23. Reconstructing stratigraphy: a discrete sampling approach

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23.1 Introduction

When defining stratigraphy over a certain geographic area, there are essentially two techniques for obtaining sample sequences upon which such stratigraphy is based. The first technique involves continuous sampling (or removal) of stratigraphic sequences and is used mainly when excavating archaeological layers where stratigraphic order is the only available source of information, or when geological characterization of strata is of no particular significance. Such cases arise, for instance, in urban archaeology or in excavations of settlements (megaliths, isolated architectural units, etc.). The Harris Matrix approach (Harris 1989) and modifications of it (Desachy & Djindjian 1991), represent a formalized approach for reconstructing stratigraphy based upon continuous sampling sequences.

The second technique involves discrete sampling of stratigraphic sequences from which a stratigraphy over the entire archaeological area is to be deduced. This technique is of importance when excavating strata that can be identified principally by their geological and/or palaeoecological characteristics. Examples of such cases are encountered in geoarchaeological core drilling surveys, archaeological surveys or in excavations of prehistoric sites.

The purpose of this paper is to present, to our knowledge for the first time, a formalized method for reconstructing stratigraphy based upon discrete sampling sequences. The algorithm presented demonstrates the basic approach. From it more complex and sophisticated solutions can be developed.

23.2 The approach

The method for defining stratigraphy based upon discrete sampling sequences can be represented as consisting of three steps:

1. Identification and characterization of stratigraphic units using data analysis techniques.
2. Stratigraphic correlation based upon the developed algorithm.
3. Correlation with archaeological and chronological information and validation of the reconstructed stratigraphy.

23.2a Identification and characterization of stratigraphic units

When sampling stratigraphic sequences using geoarchaeological core drilling techniques, stratigraphic units are characterized principally by sedimentological and palaeoecological variables. For instance, sediments can be described and identified on the basis of the following parameters: grain size data, sediment colour, morphology of stones, presence of microfaunal assemblages such as foraminifera, ostracods or diatoms, presence of macrofaunal assemblages such as mollusca, presence of microfloral remains such as pollen, and/or presence of macrofloral vestiges such as seeds.

Analysis of such data describing various stratigraphic units, using data analysis techniques and in particular correspondence analysis and various cluster analyses, reveals structures, generally a mix of clusters and parabolic curves. *Stratotype* obtained in this manner reflect depositional environments in terms of their energy, hygrometry, temperature, salinity or other climate-related gradients.

23.2b Correlation of stratigraphic units

Having found stratotypes, a description of each sedimentary sequence in terms of stratified stratotypes is then obtained (a stratigraphic sequence may have the same stratotypes: a stratotype present more than once in the sequence, and/or gaps).

The sedimentary sequences obtained can then be correlated in order to reconstruct the overall stratigraphy. To achieve this, the following basic algorithm was developed.

Assume five stratotypes (A, B, C, D, E) and five sedimentary sequences (e.g. cores) described in terms of those stratotypes (Fig. 23.1).

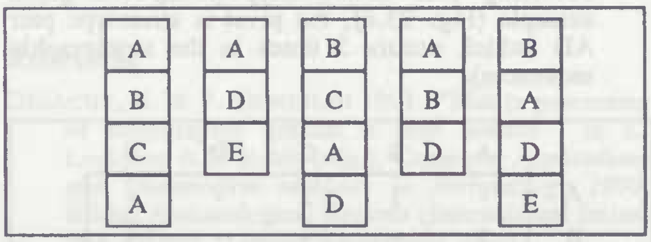

Figure 23.1.

The proposed algorithm is as follows :

a) Construction of an occurrence table.

A table of occurrences for pairs of consecutive stratotypes is constructed. (Entries in this table indicate the number of occurrences for each consecutive pair of stratotypes). For the above given sedimentary sequences the occurrence table is given in Fig. 23.2: 2 (A>B), 1 (B>A), 2 (C>A), 2 (B>C), 3 (A>D), 2 (D>E), 1 (B>D).

Figure 23.2.

	A	B	C	D	E
A	-	1	2	-	-
B	2	-	-	-	-
C	-	2	-	-	-
D	3	1	-	-	-
E	-	-	-	2	-

b) Search for cycles

Multiple occurrence of a stratotype in a sedimentary sequence, or a cycle, may represent a problem in a reconstruction of a sedimentary sequence. Therefore, in order to detect a presence of cycles, a second table is constructed. This table (Fig. 23.3) is obtained by applying the transitivity rule to the occurrence table; entries along the diagonal indicate the presence of cycles.

	A	B	C	D	E
A	(1)	3	2	-	-
B	2	-	-	-	-
C	1	2	-	-	-
D	4	3	1	-	-
E	2	1	-	2	-

Figure 23.3.

In Fig. 23.3, the stratotype A appears twice in the sequence : 1(A > A). The final sequence has six units:

A, A, B, C, D, E.

c) Ordering of stratotypes

Returning to the table of occurrences, ordering stratotypes is accomplished by the following algorithm:

i) Searching for the pivot (the most frequently occurring pair of stratotypes). In the given example (Fig. 23.4), the pivot is stratotype pair AD (which occurs 3 times in the stratigraphic sequences).

	A	B	C	D	E
A	-	1	2	-	-
B	2	-	-	-	-
C	-	2	-	-	-
D	(3)	1	-	-	-
E	-	-	-	2	-

Figure 23.4.

ii) Determining stratotypes that occur above the pivot. This is accomplished by iteratively searching along the rows of the occurrence table for the entry with the highest occurrence. In the given example, starting with the row A (since the pivot is AD), stratotype C has the highest occurrence. Then, in order to determine a stratotype above the stratotype C, row C is examined in the same manner. Here, it is the stratotype B that occurs above the stratotype C, etc. (Fig. 23.5).

The stratigraphic sequence is now:

A/B/C/A/D...

	A	B	C	D	E
→ A	-	1	(2)	-	-
→ B	(2)	-	-	-	-
→ C	-	(2)	-	-	-
D	~~3~~	1	-	-	-
E	-	-	-	~~2~~	-

Figure 23.5.

iii) Determining stratotypes that occur below the pivot. This is accomplished by iteratively searching along the columns of the occurrence table for the entry with the highest occurrence. In the given example, starting with the column D (since the pivot is AD), stratotype E has the highest occurrence. Examining, in turn, column E, no posterior stratotypes are found (Fig. 23.6).

	A	B	C	↓ D	↓ E
A	-	1	2	-	-
B	2	-	-	-	-
C	-	2	-	-	-
D	~~3~~	1	-	-	-
E	-	-	-	(2)	-

Figure 23.6.

Thus, the complete stratigraphic order is obtained. For the given example, it is :

A/B/C/A/D/E.

d) Completion of individual stratigraphic sequences.

Having obtained a complete stratigraphic order, each stratigraphic sequence can now be completed in view of that order and correlation between sequences can be established. For the given example, this completion and correlation are shown in Fig. 23.7:

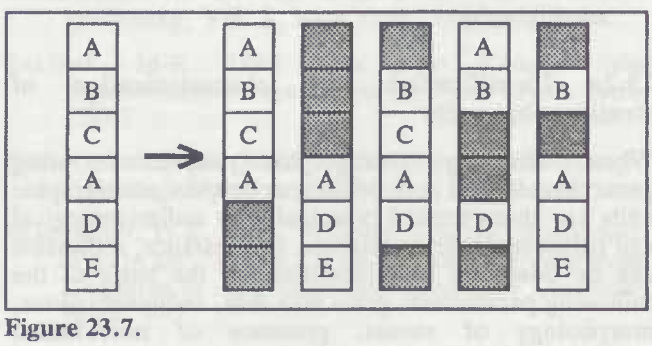

Figure 23.7.

There are cases, however, when completion and correlation of stratigraphic sequences are either ambiguous or they can not be determined. A few examples of such cases follow.

i) Complete cycles of stratigraphic units

An example of such cases is shown in Fig. 23.8 for a cycle of three stratotypes.

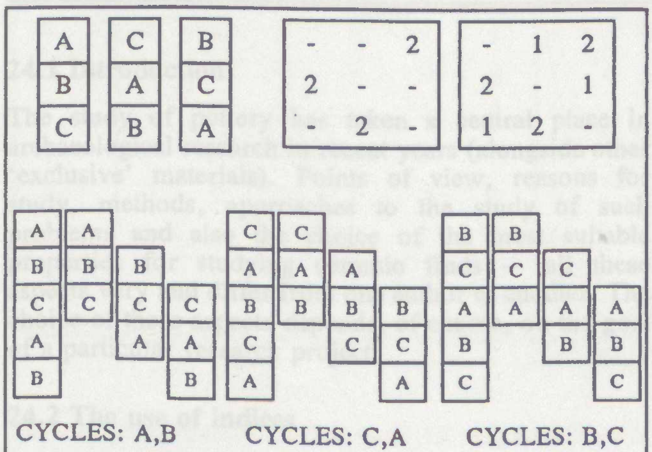

Figure 23.8

There are two indeterminate cycles among the three stratotypes. By convention such stratigraphic units are represented as an only unit figured by A/B/C.

ii) Multiple matching of a stratotype to a stratigraphic sequence.

Ambiguity may arise if there is not a unique solution to match a stratotype with a stratigraphic sequence. In those cases, the stratigraphic sequence is conventionally represented in the manner shown in Fig. 23.9.

23.2c Correlation with archaeological and chronological information and validation of the reconstructed stratigraphy

In order to deal with potential problems of non-unique solutions or indeterminations, additional information may be introduced. The obtained stratigraphic information can than be correlated with information pertaining to the depth of individual stratigraphic units or with chronological information obtained either by absolute or relative dating. This correlation permits the reconstruction of the real stratigraphy and the verification and validation of the proposed model (Fig. 23.10).

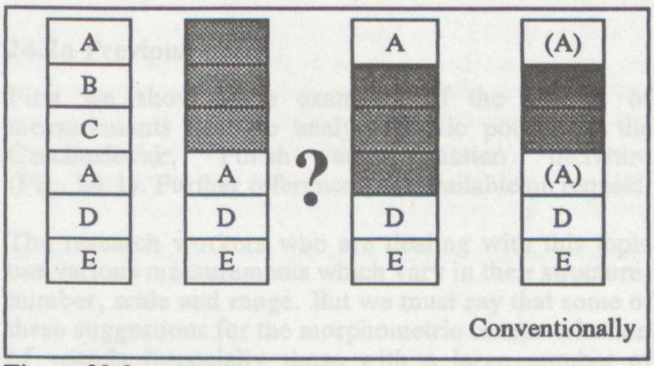

Figure 23.9

23.3 Conclusion

The proposed algorithm for correlation of stratigraphic units of discrete sampling sequences represents a basic formalized approach for the reconstruction of an overall stratigraphy. From it, more complex and sophisticated algorithms can be developed. Computerized algorithms based on the proposed model can also be constructed. However, the advantage of the presented algorithm is its simplicity and ease of use. Correlation of the algorithm results with archaeological information can help resolve possible ambiguities.

References

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Figure 23.10.