

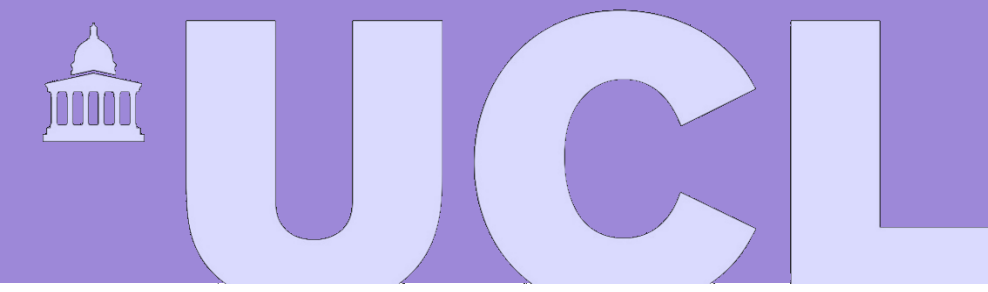
Detecting foraminiferal photosymbiosis in the fossil record: a combined micropalaeontological and geochemical approach

Rehemat Bhatia^{a*}, Bridget S. Wade^a, Shari Hilding-Kronforst^b, John Spratt^c, David P. Matthey^d & David J.R. Thornalley^e

^a Department of Earth Sciences, University College London, London, WC1E 6BT, UK
^b Dept of Geology and Geophysics, Texas A&M University, USA
^c Core Research Laboratories, Natural History Museum, London, SW7 5BD, UK

^d Department of Earth Sciences, Royal Holloway University of London, Egham, TW20 0EX, UK
^e Department of Geography, University College London, London, WC1E 6BT, UK

*rehemat.bhatia.13@ucl.ac.uk



1. Introduction

Species of planktonic foraminifera have different geochemical offsets, which occur due to varying depth habitats and the presence of photosymbionts, complicating our understanding of the palaeoclimate signals we obtain. Size restricted carbon isotope analyses are commonly used to interpret photosymbiotic relationship in extinct foraminiferal taxa¹. However, the use of carbon isotopes is limited, in that carbon isotope data varies with shell size in both symbiotic and asymbiotic taxa. Modern symbiotic taxa (Fig. 1) exhibit cyclic Mg/Ca banding in their shell walls². Whilst Mg/Ca also varies with shell size, the presence of Mg banding is a feature which is independent of shell Mg/Ca concentration. Therefore, the use of this feature is complementary, and may help to validate (or invalidate) carbon isotope data.

2. Mg/Ca banding presence in the fossil record: a study on Eocene and Miocene taxa

Materials and methods

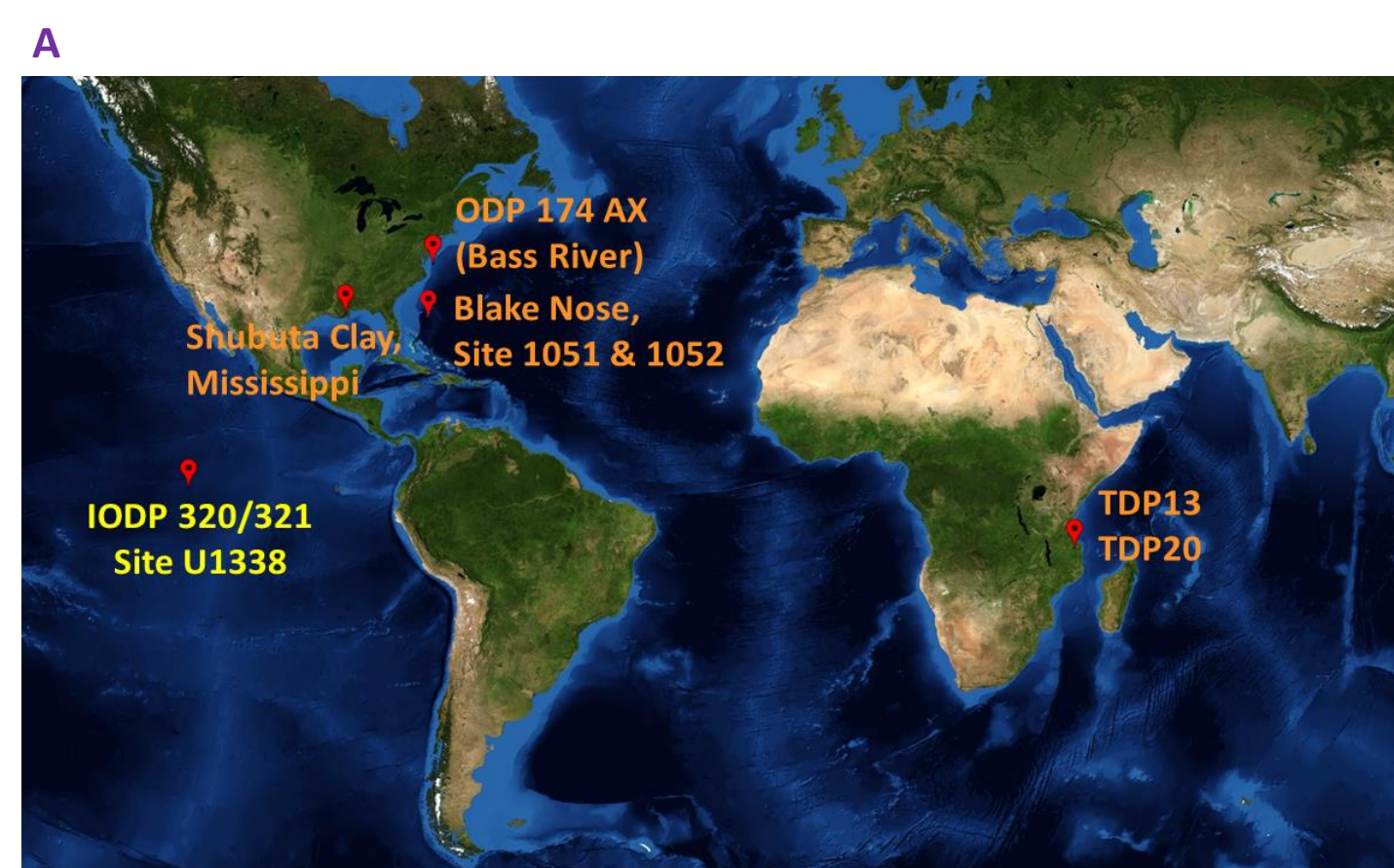


Figure 2: [A] Sample locations: Miocene age samples denoted in yellow, Eocene age samples denoted in orange. [B] Some foraminiferal species analysed. All scale bars 100 µm. [i] *Globigerinoides subquadratus* [ii] *Dentoglobigerina tripartita* [iii] *Turborotalia ampliapertura*

Well preserved middle Miocene³ and Eocene^{4,5} age specimens (Fig. 2) mounted in epoxy resin, and polished to expose foraminiferal walls. 5 – 8 specimens analysed via EMPA. Pre-analysis cleaning method involved using methanol and 18.2 MΩ cm⁻¹ Milli-Q water⁶. Element maps (Fig. 3 and 5-7) generated using a Wavelength Dispersive Cameca SX-100 and Jeol8100 electron microprobe, utilising a low accelerating voltage (15 kV) and beam current (10 nA). Data calibrated to a calcite standard.

Results: Does Mg/Ca banding exist in fossil taxa?

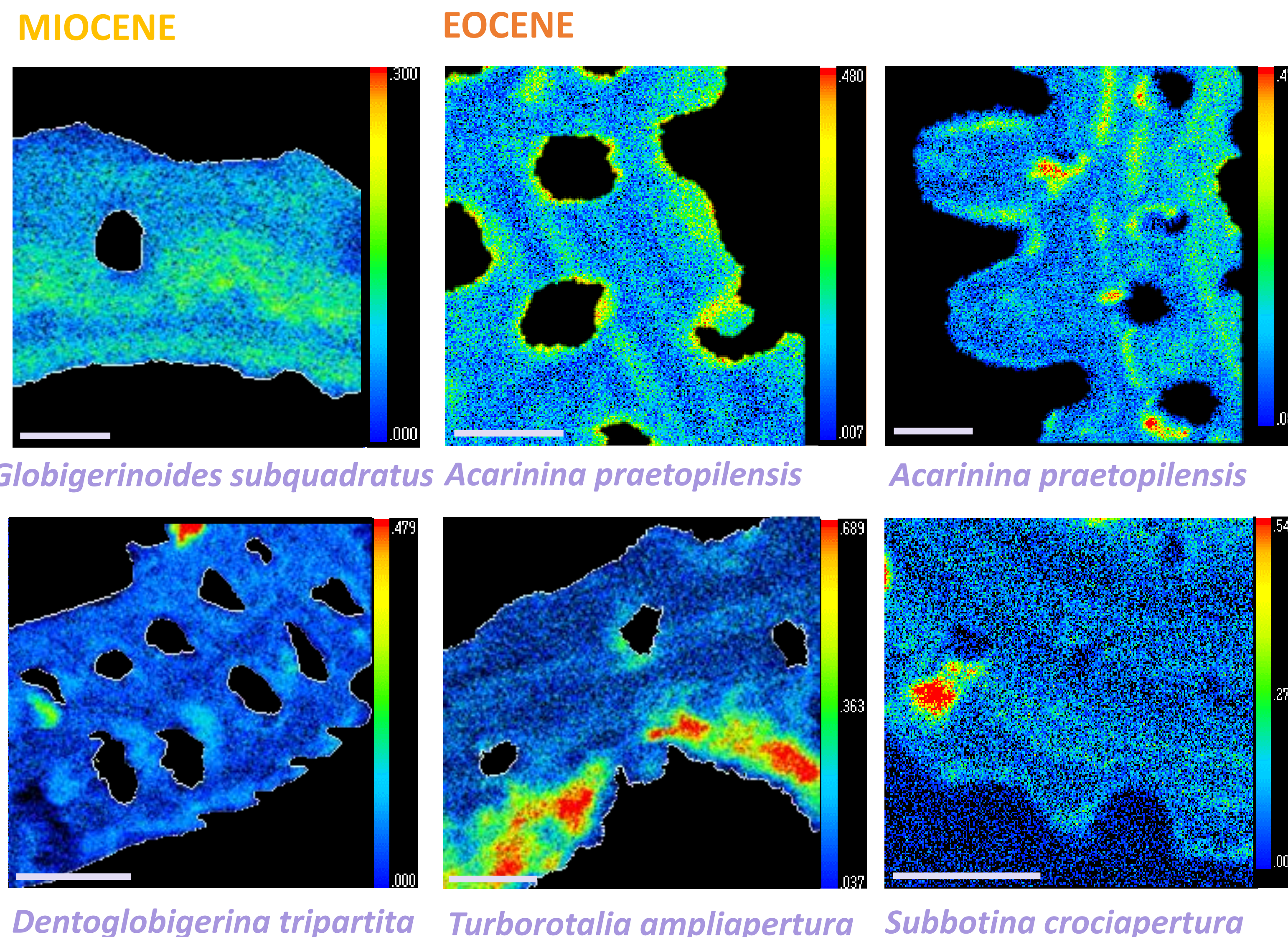


Figure 3: Trace element maps of surface and thermocline dwelling species of Miocene and Eocene foraminifera. Mg bands present in surface dwelling, symbiotic species but are absent in thermocline dwelling species. Scale bars are 20 µm and all geochemical data are in wt%.

Comparing trace element maps and δ¹³C trends

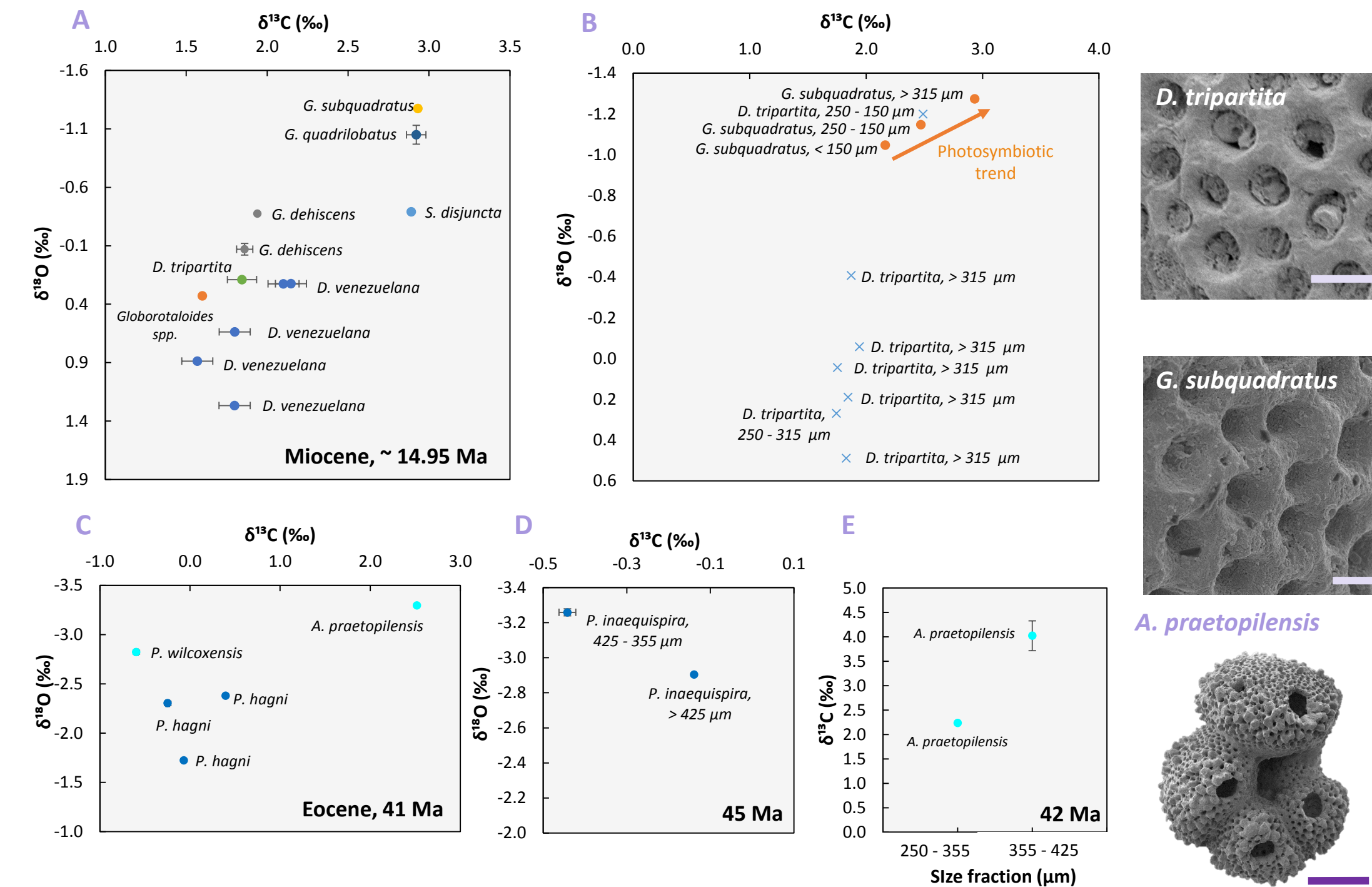


Figure 4: Carbon and oxygen isotope data and SEM images of species analysed. [A & C] Carbon oxygen cross plot showing depth habitats of various Miocene and Eocene species. [B] δ¹³C and δ¹⁸O cross plot for various size fractions of surface dweller *G. subquadratus* and thermocline dweller *D. tripartita*. Increase in δ¹³C with size suggests *G. subquadratus* is symbiotic, and lack of relationship between size and δ¹³C suggests *D. tripartita* is asymbiotic. [D] Graph showing no increase in δ¹³C with size (suggesting an asymbiotic ecology) for thermocline dweller *P. inaequispira*. [E] Graph showing an increase in δ¹³C with size for surface dweller *A. praetopilensis*, suggesting a symbiotic ecology [F-I] SEM images of foraminiferal walls showing presence and absence of spine holes. All scale bars 100 µm, except for G & I (10 µm).

If not symbionts, what else could the banding be related to?

Organic membranes? New chamber growth? Mitochondrial activity?

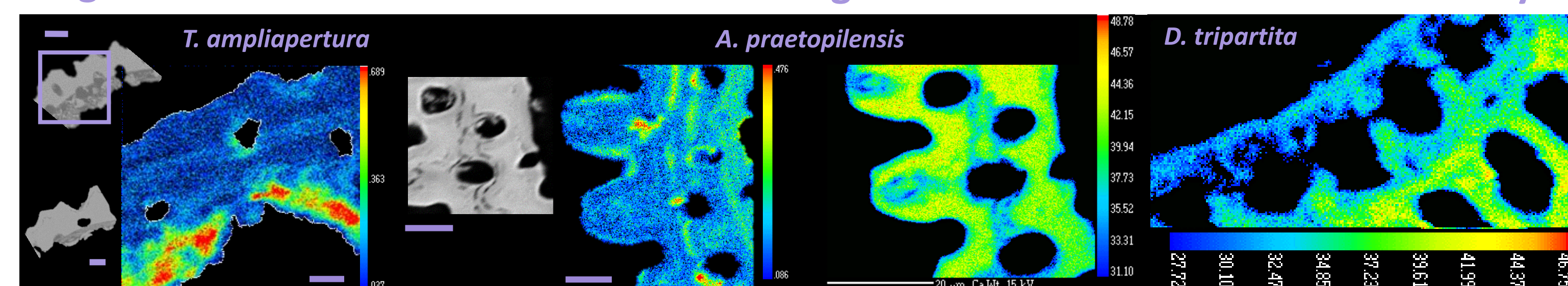


Figure 5: Organic membrane position seen on SEM images does not match position of Mg bands seen in element maps of thermocline species, but does appear to match some of the Mg bands seen in surface species. Ca maps of surface species also show areas of lower Ca concentrations which has been previously associated with organic membranes². New chamber growth⁷ and mitochondrial activity⁸ have also been suggested as other causes of Mg banding, however our size restricted carbon isotope data can further help to suggest symbiotic ecologies for species which have Mg banding. All scale bars 10 µm.

4. Summary and conclusions

- We present multispecies stable isotope and trace element analyses to resolve palaeoecology of various species of Miocene and Eocene planktonic foraminifera. For the first time it is shown that *P. inaequispira* is asymbiotic and *P. wilcoxensis* is a surface dweller.
- Element maps show that Mg bands are present in surface dwelling foraminifera and absent in deep dwelling foraminifera for both Miocene and Eocene species. δ¹³C data show that surface dwellers are photosymbiotic and thermocline dwellers are asymbiotic.
- Preliminary Mg and stable isotope data from middle and late Eocene hantkeninids shows a shift from an asymbiotic to symbiotic ecology.

3. Hantkeninid ecology changes in the Eocene: preliminary results

Hantkeninid ecology has been suggested to change from a thermocline depth habitat in the middle Eocene to a surface depth habitat in the late Eocene⁹. Our results suggest the change in depth habitat also results in an acquisition of photosymbionts (Fig. 6A, C and D). Preliminary Mg element maps also appear to display more prominent Mg bands in the late Eocene (Fig. 6F).

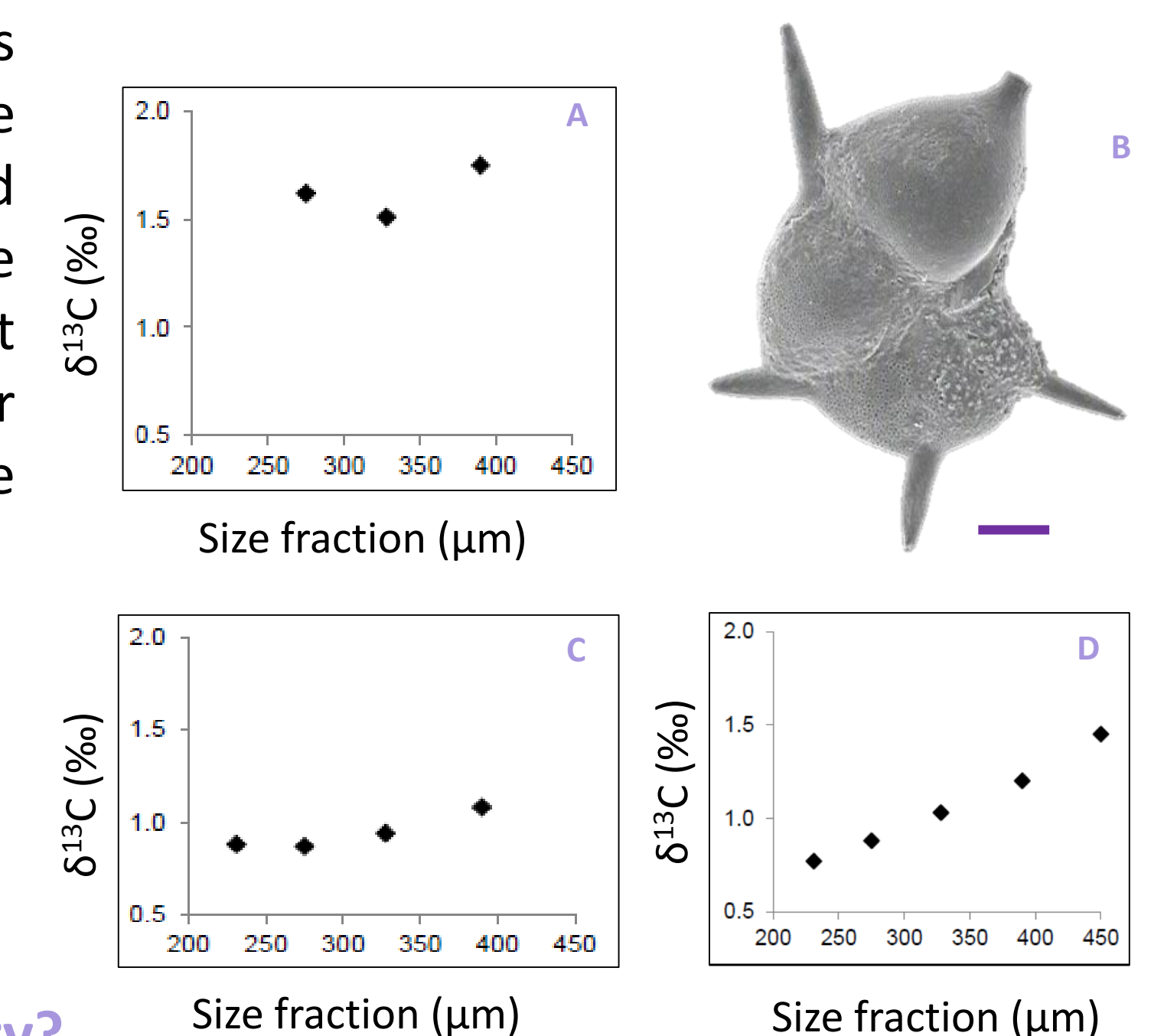


Figure 6: Stable isotope data for middle Eocene hantkeninids from Sites 1051 and 1052 [A, C] and late Eocene hantkeninids from the Shubuta Clay [D]. [B] SEM image of *Hantkenina primitiva*. [E] Mg map of middle Eocene species *Hantkenina lehneri*. [F] Mg map of late Eocene species *Hantkenina primitiva*.

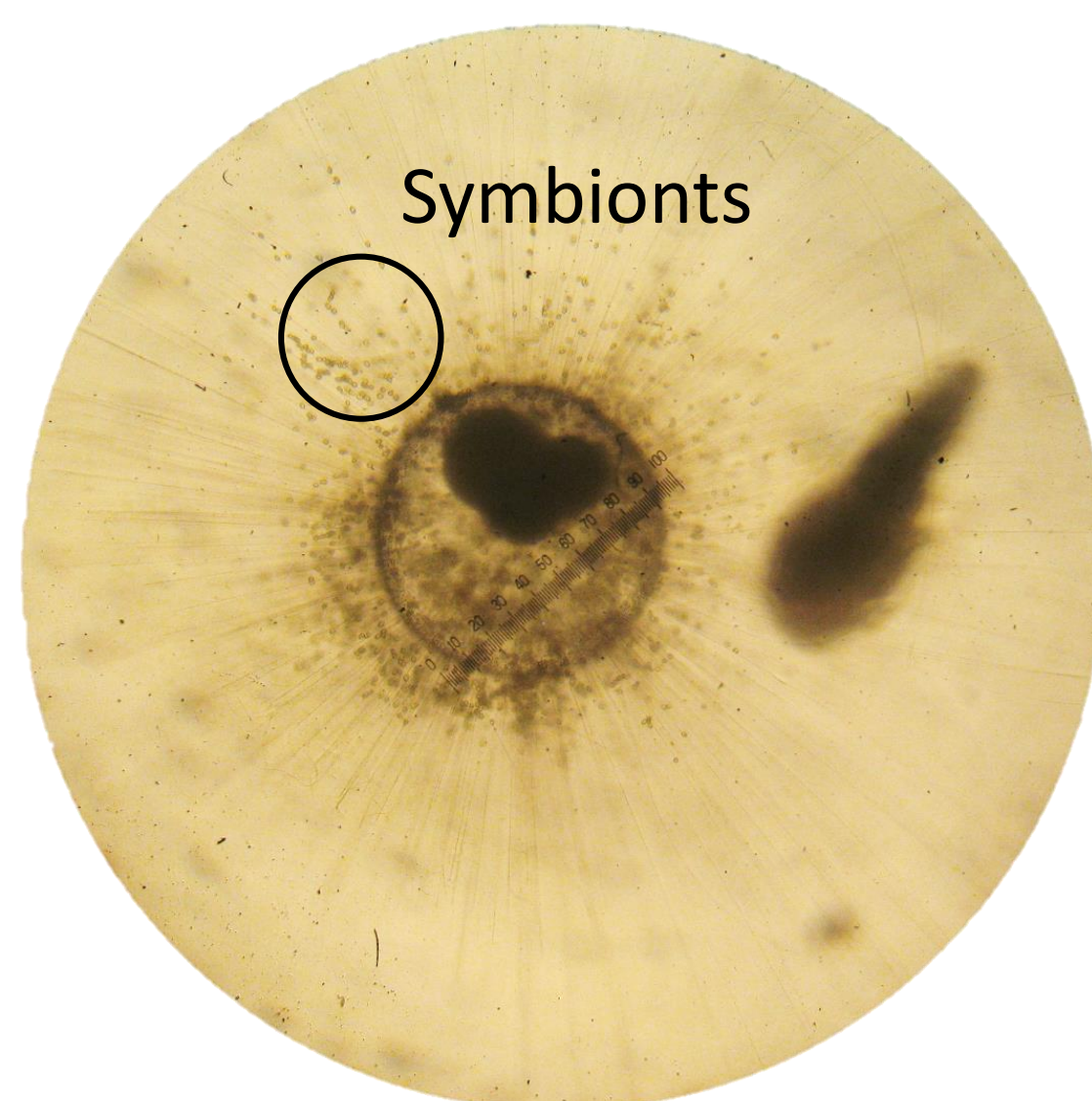


Figure 1: Modern symbiotic species *Orbulina universa*