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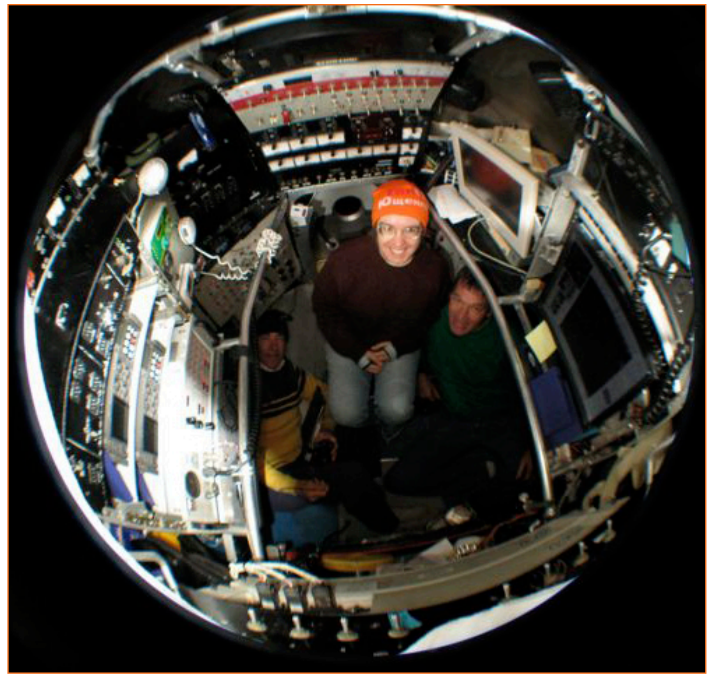
CORKS in the Crust: Part 2

Seismicity at Endeavor Ridge and Middle Valley

Summary

"CORKS in the Crust: Part 1" provided an introduction to fluid pressure data recorded by CORKS on the Juan de Fuca. We can link this data to measurements collected by other systems to draw conclusions about a variety of events taking place in the ocean's crust. Katherine Inderbitzen, a graduate student at the University of Miami's Rosenstiel School of Marine Science, wrote these exercises between dives in *DSV Alvin* to service CORKS near the Juan de Fuca Ridge. This activity requires some knowledge of earthquakes, but all it takes is a little analysis—don't over think your answers!



Katie Inderbitzen, the author of this activity, is a graduate student at the University of Miami. Here she is in the DSV Alvin *on her first dive which was to Ocean Drilling Program Site 1026B. (Photo: Mark Spear)*

Learning Objectives

Students will be able to:

- Link fluid pressure data to additional measurements
- Draw conclusions about these linkages for ocean crustal events

National Science Education Standards

Standard A: Science as Inquiry

Standard D: Earth and Space Sciences

Ocean Literacy Essential Principles

2. The ocean and life in the ocean shape the features of Earth.
7. The ocean is largely unexplored.

Target Age: Undergraduate students

Time: One class period

Materials

- Geological references and texts
- Internet access

Background

By observing the long-term formation pressure effects from tides, CORK pressure data sets also allow us to investigate transient fluid pressure events within the porous crust. These transient events are often closely related to seismicity in the region. A well-documented example of fluid pressure responding directly to local seismicity occurred between June 8 and 13, 1999 on the Endeavour Segment of the Juan de Fuca Ridge (Figure 1). The earthquake swarm was centered (approximately) at 47°54.9'N 129°16.0'W, and pressure transients were recorded at Ocean Drilling Program (ODP) Sites 1024, 1025, 1027, and 857. Sites 1024, 1025, and 1027 are located on the ridge flank, east of the earthquake swarm, while Site 857 is located in Middle Valley to the northeast of the swarm (Figure 2).

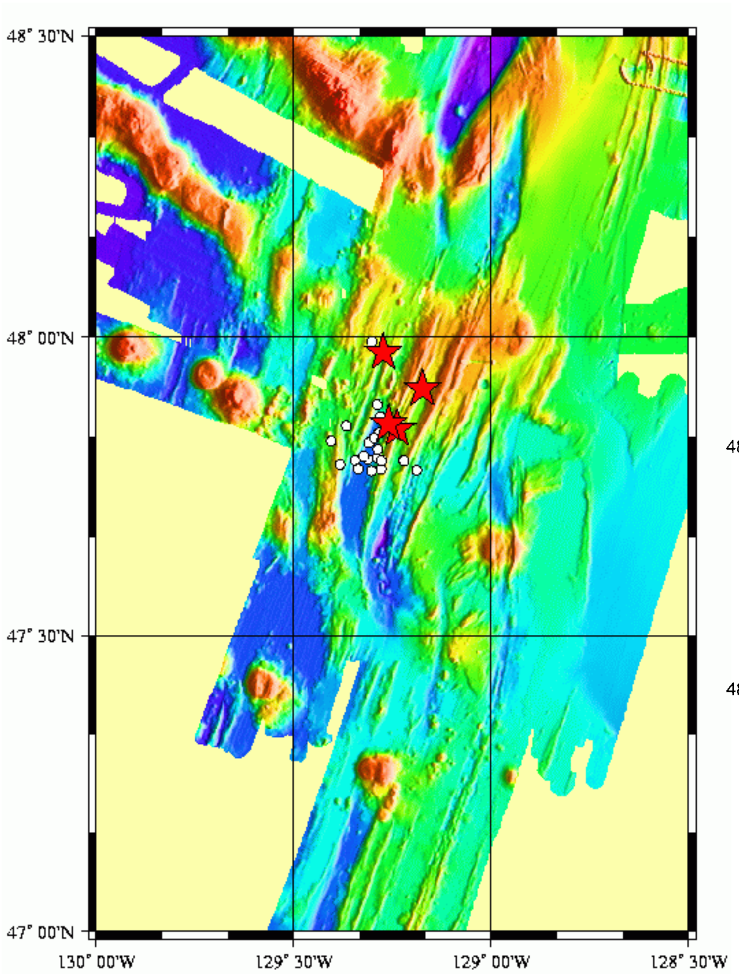


Figure 1. Earthquake epicenters for the Endeavour swarm (from www.pmel.noaa.gov/vents/acoustics/seismicity/nepac/endeav0699.html)

Early detection of earthquakes on the Juan de Fuca Ridge is possible with the U.S. Navy's SOSUS (SOund SUrveillance System) hydrophones. For information about how hydrophones detect earthquakes, please visit: *www.pmel.noaa.gov/vents/acoustics/seismicity/seismicity.html*.

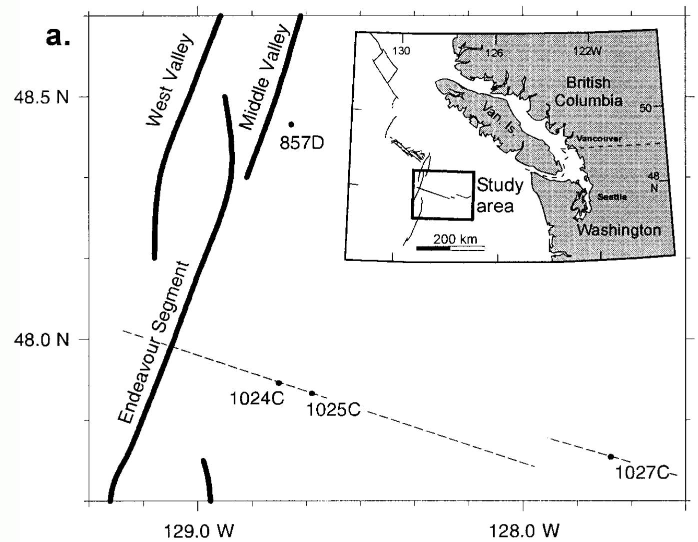


Figure 2. Map showing the location of the CORK borehole observatory sites relative to the Endeavour segment of the Juan de Fuca Ridge (from Davis et al., 2001).

What To Do

These activities refer to "CORKS in the Crust: Part 1." Be sure to have your answers on hand while you analyze the following data for a better understanding of seismic events. Answer the following questions on your own paper and be prepared for a class or small group discussion.

Endeavor Ridge Seismicity: June 1999

1. Recall what you learned in the exercise about tidal pressure in the crust. How do you think a transient pressure event superimposed on a pressure record would look graphically? *(Hint: would the record's periodicity or amplitude change?)*
2. Seismic events are comprised of dilatational (volumetric expansion) and compressional components. The 1999 Endeavour earthquake swarm has been attributed to an episode of seafloor spreading that did not involve magma injection into the crust, however, there is reason to believe that fault-slip occurred (Davis et al., 2001). In order for fluid pressures to behave as in Figure 3 immediately following the earthquakes, was the dilatational or compressional seismic component dominating the fluid response? *(Note that tidal effects have been removed from the data for this example.)*
3. Hydrothermal fluid contained in the porous crustal reservoir is responsible for mineralogical alteration of the crust over time. As pore spaces are filled with minerals, the alteration reduces porosity/permeability. Will fluid flow induced by seismic strain occur in the same or a different direction from buoyancy-driven (i.e., heat rises) hydrothermal flow? Do you think the difference in flowpath will affect crustal alteration?

4. Darcy flow is an important mechanism that generates pressure gradients driving horizontal flow in the porous oceanic crust following an episode of seismic strain. This is essentially a pressure "front" with an initial pressure increase followed by a drop in pressure (for a single fixed point). If we assume Darcy flow radiated eastward following the Endeavour earthquake swarm, initially increasing formation fluid pressure, what process in the crust would describe the subsequent decay in formation pressure? *(Hint: you may need to review "CORKS in the Crust: Part 1.")*
5. Recall that Sites 1024, 1025, and 1027 are kilometers away from the center of the earthquake swarm. However, the fluid pressure transients recorded at these sites are significant in magnitude. What does this say about the crustal fluid reservoir on the ridge flank? Is it well connected or poorly connected to the fluid reservoir near the ridge crest?
6. Hydrothermal convection is critical in the cooling of young oceanic crust. Fluids circulating through the porous crustal reservoir efficiently remove heat at the ridge crest, creating spectacular black smoker chimney structures and regions of diffuse fluid flow. Based on your answer to question 5, do you think that hydrothermal convection is a process that only happens near the ridge crest, or does it persist farther away from the ridge? How do you think we should look for evidence of hydrothermal convection in oceanic crust?

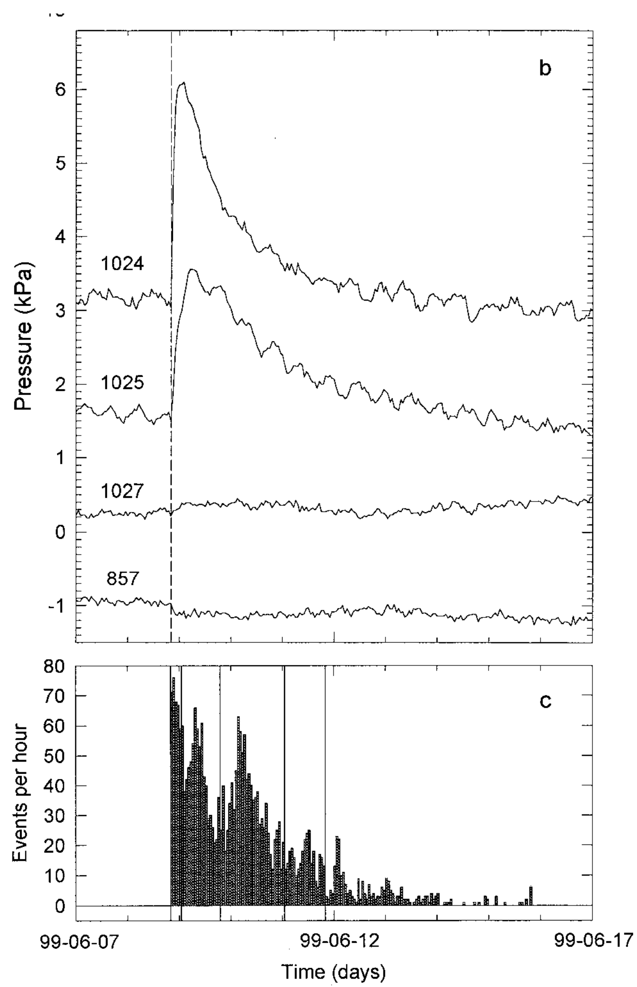


Figure 3. Fluid pressures and seismic activity associated with the 1999 Endeavour earthquake swarm (from Davis et al., 2001).

Middle Valley Earthquake Swarm: Sept. 2001

Unlike the Endeavour earthquake swarm in 1999, the Middle Valley event in 2001 was not confined to an isolated section of the ridge crest. As shown in Figure 4, the earthquake source migrated south along the ridge over a period of approximately 20 days. Also marked are the locations of some vent fields and CORKed ODP Sites.

A fluid pressure response was recorded at Site 857 approximately five days after the earthquake swarm began. Site 857 is located in Middle Valley on sediment-sealed crust. For the following discussion activities, please read the Davis et al., 2004 article in *Nature* found at http://www.pmel.noaa.gov/vents/acoustics.html.

1. How does the fluid response to the Middle Valley event compare to the response to the Endeavour earthquake swarm in 1999? *(Hint: look at Figure 2 in Davis et al., 2004)* What do the differing responses tell us about the type of spreading event that caused the Middle Valley earthquake swarm? Does the data indicate a dilatational or compressional response?
2. Following the Middle Valley swarm, a rapid response cruise was dispatched to investigate any changes to hydrothermal venting in the area. No significant increase in hydrothermal venting was detected in the water column (Davis et al., 2004). Based on your answer to number 1, what does this lack of a hydrothermal response say about the Middle Valley event? *(Hint: Was seawater or magma injected into the crust?)*

References

Davis, E. E., K. Wang, R. E. Thomson, K. Becker, J. F. Cassidy, 2001, An episode of seafloor spreading and associated plate deformation inferred from crustal fluid pressure transients, *Journal of Geophysical Research*, v. 106, p. 21,953ˆ21,963

Epicenters through Sept. 12 | *Epicenters through Sept. 20*

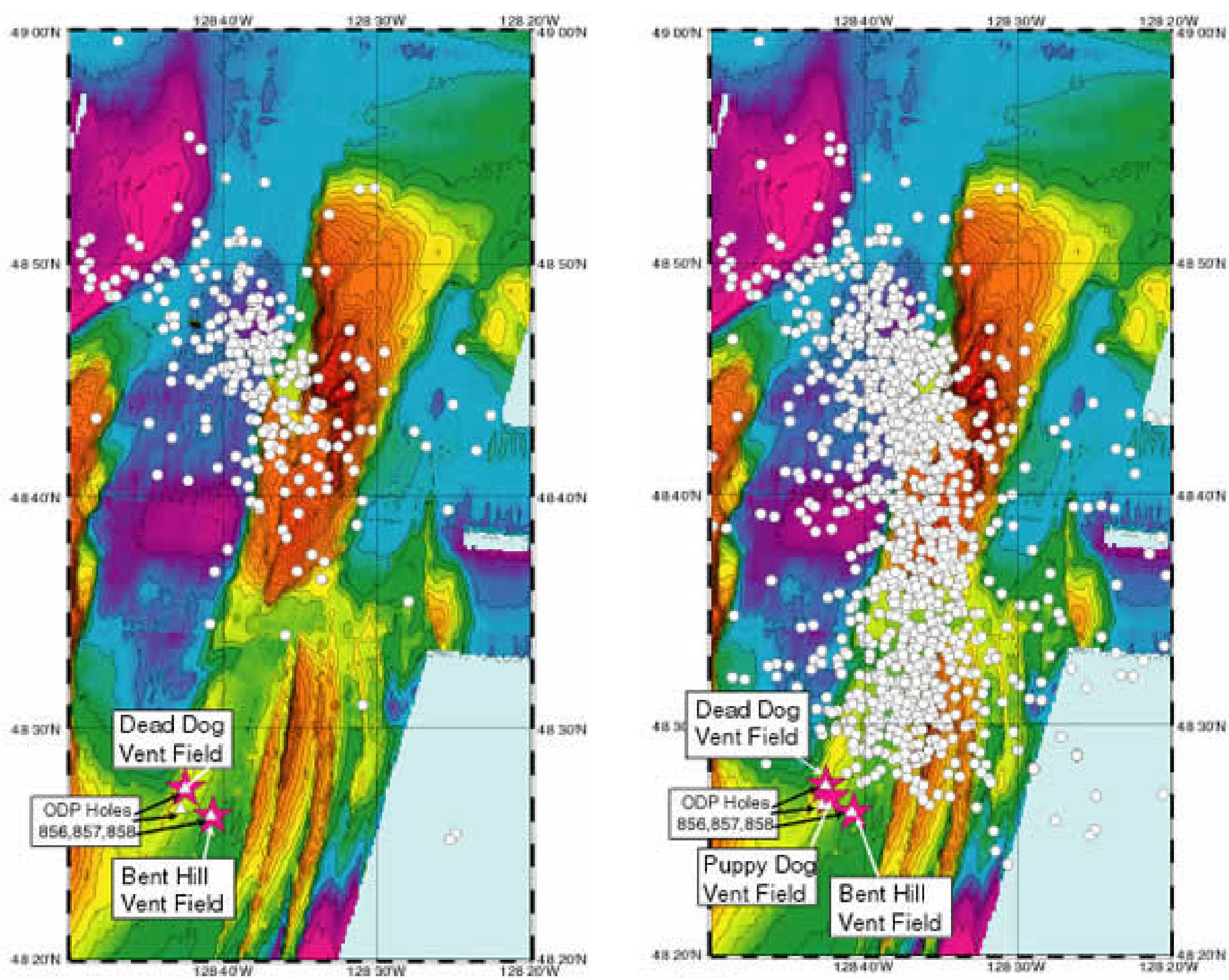


Figure 4. Earthquake epicenters in Middle Valley during the 2001 event (from http://www.pmel.noaa.gov/vents/acoustics/seismicity/nepac/middlevalley01.html)

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