METAMORPHIC ROCKS: WHY ROCKS BEND AND FOLD
PART 1: VIEWING STRUCTURES IN THE FIELD AND LAB

BRITT ARGOW: Keith Klepeis, Associate Professor of Geology at the University of Vermont. We join him today at Clay Point, a rock outcrop on the shores of Lake Champlain in western Vermont.

KEITH KLEPEIS: We're standing on the shores of Lake Champlain in Vermont. And one of the reasons why we come here is because rock exposures along the lake shore like this one behind me contain wonderful features that allow us to reconstruct a geological story about this particular part of Vermont. So what I'm going to do here is I'm going to take a look around. We want to use our powers of observation to see if we can piece together a story at this particular exposure.

ARGOW: When Professor Klepeis looks at this rock, he sees layers.

KLEPEIS: Now, when I start looking around, one of the most distinctive features I see is rock layering. And I see this rock layering expressed two different ways. On this side of the rock exposure, I see some of these dark layers and light layers that are mostly horizontal. Some of them are a little bit curved, but this horizontal orientation is dominant. And I can trace that all the way up the rock cliff face. Now, when I trace these horizontal layers across the outcrop, something happens. On this side, the rock layers are almost vertical. And this is really unexpected.

ARGOW: Why do you think vertically layered rocks would be unexpected? Typically, layered rocks are formed by the transportation and deposition of sediments--broken-down pieces of rock. As sediments fall down through the water, they build up in horizontal layers and are eventually buried. As pressure increases, the layers harden into solid rock. These horizontally layered sedimentary rocks are found all over the globe. Vertically layered rocks, however, are not as common.

KLEPEIS: It's hard to imagine, if sediments are percolating down, how they could accumulate into vertical layers. So it makes sense that these layers, which look an awful lot like this, probably once were oriented in a horizontal geometry and then later removed in some way to this vertical position.

ARGOW: For Klepeis, the border between the horizontal and vertical layers is an important clue. Tracing the transition line, he discovers a horizontal layer next to the vertical layers. This layer looks like it could be a part of this layer. With this information, Klepeis comes up with an idea. He believes that this was once a single rock that was somehow bent. But how could hard rock bend? The next step in Klepeis's investigation is to create a model.

KLEPEIS: So one of the things we can do as geologists to try to explain features we see in outcrops is to use models. And I'm going to see if I can create a model here to explain some of the features at Clay Point. And I'm going to use Play-Doh. And this is very easy to work with. There's one part of the outcrop we had horizontal layers, and in another part we had vertical layers. So I'm going to see if I can reconstruct those two different expressions.

ARGOW: With the idea that the outcrop used to be a single horizontally layered rock that was later bent, Klepeis attempts to recreate how the vertical layers might have formed. After several attempts, he is finally satisfied with a model that he thinks might work.

KLEPEIS: So I've got my model here, and it has a couple of features that remind me of Clay Point. It's got horizontal layering here, and it's got vertical layering here and here. And that matches quite closely to two different expressions of rock layering at Clay Point. However, it's got another feature. It's got some curvature there. And I don't remember seeing that on the Clay Point exposures. So there's two possibilities. One, my model might be wrong, or two, maybe I didn't look closely enough at the Clay Point exposures, and maybe I missed something. So let's take another look at those exposures and see what we can see. Now, the place where this curve zone should be, if my model is right, is right up in that zone there. I'm going to climb up there, take a look around and see what we can find out. Okay, so I'm standing here now where that curve zone should be. And look at this; this is really great. I see some jagged rock. In fact, it looks like this rock is broken off. So maybe that curve zone has broken away, and I no longer see it. So it might just be that my model is right. And I'm going to just take a look here. And look at this. If I look at these layers from slightly different angles, it looks like maybe these layers originally connected up with the layers below my feet. And if you take me out of the picture, I wonder if you could reconnect where these layers were before this rock broke off. Maybe this area of broken-off rock was indeed one of these curve zones. And maybe this flat layering, this horizontal layering here, was indeed connected to this steep layer and this vertical layering below here, just like our model predicts. So if that is right, it looks like this entire sequence of rock layering was folded over. And that folding can explain this vertical layering we see down here below. Now, what we can do is we can take samples back to the laboratory and look at them under the microscope. So we're going to take a sample from the horizontal layering and compare it to an area hat looks like it's been folded where the layering is vertical.

ARGOW: And when viewed under a microscope, it allows us to see the tiny details of a rock. This is a thin section from the horizontally layered rock. This view is an extreme close-up of one of the layers. The different speckles are different minerals, which are in a mostly random arrangement. This is a characteristic observed in many sedimentary rocks. This is the vertically layered rock. The folds and curves show us that the rock structure has changed at the mineralogical level. The minerals are not randomly ordered, but instead are lined up in certain directions. Additionally, this subtle change in color, where the rock becomes darker, is an indication that the chemical makeup of the rock has also changed.

These clues support Klepeis's theory about what might have happened at Clay Point. They also help shed light on what type of rock we find there. Sedimentary rocks – rocks formed from the breakdown of preexisting rock. Now, based on our observations, we believe the rock at Clay Point is a sedimentary rock. But part of it has folded and changed. It not only looks different at the outcrop scale, but when we look at it under the microscope, we can see that its mineral structure is also different. We categorize rocks that have changed like this into a group called metamorphic rocks.