History of the Gulf of Mexico “Dead Zone”

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Introduction

Student analysis of the last 1000 years of the Gulf of Mexico hypoxia zone (informally “dead” zone) by using relative abundance of low-oxygen tolerant benthic foraminifera. In this example of environmental micropaleontology, students evaluate whether the “dead” zone has existed in its current form for many centuries or has become more intense in the modern period of increased anthropogenic organic input. The activity uses data developed by Lisa Osterman and colleagues at the USGS (see web activity for references).

Goals of the Gulf of Mexico “dead zone” exercise are:

1) how paleontologic methods developed for Deep Time can be used to investigate shallow time;
2) use of fossils to infer paleoenvironmental conditions
3) Interpret patterns of hypoxia for individual cores using foram abundance;
4) Synthesize hypoxia patters across all locations through time
5) Evaluate how historical record supports, modifies, or refutes the hypothesis that modern hypoxia is driven by anthropogenic effects.

This also gives students an opportunity to wrestle with the complexity of getting decent graphs out of Excel.

Background for Students

The initial section of the lab gives background on Gulf of Mexico hypoxia (Figure 1) and how benthic forams can be used to infer low-oxygen conditions through time. The scientists studying modern hypoxia connect it to increasing anthropogenic fertilizer runoff in the drainage basin of the Mississippi River. Rivers supply not only runoff of anthropogenic fertilizers but nutrients derived from natural erosion in the drainage basin. To test the idea that recent years are different requires suitable historical data.

Micropaleontologists establish an “index” (percent of total forams) of low-oxygen tolerant forms. The exercise uses the “PEB” index, which sums the proportion of *Protononion atlanticum*, *Epistominella vitrea*, and *Buliminella morgani* among all forams.

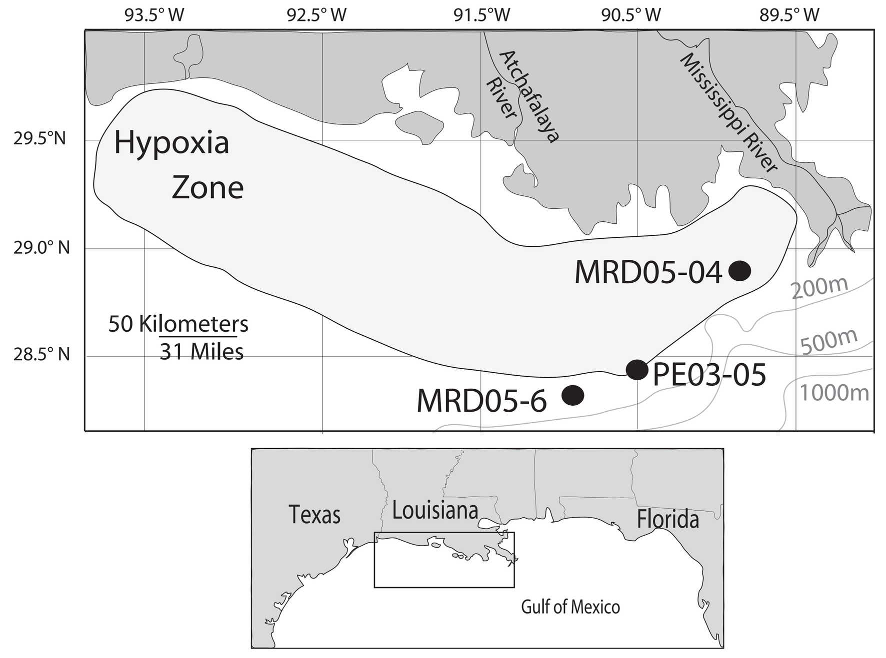

Figure 1. Location of the hypoxia zone as measured by Rabalais and others (1999), and the locations of the cores in the student exercise. Shelf bathymetry is shown in meters of water depth.

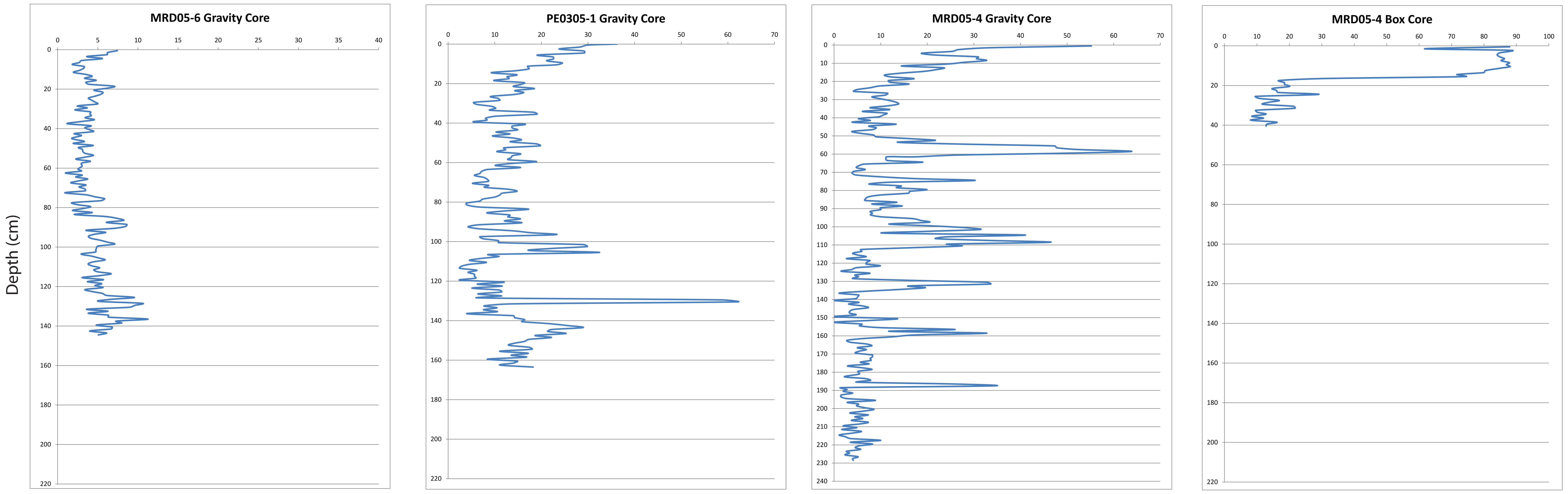

Figure 2. PEB Index (x-axis) versus depth for four cores (see Figure 1 for locations). All graphs plotted to rougly the same vertical scale to ease comparisons from core to core.

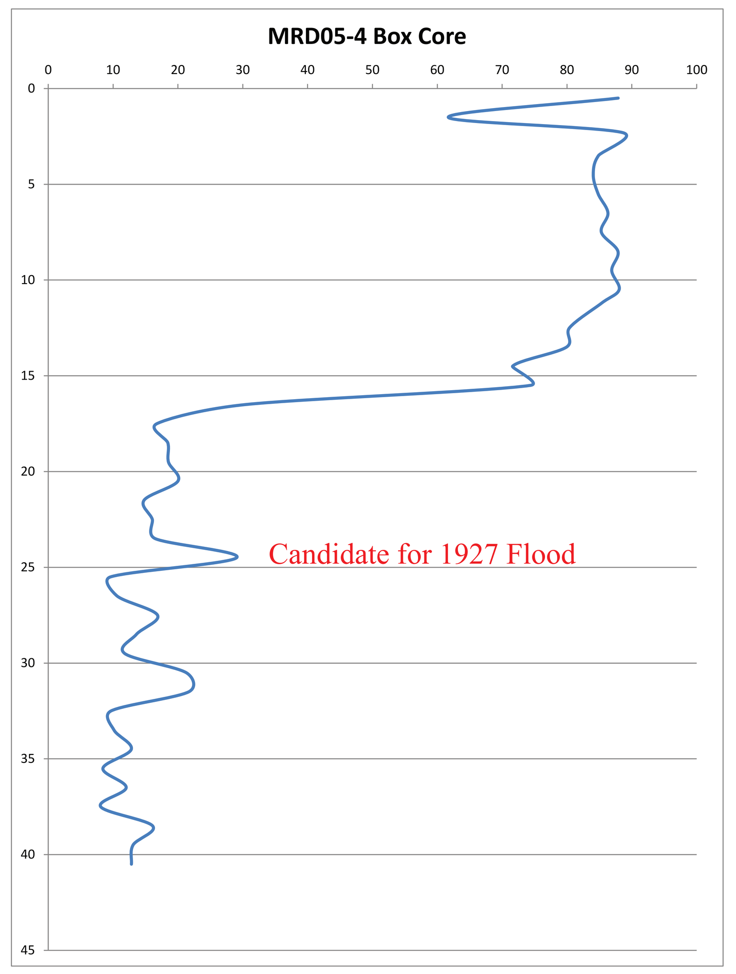

Figure 3. MRD05-04 Box core plotted to expand the y-axis for detail.

Table 1: Core Location

Core Name	Latitude	Longitude	Water depth (m)	Core Length (m)
MRD05-6 Gravity Core	28.3	90.9	65	1.53
PE0305 Gravity Core 1	28.4	90.5	47	1.64
MRD05-04 Gravity Core	28.9	89.9	38.5	2.39
MRD05-04 Box Core	28.9	89.9	38	0.41

Both box cores and gravity cores are taken by dropping a sampling device suspended from a boat into the ocean bottom. Gravity cores are cylindrical and can reach a greater depth. The MRD05-04 box and gravity cores are from very nearly the same spot.

Student Activity

Student Data

Students get a version of Figure 1 without core locations and a spreadsheet that gives foram data from four cores (locations in Table 1). Most cores give the abundance of each of the PEB taxa plus all other forams combined; PE0305 has all species individually (data from USGS Open-File Reports, see references). This requires students to calculate the PEB index in different ways. The data include interpolated ages from Lead-210 for the entire MRD05-4 box core.

Student Tasks

1) Get data, make graphs, and print (since my students don’t have computers in class, this is done as homework). They are instructed to
   a) calculate PEB on a 100-point scale;
   b) make graphs so depth increases downwards;
   c) scale all the cores to roughly the same depth scale (so PEB curves are comparable from core to core). This means the box core is plotted twice (once with depth to ~220 cm and once expanded for more detail). See Figure 2 and 3 for examples.

2) Determine where the cores are in relation to the modern hypoxia zone, interpret PEB through time, interpretation (see next column).

Making the Graphs

Most of my students seem to have limited familiarity with graphs or making graphs in Excel. (I think Excel is to serious statistical graphics as paint-by-numbers is to fine art, but it is a program all the students have.) They get the data well in advance with graphical hints. Then I spend part of an class period demonstrating how to make the graphs in Excel.

Interpretation Questions For Students

Compare the record of PEB index for the cores. Where do the cores occur in relation to the modern hypoxia zone? What does the PEB index tell us about the nature and extent of the “dead zone” over the last 1000 years? Probably the largest Mississippi River flood of the 20th century occurred in 1927. Can you identify candidates for the peak anoxia that would have been associated with that flood?

Recall that the scientists who discovered the modern hypoxia concluded that it was driven by the supply of anthropogenic fertilizers running off in the drainage basin of the Mississippi River, that is, major hypoxia is a recent phenomenon. What do these longer-term data tell us about this hypothesis?

Instructor Information

Core Name	Lat. (N)	Long. (W)	Water depth (m)	Position rel. to hypoxia
MRD05-6 Gravity Core	28.3	90.9	65	Farthest
PE0305 Gravity Core 1	28.4	90.5	47	At Edge
MRD05-04 Gravity Core	28.9	89.9	38.5	Within
MRD05-04 Box Core	28.9	89.9	38	Within

Basic Solution

A rough summary of interpretations:

MRD05-6, outside the modern hypoxia zone, has low PEB values throughout.

PE0305, on the edge of the hypoxia, has a record of periodic spikes in PEB index (implying hypoxia) with an increase in index in the shallowest 15 cm of the core.

The MRD05-04 cores are within the modern hypoxia zone. The gravity core, with the longer record, has relatively low PEB indexes at the bottom, periodic spikes upward (consistent with floods), and a striking increase in the shallowest 25 cm.

The MRD05-04 box core shows a striking, fairly consistent increase in the shallowest 17 cm.

All of these data are consistent with an increase in low-oxygen intensity over the youngest part of the record. This would then support the hypothesis that anthropogenic organic runoff makes a major contribution to today’s hypoxia.

Interpretation of Major Flood

MRD05-04 Box core Pb^{210} dates imply that 1927 was at 26.5 cm depth. This is an interpolation. The PEB index, however, has a peak at about 24 cm. This suggests to me that the latter depth is a better estimate for 1927. Using a depth of approximately 24 cm and assuming similar sedimentation rates for all cores (a questionable assumption), we can see a similar peak in PE0305-1 but not so much for MRD05-6 (the core farthest from the modern hypoxia zone).