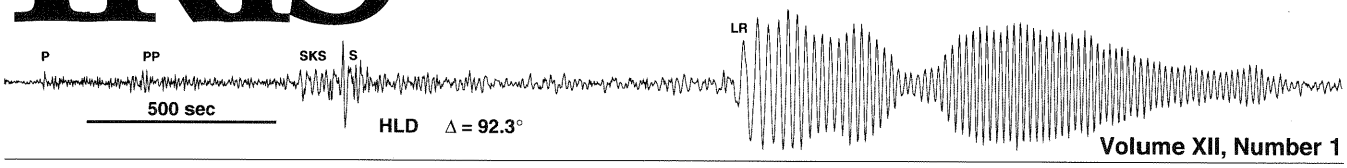
IRIS Newsletter



Volume XII, Number 1

PASSCAL Meets the Rocky Mountain Front

*Art Lerner-Lam, Lamont-Doherty Earth Observatory and the RMF Field Party**

Heading west on Interstate 70 across Kansas and eastern Colorado is a lesson in distance, giving one a good sense of what precisely is the tradeoff between velocity and travel time. Doing it with a rental truck full of PASSCAL shipping containers, batteries, solar panels, garbage cans, insulation, shovels, exabyte tapes, computers, pencils, field books, tents, sleeping bags, food, more exabyte tapes, wire reels, tools, a few JGRs and field guides, and a selection of awful cassette tapes and a bad radio, may not be the stuff of dreams for most people, but after three days of driving, that first view of the Rocky Mountain Front, of Pikes Peak and Mt. Evans from just east of Limon, is more than enough justification for the effort. It is not hard to imagine why the Conestogas headed southwest, trying to get around Pikes Peak and the Wet Mountains, eventually finding Raton Pass to Santa Fe, and why the railroads first chose the route through Cheyenne and then later through Raton. The Front Range is just too imposing, a Chinese Wall precluding easy exploration.

There is no hint of a gradient, yet the highest point in Kansas is near the border with Colorado and you arrive at the base of the Front Range more than 1.6 km above sea level. Mesozoic sediments, which haven't done much to impede the progress of the interstate east of Golden, are suddenly steeply dipping unconformably against the Proterozoic forming a visually stunning sequence of hogbacks and flatirons. I-70 cuts through them and begins a short 10-km climb to Bergen Park, home of the US NSN station GOL, at elevation 2.4 km. Mt. Evans, rising to more than 14,000 feet, is just to the southwest. The Continental Divide is a few more kilometers further along and is traversed either by crossing Loveland Pass or by taking the easy route through the Eisenhower Tunnel. Dropping down through Keystone, you then climb along a major Laramide fault past Copper Mountain (if the sun is right, you can see slickensides, or so says the guidebook) and cross Vail Pass. A bit more flat running, albeit at 8000 feet, and you wind down through Glenwood Canyon, where even a seismologist can pick out the unconformity. Just west of Glenwood Springs is the Grand Hogback marking the western limit of the central Rockies. We've traveled just about 200 km and have experienced more than 2 km of relief.

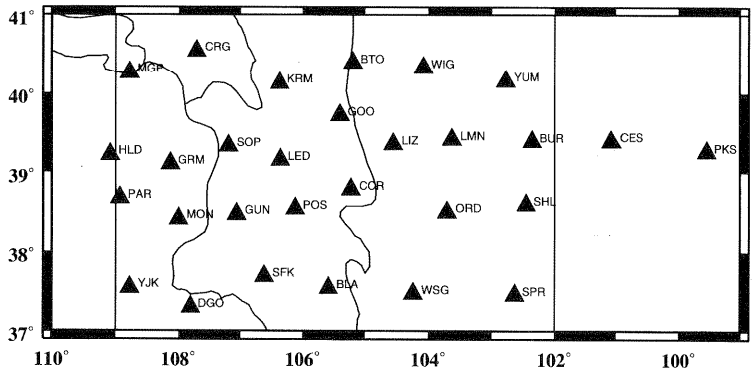


Figure 1. Network map with triangles indicating station position. The 1991 feasibility study occupied the central east-west line, except for the two stations in Kansas. Curved lines are geological province boundaries, clockwise from upper left: Unita uplift, reactivated craton, Rockies, and Colorado Plateau.

NSF and, presumably, most of the IRIS membership require more than a travelogue to justify funding. The same front range that slowed the covered wagons appears to do the same to surface waves and body phases. Steve Grand's North American tomographic models, as well as regional work by Helmberger, Priestley and others, have for years shown that the fast mantle beneath the North American Craton gives way to slow mantle beneath the Basin and Range. It has been argued by Jordan, for example, that this is representative of the transition between normal convecting mantle and the dynamically-stabilized upper mantle beneath cratons otherwise known as tectosphere. While the average velocities beneath old continents and the tectonized Basin and Range are not much in doubt, in detail it is not known where or how rapidly the lateral transition in upper mantle structure takes place. As Steve Shapiro and Brad Hager have shown, the morphology of this

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What's Inside

From the Execom Chair

The path to our ultimate goal of a 128-station permanent global network and 6000 PASSCAL-standard channels requires funding, elbow grease, and fruitful collaboration with fellow seismologists outside the United States. However, coasting to the finish line is neither possible nor desirable. Funds to capitalize fully the GSN and the PASSCAL instrument pool are not yet in view, and cannot be sought from NSF alone. Funding is necessary from other sources, both public and private.

With the end of the Cold War, the rationale that has motivated funding for basic research is being reevaluated. Scientific fields with clear application to 'the national agenda' have an advantage in the current environment. Seismologists, and IRIS in particular, have much to contribute to the issues of earthquake hazard, resource exploitation, nuclear test-ban monitoring, and nuclear waste disposal. These contributions are not always self-evident to policy-makers, and so require frequent articulation. IRIS will continue to take a leading role in this effort, both directly and by helping coordinate efforts by individual researchers.

Whatever 'role' is decided for basic research in the national agenda, it will be easier to justify support for fields that capture the imagination of the nonscientist. The nonscientist audience of a university professor is composed mainly of undergraduates, both geology majors and enrollees in the introductory courses. Seismology has several pedagogical advantages relative to other subfields of the physical sciences. Academic seismology now has the tools to bring interesting data and scientific problems nose-to-nose with undergraduates at the level of a Geology 101 lab. Never underestimate the challenge of finding a hypocentre and source mechanism from the previous day's event, without a computer, from a dozen seismograms and the Jeffreys-Bullen Tables. (Yale undergraduates are often astonished that an earthquake in Tonga can be recorded in New Haven — don't ask me why.) The software tools of the Data Management System are at the disposal of university seismologists, and innovative uses are encouraged. •

Jeffrey Park, Chair

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western edge can provide constraints on the long-term stability of cratonic upper mantle. In addition, there are questions concerning the existence of a mantle low-velocity zone and lid, crustal thickness variations, and the characterization of smaller-scale features noted by Hearn, Dueker and Humphreys and others and their relation to crustal deformation and volcanism. Surprisingly, the transition from front range to craton has not been well-studied by seismologists. To fill in this gap, Gene Humphreys, Steve Grand, Tom Jordan and I proposed a long-duration passive broad-band deployment of PASSCAL instruments with about 1000-km aperture. We proposed a suite of analytical studies including body-wave tomography, forward body-wave modeling, and surface wave dispersion and scattering measurements and inversion. PASSCAL instruments are the ideal facility for this type of meso-scale structural study.

The Front Range represents the furthest advance of the Laramide, itself the last, most far-reaching and unusual of a series of western US compressional events which deformed the late Devonian continental margin. The two essential questions motivating the RMF experiment are: What are the dynamics of the recent uplift of Laramide structures and the High Plains? and, What is the extent to which the existence and persistence of the North American mantle root affects intra-continental deformation in the cordillera?

The array is shown in Figure 1, with an east-west axis extending about 1000 km. We sought a nominal station spacing of 100 km, but in places we moved instruments during the experiment to densify coverage of particular features. In the summer of 1991, we deployed ten instruments for 2 1/2 months along I-70 for a feasibility study. In 1992, we reoccupied these sites and in addition deployed another twenty instruments for nearly eight months in a two-dimensional array. Power was supplied by solar panels and batteries, and the seismometers were installed in shallow insulated pits on tile or cement pads. We sampled continously at 10 Hz, which required site visits every two weeks. With the kind cooperation of Tom Boyd and Phil Romig at the Colorado School of Mines, we were able to set up two field computers in Golden. Data pickup was by disk swapping, and we attempted to extract events from the continuous data stream in the field lab. Station locations were obtained from topo sheets and by hand held GPS receivers; we also tested several of the new GPS clocks which write their locations into the REFTEK log files. A GOES clock writing to a triggered data stream was used as an independent time standard.

We peppered the High Plains with triangles, making it as far east as Palco, KS, where we deployed an STS-2 on Don Steeples' farm. The good people of Palco thought we were the advance team for the Hell's Angels but, not surprisingly, in the midst of the oil fields, they were familiar with earthquakes and seismologists, not to mention Don Steeples. Western Kansas, despite its rural moniker, is almost completely covered by cellular telephone service and Pizza Huts. It would have been a good place to test the new REFTEK cellular modems, but we were forced to dial up pizza rather than UTILITIES/DAS STATUS over the truck phone. And, to our dismay, instead of just confirming our order, the Pizza Hut guy said, "ARE YOU SURE?"

In eastern Colorado, with typical academic conceit, we showed off our handheld GPS receivers to the farmer on whose wasteland we had just dug a tractor-busting hole. He did not agree with the displayed elevation (in meters), and so he whipped out a solar-powered calculator from his coveralls and did the conversion. We thus ate a bit of humble pie and went back to the manuals to read up on GPS vertical accuracy.

Rolling west, hubs free, guidebooks open, hand terminals charging, we continued deployment in the Front Range. Emerging onto the Colorado Plateau, the flat mesas of Green River, Morrison, all the textbook names,

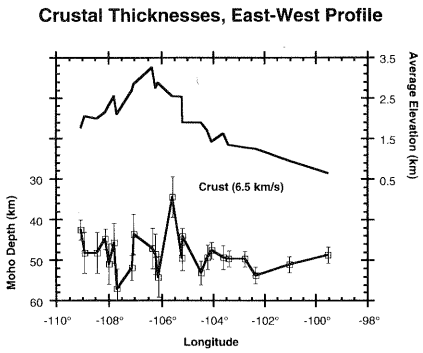

Figure 2. An interpretation of average Ps Moho-converted phase delays in terms of crustal thickness, projected on an East-West profile. *(From Anne Sheehan et al., 1992)*

dominate the topography. Dinosaur country. We put a station just north of the Book Cliffs, south of the Uintas, near Dinosaur. In Dinosaur, just off Brontosaurus Way is the Dinosaur Baptist Church. Not only were they warm-blooded, but apparently they had religion too. T. Rex the Baptist! Instead of a friendly pastor, velociraptors are at the door.

More stations were deployed in southwestern Colorado, in the San Juans, the Uncomphagre uplift, and the Paradox Basin. Some problems surfaced. The GPS clocks kept locating our stations in someone else's experiment, but Paul Passmore, president of REFTEK, sent us new chips for the fix. After convincing the Lamont Instrument Center that we had a truck-mounted portable clean lab and air filtration system and would wear surgical gloves and put anti-static mats on the ground, we swapped the chips in the field. Passmore eventually decided that we were having too much fun on our own, and so he showed up sneakered and capped to help out. One cold clear night on Pike's Peak, wedged in the cab of the field truck, he resoldered every connection in a STS-2 control box. Paul had no reservations about taking stuff apart in the field; he would set a shipping container on end to serve as a workbench and array his tools on the tailgate. We all sensed this was where he'd rather be.

Once the data are sorted by event, a number of quick analysis techniques can be applied not only for quality control but also to derive some first-order observations from the seismograms. For example, the popular receiver function method extracts boundary interaction phases by deconvolving the vertical-component P-arrival complex from the radial component. Anne Sheehan, Geoff Abers, Jacob Lawrence and Sean Chen computed receiver functions for the 1991 and 1992 data using Abers' time-domain deconvolution code and found clear Ps conversions due to interactions at the Moho and the base of the Denver Basin. The preliminary interpretation of these phases in terms of crustal thickness is shown in Figure 2. The topographic and Bouguer gravity profiles argue for short-wavelength or local compensation of the Rocky Mountain topography. The gravity data can be modeled by an Airy root in the crust but typical crust and mantle densities would require more than 10 km of relief on the Moho correlated with the topography. Our initial conclusion is that this correlated Moho relief is not supported by the converted phase data, and that the compensation must occur in the upper mantle. The mechanism of this compensation may be lithospheric thinning, but Martha Savage has found no clear evidence of anisotropy to support this.

Surface wave dispersion measurements support the notion of different lithospheric structure just east and west of the Rocky Mountain Front. Sean Chen obtained two-station phase velocities with a cross-correlation procedure and found that fundamental mode Rayleigh waves at periods between 30 and 50 s are about 10% slower beneath the mountains than beneath the high plains, as shown in Figure 3. We have not yet inverted these observations for differences in average velocity structure, nor have we isolated the locus of the lateral transition in the mantle, but the morphology of the dispersion difference is consistent with slower lithosphere/asthenosphere structure or perhaps a shallower asthenosphere beneath the tectonized crust. Some initial body-wave work done by the Oregon group supports this general picture, but there are enticing small-scale features beginning to appear as well.

The interpretation of intermediate period surface waves is complicated by the strong refraction and scattering they suffer as they traverse the Front Range structure. We are currently characterizing the refraction or scattering using frequency-dependent measurements, but initial measurements by Chen suggest that significant refraction of 20-s surface waves is occurring on the scale of the station spacing.

The advantages of the PASSCAL instrumentation for this type of experiment are clear. Apart from the dense coverage of a previously unilluminated tectonic transition, the array provides measurements of the intermediate period wavefield at inter-station spacings not commonly deployed. The coherence and distortion of the wavefield at these

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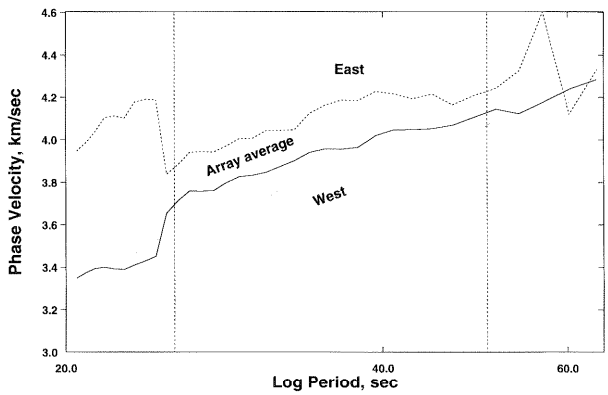

Figure 3. Two station phase velocity measurements. East and West refer to inter-station path averages east and west of the Front. Curves outside vertical lines reflect phase measurement noise.

Rapid Earthquake Analysis at Harvard

Göran Ekström, Harvard University

Since the fall of 1991, the Harvard seismology group has been routinely analyzing larger earthquakes around the world within 24 hours of their occurrence using data from the Global Seismographic Network (GSN). Results from the analysis are distributed via electronic mail to interested parties in the U.S. and abroad. The objective is to provide the community with additional useful information about earthquakes as soon as possible after they occur. Our analysis provides a scalar moment, an earthquake focal mechanism in terms of a moment tensor, and, in some cases, a better estimate of the earthquake hypocenter. The rapid dissemination of earthquake source parameters has proved useful to different research groups in their planning of scientific responses to individual earthquakes, and we hope that this information will be useful in the estimation and mitigation of continuing earthquake hazards.

The Quick CMT

The rapid earthquake analysis is in many aspects similar to our systematic and ongoing project of analyzing global seismicity using the centroid-moment tensor (CMT) algorithm initially developed by Dziewonski, Chou and Woodhouse. In that project, earthquakes with magnitudes greater than 5.0 are systematically analyzed using data from all GSN stations with a delay of approximately three months. In our rapid analysis, which results in what we call 'quick CMTs', we are limited to using stations from which data are available in nearly real time. The CMT algorithm operates like a matching filter. The earthquake focal mechanism (the moment tensor) and the best point source location in space and time (the centroid) are determined by matching observed long-period seismograms (periods greater than 45 seconds) with complete synthetic waveforms calculated by summation of the Earth's normal modes. In theory, a single horizontally polarized seismogram contains sufficient information to determine the moment tensor of an earthquake. In 1986 we used this principle to estimate earthquake focal mechanisms for several earthquakes using seismic records from only the Harvard station HRV. In practice, of course, more robust and reliable earthquake parameters can be obtained when seismograms from several stations in different azimuths from the earthquake are available. In 1986 remote, rapid access to seismic data became a reality with the development at Harvard of the IRIS-1 prototype data logger, which made it possible to call up the seismic station and retrieve data over standard phone lines using a modem. Several IRIS-1 and IRIS-2 systems were installed during 1987–1990; during these years quick CMTs were calculated for a small number of significant earthquakes using dial-up data. In 1990 we started distributing quick CMT results via electronic mail. In 1991 the global coverage of dial-up stations was sufficient to attempt to routinely study all earthquakes with magnitude greater than 6.5 within a day of their occurrence. It became clear, however, that we were beginning to spend large amounts of time (and money) calling and transferring data from more than ten stations over the modem. In 1992, arrangements were made with the IRIS Data Management Center (DMC) in Seattle for long-period waveforms collected by the IRIS Gopher system to be copied automatically to a computer at Harvard. This cooperation has streamlined and simplified our operation. We can now routinely calculate and distribute quick CMTs for all earthquakes with a magnitude greater than 6.0.

The data flow in the current implementation is shown in Figure 1. The analysis is initiated by an electronic mail message from NEIC (USGS), usually issued within a few hours of a large or otherwise significant earthquake. This message provides us with the origin time and a preliminary hypocenter of the event. The same information is sent to the DMC, where it automatically triggers the Gopher system which starts collecting seismograms from the approximately 20 IRIS GSN stations with dial-up capability. Long-period data retrieved by the Gopher system are copied in SAC format to the Harvard computer. Usually data for more than a dozen stations are available within a few hours after an earthquake with magnitude greater than 6.0. The analyst at Harvard reformats the data into a standard Harvard data format, and performs the usual

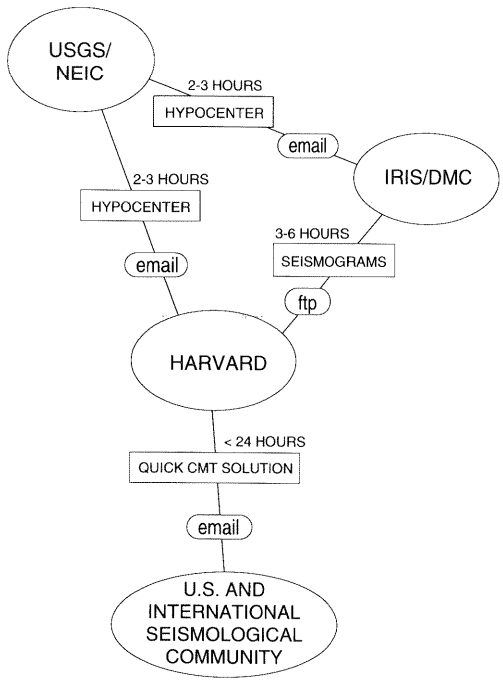

Figure 1. Earthquake information and data flow. Earthquake parameters as well as seismograms are distributed and shared over the Internet.

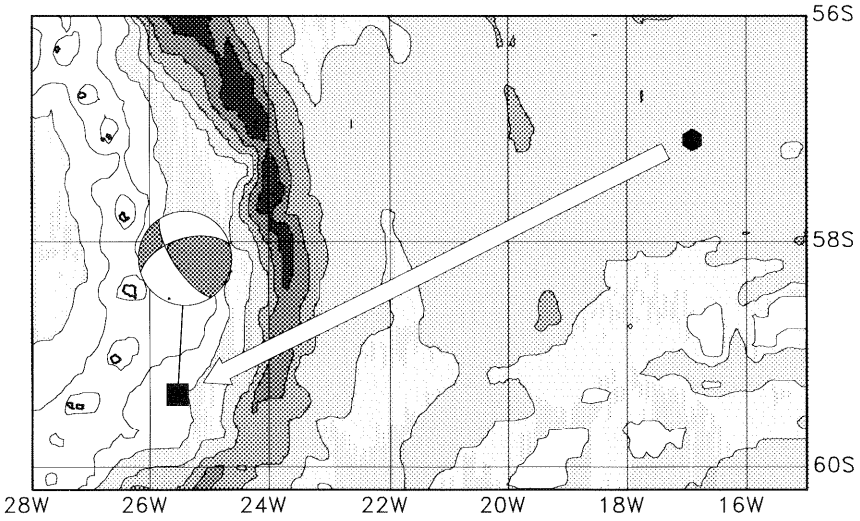

Figure 2. Earthquake relocation required for the South Atlantic earthquake of January 10, 1993. The white arrow points from the preliminary hypocenter reported by the NEIC (solid hexagon) to the quick CMT centroid location (solid square). The quick CMT focal mechanism is shown in lower hemisphere projection.

CMT analysis. After verifying the results, a mail message is prepared which is distributed to interested scientists, often within 12 hours of the earthquake.

The number of dial-up stations continues to grow and, more importantly, the distribution of stations around the globe is becoming more uniform. With the improving network, quick CMT results are becoming more robust. Comparisons show that the quick CMT results for events with magnitudes greater than 6.0 are very similar to those obtained using data from the entire GSN several months later.

Refined Hypocenters

Occasionally our quick analysis requires that the centroid of the earthquake be moved a significant distance from the initial hypocenter reported by NEIC. An extreme example of this is illustrated by the earthquake in the southern Atlantic Ocean on January 10, 1993. The relocation required in our analysis is shown in Figure 2. Based primarily on a large number of PKP phases recorded in North America, the initial NEIC location for this magnitude 6.3 earthquake was far from any plate boundary, several hundred kilometers east of the South Sandwich Islands trench. An initial CMT analysis showed that this location was incompatible with the waveform data. After several iterations, the CMT centroid location for the earthquake converged to a location close to the South Sandwich Islands trench and plate boundary, more than 500 km from the reported epicenter. We obtained a good fit to the waveform data with the source at the centroid location, which also agrees well (within 50 km) with NEIC's later revised epicenter. This unusual example highlights the dearth of good phase data available for quickly locating earthquakes in the southern hemisphere and also demonstrates the utility of using even a small number of full waveforms in hypocenter determinations.

Automated Earthquake Analysis

The analysis described in the previous sections requires human intervention at almost every step of the data processing. If the analysis were automated, source parameters could be determined with shorter delays. A particular motivation for attempting to speed up the analysis is the opportunity of providing source parameter information that can be used in the calculation of tsunami generation, propagation, and predicted impact in the Pacific Basin. Because typical tsunami travel times across the Pacific Ocean or to Hawaii are five to ten hours, reliable information about the scalar moment and focal mechanism of earthquakes in the Pacific Basin, available within one or two hours after the earthquake, could be used to predict tsunami heights before the arrival of the ocean wave. In an attempt to demonstrate the feasibility of implementing such a system, we have developed and are now testing a fully automated algorithm for earthquake analysis.

Figure 3 shows the information flow and processing steps in the new algorithm. An electronic mail message from the NEIC is read automatically and waveforms from the IRIS DMC are translated and associated with the hypocenter by programs that are activated every 10 minutes by the UNIX *cron* utility. Other regularly activated programs associate the correct instrument response with each waveform and calculate six synthetic moment tensor kernels for the hypocenter-to-station path corresponding to each station/component seismogram. Each single station/component seismogram is then filtered and cross correlated with the synthetic waveform kernels in two frequency bands. Body waves arriving before the first Rayleigh and Love waves are filtered around 60 seconds period. The first Rayleigh and Love waves (R1 and G1) are filtered with a peak sensitivity around 200 seconds. The correlation results for each station/component trace are stored together with a few additional parameters which reflect the quality of the data trace and the optimal fit that can be obtained with the synthetic waveforms. Whenever correlation results for a new station/component are calculated, an inversion for a combined source mechanism based on the results of all analyzed station/component traces is performed. A file containing the updated source parameters for

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the earthquake is placed in a public directory and can also be mailed electronically to interested parties.

At the time of writing, the automatic processor has been operating for six weeks. The results are encouraging. Figure 4 shows comparisons between the six most recent automatic moment tensor solutions and the corresponding quick CMT solutions obtained by standard manual processing. There is good general agreement between the results of the two methods of analysis. The largest difference is observed for the Mariana Islands earthquake of January 18, 1993, for which the Gopher system did not collect data from the complete dial-up network. For the other events, including the large and unusual Hokkaido, Japan earthquake on January 15, 1993, we obtain very similar results using the two methods. The automatic processing generally produces slightly smaller scalar moments, primarily due to the inclusion of portions of noisy traces and to the lack of an attempt to relocate the earthquake hypocenter to obtain an optimal fit to the data. When the initial hypocenter is poor, the results of the automatic processor are adversely affected. We are currently considering ways in which relocation can be efficiently incorporated in the automated analysis.

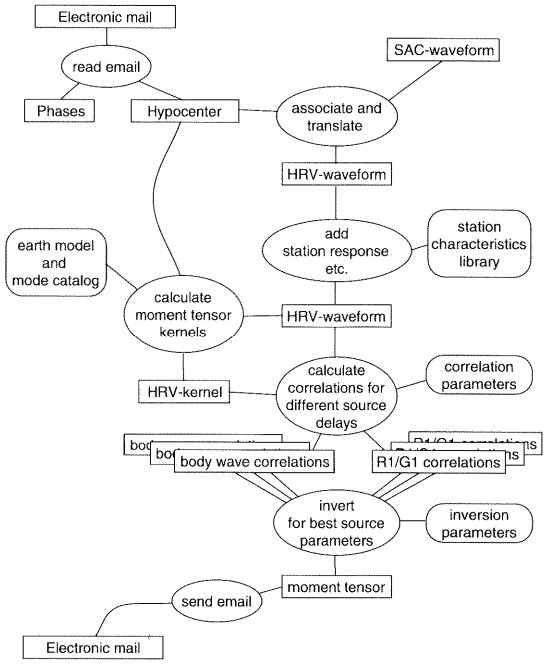

Figure 3. Processes and information flow in the automatic earthquake analysis system. Information (e.g. 'hypocenter'), processes (e.g. 'read email') and resources (e.g. 'earth model') are distinguished by the different object shapes.

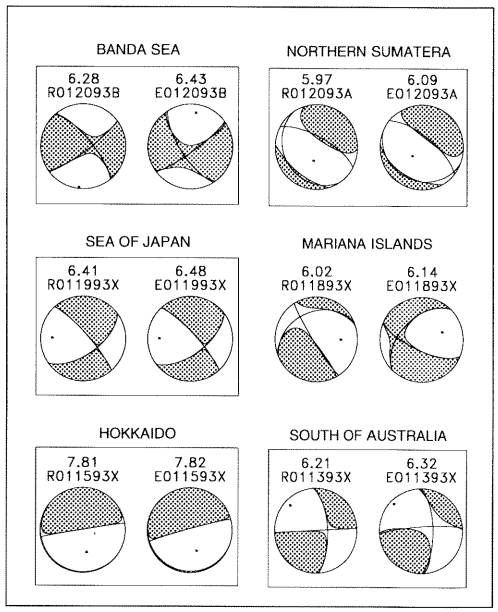

Figure 4. Comparisons between automatic (left) and manual (right) results for the six most recent earthquakes that we have analyzed. The moment magnitude and the date of the earthquake are given above each focal mechanism. The Mariana Islands earthquake was initially reported with a magnitude less than 6.0, so the IRIS Gopher system did not collect a full set of seismograms for this event. This may be one reason for the discrepancy seen between the automatic and manual results.

Distribution of Results

The results from the quick (manual) CMT analysis are distributed via email to anyone who is interested and are also available from the IRIS DMC. The results from the automatic analysis are available directly via anonymous ftp to seismology.harvard.edu (128.103.105.101). The regularly updated CMT catalog, which contains source parameters for approximately 10,000 earthquakes since 1977, is also available from this Internet address. Questions about the rapid earthquake analysis project can be directed to the author at ekstrom@geophysics.harvard.edu. Our work benefits tremendously from the cooperation and services provided by NEIC and IRIS DMS, and from the infrastructure supported by the operators of the Internet. Earthquake research at Harvard, including this project, is funded by the National Science Foundation. •

This Issue's Bannergram: The seismogram on the cover shows the radial component from HLD (Harley Dome, Utah), the westernmost station installed as part of the Rocky Mountain Front Experiment, at an epicentral distance of 92.3° from a magnitude 5.9 earthquake in the Santa Cruz Islands on August 4, 1992. The complex beating in the surface waves is typical of that observed for propagation through mixed oceanic and continental paths. •

Digital Signal Processing Workshop

The IRIS Data Management System (DMS) is sponsoring a workshop on "First Principles of Digital Signal Processing for Seismologists". The course is being organized by Steve Malone and Ken Creager of the University of Washington as part of their activities as the hosting institution of the IRIS Data Management Center. The course will be given by Frank Scherbaum of the University of Munich, Germany.

Digital signal processing has become more and more an integral part of observational seismology. While it offers unprecedented power in extracting information from seismic signals, it comes at the price of having to learn a variety of new skills. Dealing with digital data requires at least a basic understanding of digital signal processing in order to apply the 'new tools' correctly. Taking the calculation of true ground motion as the guiding problem, this two day course will cover the basic theory of linear systems, the design and analysis of simple digital filters, the effect of sampling and A/D conversion, and an introduction to spectral analysis of digital signals. The course will consist of lectures interleaved with hands-on exercises. Examples and exercises will use PITSA 3.2, a program written by Frank Scherbaum and Jim Johnson, which recently has come out in Volume 5 of the IASPEI software library. The IRIS DMS has supported the development of a version of PITSA for SUN workstations, which will be available for distribution to all IRIS member institutions at no charge.

A network of computers, most likely IBM PCs, will be available for use during the workshop. It is our goal to have a maximum of two users per computer so that participants will gain hands on experience using the PITSA program while learning the principles of digital signal processing.

The workshop will take place May 22-23, 1993 prior to the Spring AGU in the Washington, DC area. Registration is limited to 24 people. Preference will be given to individuals that are from IRIS institutions, with a good geographic distribution. Individuals who return their registration forms early will also be given preference.

The IRIS DMS will provide support of $175 for each attendee to help defray the costs of the hotel and meals for the two day course. Hotel and travel arrangements will be the responsibility of the participants.

The deadline for applications is April 15, 1993. Successful applicants will be contacted and given additional information shortly thereafter. To obtain a registration form contact Kris Skjellerup at the IRIS DMC. We will fax the form to you and will accept fax registrations in return. •

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Tim Ahern, DMS Program Manager

Installation of Yuzhno-Sakhalinsk Summer 1992

In April, 1992, Bob Young and Steve Roberts, of the USGS Albuquerque Seismological Laboratory (ASL), were ready to send a 15,000 pound, 630 cubic foot shipment of the station equipment to be installed at Yuzhno-Sakhalinsk (YSS) on Russia's far eastern coast. Bob had been trying unsuccessfully to arrange for shipment by various standard means (commercial air carrier, surface, etc.) when he hit upon the idea of chartering a Russian cargo plane to fly directly to Sakhalinsk from Albuquerque. Upon telling the government contracting officer of his idea, her response was: "You want to do WHAT?" One can imagine the "sole source" statement Bob had to write to justify using Aeroflot instead of the U. S. flag carrier normally required by U. S. Government procurement regulations.

As it turned out, the least expensive, most efficient way to get both the equipment and people to Sakhalinsk was via Anchorage, Alaska. The shipment was sent by truck, via the AlCan Highway, to Alaska Airlines (Aeroflot's general agent in Alaska) in Anchorage, arriving there a few days before Steve and Bob. Under the supervision of Bob and Steve, the entire shipment was checked and put aboard the chartered Aeroflot AN-26B turbo-prop cargo plane. They then rode on the same plane with their equipment to Sakhalinsk by way of Khabarovsk, sharing the plane with two Russian citizens who were on their way home. Bob and Steve literally kept their eyes on the shipment for the entire 26 hour journey- no problem with lost or damaged shipments here! The station was up and running by 1 June 1992, and has been producing good data ever since. •

Charles R. (Bob) Hutt, Chief, ASL

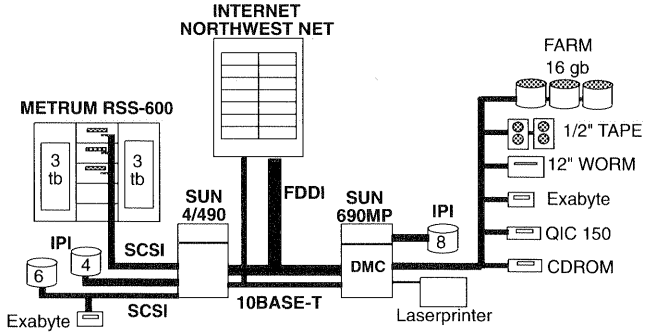
FARM: Fast Archive Recovery Method
The IRIS Disk FARM of Preassembled SEED Data Sets

Tim Ahern, Program Manager, IRIS Data Management System

For several years the IRIS Data Management Center has preassembled data products of earthquakes with particular significance. Recently we have begun a more systematic method of producing these data products. We are now routinely assembling all GSN data for earthquakes of magnitude 6.0 or greater. We are using the algorithm developed by the USGS National Earthquake Information Center for their frequently used event CDROMs. In order to make these products useful as soon as possible, we are beginning the production of these FARM products for the month of January, 1992 and working forward to the present. Once 1992 is complete we will begin building similar SEED volumes starting in December 1991 and working backward in time. At the time this newsletter is published, the first six months of 1992 should be complete.

It is important to stress that data in the FARM archive will have gone through the full IRIS quality control procedures. This is in contrast to data obtained via GOPHER, which are "buyer-beware" data directly from the station processors. Any users of GOPHER data are encouraged to re-access data from the FARM, before publishing their results, to take advantage of any corrections introduced during the quality control processing.

The following diagram shows the two central servers that are presently in service at the IRIS DMC.



The main user interface computer, a SUN 69MP (dmc.iris.washington.edu), at the IRIS Data Management Center is attached to the 6 terabyte Metrum mass storage system through a SUN 4/490 server. The 4/490 is used to generate the databases as new data are archived at the DMC as well as doing the majority of the work necessary to service user requests for data. The 4/490 is not accessible by the general community. The 690MP contains copies of the IRIS databases that users can access through the Electronic Bulletin Board. This SUN 690MP now has considerable processing and storage capacity to support the ever increasing demands placed on it by the seismological community. DMC is configured with 8 gigabytes of very fast IPI disk used to store the information in the IRIS DIRTS database for all data archived in the mass storage system. These disks are accessed whenever users use SPROUT, XRETRIEVE or the soon to be released XTRACT. To support the development of the systematically assembled SEED data products in FARM, 8 high speed SCSI-2 disk drives were added to the 690MP. These disks provide 16 gigabytes of additional storage capacity to store the disk FARM products.

The 690MP will soon be connected to a 100 Megabit per second Fiber Distributed Data Interface (FDDI) link to the IRIS 6 Terabyte mass storage system through its associated SUN 4/490 server. The 4/490 based mass storage system is located within 20 feet of the main NSFNet node in the Pacific Northwest which currently supports T3 communication rates up to 45 megabits per second. This connectivity to the INTERNET should insure high performance access to the large amount of data in the FARM.

The FARM is mounted in the anonymous ftp area of dmc. The directory structure for FARM is as follows:

```
~ftp/pub/products/farm/
        1989/    1990/    1991/    1992/
        Jan/     Feb/     Mar/     ... etc.
```

Under the various monthly directories you will find several files with the following naming convention:

YYMMDD_HHMM and YYMMDD_HHMM.contents

where YY is the year, MM is the month, DD is the day, HH is the hour, and MM is the minute of the event in question. For instance the first event in January has files named:

920102_1640 and 920102_1640.contents

The *.contents* file contains the output of the RDSEED, *"c"* option and is a simple way of determining which stations are included in the corresponding SEED volume.

In general the SEED volumes are between 5 and 15 Megabytes in size and include data from several channels for each station. The channels included are the Short Period (S), Broadband (B), and Long Period (L) channels as available at given stations for the various events.

To assist you in using the IRIS DMC FARM, an example of how to access the FARM products is shown on the opposite page.

Before transferring the SEED volume to your local computer, please make sure that you have adequate disk space and have write permissions in the directory on your own computer. These are the two most common problems users experience in transferring information to their local computers.

AFOSR Call for Proposals

The Air Force Office of Scientific Research (AFOSR) has submitted an announcement to the Commerce Business Daily (CBD) for a major solicitation for research in seismology. This Broad Agency Announcement will be the only detailed solicitation by the Air Force during calendar years 1993 and 1994. All proposals must be received by **April 26, 1993**; the start date goal is October/November 1993. Complete details are available in the CBD. Ask your business office to obtain a copy. If they are unable to obtain a copy for you please contact Dr. Stanley Dickinson at AFOSR. •

New GSN Sites

Two new sites began operation in Russia in December, 1992 - LVZ, Lovozero and NRIL, Norilsk. PMSA, Palmer Sation, Antarctica was installed March, 1993. •

PASSCAL Contacts

Questions regarding the PASSCAL program including such things as instrument use policy, preliminary experiment planning, and future schedules should be addressed to IRIS Headquarters in care of:

Jim Fowler
IRIS
1616 N. Ft. Myer Dr., Suite 1050
Arlington, VA 22209
(703) 524-6222
jim@iris.edu

Once an experiment has been scheduled and field preparations are under way, you should contact the appropriate instrument center. Information on names and addresses of PASSCAL personnel are available through the Internet via the finger command (finger passcal@iris.edu). •

```
                    RDSEED version 3 release 3
        IRIS Standard for Exchange of Earthquake Data (SEED) data reader

+-------------------------------------------------------------------------+
|  Volume Header  |   General information about this tape  |  SEED tape  |
+-------------------------------------------------------------------------+

SEED Format version:                    2.1
Logical record length:                  4096 bytes
Starting date of this volume:           1992,002,00:00:00.0000
Ending date of this volume:             1992,003,00:00:00.0000
Volume Station Header Index:
Station  Station header starts at record
AAK            3
ALE            7
ANTO          11
BJI           13

               etc...
Time spans in this data set:
                          Time, start of span     Time, end of span       Flag
        Time span  1:  1992,002,00:00:00.0000  1992,003,00:00:00.0000  P
Stat  Loc Chn Start date and time    Record Sub End date and time
AAK       BHE 1992,002,16:49:28.8858 130    1   1992,002,17:14:37.6398 137
AAK       BHN 1992,002,16:50:33.9860 138    1   1992,002,17:12:33.9394 144
AAK       BHZ 1992,002,16:51:46.7862 145    1   1992,002,17:13:41.6396 151

                                        etc....
```

The present disk farm at the DMC should have the capacity to store about five years of event data on-line. Users will be able to access these data without interacting with the DMC staff. SEED volumes that are too old to remain on-line will be migrated to the 6 terabyte mass storage system operated by the DMC. When needed, a facility will be added to the bulletin board whereby users can cause these older volumes to migrate from the Metrum mass storage system to a reserved area in the disk farm. While access will not be immediate, we anticipate delays will only be a few minutes.

The IRIS DMC wants to make sure that the products that we are making available through the FARM meet the majority of user's needs. You are encouraged to let us know if you think our windowing criteria or event selection criteria should be modified. You can send your comments to tim@dmc.iris.washington.edu. •

ftp dmc.iris.washington.edu

userid	**ftp**
password	**your_name**
	cd pub/products/farm/1992/Jan
	ls -ls

The above command will show you file sizes and creation times.

```
200 PORT command successful.
150 Opening data connection for /bin/ls (ascii mode) (0 bytes).
total 28122
 5128 -rw-r--r--  1 root      5242880 Nov 24 23:22 920102_1640
   15 -rw-r--r--  1 root        14858 Nov 24 23:23 920102_1640.contents
 7976 -rw-r--r--  1 root      8159232 Nov 30 21:49 920113_1158
   26 -rw-r--r--  1 root        26270 Nov 30 21:49 920113_1158.contents
14952 -rw-r--r--  1 root     15302656 Dec  1 23:52 920120_1337
   25 -rw-r--r--  1 root        25388 Dec  1 23:53 920120_1337.contents
  226 Transfer complete.
```

binary
get 920102_1640.contents

From another window on your local computer, type:

view 920102_1640.contents

If the associated SEED volume contains what you wish then type:

get 920102_1640
quit

A Volksseismometer?

Guust Nolet, Princeton University

The impact of the new digital broadband instrumentation is evident to anyone who is even remotely informed about the field of seismology. As so often happens in science, the new information that is provided by broadband seismographs generates even more questions than it answers. One of the pressing problems is the spatial aliasing of the wavefield, in the sense that seismometers are usually placed much farther apart than the correllation length of perturbations in the seismic wavefront. The obvious solution, then, is to put more seismometers on the surface of our planet. At reasonably low frequencies, say 0.1 Hz or lower, the problems of spatial aliasing, at least on a regional scale, could be greatly improved if amateurs and schools take seismometer deployment in hand.

Not everyone is comfortable with the idea of involving amateurs, let alone inexperienced high school students, with real science. Yet there are several nationwide programs, involving science museums, schools and individual amateurs, to provide significant data on issues ranging from measuring ozone (program 'Smog Watch') to the variability of stars ('Hands-on Universe'). So why not on seismic waves? An important reason that amateur seismology has so far led only a marginal existence is the high cost of a broadband sensor. The necessary investment of at least thousands of dollars thus far prohibits any significant participation by nonprofessionals.

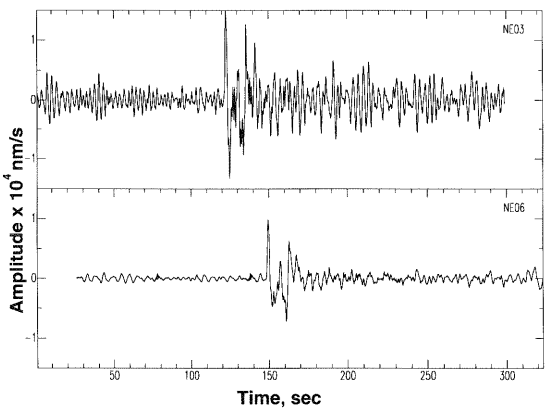


Figure 1. Vertical components of NARS stations NE03 and NE06 for a magnitude 5.9 shallow event in the Aleutians show a very strong difference in noise amplitude between the two stations, as well as in the effect of soil amplification on the P wave.

But this may soon change. Stimulated by the submission of the Princeton Earth Physics Project (PEPP) as an educational proposal to NSF, a meeting of industrial and academic research groups was held at IRIS headquarters on October 9, 1992, where possibilities for a low priced sensor with acceptable noise characteristics were discussed.

Among the most interesting developments reported at the October meeting were:

• Teledyne-Geotech is developing a complete, 3-component system including A/D conversion and serial output using a solid state accelerometer with a capacitance transducer. The bandwidth would be between 20 Hz and 100 sec or more. This instrument is likely to come out of the development stage by late summer 1993. It will be priced for 'easy budget approval', perhaps around $500.

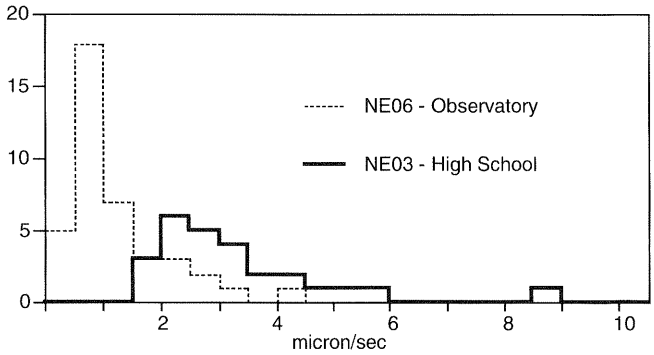


Figure 2. Noise histogram for NE03, the high school station, peaks between 2 and 3 micron/sec, while the observatory site, NE06, peaks below 1 micron/s.

• Jet Propulsion Lab is developing a miniature sensor for the Mars Environmental Survey mission (MESUR). This instrument is also still under development, and uses some known design elements, such as a high Q silicon spring, reminiscent of the Block and Moore instrument, but combined with new technologies (sensing through use of electron tunneling, or with an ultra high frequency capacitive sensor). Bandwidth (0.05-20 Hz) can probably be extended to cover 100 sec waves, and a simplified sensor with the size of a cigarette package might eventually sell for a few hundred dollars.

• PMD Engineering, a small company with strong ties with the Institute of Physics of the Earth in Moscow, presented the first prototype of a 'molecular seismometer'. This instrument uses the inertial mass of an electrolytic fluid that conducts a small current. When this fluid is accelerated it changes the current. The prototype was tested for several days alongside a Guralp at Lamont, and gave a satisfactory response up to a periods of 15 seconds. With improved electronics and possibly a change in dimensions of the capillary system, the molecular seismometer could be made sensitive to lower frequencies. A revised prototype has just been installed at Princeton University alongside an STS-2 for further testing. The cost of this instrument is expected to be comparable with the other two designs.

How useful can a school network be? Some indication is given by the experience of the NARS array in Europe. In order to obtain a dense station spacing while keeping costs to a minimum, many of the NARS stations have been installed outside official observatory sites, in private homes, wine cellars and even in a catacomb. Figure 1 shows a comparison

of the noise and signal levels of the vertical component in station NE03, installed in a high school in Logumkloster (Denmark) with that in the seismological observatory of Dourbes (Belgium, NEO6). NE03 is representative of a station under the worst possible conditions: located near the border between Denmark and Germany in a region of substantial sedimentary thickness, it is subject to large microseismic noise. The seismometer was placed in the basement of the school. It is probably representative of what could be obtained from any U.S. school situated near the Atlantic coast, but much too pessimistic for one located farther inland. Station NE06 is located about 200 km from the North Sea but it is on hard rock. It would be representative of what can be obtained under more moderate conditions. Yet the P wave of this Aleutian event (magnitude 5.9) has a maximum amplitude of 15 microns/sec and rises above the noise even at this high school site. Figure 2 shows histograms of the maximum peak-to-peak noise at each of the stations measured from 2 minute windows in front of triggered P waves. While the noise level at the high school site, Logumkloster, peaks between a level of 2 and 3 microns/s, the peak at Dourbes Observatory is below 1 micron/s. In Logumkloster, the STA/LTA trigger generally failed for P waves with peak-to-peak amplitude below 5 microns/sec.

Such observations help us to formulate minimum criteria for a low cost seismometer. Although a definite limit has not yet been set for the PEPP project, it seems that the following specifications for a 'Volksseismometer' would give useful data for research purposes: - bandwidth 0.015 to 30 Hz - instrument noise level below 0.1 micron/sec (vertical) - clipping level above 500 micron/sec. This would bring the noise level far below the ambient noise for a sensor installed in the basement of a well-founded building. The participants at the meeting generally agreed that such specifications are feasible within a modest budget. The biggest problem so far seems to be the inclusion of an accurate clock. The optimal solution for that is probably dependent on the region. •

the IRIS CONSORTIUM

The IRIS Newsletter is published quarterly by The IRIS Consortium. Please address your letters or inquires to:

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The Incorporated Research Institutions for Seismology (IRIS) is a consortium of over 75 research institutions with major commitments to research in seismology and related fields. IRIS operates a facilities program in observational seismology and data management sponsored by the National Science Foundation. Major funding for IRIS programs is provided by the National Science Foundation through its Division of Earth Sciences and the Air Force Office of Scientific Research.

The IRIS Newsletter welcomes contributed articles. Articles should be less than 1000 words and four figures. Please send articles or requests for details on submission of articles to the address listed above. Electronic submission is encouraged.

Executive Editor: David Simpson (simpson@iris.edu)
Production Editor: Denise Dillman Crump (denise@iris.edu)

Continued from page 3

frequencies and wavelengths, where so much of the energy is sensitive to the lithosphere and the asthenosphere as well as the crust, should provide a new source of raw material for a host of studies focused on the relationships between crustal and mantle deformation.

Data processing is continuing at Lamont and Oregon, and involves several tens of gigabytes of raw data. The continuous records will be distilled into an event-sorted database with correct time, which should be on the order of ten gigabytes or less. These events will be kept on line on a mass store, along with the metadata describing the array and site characteristics. The availability of the data will be announced coincident with the final data report to PASSCAL. In the interim, questions should be forward to lerner@ldeo.columbia.edu or the other PIs.

Funding for the Rocky Mountain Front Experiment was provided by the Geophysics Program of the National Science Foundation, with subsidiary funding from NSF's Research Experience for Undergraduates (REU) and the EarthWatch Foundation.

We are on the southwest slope of Mt. Blanca, Saturday night, about 10:30, just after a snowstorm has broken. This is the last station to be picked up and the end of the experiment. We can make out Blanca only by the absence of stars to the northeast. Grinding up through two feet of fresh snow, we have cleverly been counting on the Omega antenna to mark the site. Of course, the antenna would have to be white and difficult to pick up. We go by the odometer, the portable GPS, and breaks in the vegetation until Sean spots the solar panels mounted on a small tree. It takes about an hour to dig out the instruments and winch out the vault, and about another 15 minutes to pack everything away for the drive back to Bergen Park. We pack a truck the next day, reducing the field lab from organized clutter to an empty room. The drive back to Lamont seems longer than the drive out, even though we're trying to make it back for Christmas. None of us wants this to end. •

*Rocky Mountain Front Participants:

PIs: Steve Grand (Univ. of Texas, Austin), Gene Humphreys (Univ. of Oregon), Tom Jordan (MIT), Art Lerner-Lam (Lamont-Doherty).
Participants: Univ. of Texas, Austin: Duk Lee, Mark Riedesel; Univ. of Oregon: Ken Dueker, Randy Palmer, Pat Ryan, Chris Bryant, Bill Vediker, Arlo Guthrie; MIT: Jim Gaherty, Steve Shapiro; Lamont-Doherty: Anne Sheehan, Sean Chen, Hong-Sheng Guo, Joe Greer, Jonathan Schwartz.
Undergraduate interns: Russ Silver (UCSC-NSF), Jacob Lawrence (UNC-NSF), David Jones (Harvard- NSF).
IRIS: Larry Shengold, Jim Fowler.
Others: Dick Hilt (Colorado College), Paul Passmore (REFTEK), Jim Spurlin (Colorado School of Mines), Rick Knapp (Science Teacher, Ramapo Central School District), 6 high school juniors funded by Earthwatch.
With assistance from: Martha Savage and Craig Jones (Univ. of Nevada, Reno), and Geoff Abers (LDEO).

CALENDAR

MARCH

30-31 Execom Meeting, Seattle, Washington

APRIL

4-8 EUG, Strasbourg, France

13-16 SSA, Ixtapa, Mexico

MAY

2-5 National Earthquake Conference, Memphis, Tennessee

24-28 Spring AGU, Baltimore, Maryland

JUNE

10-14 Fifth Annual IRIS Workshop, Waikoloa, Hawaii

OCTOBER

1-4 National Survey for Seismic Protection International Conference, Yerevan, Armenia

New Member

IRIS welcomes Ecole Polytechnique of Montreal, Canada as a new foreign affiliate. Marianne Mareschal will be the representative liason on the Board of Directors. •

Fifth Annual IRIS Workshop

Royal Waikoloan Hotel
Waikoloa, Hawaii (the Big Island)
Thursday, June 10 - Monday, June 14, 1993

Registration and travel information forms are now available for the Fifth IRIS Workshop. If you have not received them, please contact the IRIS Office. The registration deadline is **April 15**.

An icebreaker and registration will kick off the activities on Thursday evening. Scientific sessions and discussion groups will be held all day Friday and Saturday morning and evening. An optional field trip to Hawaii Volcanoes National Park on Sunday will be followed by a scientific session that evening. Monday will feature a concluding session with adjournment around noon.

Scientific Sessions will be held on the following topics:

- Ocean Lithosphere Strucure and other News
- Strain and Earthquake Preparation - What can We Observe?
- Heterogeneity and Resolution in Lithospheric Imaging
- Anisotropy and Mantle Flow
- Imaging and Understanding Volcanoes

Discussion topics for Special Interest Groups (SIGS) will include:

- Listening in the Oceans - Technologies for Seismic Observations in the Oceanic Environment
- Bumps in the Night: Challenges for Monitoring Nonproliferation
- Observation and Theory - Wavetrains Passing in the Night?
- Illuminating the Lithosphere from Above and Below - Active and Passive Seismic Experiments
- Volkseismometer - The High School Seismograph Project
- Why Haven't We Predicted Earthquakes Successfully? - Clues from Crustal Strain

Talks at the scientific sessions will be by invitation only. All participants are encouraged to bring posters. Poster displays will be grouped around the topics of the scientific sessions and SIGS, but posters on any IRIS-related subject are welcome. One page abstracts for posters should be submitted to the IRIS Office by **May 3**.

Participation in the Workshop is not limited to IRIS members and all interested parties are welcome to attend, subject to availability of accommodations.

General questions concerning the Workshop may be directed to Liz McDowell (liz@iris.edu) or Denise Crump (denise@iris.edu) at IRIS headquarters (703/524-6222). See you in Hawaii! •

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