The Southern California Seismographic Network

CLARENCE R. ALLEN

Virtually everything that is known about the seismicity of the southern California region comes from the seismographic network that is centered at Caltech's Seismological Laboratory. This network was initiated in 1926 by the Carnegie Institution of Washington, operated for many years by Caltech alone, and most recently expanded as a joint effort between Caltech and the U.S. Geological Survey. More than 17,000 local earthquakes have been located and analyzed by the Seismological Laboratory during this period, and it is this body of data, in addition to the sparse pre-1926 historic record of "felt" earthquakes, together with the geologic knowledge of our active faults, that primarily determines our judgments concerning earthquake risk in various parts of the southern California region.

In the years following the 1906 San Francisco earthquake, geologists came to realize that the San Andreas fault—the culprit responsible for the 1906 disaster—was just as much a feature to be feared in southern California as in the north. In fact, we now know that an earthquake comparable to the San Francisco event occurred along the fault's southern segment, adjacent to Los Angeles, as recently as 1857; and most geologists and seismologists expect a repeat of the 1857 event before San Francisco is again shaken by a great quake.

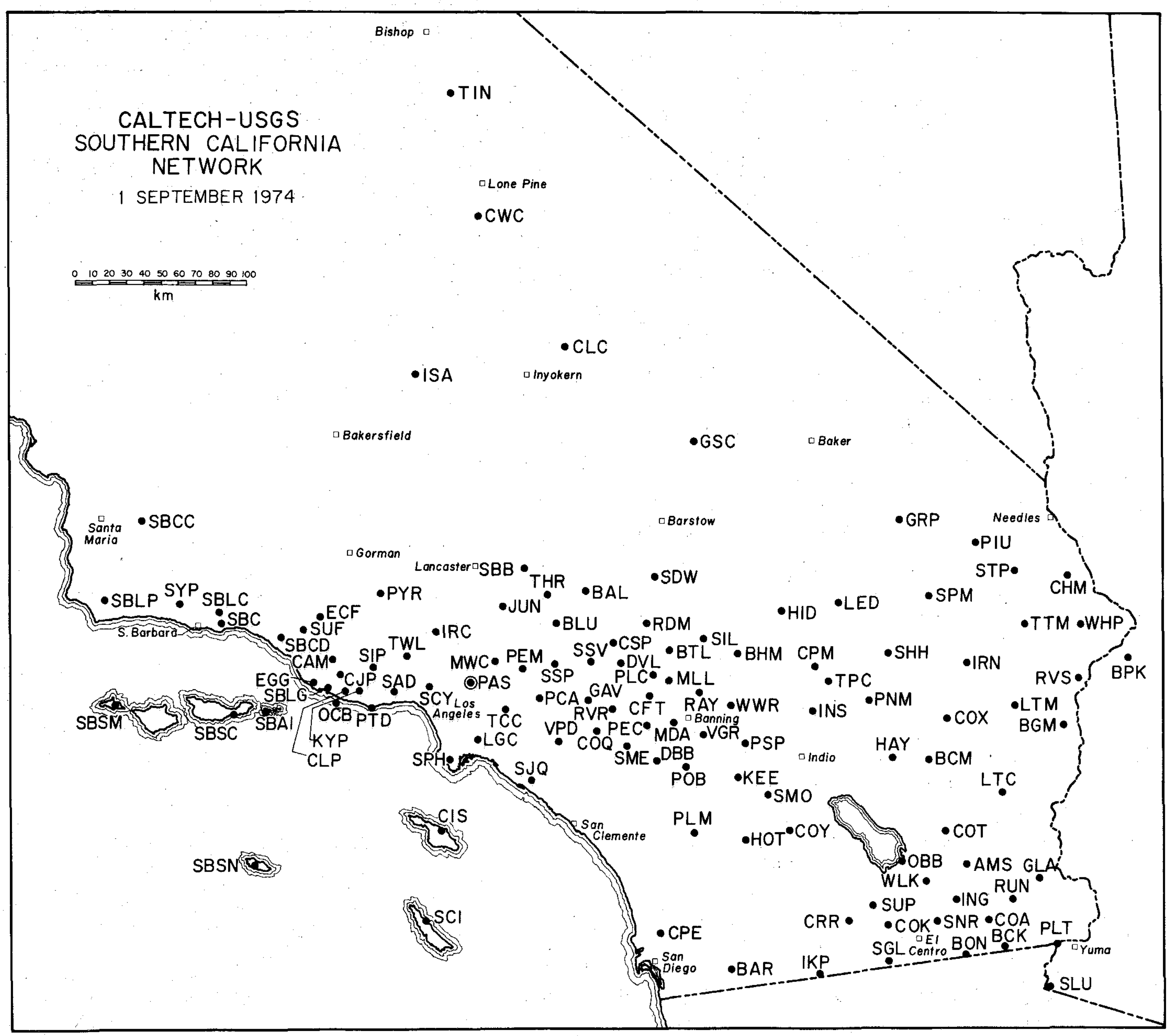
It is mainly because of this concern for southern California that pressures for a seismographic network began to be exerted as early as 1916, and by 1932, when routine epicentral locations of earthquakes throughout southern California began, some six outlying seismographic stations in addition to the Pasadena headquarters were in operation. And shortly thereafter, the team that was formed by Beno Gutenberg, Charles Richter, and Hugo Benioff had made Pasadena a byword among seismologists and geophysicists the world over.

Even with the recent move of the Seismological Laboratory to the new Seeley G. Mudd Building of Geophysics and Planetary Science on the Caltech campus, the Pasadena Seismological Station will have its instruments continuing to operate at the original location about three miles to the northwest. (They were located there initially because of the firm granitic foundation.) By 1974, however, the Pasadena station itself was only one of more than 100 stations comprising the southern California network—one of the largest and densest seismographic "arrays" anywhere in the world (right).

The original purpose of the Seismological Laboratory and its network was to help solve "the earthquake problem in southern California." Over the years, however, the work of the Laboratory has gradually encompassed broader geophysical problems. Even the seismographic network itself has been used as much in attacking wider problems, such as the nature of the earth's interior, as it has been in strictly local problems. Nevertheless, even after almost 50 years, "the earthquake problem in southern California" still remains a major challenge, and new impetus has recently been put into this effort, particularly with regard to earthquake prediction.

The one seismographic instrument common to all outlying stations, and in many cases the only instrument, is the so-called short-period vertical seismometer—recording the vertical component of ground shaking and "tuned" to those frequencies typical of local earthquakes (a few cycles per second). In addition, some stations contain instruments that record the horizontal component of ground motion, and one of the major contributions of the Laboratory has been the design and installation of long-period seismographs—instruments that are "tuned" to the low frequencies typical of distant earthquakes. And a number of key stations contain Wood-Anderson torsion seismographs—the instruments used in the original definition of earthquake magnitude by Richter in 1935, which are still essential in determining magnitudes of local shocks.

Seismographic stations of the southern California network, operated jointly by Caltech and the U. S. Geological Survey. Seismic signals from most of these stations are telemetered to Pasadena on leased telephone lines or by radio. A few such stations are operated co-operatively with other groups such as the California Department of Water Resources and the University of California at San Diego.

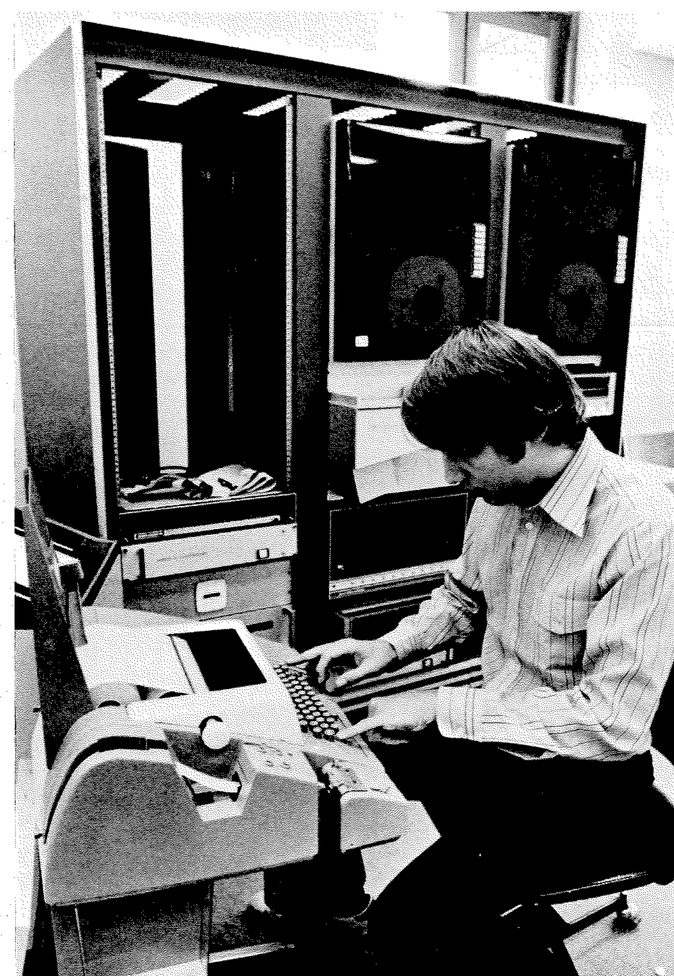


AMS Amos
BAL Baldy Mesa
BAR Barrett
BCK Brock's Farm
BCM Big Chuckwalla Mts
BGM Big Maria Mts
BHM Bighorn Mts
BLU Blue Ridge
BON Bonds Corner
BPK Black Pk
BTL Butler Pk
CAM Camarillo Hills
CFT Crafton Hills
CHM Chemehuevi Mts
CIS Catalina Island
CJP Conejo Pk
CLC China Lake
CLP Clarks Pk
COA Coachella
COK Cook Rch
COQ Corona Quarry
COT Chocolate Mts
COX Coxcomb Mts
COY Coyote Mtn
CPE Camp Elliot
CPM Copper Mtn
CRR Carrizo
CSP Cedar Springs
CWC Cottonwood
DBB Double Butte
DVL Devil Canyon
ECF Echo Falls
EGG Egg Rch
GAV Glen Avon
GLA Glamis
GRP Granite Pass
GSC Goldstone
HAY Hayfield
HID Hidalgo Mtn
HOT Hot Springs Mtn
IKP Inkopah
ING Ingram Rch
INS Inspiration
IRC Iron Canyon
IRN Iron Mts
ISA Isabella
JUN Juniper Hills
KEE Keen Station
KYP Key Point
LED Lead Mtn
LGC Lakewood Golf Course
LTM Little Maria Mtns
LTC Little Chuckwalla Mtns
MDA Mt Davis
MLL Mill Creek
MWC Mt Wilson
OBB Obsidian Butte
OCB Ocean Bottom
PAS Pasadena
PCA Pomona
PEC Perris
PEM Pine Mtn
PIU Piute Mts
PLC Plunge Cr
PLM Palomar
PLT Pilot Knob
PNM Pinto Mts
POB Polly Butte
PSP Palm Springs
PTD Point Dume
PYR Pyramid
RAY Raywood Flat
RDM Round Mtn
RUN Ruthven
RVR Riverside
RVS Riverside Mts
SAD Saddle Pk
SBAI Anacapa Is
SBB Saddleback Butte
SBC Santa Barbara
SBCC Colson Canyon
SBCD Casitas Dam
SBLC La Cumbre Pk
SBLG Laguna Pk
SBLP Lompoc
SBSC Santa Cruz Is
SBSM San Miguel Is
SBSN San Nicolas Is
SCI San Clemente Is
SCY Stone Canyon Res
SDW Sidewinder Mine
SGL Signal Mtn
SHH Sheephole Mts
SIL Silver Pk
SIP Simi Pk
SJQ San Joaquin Res
SLU San Luis
SME Santa Rosa Mine
SMO Santa Rosa Mtn
SNR Schaffner Rch
SPH San Pedro Hill
SPM Ship Mts
SSP Sunset Pk
SSV San Sevaine
STP Stepladder Mts
SUF Sulfur Ridge
SUP Superstition Mtn
SYP Santa Ynez Pk
TCC Turnbull Canyon
THR Three Sisters
TIN Tinemaha
TPC Twentynine Palms
TTM Turtle Mts
TWL Twin Lakes
VGR Vista Grande
VPD Villa Park Dam
WHP Whipple Mts
WLK Wiest Lake
WWR Whitewater

A Caltech telemetered seismometer vault, with an AT&T microwave repeater station in the background, at station GLAMIS, near the California-Arizona border north of Yuma.

The traditional and still widely used method of seismographic recording has been by means of a fine light spot focused on a sheet of photographic paper mounted on a rotating drum. The paper must of course be changed daily, and over the years a number of organizations have contributed to our understanding of local earthquakes by providing personnel to change records. For example, stations at Tinemaha (TIN) and Cottonwood (CWC) are serviced daily by personnel of the Los Angeles Department of Water and Power, China Lake (CLC) by the U.S. Navy, Hayfield (HAY) by the Metropolitan Water District, and Riverside (RVR) by the Riverside Fire Department. Because the timing of the arrival of earthquake waves at a station is critical—normally measured to the nearest tenth of a second—each station must be equipped with a radio receiver that is programmed periodically to receive U.S. Bureau of Standards time signals, so that the station chronometer (which puts a mark on the record every minute) can be calibrated against a standard time base.

Partly because of these logistical problems—the necessity for daily servicing and the maintenance of radio receivers at each station—almost all of the network expansion since 1966 has been with equipment that continuously telemeters signals to Pasadena, using a frequency-modulated tone on leased telephone lines or by radio links. In this way, the size of individual stations can be reduced to a simple buried box (right, above), and the time code can be added to all signals together at Pasadena. In addition—and perhaps most important—the signals are immediately visible in Pasadena, so that an earthquake can be located as rapidly as the data can be processed. One of our principal projects at the moment is to feed the telemetered signals directly into a computer on a real-time basis, so that an earthquake location and magnitude can be automatically obtained within a few seconds of the event. Preliminary results suggest that this should be possible within the near future, utilizing the Seismological Laboratory's new NOVA 1200 "mini" computer (right).



Graduate student Larry Burdick locates an earthquake using the Laboratory's NOVA computer.

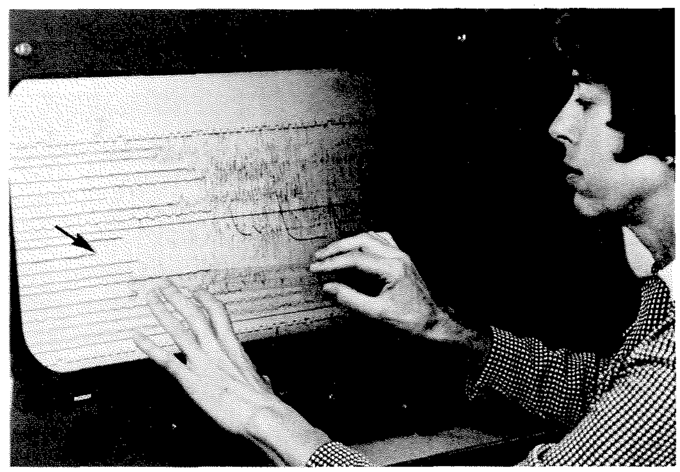
Even with the present system of data analysis at the Laboratory, in which the arrival times of seismic signals from the various stations are read manually and these data then entered directly into the computer keyboard, relatively quick epicentral locations are possible. The 1971 San Fernando earthquake, despite its 6:01 a.m. occurrence, was accurately pinpointed within about one-half hour. And the similar sized Borrego Mountain earthquake of 1968, which occurred at about 6:30 p.m., was located quickly enough so that portable instruments were operating in the epicentral area (a 200-mile drive from Pasadena) and the fault trace identified in the field by midnight.

One of the public service obligations of the Laboratory, in addition to serving the news media, is the notification of responsible authorities concerning potentially damaging earthquakes. For every local shock above magnitude 5.0, we must relay prompt epicentral and magnitude data—on a 24-hour basis—to federal and state disaster authorities and agencies such as the California Division of Safety of Dams and the U.S. Army Engineers.

During the past couple of years, a major expansion of the network has taken place in collaboration with the U.S. Geological Survey, which has not only provided additional funding but has also stationed two Geological Survey scientists at the Seismological Laboratory in connection with management of joint parts of the network. A total number of 300 stations is envisaged within the next few years, and it is clear that this network expansion will also necessitate improved data analysis facilities and methods.

Other groups besides the Geological Survey continue to support parts of the network operation. Particularly in recognition of the Laboratory's public service activities, the State of California is now providing limited annual support, and the Office of Naval Research has recently helped with the offshore stations and epicentral determinations. Likewise, the National Science Foundation and the Atomic Energy Commission have aided the network. And a particularly valuable source of help for many years has been the Earthquake Research Affiliates, a group of private companies and public utilities that give continuing support both to Caltech's Seismological Laboratory and to its earthquake engineering group.

What is the scientific justification for a 300-station network? The opportunity for greatly improved earthquake locations is probably not sufficient argument in itself, although this will certainly provide added insight into the nature and exact locations of our active faults, and more homogeneous statistics will be valuable for engineering purposes. But our real hope is that by continuously monitoring earthquakes and their physical parameters, we will recognize temporal changes that systematically precede earthquakes, and thus, eventually, develop an earthquake-prediction capability. Members of the Laboratory staff have already observed marked changes in seismic velocities that apparently preceded two local earthquakes



Technician Shirley Fisher reads a record of the San Fernando aftershock of March 9, 1974 (magnitude 4.5). Telemetered seismic signals from 18 outlying stations are recorded together on 16-mm film (here enlarged), with WWVB radio time signals at top and bottom. The first arriving signal (arrow) is from Iron Canyon, the station closest to the epicenter. More distant stations have successively later arrivals.

in a way that is consistent with theoretical models of strain build-up and resulting fracture. But to test the general applicability of this model, far greater seismographic coverage is necessary than we have at present.

Perhaps the day is not too far off when the Seismological Laboratory will not only be reporting earthquakes *after* they happen, but we will have also developed a predictive system that is sufficiently reliable for some sort of meaningful warnings to be issued *before* an event. This field involves many very serious problems, both scientific and social, but it is also probably the most exciting research effort in which the southern California network has ever been involved. □