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# FISCHERPLOTS: An Excel spreadsheet for computing Fischer plots of accommodation change in cyclic carbonate successions in both the time and depth domains ☆

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**Abstract**

Fischer plots are plots of accommodation (derived by calculating cumulative departure from mean cycle thickness) versus cycle number or stratigraphic distance (proxies for time), for cyclic carbonate platforms. Although many workers have derived programs to do this, there are currently no published, easily accessible programs that utilize Excel. In this paper, we present an Excel-based spreadsheet program for Fischer plots, illustrate how the data are input, and how the resulting plots may be interpreted. The plots can be used to derive periods of increased accommodation, shown on the plots as a rising limb (which commonly matches times of more open marine, subtidal parasequence development). Times of decreased accommodation, shown on the plots as a falling limb, generally are coincident with thin, shallow, peritidal parasequences.


*Keywords:* Excel spreadsheet; Fischer plots; Sea level; Accommodation space; Parasequence

## 1. Introduction

Fischer plots are a graphical method to define accommodation changes (sea level plus tectonic subsidence), and hence depositional sequences, on "cyclic" carbonate platforms, by graphing cumulative departure from mean cycle thickness as a function of time (Fig. 1; Goldhammer, 1987; Read and Goldhammer, 1988; Sadler et al., 1993). Sadler et al. (1993) reviewed the use of Fisher plots and suggested that, instead of a time scale as originally used, the horizontal axis of the plots should be labeled by cycle number, to avoid the problem of the poor absolute time control on the stratigraphic record. They also recommended the use of a minimum of 50 cycles, in order to separate non-random from random fluctuations. Day (1997) transposed Fischer plots into the depth domain by plotting cumulative stratigraphic thickness rather than cycle number. This allows the Fischer plots to be drawn

☆Code available from server at http://www.iamg.org/CGEditor/index.htm.

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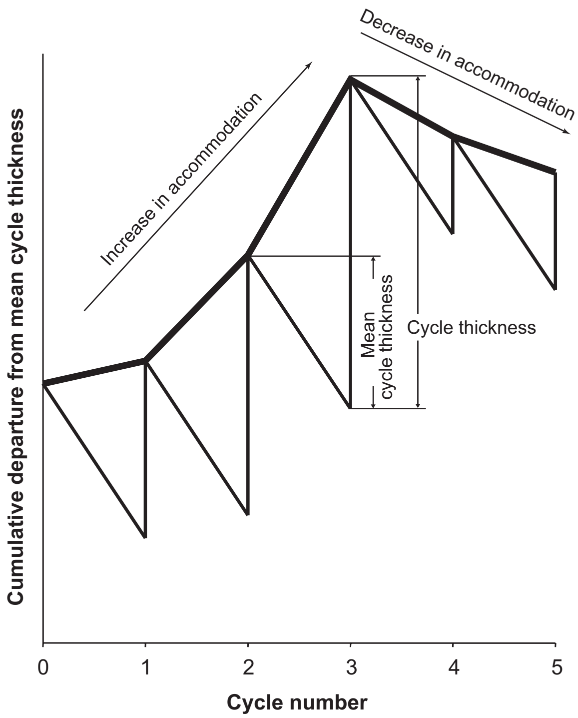


Fig. 1. Portion of hypothetical Fischer plot showing changes in accommodation space as a function of cycle number. Thin vertical lines are individual cycle thicknesses. Increase in accommodation is shown by thick line sloping up to the right,

directly alongside stratigraphic columns to plot accommodation change.

Read and Sriram (1990) developed a computer program for the construction of Fischer plots. It was written in VS FORTRAN version 2.0, and it plotted relative sea-level curves, subsidence vectors and cycle thicknesses against time, using calculated average cycle period. The input data included locality name, horizontal scale (years per inch) and vertical scale (meters per inch), total duration of plot (millions of years), subsidence rate (meters per thousand years), average cycle period (years), starting elevation, and time increment (years).

Besides computer language, the fundamental difference between FISCHERPLOTS described here and the earlier programs is in the input, as well as the output data. Namely, instead of inputting the data on cycle thicknesses, time, and subsidence, the FISCHERPLOTS require no information on age or subsidence, only data on cycle thickness and number of covered intervals in the section. Sadler et al. (1993) and others used Excel to generate such plots but these workers did not publish the code. This paper presents an easy to use Microsoft Excel spreadsheet program for Fischer plots.

## 2. Fischer plots and cyclic carbonate platforms

Cyclic carbonate platforms consist of many repeated shallowing upward, meter-scale cycles (or more correctly, parasequences) bounded by marine flooding surfaces; each parasequence results from repeated marine submergence of the platform, followed by shallowing to sea level. Parasequences may form by Milankovitch-driven, high-frequency changes in sea level related to orbital eccentricity, and tilt and wobble of the earth's axis (Fischer, 1964; Imbrie, 1985). This is supported by the apparent correlation of Pleistocene deep-sea and coral-reef records with orbital climatic oscillations (Berger, 1984; Hays et al., 1976; Imbrie, 1985).

Some workers have appealed to autocyclic processes to form parasequences. In this scenario, progressive decrease in the area of the subtidal carbonate factory occurs as tidal flats migrate across the platform with shallowing. This shuts down sedimentation, and allows long-term subsidence to deepen the platform until carbonate sedimentation once again resumes (Ginsburg, 1971). Random processes inherent to the carbonate system also have been invoked as the cause of cycle development (e.g. Drummond and Wilkinson, 1993; Wilkinson et al., 1999). Evidence against autocyclic processes as the dominant cause of parasequence development includes presence of subaerial exposure surfaces capping many cycles, development of parasequences in purely subtidal successions (Dunn, 1991; Goldhammer et al., 1993; Hardie et al., 1991; Osleger, 1991), the fact that sea level was probably never stationary for long time intervals (Koerschner and Read, 1989), that excessively long lag times are needed to make autocycles (Grotzinger, 1986), and that bounding surfaces of cycles commonly can be traced across the platform (Borer and Harris, 1991; Zühlke et al., 2003). Spectral analysis of cyclic successions has also shown a Milankovitch (and even sub-Milankovitch) periodic driver forming cyclic platforms (Bond and Kominz, 1991; Goldhammer et al., 1993; Hinnov and Goldhammer, 1991; Yang and Kominz, 1999; Zühlke et al., 2003). Thus, sea level is generally invoked as the driver forming most parsequences on platforms, with some random, autocyclic processes involved.

Fischer plots (Fischer, 1964; Goldhammer, 1987) were originally used to search for evidence of Milankovitch-scale (20–400 kyr) eustatic sea-level oscillations in peritidal successions, but it was subsequently recognized that they also were capable of qualitatively extracting long-term (1–5 myr) relative sea-level changes from carbonate platform records (e.g. Goldhammer, 1987; Koerschner and Read, 1989; Montañez and Read, 1992; Osleger and Read, 1991; Read, 1989; Read and Goldhammer, 1988; Read et al., 1991; Soreghan, 1994). Rather than extracting relative sea-level change, the plots of peritidal successions more correctly plot changes in accommodation (sea level plus subsidence). Thus, the plots allow recognition of depositional sequences within cyclic platform successions, which may be relatively hard to define given the subtle facies changes within the cyclic successions. In addition, many cyclic successions lack a simple disconformity at the sequence boundary, but instead have a zone of close-spaced disconformities, or siliciclastic-prone units (sequence boundary zone; Montañez and Osleger, 1993).

Since they were first introduced, Fischer plots have been criticized (Boss and Rasmussen, 1995; Burgess et al., 2001; Drummond and Wilkinson, 1993) on the basis of subjectivity of cycle picks. However, it has been shown that the few cycles in which subjective picks are involved make relatively little difference to the overall form of the curves (Sadler et al., 1993). Plots using cycle number are valid if the forcing mechanism, such as precessionally driven sea-level changes, is approximately metronomic, over the relatively limited time intervals of most plots. The plots also imply that cycle thickness is a proxy for accommodation for each sea-level cycle, a problem that becomes greater with increasing magnitude of sea-level changes (as in icehouse worlds), or where successions are not peritidal but deeper subtidal, and hence not accommodation limited.

In subtidal (that is, non-peritidal) successions, Fischer plots likely graph changes in productivity or subtidal accumulation rates. On aggraded greenhouse platforms dominated by pertidal cycles, the plots likely graph changes in accommodation. This is because the bulk of the high-frequency sea-level changes are preserved as carbonate cycles, the lowstand (shelf margin wedge) cycles are present on the platform sampled by the stratigraphic section, and the parasequences fill in most of the available accommodation generated by the small, high-frequency changes in sea level. In this ideal situation, it is possible to estimate the magnitude of sea-level change once the effect of loading has been removed, assuming linear driving subsidence (Read and Goldhammer, 1988). However, most plots are from non-ideal situations, and they can be used to only qualitatively estimate the sea-level rises and falls. Stratigraphic completeness (that is, the requirement that most of the sea-level cycles are preserved, with few missed beats and limited erosion) is less of a problem on greenhouse platforms, where sea-level changes are small, and the duration of the emergence events at the end of each high-frequency sea-level cycle is small (few thousand years duration).

Despite their presumed conceptual shortcomings, Fischer plots have become widely used to extract accommodation changes from carbonate platform successions. This then allows sequences to be defined on the cyclic platforms, which would otherwise be difficult to pick. We recommend where possible that Fischer plots of several different sections be used to define accommodation. With multiple sections, the plots should show good correlation and then can be used to document changes in accommodation. If they do not correlate, then there could be local tectonics involved, or a great deal of autocyclic parasequence formation involved. The transgressive systems tracts are defined by the rising limbs of the Fischer plots, and the highstand sytems tracts by the highest parts and falling limbs of the plot. Low-stand tracts are presumed to be represented by the lowest positions of the plots; however, where low-stand tracts are seaward of the platform margin, the plots on the shelf may only be tracking the transgressive and highstand systems tracts of sequences. Consequently, accurate placement of sequence boundaries using the plots is complicated by whether the plots include the low-stand systems tract cycles (actually shelf margin wedge cycles). Where they include the shelf margin wedge cycles, the sequence boundary would be placed within the zone of disconformities before the start of the shelf margin wedge cycles on the plot (on a typical sea-level curve, about halfway down the plot, or at the point of maximum fall rate). If the shelf margin wedge is missing, then the actual sequence boundary would be at the bottom of the falling limb of the plot. Thus, it is best to use a combination of lithologic data (presence of clastics in cycles, and disconformity zones), and a regional cross section of the platform, in conjunction with the Fischer plots, to define the sequence boundaries.

## 3. Program description

Use of the Fischer plot program is given below, with detailed instructions on data input, and reading output. These are plots of cumulative departure from mean cycle thickness (accommodation) versus cycle number (a proxy for time). It will also generate plots of cumulative departure from mean cycle thickness versus cumulative thickness (stratigraphic position), that is, Fischer plots in the depth domain.

*Assumptions*: All thicknesses are measured in meters (although any other unit can be used, since this application does not use units in calculations and plotting).

*Required input*: Number of covered intervals, thickness of each cycle in stratigraphic section between each covered interval, and thickness of each covered interval.

*Optional input*: The stratigraphic position at which the plot starts.

*General information*: The application uses a few simple conventions. Yellow color denotes cells where the user should input the data. Also, only three buttons are used to manage the application. The buttons are arranged in the order that suggest the sequence of their use. Furthermore, the buttons become sensitive or insensitive as appropriate.

*Note that the user needs to "enable macros" to use the program which may require security to be set to moderate.*

The application has three states. The first state is characterized by an almost empty sheet and the only yellow cell ready for input is the cell for the number of covered intervals. This is the first data the user should enter (Fig. 2). After the number of covered intervals is given, the button "Start input of data" should be clicked.

This leads to another state where the sheet is populated with cells for input of data (thickness of each covered interval or in subsurface, intervals lacking core coverage, and thickness of each cycle in each cyclic section between no-data intervals). Information computed from the input data is also displayed on the sheet (e.g. total number of cycles, average cycle thickness, integer number of cycles assigned to each covered interval based on covered interval divided by mean cycle thickness). After the data are entered (or copy–pasted from another file), the user should click on the "Draw Fischerplots" button. Fig. 3 shows a sheet prepared for the data input when the number of covered intervals is set to 2 in the first step. Fig. 4 shows the sheet with the correctly entered data (note that the "Initial thickness" box is left empty, which will cause the Fischer plot to start at the base of the measured section; that is, the datum is assumed to be zero if not specified). If a distance is specified for the "initial thickness" box, the plot will start from this stratigraphic position.

All entered data are then checked for consistency and, if everything is OK, the two Fisherplots are drawn in two new sheets (the third state). Fig. 5 shows the input data sheet with the calculated values (average thickness, total number of cycles, assigned cycles for covered intervals). An example of a Fischer plot (for the data from Fig. 5) is given in Fig. 6. If there is some inconsistency in the data, the user is informed about the problem and the invalid data in the cell are pointed out. The user has to correct the data, and the "Draw Fischerplots" button should be clicked again. After the Fischerplots are produced,

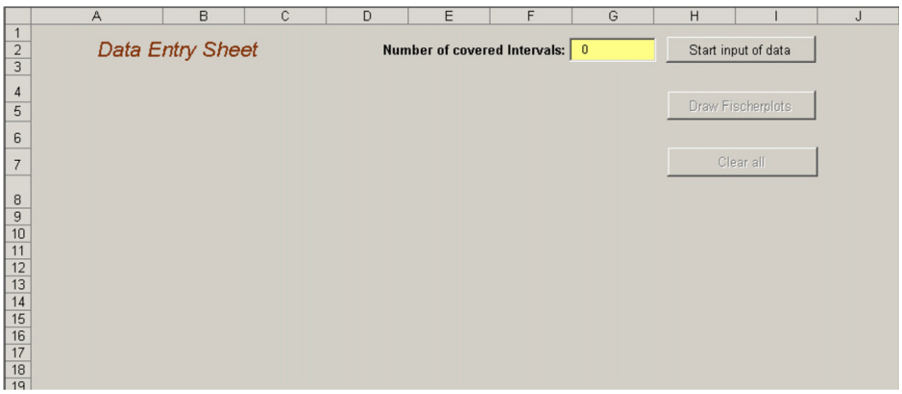


Fig. 2. Visualization showing display at start of program.

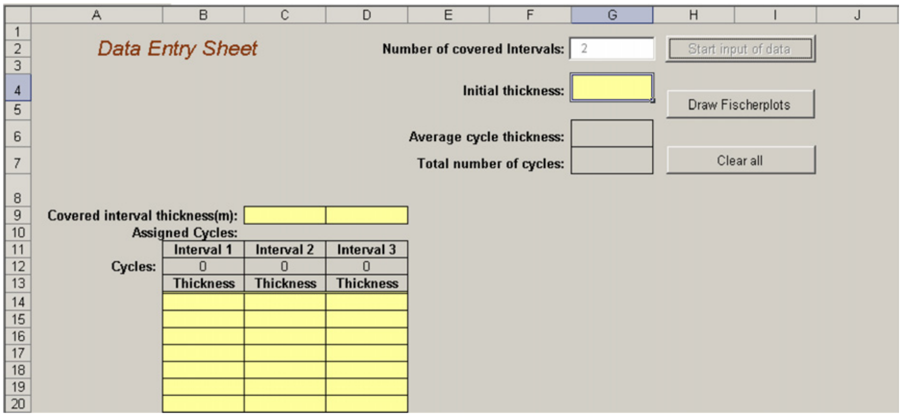


Fig. 3. Figure showing sheet ready for data entry. Data set has 2 covered intervals and so has three columns for entry of cycle thicknesses.

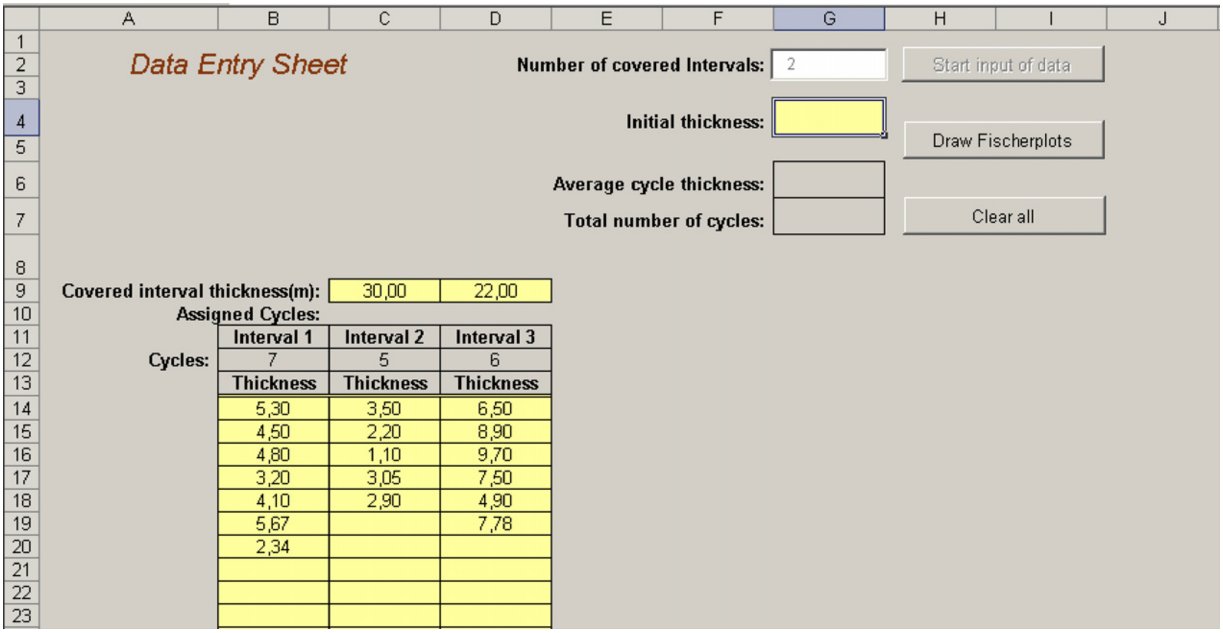


Fig. 4. Sheet after cycle thickness data have been entered.

the data can be modified, based on different cycle picks for example, and the button "Draw Fischer-plots" can be clicked again, which will draw new Fischerplots.

If for some reason data have been entered incorrectly, the user can click the "Clear all" button at any time, and this will clear all data entered up to that point, and the user can start the input of data from the beginning.

By clicking on the "show calculations" box, two additional sheets will be shown. The first shows cycle number, cycle thickness, cumulative thickness, and cumulative departure (from average cycle thickness). In the second sheet, the first column shows cycle number, with all cycles repeated except for first cycle, in order to generate two $Y$ values for a single $X$ value, except for the starting point. These paired values are also shown in the subsequent columns in order to calculate the plot. The second data column, sheet 2, shows the calculated cumulative thickness, and the third data column, sheet 2, shows the cumulative departure data (from mean cycle thickness). The sheets can be saved at any stage of use. Subsequent re-loading of the saved sheet will restore the application state, and the work can continue from where the sheets were last saved.

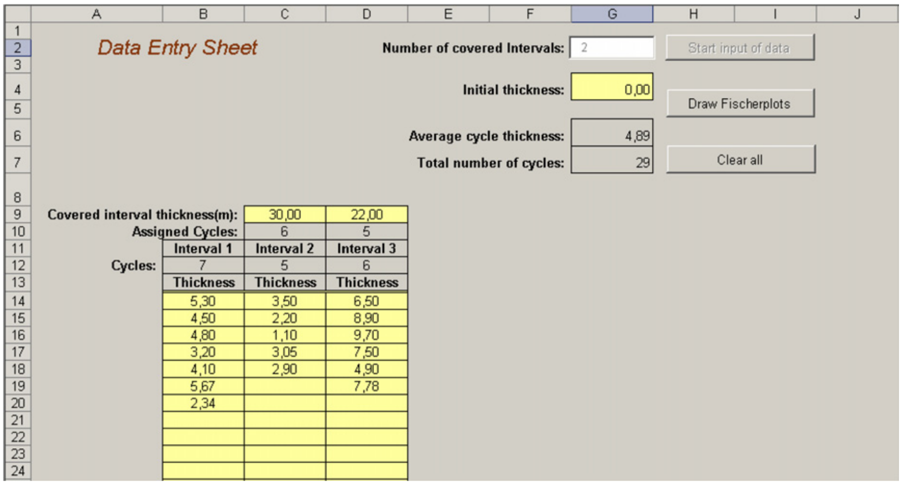


Fig. 5. Sheet showing where starting stratigraphic position is entered into the second top box in upper right, labeled ‘‘initial thickness’’ (0.00). If for instance, the plot needed to start at, for example, 50 m, then this figure would be entered into this box. Average cycle thickness and total number of cycles are computed automatically and given in respective boxes.

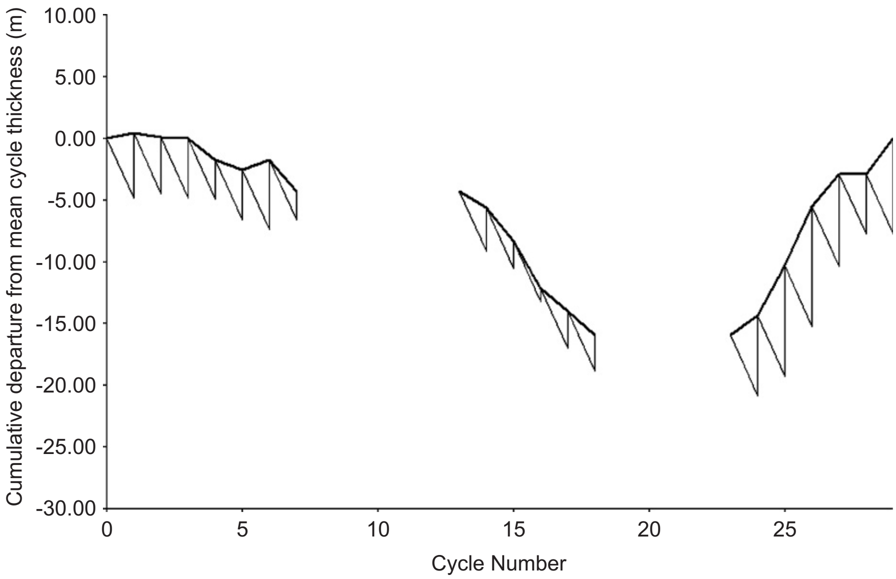


Fig. 6. Example of Fischer plots drawn from input data, where cumulative departure from mean cycle thickness is plotted against cycle number (proxy for time). Two covered intervals are present (blank on plot). Note that this example has less than the required number of at least 50 cycles for a robust plot, but is just used as an illustration.

## 4. Example

The cyclic carbonate section used here as an example is from Lastovo Island, Croatia. The section is Late Jurassic (Tithonian), 750 m thick and composed of many shallowing upward parasequences. A total of 333 cycles were picked, and the section contains a 70 m covered interval. The facies composing the parasequences (Husinec and Read, 2007) include dasyclad-oncoid mudstone-wackestone-floatstone (‘‘deeper’’ lagoon), skeletal-oncoid wackestone-packstone (moderately shallow lagoon), skeletal-intraclast-peloid packstone and grainstone (shoalwater), radial-ooid grainstone (hypersaline shallow subtidal/intertidal shoals and ponds), lime mudstone (restricted lagoon), and fenestral carbonates and microbial laminites (tidal flat).

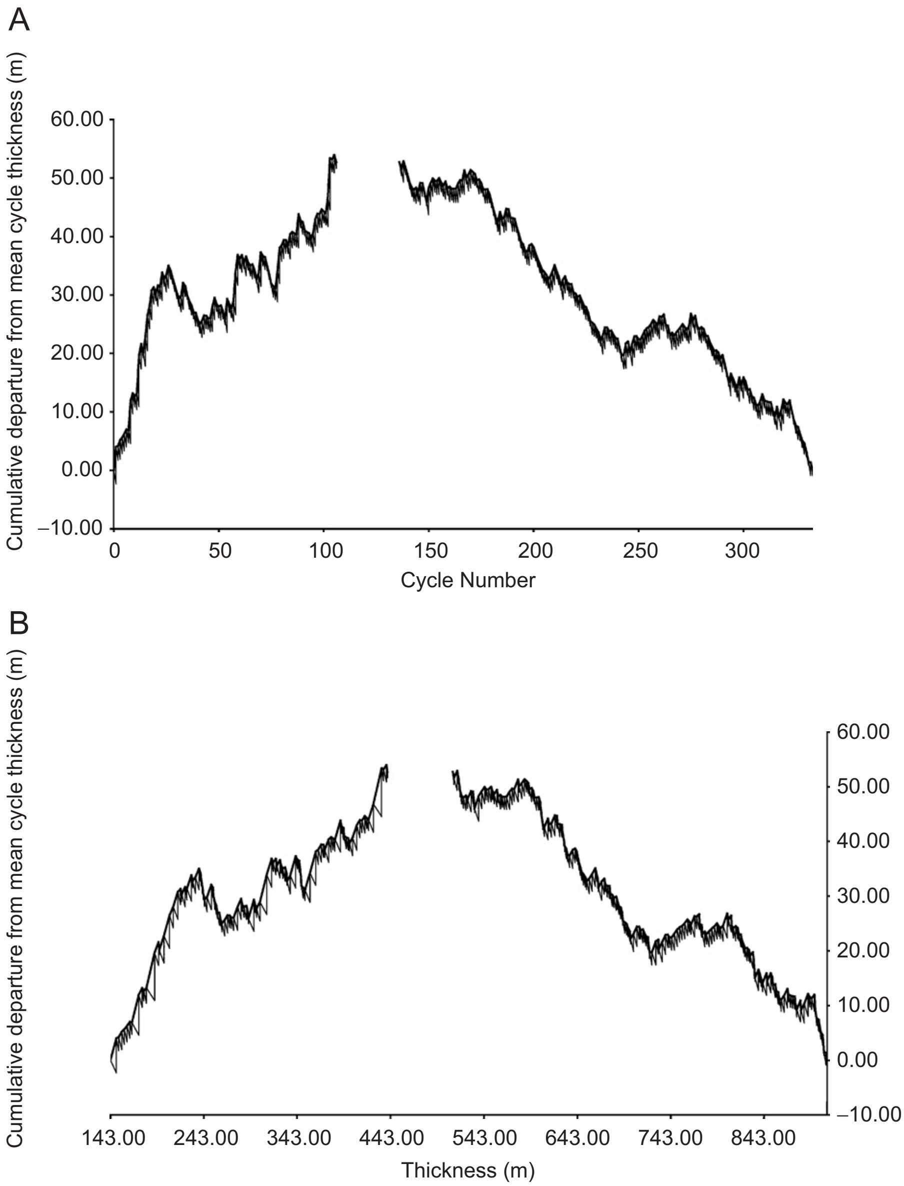


Fig. 7. Fischer plots of Late Jurassic (Tithonian) carbonate platform interior succession of southern Croatia (Lastovo Island). (A) Cumulative departure from mean cycle thickness as a function of cycle number. (B) Cumulative departure from mean cycle thickness as a function of thickness.

### *4.1. Data input and calculations*

We used FISCHERPLOTS to calculate cumulative departure from mean cycle thickness as a function of cycle number and thickness. The procedure is as follows: firstly, input a thickness of the covered interval (70 m), and then we pasted (using Paste Special function) our data on cycle thicknesses for both intervals (bounded by a covered one) from an Excel file with our data. FISCHERPLOTS calculates the following for the 303 cycles in the section; average cycle thickness of 2.30 m; and a total of 30 cycles for the covered interval based on covered interval thickness divided by mean cycle thickness. FISCHERPLOTS then calculates cumulative thickness, and cumulative departure from mean cycle thickness. The cycles are numbered from the designated base of the section, and the cycle number will also include any assigned number of cycles from each covered interval.

### 4.2. Plotting cumulative departure from mean cycle thickness as a function of cycle number

Using FISCHERPLOTS, we constructed a plot of cumulative departure from mean cycle thickness as a function of cycle number. The plot (Fig. 7A) shows a long-term rise and fall. On this are superimposed four third-order accommodation events (0.5–5 myr long). Third-order sea-level cycle 1 starts at the base of the studied succession, and is composed of a rise and fall up to cycle 46. Third-order sea-level cycle 2 is a short-term rise and fall up to cycle 77. Third-order sea-level cycle 3 has a rapid rise up to cycle 105, followed by a covered interval, and a relatively stable sea-level to cycle 178, and then a long-term fall to cycle 243. Third-order sea-level cycle 4 has a relatively low rise and a longer-term fall to the end of the studied succession (cycle 333).

### 4.3. Plotting cumulative departure from mean cycle thickness as a function of thickness

We chose the starting point of our plot at the 143 m tag of the succession (beginning of Tithonian). We used FISCHERPLOTS to graph a cumulative departure from mean cycle thickness as a function of thickness. The resulting plot (Fig. 7B) has the same trends as the one illustrated in Fig. 3A, except that here FISCHERPLOTS plotted cumulative departure from mean cycle thickness against thickness. This may further allow us to easily integrate the resulting accommodation history plot alongside the stratigraphic section log, enabling us to visualize stratigraphy/lithology and sea-level cycles on a single column.

## 5. Conclusions

We present a simple method of generating Fischer plots of cumulative departure from mean cycle thickness plotted against either cycle number or stratigraphic distance, using an Excel spreadsheet program. The only data that need to be input are number and thickness of covered intervals (or uncored intervals in core), and cycle thickness data. An example is given and the mode of interpretation provided.

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## Appendix A. Supporting Information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.cageo.2007.02.004.

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