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Cycle stratigraphic analysis of the Boda Siltstone Formation

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PhD thesis abstract

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Introduction, research background

The study of the Boda Siltstone Formation, one of the potential host rocks for radioactive waste disposal, and of its geological environment, the Western Mecsek Mts. dates back to several decades. To decide on the location of the suitable disposal area, a detailed knowledge on the geology of the formation is necessary. An important point in assessing suitability is the homogeneity of the sequence. Although the buildup of the thick succession used to be described as unvaried and homogeneous, it is composed of four distinct lithological types, which provides an opportunity for cycle analysis.

Aims of the research

The aims of my research were the following:

- to examine the cyclicity of the formation at small and large scales, to define characteristic cycles, incomplete cycles and rhythms and to describe their depositional environment;
- to define and describe ideal, modal and theoretical cycles;
- to define lithological and sedimentological types and to examine the possibility of connecting them to cycles;
- to compare and analyse cycles based on colour change, texture, structure and geophysical properties;
- to analyse statistically the thickness of cycles and rhythms (variability and distribution of cycle and rhythm thicknesses and their relations);

- to determine the thickness of units considered to be homogeneous at small and large scales.

To achieve these goals, I carried out:

- a sedimentological and cycle stratigraphic analysis of representative outcrops and of boreholes drilled after 2005;
- a re-evaluation of previous borehole documentations;
- and a mathematical and statistical analysis of available sedimentological data.

Research methods

Data sources

For cycle stratigraphic analysis I used data from boreholes which exposed thick sections of the Boda Siltstone: the boreholes BAT-4, BAT-5, XV structural well, Ib-4, Bo-5 and Bo-6.

The available data about the boreholes were the following:

- well logs measured by Geo-Log Ltd.,
- complete geological documentation,
- previous description and documentation of outcrops in the study area,
- high-resolution images of the drill cores taken with ImaGeo core scanner,
- and LIPS measurements of drill cores and samples.

Methods

From the geological log of boreholes and exposures I compiled a database appropriate for processing with software. For this I carried out a statistical analysis of rock types documented in the six boreholes (BAT-4, BAT-5, XV structural well, Ib-4, Bo-5 and Bo-6) which were detailed enough for interpretation; this was inevitable for a cycle stratigraphic study. I distinguished 9 main rock types in the six boreholes and three surface exposures. For this I processed more than 400 m of drilled cores and scanned images and electronic and printed documentation of a further nearly 2000 m of boreholes. Based on the geological documentation texts I identified the characteristics that might be used to detect cycles (or possibly rhythms). I extended the existing tables with further characteristics which were important in describing the formation (type of dolomite/dolomarl, thickness, character etc.).

I displayed borehole logs with the software Strater using the database compiled from the documentations. I analysed this database and the geophysical measurements with Grapher and Past as well.

When describing the cycles, I used the following terms:

1. Theoretical cycle: a cyclic succession containing all beds (elements) and recorded during observation.
2. Modal cycle: the most frequent cycle of the formation but not necessarily containing all elements.
3. Ideal or model cycle: an idealised cycle defined after the analysis of cycles in the formation that describes the entire cyclic process.

4. Incomplete cycle: a variety of the previous cycle types (1-3), where one or more cycle members are missing (e.g. due to erosion) but is made up of at least 2-3 members.

5. Rhythm: it is composed of two alternating members and cannot contain more members due to its stratigraphical position.

During the examination of cycles, I carried out both small- and large-scale analysis. In the large-scale phase, I tried to subdivide the entire sequence into major units containing several cycles or cycle groups. Subdivision criteria were e.g. the appearance or disappearance of layers (e.g. dolomitic or sandstone intercalations) typical of the given unit. To analyse cyclicity, I used Markov analysis and time series analysis.

Results

In the dissertation I primarily give a general cycle stratigraphic analysis of the formation; besides this, I define and describe the cycles composing the sequence. I use these data to extend our present knowledge on the homogeneity of the formation. The large-scale examination helps the correlation between boreholes (horizontal distribution, homogeneity), since in the idealised sequence units of similar lithology have identical cyclic composition. The small-scale analysis provides explanation for the sedimentary processes and their cyclic changes.

1. I developed a methodology necessary for the cycle stratigraphic analysis of the Boda Siltstone Formation. Its main constituents are: large- and small-scale examination, colour studies, spectral and Markov analysis.
2. Based on boreholes and exposures, I defined the cycles and rhythms typical of the formation. I carried out the analysis using all rock types in the case of the borehole Ib-4 and using the main lithotypes – sandstone (A), siltstone (B), claystone (C) and dolomite (D) – in the

other boreholes and exposures. I calculated that the most frequent and expected cycles are the following (in order of frequency): AB, CD, AC, ABD, BDB, BD, ABC, ACD, BC.

3. To the nine cycle types typical of the entire formation I added the cycles built up of the nine rock types of the borehole Ib-4, where I subdivided the formation in more detail using a more subtle classification of grain size ranges. Based on these, I identified cycles with the following compositions: silty claystone – silty sandstone – clayey siltstone, sandstone – clayey siltstone, clayey dolomite – clayey siltstone, clayey dolomite – clayey siltstone – silty sandstone.
4. I defined the theoretical, modal and ideal cycles of the formation. I identified the theoretical cycle of the formation based on the sequence of the borehole Ib-4; it contains grain sizes ranging from coarse sandstone to claystone and closes with a dolomitic member. I identified modal cycles as having a composition of AB, ABC, CD and BD. In the Őrház Member I detected a cyclicity based on the grain size of sandstone.
5. Using large-scale analysis, I subdivided the formation into major units from new aspects. I defined the units based on the appearance or disappearance of marked, sedimentologicaly important rock types. The limits of these units were provided by dolomitic or sandstone intercalations. Using these criteria I subdivided the formation into 80-150 m thick units.
6. During the small-scale analysis, I identified the modal cycles of the major subunits. Thus the typical cycles of the units lacking dolomitic intercalations are AB, ABC, AC, BC. Besides these, in successions containing all lithotypes BD, BCD, CD and BDB may occur as well. In parts of the succession lacking sandstone, the cycles CD and CDC dominate, occasionally with BD(B) and BCD types.

7. No cyclicity could be inferred from the colour changes of the formation. However, GIS methods could be utilized in distinguishing between similar colours, e.g. in the case of transitions between the typical brownish-red and reddish-brown. The developed colour analytical method will be useful in cycle stratigraphy if the criteria defined in this paper will be considered during scanning, since the software is teachable and is already partly able to recognise rock types.
8. I carried out a statistical analysis of the thickness of cycles. The average thickness of AB cycles dominating the sequence is 0.5 m, that of ABC cycles 1.0 m, while 1.2 m of the type BD and 2.0 m of the type CD. In case of the latter type, I recorded a millimetre-scale alternation as well.
9. Geophysical well logs proved the existence of characteristic cyclic units detected by other methods and also the thickness of the comprising cycles. I also reported cyclicity in the clay content of the formation. Based on natural gamma and resistance values, I defined previously unknown cycles with thicknesses of 7 m and 12 m. I could apply this to units considered as homogeneous, thus the natural gamma values can be used in the cycle stratigraphic analysis of the formation. I stated that it is not worth carrying out cycle analyses based on calculated albite contents during future studies, because it gives no extra information compared to other methods.
10. Through the cycle stratigraphic studies I extended our knowledge on the homogeneity of the formation. I concluded that the Boda Siltstone is built up of 80-150 m thick units, which are homogeneous from the aspect of isolation properties.

Possibilities for the utilization of the results, further research

When choosing the potential host rocks for radioactive waste disposal, a primary criterion is vertical and horizontal homogeneity. The Boda Siltstone cannot be considered entirely homogeneous; it can be subdivided into three distinct parts: the Őrház Member and two other, 350-450 m thick units. Because of its lithology, the Őrház Member is inappropriate as a host rock, thus only the two upper units deserve further studies.

Since the studied boreholes are located too far apart to determine lateral changes of homogeneity (because of the frequent lateral facies changes), only vertical tendencies can be characterised at the present state of studies. In spite of the internal inhomogeneities, at a geological scale (or from the aspect of the establishment of disposal facilities) each of the three units of the formation can be considered vertically homogeneous. However, further studies are needed to evaluate horizontal homogeneity.

Besides homogeneity studies, the research includes numerous subtopics, thus future research directions are also considerably varied. Among these I consider important the following:

- A detailed study of the intercalations previously described as dolomitic, since in several cases these turned out to be silty layers. For this mineralogical and petrographical studies and LIPS measurements are needed. LIPS measurements are useful in the field, because there it is difficult to identify the rock type of the intercalations. These studies could provide a more detailed picture of the lithology of the formation and thus of the sedimentary environment as well.

- The analysis of well logs in further boreholes. Including other shallow wells in the studies would provide a more exact picture of the cyclicity of the formation, which could be a reliable correlation tool.
- The quantification of albite through well log methods. This could provide new cycle stratigraphical knowledge and a better understanding of the homogeneity of the rock.
- A study of the horizontal homogeneity of the formation. This would require the cycle stratigraphical correlation of several, close-lying boreholes.
- A correlation of the sequence of the Boda Siltstone between the Gorica Block and the anticline. This would be possible through a cycle stratigraphic study. However, this would require at least one sequence from the area of the anticline processed with a detail similar to that of the borehole Ib-4.
- Recognition and identification of paleosols and a modern sedimentological analysis in order to identify subaerial events.

List of publications

Publications related to PhD topic

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2. **HALÁSZ A.** 2006: *A Watt-tenger, mint a Jakabhegyi Homokkő Formáció recens fáciesanalógiája.* – In. BARANYAI G. – TÓTH J. (szerk.): Földrajzi Tanulmányok a Pécsi Doktoriskolából V., PTE Pécs, 2006, pp. 9-25.
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