# Imaging the Elysian Park Thrust, L.A. Basin, with SCSN Data

*John N. Louie*
Seismological Laboratory (174), University of Nevada, Reno

## Table of Contents

A. Application for Federal Assistance SF-424  
cover

C. NEHRP Proposal Information Summary (filed electronically)  
1

D. Table of Contents  
3

E. Abstract  
4

F. Budget  
5

G1. Significance of the Project  
7
   Objectives and NEHRP Priorities  
7
   Background and Significance  
8

G2. Project Plan  
13
   Methods  
13
   Work Plan  
14
   References  
15

G3. Final Report and Dissemination  
17

G4. Related Efforts  
17

G5. Curriculum Vita of John N. Louie  
18

G6. Institutional Qualifications  
19

G7. Project Management Plan  
19
   Budget Justification  
20

G8. Current Support and Pending Applications of John N. Louie  
21
Imaging the Elysian Park Thrust, L.A. Basin, with SCSN Data

John N. Louie
Seismological Laboratory (174), University of Nevada, Reno

E. Abstract

A key issue in estimating the earthquake hazard to the Los Angeles area is the hidden sub-surface geometry of blind thrust faults. The Elysian Park thrust, for example, has a poorly known width through the seismogenic crust, and is thus at the center of a current controversy over the maximum magnitude event that it could produce. Competing thin- and thick-skinned compressional tectonic models allow very different fault widths within seismogenic depths, leaving poor maximum magnitude estimates. The segmentation of the Elysian Park fault system is even less well known; as is true for the other thrusts along the northern margin of the Los Angeles and San Fernando basins that produced the 1971 San Fernando, 1987 Whittier Narrows, and 1994 Northridge earthquakes.

Information on blind thrust geometries might be found using three established techniques. Aftershock sequences can locate seismogenic segments; industry seismic reflection surveys can yield fault-bend-fold estimates of thrust geometry; and crustal reflection-refraction experiments can show velocity discontinuities and crustal structure. The Southern California Earthquake Center has applied all three techniques to the northern margin of the Los Angeles and San Fernando basins, yet none have resolved the geometry of the Elysian Park thrust, or even the simpler quandary between thin- and thick-skinned models.

We propose to resolve thrust geometries along the northern margin of the Los Angeles and San Fernando basins with a new technique that adds additional constraining data, and should corroborate and link the aftershock, industry, and refraction results. Our technique uses forward- and back-scattered fault reflections from earthquakes, recorded on Southern California Seismic Network stations, to image fault geometries in three dimensions. During a previous project, we used our technique to image a mid-crustal bright spot in the same location as was found by a large reflection-refraction experiment. We then produced an image of the Northridge source zone that establishes the underlying segment of the Elysian Park thrust as a moderately dipping thick-skinned fault system cutting the Moho.

We will generate whole-crustal, three-dimensional structural images below earthquake sequences along the northern basin margin. Structures will be interpreted from these images with statistical verification, and will be corroborated where possible with existing aftershock, industry, and refraction results. This work will illuminate the geometry, seismogenic width, and segmentation of these very dangerous fault systems, allowing more accurate seismic hazard estimates.
F. Summary Budget
Detail Budget
Imaging the Elysian Park Thrust, L.A. Basin, with SCSN Data

John N. Louie
Seismological Laboratory (174), University of Nevada, Reno

G1. Significance of the Project
Objectives and NEHRP Priorities

This one-year project will image crustal fault structures below earthquake sequences along the northern margin of the Los Angeles and San Fernando basins in southern California (Fig. 1). Observing the geometry, segmentation, and dip of major fault segments below each sequence will constrain models for neotectonic activity, tectonic history, and deformation processes across this complex plate boundary region. In addition, locating and characterizing the subsurface geometries of active faults such as the Elysian Park thrust will allow more accurate assessments of earthquake potential and hazard in Los Angeles.

The advent of regional seismic networks in California that record digital seismograms from hundreds of stations makes this crustal reflectivity profiling possible even in the absence of conventional active-source seismic data. Work with data from the 1991 Sierra Madre event and its aftershocks shows that a three-dimensional prestack migration algorithm reproduces the lower-crustal bright spot seen in a section below the San Gabriel Mountains by the Los Angeles Region Seismic Experiment (LARSE) Line 1 (Chavez-Perez and Louie, 1998; Fig. 2). Data from aftershocks of the 1994 Northridge earthquake show that this technique images the geometry of blind thrusts, including the fault that generated the 1994 event, as well as prominent deeper structures. The images tested the existence and configuration of thrust ramps and detachments proposed from balanced-section reconstructions of shallow-crustal profiles and borehole data (Chavez-Perez and Louie, 1998). Our location of a 45° north-dipping reflector below the northern margin of San Fernando Valley, that cuts the Moho, supports thick-skinned rather than thin-skinned compressional tectonic models.

The project proposed here will use regionally-available data and new analysis methods to identify potential fault structures along the northern margin of the Los Angeles and San Fernando basins, and initiate the evaluation of their earthquake potentials within existing models for faulting and neotectonics. We will achieve this with 3-d, wide-angle, prestack depth migration of swarm event and aftershock seismogram traces recorded on the short-period vertical stations of the southern California regional seismic network, through optimized 3-d velocity models. It complements seismicity and focal mechanism work by imaging entire volumes rather than having to associate events to certain faults. Further, it can image below the seismogenic zone.

This project will address mainly Element II of the NEHRP research priorities for Southern California. It will “Use waveform data to determine earthquake source parameters and crustal structure,” and partly “Investigate Quaternary faulting and develop regional models of active deformation” as well. By concentrating on the width of the Elysian Park fault system in the seismogenic upper crust at the northern margin of the Los Angeles basin, this project will “Characterize the behavior of active faults segments and clarify differences between seismic and aseismic processes,” where “The Los Angeles, Ventura, and San Bernardino basins are of particular interest.” Element I will be addressed somewhat as this project maps the subsurface geometry of the Elysian Park system, since “...the USGS will produce accessible GIS databases of active earthquake source zones with up-to-date information on slip rates and recurrence intervals.”
Background and Significance

A key issue in estimating the earthquake hazard to the Los Angeles area is the hidden subsurface geometry of blind thrust faults. The Elysian Park thrust, for example, has a poorly known width through the seismogenic crust, and is thus at the center of a current controversy over the maximum magnitude event that it could produce. Competing thin- and thick-skinned compressional tectonic models allow very different fault widths within seismogenic depths, leaving poor maximum magnitude estimates. The segmentation of the Elysian Park fault system is even less well known; as is true for the other thrusts along the northern margin of the Los Angeles and San Fernando basins that produced the 1971 San Fernando, 1987 Whittier Narrows, and 1994 Northridge earthquakes.

This project will refine and apply a new crustal imaging technique to the northern margin of the Los Angeles and San Fernando basins in southern California. Its primary purpose is to locate and characterize the subsurface geometry of crustal faults, particularly the dangerous Elysian Park thrust system. Previously hidden faults may become apparent in imaged cross sections. Find-
ing fault geometry will constrain or test tectonic and seismological models that have been proposed previously. We will finish the project by completing a three-dimensional view of the overall framework of fault geometries across this region of complex plate boundary transition. We will compare and verify our interpretations of fault geometry against the results of aftershock relocation, fault-bend-fold analysis, and crustal reflection-refraction experiments where they are available.

We have begun under previous NSF funding with studies of structures near the Sierra Madre and Northridge earthquakes. Chavez-Perez and Louie (1988) undertook the imaging of a section below the San Gabriel Mountains near the LARSE Line 1 from seismic network recordings of the June 28, 1991 M5.8 Sierra Madre event and its aftershocks (Hauksson, 1994) to reproduce the lower-crustal bright spot seen by Fuis et al. (1996). Fig. 1 shows the locations of LARSE Line 1 and the section we used to depict a 50 km long by 40 km deep image of crustal structure in this region. The image shows the prestack Kirchhoff-sum 3-d depth migration (using a velocity model without lateral variations) of records from 18 events, including the Sierra Madre mainshock. The data set included as few as 18 and as many as 102 seismograms from each event, all having impulsive P-wave picks.

Fig. 2c shows the stack of explosion seismograms by Fuis et al. (1996). Note the highly reflective zone at approximately 16 to 19 km (5.5 to 6.5 s). Fig. 2a shows our Sierra Madre migration, and Fig. 2b shows a migration of noise estimated from the data. The noise migration allows us to identify all the artifacts of the imaging process, and of the geometric distribution of aftershocks and network stations. Comparing the two sections, a strong north-dipping reflective zone at 15-20 km depth below the northern side of the San Gabriel Mountains is clear. Fig. 2a also suggests the reflective bright spot extends north below the San Andreas fault into the Mojave Desert.

Fig. 2d overlays our migration on the LARSE Line 1 stack of Fuis et al. (1996) at the same scale, and at corresponding locations. The locations on the two sections of the bright spot reflector correspond well, and there are hints that both sections also are imaging a diffractor at about 10 km depth below the southern side of the San Gabriel Mountains. It is remarkable that the narrow-angle LARSE Line 1 explosion data and the very wide-angle aftershock network records can show exactly the same reflective structure. Further, this fact suggests not only the veracity of the lower-crustal reflective zone, but also the accuracy of both data sets and imaging methods (Chavez-Perez and Louie, 1998).

According to Fuis et al. (1996) the top of this lower-crustal reflective zone represents a “block boundary,” or change in rock properties, in the crustal framework of southern California. They propose that the top may be a decollement or an igneous contact, and it may be young or old. In fact, the depth to brittle-ductile transition seems to be defined by this reflective structure. This is important because lateral variations in lithology seem to control the depth extents (and thus the magnitudes) of potential future earthquakes. These depths, which seem to correlate to the presence of schist and mylonitized basement rocks, can be determined from the depth of the current background seismicity (Magistrale and Zhou, 1996) and from seismic images like those of Fig. 2a (Chavez-Perez and Louie, 1998).

In the area of the 1994 Northridge event to the west at the northern margin of San Fernando Valley, seismological evidence for the mainshock faulting, the focal mechanism, and the spatial distribution of aftershocks (Hauksson et al., 1995) are all consistent with either thin- (Davis and Namson, 1994) or thick-skinned (Yeats, 1993; Huftile and Yeats, 1996) hypotheses for blind-thrust
Figure 2: crustal image from Sierra Madre event and aftershock data along section A of Fig. 1. Comparing the data image (A) to the image derived by a simple estimate of noise by resampling (B) shows a prominent zone of reflectivity 15-19 km below the San Gabriel Mts. The image suggests the lower crustal reflective zone (LCRZ) of Fuis et al. (1996; C), and correlates very well with it in (D).
compression. The thin- or thick-skinned interpretation of the 1994 Northridge earthquake is especially dependent on accurate characterization of complex fault geometries (Mori et al., 1995), particularly as fault orientation may have a large affect on the seismic potential transmitted from other historical events (Stein et al., 1994). Developing Suppe and Medwedeff’s (1984) ideas for the local well and geologic data, Davis and Namson (1994) proposed a model of thrust ramps driving blind thrusts below the San Fernando Valley that Chavez-Perez and Louie (1998) tested against crustal reflection images (Fig. 3).

Our crustal images below Northridge migrate only short-period, high-gain vertical components from SCSN network stations. Fig. 3a shows the migrated crustal section 50 km wide and 40 km deep that runs north from the Northridge epicentral area (Fig. 1). The migration utilized a 1-d velocity model and 823 wide-angle seismograms having high-quality impulsive picks from 27 shallow Northridge aftershocks. Fig. 3b is the migration of noise derived from the aftershock data set, again showing the imaging and geometric-coverage artifacts. At least two north-dipping and one south-dipping structure appear on the data migration (Fig. 3a), and do not appear on the noise migration (Fig. 3b). We propose to refine our images by using, among others, the 3-d velocities of Zhao and Kanamori (1995) in a fully 3-d migration.

Fig. 3c compares Chavez-Perez and Louie’s (1998) wide-angle SCSN data migration against aftershock locations and part of Davis and Namson’s (1994) balanced cross section. The south-dipping reflector just below the Pico Thrust (as proposed by Davis and Namson, 1994) may be an image of the seismogenic fault. Fig. 3d presents Chavez-Perez and Louie’s (1998) interpretation of a strong, north-dipping reflector, which appears just above the location of the Elysian Park Thrust as proposed by Davis and Namson (1994) in Fig. 3c. However, Fig. 3d suggests this structure may not merge into a mid-crustal detachment, but continues down below the Moho. Chavez-Perez and Louie (1998) believe this structure to be evidence in favor of the thick-skinned compressional models of Yeats (1993), and of Huftile and Yeats (1996).

We expect that the addition of LARSE Line 2 explosion records that will be shot in 1998, and of optimized 3-d velocities (Magistrale et al., 1996; Hauksson and Haase, 1997) will improve structural definition and detail in the Northridge section. This may allow us to address the presence or lack of a mid-crustal detachment in the western Transverse Ranges (Webb and Kanamori, 1985; Yeats, 1993; Davis and Namson, 1994; Huang et al., 1996; Huftile and Yeats, 1996). Huang et al.’s (1996) results do not support the existence of a regional-scale seismically active detachment in southern California. Only in the western Transverse Ranges is there some suggestion of a large detachment surface at a depth of about 13 to 14 km as compared with the proposed depth of about 22 km by Davis and Namson (1994).

In addition to our on-going work to refine the results of Chavez-Perez and Louie (1998) at the Sierra Madre and Northridge zones, we will complete the evaluation of the northern margin of the Los Angeles and San Fernando basins by examining other sequences in the area. The 1987 Whittier Narrows earthquake sequence (Hauksson et al., 1988; Michael, 1991) was the first blind-thrust event to strike a major urban area, and occurred on a structure not previously recognized as seismogenic. Hauksson (1990) was able to identify, if not characterize, the very dangerous Elysian Park thrust system below downtown Los Angeles from a combination of seismicity and geologi-
Structural mapping such as by Bullard and Lettis (1993) and Hummon et al. (1994) can help to identify additional potentially dangerous blind thrusts. However, their driving mechanisms (Suppe and Medwedeff, 1984; Davis and Namson, 1994) are, as for the Northridge event, supposedly deep and remotely transmitted via thrusting on huge detachments. As the deep thrust locations must be geologically projected from the uppermost few kilometers of structural data, an image of fault geometry will greatly constrain the form of the thrust system, and therefore its sensitivity to historical earthquake sequences, as in Lin and Stein (1989). If there is a regional detachment at the base of the crustal ramps, we may be able to see it as a strong reflector in an aftershock migration image.

Figure 3: crustal imaging below the 1994 Northridge sequence from aftershock data, along section B of Fig. 1. The white ovals indicate structures from coherent reflections and diffractions in the data image (A) that do not appear in the noise image (B). (C) superimposes the thin-skinned interpretation of Davis and Namson (1994), and earthquake locations, on the data image; (D) gives the thick-skinned interpretation of Chavez-Perez and Louie (1998). The Moho is at about 32 km depth in this area.
G2. Project Plan

Methods

Chavez-Perez and Louie (1998) carried out the search for scattering structures, like steeply-dipping and thrust faults, ramps and detachments, with the assumption that these scatterers radiate isotropically (e.g., Wu and Aki, 1985; Lay, 1987; Revenaugh, 1995c). Under this simple assumption, valid for structures that form variations in Lame’s elastic parameter lambda, the search for crustal structures becomes attainable, practical and unusually inexpensive (Chavez-Perez and Louie, 1997).

Chavez-Perez and Louie (1997; 1998) examined published experimental results from exhumed crustal fault zones, and concluded that the high P-wave reflectivity of fault zones compared with their S-wave reflectivity gives them just this type of isotropic reflectivity. Thus a very simple imaging technique based on isotropic reflectivity will preferentially image fault zones and not image non-tectonic reflectors such as batholith boundaries. Chavez-Perez (1997), and Chavez-Perez and Louie (1997), ran extensive tests of this idea with elastic synthetic seismograms, and showed that preferential fault imaging will take place, even with the relatively sparse source and receiver sampling given by the actual earthquake locations and seismic network distribution in southern California.

The key simplification is to treat forward-scattered reflections identically to back-scattered reflections. The distribution of the seismic network places both within the data sets. The forward- and back-scattered reflections from a boundary that is primarily a change in shear modulus or density will have opposite signs, and cancel out in the Kirchhoff summation. Reflections from a lambda change, prominent in fault zones, will have the same sign and thus reinforce. The LCRZ image in Fig. 2 we constructed almost equally from forward- and back-scattered reflections, suggesting it is a deep mylonite zone dominated by P-wave (and lambda) reflectivity.

All the data needed for this project are already available at the SCEC data center, and much is on-line and accessible to the Internet. Imaging below each sequence requires downloading and processing data from 50-500 events, assessment of 3-d velocity models, and 3-d prestack Kirchhoff migration with statistical assessments and validity checks. Such a migration, backed up by a sufficiently detailed velocity model, can even image the fine structure of steeply-dipping faults together with the detailed seismic stratigraphy of near-horizontal sediments (e.g., Pullammanappallil and Louie, 1994; Chavez-Perez et al., 1998). Picking of reflections observed in the seismograms (Pullammanappallil and Louie, 1993) or an optimization based on coherency criteria without requiring picks (Pullammanappallil and Louie, 1997) can also yield highly detailed velocity results.

Revenaugh (1995a, b) has used unsigned, long period data from similar sets of stations, and teleseisms, with a similar Kirchhoff migration method to find crustal-scale images of scattering property variations. Revenaugh (1995c) has been able to correlate regions high in scattering potential with slip concentrations during earthquakes on known faults.

On the other hand, Chavez-Perez and Louie (1998) used signed, high-frequency seismograms from local and regional events at the same stations. While Revenaugh’s (1995a, b, c) objective is to estimate a characteristic parameter of a known fault, ours is to detail the location and geometry of faults, without providing much information on characteristic properties. In this way our work is complementary to Revenaugh’s. He interprets regional scattering potential variations.
on a crustal scale, where we locate major structures with 1-3 km resolution.

Revenaugh’s (1995c) impact is on proposing likely areas of strong, frequent aftershocks, and on strength variations along fault systems. He correlates scattering strength and rupture (slip) magnitude, as tested at Landers. We impact assessments of seismic potential by locating faults, some of which may have been projected geologically and some of which may not have been known previously. We also delineate fault geometry and the thickness of the seismogenic crust, to constrain models of fault system segmentation and slip variability, as at Northridge and Sierra Madre.

We demonstrate that these images show reflective structures, and that we can use clipped high-gain seismograms as sign-bit data (O’Brien et al., 1982) to yield valid geometric imaging. Chavez-Perez and Louie’s (1998) work with data from the 1991 Sierra Madre and 1994 Northridge earthquake sequences produced images structures related to proposed lower crustal reflective zones, and blind thrust fault systems and regional detachments. We propose to further investigate the use of repeated bootstrap resampled imaging statistics to better separate imaging artifacts from structures, and will investigate several coherency enhancements to migrations used in the petroleum industry, such as the partially coherent migration of Lee et al. (1993), and migration operator anti-aliasing criteria. We will also pursue additional elastic synthetic seismogram modeling to define the utility of shear modulus rather than lambda variation images, and thus investigate the use of P-S, S-P, and S-S scattered arrival imaging.

Work Plan

1) For magnitude 2 to 5 earthquakes on the northern margin of the Los Angeles and San Fernando basins we will copy CUSP MEM and GRM files via Internet FTP from the SCEC Data Center to UNR, and store them on the project disk.

2) After conversion to a seismic processing format, the seismograms will be filtered, culled, muted, and selected for having had impulsive picks made on them by the SCSN.

3) Traces with down picks will be sign-reversed.

4) Migrate traces using a 3-d Kirchhoff-sum algorithm into 2-d sections and 3-d volumes, using travel times computed from available 3-d velocity models with Vidale’s (1990) method.

5) In areas where a 3-d velocity model is not available, or not detailed enough, we will estimate one from first arrival and reflection coherency data using the Monte-Carlo techniques of Pullammanappallil and Louie (1997).

6) Create noise estimates from the data sets, and migrate applying statistical coherency criteria in the prestack or migrated image planes, as in Louie and Pullammanappallil (1994). This reveals the geometries of artifacts in the migrations, and defines resolution.

7) Use partially coherent migration (Lee et al., 1993) and anti-aliasing filters to alleviate wavefield sampling and aliasing problems, and improve image resolution.

8) Examine migrated image volumes to interpret fault geometry, and devise tests of existing tectonic hypotheses (e.g., the presence of mid-crustal detachments).
9) Corroborate fault geometries interpreted from image volumes with existing aftershock relocations (e.g., Hauksson et al., 1995), locations and sizes of fault-bend-folds in industry reflection surveys (e.g., Davis and Namson, 1994), and crustal velocity and structure models from LARSE reflection-refraction experiments (e.g., Fuis et al., 1996).

10) We will make all results and interpretations available on the Internet and in peer-reviewed publications for discussion by the tectonic and seismological communities.

References


Chavez-Perez, Sergio, 1997, Enhanced imaging of fault zones in southern California from seismic reflection studies: Doctor of Philosophy Thesis in Geophysics at the Univ. of Nevada, Reno.


**G3. Final Report and Dissemination**

The results of our research will be presented at conferences and submitted to refereed journals. In addition, we will furnish all required reports as delineated in the contract.

**G4. Related Efforts**

Project titles in the “Current Support and Pending Applications” (see below) indicate that the principal investigator is active in areas of work relating to fault structure, seismic imaging, and tectonics and structure of the Nevada/California region. Work also continues on the problem of Yucca Mountain site characterization, with a number of Seismological Lab scientists and graduate students presently working in this area. UNR runs seismic networks in the Great Basin region that collect and archive earthquake seismograms using methods very similar to those employed at the SCEC Data Center at Caltech, so the PI is well-prepared to assemble and process SCSN data.
G5. Curriculum Vita of John N. Louie
G6. Institutional Qualifications

As one of the statewide research agencies of the University of Nevada, the Seismological Research Laboratory is headed by a Director (J. Anderson) who reports to the Dean, Mackay School of Mines. The current research staff consists of ten professional seismologists. Other professionals include a Research and Design Engineer. Technical staff members include two seismographic technicians, one record analyst, 1.5 FTE of computer support personnel, and ten graduate research assistants. The Seismological Laboratory operates the Western Great Basin Analog Seismic Network (USGS Funding), the Southern Great Basin Analog Network (USGS Funding), the Yucca Mountain Digital Seismic Network (DOE-TRW Funding), 11 UNR digital stations, and five broadband digital stations (provided by the W. M. Keck Foundation).

After ten years of operation of computer-based digital seismic acquisition, over 25,000 local events have been located, and these and many more regional and teleseismic events and blasts have been archived, leading to over archived 500,000 digital seismograms. Data bases from paper records and other analog sources extend back to 1916 (e.g. a collection of Wiechert smoked-paper recordings). Earthquake data are now manipulated using derivatives of the CUSP and Earthworm systems developed by the USGS, allowing us to interchange both real-time and archived catalog and seismogram data with the SCSN network through the SCEC Data Center at Caltech.

Computer hardware consists of fourteen Sun workstations with speeds from 33 to 167 MHz, six Pentium II UNIX workstations, numerous PCs and Macintoshes, and a VAX cluster system. These processors are used mainly for research applications and provide a basis for analysis of the accumulating network data base. Seismic reflection data sets are processed both with John Louie’s “Resource Geology” UNIX system for research, and with the industry-standard Halliburton Promax system, donated to the Lab by William Lettis & Assoc.

Additional equipment is available for field work and special investigations. The seismology group has 15 portable Reftek seismographs and 8 PRS-4 portable digital seismographs. We have three sets of Kinemetrix 5-second seismometers, 10 sets of 1-Hz S13 seismometers and several Guralp CMG5 and CMG4 broadband seismometers. The W. M. Keck Foundation recently donated to the Mackay School of Mines a 48-channel Bison Galileo-21 reflection-refraction recording system, with 700 m cables for 8-Hz refraction geophones; and a high-resolution 210 m segmented roll-along cable with 48 groups of 6 100-Hz geophones each.

G7. Project Management Plan

The project will be managed by the principal investigator. Time schedules and allocations of responsibilities are outlined in the following table, and associated costs are given in the proposed budget. Project reports will be issued in the USGS summary volumes.

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Time</th>
<th>Proposed Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. Louie</td>
<td>9 days</td>
<td>General supervision, method development</td>
</tr>
<tr>
<td>UNIX System Administrator</td>
<td>1 week</td>
<td>Computer and network maintenance</td>
</tr>
<tr>
<td>Graduate Student</td>
<td>12 months</td>
<td>Velocity inversion, imaging, reporting</td>
</tr>
<tr>
<td>Undergraduate Student</td>
<td>230 hours</td>
<td>Seismogram downloading, graphics</td>
</tr>
</tbody>
</table>
BUDGET JUSTIFICATION

The Seismological Laboratory maintains a network of workstations that this project will employ for reduction and processing of seismic data. This network of machines costs more than $20,000 per year to maintain, and the amount requested reflects the expected 15% proportion of use of this network by this project’s 3-d processing and modeling tasks. As exemplified by the intrusion at UNR in late 1995 of an outside “hacker” and the subsequent vandalism and loss of use, all computers connected to the Internet require maintenance, monitoring, upgrades, and system administration to remain usable by research projects. Since this project requires the use of computers with full-time Internet connections and vulnerability to acquire seismogram data and disseminate results, a contribution to the professional salary of a departmental UNIX and network system administrator is included as a direct cost.

To assist the departmental UNIX and network system administrator and the graduate student, the funds proposed for an undergraduate at 5 hours/week will provide support for data transfers from the SCEC data center, for routine elements of the data processing, and for data dissemination activities. The Department of Geological Sciences at UNR, in which the PI holds a 40% teaching appointment, at this time has more than a dozen undergraduate majors enrolled in its Geophysics B.S. degree program. Thus funding of the undergraduate position will enable one of these students to gain significant research experience at an important stage of his or her career.

Although academic institutions do not normally request telephone line fees, telephone toll charges, or postage as direct costs, the University of Nevada, Reno is unable to provide its research units with sufficient communications support for research projects or graduate students. Since performance on this project requires communication between the assigned graduate and undergraduate students and the SCEC data centers providing the network seismogram data, these charges are part of the project’s direct costs.

The materials and supplies request is further increased because it includes a 9 gigabyte or larger hard disk. Such disks are currently available for under $2000, and so are not considered to be permanent equipment by UNR. The 9 gigabyte disk will be used throughout the project year exclusively to store seismograms downloaded from the SCEC data center.
G8. Current Support and Pending Applications of John N. Louie