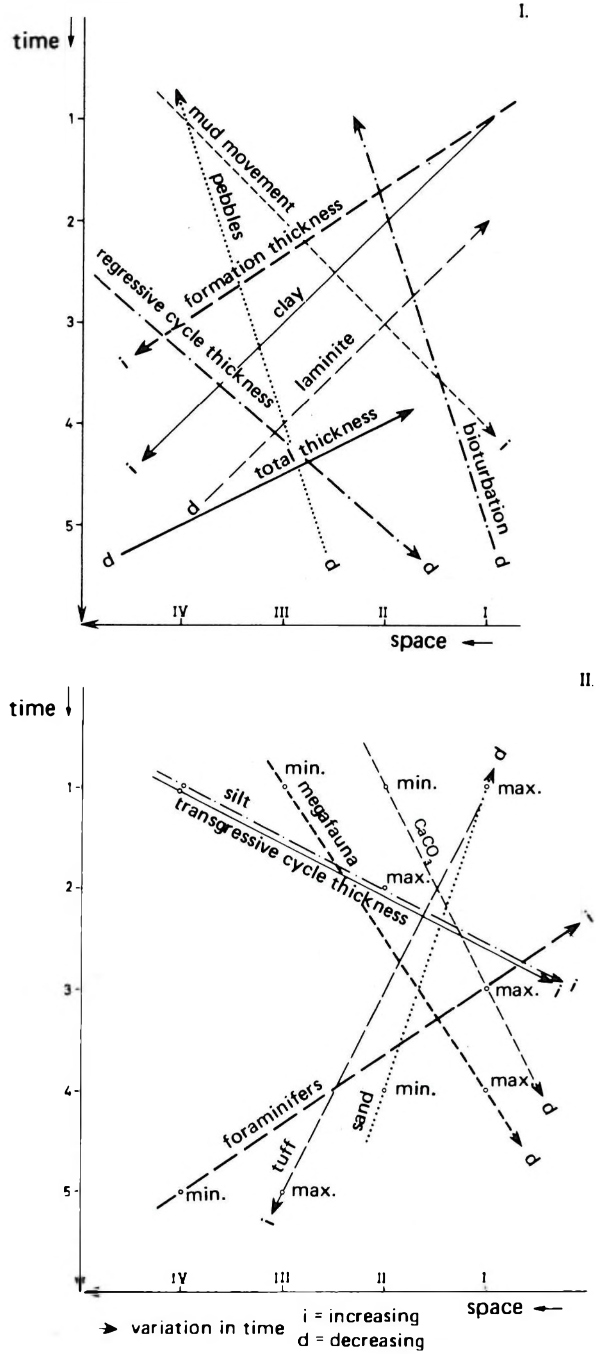


Fig. 27. Correlation regularities of the sedimentological events of the Karpatian molasse (upon the method of minimum-maximum extreme points)

– the number of megafaunal taxons and
– the number of foraminiferal taxons.
– It changes in dependence upon basement morphology (stream conditions)
– the microcycle thickness,
– the sand/silt proportion,
– the carbonate content,
– the frequency of specific sedimentological features and
– the frequency of specific fossils.

(c) In relation to basin edge–basin, some additonal details may be interesting as well as

– the average thickness of psammitic and pelitic rocks changing in opposite directions,

– the site of appearance of bioturbation, laminite formation and mud movements etc.

Possibilities of the correlation in space and time of the Karpatian formations taken for example in this study are shown in Fig. 27.

* * *

The author has conducted studies in various Neogene facies areas (continental, paralic and marine) by adopting this method outlined above. The pertinent statements have been based upon much more data than included in this paper, and even data interpretations through map projections have a wider field in up-to-date geological studies.

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