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A short walk up a Naked Mountain

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Turn back from the peaks of the Karakorams and face due south. Here lies the true horror of the Himalayas. This time there is no deep and distant perspective; the horizontal is unrepresented. You are staring at a wall; it rears from the abyss at your feet to a height for which the neck must crane back. Such is Nanga Parbat, 'the Naked Mountain'; its navel now confronts you. More a many peaked massif than a single mountain, Nanga Parbat marks the western extremity of the Great Himalaya; it is a buttress worthy of its role.

John Keay "The Gilgit Game".

Figure 1. North face of Nanga Parbat. Crest of gray moraine deposit at base of slope is at 15,000 feet. The summit peak is over 26,000 feet.

Nanga Parbat, Urdu for Naked Mountain, is an 8000+ m peak on the northernmost edge of the Western Himalayan Syntaxis (Figure 2). The mountain, named for its southern face which is so steep it holds no snow, exhibits the world's greatest continental relief, ~7000 m in 21 horizontal km. As you approach the mountain, a sign on the Karakoram Highway advises you to look toward the peak of 'Killer Mountain', Nanga Parbat's second name.

Nanga Parbat, part of the Nanga Parbat-Haramosh massif, is an anomalous north-south extension of Indian crust into the Karakoram of Asia. The rocks of the massif are

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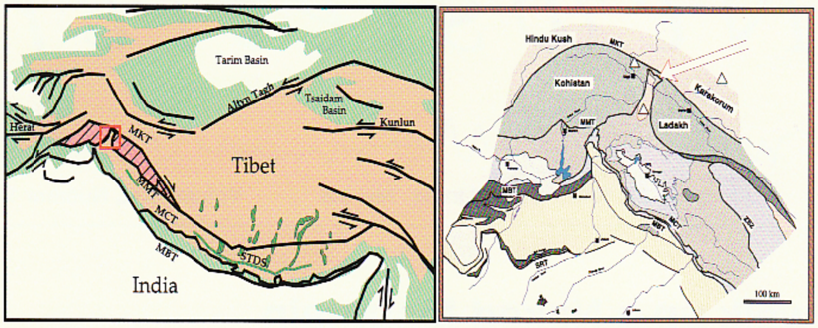

Figure 2. Regional and local setting. Area in pink on the regional map is the Kohistan-Ladakh island arc terrain. Red box outlines Nanga Parbat and is enlarged at right. The rocks of the massif are predominantly 1.85 Ga Pre-Cambrian gneisses of Indian crust exposed from beneath Asia. MKT=Main Karakoram Thrust, MMT=Main Mantle Thrust, MCT=Main Central Thrust, MBT=Main Boundary Thrust, STDS= Southern Tibetan Detachment System, ZSZ=Zanskar Shear Zone

predominantly 1.85 Ga Pre-Cambrian gneisses (Zeitler et al., 1989). To the west and east lie mafic rocks of the Late Cretaceous and Eocene Kohistan-Ladak Island arc captured during the collision of India and Asia. The contact between the island arc and Indian plate rocks, the Main Mantle Thrust, is equivalent to the Indus suture in the central and eastern Himalaya.

The rocks at Nanga Parbat are unique in that they exhibit very young high-grade metamorphic and igneous activity, very high strain rates, and what can best be characterized as fierce and sustained exhumation at rates locally as high as 5 km/My for the last 3 My (Winslow et al., 1994; Zeitler et al., 1993). At Nanga Parbat, substantial reworking of the crust occurs today, although the initial collision between India and Asia occurred ~55 My ago. Perhaps even more remarkable is that at Nanga Parbat there is virtually no evidence for early Himalayan metamorphism. While these rocks were clearly involved in a major collisional event, recent processes have completely obliterated any igneous or metamorphic signature of the original collision.

The highest grade rocks at Nanga Parbat are highly migmatized and intruded by kilometer-sized granite plutons and granitoid dikes and veins. These intrusions yield ages as young as 1 Ma (Zeitler et al., 1993). Stable-isotope results from rocks in the core of the massif and in fault zones adjacent to the massif indicate that a two component hydrothermal system is active, a shallow level system dominated by fracture flow of meteoric waters and a deeper system involving circulation of magmatic or metamorphic fluids (Chamberlain et al., 1995). Active hot springs and evidence of recent hydrothermal activity are abundant within the massif and along its margins.

In order to characterize the active processes reworking the continental crust at Nanga Parbat we have embarked on a multidisciplinary study using techniques in geochronology, petrology, structural geology, geomorphology, geochemistry, and geophysics. Our primary objective is to assess the processes responsible for the severe tectonic and metamorphic overprinting observed at Nanga Parbat, processes that are usually taken as an indication of plate collision.

Extremely rapid exhumation, the presence of hot springs, young intrusive rocks and young metamorphism all suggest an anomalous thermal structure and perhaps even partial melt zones or magma lie beneath Nanga Parbat,

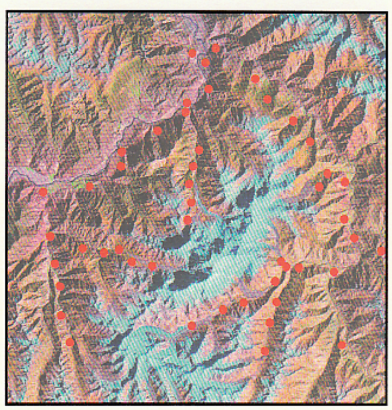

Figure 3. Thematic mapper image with station locations. Stations, shown by red circles, were located along the Indus River section (NW side of Nanga Parbat Massif) and the Astor River section (NE side of Nanga Parbat Massif). Access to the interior of the massif was gained along three primary glacial valleys, Bunar Das (west side), Tato Valley (NS off the Indus river), and Rupal Valley (south side). Ice is blue.

This issue's bannergram:

Displacement waveform recorded at San Pablo, Spain. The earthquake is a moderate sized event (Mw = 5.8) which occurred in central India. The event was unusually deep for an intraplate event (36+/-4 km), resulting in a very clean waveform at teleseismic distances. The record is essentially three pulses: direct P, pP (delayed by 11 seconds, negative polarity) and sP (14 seconds behind P, negative polarity) The ratio of the three phases can be used to determine the focal mechanism, which is an east-west striking thrust. *Terry Wallace University of Arizona*

Figure 4. Local road on the Astor River section. Road has 21 hairpin turns. Short period station was deployed 200m north of hairpin 19.

making it an ideal candidate for seismic studies. In 1996, we deployed 60 IRIS PASSCAL instruments, (10 broadband and 50 short period stations), in NE Pakistan to record local and regional events. Our principal goal is to characterize the crustal structure and fault kinematics at Nanga Parbat. Ultimately, we hope to infer the thermal structure beneath the massif and to help constrain geodynamic models of uplift.

Deploying seismometers in the Himalayas of Pakistan is an interesting experience. Our deployment was the culmination of several years of logistical field work including many visits to various ministries in Islamabad, numerous cups of tea, scouting visits to the field area and a pilot project conducted in late summer/early fall of 1995. By the time our experiment was finished, the PASSCAL instruments had been transported by almost every means imaginable: airplane, Bedford truck, local jeep, porter's back and donkey. The topography in the area is extreme (Figure 3). The majority of the array (56 of 60 stations) was deployed in an area roughly 60 x 60 km in and around the massif. Four broadband instruments were deployed in a more regional context to help locate regional events. Of the remaining six broadband instruments, three were deployed on the west side of the massif and three on the east. The short period stations at Nanga Parbat were deployed flanking the west and east sides of the massif along the Karakoram Highway and Astor river sections. Access to the interior of the massif was obtained along three primary glacial valleys, Bunar Das, Tato Valley, and Rupal Valley. Sites in these three valleys sit on Nanga Parbat gneisses. Reference sites, not on Indian crust, were deployed on the mafic rocks of the Kohistan-Ladak island arc. Station elevations ranged from 1100 - 4100 m. Station spacing varied between 1 and 10 km.

Figure 5. Makeshift bridge crossing glacial stream.

Our array recorded data for four months. We deployed our stations in Late May and early June as the snowline receded and we pulled them out at the end of September as the snowline advanced. This past year was an unusually late and wet winter. During our deployment, in May, we had to contend with an amazing array of landslides, rockfalls, high water, low snow, and active mud flows, all contributing to road blocks. Local jeeps ran shuttles between roadblocks. We moved our equipment by a series of leap frogging jeep rides, portering the equipment across the road block, then reloading in new jeeps to carry on. About half of our sites could be accessed fairly easily along roads and a short walk (Figure 4). The remaining sites could only be accessed by trekking (Figure 5). At the beginning of our field season a loop up and back one of the glacial valleys took between 5 and 7 days. By the end of the field season, with our lungs and legs in better shape it took only 3-4 days. We found ample bedrock sites in the area and general interest in what we were doing and lots of help setting up sites and servicing the instruments (Figure 6).

For the most part, our stations were sited away from villages. We worked in remote valleys at relatively high elevation and arranged for local

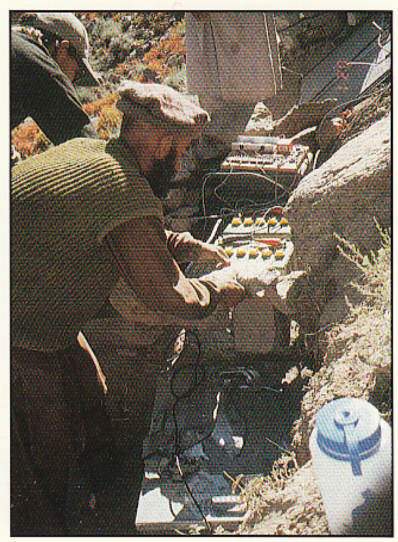

Figure 6. Typical site installation.

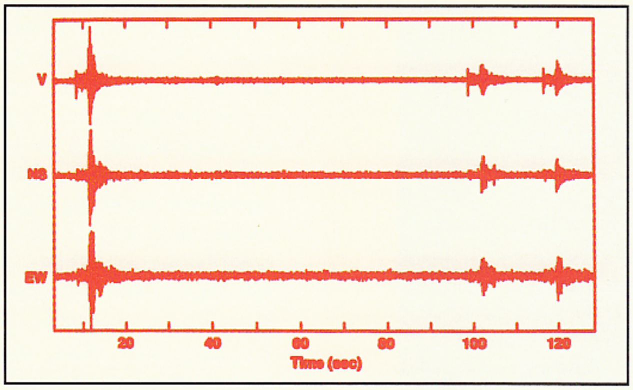

Figure 7. Record section from local event (s-p=3.2s). Three small magnitude events were recorded within a single three minute triggered window. Event locates beneath Tato Village.

shepherds to watch the stations between service runs. We serviced the stations on a three week interval. We rarely had problems receiving permission to site stations, although one person later changed his mind because he was worried the station might be damaged and he would be held responsible. When we arrived to service this station we found it was gone. The original chowkidar (watchman), had talked one of his neighbors into having the 'macheen' located on his property. Together, they dug up and redeployed a short period station and did quite a respectable job. The L22 was oriented almost due north, was buried 12" deep in soil on bedrock, the solar panels were facing south ~30° from horizontal, and all the cables were properly connected. As it turns out, the powerboard had shorted during the move, so there was no station power, but other than that, the installation was great!

One of our more delicate negotiations took place after we installed a broadband station in Eid Gah near Astor Village. The day after our installation, a massive mudflow started. The mudflow ran for three days, washed out the only road servicing the village and nearly damned the Astor river. The local villagers were convinced that our station had triggered the flow. It took much talking, drinking of tea, and intervention from the head cleric to calm things down and, as we were temporarily stuck in the village, this made for a rather anxious few days. In another village, we arrived to service a broadband station and found that the local watchman had chained his (large!) dog to the site to serve as a watchdog.

As we begin to analyze our data we have identified some 2000 associated events. Primary source locations in the region include: the Pamirs and Hindu Kush to the northwest, the Karakoram and NE terminus of the Baluchistan arc to the north and northeast, the Himalayan arc to the southwest, the Hazara arc and Kashmir to the south and southeast. While we anticipated recording these regional events, prior to our survey little was known about the local seismicity at Nanga Parbat. A temporary regional array deployed as part of the Karakoram Project recorded only three events near the massif in a six week recording window (Yielding et al., 1984). However, our array recorded as many as 5-8 small magnitude local events per day (Figure 7). Preliminary locations indicate that local seismicity is restricted to very shallow depths consistent with high geothermal gradients and a shallow brittle-ductile transition as suggested by the petrologic observations. Some of the local events show evidence of shear

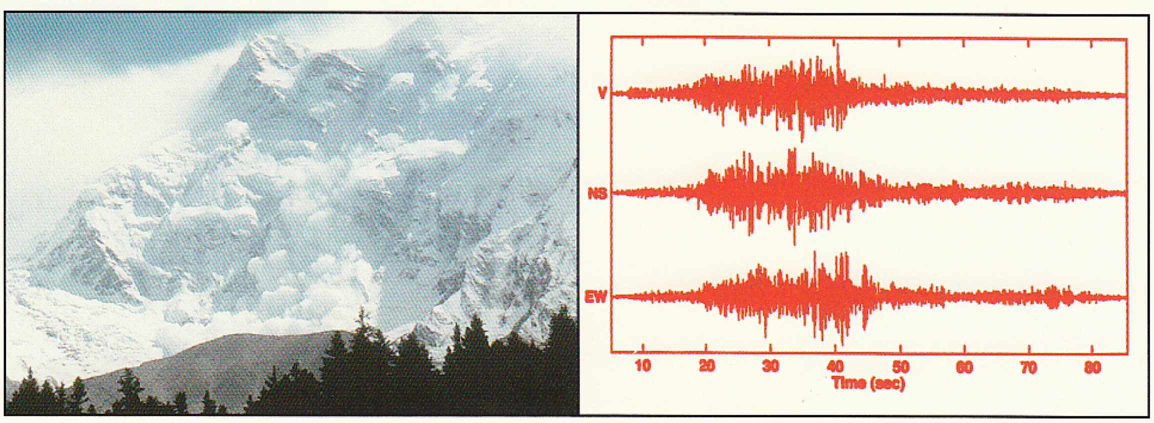

Figure 8. Avalanche off north face of Nanga Parbat, and associated record section.

wave splitting, presumably due to anisotropy associated with the metamorphic fabric of the rocks. We have also recorded events associated with hydrothermal activity at the Tato hot springs. Nanga Parbat is also very active in terms of avalanches and rockfalls and we recorded these as well, both on film and on our stations (Figure 8). Other sources of triggers were local goats. Even though we were in remote valleys at high elevation there were goat tracks everywhere.

Strong thermal anomalies will result in seismic velocity and attenuation anomalies that we hope to map using seismic tomography. Even small percentages of partial melt (on order of 2%) cause a rapid decrease in P and S wave velocity, and attenuation increases by 3-4 orders of magnitude. While we have regional source locations from a variety of azimuths and abundant local events, by far the most abundant source is the Hindu Kush. Events from this region originate at 200-300 km depth approximately 200 km to the northeast and serve as a beam source to illuminate the structure beneath the massif.

Another objective of our study is to use local seismicity to map the geometry and kinematics of active faults responsible for uplift at Nanga Parbat. While remarkably high denudation rates have exposed the Indian-plate rocks from beneath the over thrust Kohistan terrane, the actual uplift mechanism is not clear. As yet no obvious young extensional faults have been identified, so, at least for now, tectonic denudation as observed in other parts of the Himalaya does not seem a viable mechanism. The massif is bound on the west by the Raikot-Liachar fault which has been mapped as both a thrust fault and as a strike-slip fault. The fault is a young active feature that in certain places thrusts Pre-cambrian gneisses over glacial till. Surface mapping provides no constraints on the geometry of the fault at depth, and kinematic indicators in the fault zone itself are ambiguous in terms of a consistent sense of shear.

Our study at Nanga Parbat is still a work in progress. As far as we know, this is one of the densest deployments of seismometers in a active mountain belt. Our data set has the potential to look in detail at fault-slip behavior along a major crustal thrust fault as well as identify the presence or absence of partial melt zones in the crust beneath the massif. As we progress with our analysis, we have the great advantage of being able to help constrain our seismic observations with petrologic, geochronologic, structural, and magnetotelluric data. The ability to integrate multi-disciplinary data sets is valuable asset in this project.

Acknowledgments:

This research is supported by the Continental Dynamics Program, Earth Sciences Division of the National Science Foundation. Technical support was provided by the IRIS PASSCAL Instrument Centers at Lamont-Doherty Earth Observatory and Stanford University. Special thanks to Paul Friberg, Carl Ebeling, and Bill Koperwhats who endured many days of bindi and dal, and much more. We also gratefully acknowledge the field support provided by Chris Taylor, Alexander Stine, Jeff Johnson, and Lindsay Hinck.

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Real time access to multiparameter geophysical observatories in Northern California

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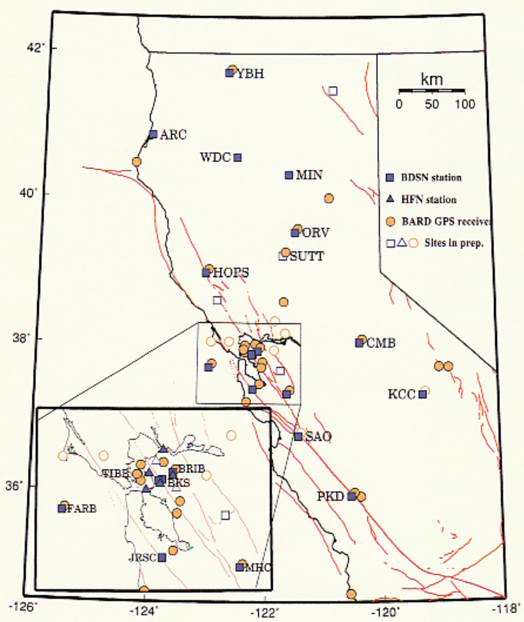
Recent technological advances in the area of digital recording and telemetry now make it possible to design and implement remote instrumentation that can record a variety of geophysical parameters at required sampling rates, and can transmit those in close to real time to a central processing facility. We here describe how, at the Berkeley Seismological Laboratory (BSL, formerly Berkeley Seismographic Station), we are taking advantage of this state-of-the-art technology to acquire and telemeter broadband and strong motion seismic data on the one hand, geodetic data from continuously operating GPS receivers and/or electromagnetic data on the other, as well as other auxiliary channels such as barometric pressure and temperature.

The BSL is involved in three expanding regional geophysical networks. The Berkeley Digital Seismic Network (BDSN) and the Hayward Fault Seismic Network (HFN) currently count, respectively, 15 and 5 operational stations. BARD (Bay Area Regional Deformation Network), a geodetic network of permanent GPS receivers deployed in cooperation with other institutions*, counts ~30 stations, 11 of which have been installed and are operated by the BSL. Of the latter, 9 are collocated with BDSN stations.



BDSN, HFN, and BARD sites

Figure 1. BDSN (broadband seismic), HFN (borehole seismic) and BARD (geodetic GPS) sites.

The BDSN stations are equipped with three component broad-band seismometers (STS-1 or STS-2 except for the Farallon Island site, which has a three-component Guralp CMG-40T), three component FBA-23 strong motion accelerometers (2g), and 24-bit Quanterra data loggers (of the Q935 or Q4120 type, with GPS clocks). Broadband data sampled continuously at 20Hz, 1Hz and 0.1 Hz, as well as triggered 80Hz broadband and strong motion data, are transmitted continuously to UC Berkeley, where data processing, along with information from the short-period Northern California Seismic Network (NCSN) operated by the U.S. Geological Survey is performed in quasi-real time and key earthquake parameters, such as moment magnitude and seismic moment tensor are broadcast in automatic mode (REDI program, Gee et al., 1996; Pasyanos et al., 1996).

The borehole HFN stations are designed to study microearthquakes along the Hayward Fault (down to magnitudes smaller than 0) and potentially gain insight into nucleation processes of large earthquakes, and are equipped with 6-component downhole packages (3 component Wilcoxin 731A accelerometers and 3 component Oyo HS-1 velocity transducers installed at depths of 40m to 170m) with Quanterra Q4120 recorders, affording sampling rates up to 1000 Hz. Auxiliary channels logged on the Quanterra's and sampled at 1Hz transmit data from temperature and pressure sensors located in the vicinity of the seismic sensors, and provide valuable information to effect noise reduction corrections, either through installation improvements or using correlation procedures directly on the time series (figure 2). In addition, two of our sites (SAO and PKD, figure 1) represent prototype ULF electromagnetic (EM) observatories, and are equipped with 3 orthogonal magnetic field sensors (10-4 to 20Hz) and two electric dipoles (DC to 20Hz), sampled at 40 Hz and recorded in the Quanterras. These observatories are part of a monitoring program to document potential precursory signals to earthquakes.

Until a year and a half ago, our telemetry system relied on standard analog telephone lines and, for some sites, piggy-backed on the microwave network maintained in northern

California by the US Geological Survey. The Quanterra data loggers made it possible, through packetized transmission, to telemeter continuously all seismic and auxiliary data from the BDSN stations, but the data rates required for transmission of the high frequency HFN data were not suitable for this type of standard telemetry. Also, BARD data were downloaded once every 24 hours over separate dial-up phone lines. Over the past two years, with the aid of a grant from PacBell's California Research and Educational Network (CalREN) to Caltech and U.C. Berkeley, the BSL has installed a state-of-the-art frame relay digital network to replace the point-to-point analog leased lines used to acquire real-time data from its regional stations.

Frame relay technology offers a number of significant benefits over analog leased lines. With point-to-point analog leased lines, each seismic station required a dedicated circuit between the seismic station and UC Berkeley, and used a standard modem with a maximum of 9600 baud to 18,000 bit/second to provide a single RS-232 async circuit. The frame relay network uses digital phone circuits that can support 56Kbit/second to 1.5Mbit/second throughput. Frame relay is a packet -switched network, which allows a site to use a single frame relay phone circuit to communicate with multiple remote sites through the use of permanent virtual circuits (PVCs). Frame Relay Access Devices (FRADs), which replace modems in a frame relay network, can simultaneously support multiple interfaces such as RS-232 async ports, synchronous V.35 ports, and ethernet connections.

Our CalREN grant provided for a 56Kbit/second line at each of the remote seismic stations, and a single 1.5Mbit/second T1 line at UC Berkeley to receive the data from all stations. We were also granted an additional 1.5Mbit/second T1 circuit at UC Berkeley and a corresponding T1 circuit at USGS Menlo Park to be used for the real-time exchange of seismic data between the Seismological Laboratory and Menlo Park.

Multiple goals have been reached through the use of the frame relay network:

(1) Increased bandwidth between our remote observatories and UC Berkeley to support higher rate seismic data and new data channels from existing data loggers. This, in particular, has made it possible to telemeter high-frequency data in near real time from the borehole HFN stations. In particular, we can now make use of the central UC Berkeley site triggering capabilities to remotely enable triggered recording at all these stations, a powerful procedure to eliminate false triggers and reduce the amount of data recorded at high sampling rates.

(2) Ability to telemeter data from multiple instruments such as GPS receivers, electromagnetic sensors, or multiple seismic data loggers from a single site to UC Berkeley. In particular, with the installation of the frame-relay hardware, we are now continuously acquiring GPS data, sampled every 30 sec, from 10 of our 11 BARD sites. This opens up the possibility, in the very near future, to process geodetic data in near-real time (within minutes after the occurrence of an earthquake), along with the seismic data, if sufficiently accurate satellite orbits are available within the same time frame. Fluctuations in the regional and local deformation field can thus be followed at different time scales and, in particular, the geodetic data can provide complementary constraints to seismic data for source parameter estimation of large earthquakes. We are working on the development of algorithms towards this goal (Murray et al., 1996). A particularly important application is for tsunami warning, in our case in the northernmost part of California, in that geodetic data can provide instantaneous estimates of local

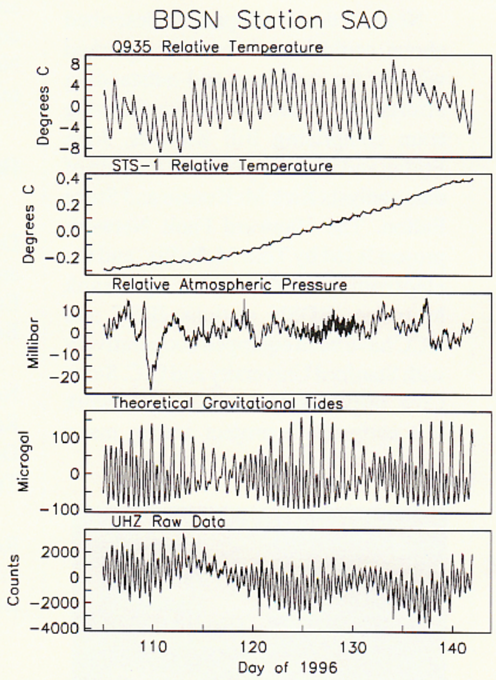


Figure 2. Plot comparing the UHZ raw data (0.01 Hz sampling rate) at BDSN station SAO (in counts), for a period of 40 days, with the theoretical gravitational tides, the relative atmospheric pressure, the STS-1 seismometer temperature, and the Q935 datalogger temperature. The diurnal temperature variation of the digitizer and the annual temperature variation of the seismometer have the largest effect on the raw data for the vertical component while the pressure has a smaller effect (for horizontal components the latter effect is larger). Procedures for optimum broadband station installations as developed (and still in progress for improvements) can be found on our WWW page at http:\\ www.seismo.berkeley.edu

displacements (Ellsworth, personal communication).

(3) Practical improvements in the operation of the telemetry: this includes (a) better control of telemetry costs, since frame relay costs are determined by a combination of flat rate and data throughput need instead of mileage based rates, (b) improved control of our remote seismic sites by providing "remote console" control at UC Berkeley of our seismic data loggers (c) possibility of remote configuration, monitoring and diagnostics for communications hardware and telemetry circuits, (d) error free communications handling for async circuits.

One of our most recent installations that has particularly benefitted from the frame-relay system is the Farallon Island site (Figure 3), a BDSN and BARD site located 30 km off-shore beyond the San Francisco Golden Gate bridge, which includes a radio connection to the relay station at Mount Tamalpais. This remote site is a wild-life refuge and is unaccessible for visits for over half of the year. The frame-relay connection allows, for example, remote two-way monitoring of station state-of-health as well as upgrade of station software. Our Parkfield (PKD) and Sago (SAO) sites, on the other hand, represent prototype multiparameter observatories, with continuous acquisition and telemetry of broadband (and strong motion) seismic, geodetic, electromagnetic and auxiliary (temperature and pressure) data.

The availability of powerful data-loggers and reliable, large bandwidth telemetry opens up further opportunities for system enhancement and potential cost savings. For example, up till now, we have been transmitting continuous GPS and seismic data channels to UC Berkeley through separate virtual circuits on our frame relay lines. Our most recent development, with support from the IRIS/GSN, has been to integrate the GPS datastream into the Quanterra data logger, where the GPS data can be written to disk and/or tape, and incorporated with the seismic and related data from the Quanterra into a single real-time telemetry channel. This provides on-site buffering and storage of GPS data and should create a more reliable data path for the continuous telemetry of the GPS data. This software, initially designed for Ashtech receivers, is now under final testing and will soon be ported to other brands of GPS receivers with the aid of the IRIS/GSN and UNAVCO. It will be made available to the IRIS community.

Acknowledgments

None of the developments described above could have been accomplished without the sustained and outstanding efforts of the BSL field engineering team comprising Bill Karavas, John Friday and Dave Rapkin, and the help of data analysts Rick McKenzie and Steve Fulton. The Hayward Fault Network project is led by Tom McEvilly, and the electromagnetic project by Frank Morrison. BDSN stations JRSC and KCC have been equipped cooperatively with Stanford University and U.C. Santa Cruz, respectively. The BARD network is a cooperative project among many institutions, which, in addition to UC Berkeley comprise USGS/Menlo Park, Stanford University, UC Davis, UC Santa Cruz, Lawrence Livermore National Laboratory. Also, the NGS, JPL and SIO contribute data to BARD from their permanent GPS stations in northern California. Data from the Berkeley Seismological Laboratory networks are available through the Northern California Earthquake Data Center (NCEDC, WWW address:

http://quake.geo.berkeley.edu).

The CMB (Columbia College, BDSN) station is part of the IRIS/GSN network and stations BKS, SAO and WDC also contribute data to the National Seismic Network through independent satellite telemetry. •

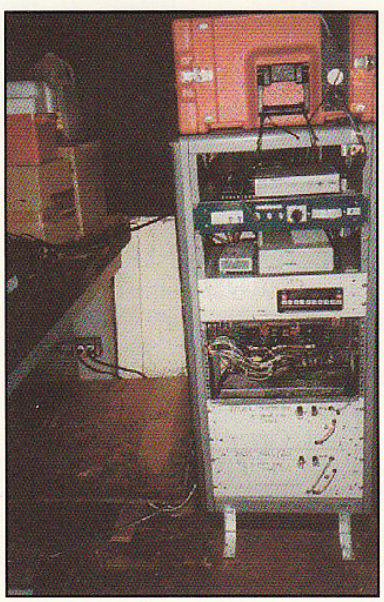


Figure 3. Photograph of the BDSN Farallon Islands (FARB) equipment rack and battery installation. The Quanterra Q4120 data logger (orange) is strapped to the top of the rack and the batteries are to the left of the rack in a restraining enclosure on the floor. The equipment in the rack from top to bottom is: Cylink spread spectrum radio; seismometer control panel; Freewave spread spectrum radio and frame relay access device (FRAD), Ashtech GPS receiver, power supply distribution equipment and, finally, duplicate power supplies.

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National Earthquake Hazards Reduction Program

David W. Simpson

On Behalf of the IRIS Consortium and the Seismological Society of America

Testimony presented April 14, 1997, before the Basic Science subcommittee of the Committee on Science, House of Representatives, U.S. Congress

Thank you Mr. Chairman for the opportunity to appear before the Subcommittee's Hearing on the National Earthquake Hazards Reduction Program. My name is David Simpson and I am here today representing the Seismological Society of America, of which I have been a member for 25 years, and as president of the IRIS university Consortium.

In discussions of NEHRP we frequently hear references to "the lessons learned" from earthquakes such as Loma Prieta, Northridge and Kobe. As a reminder that no modern US city, in fact no modern city anywhere in the world, has yet experienced the direct effects of a truly great earthquake, I suggest that it is more appropriate to consider the experience of the recent earthquakes in California and Japan as "warnings given" rather than "lessons learned". We must resist developing a sense of false security from the relatively low loss of life and property that these earthquakes produced.

Loma Prieta and Northridge were not large earthquakes. Both of them occurred outside the highly developed urban centers of San Francisco and Los Angeles. The loss of life and property were significant, but they were mere harbingers of what can follow a great earthquake in a modern urban area.

Strategies to reduce earthquake risk demand a close coordination between earth scientists, engineers, civic planning officials and those responsible for disaster mitigation and response. NEHRP has been exemplary in the foundation it provides for an interagency and interdisciplinary approach to earthquake hazard mitigation. NEHRP is succeeding.

It has forever changed the way in which the public perceives earthquakes and, over the past 20 years, it has impacted in fundamental ways the course of research in seismology, earthquake engineering and disaster planning.

At the core of NEHRP lies a concerned and dedicated group of scientists, engineers and civil servants who are proud of our accomplishments, but critically aware of the inadequacies of the current program.

There is a growing frustration that, within the current funding levels appropriated for NEHRP, we simply cannot accomplish the important work that needs to be done to reach the significant and attainable goals of this program.

Following the Kobe earthquake, Japan realized that its earthquake mitigation program - already superior in many ways to the US program - was in serious need of improvement. As a result, Japan has embarked on a major upgrade of its earthquake monitoring network and a strengthening of its research programs in earthquake studies.

To reach our potential to reduce earthquake losses in the US, NEHRP is in critical need of similar attention.

In the spirit of "lessons learned" and "warnings given", I strongly encourage your committee to carefully review the level of support proposed for NEHRP during this reauthorization, and consider the lasting return that would result from a significant acceleration of investment in this program. If we heed the "warnings given" by these recent earthquakes, as Japan has, we should be investing in hazard mitigation research and implementation at several times the rate that we are today.

The current investment in NEHRP of less than $100 million per year is only a small fraction of the loss suffered in even a moderate event like Northridge. Sums well in excess of the NEHRP budget are being spent to retrofit bridges, buildings and other structures in California for which there is virtually no quantitative data with which to evaluate their performance in strong ground shaking.

In my written testimony, and in the accompanying letter from the Seismological Society, we provide examples of areas where increased federal support for NEHRP would have a measurable impact over the next decade. Let me summarize only a few of these here.

The infrastructure for the collection of basic earthquake data requires a major upgrade.

NEHRP seismologists and engineers have reached a state where data essential for their research simply do not exist. The necessary technologies are available, but funding constraints prevent the deployment of much needed strong motion sensors and upgrades to regional networks.

Interdisciplinary research needs to be encouraged through all components of NEHRP.

With increasing concern about the specification of strong ground motions, the intersection between engineering and seismology is especially ripe for expanded joint effort.

As a source of new ideas and the training for future professionals, both in research and applied fields, the health of university research programs is critical to the future health of NEHRP. At current funding levels that future health does not look good. I encourage restoration of funds recently lost to the

USGS grants program and expansion of the fundamental studies program at NSF.

Earthquakes cannot be prevented. We cannot completely eliminate losses from earthquakes. We cannot promise that earthquakes can be predicted. We can, however, assure you that the continuation of a healthy and expanded NEHRP will improve our understanding of earthquakes, their mode of occurrence and the motions they produce.

Translated into engineering design and practice, this knowledge will enhance the seismic resistance of buildings and structures and significantly reduce losses in earthquakes.

Incorporated in disaster planning, this knowledge will aid in preparing the response to inevitable earthquakes as they occur.

Transmitted to the public, this knowledge will increase awareness of earthquake hazards and the means that individuals can take to prepare for earthquakes and protect their own lives and property.

While I am here today representing the seismological community, I cannot plead for a special case for the Earth Sciences and our research programs alone. Increased support is required throughout all sectors of NEHRP. I say this acutely aware of the pressures you are under to balance the federal budget.

In NEHRP, however, we are not preparing for some hypothetical threat to our national security, but rather to an inevitable occurrence. The time between major earthquakes in the US is much longer than the federal budget cycle, and it may be tempting to put off investment in earthquake research in order to respond to more immediate short-term pressures. A major earthquake *will* occur within the United States, and if we are not prepared, the financial and human consequences of this single event will be more comparable to the ravages of war than to the impact of other natural disasters such as the flooding we now witness in North Dakota.

I again stress that NEHRP is working - but more needs to be done. We look for your support to allow this important program to continue to contribute to the well being of the nation - now and in the future. •

The expanded text of the full version of this testimony can be found on the Web at http://www.house.gov/science/hearing.htm#Basic_Research *along with the testimony of the other witnesses at this hearing:*

Richard W. Krimm	*Federal Emergency Management Agency*
Patrick Leahy	*U.S. Geological Survey*
Kerry Sieh	*California Institute of Technology*
Elbert L. Marsh	*National Science Foundation*
Joanne Nigg	*Earthquake Engineering Research Institute*
Robert Hebner	*National Institute for Standards and Technology*
Daniel P. Abrams	*The NEHRP Coalition*
George Lee	*National Center for Earthquake Engineering Research*

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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.

Executive Editor: David Simpson (simpson@iris.edu)
Production Editor: Anne DeLaBarre Miller (anne@iris.edu)

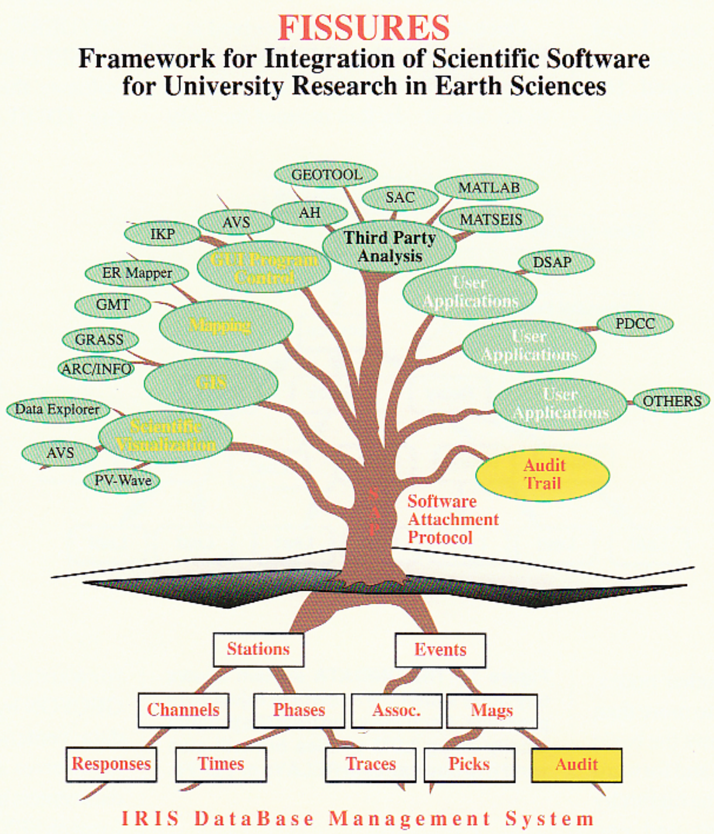
In Memory

We would like to remember one of our most active members, Prof. Robert P. Meyer (b. 12/24) of the University of Wisconsin who died of leukemia on April 10, 1997. Bob was a dynamic scientist who excelled at data acquisition and instrument design. He was active in PASSCAL from its inception. He taught at the University of Wisconsin-Madison for more than 40 years, and is survived by his wife, Prof. Marion Meyer (zoology) and four children.

FISSURES: A workshop on a framework for seismic software

Terry C. Wallace, Ken Creager and Tim Ahern

The IRIS DMS hosted a three-day workshop in Rolling Meadows, Illinois, in early May to discuss the future of software used in seismological research. During the preparation of the IRIS-2000 proposal, it became apparent that the seismological community wanted assistance with handling seismic data. In the early years of IRIS, typical data sets were small, and most of the analysis tools were home grown. However, the IRIS DMC now collects and distributes gigabytes of seismic data daily, and researchers complain that a great deal of time is being spent de-veloping software systems to manage these data. As a starting point for discussions of software development, the DMS Standing Committee developed a framework called FISSURES (**F**ramework for **I**ntegration of **S**cientific **S**oftware for **U**niversity **R**esearch in **E**arth **S**ciences). Figure 1 graphically depicts the FISSURES concept; seismic data and derived information such as arrival picks and associations need to be managed and used in a whole suite of analysis, visualization, or data management tools. Currently there is no established protocol for how the data are organized; this is a serious impediment to exchange of data and using disparate tools like SAC and MATSEIS.



The workshop was attended by 40 seismologists and several representatives from industry with expertise in computer software systems. The first two days of the meeting dealt with brief presentations of seismological experience, data management systems and issues, software tools, and where other software systems are heading. The third day focused on defining the problems seismologists face and how FISSURES might be implemented. There was general agreement that the following were problems:

1. Seismologists do not always know what data descriptions are already available and which descriptions are essential for all processing tools.

2. Since there is no established protocol for both descriptions, seismologists write the same interfaces between data and software over and over.

3. Many data sets are incomplete, or evolve with time, which requires dynamic bookkeeping. Further, there are problems establishing an audit trail that tracks the processing/archiving history.

4. The principal software tools (SAC, MATSEIS, GEOTOOL, etc.) want different seismic descriptions. How can the transfer between tools be optimized?

5. Any change must have some level of "future proofing." The changes in software and programming are rapid, so a data system must be flexible.

Further, there was agreement that the approach for imple-menting FISSURES is to take some simple steps and make something "work."

The FISSURES organizing committee is working on defining some simple seismic objects and will try some simple implementation pilot projects. •

Applying UNIDATA's IDD/LDM to SPYDER® Data

Rob Casey & Tim Ahern
IRIS Data Management System

UNIDATA is an NSF funded program in the Atmospheric Sciences. Although the specific goals of UNIDATA are different from IRIS's, one of their main missions is to provide data to the atmospheric community, similar to the IRIS DMS mission of providing data to the seismological community. UNIDATA has developed the Internet Data Distribution (IDD) and Local Data Management (LDM) systems to meet this need. Developed for atmospheric sciences, the technology has been easily adapted to seismological data.

The general concept is similar to a pyramid scheme. Any participating node within the IDD structure can inject products into the system. These products are forwarded to a small number of other locations running the IDD/LDM system and those in turn forward it to other nodes, and so on and so on. It should be clear that just having four layers of participating centers each forwarding data to only 5 other nodes, products can be forwarded to more than 150 locations. Figure 1 shows the basic scheme. Nodes that receive and forward products to lower levels in the hierarchy are called RELAY nodes and end members of a chain are called LEAFs. UNIDATA has developed a socket-based system that is far more robust than standard UNIX utilities and a monitoring capability is under development to identify problem areas and eventually to dynamically route products around problem RELAYs.

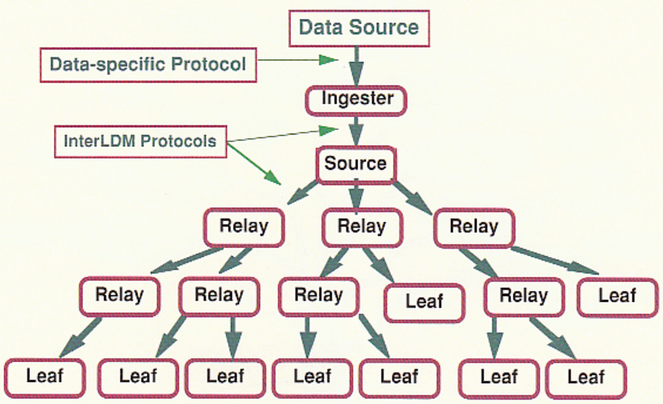


Figure 1. The UNIDATA system allows any node within the system to inject data products. Each relay can treat the product locally using LDM utilities but will also send it to downstream RELAYs or LEAFs.

A huge amount of data can be forwarded in this manner to a large number of institutions without saturating a single node of the Internet. A potential advantage for IRIS would be the use of this method for sending data to additional distribution sites in Europe, Asia, South America and Africa, eliminating the need to send multiple copies of identical data over the oceans.

Once data products are received at a RELAY or LEAF, the LDM determines if a product is of local interest and what to do with it. In this manner the only local computing resources that are required are Internet capacity, temporary buffers, and storage for data extracted for local use. The remainder of this article will provide details of the initial test of the IRIS implementation of UNIDATA's system.

To identify data packages with seismological content, the UNIDATA system will be expanded to include a *feedtype* of SEISMIC. Initially IRIS has only defined one product, SPYDER®, to be transferred with this *feedtype*. SPYDER® data are those data that the IRIS DMS recovers from broadband stations of the IRIS GSN, cooperating FDSN stations, and other stations in response to alerts sent by the NEIC. SPYDER® data are now available in full SEED format and it is these SEED volumes that are transmitted through the IDD/LDM system. When a SPYDER® alert message is received at one of three international data centers (ORFEUS, GEOFON, and IRIS DMC), up to 14 cooperating data centers running SPYDER® nodes are contacted automatically and requested to recover specific time windows from stations for which they have agreed to recover data. The connections to these stations are normally done using high speed modems, or in some cases, Internet connections to the stations. These data are then forwarded to IRIS, ORFEUS or GEOFON by the Internet and then these data centers exchange data between themselves so that in general all three data centers have all of the data recovered for each SPYDER® event. This process normally takes from a few minutes to a few hours.

Periodically, SEED volumes are built that contain all of the data that have been recovered up to that time. These SPYDER® SEED volumes are injected into the IDD/LDM system. Each SPYDER® product is tagged (in LDM protocol) with specific information about the time, location and magnitude of the event. When the SPYDER® data product is received at an IDD/LDM location, the LDM software scans the product information and if it is determined that the product is of local interest, a user definable process is invoked. In the IRIS implementation this process is called SLUICE, an appropriate name since it is the technique to recover that portion of data of highest value to the local scientists. For instance the SLUICE process can be used to indicate that one is only interested in events from the Tonga trench, deeper than some depth and for data from only specific stations and/or channels. Ultimately SLUICE invokes RDSEED, and data can be translated into whatever analysis format an individual scientist wishes to use. Only data of specific interest are left on a user's computer system and those data have already been converted into the format desired at that institution.

The initial test of the IDD/LDM system took place between IRIS, UNIDATA, University of Arizona, University of Michigan and Harvard University as shown in Figure 2. The system is stable and we believe it is an appropriate time to begin propagating the IDD/LDM approach to seismic data transfer to as many IRIS universities as possible. By installing the IDD/LDM system you will receive all SPYDER® data automatically and you will be able to customize locally such things as stations extracted and analysis format. Installation of the IDD/LDM system and the related SLUICE system will take a small amount of a knowledgeable person's time, normally that of a systems administrator. If your institution would like to participate in this new method of timely information transfer, please fill out the form found on the WWW at

URL=http://www.iris.washington.edu/FORMS/IDD.form

You will be contacted by Rob Casey when it is time to install the software at your location. UNIDATA has already installed IDD/LDM software at more than 100 different universities in the United States and you might find it useful to contact your local atmospheric science department since the software might already be installed at your university and you may already have local expertise that will be of great benefit. •

Staff News

Gregory van der Vink has been elected to the Council on Foreign Relations after being nominated by John H. Gibbons, Science Advisor to President Clinton. Greg has also been appointed to the "Red Team", which is providing the US Administration with an independent assessment of the verifiability of the Comprehensive Test Ban Treaty.

We want to welcome Candy Shin, Accounting Manager to the IRIS Headquarters' staff. She is originally from Tennessee and comes to the DC area by way of California. For the past 2 years she was a member of the Audit Group of the Office of Inspector General, Department of Energy.

Candy received her BA in Mathematics from Vanderbilt University in 1987. She graduated Magna Cum Laude and is a member of the Phi Beta Kappa honor society. Candy then received her MS in Accounting from Memphis State University in 1993. She was a recipient of the Financial Executives Institute Scholarship. •

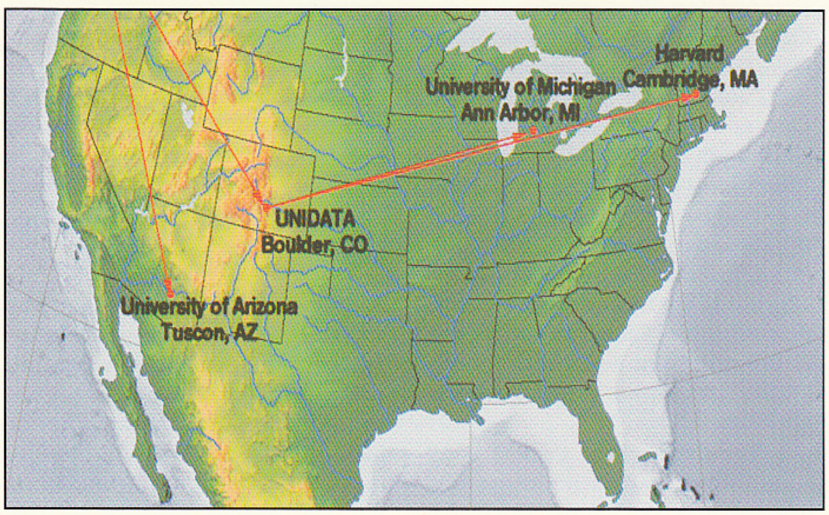


Figure 2. The initial test of the IRIS implementation of the IDD/LDM system was conducted between the IRIS DMC, the UNIDATA Program Center, the University of Arizona, Harvard, and the University of Michigan.

Lessons from Armenia and Sakhalin for Central Asia

Report of a Workshop in Almaty Kazakstan Oct. 1996

"Strategies for Urban Earthquake Risk Management for the Central Asian Republics"

Vitaly Khalturin, Lamont-Doherty Earth Observatory
Brian Tucker, GeoHazards International

The capitals of all of the Central Asian republics of the former Soviet Union are subject to damaging earthquakes. Almaty was destroyed twice, in 1887 and again in 1910. Devastating earthquakes occurred near Bishkek in 1885 and near Dushanbe in 1907. Ashgabad was totally destroyed in 1948, when more than 40,000 people died. Tashkent suffered from earthquakes twice, in 1886 and 1966.

During the last decade it has become clear that the actual values of seismic hazard and seismic risk in Central Asia are much higher than were indicated on the 1978 seismic zoning map of the Soviet Union and officially accepted in the building regulations for the area. There are several factors which support this statement.

1. All the destructive earthquakes of the last decade in the former Soviet Union occurred with a maximum intensity of 1 to 3 units higher than was expected from the official seismic zoning map. On this map, Almaty was located in a zone where intensity IX repeats once per 1,000 years; whereas intensity IX-X has been observed there twice in the last 110 years. The two most devastating earthquakes during the last decade in the former Soviet Union almost completely destroyed Septak and Leninakan (Armenia) in 1988 and Neftegorsk (Sakhalin Island) in 1995. Both towns were located in zones of expected intensity VII, whereas the observed intensity reached IX-X.

2. Microzonation maps of the capital cities showed the maximum expected intensity increasing from IX to X MSK in some areas, which occupied as much as 20-40% of the total city area. Construction in such areas is prohibited by the building code, but these regulations have been largely ignored and extensive construction has taken place in many of these regions.

3. Only after the 1988 Armenian and the 1995 Sakhalin earthquakes was it recognized that the seismic resistance of Soviet-era buildings is significantly lower than was officially proclaimed. In the northern part of Leninakan, Armenia, more than 95% of frame-panel building collapsed and caused more than 9,000 deaths, out of total population of 25,000 in that part of the city. All sixteen of the large panel construction buildings in the same region remained standing. Both types of buildings were presumed to be designed to withstand intensity VIII. The Neftegorsk earthquake caused the total collapse of all seventeen large-block buildings in the town. The earthquake struck at night and almost all inhabitants of these buildings, about 2000 people, were killed. At the same time, buildings of other types of construction survived.

Millions of people in Central Asia live in the same types of buildings as those that collapsed in Armenia and Sakhalin. If an earthquake of the same size occurs near one of the Central Asian capitals, the tragedies of Leninakan, Spitak and Neftigorsk will be repeated on a much bigger scale, unless urgent measures are taken.

4. The ability of the Central Asian republics to assess seismic risk has dramatically decreased since the collapse of the USSR. Financial support for science has been cut to a critically low level. Many experts have emigrated. Science and technical collaboration with Russia has been strongly curtailed. Scientists and engineers have become isolated, having little contact with their colleagues in neighboring republics or western countries.

The lessons of Leninakan and Neftegorsk have alarmed many specialists in the Central Asian republics and abroad. Recognizing the urgency of addressing Central Asia's urban earthquake risk, GeoHazards International, a nonprofit organization dedicated to improving earthquake safety worldwide, organized a workshop to review the actual parameters of seismic hazard; assess the vulnerability of the Soviet-era residential buildings and develop a strategy for reducing the earthquake risk. Support was obtained from a wide variety of organizations, including NATO, USGS and IRIS. The workshop was held in Almaty, Kazakstan, in October 1996, and involved more than fifty experts from across Central Asia and around the world.

Main results and recommendations of Almaty '96 meeting

The earthquake specialists who gathered at the Almaty workshop analyzed the available published information as well as reports prepared by each republic especially for the meeting. They concluded that there is a high (about 40%) probability that during the next several decades, a large earthquake will occur near one of the Central Asian capitals. Such an earthquake could produce maximum intensity in the urban areas of about IX. It could cause tens of thousands of fatalities and at least one hundred thousand serious injures. Up to half of the city's residential buildings could collapse or be damaged beyond repair. Such an event would cause human and economic losses greater than that already experienced in Armenia and Sakhalin, unless corrective action is taken soon.

In order to confront this crisis, projects must immediately be initiated that take into account Central Asia's current social, political, and economic conditions, and address the following five broad needs:

• *Inform the people most at risk.* Responsible officials in each republic must undertake a detailed inventory and ranking of vulnerable buildings in their capitals and notify the occupants of Soviet-era residential buildings of the high vulnerability of some of these buildings.

• *Rehabilitate existing buildings.* A seismic rehabilitation program should be launched in the capital of each republic to upgrade all highly vulnerable multifamily residential structures.

• *Regulate new construction.* New seismic design codes should be written. Designs that minimize sensitivity to construction quality, such as large panel buildings, are desirable. Liability for illegal construction must be established.

• *Unite and support local experts.* Local experts are now underfunded and isolated. They must reestablish contact with each other and create new links with international colleagues through Internet connections, attendance at international conferences, subscriptions to professional journals, and participation in cooperative research projects.

• *Continue and extend risk assessment.* A network of strong-motion accelerometers should be established across each capital city and in standard buildings. Reasonable knowledge of all three components of seismic risk - seismic hazard, seismic vulnerability of buildings, demographic and economic information - have to be determined by modern techniques with acceptable accuracy.

The Almaty '96 workshop was not a scientific conference, but a meeting of experts who are concerned about the seismic threat in this region where seismic risk is increasing, while the ability of the new republics to manage it is drastically decreasing. The common opinion was that meeting was successful and useful and both the Central Asian and western experts wished to continue their interactions and convene a follow-up meeting in 1997.

Dr. Mustafa Erdik (Turkey) proposed to hold the next Central Asian meeting in Istanbul during the 8th World Conference "Soil Dynamics and Earthquake Engineering" (SDEE`97) which was held on July 20-24, 1997 in Instanbul The main goals of this meeting were:

• To coordinate the techniques for estimation of the seismological, engineering and economic parameters which are necessary for reasonable seismic risk estimation and mitigation in urban areas in Central Asia.

• To support direct contacts between western and Central Asian experts in planning and realization of the cooperative research programs and projects.

• To hold the discussions between Central Asia experts and representatives of international programs about the goals, forms and topics of future cooperation with the Central Asian republics.

• To help as many Central Asian experts as possible to participate in the World Conference in order to broaden contacts with the international science community.

For more detailed information please contact Brian Tucker (tucker@pangea.stanford.edu) or Vitaly Khalturin (vkhaltur@ldeo.lamont.columbia.edu). •

GSN Update

Six new GSN sites have been installed since the last Newsletter. In addition, BFO, Black Forest Observatory, has joined the GSN as a new Affiliate Station. IRIS/USGS teams (Albuquerque Seismological Laboratory) have completed new installations in Mexico, China, Chile, and the South Pacific. TEIG, Tepich, Yucatan, Mexico is a cooperative joint station with the Mexican National Seismic Network (MNSN). MDJ, Mudanjiang, China is a cooperative joint station with the New Chinese Seismographic Network (NCDSN). LVC, Limon Verde, Chile is a cooperative joint station with the Germany's GEOFOrschungsNetz (GEOFON). PTCN, Pitcairn Island is a cooperative joint station with the Japan's Science and Technology Agency. IRIS/IDA (University of California, San Diego) teams have completed new installations at HOPE, South Georgia Island in the South Atlantic, and COCO, Cocos Keeling Island in the Indian Ocean. •

Calendar

1997

Aug. 18-22	IASPEI Thessolaniki, Greece
Oct. 19-22	GSA Salt Lake City, UT
Nov. 2-7	SEG Dallas, TX
Dec. 8-12	AGU San Francisco

1998

May 26-29	AGU Boston, MA
July 8-12	IRIS Workshop Santa Cruz, CA (tentative)

1999

May 7-11	IRIS Workshop Samoset, Rockport, Maine

New Members

IRIS welcomes as a new member: Macalester College, St. Paul, Minnesota, John Craddock, Representative •

IRIS Headquarters New Offices

IRIS headquarters has moved their offices from Arlington, Virginia to Washington, DC. We have relocated to the American Association for the Advancement of Science (AAAS) building in downtown Washington. World-class architects Pei Cobb Freed & Partners created this environmentally-sensitive, energy-efficient, black granite structure. Along with AAAS, we join the American Meteorological Society, Association of Women in Science, Association of Universities for Research in Astronomy, Carnegie Mellon University, Commission on Professionals in Science and Technology, Communications Consortium Media Center, Natural Resources Defense Council, University Corporation for Atmospheric Research, and the Washington Academy of Sciences. We look forward to a long and happy association!

IRIS Headquarters is located just one block from the Metro Center subway stop. We would be pleased to provide you with space to work, relax, or read email. Please stop by and visit any time you are in town! •

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