Simulating the Paleozoic Geology of SE Minnesota

The purpose of this exercise is to demonstrate, in a fun and creative way, how the rise and fall of the oceans during the Cambrian and Ordovician Periods created the "layer cake" geology of southern Minnesota. The exercise primarily illustrates the concepts of transgression and regression - the idea that as the seas moved in (transgressed) and out (regressed) over the land surface, the environments of sediment deposition also moved and laid down the layers of sediment (now sedimentary rock) that we see today. We will use Playdoh to simulate rock layers.

Geologic Background

During the Cambrian and Ordovician periods (520 - 445 million years ago), Minnesota experienced four major transgression/regression cycles of the sea. A typical coastal profile in a tropical setting (Minnesota straddled the equator during this time) progresses from a beach/nearshore environment dominated by wave action to an offshore deep where waves don't reach the ocean floor to an offshore carbonate platform or reef (Figure 1A). In the beach environment, wave action winnows out the finest sediment and leaves behind sand. The fine sediment (silt and clay) eventually settle to the ocean floor in the offshore deep environment. Some distance from shore in clear water, a carbonate platform or reef commonly builds up by marine organisms and chemical deposition of carbonate.

Figure 1. Idealized cross section of a tropical coastal area. A) Shows the three general environments of deposition and the types of sediment that accumulates in each; B) Shows how these environments migrate shoreward due to transgression; and C) Shows how a blanket of sand is commonly deposited due to regression of the sea.
When the seas transgressed the land from south to north, the sands of the beach environment moved inland, followed by the muds of the offshore deeps, and then followed by the limey muds and marine fossils of the carbonate platform (Figure 1B). As each environment moved over an area, it deposited its sediment on top of that of the previous one. When the seas regressed from the land, the erosive power of the waves as the shoreline moved south commonly caused a thin layer of beach sand to cap the top of each cycle (Figure 1C). When the sediment surface was exposed to air, it weathered such that a rusty soil commonly developed and some erosion occurred. This surface of no deposition and possible erosion is called an unconformity. When the strata above and below the unconformity are parallel, it is called a disconformity.

Part 1: Laying down the Sediment Layers

On the base map of southern Minnesota, you will lay down layers of sediment that simulate the first 3 cycles of transgression and regression of the 3 main marine environments (Beach (sand), Offshore Deeps (silt & mud), Carbonate Platform (limestone) as told in the Geologic Story below. Realize that this description of events is a very simplified and somewhat modified version of the commonly accepted geologic story. For example, we are not sure if Cambrian and Ordovician sediments were ever deposited in east central Minnesota. The story here assumes they were and were subsequently eroded away.

<table>
<thead>
<tr>
<th>The Story of Cambrian and Ordovician Transgressive/Regressive Cycles in Minnesota</th>
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<tbody>
<tr>
<td>1. Middle Cambrian - Seas transgressed all of southern Minnesota. The shoreline of this ocean reached as far north as Duluth. Off-shore deeps reached as far north as Hastings. Carbonate platform barely reached over the Iowa border before the seas regressed out of the state leaving a blanket of sand.</td>
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<tr>
<td>2. Upper Cambrian - Seas transgressed all of Minnesota with the offshore deeps reaching to nearly Pine City and the carbonate platform reaching Hastings. Seas regressed slowly at the end of Cambrian time leaving a thick blanket of sand.</td>
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<tr>
<td>3. Lower Ordovician - Seas quickly transgressed over all of Minnesota and stayed for a long time. The carbonate platform reached at least to Pine City. Regression was quick with no sand deposited.</td>
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<tr>
<td><strong>--don’t go beyond this event--</strong></td>
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<tr>
<td>4. Upper Ordovician - Sea steadily migrated northward with the carbonate platform progressing to Pine City.</td>
</tr>
<tr>
<td>5. Upper Ordovician - A minor regression pulls the carbonate platform back to the Iowa border and offshore deeps cover most of southern Minnesota. Another transgressive surge and long stand caused the carbonate platform to cover all of southern Minnesota. The final regression is quick with no sand deposition.</td>
</tr>
</tbody>
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To create a more realistic model, keep in mind the following:

- Make Precambrian bedrock highs first. Throughout Cambrian time, the seas wedged their way between the broad topographic highs of the Wisconsin Dome and the Transcontinental Arch-Sioux Ridge. Precambrian bedrock near Taylors Falls (basalt) and New Ulm (quartzite) stood as islands in the sea. Make these bedrock highs with the white or yellow Playdoh color. By Ordovian time, the sea overrode these features.
- Use the yellow or white Playdoh for sand, the red for shale, and the blue for limestone.
- Make all layer thin so as not to run out, but show somewhat thicker layers if the transgression or recession was particularly slow; thinner if it was rapid.
- Also, sediment thickens toward the deeper water (S) and thins toward the shore (N).
- Another simplification is that the sea was confined between the high ground of the Wisconsin Dome to the east and the Transcontinental Arch and Sioux Ridge to the west.
- Although we cannot directly date sedimentary rocks, the age of each transgression is recorded in unique fossil assemblages. Portrayed by embedding fossil sprinkles in your limestone layers.
- During regressions when the sediment is exposed to the atmosphere, it will become chemically weathered. Show this by sprinkling red sugar crystals on your regression surface.
Part 2: Retelling the Story in a Cross Section

Of course, we have interpreted the story given above from reading the rocks that are still preserved in southeastern Minnesota. Much of this story comes from the rocks we see at the surface. Thanks to down-cutting by the Mississippi River and its tributaries during the last recession of the glaciers, we have a 3-D view of some of this geology along the river bluffs of southeastern Minnesota. Still the majority of the information that went into this geologic interpretation comes from thousands of wells drilled into the subsurface. In this second part of the exercise, we will acquire similar drilling information of the deeply buried geology we have created and will compile it in a geologic cross section. Although you will drill the holes as a group, each person should construct their own cross section from the “drill cores”.

Instructions:
1) Using the clear plastic straws provided. Drill at least 5 "rock cores" along a north-south profile across your map. (Helpful Hints: roughen up the drill bit with a razor; drill by twisting the straw in one direction only; do not push to hard, let the drill do the work).
2) On graph paper, draw a surface profile and mark the locations of your drill sites. 1Pt
3) Transfer the layer information from each of your cores at the appropriate drill site USING 3X VERTICAL EXAGGERATION 1Pt
4) Interpolate the geologic contacts from core to core, and color the units of your cross section. 1Pt
5) Determine the likely formational names of your units based on the information given in the figure 1Pts below. Note any special features (e.g., fossil beds, weathering horizons).
6) Turn in your cross section at the next class (one section per person) Key 1Pt

Figure 2. Stratigraphy of Cambrian and Ordovician formations found in southern Minnesota, northern Iowa, and southwestern Wisconsin. Curve on right portrays the four major transgression/regression cycles interpreted to have been caused by the rise and fall of sea level. Note that the cycles are separated by unconformities (squiggly thick lines) which represent prolonged periods of non-deposition and some erosion. (Diagram modified from Tony Runkel, Minn. Geological Survey, 1997)