TAXONOMY, STRATIGRAPHY AND PHYLOGENY OF THE MIDDLE MIOCENE *FOHSELLA* LINEAGE: GEOMETRIC MORPHOMETRIC EVIDENCE

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Ages of the lower part of the record are based on astronomically tuned benthic foraminifera $\delta^{18}O$ (Holbourn et al., 2013). Miocene isotope event 3 (Mi3, 13.9 Ma) occurs at ~486 mbsf. Ages of the upper part of the records (Fig. A1) are extrapolated using average sedimentation rates for the 455–480 mbsf interval. Black squares represent the benthic foraminifera isotopic data available for astronomic tuning in Holbourn et al. (2013).

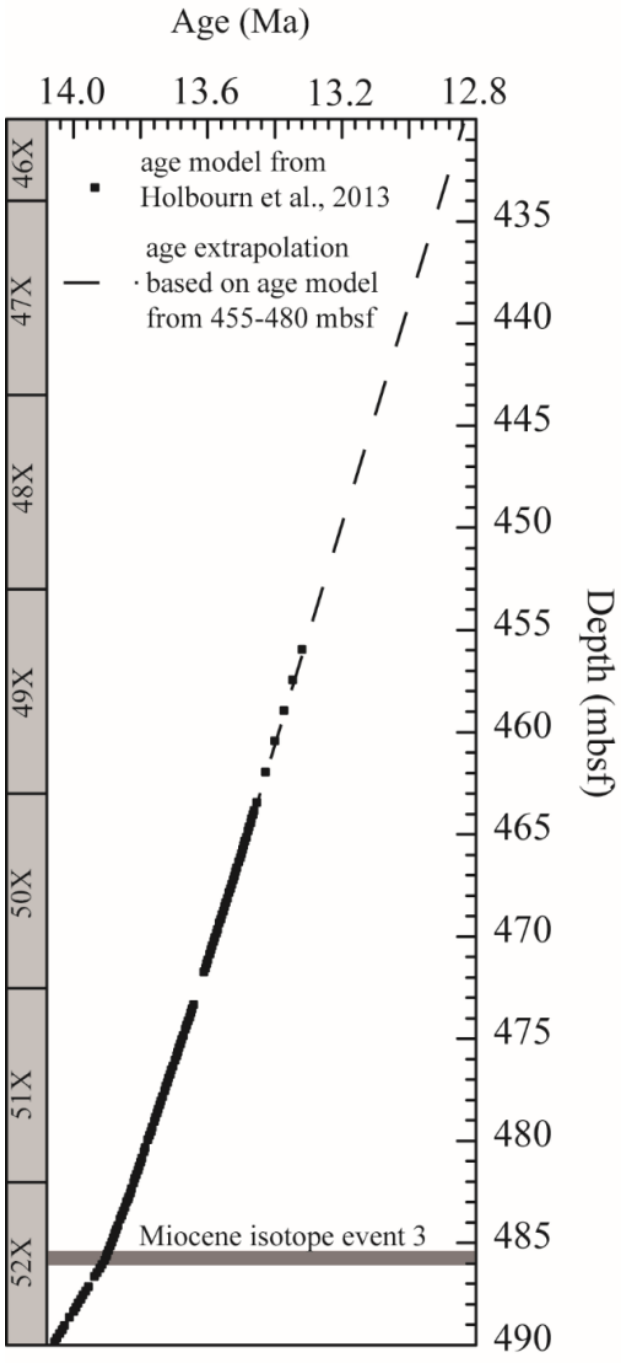

FIGURE A1. Age model used in this study for Hole 806B.

The placement of landmarks and semi-landmarks is central to geometric morphometrics. Different configurations of landmarks and semi-landmarks may give different results. In this work, we follow several criteria in the placement of landmarks and semi-landmarks.

First, adequate coverage of the test: One might prefer placing landmarks and semi-landmarks only in the last few chambers because they are more characteristic in terms of taxonomic subdivision. However, we believe that the adult morphology of a planktonic foraminifera being the product of its growth history, information from the juvenile chambers, at least those in the last whorl, should be included in the analysis. Furthermore, in geometric morphometrics, it is a configuration, not an individual landmark, that composes a datum (Zelditch et al., 2004). As an integrated entity, the test of a planktonic foraminifera should have adequate landmarks and semi-landmarks to capture the configuration of its chambers over the test.

Second, the repeatability: Landmarks and semi-landmarks should be found repeatable and reliably from sample to sample. Otherwise large sampling errors might be introduced into the data. For example, the last chamber of the *Fohsella* lineage is often broken or deformed. Although it is characteristic in the *F. lobata* morphotype, it cannot be sampled repeatedly over the population. On the other side, the early juvenile chambers (eighth, ninth or earlier chambers) are too small to observe in our light microscope photos. Therefore, landmarks cannot be placed precisely for these structures.

Third, adequate semi-landmarks to capture curves: A sufficient number of semi-landmarks are necessary to be able to trace the curves of foraminiferal test. For example, if there are too few points to cover the last chamber of *F. lobata*, the morphometric analysis will not be accurate. On the other hand, if there are too many semi-landmarks along the suture of juvenile chambers, they are all clustered up and look uneven. Therefore, selecting an appropriate number of semi-landmarks based on the samples being analyzed is important.

Based on these criteria, we performed ten experiments for a small data set with types and selected specimens in pulished Figures 7 and 8. Different configurations of semi-landmark curves and numbers of semi-landmarks are used in each experiment. The purpose of these experiments is to figure out whether the ordination of PC1 and PC2 are stable when the configuration of semi-landmarks changes. As can be seen from Figure A2, the ordination of PC1 is very stable regardless of changes in the placement of semi-landmarks. The relative position of holotypes remains unchanged.

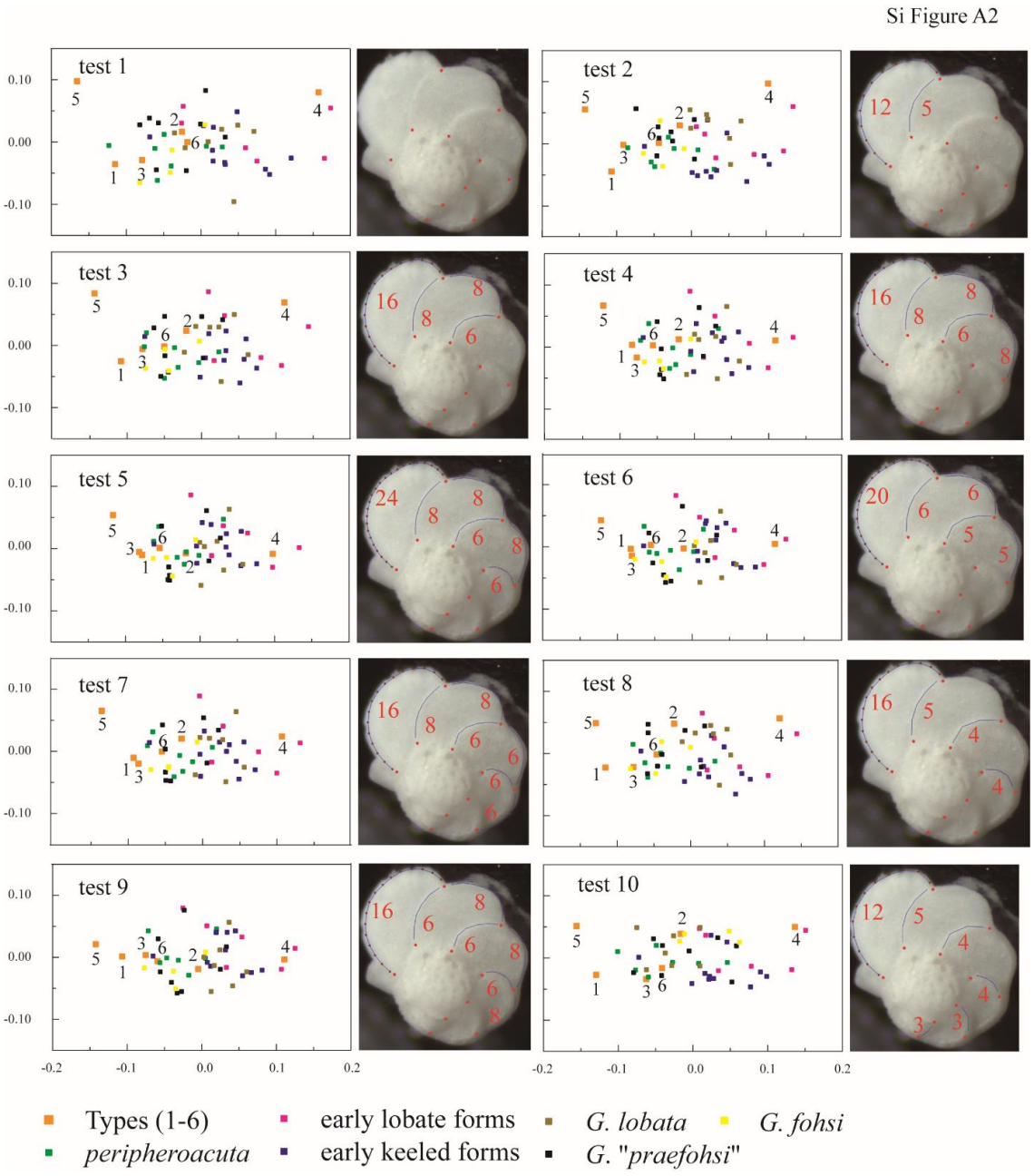

FIGURE A2. Sensitivity test of the ordination of PC1-PC2 under different configuration of semi-landmarks. Blue curves represent the placement of semi-landmarks along sutures or peripheral margin. For example, in test 1, no semi-landmarks is placed. In test 7, there are 7 semi-landmark curves. The number of semi-landmarks of each curve is indicated by the red number next to the curve. All specimens analyzed in these trials are illustrated in Figure 7 and Figure 8. Configuration of test 10 is used in this study. From the relative position of the type specimens, it is clear that the ordination of PC1 is robust across experiments. Number **1**–**6** indicate type specimens, **1** *F. peripheroacuta* (holotype); **2** *F. praefohsi* (holotype); **3** *F. fohsi* (holotype); **4** *F. lobata* (holotype); **5** *F. robusta* (paratype); **6** *F. "praefohsi"* (Kennett & Srinivasan, 1983).