THE APPLICATION OF MATHEMATICAL METHODS FOR STRATIGRAPHIC CORRELATION OF QUATERNARY DEPOSITS

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Abstract : The mathematical methods and computers for stratigraphic correlation of Quaternary deposits have been applied, because on account of various reasons, this problem can't be completely solved using only methods of biostratigraphy and geochronology. The stratigraphic correlation of tills has been executed by using the results of lithological and geochemical investigations and mathematical-statistical methods. The application of the factor and cluster analysis have been most effective. Absolute data of the results of various laboratory investigations have been used for stratigraphic division of geological sections, while relative data (lithological and geochemical coefficients or pair correlation coefficients) have been used for stratigraphic correlation between the sections. Minimum number of samples necessary for statistic characteristics of each till has been obtained experimentally. Therefore the dependence of variation coefficient on the number of samples has been analyzed. The most reliable results of stratigraphic correlation of tills have been obtained using data of chemical (silicate) analysis.

Key words : Till, Lithological, Geochemical, Statistical analysis, Cluster analysis, Factor analysis.

INTRODUCTION

Reliable correlation of Quaternary deposits is one of the most complicated problem in investigating of Quaternary thickness. In Lithuania it is especially urgent in the zones of marginal deposits where thickness of Quaternary deposits reaches more than 200 - 250 m. (Baltrunas and Bitinas, 1984). The Quaternary thickness can be investigated only by boreholes. Quaternary deposits are frequently dislocated, folded, that's why tills and meltwater deposits of the same age often appear several times in one borehole. Interglacial deposits as well as deposits suitable for age determination by methods of absolute geochronology (radio-carbon, amino-acids, thermo-luminescence dating, etc.) are found very seldom. So, stratigraphic correlation of the whole thickness of Quaternary deposits is carried out on the basis of correlation of tills. Up to now till gravel petrographic analysis was one of the most popular methods of stratigraphic correlation of tills in Lithuania (Gaigalas, 1979). But this method is not very precise and it requires much drill core, large gravel concentration in till, etc. It was clear that it is impossible to solve the problem of till correlation without mathematical methods. It turned out that most suitable methods for this purpose would be the method of D.A. Rodionov (1981) and factor or cluster analysis (Davis, 1973). Therefore, lately detailed lithological (granulometric, mineralogical analysis) and geochemical (chemical, spectrum analysis) investigations of till as well as mathematical-statistical processing of the obtained results have been applied in stratigraphic correlation of tills.

STRATIGRAPHIC DIVISION OF TILLS IN SECTIONS

At first the method of D.A. Rodionov was used for stratigraphic division of Quaternary tills in sec-

tions. But according to this method it is difficult to understand if the distinguished boundary has a stratigraphic meaning or if it only separates crust of weathering, till floe, basal and ablation till, etc. (Fig. 1) It has been determined experimentally that factor or cluster analysis is more suitable for this purpose. Similar results have been obtained by both methods - geological vertical section has been divided into relatively homogeneous till layers or their parts (Fig. 2). Moreover, these methods enable to distinguish the so called anomalous samples, that were taken from floes, crust of weathering, etc. By the way, while dividing the section according to the results of factor analysis, it is expedient to analyze distribution of samples not only with respect to the 1-st and 2-nd factors (as in Fig. 1) but also to the 1-st and 3-rd as well as to the 2-nd and 3-rd factors.

CORRELATION OF TILLS BETWEEN SECTIONS

Correlation of the divided till layers between vertical sections have been carried out using the same methods: factor and cluster analyses. But in this case, taking into account the specific character of till formation, not the primary results of the analyses but the derivative parameters (lithological and geochemical coefficients or pair correlation coefficients) have been used (Table 1). The most reliable results have been obtained using first of all data of chemical analysis (Fig. 3) and data of spectrum and mineralogical analyses as well. Results of vertical section correlation serve as a basis in making geological profiles (Fig. 5). Certainly distinguished interglacial deposit layers are as control factors of trustworthiness of till correlation.

Fig.2. Interpretation of results of factor (A) and cluster (B) analyses (preliminary stratigraphic division of tills) carried out on the basis of chemical analysis of tills (borehole No 900). Conventional signs in Fig. 1.

PROBLEM OF TILL CORRELATION

There are many factors which have serious influence on the results of till correlation: condition of drill core, quality of sampling, precision of an applied method, subjective mistakes of analyst. But there exists one problem that has an influence not only on the precision of correlation, but it also determines the expense of the method itself. This is a problem concerning the amount of samples to be analyzed from a separate till layer of a separate section. It has been tried to solve this problem experimentally: dependence of the main statistic parameters of the results of various analyses on the amount of samples has been analyzed. The samples have been taken from a thick, rel-

atively homogeneous till layer, distinguished according to the above described method (Fig. 3, borehole No 911, till layer 4). Analyzing the dependence of variation coefficient on the amount of samples graphically (Fig. 4) it is evident how this coefficient is approaching its theoretical meaning (constants). In this case (Fig. 4) it is considered that 15-17 samples for chemical analysis are sufficient to make a trustworthy characteristics of a till layer in section. Thus it is possible to determine the minimum quantity samples (for various types of analysis) necessary for the characteristics of a separate till layer in order to make a trustworthy correlation of sections.

Fig.3. Grouping of till layers according to factor analysis. Factor analysis carried out on the basis of matrix of geochemical coefficients (Table 1). Conventional signs in Fig. 1.

Table 1. Geochemical coefficients of tills of some boreholes in North - East Lithuania (Fig. 3)

Number of borehole	157			911					875			922		900					896	
	1	2	3	1	2	3	4	5	1	2	3	1	2	1	2	3	4	5	1	2
SiO ₂ /Al ₂ O ₃	9.78	8.40	9.67	7.54	8.24	9.26	8.32	10.00	7.64	14.73	11.80	7.02	7.60	7.43	9.55	9.86	9.17	13.34	12.09	14.14
SiO ₂ /CaO	8.62	10.19	14.13	7.76	7.58	7.58	6.83	8.42	10.34	23.30	16.75	7.06	8.69	6.52	7.35	7.50	5.99	17.36	9.25	15.75
TiO ₂ /Al ₂ O ₃	0.02	0.02	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.05	0.04	0.04	0.05	0.03	0.03	0.03	0.03	0.05	0.05	0.06
Al ₂ O ₃ /K ₂ O	2.68	3.03	2.96	2.78	2.78	2.40	2.47	2.66	2.79	2.53	2.53	2.69	2.95	2.44	2.72	2.68	2.63	2.91	2.41	2.38
Al ₂ O ₃ /FeO	11.53	8.45	11.16	9.26	8.07	8.94	9.01	8.74	8.16	8.45	8.85	10.14	7.61	7.71	10.74	6.13	9.21	9.03	7.07	7.54
Na ₂ O/Al ₂ O ₃	0.08	0.08	0.07	0.07	0.08	0.07	0.06	0.10	0.08	0.12	0.12	0.07	0.07	0.07	0.08	0.09	0.08	0.13	0.10	0.10
CaO/Al ₂ O ₃	1.14	0.82	0.68	0.98	1.09	1.22	1.22	1.19	0.74	0.63	0.70	0.99	0.87	1.14	1.30	1.32	1.53	0.77	1.31	0.90
K ₂ O/Na ₂ O	4.88	4.19	4.60	4.84	4.81	5.63	6.41	3.97	4.49	3.34	3.40	5.20	4.82	5.53	4.54	4.30	4.70	2.70	4.10	4.19
Fe ₂ O ₃ /FeO	2.73	1.86	2.96	2.23	1.93	2.00	2.12	1.93	1.97	1.89	2.02	2.63	1.54	1.95	2.98	1.20	2.20	1.75	1.41	1.20
CaO/MgO	2.21	2.54	2.26	2.47	2.83	2.20	2.03	2.49	2.15	2.69	2.50	1.96	2.48	2.13	2.33	2.44	2.24	3.07	2.46	2.06
Amount of samples	12	7	7	12	10	13	21	9	14	9	24	7	14	13	11	8	21	18	16	15

Table 1. Geochemical coefficients of tills of some boreholes in North - East Lithuania (Fig. 3)

CONCLUSIONS

The technological process of till stratigraphic correlation contains a few cycles of data treatment by mathematical - statistical methods and successive geological interpretation: detailed sampling of tills → laboratory analyses (mineralogical, chemical, spectrum, etc.) → selection of mathematical - statistical methods for data processing → data processing (factor, cluster analysis) → preliminary stratigraphic division of tills in the geological vertical sections → calculation of characteristics for each distinguished till layer (mineralogical or geochemical coefficients, coefficients of pair correlation, etc.) → grouping of till layers between sections (factor, cluster analysis) → final stratigraphic division of geological vertical sections and making of geological profiles.

The most precise results of stratigraphic correlation of tills have been obtained using data of chemical (silicate) analysis.

Fig.4. Dependence of variation coefficient (V) on the number of samples (N). Results of chemical analysis of relatively homogeneous till layer (Fig. 3, borehole No 911, till layer 4).

Fig.5. Geological profile of Quaternary thickness in North - East Lithuania carried out on the basis of results of computer stratigraphic correlation of tills. Conventional signs in Fig. 1.

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