Sun Lithoprobe Peers Deep Into Our Geologic Past

Standing a few feet away, it feels like the world's best foot massage. Canadians out here on Vancouver Island call it The Vibrator. The squat truck, named Vibroseis, was actually invented at Conoco in the late 1950's as a spinoff of radar studies, according to geologist Fred Cook.

Today, its hydraulic hammer sends energy pulses into the ground near a logging road on this West Coast island. The resulting seismic echoes reflect back to the surface from the rocks below. Over 250 seismic instruments carefully positioned along six miles of rugged terrain record the reflections on magnetic tapes.

During three months in the field, earth scientists will log about 500 tapes and send them to the Lithoprobe Seismic Processing Facility (LSPF) at the University of Calgary. Lithoprobe is the largest earth science research project ever undertaken in Canada. Formed in 1987, the consortium of scientists from universities, federal and provincial governments, and the petroleum and mining industries, investigates the 60-mi thick lithosphere--the Earth's outer crust. The effort, now in its third funding phase, investigates yearly a half dozen geologic study areas in Canada.

"We know more about the surface of Venus, Mars, and Mercury than we do about the earth below our feet," explains Cook, who is LSPF's director. "Understanding the geometry of faults at depth helps us understand earthquakes better. In many areas, we know faults localize fluids that carry gold, lead, zinc, and copper. This can help us find more minerals and exploit them."

In March, Lithoprobe's researchers started using powerful Sun workstations to help transform the thousands of echoes recorded on tapes into pictures-- line drawings, really-- that show other scientists where to look for oil, gold, and underground steam and how to predict earthquakes and volcanos.

So, What's The Hurry?

Until Lithoprobe installed the four multi-tasking workstations, selecting the correct sonic blips for one set of drawings took more than a year.

markwlyon@mac.com

Because the consortium's 300-odd investigators work at remote sites across Canada, they lacked efficient access to their tapes stored in Calgary along with 6,000 others from various LSPF projects. And even if a worker got time on LSPF's Cyber central mainframe, he could spend hours or days transmitting gigabyte-sized files. Furthermore, if he worked in Toronto, for example, he waited two days for a courier to deliver a print out.

The new Sun workstations cut this processing time in half, Cook says, by giving more people the opportunity to work more intensively on the seismic data. Where an investigator in the past had to do all the processing remotely on the single Cyber, he now breaks the job down into smaller tasks and process them separately on the Suns.

From the thousands of recorded pulses, called traces, he selects the appropriate ones and filters them so the computer will produce a recognizable drawing of the underground formations. It's somewhat like a ham radio operator trying to receive clearly many faint signals all at once.

To begin the process for Vancouver Island, the investigator sends the raw tapes to a local contractor who removes unwanted noises like wind, passing cars, or aircraft accidentally recorded during the soundings. From these rough traces, he can plot an indistinct picture of subsurface features, one even experts find hard to interpret.

Next, he uses the Sun workstation running Insight-1, an interactive seismic processing package from Inverse Theory and Applications, Inc. (ITA) of Calgary to further refine the signals. This Unix-based program contains more than 100 applications to help earth scientists perform special types of seismic data processing.

"It takes tremendous advantage of Sun's graphics," Cook said. "Visual interpretation is a very attractive tool for researchers working with large amounts of data. Better graphics make it easy for them to display and analyze seismic sections."

Seismic Processing Simplified

To process the Vancouver data on the Sun workstation, the investigator types, "VAL", meaning variable area lookup, at the command line. A popup menu appears and he clicks his mouse on one entry to produce a list of filenames for the Vancouver project. Searching through the list and clicking on the desired file enters it to the program.

Now the high resolution screen shows the file as a box containing many closely spaced vertical lines that each represent a Vibroseis pulse echoed to one of the 250 recorders used on Vanvouver Island. The vertical component is time, which can also be thought of as depth into the earth, since pulses start from the top of the box and travel down to the bottom. Irregularities appearing along the line show the depth where the signal bounced off a union where two rock layers join.

The investigator chooses the number of vertical traces displayed on each screen from a few to a thousand. In one screen he shows unaltered traces, in a second he may show the same traces but change their frequency slightly. By alternating between screens he can see how the change effects the final picture. For this, Insight-1 takes advantage of Sun's 8-bit color. It assigns a different black and white screen to each of the eight color bits to show the investigator eight different views of the trace.

Once the investigator satisfies himself that he has selected the best number of traces, he moves on to another menu-driven program. Now, using VAQ, or variable area quick, the researcher edits individual traces on a file by file basis. Using his mouse to click on VAQ's series of menus, he edits, or eliminates, or adjust traces until he is satisfied. When he clicks on the kill box, for example, every time thereafter that he clicks the cursor on a trace, it will be eliminated from the file.

When the investigator completes this phase of his work he continues to another program to perform refraction analysis. This removes distortions in the signals caused by soil or other conditions near the surface. It is one area where Sun's interactive workstations have dramatically improve LSPF's analysis, says Kris Vasudevan, LSPF's manager.

Previously, LSPF accomplished this job also through batch processing on the Cyber. Not only does the investigator now see the results of his actions in realtime, but the Sun's high speed computational power speeds up the graphic plotting of LSPF's very large files. "And if he decides wrong, he can edit his choices on the screen," Vasudevan says.

Each file shows the traces from one Vibroseis pulse, or shot record. To complete the project, he will process thousands of shot records on Cyber using the parameters he selects on the Sun. Combining files from many shot records gives the most precise image of the subsurface.

Multi-tasking Helps Underground Research, Too

The Suns also speed up another complicated task, Vasudevan continued. Velocity analysis is the search for velocity function of the reflected energy pulses that best reveals the subsurface features. "In the past the investigator picked some velocity and plotted it on rolls of paper," Vasudevan recalls. "With a colored pen and a lens, he followed the hyperbolic curve to find the correct velocity. He could spend a few minutes or a few hours, depending on how accurate he wanted to be."

But on the workstation it takes a few minutes, according to Vasudevan. "Accuracy improves because he has the ability to repeat the process as many times as he wants until he is happy with the analysis. With interactive workstations he carries out the process and sees results with phenomenal speed. There's no equivalent in the hardcopy world."

Workstations help remote site researchers select parameters for small data sets that they then run on the Cyber to perform crustal data processing, Vasudevan continues. "But they can also do research into smaller data sets and can carry out R&D in the background using the full multi-tasking potential of the machine." These benefits can't be measured in terms of cost, he adds. "Our major objective in acquiring the Suns was to provide people with immediate feedback on their work," Cook notes. "Previously, every little step had to go by courier. That was two or three days per step. Now they work interactively and they can check 100 steps very quickly."

The Sun workstations reduce LSPF network traffic because their processing power lets workers accomplish sophisticated analysis at the remote sites, Cook continues. "In the past people used PC's as terminals and they didn't do local processing. Now researchers connect to the network when they want to run big jobs. So the workstations improve overall efficiency by doing more local processing."

"Also we knew the machines would communicate with our mainframe," Cook adds. "It was an important consideration, because it wouldn't do us any good to do something on the Sun and not be able to communicate it."

The Future Of Discovering The Past

Lithoprobe's seismic research will progress even faster as investigators discover more ways to enhance data with the new workstations, according to Professor Cook. "For example, we're developing techniques to produce line drawings of subsurface details without a lot of interpretation."

Previously, a scientist abstracted a line drawing of the stratified rock and faults by generalizing on the pattern created by seismic traces. "He had to make a decision about what to incorporate in the line drawing," Cook says. "We are in the process of removing that bias by automating the procedure."

Researchers are also using workstations to develop utilities to link the Sun's interactive Insight-1 applications with the Cyber mainframe's DISCO seismic batch processing programs. This will let them quickly move parameters selected in small data sets on the Sun workstations and apply them to the larger data sets processed on the Cyber.

As more analytical tools develop, Professor Cook expects to see continued results from Lithoprobe's investigations. "In Western Canada, we've already found faults that we didn't know existed. We can image them to a depth of about 25 miles. And we've found features that might be magma buried beneath volcanic centers on the West Coast. Understanding the lithosphere is essential to a fundamental knowledge of the processes that cause earthquakes, volcanos, mineral and petroleum deposits and other features that effect the way we live."