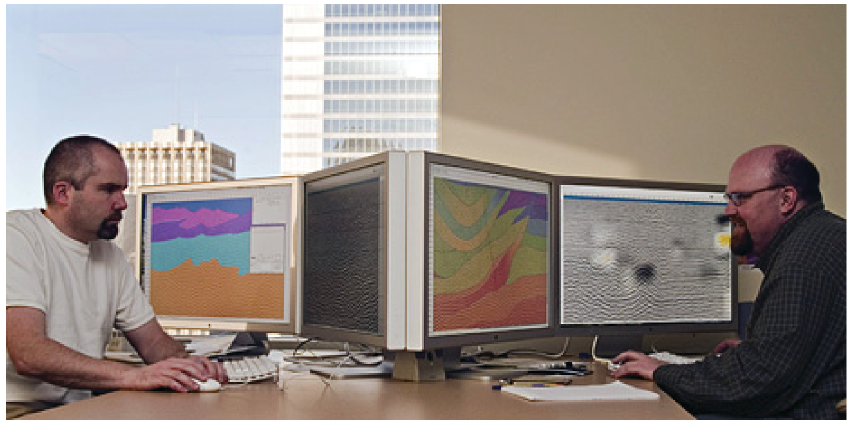
Thrust Belt Imaging

The Tools for Accurate Seismic Imaging

By Tim McIntire



Gittins (left) and Vestrum (right) process seismic imagery using dual 30-inch Apple Cinema Displays, each with eight megapixels of viewable data.

The high-risk, high-reward business of oil and gas exploration relies heavily on the accurate analysis of seismic images. Drilling in the wrong place can cost anywhere from $1 million to $10 million per occurrence, so risk mitigation is taken seriously.

Using an Apple Xserve cluster and 30-inch Apple Cinema Displays, Thrust Belt Imaging (TBI) has been able to implement new and improved seismic image processing techniques that drastically reduce risk. The accuracy of the new image processing algorithms—combined with efficient processing time from their eight-node Xserve cluster—enables TBI's clients to bring oil and gas exploration back to gas-rich foothills that were once written off as too difficult to analyze.

"Anisotropic effects are traditionally ignored in seismic imaging," TBI co-founder Rob Vestrum explains. "Thrust Belt Imaging uses an anisotropic depth migration algorithm to correct for imaging and positioning problems in seismic data, allowing image interpreters to make informed, accurate decisions."

Rob Vestrum, Dale Schack, and Jon Gittins founded TBI in 2005 and have quickly built a reputation as the go-to guys when traditional imaging techniques, which ignore anisotropic effects, aren't up to the task. Their mission is to mitigate the risk of searching for oil and gas in thrust belts found in the rocky foothills of numerous regions around the world, including parts of Canada and South America. Such regions are traditionally difficult to explore because of anisotropic effects, which make objects look different depending on the direction of measurement, leading to inaccurate drilling decisions. TBI was founded on powerful new methodologies for seismic imaging, but they knew that to go to market, they needed a stable, powerful compute platform to serve their clients, which include behemoths such as Shell and BP.

At a Glance

TBI's founders knew that setting up a powerful, stable computing infrastructure was key to their success. Two solutions were required: a set of interpretative workstations from which geophysicists could analyze high-resolution imagery and a high-performance computing cluster that returned rapid results for complex imaging algorithms. TBI found that Apple had perfect solutions for both requirements.

Apple Solution

TBI's geophysicists use Power Mac G5 workstations powering dual 30-inch Apple Cinema Displays to complete complex analyses of seismic imagery. Image processing tasks, including new algorithms for dealing with anisotropic effects, are sent to an eight-node Apple Xserve cluster controlled by Xgrid. Maintenance is handled through Apple Remote Desktop, allowing TBI's small team to focus on science and forgo a full-time system administrator.

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Dale Schack

Dale Schack examines TBI's eight-node Xserve cluster. The cluster is managed and administered through Xgrid and Apple Remote Desktop, making visits like this purely recreational.

Deciding to Go Mac

The process of seismic imaging starts with data acquisition, which involves laying out thousands of evenly spaced surface charges that are detonated while sensors record the resulting vibrations. In simple terms, this method is a low-frequency ultrasound of the earth. The resulting datasets are measured in terabytes, and each image can require several hours of processing before it can be viewed in a meaningful way. TBI's clients use the imagery to determine which areas should be drilled for oil and natural gas extraction.

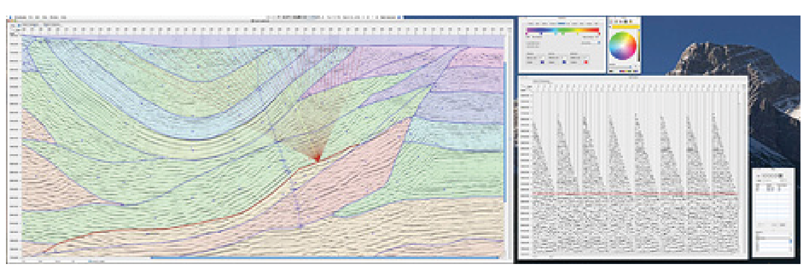
With extensive backgrounds in seismic imaging using solutions such as UNIX-based workstations, Linux-based clusters, and NeXTSTEP Workstations, TBI's founders were well positioned to make solid IT choices to launch their company. To start, they had to make two key decisions. First, they had to agree on the interpretive workstations for their hands-on image analysis. And second, they needed to choose a hardware and software solution for the back end.

The first decision was easy, says Schack. "It was a no-brainer to pick Apple for the interpretive workstations. Besides the availability of 30-inch displays, Mac OS X comes with Xcode, incredibly rich development libraries, 64-bit addressing, and OpenGL graphics."

When TBI launched, the company needed the interactive analysis application up and running as soon as possible. With the rich library of tools and open source compilers in Xcode, the integrated development environment in Mac OS X, TBI was able to quickly set its focus on geophysics and geology rather than software development and maintenance. Xcode includes the GNU Compiler Collection (GCC), Interface Builder, and powerful debugging features, as well as the ability to compile universal binaries, which run natively on both PowerPC- and Intel-based Mac systems.

The second decision TBI had to make was what to use for the back end—the compute environment that would do the heavy lifting, pushing results and feedback to the scientists' workstations. From prior experience, TBI had found that although Linux clusters seemed cost-effective on the surface, the time spent on system administration, hardware problems, and software development negated much of the perceived savings. With Mac OS X's UNIX base, TBI could use Apple hardware for both cluster and desktop computing.

The benefits of running on a single, unified platform are immense. Before the availability of Mac OS X, a platform capable of running UNIX-based applications and desktop productivity software side by side, the standard solution was to have two computers at each scientist's desk, one with an OS geared for science and one with an OS geared for productivity. TBI takes the unified OS theory a step further by using a single OS for visualization workstations, desktop productivity, and cluster computing—without compromise in any of these uses.



TBI's homegrown Structures application: TBI geophysicists run Structures on their interpretive workstations to analyze seismic imagery and determine which processes to send back to the Xserve cluster for additional processing.

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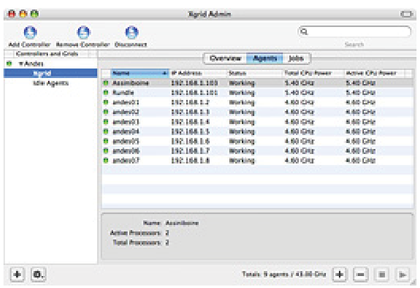
>
> Dale Schack

Getting Up to Speed, Fast

"I set up the eight-node Xserve cluster the night it arrived, and the next morning we were running jobs," says Schack. "We're talking about a 24-hour period between when the hardware arrived and when we were up and running. The cluster was just amazingly simple to set up, and the tools to do it were included for free."

Mac OS X Server comes with Xgrid Admin and Server Admin, which can be used to set up a distributed computing environment. One system is set up as the Xgrid controller, while each Xserve in the cluster runs the Xgrid agent, making it available for running distributed jobs. On occasion, TBI even adds the Power Mac G5 desktop systems to their list of agents so that they can get some extra compute cycles. "With just a flick of a switch, an additional six processors are available," says Schack.

After the hardware solutions were in place, TBI had to get its software up to speed. A large part of the decision to implement an Apple hardware solution was the advantages that TBI would gain on the software side. An in-house visualization tool had to be coded for use on the interpretive workstations. Xcode was the perfect development environment for the task.

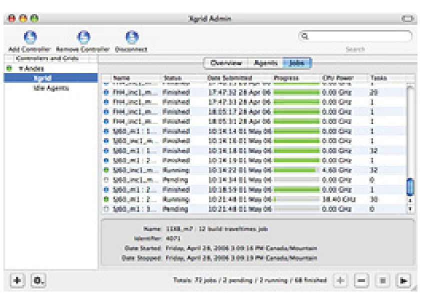


Active agents on TBI's Xserve cluster, as seen through Xgrid: seven compute nodes and two interpretive workstations process data.

Focus on the Science

The ease of development using Mac OS X and Xcode's friendly environment allowed TBI to focus on science right out of the gate, cutting development time and overhead to a minimum. "Because Mac OS X is UNIX based, all the free software that we use out there is going to work with a couple of tweaks in the make files," says Schack. "We can focus on the geophysics and geology side of what we're doing. All the extraneous stuff is removed and handled for us; otherwise, we couldn't have set things up in the time we did."

By using Apple's vector libraries for the Power Mac G5's AltiVec instruction set, TBI was also able to optimize codes while ensuring a smooth transition to Intel's Streaming SIMD Extensions (SSE) instruction set in their future roadmap and on their Intel-based iMac computers, which they use for development.



The Jobs view in Xgrid Admin shows the Xserve cluster's queue with a list of pending, running, and finished jobs.

TBI develops custom codes for much of their processing, but it was also important that they choose a platform capable of using existing applications and familiar tools. One such application is called Seismic Unix, a UNIX-based seismic processing and research environment (developed at the Center for Wave Phenomena, Colorado School of Mines). "We knew Seismic Unix ran well on Linux, so we just picked up a copy and compiled it," Schack says. "With a couple of tweaks, it ran on Mac OS X. It took maybe half a day of figuring out one of the make files, and we were done."

After getting the interpretive workstations up and running, they placed the Xserve cluster order, and the development focus shifted to Xgrid. "We're a small shop," Vestrum explains. "We didn't want to have to write a lot of software to manage the cluster, and we didn't want to buy a really big cluster-management system. Xgrid, which comes with Mac OS X, does a great job with almost no setup. We wrote a couple of scripts to manage our jobs for us, and Xgrid does the rest."

TBI uses Python scripts to create a series of anisotropic migration jobs to send to the cluster. The scripts run from a single command line that sends an Extensible Markup Language (XML) property list to the Xgrid controller, which in turn spreads the tasks across the cluster for processing.

Apple Technology at Thrust Belt Imaging

Operating system

- Mac OS X Server Tiger
- Mac OS X Tiger

Hardware

- 3 2.7GHz Power Mac G5 Dual interpretive workstations
- 1 2.5GHz Power Mac G5 Dual software development workstation
- 3 2GHz Intel-based iMac software development workstations
- 2 17-inch PowerBook G4 presentation laptops
- 8 30-inch Apple Cinema Displays
- 1 20-inch Apple Cinema Display

Storage and cluster

- 1 dual 2.3GHz Xserve G5 (head node)
- 7 dual 2.3GHz Xserve G5 (compute nodes)
- 1 Xserve RAID (7TB of total hard disk space)
- Fibre Channel connection to head node

Administration tools

- Apple Remote Desktop
- Mac OS X Server administration tools, including Server Admin, Server Monitor, Workgroup Manager
- Xgrid
- NFS

Development tools

- Xcode
- Cocoa frameworks
- OpenGL framework
- Accelerate framework
- Xgrid framework
- X11
- Bash
- iTerm 0.8.0
- Aquamacs Emacs 0.9.9c
- Subversion 1.3.1
- Apache 2.2
- Python 2.4.3

Technical support

- AppleCare

A Rock-Solid Interpretive Solution

Although much of the industry has moved toward a data-driven approach to seismic image analysis, largely limiting itself to oceanic exploration in which there's more data density and less noise, TBI takes an interpretive approach to image the subsurface below rugged environments. To an analyst, interpretive results are only as accurate as the monitor displaying the imagery. TBI can display 5120-by-1600 seismic images on 30-inch Apple Cinema Displays, making them a key component in TBI's decision to use Mac systems.

"For our interpretive workstations, what we needed first and foremost were large displays—the larger the better," Schack says. "Apple has these beautiful 30-inch displays; by combining a Power Mac G5 with a nice graphics card, you can drive two of them. With the amount of data we need to display, this seemed like a natural solution."

Gittins adds: "The increase in productivity resulting from the size of the displays cannot be overstated. The larger displays allow me to look at the data in detail while retaining an understanding of how the details fit within its geologic context. I cannot imagine going back to smaller displays."

TBI works hand in hand with its clients. They often sit together at TBI's interpretive workstations to analyze the data, making decisions on velocity models and parameters to send back to the cluster for processing. A fast, user-friendly experience is crucial to a positive exploration process.

"When we sit down with a client, we can try a few different interpretations and send them off to the cluster," Vestrum says. "In 10 minutes, we get back all the calculations we need. On a single system, this would have taken most of the day. While we're waiting for results, we look at another dataset. We need really fast turnover so we can be experimental."

At the end of an interpretive session, the geologist will have a new velocity model. TBI's Python script is then executed, which creates a sequence of jobs designed to run one after another. Each job has approximately 40 tasks. Xgrid sends each task out to a different processor on the cluster and returns the results.

Working in a Stable Environment

The long-term benefits of using Apple's hardware solutions and robust development environment are already beginning to appear, including the luxury of not needing a full-time system administrator to care for TBI's compute environment. In fact, since moving the cluster into their machine room months ago, TBI's developers and users need an excuse just to visit the hardware.

"We originally had the system running in our office space while the machine room was being built out," Schack says. "We would watch the system whenever we submitted a job to the cluster, just to watch the processors light up. Since we moved the cluster into the machine room, we haven't had to go in there once, aside from taking a picture for this article. I can control everything through Apple Remote Desktop and have never had a problem with the hardware."

Software (productivity)
- iWork (Pages, Keynote)
- Safari
- Mail
- iCal
- Address Book
- BluePhone Elite 1.0.8
- Salling Clicker
- OpenOffice 2.0.2
- Microspot X-RIP 1.6
- Transmit FTP 3.5

Software (processing, internal)
- Structures (interactive)
- tbi2dtt (command line)
- kmig2d (command line)

Software applications (processing, third party)
- Seismic Unix
- MASTT
- Velanal
- Omega2

TBI uses Apple Remote Desktop, Apple's desktop management solution, for software installations, package updates, and detailed reports of system status. Tasks can be completed in parallel, so large clusters can be administered in the same amount of time as a single desktop computer.

Massive, Multiplying Datasets

Modern-day seismic imaging involves acquisition of massive three-dimensional datasets covering anywhere from 200 to 800 square kilometers. Data is grouped in 25-by-25-meter bins, each containing 30 to 60 seismic traces. Floating-point values are recorded every two milliseconds for four to eight seconds. The process creates three-dimensional datasets of approximately 50GB to 200GB, which is just the starting point for Thrust Belt Imaging. The interpretive analysis process is an iterative approach with each step duplicating the original dataset using improved velocity models to clarify the images. The end result is more than 10 times the size of the initial dataset, creating output in the range of 0.5TB to 2TB.

Xserve RAID is used for the storage solution. Each Xgrid agent (compute node) on the cluster needs access to the dataset when performing anisotropic depth migration. The Xgrid controller (head node) is attached to the Xserve RAID with Fibre Channel and serves data to the Xserve cluster nodes via Network File Systems (NFS). The Xserve RAID configuration includes 7TB of available disk space onboard. Xserve, Xserve RAID, and Xgrid join to form an integrated, single-source solution for high-volume parallel data processing that would quickly overwhelm standard, serial approaches.

Sometimes 32-bit Isn't Enough

Massive datasets are often tied to massive memory requirements; TBI's processing approach is no exception. Accurate measurements of the time for a sound wave to travel from shot location to receiver location compose the base component for seismic images. After interactively generating an updated velocity model, TBI's anisotropic ray tracer is applied on the model, generating a 1GB to 4GB cube of travel times. The Xserve compute nodes in TBI's cluster are responsible for the lion's share of processing, with each node running processes in 4GB of onboard RAM.

TBI's interpretive workstations (Power Mac G5s with dual Apple Cinema Displays) are multipurpose machines, running high-end graphical environments for geophysicists while simultaneously executing the same memory-intensive tasks running on the cluster. To avoid costly page swaps, each interpretive workstation is equipped with 6GB of RAM, surpassing the 4GB maximum in 32-bit solutions.

AppleCare for On-Demand Solutions

Thrust Belt Imaging is a big proponent of AppleCare. Although its trouble-free environment has not required using the service for hardware problems, the company has called on Apple's experts for user-support issues, including assistance in making a complex bid template in Pages and connecting printers outside its local subnet. Vestrum explains, "We use AppleCare at key moments when we need information to make something happen quickly."

Future Exploration

TBI is opening new areas to explore for oil and natural gas without traditionally high-risk drilling from uncertain image analysis. As energy companies realize the benefits garnered from making accurate corrections for anisotropic effects, the natural resources in rocky foothills such as those found near TBI's home in Calgary will be used more efficiently, benefiting both TBI's clientele and regional economies. As TBI's project base grows, so will its Xserve cluster. Xserve is a proven supercomputing platform that has been scaled up to thousands of nodes in production and the research environment.

"It's just rock-solid, steady, and hums through the jobs," Schack says of TBI's Xserve cluster. "It's fantastic. I know I sound like a rabid Mac fan—which I wasn't—but after the ease of this experience, I'm thinking of becoming one."

For More Information

For more information, please visit www.apple.com/science.