

Wanted: Dead and Well-Preserved... “Mohawk Guy” and his Band of Neogene Planktic Foraminifer Friends

Summary

Students use foram “Bio Cards” to read and interpret authentic scientific data and build a graphic representation to unlock ancient history stored within sediment cores from the western equatorial Pacific. In this activity, a research project, scientist, and foram species have been personalized to help students make connections between the scientific process and the people who conduct scientific research.

Learning Objectives

Students will be able to:

- Read and interpret authentic data.
- Build a graphic representation of that data.
- Compare paleoceanographic events and their effects on biota living in the past.

National Science Education Content Standards

- Standard A: Science as Inquiry
- Standard C: Life Science
- Standard D: Earth and Space Science

Target Age: Grades 5-12

Time: Two to five class periods, depending on the background knowledge of students.

Materials

- Student Data Sheets
- Bulletin Board Paper or Giant Graph Paper (Giant Graph paper will save time and effort (<http://www.eaeducation.com> #531108; Big graph paper rolls: 100 ft., 2 cm sq., 30 inches wide: ~ \$20)
- “Wanted” Poster, included
- Foram Bio Cards, included
- Foram Section Cards, included

- Crayons or highlighters: Yellow, Green, and Blue
- Ruler or straight edge
- Figure 11 from Dr. Leckie’s Science Report, ODP Leg 130, Site 806
- Figures 1 and 2 from ODP Leg 130 reports
- Annotated Interpretations, included

Background

The study of fossil foraminifera—single-celled microfossils preserved in ocean sediments and retrieved through scientific ocean drilling—has revealed important paleoceanographic events throughout Earth’s history. From these tiny creatures, scientists can learn about the ancient environment, past climate change, plate tectonic movements, changes in ocean productivity, circulation, and much more. As a result, deep ocean sediment cores are significant because they reveal a record of history locked into sediments—deposited during different time intervals—that are now buried beneath the seafloor. Scientists examine these sedimentary layers to reconstruct ancient environments.

Ocean Drilling Program (ODP) Hole 806 B (Leg 130) was chosen for this study because it showcases a long record (> 700 m or 2200 ft.) of fossil planktonic foraminiferal assemblages. This record allows scientists and students to correlate assemblage information to environmental conditions at various times and to assess how the environmental conditions affected the biota. Scientists identified 110 species of planktonic foraminifer from the late Oligocene through the Pleistocene taken from 230 samples found at different levels and depths at Site 806. This activity focuses primarily on the dominant species (taxa) that lived during the Neogene and Quaternary periods (early Miocene

through the Pleistocene epochs, approximately 23 million years ago to 11.5 thousand years ago). Hole 806 B documents six important intervals or events that reveal changes in the environment and the structure of the foraminiferal assemblages during this time period.

History needs markers, as seen in modern history (e.g., Revolutionary War, Industrial Revolution, Civil War, and Hurricane Katrina), as well as more context to better understand the true meaning behind the numbers. For example, the U.S. takes a census of its population every ten years and extrapolates the data to find out how many people live in different regions of the country, as well as ethnicity, jobs, and other important data. If we looked back at the population during certain time periods, we might notice lower populations (more deaths/ fewer births) or shifts in locations (e.g., ghost towns, movement to big cities and away from farms). If we put a period of time or people with this information, then we might better understand what happened and why. For a modern day perspective, New Orleans in 2007 (after Hurricane Katrina) is quite different than what it was when the census was taken in 2000.

This kind of example can help illuminate relative age in a modern time frame that students can understand. It also helps convey that scientists do the same thing. Scientists take a "census" of what is in the region and compare it to other regions from one time period to the next. As scientists collect data for such things as species richness, diversity, variability, and extinctions and relate that data to specific time periods (e.g., middle Miocene, early Pliocene), they can make comparisons to paleoceanographic events and other measurable changes in the environment. By doing so, scientists begin to build a picture of the ancient environment and how ecological conditions changed over time.

Important Concepts for Students to Understand:

- **We have one big ocean, separated into a number of basins.**
- **One thing can affect another, even if it's not in the same region.** The circum-Antarctic circulation, the growth of ice sheets, or the closing of a seaway (oceanic passageway) in one part of the world could affect the tropics in another part of the world.
- **Other parameters or variables might affect organisms by causing changes.** In a **marine environment**, the demise of an organism, the turnover rates (extinctions plus rate of specia-

tion), and the number of species could be affected by benthic turbulence, seasonal changes, dissolved oxygen, dissolved nutrients, pH, temperature, water clarity, salinity, or depth. In a **terrestrial environment**, homes, stores, businesses, roads, and industry coming into an area drastically affect habitat for animals living in fields or forests.

- **As one species becomes extinct or disappears, other species may move into that niche to replace it.** If we hunt and greatly reduce predators such as coyotes or wolves, then deer populations explode. As circumstances change over time, the ecosystem and organisms living there are affected too. After the last ice age, numerous animals became extinct, climate changed, and terrestrial ecosystems shifted north with the retreating ice. As ice melts in the Arctic today, some marine organisms are beginning to move further north.
- **A drill site represents a stationary place on Earth (over an interval of time),** which holds a record showing that as circumstances—such as climate and ocean circulation—change, some organisms go extinct and new ones move in to fill vacated niches.

In this activity, Foram Bio Cards and Mug Shots from a "Wanted Poster" engage students in geological and biological activities by personalizing an amazing group of one-celled protists. As students build a Graphic Representation of the dominant species found at Hole 806 B, they begin to read and understand authentic data collected during Ocean Drilling Program (ODP) Leg 130. The visual leads students to interpret and make comparisons as to which planktonic foraminifers were found in abundance or how they were affected by paleoceanographic events during the Neogene-Quaternary time. (See the Background Information Page: "Hole 806 B: Six Important Intervals or Events during this Timeframe").

Introductory Activities and Additional Background Information

- Bio Card: Research Scientist, Dr. Mark Leckie
- Bio Card: The *JOIDES Resolution* research drilling vessel
- Introductory Activity: "We're Not in Kansas Anymore...Where in the World is Site 806 B?" This activity will give students the opportunity to use *Google Earth* to find specific regions of the world before plotting the coordinates and location of Hole 806 B. The students will

find the latitude, longitude, and elevation of their school, home, Hole 806 B, and nearby landmasses in the western equatorial Pacific, such as Guam, the Marshall Islands, Solomon Islands, and Papua New Guinea.

- Information Page: "Why Study Forams?" This background reading will provide basic information about foraminifera and why these single-celled microscopic organisms are significant.
- Information Page: Hole 806 B: "Six Important Intervals or Events during this Time Frame"
- Vocabulary List
- Sea Surface Temperature Map (http://www.ssec.wisc.edu/data/sst/latest_sst.gif)

A world map that depicts the temperature gradient between climate zones from the equator to both poles. Organisms follow the climate zone. These belts, based on temperature, go around the planet.

What to do

Note: It may work best for some classes to divide this lesson into two parts, e.g., Day 1: Sections I and II and Day 2: Section III; 5th and 6th graders may need three to five days.

I. Introduction: Using PowerPoint, a wall display, computer access to the Deep Earth Academy website, or individual sets of photos for each group.

- A. Introduce the scientist, the drilling vessel, and the Wanted Poster with mug shots.
- B. Look at the "Why Study Forams?" information page and lead a class discussion regarding why forams are important.
- C. Introduce vocabulary with cartoon/ drawing.
- D. Display the Sea Surface Temperature Map and have a class discussion of what it means.

II. Go through the introductory activity: "We're not in Kansas Anymore...Where in the World is Site 806 B?"

III. Activity: Building a Graphic Representation of Dominant Taxa of Planktonic Foraminifera in Hole 806 B from ODP Leg 130, Site 806, Hole B.

1. Divide class into small groups of 3 to 4 students.
2. Refer to Figure 1 and Figure 2 for additional information. These two graphics are from original ODP Leg 130 reports.
3. Hand each group a packet of 19 Foram Bio Cards.

4. The students will sort these cards into categories and explain their grouping. (Emphasize that there are no right or wrong answers). This gives students a chance to become familiar with forams and to compare and discuss characteristics and similarities between each species. Ask students to share their thoughts with the class.
5. Give each student a Foram Section Card and a Student Data Sheet. There are 24 section cards, so each student might be responsible for one card within their group. If the class consists of more than 24 students, then pair additional students to Section Cards that have more species (e.g., Section Cards 3, 4, 6 have eight or nine species on the cards, while some Section Cards only have 3 or 4 species).
6. Each group will look at one section card at a time. Assign each group a *Keeper of the Cards* to hold all 19 Foram Bio Cards until needed.
7. Have the students work together within their groups as they gather data for each Section Card given to their group. Each group might have four Section Cards.
 - a.) One of the students holding a Section Card will request the Bio Cards listed on his/her card from the *Keeper of the Cards*. The students may refer to the species by its nickname. (Note: The nickname, such as ***Sponge glob***, which is listed under the formal name on the Bio Card also mimics Linnean binomial nomenclature, i.e., *Genus species* (Genus is capitalized, species is not; both are in italics, or underlined).
 - b.) The students will determine from the Bio Card if the individual species in that specific level is a Surface dweller (S), Thermocline dweller (T), or Deep Sea dweller (D). Turn the Student Data Sheet on its side: Level 24 (bottom).
 - c.) The students should record this information on their Data Sheets by marking "S", "T", or "D" at the corresponding level under the species that it represents. The students will do the same for each of their Section Cards.
8. The students will begin to build the Graphic Representation section by section to show the dominant species in Hole 806 B. The graph built by the class will match the Student Data Sheet.
 - a. See the photo on this page of the giant graph paper: Cut off a section from the roll

with 38 squares across and 36 squares up. Count up six squares from the bottom and draw a line across the page with a Sharpie marker. Count down six squares from the top and again draw a line across the page. Within these two dark lines, number 1–24 down each side of the page. Write the names of each species in the same order as the Student Data Sheet. Skip a line between each species. Title the Graphic Representation at the top of the page: "Foraminiferal Planktonic Assemblages, Dominant Taxa: Hole 806." (Note: You may use an overhead transparency of the Student Data Sheet instead, or alongside the giant graph paper.)

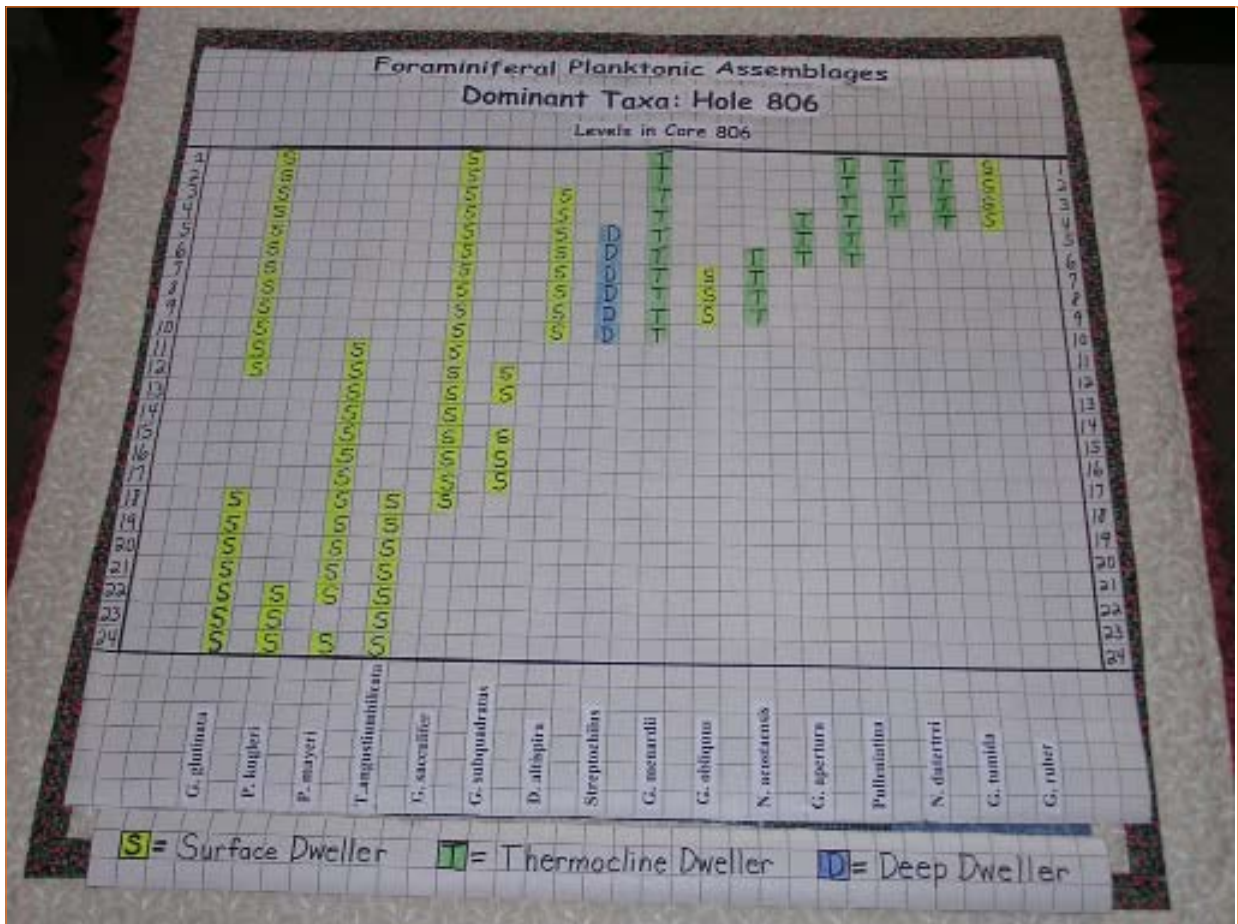
- The students will begin building the graph from the bottom level (Section 24) up to the top level (Section 1). You can build the Graphic Representation using giant graph paper, bulletin board paper, or an overhead projector to enhance the Student Data Sheet.
- Review or discuss the Law of Superposition and Relative Age, which teaches that the

oldest layer is at the bottom and was laid down first when it was deposited horizontally. The younger sediment is at the top and it is above the older layers.

- The first group of students (with Section Cards 24, 23, 22, and 21) will begin by recording the type of dweller in the box in the corresponding section under the species it represents on the Graphic Representation.
- As students build the Graphic Representation, encourage the class to note and discuss pattern changes and differences, as well as to make comparisons. Students will record data on their own Student Data Sheet as each group of students comes up to record their sections on the Graphic Representation. See the Answer Sheet for more information.

Questions to Think about and Discuss

- Do you notice any pattern changes from one level to the next? When a species disappeared (became less dominant for awhile or became extinct) did you notice if another species moved in to fill the niche left vacant?



Your completed Graphic Representation on giant graph paper should look like this,

Lead the students to notice pattern changes and discuss what might have happened. (e.g., In Section 24 – 21: *P. kugleri* was dominant and then abruptly disappeared. When it became extinct, *P. mayeri* filled its niche and became more abundant). When extinction events were quickly followed by a marked increase in taxa—or when the first occurrence of new taxa (species) comes in to fill a niche of an extinct or last occurrence of a species, then it is thought that they may have shared similar ecological niches. Encourage students to look at the Foram Bio Cards or the Wanted Poster to observe and compare morphology or tests (shells) built by the different species of forams. Even microorganisms build their shells to protect their bodies and to meet their needs to survive ecological conditions.

By looking at the Graphic Representation and the Foram Bio Cards, the students will be able to determine which species disappeared or

to meet their needs for survival. Even small changes can make a difference (e.g., temperature, salinity, pH, dissolved oxygen, sedimentation rate, or changes in circulation or current). Species competition may have been a factor, especially in nutrient-poor areas, or when conditions changed. When one species died, then another species may thrive and become more abundant.

- c. What can initiate “turnover rates” among the species?

A specific species will increase, decrease, or become extinct when it can't compete within its niche, or when other species can adapt better to new conditions.

- d. How many species were dominant during different periods:

Levels 24 – 21? (Up to four species)

Levels 20 – 17? (Up to five species)

Levels 16 -13? (Up to three species---Why did it suddenly decrease?)

Levels 12 - 9? (Up to nine species---Why did it dramatically increase?)

Levels 8 – 5? (Up to nine species ---Did the species remain the same, or did some species increase or decrease during this time? Did students notice any last occurrences or first occurrences that coincided?)

Levels 4-1? (Up to nine species).

Demise or Disappearance of Species	→ Filled Niche (+) or Replaced by
<i>P. kugleri</i> (1)	<i>P. mayeri</i> (1)
<i>T. angustumbilicata</i> (1)	<i>G. sacculifer</i> (1)
<i>G. acostaensis</i> (2)	<i>Pulleniatina primalis</i> (2)
<i>G. fohsi</i> (2)	<i>G. menardii</i> (2)
<i>P. mayeri</i> (1)	<i>D. altispira</i> (1)
<i>D. altispira</i> (1)	<i>G. ruber</i> (1)
(1) = Surface Dweller (2) = Thermocline Dweller	

became extinct, and the species that replaced it or filled the niche. It would help the students to pull these Bio Cards and place each of the species in a line to show the order in which each species came in to replace the other. By doing so, the students will be able to compare the foram species and note any changes: (e.g., foram species replacements: *P. kugleri* > *P. mayeri* > *D. altispira* > *G. ruber*).

- b. Why do you think that one species decreased or became extinct while other species remained dominant? What biotic (living) or abiotic (non-living) factors could have affected the organisms and their environment?

Different species need specific conditions

- e. Have students highlight or circle any of the species names (listed at the top of the chart) that made it to Level 1. Point out that these species are still living in our oceans today.

- f. Encourage students to notice changes with depth dwellers. What type of dwellers lived in the lower sections?

Surface dwellers

- g. Did the students notice any abrupt change in dwellers? If so, what changes did they notice and at what level?

Surface Dwellers were dominant from Level 24 up to Level 11. Then something dramatic happened to change the distribution of dwellers (from Level 10 through Level 1). Suddenly, there was an equitable distribution of different

types of dwellers: Surface, Thermocline, and Deep dwellers. The students should discuss what they think might have happened to abruptly change the distribution. Let the students discuss their thoughts before referring to the Annotated Interpretations or Paleoceanographic Events and Intervals (See number 10 below). The chart will show students different events that coincided with the demise or increase of the biota.

h. What variables could change because of depth?

Water clarity, benthic turbulence, substrate character, water column stratification, seasonal changes in water mass and water chemistry (pH, temperature, salinity, conductivity), organic matter flux, dissolved oxygen content.

10. Refer to the Annotated Interpretations and Paleoceanographic Events and Intervals to compare the increase or demise of specific species, and how this affected the biota and environmental conditions.

The students will note the Paleoceanographic events, and discuss how these events coincided with and might have affected the biota. When comparing the events to the Graphic Representation, students will see that dramatic changes in the distribution of depth dwellers coincided with the closing of the Indo-Pacific Seaway. It is thought that this event changed the equatorial surface current mass and caused shoaling of the thermocline. This changed the thermocline position, as well as increased productivity. More species became dominant, which indicated that conditions were good and the community was thriving. Refer back to the Introductory Information and review the vocabulary for thermocline and shoaling of the thermocline.

Discuss the following: What is a thermocline and why is it significant? What role does it play in the ocean?

Changes in position of the thermocline in relation to the euphotic zone and chlorophyll maximum could change the physical structure of the upper water column. It could initiate successive turnovers (competitive exclusion and adaptive radiation).

Useful Links

- Core Photos at Hole 806 B. Submit request for Leg 130, Site 806, Hole B (pdf files) at <http://iodp.tamu.edu/janusweb/imaging/photo.shtml>

- Photos and Information on Coring Tools (pdf files): <http://www-odp.tamu.edu/publications/tnotes/tn31/tn31.htm>

(Technical Notes and ODP Publications, such as *Initial Reports* and *Science Reports* may also be accessed from this site).

Extended Activities

1. **Show the effects of increased nutrients:** Take two plants and add fertilizer (like the brand, Miracle Grow, but be sure to follow the directions because over-fertilization can also poison and kill the plant) to one of the plants. Observe and record how both plants respond. The increased nutrients will show that what happens to land plants also pertains to plankton in the world's ocean.
2. **Satellite images of chlorophyll in winter/spring:** This site has great color images that portray seasonal changes of chlorophyll in the surface ocean by measuring chlorophyll from space. This shows how the same thing—seasonal changes in photosynthesis—that happens to our deciduous trees and grass on land also happens in the ocean. We can see this phenomena in the surface ocean by the spring bloom of phytoplankton (microscopic algae). <http://oceancolor.gsfc.nasa.gov/SeaWiFS> (Teacher Resources)
3. **Comparison to another region:** DSDP Leg 28, Site 270, Ross Sea, Antarctica, was drilled using the drilling vessel, *GLOMAR Challenger*: Fossilized planktonic foraminifer found at Site 806 in the tropical ocean of the western equatorial Pacific can be compared to the fossil and living planktonic and benthic foraminifer assemblages faced with environmental conditions found in an extreme cold region. ACTIVITY COMING SOON.

Written by

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Acknowledgements

This activity is based on an article by William P. Chaisson and R. Mark Leckie in the ODP Leg 130 *Scientific Results* volume (1993). Available at: http://www-odp.tamu.edu/publications/130_SR/VOLUME/CHAPTERS/sr130_10.pdf

Student Data Sheet: Answers

Species	Dominant Taxa: Hole 806																							
	Levels in Core 806 B																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
<i>G. ruber</i>	S	S	S	S																				
<i>G. tumida</i>	T	T	T	T																				
<i>N. dutertrei</i>	T	T	T	T																				
<i>Pulleniatina</i>	T	T	T	T	T																			
<i>G. apertura</i>				T	T	T																		
<i>N. acostaensis</i>						T	T	T	T															
<i>G. obliquus</i>								S	S	S														
<i>G. menardii</i>	T	T	T	T	T	T	T	T	T	T														
<i>Streptochilus</i>					D	D	D	D	D	D														
<i>D. altispira</i>			S	S	S	S	S	S	S	S														
<i>G. subquadratus</i>											S	S			S	S	S							
<i>G. sacculifer</i>	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S				
<i>T. angustumbilli</i>																		S	S	S	S	S	S	S
<i>P. mayeri</i>											S	S	S	S	S	S	S	S	S	S	S			
<i>P. kugleri</i>																					S	S	S	S
<i>G. glutinata</i>	S	S	S	S	S	S	S	S	S	S										S	S	S	S	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Legend: S- Surface dweller (yellow) T- Thermocline dweller (green) D- Deep dweller (blue)

The Original Data: Figure 11

Graphic representation of major changes in planktonic foraminiferal populations throughout Neogene in Site 806.

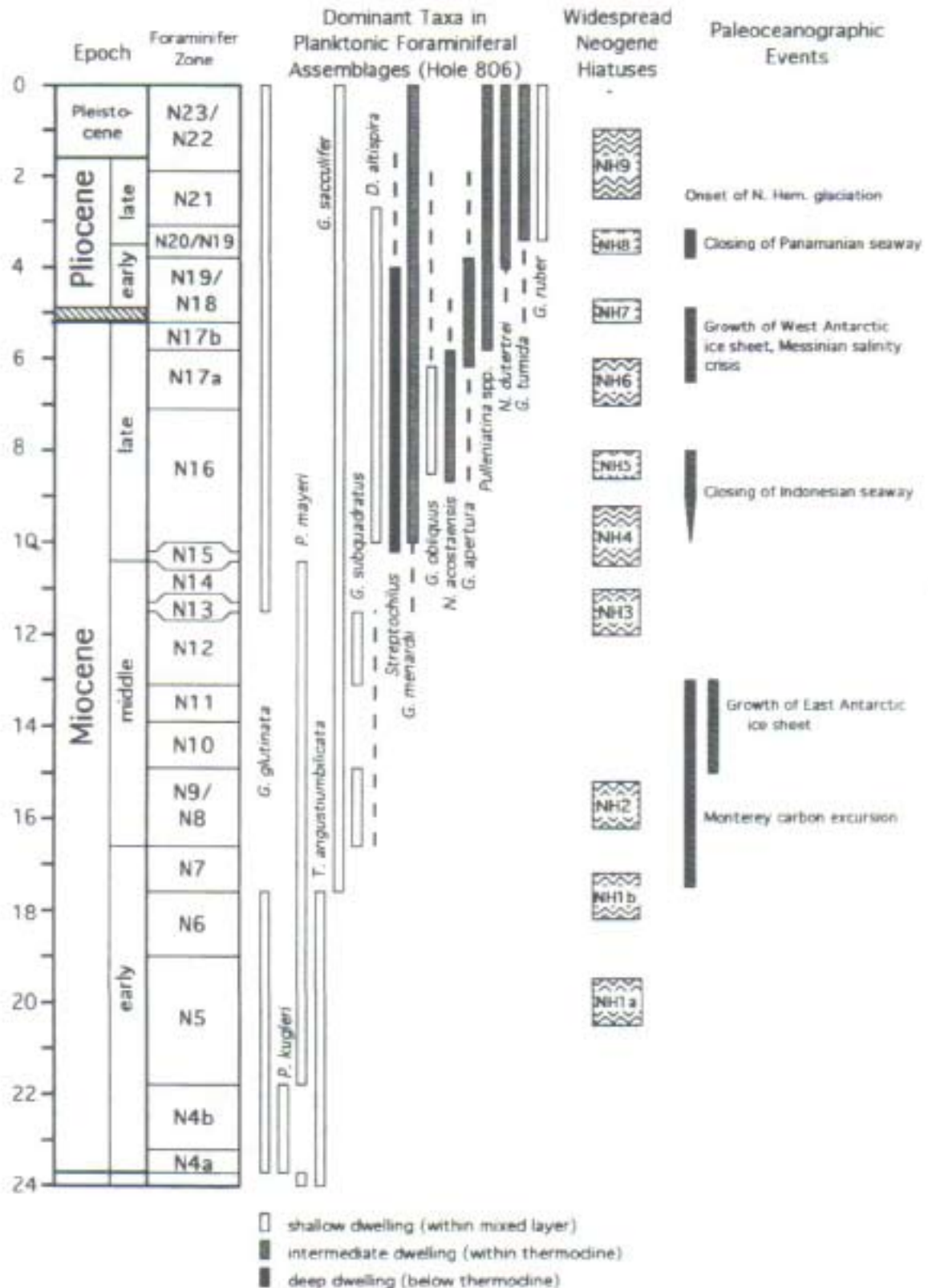


Figure 11. Graphic representation of major changes in planktonic foraminiferal populations throughout Neogene in Site 806. Ages of widespread Neogene hiatuses from Keller and Barron (1987) and Barron (1989). (N.B., Keller and Barron assign an age of 11.8–12.9 Ma for Hiatus NH3, whereas Barron assigns an age of 11.0–12.0 Ma.) Major paleoceanographic events summarized from Kennen et al. (1985) and Thayer et al. (1989).

Background Information for Figure 11

Highlights

- Changes in foram assemblages at ~ 4 and ~10 (levels in core) are roughly parallel with Events.
- ~ 3 level: *altispira* (foraminifer) disappears and becomes extinct.
- ~ 14 level: Antarctic glaciation, but this event doesn't cause forams to change in the tropics. Scientists need more information to better understand why.

Notes on some of the dominant foraminifer taxa in Figure 11

***Paragloborotalia mayeri* (Surface Dweller)**

The extinction of this group of surface dwellers at the end of the middle Miocene coincided with the closing of Indo-Pacific Seaway and the shoaling of the equatorial thermocline. There was a marked change in planktonic foram assemblages of the western equatorial Pacific that occurred because of this. (See Figure 11 handout: a lot was happening at Zone N14/N15). The planktonic foraminiferal assemblage had a more equitable distribution of depth dwellers from late Miocene through Pleistocene age in Hole 806B possibly due to the shoaling of the thermocline initiated by the closing of the seaway.

***Globigerinoides ruber* (Surface Dweller)**

This group had a marked increase in abundance in late Pliocene age assemblages, which possibly related to a further change in circulation in response to the closing of the Panamanian Seaway during the Pliocene. During this time, there was also the onset of Northern Hemisphere glaciation. It is thought that this species might have thrived in the saltier waters of the South Equatorial current. Small changes can make a difference to what flourishes in specific regions. These changes parallel glaciation, increased equator to pole gradients, and increased trade wind strength.

***Pulleniatina primalis* (Thermocline Dweller)**

Widespread coiling change in all species of *Pulleniatina*. This species subdivides zones N19 into mid-Pliocene and lower Pliocene in tropical Pacific.

Upwelling Indicator Species

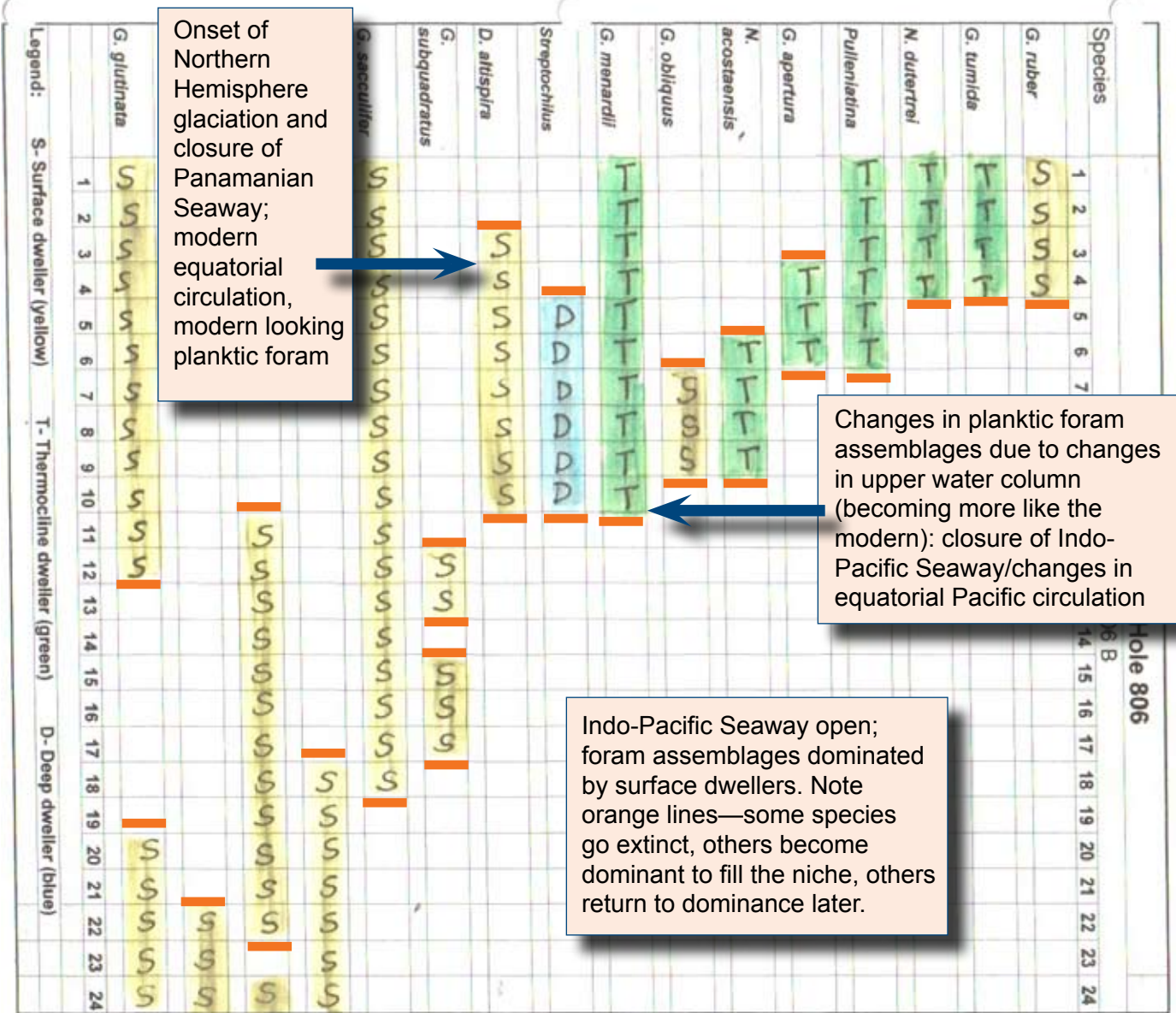
- ***Globigerina bulloides*** (Thermocline Dweller) is a cool-water upwelling indicator species. This species, along with *Neogloboquadrina acostaensis* (late Miocene) coincide with very high sedimentation rates, which may signal episodes of higher productivity in western equatorial Pacific.
- ***Neogloboquadrina dutertrei*** (Thermocline Dweller) is a warm-water upwelling indicator.

Both planktonic foraminifers, associated with upwelling and high productivity in low latitudes, are common in late Pliocene through the Pleistocene. This coincides with the time when the Northern Hemisphere became glaciated with large ice sheets (many times). As the Northern Hemisphere cooled and ice sheets formed, the temperature gradient between the equator and the poles increased, the atmosphere moved faster, and upwelling increased in a number of places, including the tropics—that's why *G. bulloides* and *N. dutertrei* increased in abundance in this region during late Pliocene and Pleistocene times.

Notes from the Initial Report of Leg 130

The entire sequence of Hole 806 B is moderately to heavily bioturbated. Foraminifer content in the sediments is highest in the middle Miocene and lower in the early Miocene and late Miocene. Climatic/tectonic events persisted through the Pliocene with shoaling of the thermoclines along the equator. Surface dwellers dominated the early and middle Miocene, with a more equitable distribution of three types of dwellers (surface, thermocline, and deep-water dwellers) in the late Miocene. There was a drastic decline in species richness in Hole 806 B as noted at zones N7, N17b, N22 / N23. This corresponded to global turnovers (rate of extinction plus rate of speciation) of planktonic foraminifer species. During the period that *G. ruber* was dominant, there was also an increase in the abundance of thermocline dwellers. Thermocline dwellers may signal renewed shoaling of the western equatorial thermocline, or could indicate the establishment of modern day circulation currents, which affected the structure of the upper water column and productivity

Annotated Interpretations



Compare the Annotated Interpretation shown above to the Background Information page, "Six Important Intervals or Events during this Time Frame."

By looking at the **Graphic Representation** and the **Foram Bio Cards**, the students will be able to determine which species disappeared or became extinct, and which species filled the niche or replaced it. It would help students to pull these bio cards and place each of the species in a line to show the order in which each species came in to replace the other. By doing so, students will be able to compare the foram species and note any changes: (e.g., foram species replacements: *P. kugleri* > *P. mayeri* > *D. altispira* > *G. ruber*).

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(1) = Surface Dweller
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