Misuse of Fischer plots as sea-level curves: Comment and Reply

COMMENT

Richard J. Diecchio
Department of Geography and Earth Systems Science,
George Mason University, Fairfax, Virginia 22030-4444

The argument presented by Boss and Rasmussen (1995), in an attempt to disqualify Fischer plots as sea-level curves, does not satisfy the conditions and assumptions necessary to properly generate Fischer plots. Boss and Rasmussen (1995, Fig. 4) successfully demonstrated that the subtidal carbonates of the northern Great Bahama Bank have not aggraded to sea level and therefore have not filled the accommodation space available to them. This is something I take for granted, but I fail to see what this has to do with Fischer plots. The case can be made that Fischer plots for subtidal limestones may not represent actual sea-level curves, but the data presented by Boss and Rasmussen did not demonstrate this.

Fischer (1964) developed an extremely useful concept for modeling sea-level change in peritidal carbonate strata. The concept was summarized by Read and Goldhammer (1988). The basic idea is that the cumulative variable thickness of carbonate cycles can be used to model changes in sea level *if one assumes that the strata have aggraded to sea level*. This model does not apply if the limestones have not aggraded to sea level. The carbonate environments of the northern Great Bahama Bank studied by Boss and Rasmussen (1995, Figs. 2 and 3) are subtidal, and do not satisfy this assumption.

Boss and Rasmussen (1995) presented several "Fischer plots," but as far as I can tell, none of them are constructed correctly. A Fischer plot compares the actual thickness of each peritidal cycle with the average thickness of all cycles in the stratigraphic section. This average cycle thickness is constant for any given Fischer plot and is assumed to represent the rate of subsidence. The cumulative variation of each cycle thickness from the average cycle thickness is what constitutes the Fischer plot. In Figure 1, A and B, Boss and Rasmussen (1995) used average cycle thicknesses that are not the numerical average of the thickness of the cycles presented. Because of this, the "sea-level curve" does not begin and end at the same point on the y-axis, as it should. It may be that the figures are depicting only part of a Fischer plot, but if so, Boss and Rasmussen should have stated that. Parts C and D on their Figure 1 use a variable average cycle thickness. These are not Fischer plots, because they violate a basic premise of such plots—i.e., that average cycle thickness (mean subsidence vector of Fischer, 1964) is constant.

To generate a Fischer plot, one must calculate the average cycle thickness. It has been recommended (Sadler et al., 1993) that Fischer plots contain a minimum of 50 cycles. Boss and Rasmussen (1995, Fig. 5) presented Fischer plots for one cycle, the Holocene cycle. This seems like an exercise that compares the thickness of the one cycle to itself. Regardless, I cannot interpret their plots, because they do not explain the parameters "actual relative sea level" and "actual accommodation," which are plotted against each other in the Boss and Rasmussen figures. Because the two parameters are not equal, they proposed that the Fischer plot concept does not work. I contend that these are not Fischer plots because the parameters are different from those for Fischer plots and because the plots do not indicate variation of thickness from an average. Even if they were Fischer plots, I would not expect them to be valid for a subtidal area unless or until it can be demonstrated that the sediment aggrades to sea level. Boss and Rasmussen (1995) stated that the Holocene cycle they were trying to model (Fig. 5) was not yet complete. Fischer cycles consist of the strata deposited during successive sea-level lowstands. The Holocene cycle Boss and Rasmussen referred to is still undergoing a rise in sea level. For this reason, I do not see how one can yet model this cycle using Fischer plots.

REFERENCES CITED

Boss, S. K., and Rasmussen, K. A., 1995, Misuse of Fischer Plots as sea-level curves: Geology, v. 23, p. 221–224.

Fischer, A. G., 1964, The Lofer cyclothems of the Alpine Triassic: Kansas Geological Survey Bulletin, v. 169, p. 107–149.

Read, J. F., and Goldhammer, R. K., 1988, Use of Fischer plots to define third-order sea-level curves in Ordovician peritidal cyclic carbonates, Appalachians: Geology, v. 16, p. 895–899.

Sadler, P. M., Osleger, D. A., and Montanez, I. P., 1993, On the labeling, length, and objective basis of Fischer plots: Journal of Sedimentary Petrology, v. 63, p. 360–368.

REPLY

Stephen K. Boss
Department of Marine, Earth and Atmospheric Sciences,
North Carolina State University, P.O. Box 8208, Raleigh,
North Carolina 27695-8208
Kenneth A. Rasmussen
Department of Geology, Division of Mathematics,
Science and Engineering, Northern Virginia Community College,
Annandale, Virginia 22003

We heartily agree that Fischer (1964) developed an elegant method for graphically illustrating the cyclic nature of many carbonate successions, and the methodology for constructing these plots is not disputed. What is at issue is the hypothesis that these plots are reliable representations of past fluctuations of eustatic sea level (Read and Goldhammer, 1988).

Diecchio (Comment above) suggests that parts A–D of our Figure 1 were improperly constructed because the average cycle thickness (subsidence correction) used was neither the mean of the individual cycle thicknesses nor constant. Though the original intent of Figure 1A (Boss and Rasmussen, 1995) was largely schematic, it is noted that the average cycle thickness was the mean (28.41666; dimensionless units) of the individual cycle thicknesses (43, 44, 66, 50, 31, 36, 13, 9, 13, 11, 7, 18). For convenience in plotting the original, this mean was rounded to 28 and used as the constant subsidence correction at each step. Because the expected cumulative effect of underestimating the mean (i.e., underestimating subsidence) in this way would be a minor positive residual at the terminus of the plot, Figure 1A (Boss and Rasmussen, 1995) appears to be constructed properly. Though not apparent in the original figure, the insignificance of rounding the mean is illustrated here (Fig. 1). Whereas it is recognized that a precise cumulative plot of residuals about the mean of any distribution should necessarily begin and end at the same point (Fig. 1, upper; Sadler et al., 1993), it is suggested here that this explicit requirement is additional evidence that Fischer plots are not accurate representations of eustatic sea-level. As stated by Osleger and Read (1993), the starting point

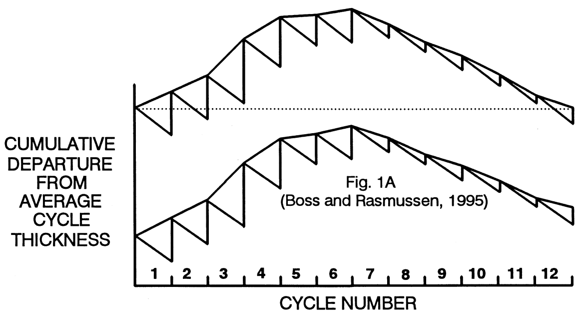

Figure 1. Comparison of Fischer plots constructed using mean cycle thickness (subsidence correction) of 28 dimensionless units (lower plot; reproduced from Fig. 1A, Boss and Rasmussen, 1995) and, more precisely, 28.4166 dimensionless units (upper plot), as discussed in text. Cumulative effect of rounding mean is expressed as insignificant positive residual at terminus of lower plot.

of Fischer plots is chosen arbitrarily. Assuming that this starting point connotes "sea level" at the beginning of a given stratigraphic succession, the return of "sea level" to precisely this position at the terminus of the succession seems extraordinary; that this should be the case for *every* cyclic limestone succession seems highly improbable.

We agree that parts B–D of Figure 1 (Boss and Rasmussen, 1995) were constructed using nonstandard assumptions—we stated these explicitly in the caption. However, the purpose of parts B–D was simply to illustrate that plots of similar gross morphology were obtainable by using very different input assumptions. Similar characteristics of Fischer plots have been noted previously (Drummond and Wilkinson, 1993; Sadler et al., 1993), and it is not clear that input parameters giving rise to a particular shape can be differentiated objectively from stratigraphic data (Wilkinson et al., 1995).

Diecchio (Comment above) equates average cycle thickness with average subsidence rate. He also indicates that one must be able to determine the average cycle thickness from a stratigraphic succession to construct a Fischer plot and concludes that our Figure 5 (Boss and Rasmussen, 1995) does not show Fischer plots, because one cannot determine average cycle thickness from a single cycle. Average cycle thickness and average subsidence rate are measured in different units (e.g., metres and m/ka, respectively) and therefore are not equivalent. It has been argued that average cycle thickness is the product of average subsidence rate and average cycle duration (Wilkinson et al., 1995; Koerschner and Read, 1989), and we suggest that this relation may be used to estimate average cycle thickness for a single cycle. Given an average subsidence rate of Great Bahama Bank of 0.02 m/ka (Pierson, 1982) and a Holocene duration of 10 ka, the average thickness of Holocene sediments on Great Bahama Bank was calculated as 0.20 m, and this constant value was used to correct observed sediment thickness for subsidence in Figure 5 (Boss and Rasmussen, 1995). Thus, these single-cycle (Holocene) plots are constructed according to the same criteria used to construct the single-cycle components of longer plots (Sadler et al., 1993; Osleger and Read, 1993; Read and Goldhammer, 1988; Fischer, 1964).

The demonstration that plots constructed from subtidal sediments are not predictors of eustasy (Boss and Rasmussen, 1995, Fig. 4) appears to be a point of agreement. Therefore, it seems appropriate to openly question eustatic sea-level interpretations for Fischer plots derived from carbonate successions containing appreciable numbers of subtidal cycles.

Finally, Diecchio (Comment above) suggests that eustatic sea-level interpretations for Fischer plots are valid only "if one assumes that the strata have aggraded to sea-level," implying that this can be demonstrated only for peritidal carbonate successions. At issue, however, is whether or not peritidal complexes form at the accommodation peak (Wilkinson et al., 1995; Soreghan and Dickinson, 1994, 1995; Fischer, 1964). We have presented an alternative hypothesis, that peritidal caps may form on subtidal sediments at any point along the declining limb of an accommodation curve (i.e., during eustatic sea-level fall) (Boss and Rasmussen, 1995; Soreghan and Dickinson, 1994), and it seems equally plausible. Given the ambiguity in determining at what stage in an accommodation history peritidal facies develop (Wilkinson et al., 1995), it is maintained that Fischer plots of peritidal cycles ought not to be viewed as unequivocal measures of the absolute magnitude of sea-level variation (Soreghan and Dickinson, 1994, 1995; Wilkinson et al., 1995).

REFERENCES CITED

Boss, S. K., and Rasmussen, K. A., 1995, Misuse of Fischer plots as sea-level curves: Geology, v. 23, p. 221–224.

Drummond, C. N., and Wilkinson, B. H., 1993, On the use of cycle thickness diagrams as records of long-term sealevel change during accumulation of carbonate sequences: Journal of Geology, v. 101, p. 687–702.

Fischer, A. G., 1964, The Lofer cyclothems of the Alpine Triassic: Geological Survey of Kansas Bulletin, v. 169, p. 107–149.

Koerschner, W. F., III, and Read, J. F., 1989, Field and modelling studies of Cambrian carbonate cycles, Virginia Appalachians: Journal of Sedimentary Petrology, v. 59, p. 654–687.

Osleger, D. A., and Read, J. F., 1993, Comparative analysis of methods used to define eustatic variations in outcrop: Late Cambrian intrabasinal sequence development: American Journal of Science, v. 293, p. 157–216.

Pierson, B. J., 1982, Cyclic sedimentation, limestone diagenesis and dolomitization of upper Cenozoic carbonates of the southeast Bahamas [Ph.D. thesis]: Coral Gables, Florida, University of Miami, 343 p.

Read, J. F., and Goldhammer, R. K., 1988, Use of Fischer plots to define third-order sea-level curves in Ordovician peritidal cyclic carbonates, Appalachians: Geology, v. 16, p. 895–899.

Sadler, P. A., Osleger, D. A., and Montanez, I. P., 1993, On the labeling, length and objective basis of Fischer plots: Journal of Sedimentary Petrology, v. 63, p. 360–368.

Soreghan, G. S., and Dickinson, W. R., 1994, Generic types of stratigraphic cycles controlled by eustasy: Geology, v. 22, p. 759–761.

Soreghan, G. S., and Dickinson, W. R., 1995, Generic types of stratigraphic cycles controlled by eustasy: Reply: Geology, v. 23, p. 573.

Wilkinson, B. H., Frank, T. D., and Klein, R. T., 1995, Generic types of stratigraphic cycles controlled by eustasy: Comment: Geology, v. 23, p. 572–573.