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IRIS Newsletter

10 min LOOK BHZ m_b 5.4 Δ= 57.4°
Dec. 5, 1997 near east coast of Kamchatka

Volume XVII, Number 1

Shakedown at the Gates of the Lodore

Frank Vernon, University of California, San Diego;
Ken Dueker, University of Colorado; and Gary Pavlis, Indiana University

In a remote region of the western US, well known at the end of the 1800's as part of the Outlaw Trail and a hideout for Butch Cassidy and other members of the Wild Bunch, the IRIS PASSCAL Broadband Array was field tested by a team from University of California, San Diego, University of Colorado, and Indiana University. In two weeks, the telemetered broadband Lodore array was installed as an accomplice to the Deep Probe experiment and will remain on location until Summer 1998.

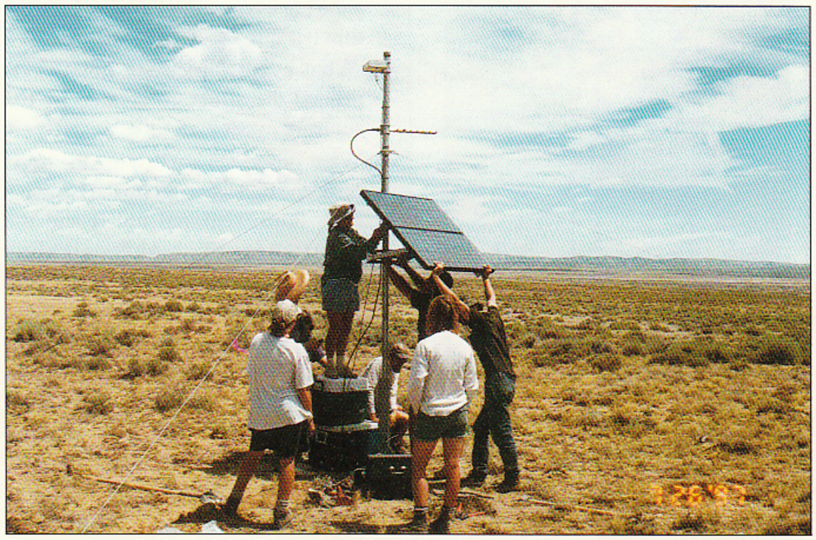

Photo 1. Installation of the first Lodore broadband array site, HIAW. This site was used as a training exercise. The team is installing the solar panels which are mounted on the antenna mast. Directly above the solar panel is the 902-928 Mhz spread spectrum antenna, with the GPS antenna on top.

The scientific motivation for choosing this outlaw hideout is to image variations in the crust and mantle across the Archean-Proterozoic suture known as the Cheyenne belt. The lithospheric suture separates the Archean Wyoming province crust to the north from the middle Proterozoic Yavapai crust to the south. The suture was formed 1.8 billion years ago when Proterozoic island arc(s) were obducted onto the passive southern margin of the Wyoming province (then part of the southern margin of the Laurentia supercontinent). Since this time numerous orogenic events have occurred with the most well understood being: (1) deposition of a thick sequence of middle Proterozoic sediments in the Uinta trough between 1.4-1.0 Ga. associated with the breakup of the Rhodina super-continent; (2) Uplift of the Unita trough along thrust faults during the 80-50 Ma Laramide Orogeny; and (3) Post-Miocene reactivation of the Laramide age Unita thrust as the

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Brown's Park normal fault and the emergence of highly alkaline volcanism nearby. Clearly, this suture zone, far from any Phanerozoic plate boundary, has been a site of recurring activity. To understand the origin of this persistent activity, well-resolved images of the crust/mantle structure are needed.

Scientific questions being addressed with the Deep Probe data sets include:

1. What is the difference in average crustal/mantle velocity structure (hence composition and/or crystal fabric) between the Archean Wyoming and Proterozoic Yavapai provinces ?
2. Are the crustal thickness and/or velocity variations still preserved from the formation of the Wyoming province passive margin at 2.1 Ga. and the subsequent Yavapai suturing event at 1.8 Ga. ?
3. If variations are found, was the suturing event a thick (pure shear) or thin (simple shear) skinned process ?
4. What events/processes have over-printed the structure created by the suturing event ?
5. What processes are driving the post-Miocene extension along the Brown's Park fault, regional uplift and the occurrence of highly alkaline volcanism (e.g., Cedar Butte and Leucite Hills) in this region ?

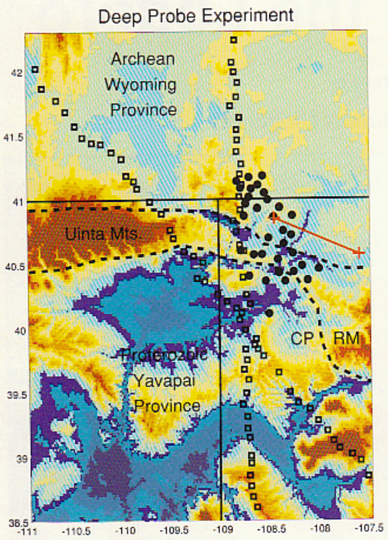

Figure 1. Deep Probe PASSCAL broad-band telemetered array and stand-alone sites. The PASSCAL Deep Probe stations are shown as the 81 squares. The N-S line was occupied from May to August and the NW-SE line from August to November of 1997. The circles are the 33 IRIS telemetered sites deployed in August 1997. The '+' symbols show the Lookout Mt. data concentration site and the Cedar Butte micro-wave bridge receiving site where the signal is place onto a frame relay circuit to Boulder, Co. The northern dotted line is the Cheyenne suture and the southern dotted line is the boundary between the Colorado Plateau (CP) and Rocky Mt. (RM) physiographic provinces. The solid lines are the Wyoming, Colorado and Utah state borders. Topography is shaded with blue and red respectively representing low and high elevations.

To address these scientific questions, a suite of seismic measurements will be used: teleseismic P and S wave travel-time measurements, receiver function analysis for crust, mantle lid, and transition zone discontinuity structure, shear wave splitting, and travel-time/amplitude modeling of the several hundred mining blasts recorded around the array. Measurement of 2,400 P-wave travel-time residuals show rapid variations in the residuals that are not easily correlated with the suture zone. The lack of significant azimuthal variation in residual patterns suggest that much of the causative velocity variations are crustal. However, if the P-wave residuals derive solely from crustal thickness variations; then, 28 km of crustal thickness variations would be required. Given that the previous active source Deep Probe refraction line (Levander et al., 1998) observed less than 10 km of crustal thickness variations across this region, the implication is that large crustal velocity and/or uppermost mantle velocity variations are required. A scientific bonus associated with the array is the large number of mine blasts recorded on a daily basis from 4 different back-azimuths. Record sections show very clear PmP arrivals from the northern blasts, but not the southern blasts

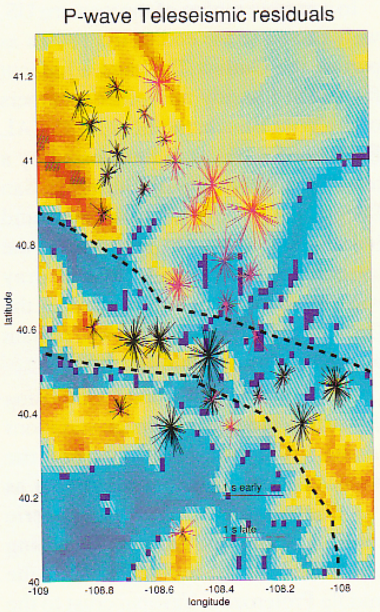

Figure 2. Teleseismic P-wave Residuals. The red and blue stick lengths are proportional to the magnitude of the teleseismic residuals as indicated by the scale bar. Each stick points in the direction of the event back-azimuth. The residuals have been corrected for elevation and sediment thickness. The data RMS is 0.21 s and the typical range of residuals for each event is 0.8 s. The suture and Colorado Plateau/Rocky Mt. province boundary are shown as dotted lines.

This issue's bannergram: Broadband velocity waveform recorded at the PASSCAL Lodore broadband array site LOOK in northwestern Colorado. The earthquake is a large (Ms 7.7), shallow event occuring near the east coast of Kamchatka on the morning of December 5, 1997. The Lodore broadband array data from this event were processed simultaneously in real-time at the University of Colorado and UCSD.

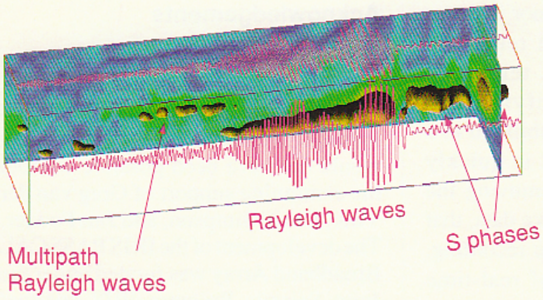

Figure 3. Array processing of oceanic Rayleigh waves by Lodore array. This is a view of the slowness-time grid with time running from right to left. The vertical component seismogram is shown on the "walls" of the volume to show the time relationship of each feature.

suggesting variations in crustal properties. One of the most exciting uses of this array will be to perform accurate slowness analysis of Pds arrivals to resolve the lithospheric stratigraphy. Previous studies around this region show large amplitude arrivals which may originate from lower lithospheric depths, but could not be unambiguously resolved from crustal reverberations. Given the success of Bostock (1997) in resolving this kind of ambiguity with the Yellowknife array, we are hopeful that even anisotropic lithospheric stratigraphy can be mapped out across the suture.

In addition to the standard single station processing techniques, the broadband array provides a wealth of new information which cannot be obtained in any other way. This new information relates to the spatial characteristics of the seismic wavefield that are essential to determining the 3-dimensional properties of the Earth's structure. One example of this array processing capability is found in the waveforms from oceanic Rayleigh waves recorded by this Lodore array. The output of a three-dimensional slowness analysis procedure developed by Repin and Pavlis (in press) is shown in Figure 3. We use volume visualization and slicing to study a 3D slowness-time grid of semblance. The view of the slowness-time grid has time running from right to left where SS and SSS phases appear as distinct coherent arrivals. These are followed by a long train of coherent Rayleigh waves. The later part of the Rayleigh wave from this event appears to be formed by a multipath mode that arrives from a distinctly different direction than the main Rayleigh wave.

These examples illustrate the scientific potential of dense broadband arrays as a tool for improved understanding of Earth structure and seismic wave propagation — the long term goal of PASSCAL from its beginnings. Some important scientific frontiers to which we believe arrays can contribute, include:

- New approaches to direct imaging of forward scattered wavefields. Most broadband experiments deployed to date do not have the areal density of stations to match that of Lodore. This opens up new frontiers for direct signal processing of waveforms to image deep structure.
- The three-component, broadband recordings with this density at this scale are a unique feature of this type of experiment. Other data sets exist with smaller scale, but greater density of stations or greater scale and more widely spaced sensors. This experiment provides a unique data set to study wave propagation at intermediate periods.
- Future experiments could consider mixed strategies of high frequency and broadband recording somewhat akin to the original ideas of the long and short period arrays at LASA. The broadband array system will make such experiments technically and economically feasible.
- Array experiments of this type can be used to focus on understanding the detailed structure of the major deep Earth transition zones such as D" or the inner core transition to the outer core.

Coupled with the development of new array processing techniques is the parallel development of the PASSCAL Broadband Array hardware, data telemetry, and data management capability. Each station in the array has an STS-2 broadband seismometer, a REFTEK RT72A-08 running special firmware for telemetry, and a FreeWave spread spectrum radio. Each seismic channel is sampled at 100, 40, and 1 sps. The data are telemetered to the central receiving site at Lookout Mountain where they are recorded on a SUN ULTRA-1 using a newly developed real-time software we call the Object Ring Buffer (ORB). The data are also sent from Lookout Mt. to the University of Colorado over a T1-frame relay connection using standard TCP/IP communications. Data are currently transmitted in real-time via the INTERNET from the computer in Boulder to each of the institutions involved in the experiment with the data arriving within 10 seconds of real-time. In addition the waveform data are written to disk in mini-SEED format immediately after each data packet is received, ready for sending to the IRIS Data Management Center. The ORB software allows this to happen with a minimal load on each computer, and is exceptionally extendible for distributed processing if the copies were cascaded from the original machine.

The installation of each broadband array site is very similar that of a standard PASSCAL broadband station. The only significant difference is that no local disks are used, and instead an antenna pole is installed. An additional requirement is that each site must have line-of-sight to the central telemetry site (or a repeater). However, the power requirements and installation times are similar between the two types of stations. The advantages of using the spread spectrum telemetry include using small antennas, eliminating radio licensing problems, allowing extensive telemetry error detection and retransmission. The installation of the 33 free field stations with telemetry to the recording system on Lookout Mountain was completed in 5 days. In the follwoing week, the link between lookout Mountain and CIRES in Boulder, Colorado, was established with real-time data being distributed over the Internet to Indiana University and UCSD.

There are a couple of major practical advantages in using the PASSCAL telemetry array system instead of the traditional stand-alone system. The first advantage is the ability to monitor the entire system in real-time, so there are no delays in identifying when a station goes down. Additionally, there is continuous state-of-health information for each station to assist in diagnosing problems before field teams are sent. Several stations have lost power due to flooding and other weather related problems, yet each station was only off-line a few days.

The second advantage is the remote data buffering at the central telemetry site, which was extremely useful in the Lodore array when the intermediate telemetry site Cedar Mountain (between CIRES and Lookout Mt.) was struck by lighting and we lost connection for about one week. In spite of loss of the telemetry link, we were able to recover all the data because of the two week array archive backup on Lookout. With the data redundancies and elasticity built into the PASSCAL Broadband Array system, there has been a 98% data return since the array became operational. Outside of the above mentioned problems with individual stations going down, or system maintenance, over 99.99% of the data have been recovered.

Finally, we are increasingly convinced that the telemetry strategy used in the broadband array can, for many experiments, prove to be a significant cost savings. There is a minor increase in initial site preparation related to defining the radio telemetry communication and verifying that communication can be established to a site. This additional cost is quickly recovered, however, by removing the need for site visits to retrieve data, that are necessary in standalone recording, and by the efficiencies of real-time processing, which allows the data to be stored in a form immediately ready for analysis and distribution.

The Lodore test deployment of the PASSCAL Broadband Array will be completed in early summer of 1998. It is then scheduled to be redeployed to South Africa as part of the Carnegie and MIT experiment funded by the NSF Continental Dynamics Program. During 1998 a second array will be built and be ready for deployment in 1999. By 1999 both arrays will be considered part of the operational PASSCAL program. PI's who desire to make use of the real-time telemetry and array processing capabilities should apply to the PASSCAL program using the same procedures as requests for the current PASSCAL equipment. •

Acknowledgements

Special thanks to Danny Harvey, Dan Quinlan, Glen Offield, Marina Harkins, and Adam Edelman, and the field team for their exceptional efforts. This project would not have been possible without the continuing support of Greg van der Vink, David Simpson, and Jim Fowler. The development of the IRIS PASSCAL Broadband Array was funded under the Joint Seismic Program IRIS contract 0193. Additional funding was provided by the IRIS PASSCAL contact 0246. Deep Probe funding was provided by the NSF Grant EAR-9418252.

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Photo 2. Training session for installation of the STS-2 seismometer in an IGPP "mini-vault". The mini-vault has been oriented to true North by gyrocompass and set in quick drying cement. The field technician is leveling the seismometer before installing the waterproof lid and insulation.

STORMS

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United States Geological Survey, Pasadena, California

During the first week of February, 1998, seven PASSCAL instruments were deployed in and around Long Valley, California. The instruments will provide supplementary recording of local events associated with the complex caldera system, which includes Mammoth Mountain, a popular ski resort. The deployment was motivated by the increased seismicity and deformation that had been observed at the caldera beginning in late summer of 1997 [*Hill et al.,* 1997]. The activity leveled off somewhat in December of 1997, but a second burst of activity starting on 12/31/97 motivated an instrument request to IRIS/PASSCAL in early January. The exquisitely timed STORMS (Short-Term Observation of Regional Mammoth Seismicity) deployment earned its name following the second day of what would prove to be the snowiest week of the season for the Mammoth Region. Despite this El Nino-generated challenge, the STORMS deployment is off to a promising start. By the end of the first week, we were able to verify healthy operation of 5 of the 7 sites, (Snowbound roads prevented a return that week to the other two). These data will be used to constrain hypocentral depths, to obtain high-resolution attenuation images of the caldera region, and to analyze any long-period or otherwise unusual seismic sources.

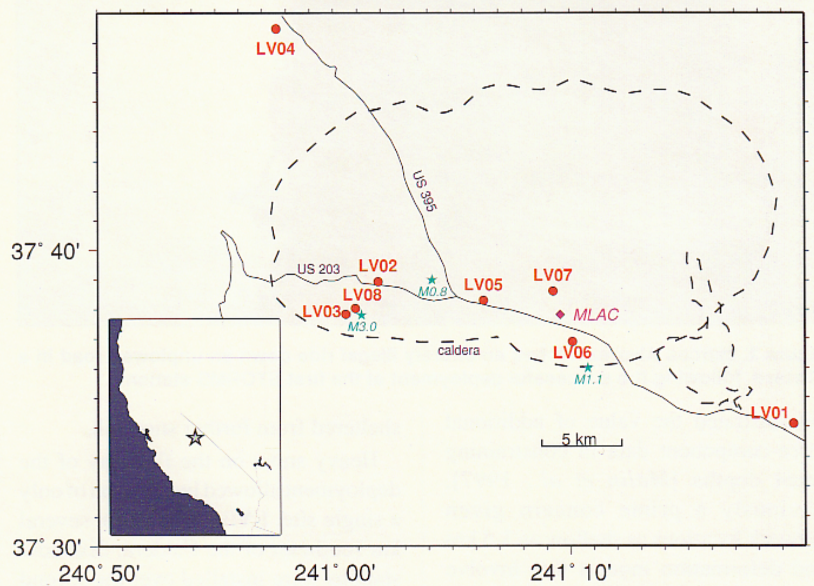

Figure 1. Map of the Long Valley region, including perimeter of caldera and Crowley Lake (dashed lines), highways (solid lines), STORMS stations LV01-LV08 (circles), and TriNet station MLAC (diamond). Stars indicate network locations and magnitudes for three events shown in Figure 3. Inset shows location of Long Valley within California.

Introduction

The Long Valley Caldera is a complex volcanic system along the eastern Sierra Nevada Mountains, California (Figure 1). The massive (600 km^3) caldera forming eruption occurred 760,000 years ago; smaller-scale activity (0.001-0.1 km^3) has taken place along the Mono crater/Inyo crater chain, east and north east of the caldera [*Bailey,* 1989]. Concern for future eruption activity initiated in 1980, when the region was shaken by three earthquakes of magnitude 6 or greater, and many thousands of smaller events. Another burst of seismic activity and increased deformation occurred in 1989 [*Hill et al.,* 1990]. The most recent period of unrest began in summer of 1997; observed ground deformation over the last 6 months of the year was comparable to that seen in 1989 (up to 10 cm over 5-10 km lines). By chance, the 1997 activity increase began during a large-scale deployment of portable seismic instrumentation [*Malin et al.,* 1997; *Hill et al.,* 1997]. The Mammoth Wave Propagation Experiment (MWPE) recorded thousands of events on an array of 60 stations. Unfortunately, seismic activity increased further after the culmination of the MWPE, hitting a peak rate of over 1000 events per day in November. At several times in late 1997, the observed seismic and deformation rates pushed close to the criteria for a USGS yellow alert ('intense unrest'; a level expected no more than once per decade).

In the absence of portable instrumentation, seismic recording in the Long Valley region is provided by CalNet, approximately 20 short-period vertical stations [see *Hill et al.,* 1979]; and a broadband station, MLAC, operated by TriNet in the central part of the south moat region (Figure 1; see http://scecdc.scec.org). Preliminary results from the MWPE have

Figure 2. Marcos Alvarez hitches an entirely illegal ride down an unplowed road in a blizzard, following the successful deployment of the first STORMS station.

demonstrated the value of additional three-component data in constraining focal depths [*Malin et al.*, 1997], obviously a prime concern given network locations as shallow as 3-5 km and deformation models that involve intrusions to similarly shallow depths.

The STORMS deployment was conceived as a smaller-scale extension of the MWPE. To maximize the utility of a combined data set, we hoped to reoccupy at least some of the MWPE sites with the eight PASSCAL instruments available. While the weather conditions precluded deployment in any of the remote, unsheltered sites used by MWPE, a consistent analysis of a combined data set should lead to a better understanding of the ongoing activity at Long Valley.

Deployment

The initial STORMS deployment was conducted by the authors, with training and intrepid field assistance provided by Marcos Alvarez from the Stanford PASSCAL instrument center (Figure 2). All sites were instrumented with L-22 2-Hz sensors, recorded with a gain of 32 dB and sampled at 100 sps. We chose sites for which reliable AC power was available, and that were at least partly-sheltered from further snowfall.

Heavy snow on the first day of the deployment allowed installation of only a single site, LV01 (Figure 1), several km southeast of the Caldera. Six more stations were installed over the second through the fourth days of the deployment, at both private and public structures. A paucity of structures in the Long Valley region (outside of Mammoth Lakes especially) led to a pragmatic station distribution. The linear swath of stations along the south moat follows I-395, along which the few occupied structures are aligned. The structures include the Sierra Nevada Aquatic Research Laboratory operated by U.C. Santa Barbara, a private fishing ranch, and an abandoned Sheriff building affectionately dubbed the 'Hanta hut' (after the field team learned that detection of the Hanta virus was what caused the building to be abandoned). The field team was hopeful that the combination of continued winter weather conditions and potentially lethal biohazard would minimize the chances of vandalism or undue cultural noise at these sites.

An eighth available instrument was not deployed during the initial deployment week because heavy snows on the last day led to closure of roads leaving Mammoth Lakes. The instrument was deployed just a few hundred meters from LV03 during a site servicing visit in early March at a site, to further investigate the observed long-period signals at LV03 discussed below.

Downloading and initial inspection of data was facilitated by a PASSCAL field workstation and the availability of the new PASSCAL database interface, pdbtools. The authors were impressed with the short learning curve associated with the data base tools, which allowed us to view data and associate events using a subset of the array for which we were able to swap disks during the week. The software allowed us to verify on-scale recording of a local M3 event that occurred on the fourth day of the deployment. We were also able to identify curious, apparent long-period signals at one site, LV03, which is both our quietest recording site (with respect to cultural noise) and the site that is furthest west. These events (Figure 3) defy trigger algorithms with their long duration and sometimes emergent onset; triggering parameters were adjusted during a final site visit to set longer minimum window lengths and pre-event recording. They do not coincide with earthquakes located by Calnet, although in several instances they preceed earthquakes by just a few seconds. An understanding of these events awaits further analysis and data collection. At present, we are only able to rule out possibilities: a) they cannot be a local site response or instrument problem because we record earthquakes with a range of magnitudes at the same site that do not exhibit unusual long period energy; b) they cannot be avalanches because they are inconsistent with recordings of avalanches set off by blasting on Mammoth Mountain at known times; and c) they cannot be intermittent cultural noise because no plausible local noise source exists.

In addition to investigating the long-period triggers at LV03, our primary goals are to relocate the events using both STORMS stations and CALNET P-wave picks, and to use the combined STORMS and MWPE data sets to obtain a high-resolution, three-dimensional attenuation image of the region using the multiple-empirical Green's function method [*Hough*, 1997; *Hough et al.*, 1997]. The analyses should provide new constraints on both the extent of the magma chamber(s) underlying Long Valley and the nature of ongoing deformation/intrusion processes. We welcome inquiries from other researchers interested in the data. •

Acknowledgments

The authors are indebted to IRIS/PASSCAL for their prompt response to our instrument request, and technical/field support that remained exemplary and inexplicably cheerful through rain, sleet, snow, snow chains, and dark of night. STORMS would not have been possible without the congenial cooperation of many individuals, including David Hill, Peter Malin, Bruce Julian, Chris Farrar, Dan Lyster, Josh Feinberg, Robert Drake, Robert Brooks, Scott Roripaugh, and Juli Baldwin.

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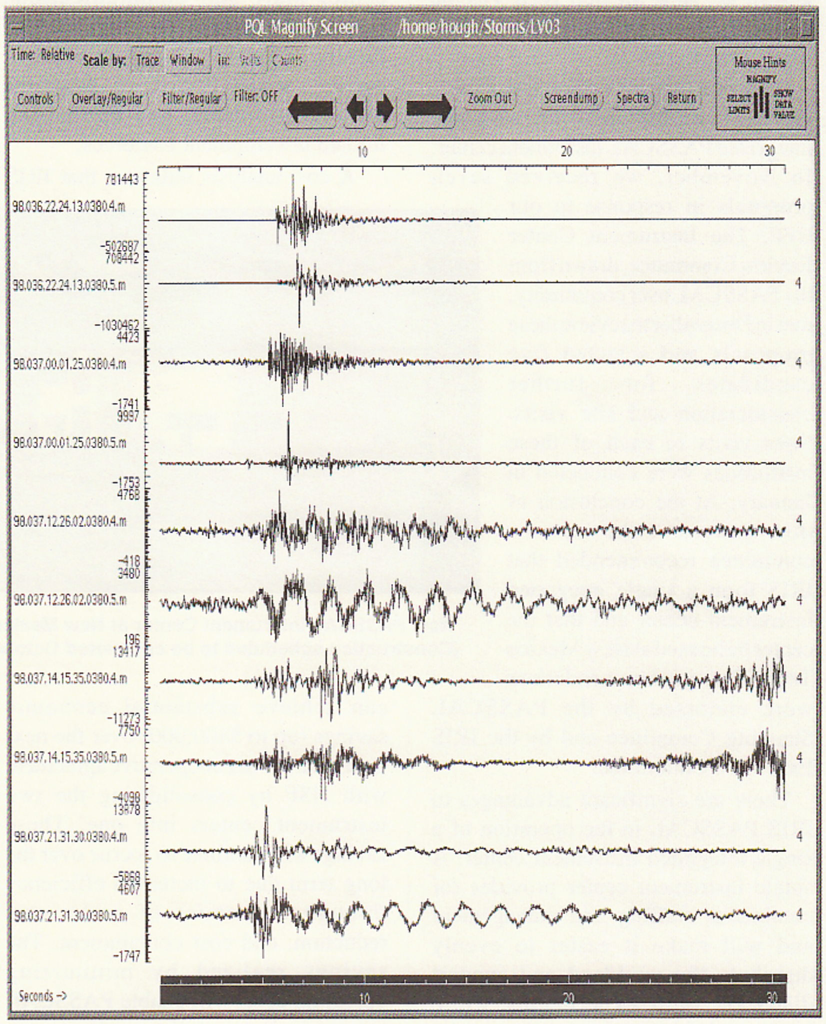

Figure 3. Vertical and NS components for five triggers recorded at station LV03. The top two triggers, from top to bottom, show recordings from a *M*3.0 event and a *M*0.8 event; the third trigger initiates a few seconds before the *M*1.1 event shown in Figure 1. The bottom two triggers are long-period signals that do not correspond to events detected by the network; dozens of similar events were recorded over the first three days of station operation.

New Integrated PASSCAL Instrument Center

PASSCAL Standing Committee: Anne Meltzer (Chair), Lehigh University
Ken Dueker, University of Colorado; Egill Hauksson, California Institute of Technology
David James, Carnegie Institution of Washington; Kate Miller, University of Texas, El Paso
Walter Mooney, US Geological Survey; Cliff Thurber, University of Wisconsin
Roy Johnson, University of Arizona; and Jim Fowler, PASSCAL Program Manager

IRIS is pleased to announce the selection of New Mexico Institute of Mining and Technology (informally known as "New Mexico Tech") as the home of a new integrated PASSCAL Instrument Center.

IRIS issued a RFP in September 1997, to member institutions to house a single integrated PASSCAL instrument center. In November, we received seven proposals in response to our RFP. The Instrument Center Review Committee, drawn from the PASSCAL user community, met in December to review these proposals and selected five candidates for further consideration and site visits. Sites visits to each of these institutions were conducted in January. At the conclusion of this process, the review committee recommended that IRIS form a single integrated instrument center and that the center be housed at New Mexico Tech. These recommendations were endorsed by the PASSCAL Standing Committee and by the IRIS Executive Committee.

There are significant advantages to IRIS PASSCAL in the operation of a single integrated instrument center. A single instrument center provides for continuous staffing and management and will make it easier to evenly distribute the workload and support disparate field experiments while maintaining ongoing initiatives in the core facility. A single PASSCAL instrument pool can more effectively service the increasing number of PASSCAL experiments utilizing more than one instrument type and eliminates inter-instrument center shipping costs. An integrated center facilitates communications amongst instrument center staff and communications between the instrument center and PIs. Finally, a single center will improve synergy across PASSCAL programs while consolidating and maximizing limited development resources.

A cost analysis indicates that IRIS can achieve substantial economic savings (up to $800,000) over the next three years of our cooperative agreement with NSF by consolidating the two instrument centers into one. These savings will continue to accrue over the long term due to increased efficiency through economies of scale, cost reduction, and cost containment. The savings realized by minimizing operating costs will enable PASSCAL to increase its capability at a faster rate, better servicing the portable array seismology community.

New PASSCAL Instrument Center at New Mexico Tech. (Construction scheduled to be completed October 1998)

The proposals we received were all of high quality making the final selection process difficult. Among the outstanding characteristics of the winning proposal were: a modern new building optimized for and focusing on IRIS PASSCAL activities, an ability to leverage manpower for operations through a vigorous internship program, a site more centrally located in the US., and the potential for new opportunities through interaction with existing programs at New Mexico Tech.

Dr. Rick Aster and Dr. Harold Tobin will be the Principal Investigators (PIs) for the new Center. Over the next 9 months, the operations from the current centers at Lamont and Stanford will be phased out and the equipment and operational responsibilities will be moved to New Mexico Tech. Fortunately, some of the current Lamont and Stanford staff have agreed to join the new instrument center at New Mexico Tech, thus helping to minimize the effect on on-going experiments. The move is expected to be completed by the end of October 1998.

IRIS would like to thank the PIs and staff of the two current centers for their outstanding service to the community. They have helped establish new standards of performance and quality in the collection of seismological data; and their contributions in areas of technological and logistical support have set the standard for seismologists throughout the world. We look forward to building on these traditions of service and excellence in support of seismological research at the new combined center. •

Seismic Experiment in Patagonia and Antarctica (SEPA)

Douglas A. Wiens, Stacey Robertson, Gideon P. Smith, and Patrick Shore, Washington University;
Emilio Vera, Sergio Barrientos, and Gonzalo Perez, Universidad de Chile;
George Helffrich, University of Bristol, UK

The Seismic Experiment in Patagonia and Antarctica (SEPA) is a two year deployment of broadband seismic instrumentation in a remote, seismically active region for which the seismic and tectonic characteristics are largely unknown. The main goals of the project are to study the unique tectonic environment off the western coasts of Patagonia and the Antarctic Peninsula. Very slow subduction may be occurring in the South Shetland trench, and rifting has recently been initiated in the Bransfield Strait [Pelayo and Wiens, 1989; Barker et al., 1991]. Another goal is to use SKS splitting measurements to determine azimuthal anisotropy and thus provide constraints on the pattern of upper mantle flow beneath the Scotia Sea region. Project SEPA may be particularly interesting to the PASSCAL community as it demonstrates the feasibility of long term unattended deployment of broadband instruments in a region with difficult logistics and a hostile environment. The experiment is supported by the Office of Polar Programs of the National Science Foundation and by the Instituto Antarctico Chileno (INACH). The seismological instrumentation is provided by IRIS/PASSCAL.

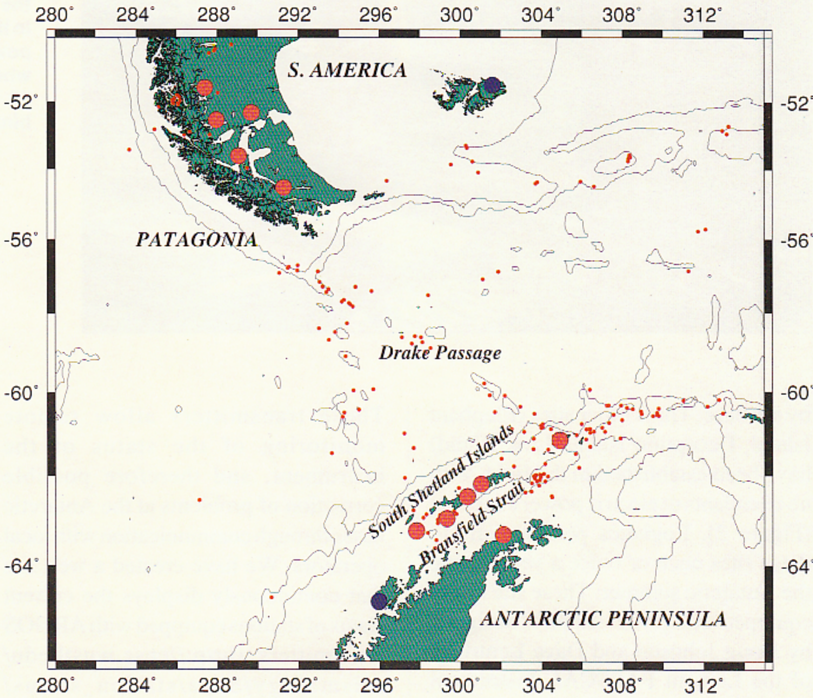

Figure 1. Map of the tectonic elements and the geographical distribution of seismic stations installed by project SEPA. Pink dots denote PASSCAL broadband station locations, blue dots denote permanent IRIS-GSN stations, and teleseismically recorded 1964-1995 earthquakes are represented by small orange dots. Tectonics of this region are complex, as demonstrated by slow subduction along the western coasts of South America and the South Shetland Islands, rifting in the Bransfield Strait, and diffuse plate convergence in Drake Passage.

Ten broadband stations were deployed in the region during January, 1997, and an eleventh station was deployed in December, 1997. Six stations are located in the Antarctic Peninsula-South Shetland Islands region and five in Chilean Patagonia (Figure 1). Each station consists of a Streckeisen STS-2 seismometer and a Reftek digital acquisition system with GPS timing. Data are recorded continuously at 1 sps and either 25 or 40 sps. The stations in Patagonia are located at sites such as ranches and park service offices that offer occasional generator-supplied electric power to charge the batteries that operate the station. In some cases, solar power supplements the AC supply. These systems have operated very reliably during the first year of the experiment.

The Antarctic stations were established on a cruise of the Chilean Naval vessel ISAZA, sponsored by INACH, during January, 1997, and were serviced on cruises of the U.S. vessel R.V. Abel J in December, 1997, and the ISAZA in January, 1998. Two types of stations have been established in the Antarctic, depending on whether the stations are located at inhabited bases or in the field. Three of the sites (Frei, Prat, and O'Higgins) are located at permanent bases operated by branches of the Chilean armed forces. The sensors at these stations are located several hundred meters from the buildings on the base, and AC power as well as occasional station servicing are provided

Figure 2. Washington University graduate student Stacey Robertson and Universidad de Chile graduate student Kenneth Lein finish installing the unattended broadband station at Low Island in the Antarctic. During the summer, the station is powered by arrays of solar panels (background), whereas during the winter, power is provided by 18 Carbonaire batteries, located in the plastic bins (foreground).

by the base. Three other sites (Elephant Island, Deception Island, Low Island) have been established in the field, with no attendants or electric power available (Figure 2). Logistics permit visits to these sites once or twice a year during the Antarctic summer. These sites were equipped with power supplies designed by Doug Johnson and Dave Lentricha of the Lamont PASSCAL Instrument Center, which use solar power during most of the year, but rely on banks of 18 Carbonaire batteries during the winter months. Two of these field sites were deployed during January, 1997, and one station, Elephant Island (Figure 3), ran continuously, unattended throughout the Antarctic winter. When serviced in December, 1997, the station had to be found by digging through six feet of snow, but it was still operating and it had nearly 4 gigabytes of continuously recorded data on the disk. This demonstrates the viability of year-around unattended operation of PASSCAL stations, even under the most extreme environmental conditions.

The stations in Patagonia and those at the Antarctic bases were outfitted with ARGOS state of health satellite transmitters to help maintain reliable operation despite their limited access. These transmitters allow remote monitoring of the status of the instrument, and therefore possible correction of problems at the Antarctic bases through communication with local operators. We have created a web site that continuously displays the current status of stations equipped with ARGOS transmitters (http://epsc.wustl.edu/seismology/Sepa/station_status/sepa_status.html); an example of this display is shown in Figure 3. More information on the entire SEPA project can be obtained on the web at http://epsc.wustl.edu/seismology/Sepa/sepa.html

We are currently analyzing data obtained during the first year of the experiment. Despite a low level of seismicity in global catalogs and very

Figure 3. Patrick Shore (Washington University) and Paul Friberg (Lamont PASSCAL Instrument Center) install banks of solar panels at Elephant Island, South Shetland Islands. The glaciers of Clarence Island tower in the background. The Elephant Island station ran unattended for nearly one year over the Antarctic winter.

slow inferred tectonic movement in this region, the SEPA project has recorded a large number of local earthquakes (mb 2- 4) near the South Shetland Trench and the Bransfield Strait. This indicates substantial seismic activity along the trench. Location of these earthquakes should help to delineate the configuration and depth extent of the downgoing South Shetland slab. These regions should help us to understand the seismicity associated with slow subduction of young lithosphere, as well as the tectonic processes that have produced major changes in the plate configuration in this region during the last 4 million years. We have also obtained preliminary results from shear wave splitting analysis of teleseismic SKS and SKKS arrivals providing constraints on the pattern of upper mantle azimuthal anisotropy [Helffrich et al., 1997]. The fast polarization directions in the Antarctic Peninsula region are oriented in a NE-SW direction, consistent with flow along the strike of the arc. In contrast, fast splitting directions in Patagonia are oriented perpendicular to the strike of the arc. Taken together with splitting measurements at recently established GSN stations at Palmer station, the Falklands (Malvinas), and South Georgia, these measurements do not suggest a clear pattern of mantle flow from the Pacific region into the Atlantic through the Drake Passage region, as proposed by Alvarez [1982] and Russo and Silver [1994].

In late 1998, we will collaborate with Leroy Dorman of Scripps in a five month deployment of 14 ocean bottom seismographs (OBS) in the South Shetland Trench and the Bransfield Strait. Some of the OBSs will be equipped with new broadband sensors developed by Precision Measuring Devices and adapted for OBS deployment by Leroy Dorman and Allan Sauter. These additional stations will provide a much higher resolution picture of the tectonic processes and earth structure of this remote location. •

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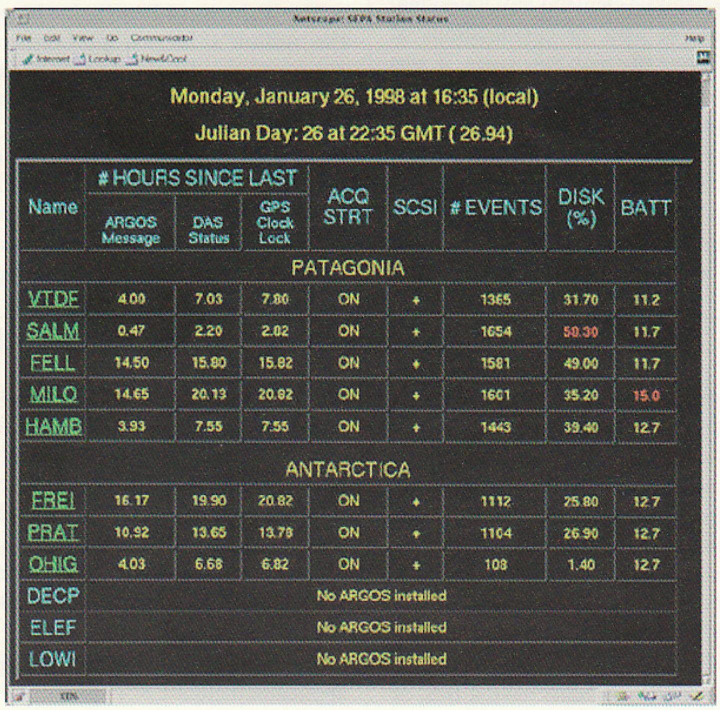

Monday, January 26, 1998 at 16:35 (local)

Julian Day: 26 at 22:35 GMT (26.94)

Name	# HOURS SINCE LAST			ACQ STRT	SCSI	# EVENTS	DISK (%)	BATT
	ARGOS Message	DAS Status	GPS Clock Lock					
PATAGONIA								
VTDF	4.00	7.03	7.80	ON	+	1365	31.70	11.2
SALM	0.47	2.20	2.02	ON	+	1654	50.30	11.7
FELL	14.50	15.80	15.82	ON	+	1581	49.00	11.7
MILO	14.65	20.13	20.92	ON	+	1601	35.20	15.0
HAMB	3.93	7.55	7.55	ON	+	1443	39.40	12.7
ANTARCTICA								
FREI	16.17	19.90	20.82	ON	+	1112	25.80	12.7
PRAT	10.92	13.65	13.78	ON	+	1104	26.90	12.7
OHIG	4.03	6.68	6.82	ON	+	108	1.40	12.7
DECP	No ARGOS installed							
ELEF	No ARGOS installed							
LOWI	No ARGOS installed							

Figure 4. Real time web-page display of PASSCAL station status. This display, on the Washington University web page, shows the current status of the SEPA instruments as relayed by ARGOS satellite transmissions, allowing station maintenance to be carried out at Antarctic bases and station servicing to be scheduled appropriately in Patagonia. This display may be found on the web at http://epsc.wustl.edu/seismology/Sepa/station_status/sepa_status.html

W.M. Keck Foundation and Sun Microsystems Provide Support for New Mass Storage Sytem at the DMC

A grant from the W.M. Keck Foundation of Los Angeles for "Access to Earthquake Data for Research and Education" and a donation of equipment through Sun Microsystem's Academic Equipment Grant Program have been used to cost share with the National Science Foundation's Major Research Instrumentation Program for replacement of the Data Management Center's mass storage system.

At the core of the IRIS Data Management System is a highly automated, multi-terabyte mass storage system. The robotic device, coupled with powerful data management software, has the flexibility to retrieve rapidly and on-demand any individual segment of data, or combinations of data. Over the past two years, it was becoming painfully obvious that the previous mass storage system, whic had provided good service for seven years, had reached the limit of its capability. Partly as a symptom of the success of the DMC in archiving and distributing data, the archive was in constant operation, and usage had reached two orders of magnitude higher than initially anticipated.

The new 50 terrabyte system (expandable to 75 terrabytes) is a D3 Redwood tape based Wolfcreek from Storage Tek. Its capacity is over five times larger than the current 9 terrabyte system. The four tape drives can read and write tapes at a speed of 11 megabytes per second for an aggregate rate of 45 megabytes per second (compared to the current aggregate rate of about 5 megabytes per second). The system is controlled by a SUN Enterprise 4000 server donated by SUN. The mass stoage system is similar to that used by NASA Goddard for EOS data.

The W. M. Keck Foundation is one of the nation's largest philanthropic organizations. Established in 1954 by the late William Myron Keck, founder of The Superior Oil Company, the Foundation's grantmaking is focused primarily on the areas of medical research, science, and engineering.

The Foundation seeks to enrich research and teaching through support for equipment, facilities, fellowships, and basic research projects at the frontiers of science and engineering. Recognizing the importance of undergraduate science instruction, the Foundation also supports excellent undergraduate college science programs and encourages multidisciplinary projects and multi-college cooperative science ventures. •

New mass storage system at the IRIS Data Management Center was obtained with funding from the W.M. Keck Foundation, the National Science Foundation's Major Research Instrumentation Program, and the SUN Academic Equipment Grants Program.

Seismological Hardware and Software Engineers/Scientists Wanted

New Mexico Tech invites applications for up to seven professional staff positions in seismological software and hardware support at the IRIS PASSCAL Instrument Center. Appointment for one software position will begin on or after July 1, 1998. Appointments for other positions will begin on or after October 1, 1998.

All applicants must have a B.S. or higher degree in engineering, computer science, physical science, or another appropriate field at the time of appointment, or three or more years of directly related work experience. Core responsibilities include local and remote support of field experiments in association with the scientific and engineering user community, which will occasionally include significant international or domestic travel to remote locales. The ability to work productively and collegially in team situations under demanding laboratory or field conditions is required.

Requirements for software support applicants include C/C++ programming ability, Unix system management expertise, and past experience in writing and supporting scientific software. Desirable background for software applicants includes seismological experience and significant facility with Tcl/Tk, perl, SQL, sh, csh, tcsh, awk, sed, postscript, SunOS, Solaris, Linux, and/or TCP/IP. Successful software applicants will be expected to work with PASSCAL staff and with the user community in the continued development of an extensive package of C code (presently used at several hundred research sites worldwide) and in the management of the Solaris/Mac/ Linux network at the Instrument Center.

Requirements for hardware support applicants include facility with testing and repairing digital data acquisition systems, field power supply systems,

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Global Seismographic Network Network Operations

IRIS/USGS Network

John S. Derr,
US Geological Survey,
Albuquerque Seismological Lab

This being Albuquerque Seismological Lab's (ASL) first contribution to the IRIS newsletter, we have some catching up to do.

Our biggest news is the approval of a new line item in the US Geological Survey (USGS) budget for operation and maintenance (O&M) of the Global Seismographic Network (GSN). The new budget line will provide us some measure of assurance that the USGS intends to continue its contribution to the IRIS GSN. Our installation and initial O&M funding had originally come from IRIS, Air Force Office of Scientific Research (AFOSR), and The National Science Foundation (NSF), with the expectation that the USGS would eventually assume the responsibility for O&M of its share of the GSN. The funding should be adequate for us to meet a goal of network up time in excess of 90% for one-third of the stations, and 80% for more than two-thirds of the stations. Stations operated and maintained by ASL are shown in Figure 1.

A major milestone in ASL's networks was the end of essentially all support for the old World Wide Standardized Seismograph Network (WWSSN), effective in January of 1997. Of the 53 stations still in operation at that time, only Albuquerque, NM (ALQ) and Quetta, Pakistan (QUE) continue to be supported. ALQ will continue in operation as a working museum, and QUE will continue to receive support until it is replaced by an IRIS system. Almost all of our usable spare modules and parts were distributed to the 28 stations which

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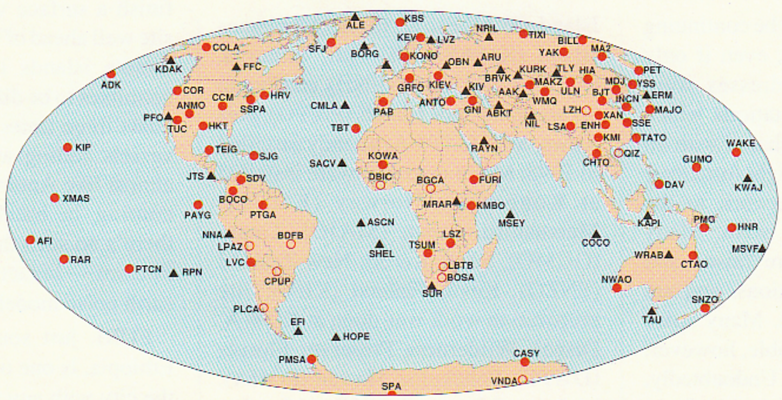

Figure 1. Stations shown as red dots are IRIS/USGS GSN stations operated and maintained by the Albuquerque Seismological Laboratory of the US Geological Survey. Other global stations which are currently operated and maintained by ASL are shown as open red circles. Stations shown as black triangles are IRIS/IDA GSN stations operated and being installed by the University of California, San Diego.

IRIS/IDA Network

J. Peter Davis,
Project IDA,
University of California, San Diego

The IDA staff has been improving both quality control procedures and the hardware used to record data at IRIS/IDA GSN stations. The change that will impact users soonest is a revision of sensor calibration values within IDA dataless SEED volumes. In the course of routine checking, a discrepancy was noticed in sensitivity between recordings of co-located high frequency seismometers and the broadband KS-54000 borehole package at a number of IDA sites. The coherence of the waveforms for each pair of components was very high across the entire passband; but after correcting for the putative instrument response, the magnitude of the transfer function differed from unity by a frequency independent value of approximately 7%.

Before any station is deployed, the entire system is subjected to a large number of quality assurance tests. Both the sensitivity of the recording system and the shape of the sensors' frequency response are determined empirically. However, the one factor that is not checked is the generator constant or sensitivity of the seismometer. In all cases, the manufacturer's value has been used. To determine which sensor's response was in error – the KS-54000's or the STS-2/CMG-3T's – the long period channels of the KS-54000 were checked for spectral lines caused by long period Earth tides. At many sites, the M2 line was well recorded, and its amplitude was compared to that predicted by modern tidal models. The measurements indicate that it was the KS-54000's sensitivity that had been overstated. When the KS-54000's sensitivity was adjusted to bring it into agreement

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Figure 2. Surface vault for seismograph station PTCN, Pitcairn Island. Left to right: Mike Warren, station chief; Jay Warren, operator; Dave Evans and Chuck Cazier, ASL; Dave Brown, Betty Christian, and Tom Christian, operators. Child in front of Dave Evans: Ariel Brown.

indicated that they would be continuing operations on their own, even if only temporarily. Email addresses were collected from all the stations which have the capability and shared with all the others, so that they might form their own mutual support network to the extent that they might wish. Many seismologists today were raised and educated with these stations, and are reluctant to let them die. Many spare parts are no longer available, however, so their lifetime is limited. Undoubtedly, the seismometers will continue to find a use, the modern hot-pen recording systems can be used as monitors for other instruments, and the old WWSSN timing system may yet be replaced in toto, extending the usefulness of these old stations even further. However, many of the old vaults, while still in operation, have been surrounded by cultural noise, so this is a good time to close this chapter in the history of seismology and move on.

By the end of 1997, ASL was operating 70 stations of the IRIS/GSN, including seven added to the network this past year: Limon Verde, Chile (LVC), Pitcairn Island (PTCN), Wake Island (WAKE), Kiritimati/Christmas Island (XMAS), Mt. Furi, Ethiopia, (FURI), Enshi, China (ENH), and Puerto Ayora Galapagos Islands (PAYG), plus Kowa, Mali (KOWA) already installed in 1998. Major upgrades were installed at Kongsberg, Norway (KONO), Matsushiro, Japan (MAJO), Guam (GUMO), South Karori, New Zealand (SNZO), Kevo, Finland (KEV); site preparation work was done at KOWA, Disney Wilderness Preserve, Florida (DWPF), Pohakuloa, Hawaii (POHA), Midway Islands (MIDW), Masuku, Gabon (MSKU), Johnston Island (JOHN), and Marble Bar, Western Australia (MBWA); and initial pre-site prep visits were made to Raoul Island (RAO), Riachuelo (RCBR) and Samuel, (SAML) Brazil, Bermuda (BEC), and Abu Simbel (ABUS), Egypt.

Some station sites can be especially interesting and challenging. LVC is high in the Atacama desert of northern Chile, where it almost never rains. The seismometers are in a 25 m tunnel and solar powered — very reliably. The DP is across the valley at the world's largest mine, Chuquicamata, where porphyry copper is extracted from a still-growing open pit. To help prevent the 18-ft wide trucks from going over the edges of the ramps, all traffic in the pit drives on the left. The station is managed by the copper mine, CODELCO. The desert south of Chuquicamata is home to four of the world's finest astronomical observatories — Cerro Tololo, La Silla, Las Campanas, and the new European Southern Observatories' Very Large Telescope at Cerro Paranal.

Pitcairn Island, was chosen by the Bounty mutineers because of its remoteness, which also makes it a natural for IRIS. A small community of Bounty descendants inhabits the island, under British rule. One of them was married to a USGS employee who was just retiring when we asked him to go "home" and help prepare the PTCN site (Figure 2). With his extensive knowledge of people, customs, and logistics, we were able to finish a surface vault on this difficult site well ahead of the schedule for other remote islands in the GSN. Access continues to be difficult: regular supply boats three times per year, plus other vessels calling at random times. It's almost like Antarctica, with data tapes coming in batches. Unfortunately, there's no such thing as a quiet site on Pitcairn — in fact, it redefined the high earth noise model.

FURI, just south of Addis Ababa, Ethiopia, is one of few sites outside of the city with any solid rock. While the old WWSSN station Addis Ababa, Ethiopia (AAE) in the middle of the city is on basalt, most of the surrounding hills are tuffs. Making matters more difficult, only the city limits have any detailed geologic maps. Fortunately, the road to the microwave relay site on top of Mt. Furi exposes one of the few basalt outcrops, beneath the only power line within miles, and that's where the tunnel was constructed. Data are telemetered back to the Geophysical Observatory of the Addis Ababa University, where we have excellent cooperation with a dedicated group of seismologists.

The Galapagos Islands are remote but easily accessible to growing numbers of tourists, scientists, and Ecuadoreans who think they are escaping the congestion of the mainland. The old WWSSN station GIE sits abandoned on the barronco (cliff) behind the Charles Darwin research station, where the data processor (DP) for the new station, PAYG, is located — convenient to a display at the visitors' center and to an Internet node which we are trying to get upgraded beyond its current capacity of 2400 bps. The seismometers are in a 100 m deep borehole in fractured basalt 8 km inland. Subsequent efforts to drill a water well encountered numerous lava tubes, showing that we were very lucky to get the hole to our target depth. Drilling the hole was a very difficult task, starting with many problems with Ecuadorian customs, then a civil uprising over fishing rights that drove Darwin station personnel into hiding on the barronco. In the drought conditions at the time of drilling, water was obtained from some tourist swimming pools. Installation, however, was done during possibly the worst El Nino on record, washing out roads and preventing a sun sight for surveying azimuth.

Another difficult site is KOWA, Mali, at the ancient Dogon village of Kowa near Mopti. The original goal was a site near Timbuktu, but Tuareg rebellions made the north side of the Niger River's inland delta unsafe. Mopti claims to be the Venice of Africa, at least during rainy season, with a climate ranging from hot and rainy to extremely hot and dry. With its sandstone lithology and cliff dwellings, the Dogon Plateau strongly resembles the Chaco Canyon area of New Mexico, and may well duplicate today many of the villages of the ancient Anasazi civilizations of the southwestern US. A 40 m tunnel in this hard sandstone provides very hot accommodations for the solar-powered seismometers (Figure 3). Data are recorded 8 km away at the Mopti-Sévaré airport, where we have a resident technician to operate the station. Developing this station was extremely labor intensive on the part of ASL because there was, and still is, no seismological establishment in Mali. Fortunately, the people are extremely cooperative and friendly (especially the street vendors in Mopti!), the honesty of the Dogon people is legendary, and the commercial assistant at the US embassy in Bamako was extraordinarily helpful. Preliminary indications are that this is a very quiet site. The engineering community in Mali kept asking, "Do we have earthquakes?" Our answer was always, "We'll see!"

In research activities at the Albuquerque Seismological Laboratory related to network performance, we developed a technique for installing borehole instruments in sand which prevents convection noise in the horizontal components at long periods. Reductions of 10 db have been achieved at SNZO and 30 db at VNDA in Antarctica. All borehole installations from now on will use this method. A video showing the methods and improvement in data is available from the lab.

Another research experiment, conducted jointly with IDA, was to evaluate different installation methods for seismometers on coral atolls by comparing the noise levels for three different types of installations: a Streckeisen STS-2 in a surface vault, a Guralp CMG3-T in a shallow borehole, and a Geotech KS-54000 in a deep

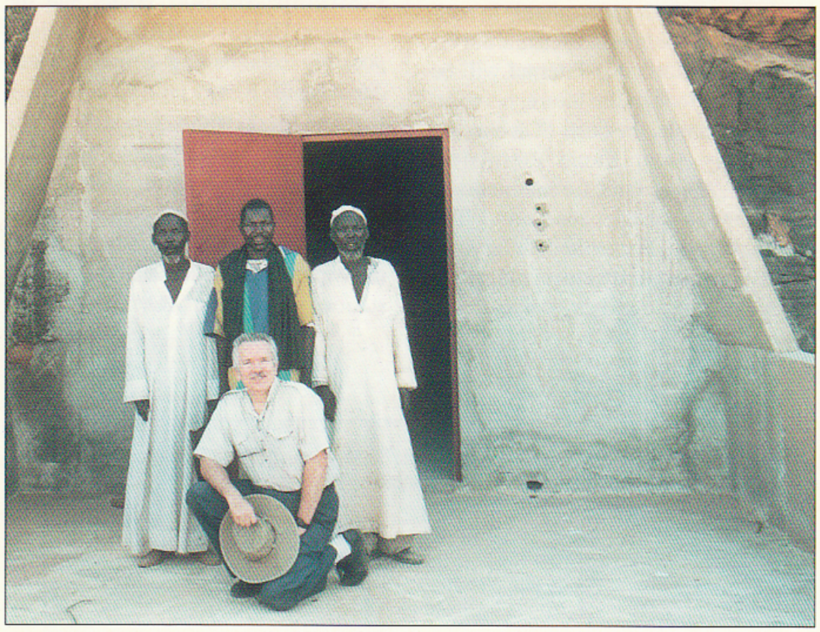

Figure 3. Tunnel vault for seismograph station KOWA, Mali. The KOWA station is part of the IRIS/USGS Global Seismograph Network, located at the village of Kowa, near Mopti, Mali (West Africa). Streckeisen STS-1 seismometers are installed on a pier at the end of the 40 m tunnel into the sandstone (grès) of the Dogon plateau. Power is provided by solar panels installed above the tunnel. Data are telemetered 8 km to a data processing computer at the Mopti-Sévaré airport. Triggered event data and continuous long-period data are accessible in near real-time via dial-in telephone. While primarily contributing to geophysical research and earthquake notification, KOWA will also be a auxiliary station for the International Monitoring System for the Comprehensive Test Ban Treaty, and the first seismograph station in Mali. Standing (l to r): Hassana Degoga, his son Aly, and Hassana's twin brother Husseini. Kneeling: Dr. John S. Derr, Chief, Global Seismograph Network, Albuquerque Seismological Laboratory. The Degoga twins share the hereditary village chief position. (Photo credit: John S. Derr, USGS)

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borehole. ASL did the experiment at WAKE, while IDA used their station COCO in the Cocos Islands. Relative spectral levels between related channels were compared for periods from 0.05 to 1600 s. Between 0.7 s and 20 s, noise levels were similar for all types of installations. The deep borehole installation is quieter by about 3-6 dB at higher frequencies and by 5-10 dB or more at longer periods. This experiment will be used to guide decisions on the installation methods used for future GSN stations on very small islands.

Significant advances have been made in availability of near real-time communications with our GSN stations, with 55 available by dial-up modem, 21 on the internet, and 30 available in real-time on our Live Internet Seismic Server (LISS). We hope that Internet will be the access mode of the future, because, where available, the costs of access are extremely low. Some countries, however, charge rates for international access that rival telephone costs. The coming changes in satellite cellular voice and data access promise to revolutionize the way we get our data, just as it will make worldwide calling from portable phones routine. Dick Tracy should have been a seismologist!

Looking forward, we expect 1998 to be a transitional year. On the up side, we plan to install DWPF, POHA, MIDW, MSKU, JOHN, MBWA, RAO, RCBR, and BEC. On the down side, sadly, we expect to close our first IRIS station, BOCO, because continuing civil unrest in Colombia makes it impossible to make repairs at the borehole. We also will be giving control of the GTSN stations to an Air Force contractor, with data availability questions still to be answered. Changes of a more neutral nature, dictated by the retirement of our Russian-speaker Bob Young and the change to USGS O&M funding, include possibly establishing a maintenance depot for the Russia far-east network in Petropavlovsk, with a contractor on site to service the network. We also intend to overhaul our working relationship with the China State Seismological Bureau, consistent with our transition in emphasis from installation of new stations to network O&M. •

the IRIS CONSORTIUM

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

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Continued from page 13, IDA

with the high frequency sensor, most of the measured tidal amplitudes fell within 0.5% of predicted.

As a final check, a tilt calibration was performed on a spare KS-54000 and the above results were confirmed. The US Geological Survey (USGS) was asked to check their stock of KS-54000s at Albuquerque Seismological Lab (ASL), and they too found wide discrepancies from the nominal generator constant. The manufacturer was then contacted, and after extensive review of factory calibration procedures, an error was discovered which could account for the observed values in the field, at least for the vertical component. The problem is being brought to the attention of all KS-54000 customers. The current IDA dataless SEED volume reflects changes made to correct the generator constant. The details of this analysis will be contained in a journal article soon to be submitted.

On the hardware side, IDA engineers have been preparing shipment of the new 24-bit data logger named the IDA Station Processor (Mk7-ISP). A prototype of the ISP has been running flawlessly at PFO since last September. In addition to recording data at higher resolution, the Mk7-ISP incorporates a number of improvements and new features. The heart of the system is a Pentium-based PC running SOLARIS. The unit consolidates the functions of operator control, data recording, and real time data access. It also provides a platform for running computationally intensive processing software and for interfacing new recording media. Most of the new upgrades will still record data on DAT cassettes, but in a fashion that is much easier on the DAT recording drives. The greater buffering capacity of the ISP will allow data to be streamed to the DAT less frequently and in larger amounts, thus promoting a longer recording life. As new recording media are developed, they can be rapidly incorporated using the SCSI interfaces

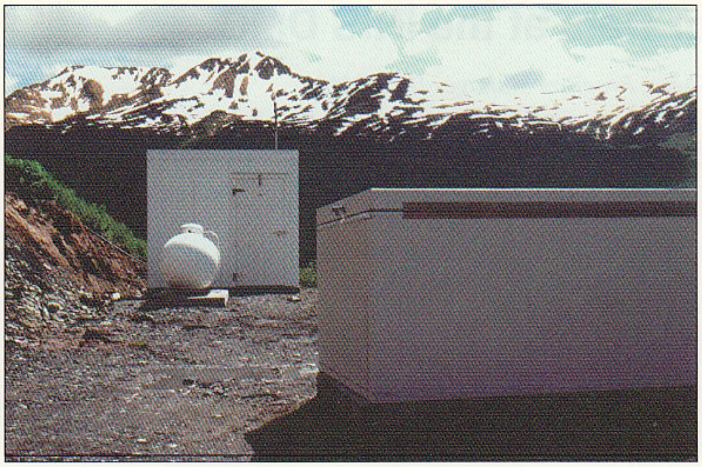


Figure 4. View of KDAK (Kodiak Island, Alaska), the newest IRIS/IDA station, showing a wellhead minivault in the foreground and a recording building in the rear. The circular tank in front of the recording building contains propane to fuel the thermoelectric generator that provides power to the station. (Photo courtesy of Todd Johnson.)

available.

The Mk7-ISP will also facilitate data acquisition from new types of instruments. The GSN, as part of the IRIS initiative to create global geophysical observatories, is seeking to collect meteorological, GPS, and possibly magnetometer data at GSN sites. Many of these sensors record data in digital form and could not have been integrated into earlier data logger designs. The Mk7-ISP easily accepts a digital data stream and therefore integration of new instrumentation is straightforward. The prototype at PFO has been recording air pressure from a Paroscientific Digiquartz™ micro-barograph, and the data from it have been flowing to the IRIS DMC along with the seismic data. All new Mk7-ISP systems will be shipped with integrated pressure sensors.

The first three Mk7-ISPs are under test at IDA and will soon be shipped to Russia to upgrade data loggers at Obninsk (OBN), Kislovodsk (KIV) and Talaya (TLY). These units will be produced in quantity over the next few months with a goal of replacing many of the remaining Mk6B units at Ala-Archa (AAK), Alibek (ABKT), Alert (ALE), Arti (ARU), Borovoye (BRVK), Kurkchatov (KURK), Norilsk (NRIL), and Easter Island Rapa Nui (RPN) by midsummer.

In addition to upgrading a large number of stations, IDA has four new stations in various stages of construction that we expect to complete by year's end. Kyahi Forest Station, Mbarara, Uganda (MBAR) will be run cooperatively with the Ministry of Natural Resources, Uganda. A borehole and posthole are being drilled into granitic gneiss that will accommodate KS-54000 and STS-2 packages, respectively. Power for the station will be supplied by solar cells; and MBAR will be the second IDA station to use INMARSAT-B for its telemetry link.

Santiago, Cape Verde (SACV) will also be a borehole containing a KS-54000. Drilling into the island's massive fine-grained basalt is expected to begin shortly, and installation will follow soon afterward. SACV will be run cooperatively with the Ministry of Infrastructure and Transportation's Laboratory of Engineering of Cape Verde (LECV) and the Instituto Superior Técnico of Lisbon, Portugal. Telemetry will consist of a spread-spectrum radio link from the station to LECV's offices in Praia, which are connected to the local Internet Point-of-Presence.

Drilling at Kappang, Sulawesi, Indonesia (KAPI) has been delayed by the recent economic instability in that country, but we are nevertheless optimistic that drilling will be completed before the end of summer. A site overlying a diorite intrusion has been prepared, and once drilling is finished, installation of the instrumentation will proceed accordingly. KAPI will be hosted by the Meteorological and Geophysical Agency (MGA) of the Indonesian government.

Based upon the GSN committee's cost/benefit analysis of drilling boreholes into coral atolls, it was decided not to drill at Kwajalein Island (KWAJ) but rather to construct a surface vault and instrument the site with STS-1s. We are still working with the local authorities to secure final permission to occupy the site that has been surveyed, and are optimistic that this will happen soon.

The number of regular users of IDA NRTS (Near Real Time System) data continues to grow. In addition to SPYDER®, the Proto-type International Data Center (PIDC) and the US Geological Survey's National Earthquake Information Center (NEIC) who have taken advantage of this capability for some time, the NOAA Tsunami Warning Centers in Hawaii and Alaska now also make regular use of the data. We are constantly looking for ways to establish new telemetry links and to upgrade old ones. Circuits to Talaya, Russia (TLY) and to Monasavu, Fiji (MSVF) were completed recently, and we hope to have data flowing routinely from them soon. We are also exploring ways of establishing a link to Alert, Canada (ALE) and of upgrading the capacity of the circuit to Eskdalemuir, Scotland (ESK). •

Mining for Data at the IRIS DMC

Tim Ahern, Program Manager IRIS DMS

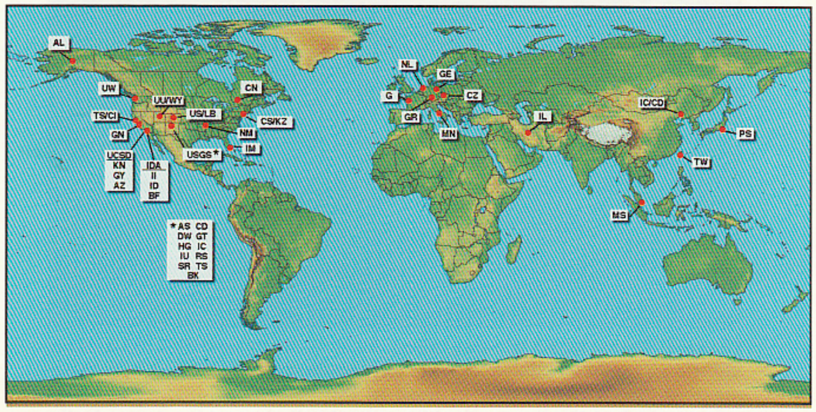


Figure 1. Data Centers from which the IRIS DMC receives permanent network data.

Traditionally, the IRIS DMC has been viewed as the data center for the IRIS Global Seismographic Network (GSN). For years that was basically a true statement. Even today, the data from the IRIS GSN program accounts for roughly half of the available data. Over the past two to three years, the amount of data from other sources has been increasing at a rapid rate. Last year alone more than two terabytes were archived at the DMC and the cumulative data volume is nearing 7 terabytes stored in roughly one million station-day files.

A primary goal of the IRIS DMC is to have fully documented data in a small number of comprehensive formats. For broadband passive source data the format is the FDSN SEED format. For active source reflection and refraction data sets, the supported format is SEG-Y. Data from SEG-Y data sets can be requested primarily as copies of the existing dataset tapes. Although these active source data sets are held in our large mass storage systems, we have not developed sophisticated data request tools for these sets. Basically, you get the entire data set when you make a request for the data.

Passive source data that arrive at the DMC in SEED format are handled in a far more sophisticated manner. The metadata (data about the data themselves) are stripped out of the SEED headers and used to populate tables in an Oracle database management system. As waveforms are archived, timing information is derived from the actual seismograms and used to update additional tables. The waveforms themselves are checked for internal consistency, and ultimately moved to the newly installed Storage Tek 50 terabyte mass storage system.

Not only does the DMC have a gold mine of data, it provides you with the picks and shovels to mine the data you need. You can find out more by referencing the IRIS DMC Data Access Tutorial at:

www.iris.washington.edu/manuals/tutorial.html

These tools are all you need to start requesting data from the DMC archive. Please pay particular attention to WEED; our most powerful access mechanism.

The IRIS DMC has received data from 23 centers around the world that represent 40 different permanent networks. Figure 1 shows the location of the various data centers from which the DMC has received permanent network data. Additionally, temporary deployments from PASSCAL broadband instruments now total 29 different experiments in 14 different countries, and all continents except Australia. Figure 2 shows the location of the broadband PASSCAL experiments whose data have been forwarded to the DMC. Data from these experiments are accessible with the same tools identified in the User Access Tutorial and, in fact, data from GSN, PASSCAL, FDSN, and many other sources of data can be merged into a single SEED volume based on the specific request you make using BREQ_FAST, XRETRIEVE, WEED or the WWW request form mechanisms.

How Do You Make Requests for Broadband Data from Any Networks?

All broadband data at the IRIS DMC are in SEED format. SEED has one field that identifies the network to which a station belongs. For instance, stations of the IRIS GSN that are operated by the USGS Albuquerque Seismic Laboratory possess network code IU; those from the IRIS GSN operated by the IDA project at UCSD are II.

Network Codes for permanent networks are permanent – once assigned they will never be assigned to another network. A list of assigned network codes for permanent networks can be found at:

www.iris.washington.edu/FDSN/networks.txt

Network Codes for temporary deployments, such as PASSCAL broadband deployments, are temporary and generally begin with an X, Y, or Z. The second letter begins with A, cycles to Z, and these codes are assigned only for specific years. For instance: XA is assigned to the MOMA experiment for

1995 and 1996, and then is reassigned to the South African Craton Experiment for 1997, 1998, and 1999. A complete list of temporary experiments for which FDSN temporary network codes have been assigned can be found at:

www.iris.washington.edu/FDSN/networks.portable.txt

More comprehensive experiment information is summarized at a series of pages such as:

www.iris.washington.edu/PASSCAL/1996-1997.html

and links shown at the top of that page are for other years. The archive status report also indicates if the data are restricted, or whether they are available for general release.

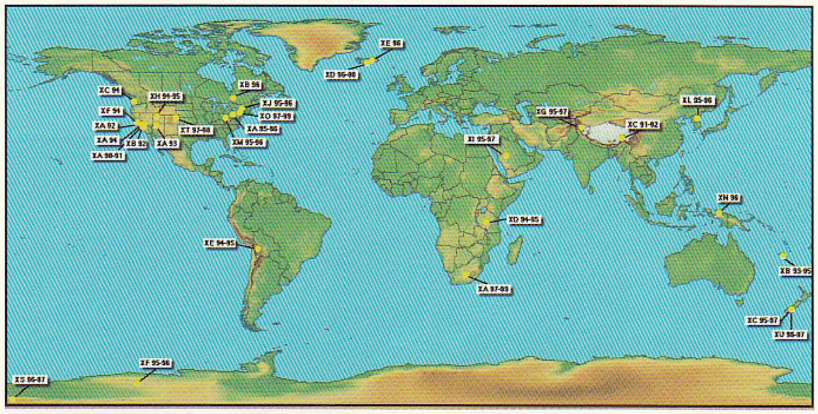


Figure 2. Broadband PASSCAL experiments whose data have been archived at the DMC.

All of the DMC request mechanisms (BREQ_FAST, XRETRIEVE, WEED, WWW) support the network code convention. The tutorial manual referenced earlier will tell you exactly how to use the Network Code in your request. If users do not specify the Network Code, only data from the core IRIS GSN networks are presently returned. These include codes IU, II, AS, SR, CD, DW, IC, GT, and, for historical reasons, TS.

The following table summarizes all of the data the IRIS DMC has in both SEED and SEG-Y formats. With proper use of the Network Code, all of these data can be easily retrieved to address your scientific questions.

If you have any questions regarding data requests or holdings, please contact Debbie Barnes at the DMC (debbie@iris.washington.edu). •

Data Source	Region	Network Code	Current Data Format
IRIS			
GSN	global	IU, II, IC,MS, BF	SEED
PASSCAL Broadband Passive	global	X?, Y?, Z?	SEED
PASSCAL Active Source	global	Not Applicable	SEGY
JSP Arrays	FSU	CS, GN, GY KZ, KN,	SEED
FDSN			
CNSN	Canada	CN	SEED
Czech National Seismic Network	Czech Republic	CZ	SEED
New CDSN & CDSN	China	IC, CD	SEED
GEOFON	Global	GE	SEED
Geoscope	Global	G	SEED
GRSN	Germany	GR	SEED
GDSN	global	AS, CD, DW , HG, RS, SR	SEED
GTSN	S. Hemisphere	GT	SEED
Netherlands Network	Netherlands	NL	SEED
MEDNET	Mediterranean	MN	SEED
Pacific 21 (formerly POSEIDON)	Western Pacific	PS	SEED
BATS	Taiwan	TW	SEED
USNSN	United States	LB, US	SEED
CNSS - US Regional Networks			
ANZA	S. California	AZ	SEED
PNSN	Northwest US	UW	SEED
TERRAscope	S. California	TS, CI	SEED
Utah Seismographic Network*	Utah/Wyoming	UU, WY	SEED
New Madrid Seismic Network*	Central US	NM	SEED
Other			
ALPA	Alaska	AL	SEED
IDA Gravimeter	Worldwide	ID	SEED
ILPA	Iran	IL	SEED
ISMS	Worldwide **	IM	SEED

* These data are soon to be made available

** The International Seismic Monitoring System (ISMS) is the network being put in place to monitor the CTBT. At the present time, only data from US stations are being made available to IRIS.

IRIS Education and Outreach Program Planning Workshop

Catherine Johnson, IRIS E&O Program Manager

Morning sunshine and participants on the steps of Airlie. (Some local DC-area participants unavailable at the time the photograph was taken).

IRIS Education and Outreach (E&O) held its program planning workshop April 22-25 at the Airlie Center, Virginia. Attendees represented IRIS member institutions, the National Science Foundation (NSF), kindergarten through college teaching, and other education and outreach programs. The workshop theme was to define goals and activities on which the E&O program should focus in the context of national science education needs, to identify the potential unique contributions of IRIS, and complementary efforts of other E&O programs.

Welcoming remarks by Adam Dziewonski and David Simpson and an introductory activity led by Sheryl Braile were followed by three feature presentations on science education by Jo Dodds (O'Leary Junior High, Idaho), Heather Macdonald (College of William and Mary, Virginia) and Nora Sabelli (NSF). Additional brief presentations covered education and outreach programs at American Geophysical Union, American Geological Institute, Southern California Earthquake Center, Geological Society of America, National Center for Earthquake Engineering Research and Univeristy Corporation for Atmospheric Research. Jayne Aubele (New Mexico Museum of Natural History and Science) addressed opportunities for informal education via museums. Anne Mahle (Teach For America) highlighted challenges facing teachers in under-resourced communities; contrasting sharply with the CD-ROM-based and web-based approaches to undergraduate courses as described by Bill Prothero and Bob Phinney. Workshop participants were reminded again and again of the vast range in needs during a panel discussion of eight teachers and post-secondary educators.

Despite a day of jury duty and a rush-hour commute to Airlie, our after-dinner speaker, Bob Ridky (NSF), gave a lively and thought provoking presentation on the National Science Education Standards which generated much discussion.

Friday began with a summary of IRIS E &O activities to date, after which the group subdivided into teams for a brainstorming session. Participants were asked to make recommendations on (a) unique contributions that IRIS can make to education and outreach, (b) short and long term initiatives, (c) assessment methods, (e) potential interactions with other E&O programs. Recommendations of the teams were synthesized in a plenary session. For the remainder of the workshop, four writing groups discussed, refined and documented ideas from the brainstorming session. Excellent spring weather combined with powerbooks rendered the meeting rooms redundant as groups worked outside in the stunning Airlie grounds.

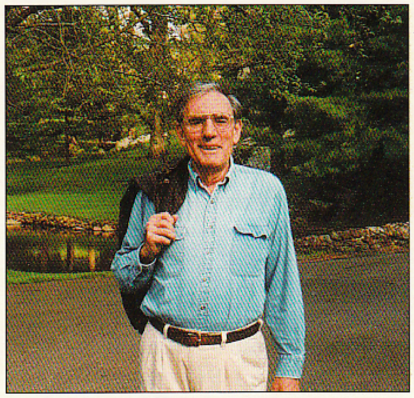
A summary of recommendations for the program will be presented at a SIG at the IRIS workshop. Publication of the program plan is scheduled for late Fall, 1998. We thank everyone who attended the Airlie workshop for their input and hard work. •

A Friday afternoon writing group at work. Left to right: Iñes Cifuentes (Carnegie), AnnMarie Cunningham (WNET), Art Lerner-Lam (Lamont), Anne Mahle (Teach For America), Catherine Johnson (IRIS), and Larry Ruff (Michigan).

Chairman of IRIS Executive Committee, Adam Dziewonski, and Don Anderson awarded Crafoord Prize

The IRIS Education and Outreach Program Planning Workshop was momentarily interrupted when the Chairman of the IRIS Executive Committee, Adam Dziewonski was called out of the room to receive a telephone call from Stockholm, Sweden. Adam was informed that he and Don Anderson, California Institute of Technology, were the winners of this year's Crafoord Prize, given by the Royal Swedish Academy of Sciences for work not covered by the Nobel Prizes.

The $500,000 prize is named for Holger Crafoord, who invented the first artificial kidney. The prize will be presented to Adam and Don by the King of Sweden in a ceremony next Fall. The announcement for the prize cites their "fundamental contributions to our knowledge of the structure and processes in the interior of the Earth".



Adam Dziewonski was notified at the IRIS Education and Outreach Workshop that he had been awarded the Crafoord Prize.

Although it is not clear whether the prize was awarded for the work they had done together or separately, Don and Adam first started working together in the early 1970s at the University of Texas at Dallas. In an interview with the Crimson, Anderson said "I consider Professor Dziewonski to be one of the most prominent seismologists in the world and I am delighted he received it." Anderson also remarked on the irony that a Nobel Prize is not offered in geophysics pointing out that Nobel made his fortune in dynamite and many geophysicists use large quantities of dynamite as sources for explosion studies of the crust and lithosphere.

In October, IRIS will celebrate the Crafoord Prize in Washington with a public lecture by Adam on seismic tomography, and a reception celebrating Earth Science Week. If you plan to be in Washington DC during Earth Science Week (October 11-17), please contact IRIS for an invitation and details. •

IRIS Education & Outreach In Las Vegas

The National Science Teachers Association (NSTA) 1998 National Convention was held at the Las Vegas Convention Center on April 16-19. With an attendance of over 19,000 K-12 science teachers, it was the largest NSTA convention ever. IRIS Education and Outreach had a strong presence at the meeting that included running a one-day pre-convention workshop, participating in the Coalition for Earth Science Education (CESE) booth, and sponsoring an informal gathering of science teachers involved in the Princeton Earth Physics Project.

"Earthquakes", a 1-day workshop for teachers, was held on April 15th and led by Larry Braile (Purdue University), Sheryl Braile (Burtsfield School, IN), Michelle Hall-Wallace (University of Arizona), and Catherine Johnson (IRIS). Participants represented a wide range of school districts across the country and classroom levels. The workshop comprised activities and exercises on earthquakes and internal structure of the Earth. The highly-advertised, enormous square footage of the Las Vegas Convention Center was well used by the group as unexpected heavy rain required indoor implementation of a walk/run S-P travel time activity. All attendees were supplied with teaching materials that included posters, books, hardcopies of all the activities covered, and information on web and CD resources. Feedback from participants was extremely positive. It is clear that IRIS Education and Outreach can make important contributions through workshops such as these.

Interest in the Earth Sciences is high among teachers - the CESE booth was visited by thousands of teachers attending the Conference. In our research world of large format posters at AGU and abundance of cheap color copies, we are often unaware of, or forget, the dire need for basic materials amongst science teachers. IRIS E&O gave out a total of over 6,000 posters and one-pagers at the meeting. Debbie Barnes (IRIS DMC) attended the convention, providing invaluable expertise - setting up and demonstrating resources available to teachers through the IRIS web page.

The Education and Outreach Program now has a web page which can be accessed via http://www.iris.edu Information on the NSTA is available at http://www.nsta.org •

Museum Display Opens to Rave Reviews

New Exhibits Underway

The seismic museum display developed by IRIS, the US Geological Survey, and the New Mexico Museum of Natural History and Science began its cross-country tour in Philadelphia as part of the Franklin Institute's "Powers of Nature" exhibit. The initial reviews from the museum have been extremely positive. According to Derrick Pitts of the Franklin Institute, "every day another museum employee says to me 'This is my favorite display in the whole exhibit and it always works!'"

Opening of the Powers of Nature exhibit at the Franklin Institute, Philadelphia, PA.

The Powers of Nature display, which is supported nationally by Subaru, includes a giant tornado tank, real-time weather displays, and the front half of a P-3 airplane in which visitors can experience a ride through the center of a hurricane. In September, the exhibit will travel to other cities including Los Angeles, Boston, Ft. Worth, and Chicago (see schedule in the Fall/Winter 1997 Newsletter). Over the next four years, the anticipated attendance is more than 5 million visitors. A sister exhibit to the seismic display will also be built at the New Mexico Museum of Natural History and Science this Fall.

Museum visitors discuss current seismicity shown on the IRIS web site display.

Building on the success of the museum display, the IRIS E&O program has received funding from the National Science Foundation to develop additional concepts for new displays. Following the announcement in the last IRIS Newsletter, proposals for new exhibits have been received and are under review. IRIS will be working with the proposers of the exhibits, the US Geological Survey, and staff from the New Mexico Museum of Natural History and Science to build the new displays. In addition, improvements to the current display will be made based on the evaluations from the Franklin Institute.

If you are interested in participating in the museum display project, please contact the IRIS Education and Outreach Program. •

Earth Science Week October 11-17, 1998

A celebration of Earth Science is being organized by the American Geological Institute for the week of October 11-17. Field trips, classroom visits, seminars, talks, and special exhibits are being planned to:

- Give students new opportunities to discover Earth sciences,
- Publicize the message that Earth science is all around us,
- Encourage stewardship of the Earth
- Share knowledge and enthusiasm about the Earth.

IRIS will celebrate Earth Science Week with a special reception and lecture at IRIS Headquarters in Washington DC, and through the release of a new poster commemorating the last 100 years of seismology.

In addition, IRIS can provide you with posters and other handouts so that you may contribute to Earth Science Week by leading a field trip, visiting a classroom, talking to a community group, writing an article, or organizing a special event or activity at a nature center, museum, or library. If you are interested, please contact the IRIS Education and Outreach Program.

You can receive more information about Earth Science Week at www.earthsciweek.org
or write:

Earth Science Week
American Geological Institute
4220 King Street
Alexandria, VA 22302
Phone: (703) 379-2480
Fax: (703) 379-7653

Students Visit Washington to Discuss Natural Disaster Mitigation

Last Fall, an experimental course on natural hazards was developed in the Geoscience Department at Princeton University by Gregory van der Vink. The course incorporated the National Science Foundation's philosophy of "integrating research and education" by involving students directly in research related to hurricanes, tornadoes, earthquakes, floods, tsunamis, volcanic eruptions, and severe weather.

Undergraduate geoscience and engineering majors, seismology graduate student Richard Allen, and Gregory van der Vink at the White House Old Executive Office Building. (Photo: Larry French)

Although the course was based on the science of natural hazards, it included the political, economic, social, legal, and engineering aspects as well. The students examined the question of why the United States was becoming more vulnerable to natural disasters. In combing through weather data, census reports, seismicity maps, and stream flow records, they were able to evaluate the frequency of natural disasters and relate that information to census data, insurance claims, and federal disaster relief bills. With natural disasters now costing the United States over $1 billion per week, mitigation requires a series of multi-disciplinary approaches, each one of which has economic, political, and legal consequences. Natural hazards therefore provide a logical entry point for interest in the Geosciences, especially for those students pursuing careers in business, law, or policy-making.

In April, the students presented their results in Washington to President Clinton's science advisor Jack Gibbons, the White House Office of Science and Technology Policy, and the National Science and Technology Council's Subcommittee on Natural Disaster Reduction. The students also met with the Congressional Subcommittee on Banking and Financial Services. Their findings and recommendations have been included in the minutes of the Subcommittee on Natural Disaster Reduction, and will be published in the Hearing Record of the Congressional Banking Committee. •

Staff News

The IRIS Data Management Center would like to welcome Tom McSweeney to the staff of the DMC in the position of Director of Software Engineering. Tom has a PhD in Seismology from the University of Washington and has been working as a consultant to the DMC for the past two years. He brings to this new position an acute knowledge of the science, rich programming skills and one heck of a commute.

We welcome to the staff Teresa Saavedra, IRIS Headquarters new Receptionist/Secretary. Teresa comes to us from American Arbitration Association in DC. •

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and precision electronic/electro-mechanical instrumentation. Desirable background for hardware applicants includes seismological experience, Unix workstation networks, and/or computer/instrumentation interfacing.

Individuals with appropriate experience spanning both software and hardware are strongly encouraged to apply.

Applicants should submit a resume, official college transcripts, a letter of professional interests, and the names and addresses/email addresses/phone numbers of three references to: IRIS/PASSCAL General Staff Search, c/o Human Resources, Box 59 New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801.

To receive full consideration, all materials must be received by June 1, 1998 for the software position beginning on or after July 1, 1998, or by July 25, 1998 for other positions. New Mexico Tech is an equal opportunity/affirmative action employer. •

Calendar

1998

May 26-29	AGU Boston, MA
June 28 - July 3	Gordon Research Conference New England College Henniker, NH
July 8-12	IRIS Workshop Santa Cruz, CA
Aug. 23-28	XXVI General Assembly of the European Seismological Commission Tel Aviv, Israel
Sept. 21-23	20th Annual Seismic Research Symposium on Monitirong a CTBT Santa Fe, NM
Oct. 11-17	Earth Science Week

New Members

IRIS welcomes as a new Foreign Affiliate: Institute of Geology, State Seismological Bureau, Beijing, Professor Qiyuan Liu, Representative •

Announcing a Special JAVA Workshop in conjunction with the IRIS Annual Workshop

The IRIS Data Management System (DMS) has arranged to have SUN Microsystems present a one day course on JAVA, object oriented programming techniques and related topics to be held on Sunday July 12, 1998 (the day after the full IRIS workshop ends).

This workshop is targeted toward IRIS community members whose normal tasks include software development. This workshop is specifically concerned with the SUN Microsystems JAVA Language. Experience in JAVA or object oriented programming languages would be beneficial but not required however, programming experience is a pre-requisite.

The workshop will begin at 8:00 AM on Sunday, July 12, 1998 and end at 4:30 PM the same day. The workshop will be held on the campus of the University of California at Santa Cruz. Flight arrangements should be made with this schedule in mind.

Attendance at this seminar will be limited to 50 people. Although a preference will be given to students, staff and faculty at IRIS institutions it is likely that most others can be accommodated as well. In the event of over subscription we will try to insure that at least one software development representative from each IRIS institution can attend. All other factors being equal, attendance at this workshop will be on a first come first served basis. Those interested in attending should register as soon as possible through the WWW

www.iris.washington.edu/FORMS/JAVA.form.htm

More information and a tentative agenda can be found

www.iris.washington.edu/FORMS/JAVA.html

There will be no charge for attendance at this workshop. IRIS will provide meals that day but no financial support will be provided for attendance at the JAVA workshop. •

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