IRC. 762-A

GEOLOGICAL SURVEY CIRCULAR 762-A

Seismic Engineering Program Report, January—April 1977

Prepared on behalf of the
National Science Foundation
Grant CA–114

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1977

United States Department of the Interior

CECIL D. ANDRUS, *Secretary*

Geological Survey

V. E. McKelvey, *Director*

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PREFACE

This Seismic Engineering Program Report is an informal document primarily intended to keep the ever-growing community of strong-motion data users apprised of the availability of data recovered by the Seismic Engineering Branch of the U.S. Geological Survey. The Seismic Engineering Program of strong-motion instrumentation is supported by the National Science Foundation (Grant CA-114) in cooperation with numerous Federal, State, and local agencies and organizations.

This issue contains a summary of the accelerograph records recovered from the National Strong-Motion Network during the period January 1 through April 30, 1977. Also included are reports on the Romanian earthquake of March 4, 1977 and the Gazli, U.S.S.R. earthquake of May 17, 1976, along with abstracts of recent reports, notes on strong-motion information sources, and the availability of digitized data. The information presented in table 1 was recovered (although not necessarily recorded) during the period January through April, 1977. This procedure will be continued in future issues in order that the dissemination of strong-motion data may be as expeditious and current as practicable.

> Note: The Seismic Engineering Program Report will no longer be published on a quarterly basis. Future issues will contain information on strong-motion records recovered from the national network during the periods January through April, May through August, and September through December.

R. L. Porcella, Editor
U.S. Geological Survey
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Menlo Park, CA 94025

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January—April 1977

RECENT STRONG-MOTION RECORDS

Thirty-two strong-motion records were recovered from the U.S. Geological Survey's national network of strong-motion instrumentation during the period January 1 through April 30, 1977. The network is supported by the National Science Foundation in cooperation with numerous government and private agencies and organizations. The 32 records obtained during this last period were recovered from instrumentation owned by 12 different organizations that are participating in this cooperative effort (table 1).

The January 8, 1977 Briones Hills earthquake swarm in Contra Costa County, California produced six strong-motion records from four sites; the maximum acceleration (0.11 g) was recorded by an instrument at the Briones Dam outlet tower station. Fifteen additional records (all less than 0.05 g maximum acceleration) have subsequently been recovered from stations in the San Francisco Bay area and may or may not be related to the January 8 events (table 1). For additional information on this earthquake swarm see "The Briones Hills Earthquake Swarm of January 8, 1977, Contra Costa County, California" by Bolt, Stifler, and Uhrhammer, in the section entitled "Notes on Strong-Motion Information Sources", in this issue.

PRELIMINARY REPORT ON THE ROMANIAN EARTHQUAKE OF MARCH 4, 1977

by C. Rojahn

The epicenter of the destructive March 4, 1977 Romanian earthquake was located in the Vrancea region of the Carpathian Mountains approximately 166 km north-northeast of the capital city of Bucharest (fig. 1). On the basis of data from a local seismograph network, K. Fuchs of the Geophysical Institute at Karlsruhe, West Germany has located the event at lat 45.87° N., long 26.75° E. at a depth of 110 km (B. A. Bolt, written commun., March 24, 1977). The National Earthquake Information Service of the U.S. Geological Survey has assigned a magnitude of 7.1 (m_b) and an origin time of 1921:54.2 GMT (2122 local time).

There were nine strong-motion accelerographs and two seismoscopes installed in Romania at the time of the earthquake. Two other accelerographs, that had been supplied to Romania several years ago under the Balkan project, were not installed. Of the nine accelerographs installed (table 2), six were located at ground level sites in Bacau, Vrincioaia, Focsani, Galati, and Bucharest (two), and three were located near or at the top of 11-, 12-, and 13-story buildings in Bucharest and Galati (fig. 1). The two seismoscopes (table 3) were located at ground level sites in Bucharest and Galati. Records were recovered from the ground level accelerographs in Focsani, Vrincioaia, and Bucharest, from the accelerographs near or at the tops of two buildings in Bucharest, and from both seismoscopes. The accelerograph in Bacau, however, was not triggered, and the two accelerographs in Galati and the one in Bucharest malfunctioned.

Of the seven records recovered, only the two seismoscope records and the two accelerograms (analog film records) from Bucharest are definitely intact; the third Bucharest accelerogram, an analog magnetic tape record, has not yet been processed and may be intact. The Vrincioaia accelerogram is incomplete because the instrument's film drive mechanism failed to operate continuously during the earthquake, and the Focsani accelerogram was inadvertently destroyed while being developed. The complete Bucharest ground record is shown in figure 2, a rough tracing of the Bucharest seismoscope record is shown in figure 3, and the partial Vrincioaia ground record is shown in figure 4. Copies of the film analog accelerogram from Bucharest (recorded at the top of a ten-story building) and the Galati seismoscope record have not yet been received from Romania.

Both the Bucharest ground level accelerograph record and the Bucharest seismoscope record were recovered from the basement of a one-story reinforced concrete frame building located at the Building Research Institute (INCERC) complex in the eastern part of the city (fig. 5). The accelerogram was recorded on a Japanese-built three-component SMAC-B accelerograph with 10 Hz natural frequency accelerometers that are critically damped. The seismoscope record was recorded on a Wilmot-type seismoscope with a natural period of 0.75 sec and damping inversely proportional to the amplitude of recorded motion (nominally, from 7 to 15 percent of critical damping).

The most notable features of the Bucharest ground level accelerograph record (fig. 2) are the 1.1- and 1.6-sec large amplitude (0.16- and 0.20-g) pulses recorded on the E-W and N-S components about 20 sec after the instrument triggered (trigger level is approximately 0.01 g vertical acceleration). After each pulse, the accelerations are lower in amplitude and higher in frequency. By contrast, there are no long-period pulses present on the vertical component where accelerations are generally in the 8- to 10-Hz frequency range with a maximum acceleration of about 0.12 g. The extent to which the amplitudes of acceleration (for each component) in the frequency range near and above 10 Hz will be affected after instrument corrections have been applied is not yet known.

Damage from strong ground shaking was most severe in Bucharest (population approx. 1.7 million), 166 km south of the epicenter, where 35 buildings reportedly collapsed and numerous other buildings sustained structural, architectural, and/or contents damage. In the small town of Vrincioaia (fig. 1), 2 km west of the epicenter, the effects of strong ground shaking were less severe; superficial cracking of adobe/wood walls in one-story dwellings (fig. 6) was typical of observed damage. In the cities of Focsani and Buzau, located between the epicentral area and Bucharest (fig. 1), unreinforced masonry walls in low-rise buildings partially or totally collapsed, and movement between structural elements and adjacent masonry in-fill walls was observed in recently constructed and engineered buildings. In Galati, to the southeast of the epicenter, about 20 older buildings were seriously damaged (none collapsed) and numerous others sustained slight or moderate damage (Youd, 1977). In several small towns to the north of Ploiesti (the city of Ploiesti and its refineries were not observed by this reporter) at least one several-hundred-year-old building collapsed and other unreinforced masonry-wall buildings were heavily damaged (G. F. Bowles, oral commun., April 6, 1977). In the cities of Craiova, Alexandria, and Zimnicea, which are located to the west and southwest of Bucharest (fig. 1), unreinforced masonry walls in low-rise buildings reportedly collapsed partially or totally. By contrast, the effects of strong ground shaking were slight in Brasov and Bacau, to the west and north of the epicenter, respectively.

None of the large dams located within 250 km of the epicenter (fig. 1) was damaged by the earthquake (G. F. Bowles, oral commun., April 6 1977). Poiana Usuli Dam, an 81-m-high concrete buttress dam located 60 km northwest of the epicenter, was closest to the epicenter. The only reported effect was that two men on and near the dam at the time of the earthquake had great difficulty in standing. On the basis of this observation the intensity of shaking would be VII on the Modified Mercalli Scale. The other three dams and their locations relative to the epicenter are: Bicaz Dam, 128-m-high gravity dam, 129 km; Vidraru Dam, 167-m-high reinforced concrete arch dam, 169 km; and Vidra Dam, 121-m-high rockfill dam, 240 km.

In Bucharest, the greatest destruction occurred in the center of the city (figs. 7 and 8), where 32 older buildings and one recently constructed and engineered building collapsed. In general, the older buildings that collapsed (fig. 8) were non-earthquake resistant structures designed and built before the 1940 earthquake, a similarly sized and located earthquake that also destroyed and heavily damaged many buildings in Bucharest. Typically, these older buildings were reinforced concrete frame structures, 7 to 14 stories high, with a soft first story (that is, in comparison to the upper stories where numerous interior and exterior walls provided lateral stiffness, the first floor was relatively open with many windows and few interior and exterior walls). Furthermore, the quality of concrete was poor (mortar could be chipped away with a pen) and there was too little steel and too few ties in the columns and beams, particularly in the column-beam joints. By contrast, modern buildings that were designed in accordance with lateral force code requirements (adopted after the 1940 earthquake) performed better than their older counterparts. With the exception of one collapsed building, a three-story reinforced concrete flat-slab building (fig. 9), structural damage to modern buildings was generally slight. Nonstructural damage, on the other hand, was extensive with cracking of in-fill masonry walls being particularly common.

On the outskirts of the city, two recently constructed multi-story buildings collapsed, and unreinforced masonry walls in many older one- and two-story dwellings were extensively damaged (fig. 10). Of the major types of modern construction in existence at the time of the March 4 earthquake (that is, multi-story reinforced concrete frame buildings with and without a soft first story; multi-story reinforced concrete shear-wall buildings; and large panel buildings composed of large precast reinforced concrete floor and wall elements), the stiffer buildings sustained less structural and nonstructural damage than the more flexible ones. Large panel buildings (fig. 11), in particular, performed very well. Their good performance may be related to the fact that their fundamental or lowest natural frequencies of vibration have been observed to be high (2 to 5 Hz (Diaconu and others, 1970)) in comparison to the predominant frequencies of high-amplitude ground motion in Bucharest (0.6 to 1 Hz).

A preliminary summary of this reporter's estimates of the Modified Mercalli intensities of shaking in the most heavily affected areas of Romania is given in table 4. On the basis of preliminary reports given by various Romanian officials immediately after the earthquake, it is estimated that approximately 1500 lives were lost, 2,000 persons were injured, and 20,000 people were left homeless. Most of the losses are believed to be related to the 35 buildings that collapsed in the city of Bucharest.

Acknowledgment.--The author gratefully acknowledges the Earthquake Engineering Research Institute and the National Science Foundation for providing the travel funds that made this investigation possible.

References:

Diaconu, E., Ciongradi, I., Vasilescu, D., Groper, M., and Rotaru, I., 1970, Experimental determination of the dynamic characteristics of some actual buildings: Conference on Earthquake Analysis of Structures, Iasi, Romania, Proc., p. 127-145.

Youd, T. L., 1977, Reconnaissance report of geotechnical observations for the 4 March 1977 Romanian earthquake: U.S. Geol. Survey Open-file Rept. 77-375, 22 p.

STRONG-MOTION RECORDS FROM THE MAY 1976 GAZLI, U.S.S.R. EARTHQUAKES

by K. G. Pletnev, N. V. Shebalin, and V. V. Shteinberg

Institute of the Physics of the Earth
U.S.S.R. Academy of Sciences, Moscow

(Editor's note: The following report was compiled by C. Rojahn using material received from N. V. Shebalin on May 23, 1977. It provides additional information on the Gazli earthquake and strong-motion records described in the last issue of the Seismic Engineering Program Report, U.S. Geological Survey Circular 736D. C. Rojahn has also included photographs of building damage in Gazli, taken during his visit to the area five months after the May 17, 1976 earthquake.)

Two days after the April 8, 1976 earthquake (M_S = 7.0, m_{PV} = 6.6) in the western Kysulkum Desert (40.5° N., 63.8° E.), the Institute of the Physics of the Earth (U.S.S.R. Academy of Sciences, Moscow) began operating portable seismic stations in the epicentral area. Initially, a station was established at Gazli, a small town 30 km south of the epicenter, and later at Karakyr Point, located very close to the epicenter of the April 8 event (fig. 12). Both stations were equipped with standard instrumentation: a permanent displacement recorder (S5S seismometers and OSB-1MP portable oscilloscope with GB-IV galvanometers, amplification factor = 100 for the horizontal components and 500 for the vertical component) and a strong-motion displacement recorder (S5S seismometers and ISO-IIM film recorder with GB-IV galvanometers, amplification factor = 100, 10 and/or 1 for the horizontal components). In addition, a triaxial self-contained optically recording accelerograph was located at Karakyr Point. The instrument was installed at ground level and has the following characteristics: sensitivity, 14.5 mm/g; frequency range, 0-20 Hz; film speed, 13-15 mm/sec; a triggering system that starts the instrument at Modified Mercalli Intensity (MMI) IV level ground motion (approx.); and a trigger delay of less than 0.2 sec. The subsurface geology at Karakyr Point consists of clay and sandstone, 1420 m thick, underlain by highly resistant metamorphic schist (fig. 13). During the weeks after the April 8 earthquake, other portable stations were installed in the epicentral area by the Seismological Institute of the Uzbek Academy of Sciences (Tashkent) and other institutions.

From April 10 to May 16 more than 100 aftershocks of the strong April 8 foreshock were recorded, some of them with felt intensities up to VI (MSK scale[1]). The main shock of the sequence occurred on May 17 at 0258:32 GMT with coordinates 40.26° N., 63.30° E.; focal depth about 25-30 km; and magnitude M_S = 7.2, m_{PV} = 6.5. The preliminary fault plane solution for the main shock gives a dip-slip mechanism. The hypothetical source model is shown in figure 12, together with the zone of MSK intensity IX. More than 100 aftershocks were recorded during the next few months; the strongest had a felt intensity of VII (MSK) at the epicenter.

The main shock of May 17 was felt in Gazli with an intensity of about IX. All brick buildings were substantially destroyed (fig. 14), all panel buildings were seriously damaged (fig. 15), and cracks appeared in asphalt roads and concrete pavements. Fortunately, the entire population of Gazli had been evacuated after the first shock of April 8 and was living in nearby temporary wooden buildings and tents. Consequently, casualties related to the main shock were held to a minimum. At Karakyr Point the only adobe building collapsed, and cracks up to 10 m long and approximately 1 cm wide were observed in the ground.

This paper presents the accelerograms of one aftershock of the April 8 event, the main shock of May 17, and four aftershocks of the May 17 event (table 5). An analog representation of the digitization of the May 17 record is shown in figure 16, and copies of the aftershock records are presented in figure 17. The hypocentral distance R is taken from S-P readings and is approximately equal to the actual focal depth.

The strong-motion record from the main shock of May 17 has some defects: the film supply was depleted while the earthquake was in progress (record is therefore limited to the first 15 sec of strong motion); some parts of the film were slightly spoiled (the record was restored by copying the record using a more suitable exposure time); and irregular film movement took place during a short interval of about one sec[2] (it is probable that the acceleration related to the film transport system was constant during this time interval and thus corresponding corrections were introduced in the record).

The May 17 accelerogram shows the unusual nature of the strong motion, particularly the gradual increase of trace amplitude (the maximum amplitude for each component is indicated approximately 8 sec after the instrument triggered). The maximum recorded acceleration is 1.3 g (one-half of peak-to-peak acceleration) at a period of 0.063 sec. The duration of strong-motion acceleration ≥0.5 g is about 6 sec, and the amplitudes of horizontal motion are approximately one-half those of the vertical motion. The aftershock accelerograms are typical of strong-motion records from nearby earthquakes. Fourier amplitude spectra of acceleration for the main shock have been computed (fig. 18). Note the high-frequency characteristics of the vertical component.

More detailed information about the Gazli earthquake will be presented in future reports.

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[1]The MSK intensity scale is approximately equivalent to the MMI scale.

[2]Editor's note: The authors have been requested to describe more precisely the nature of this irregularity.

References:

Aleksin P.A., Graizer V. M., Pletnev, K. G., Shteinberg, V. V., Zainutdinov, K. S., 1976, Kolebaniya grunta pri silnykh zemletryaseniyakh Gazli 1976. Referativnaya informatsiya "Seismostojkoe stroitelstvo" No. 11.

Shteinberg, V. V., Pletnev, K. G., Graizer, V. M., 1977, Akselerogramma kolebaniya grunta pri razrushitelnom zemletryasenii Gazli 17 maya 1976. Referativnaya informatsiya "Seismostojkoe stroitelstvo" No. 1.

ABSTRACTS OF RECENT REPORTS

WESTERN HEMISPHERE STRONG-MOTION ACCELEROGRAPH STATION LIST - 1976

The U.S. Geological Survey (USGS) maintains a network of strong-motion instrumentation for the National Science Foundation in cooperation with other Federal, State, and local agencies within the United States. In addition, cooperation is extended to similar groups in other countries throughout the world. Previous station lists published by the USGS contained information on only those stations considered to be part of the cooperative U.S. network. As more organizations throughout the world have developed networks, it has become obvious that composite lists of stations for each of the major regions of the world would be a valuable document for all concerned. This list furnishes a minimum amount of information on all of the stations in the western hemisphere known to the USGS. It is hoped that others will begin to compile similar lists for all of the stations in Europe, Asia, and the south Pacific regions. No list of this type can be complete. Only partial information is available on the more recently installed stations, and owing to rapid expansion of several of the networks, no information is yet available on some stations. This list is as complete as practicable as of March 1977. Copies may be obtained from Seismic Engineering Branch, Menlo Park.

Reference: U.S. Geol. Survey Open-file Rept. 77-374, May 1977, 113 p.

THE ISLAND OF HAWAII EARTHQUAKES OF NOVEMBER 29, 1975: STRONG-MOTION DATA AND DAMAGE RECONNAISSANCE REPORT

By C. Rojahn and B. J. Morrill

Two earthquakes occurred on the island of Hawaii on November 29, 1975, a magnitude (M_S) 5.7 event at 0335 local time and a magnitude (M_S) 7.2 event at 0447. During the larger event, a maximum acceleration of 0.22 _g_ was recorded in the southern part of Hilo, 43 km north of the epicenter. A 0.05 _g_ threshold duration of 13.7 sec was measured for the same component. Smaller amplitude accelerograph records were obtained at two other locations on the island along with four seismoscope records.

During or subsequent to the larger event, a large sector of the southeastern coastline subsided by as much as 3.5 m. A tsunami generated by the larger event caused at least one death (one person also missing), injury to 28 persons, and significant structural and nonstructural damage.

Only scattered evidence of strong ground shaking was observed in the epicentral area, and most of the several dozen nearby structures sustained little or no structural damage from ground damage.

Only scattered evidence of strong ground shaking was observed in the epicentral area, and most of the several dozen nearby structures sustained little or no structural damage from ground shaking. In Hilo, 45 km north of the M_S = 7.2 epicenter, structural and nonstructural damage was slight to moderate but more extensive than elsewhere on the island.

Reference: Seismol. Soc. America Bull., v. 67, no. 2, April 1977, p. 493-515.

NOTES ON STRONG-MOTION INFORMATION SOURCES

EARTHQUAKE IN ROMANIA, MARCH 4, 1977

David J. Leeds, Editor

A Preliminary Report to Earthquake Engineering Research Institute

This preliminary report to the Earthquake Engineering Research Institute (EERI) contains the contributions of numerous individuals, including members of an EERI reconnaissance team and a National Academy of Engineering team that inspected the areas of greatest damage during the week following the magnitude 7.2 event. Included in the report is information on damage and intensities, earthquake mechanism and aftershocks, building regulations and design criteria, structural damage in the Bucharest area, strong-motion instrumentation, ground motion results, and selected references.

Reference: Earthquake Engineering Research Institute Newsletter, v. 11, no. 3B, May 1977.

STRONG-MOTION DATABASE USER'S MANUAL

by April Converse

A Preliminary Draft, May 1977

The U.S. Geological Survey (USGS) has developed a database system to provide ready access to information about the strong-motion instrumentation network maintained by the USGS. This user's manual has been designed both to lead the new user through some of the intricacies of the system in the most effective way and to supply the experienced user with complete descriptions of all entries as they currently exist.

As is indicated at various places in the manual, the preliminary status of the data in the database does not itself do justice to the database management system designed to manipulate the data. Also, improvements in the power and flexibility of the system will eventually be made. The manual is a preliminary version that describes the USGS database management system and allows retrieval of the limited amount of information presently in the data base by persons who have access to the computing facilities at Lawrence Berkeley Laboratory.

This manual is available on request from the Seismic Engineering Branch, Menlo Park.

SUMMARY OF THE STRONG-MOTION NETWORK OPERATIONS CONFERENCE

Menlo Park, California, February 14-18, 1977

By D. A. Johnson

This report summarizes the results of the annual strong-motion conference conducted to evaluate the status of field operations and to coordinate a common approach in the operation of strong-motion instrumentation programs among numerous agencies. Various routine maintenance and record recovery problems are discussed including power supplies, threshold triggers, timers, film transport systems, lamp voltage regulation, data quality, station and instrument documentation, processing of earthquake records and data reports. The strong-motion network in the United States is briefly described including those programs operated by the U.S. Geological Survey (USGS), Army Corps of Engineers (COE), California Division of Mines and Geology (CDMG) and California Institute of Technology (CIT). Organizations represented at the conference included

USGS members from five regional offices, COE, CIT, CDMG, California Department of Water Resources, California Division of Highways, and Kinemetrics, Inc., a manufacturer of strong-motion recording equipment.

Copies of this report may be obtained by writing to the Seismic Engineering Branch, Menlo Park.

STRONG-MOTION EARTHQUAKE RECORDS IN JAPAN, 1975

v. 20, December 1976

Published by the National Research Center for Disaster Prevention Science and Technology Agency

This publication is a compilation of earthquakes recorded on strong-motion accelerographs in Japan during the year 1975. Included are reproductions of some of the strong-motion records; time, hypocenter, magnitude and intensity of each event; location and brief description of each recording station; and accelerograph component directions and maximum recorded accelerations.

Information regarding this series of publications is available from the Strong-Motion Earthquake Observation Council, National Research Center for Disaster Prevention, No. 15-1 Ginza 6-chome, Chuoku, Tokyo.

THE BRIONES HILLS EARTHQUAKE SWARM OF JANUARY 8, 1977, CONTRA COSTA COUNTY, CALIFORNIA

by Bruce A. Bolt, J. Stifler and R. Uhrhammer

Fairly precise locations of a swarm of earthquakes in the hills east of San Francisco Bay have been obtained. The largest event ($M_L = 4.3$) had an origin time of 093807.5 ($\pm$0.11 sec) 8 January 1977 (GMT), a latitude of 37° 54.31 $\pm$ 0.69 N. and longitude 122° 10.97 $\pm$ 0.50 W. and a focal depth of 9.5 $\pm$ 0.8 km. The P fault-plane solution for all earthquakes in the swarm was consistent with right-lateral slip on a plane with strike N. 28° W. and dip 65° SW. No surface rupture was observed, but the mechanism is consistent with present regional deformation. Displacement seismograms recorded at Berkeley, Calif. show an extraordinary similarity of wave form, and the calculated relative seismic energy suggests a very limited region of successive slip surfaces.

Reference: Seismol. Soc. America Bull., in press.

STRONG-MOTION EARTHQUAKE ACCELEROGRAMS DIGITIZED AND PLOTTED DATA

Publication no. 54, v. II, Uncorrected Data Part C, Accelerograms II C28 - II C43

Published by the Institute of Earthquake Engineering and Engineering Seismology, University "Kiril and Metodij", Skopje Yugoslavia

This is the first publication of the Institute of Earthquake Engineering and Engineering Seismology, University "Kiril and Metodij", Skopje, in the series of publications planned to present digitized and processed data of the earthquakes that took place in Fruili, northeast Italy, close to the Yugoslav-Italian border, in the period from May 6 to September 15, 1976. Most of these earthquakes were felt also in Slovenia, on the territory of Yugoslavia.

The disastrous earthquakes of May 6 and September 15, 1976, and a considerable number of aftershocks were recorded by instruments of the Yugoslav strong-motion network. During this period, the accelerographs installed in Ljubljana, Breginj, Kobarid and Robic produced 32 records, and 6 records were recovered from seismoscopes.

This and further publications will present only the data of the more significant records, that is, those having maximum accelerations larger than 5% g. Of the 32 records from the Fruili earthquakes, 16 have been processed and presented in this volume.

The seismological data listed in this publication, (for example, time, epicenter, coordinates, magnitude and intensity) have been obtained by seismological observatories in Ljubljana, Zagreb and Skopje.

A SURVEY OF THE CANADIAN STRONG-MOTION SEISMOGRAPH NETWORK

by Garry C. Rogers

Victoria Geophysical Observatory, Seismology Division, Earth Physics Branch, Department of Energy, Mines and Resources, Victoria, B.C.V8X3X3

At the end of 1974 there were 45 accelerographs and 75 seismoscopes deployed in Canada. The Department of Energy, Mines, and Resources and the National Research Council of Canada have installed most of the instruments, but one-quarter of them are privately owned. Three- quarters of the instruments are located near the west coast with the next largest concentration in the St. Lawrence Valley region. There is one instrument in the Arctic. The majority have been deployed to measure ground motion in populated areas, but a few have been deployed in areas of higher seismicity remote from population centers. In western Canada particular emphasis has been placed on measuring the response of different soil types and soil depths. The only major structures in the country that have been instrumented are two large dams. This paper presents descriptive information on all of the accelerograph sites in Canada and discusses the instrumentation programs presently underway.

DATA REPORTS AND AVAILABILITY OF DIGITIZED DATA

The strong-motion records from the February 9, 1971 San Fernando earthquake and most of the significant records prior to that event have been digitized by the California Institute of Technology (CIT). Processing and analysis of the data have been presented in a series of reports containing (1) uncorrected digital data, (2) corrected accelerations, velocities, and displacements, (3) response spectra, and (4) Fourier amplitude spectra.

The digitization and analysis of the significant records subsequent to the San Fernando earthquake have been carried out by the U. S. Geological Survey (USGS). A report containing digitized data and spectra for the significant records collected in 1971 has been released as Open-file Report 76-609, available upon request, and a tape containing all the numerical data is available from the Environmental Data Service (see below).

Future reports in this series will include an up-to-date collection of records from Lima, Peru (in press). Estimates of the publication dates of these future reports are as follows:

Records from 1972:	July 1977
Records from 1973:	September 1977
Records from 1974:	December 1977
Records from 1975:	March 1978

Table 6 presents a list of the records to be contained in each of these data reports.

The digitized data from the CIT digitization program are available from the Environmental Data Service (EDS) and the National Information Service for Earthquake Engineering at the University of California, Berkeley (NISEE) in the forms indicated below. The magnetic tape digital data from subsequent years will be available from EDS and NISEE at approximately the same time as the data reports are published.

CIT Volume I data (uncorrected) on cards: EDS
CIT Volume I data on tape: EDS and NISEE
CIT Volume II data (corrected) and Volume III data (response spectra) on tape: NISEE
SEB 1971 data (complete): EDS and NISEE

Inquiries should be addressed to:

1. EDS/NOAA
   National Geophysical and Solar-Terrestrial Data Center
   Mail Code D-62
   Boulder, CO 80302

2. NISEE/Computer Applications
   Davis Hall, UC Berkeley
   Berkeley, CA 94720

3. Seismic Engineering Branch, USGS
   345 Middlefield Rd., Mail Stop 78
   Menlo Park, CA 94025

Table 1.- *Summary of accelerograph records: January - April 1977*

Event	Station (owner)[1]	Station coord.	S-t time[2] (sec)	Comp	Max accl[3] (g)	Duration[4] (sec)
26 November 1976 Cent. California 1852 GMT Magnitude and epicenter unknown	Hollister, Calif. Melendy West (USGS)	36.59 N 121.19 W	-		**	
	San Juan Bautista Fire station (CDMG)	36.86 N 121.54 W	-		**	
24 December 1976 2318 GMT Imperial Valley 32.90N, 115.60W Magnitude 3.5	El Centro station 8 95 E Cruickshank (CDMG)	32.81 N 115.53 W	-		**	
	Note: One additional record was obtained from El Centro station 9 (USGS) and may be related to this event. Maximum acceleration less than 0.05 g.					
8 January 1977 0938 GMT Walnut Creek, Ca 37.91N, 122.20W Magnitude 4.3	Briones Dam Left crest (CDMG)	37.55 N 122.21 W	-	S40E	0.06	-
				Down	0.02	-
				N50E	0.05	-
	Briones Dam Outlet tower (CDMG)	37.55 N 122.21 W	1.1	N30E	0.05	-
				Down	0.04	-
				N60W	0.11	1-peak
	Oakland Woodward-Lundgren Co. (WLCO)	37.82 N 122.28 W	-		**	
	Note: Two additional accelerograph records obtained at Briones Dam outlet tower; maximum acceleration less than 0.05 g. One seismoscope record recovered at McClure residence (FMC); maximum horizontal displacement approximately 0.5 cm.					
17 January 1977 1113 GMT Imperial Valley 32.47N, 115.18W Magnitude 4.2	Calexico, Calif. Fire station (CIT)	32.67 N 115.49 W	7.0		**	
	Note: Three unidentifiable records were obtained from a nine-channel CR-1 recorder at Imperial County bldg (CDMG). Maximum acceleration less than 0.05 g.					
22 February 1977 0624 GMT Western Nevada 38.53N, 119.24W Magnitude 4.75	Walker, Calif. Fire station (CDMG)	38.51 N 119.48 W	-		**	

See footnotes at end of table

Table 1.- *Summary of accelerograph records: January - April 1977* - Continued

Event	Station (owner)[1]	Station coord.	S-t time[2] (sec)	Comp	Max accl[3] (g)	Duration[4] (sec)
15 July 1976- 22 March 1977 So. California Magnitude and epicenter unknown	Tarzana, Calif. Cedar Hill (CDMG)	34.16 N 118.57 W	4.0	N15W	0.05	-
				Down	0.04	-
				S75W	0.03	-
10 September 1976- 26 January 1977 No. California Magnitude and epicenter unknown	Berkeley, Calif. U C Evans Hall (UC)	36.87 N 122.26 W				
	Basement level		-		**	
	Fifth floor level		-	S12E	0.07	-
				Down	0.02	-
				N78E	0.05	-
	10th floor level		-	S12E	0.06	-
				Down	0.04	-
				N78E	0.04	-

Note: Additional records obtained from unidentified earthquakes include: Alemany Interchange (CSDH), San Francisco, 4 records; 3333 California St (FF), San Francisco, 2 records; Eastman Kodak (EKC), San Francisco, 2 records; Presidio (CDMG), San Francisco, 1 record, 3333 25th St (PTT), San Francisco, 2 records; 575 Market St (STO), San Francisco, 3 records; Treasure Island (CDMG), San Francisco, 1 record; Wadsworth VA Hospital (VA), Los Angeles, 2 records. Maximum acceleration less than 0.05 g.

[1] CDMG - California Division of Mines and Geology
CIT - California Institute of Technology
CSDH - California State Division of Highways
EKC - Eastman Kodak Company
FF - Fireman's Fund Insurance Companies
FMC - Frank McClure
PTT - Pacific Telephone and Telegraph Company
STO - Standard Oil Company
UC - University of California
USGS - U.S. Geological Survey
VA - Veterans Administration
WLCO - Woodward-Lundgren Company

[2] S-wave minus trigger time.
* denotes S-P interval, that is, the earthquake occurred within the instrumental run-time of a previous event.

[3] Unless otherwise noted, maximum acceleration recorded at ground or basement level.
** denotes maximum acceleration is less than 0.05 g at ground stations or less than 0.10 g at upper floors of buildings.

[4] Duration for which peaks of acceleration exceed 0.10 g.

Table 2.- *Accelerograph data, Romanian earthquake of March 4, 1977*

Station location (fig. 1)	Structure size/type	Instrument type and location	Epicentral distance (km)	Focal distance[1] (km)	Maximum acceleration (g)	Duration >.05g lvl (sec)	Total record (sec)
Bacau	11-story shear-wall bldg	MO-2 basement	78	135	**[2]	**[2]	**[2]
Bucharest	1-story frame bldg	SMAC-B basement	166	199	.20	14.7	75
Bucharest	11-story shear-wall bldg	MO-2 basement	166	199	**[3]	**[3]	**[3]
		MO-2 roof	166	199	.3	**[4]	**[4]
Bucharest	13-story frame bldg	RMT-280 12th flr	167	200	**[4]	**[4]	**[4]
Focsani	3-story brick bldg	MO-2 basement	39	117	**[5]	**[5]	**[5]
Galati	12-story frame bldg	MO-2 basement	112	157	**[3]	**[3]	**[3]
		MO-2 roof	112	157	**[3]	**[3]	**[3]
Vrincioaia	1-story shed	MO-2 ground lvl	2	110	.23	Unknown[6]	Unknown[6]

[1] Based on focal depth of 110 km.

[2] Instrument not triggered.

[3] Instrument malfunctioned.

[4] Data not yet received from Romania.

[5] Record destroyed during development.

[6] Record incomplete, film drive mechanism malfunctioned.

Table 3.- *Seismoscope data, Romanian earthquake of March 4, 1977*

Station location (fig. 1)	Structure size/type	Instrument type and location	Epicentral distance (km)	Focal distance[1] (km)	Maximum velocity (cm/sec)
Bucharest	1-story frame bldg	Wilmot, basement	166	199	42
Galati	13-story frame bldg	Wilmot, basement	112	157	**[2]

[1]Based on focal depth of 110 km.

[2]Data not yet received from Romania.

Table 4.- *Preliminary estimates of the Modified Mercalli Intensity of shaking in various parts of Romania*

Intensity of shaking	Location	Epicentral distance (km)	Focal distance[1] (km)
V	Brasov	91	143
VI	Vrincioaia	2	110
VI-VII	Craiova	288	308
	Galati	112	157
VII-VIII	Alexandria	234	259
	Buzau	80	136
	Focsani	39	117
	Ploiesti, north of	115	159
	Zimnicea	268	290
VII-IX	Bucharest	166	199

[1]Based on focal depth of 110 km.

Table 5.- *Gazli earthquakes recorded on the SSRZ accelerograph at Karakyr Point in May 1976*

No.	Date	Event time (GMT)	Coordinates Lat	Long	Magnitude M_{LH}	m_{pv}	Intensity MSK	Hypocentral distance (km)
1	9May1976	0751:15	40.6	63.9	4.8	5.2	5-6	23
2	17May1976	0258:38	40.6	63.4	7.2	6.6	9-10	22
3	18May1976	0416:24	40.3	63.5	4.5	4.7	6	17
4	19May1976	1621:40	40.7	63.5	*	*	7	14
5	23May1976	2305	40	*	4.5	4.5	6	14
6	28May1976	1405:38	40.4	63.5	4.8	4.9	6	10.5

* Data not available at this time.

Table 6.- *Records being processed for data reports*

Date of event	Station location	Maximum accl (g)†
	1972	
January 3, 1972	Managua, Nicaragua; Esso Refinery	0.15
January 5, 1972	Managua, Nicaragua; Esso Refinery	.22
	Managua, Nicaragua; National University	.12
March 4, 1972	Bear Valley, Calif.; Melendy Ranch barn	.15
March 22, 1972	Bear Valley, Calif.; Melendy Ranch barn	.16
July 30, 1972	Sitka, Alaska; Magnetic Observatory	.11
August 27, 1972	Beverly Hills, Calif.; 8383 Wilshire*	.15
	Beverly Hills, Calif.; 9100 Wilshire*	.12
	Los Angeles, Calif.; 6300 Wilshire*	.10
	Los Angeles, Calif.; 6420 Wilshire*	.15
September 4, 1972	Bear Valley, Calif.; CDF Fire Station	.18
	Bear Valley, Calif.; Melendy Ranch barn	.48
	Bear Valley, Calif.; Stone Canyon East	.18
December 23, 1972	Managua, Nicaragua; Esso Refinery	.39
Aftershock B	Managua, Nicaragua; Esso Refinery	.17
Aftershock C	Managua, Nicaragua; Esso Refinery	.32
	1973	
February 21, 1973	Port Hueneme, Calif.; U.S. Naval Laboratory	0.13
March 31, 1973	Managua, Nicaragua; National University	.60
April 26, 1973	Kilauea, Hawaii; Namakani Paio Campground	.17
August 8, 1973	Ferndale, Calif.; Old City Hall	.14
September 16, 1973	Berryessa, Calif.; CDF Fire Station	.18
	1974	
January 31, 1974	Gilroy, Calif.; Gavilan College, Bldg. 10	0.16
February 11, 1974	Los Angeles, Calif.; 420 S. Grand*	.10
	Los Angeles, Calif.; 525 S. Flower, No. Tower*	.13
	Los Angeles, Calif.; 700 W. 7th*	.18
	Los Angeles, Calif.; 533 S. Fremont*	.25
August 14, 1974	Pacoima Dam, abutment	.12
	Vasquez Rocks Park, Calif.	.10
November 28, 1974	Hollister, Calif.; City Hall	.17
	San Juan Bautista, Calif.; 24 Polk St.	.12
	Gilroy, Calif.; Gavilan College Bldg. 10	.14
December 6, 1974	Imperial, Calif.; Imperial Valley College Adm. Bldg.	.11

See footnotes at end of table.

Table 6.- *Records being processed for data reports* - Continued

Date of event	Station location	Maximum accl (g)†
	1975	
January 11, 1975	Petrolia, Calif.; General Store	0.10
	Cape Mendocino, Calif.; Petrolia	.19
January 23, 1975	Imperial, Calif.; Imperial Valley College Adm. Bldg.	.11
March 6, 1975	Bear Valley, Calif.; Melendy Ranch East	.18
May 6, 1975	Shelter Cove, Calif.; Station 2 Power Plant Yard	.18
June 7, 1975	Ferndale, Calif.; Old City Hall	.19
	Cape Mendocino, Calif.; Petrolia	.22
	Petrolia, Calif.; General Store	.19
	Shelter Cove, Calif.; Station 2 Power Plant Yard	.10
June 19, 1975	El Centro Array, Calif.; Station 6, 551 Huston	.10
June 20, 1975	El Centro Array, Calif.; Station 6, 551 Huston	.13
	Holtville, Calif.	.15
August 1, 1975	Oroville Dam, Calif.; Crest	.13
	Oroville Dam, Calif.; Seismograph station	.11
August 2, 1975	Pleasant Valley Pumping Plant, Calif.	.08
	Pleasant Valley, Calif.; Switchyard	.13
September 13, 1975	Parkfield Grade, Calif.; Jack Varian Ranch	.14
	Vineyard Canyon, Calif.	.18
November 14, 1975	Ferndale, Calif.; Old City Hall	.18
	Cape Mendocino, Calif.; Petrolia	.13
	Petrolia, Calif.; General Store	.10
November 29, 1975 0335 (local time)	Hilo, Hawaii; UH Cloud Physics Lab.	.15
November 29, 1975 0447 (local time)	Honokaa, Hawaii; Central Service Bldg.	.11

† Maximum acceleration at ground or basement level.
* The records from the upper levels of these buildings are being digitized.

EXPLANATION

- ○ Ground level accelerograph, no record obtained
- ◒ Ground level accelerograph, partial record obtained
- ● Ground level accelerograph, complete record obtained
- ▲ Ground level seismoscope, record obtained
- □ Instrumented building, no record obtained
- ■ Instrumented building, record obtained (upper level only)

Figure 1.- Map of Romania showing locations of cities affected by the March 4 earthquake, major large dams within 250 km of the epicenter, and strong-motion instruments installed at the time of the earthquake.

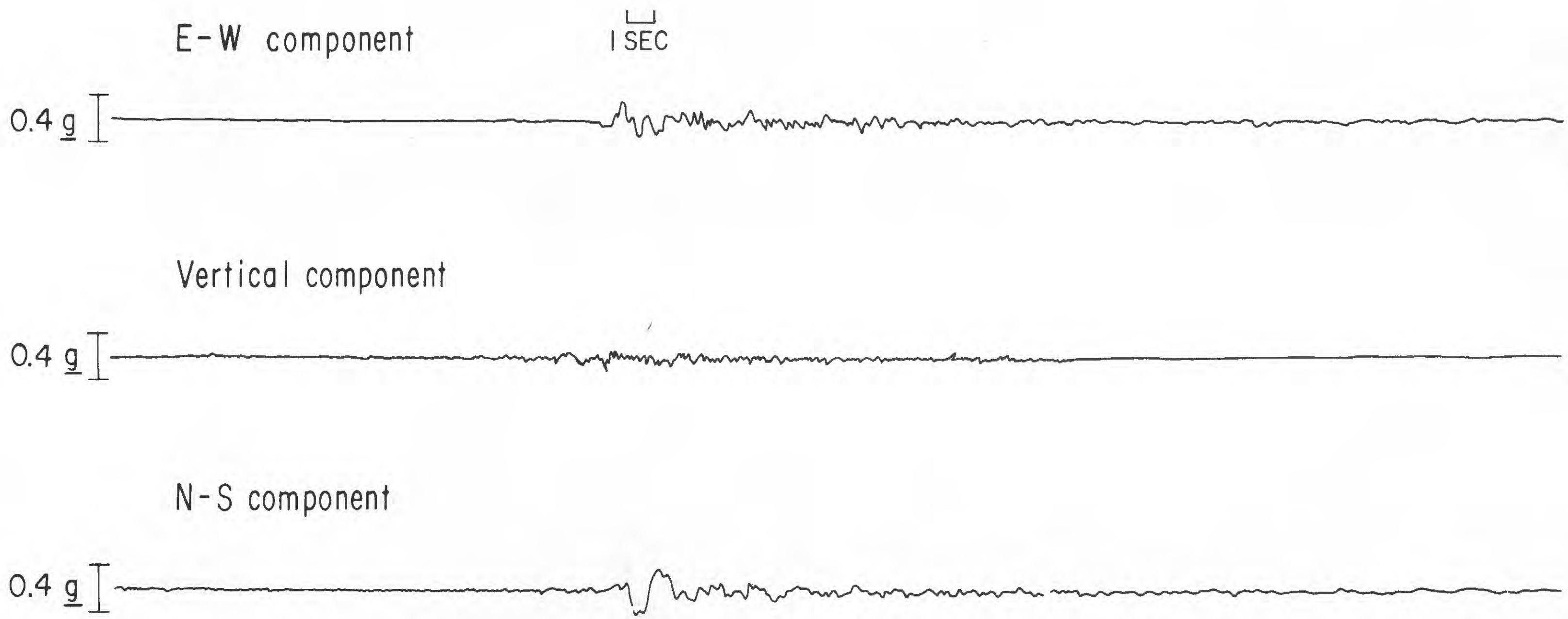


Figure 2.- SMAC-B strong-motion accelerogram recorded on March 4, 1977 in Bucharest, Romania. Recording accelerograph was located in the basement of a one-story reinforced concrete frame building at the Building Research Institute (INCERC). Record provided by G. Serbanescu of INCERC.

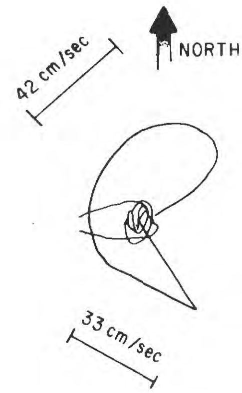


Figure 3.- Rough tracing of seismoscope record recorded on March 4, 1977 in Bucharest, Romania. Recording instrument was located in the basement of a 1-story reinforced concrete frame building at the Building Research Institute (INCERC). Velocities shown on the record were computed by INCERC personnel.

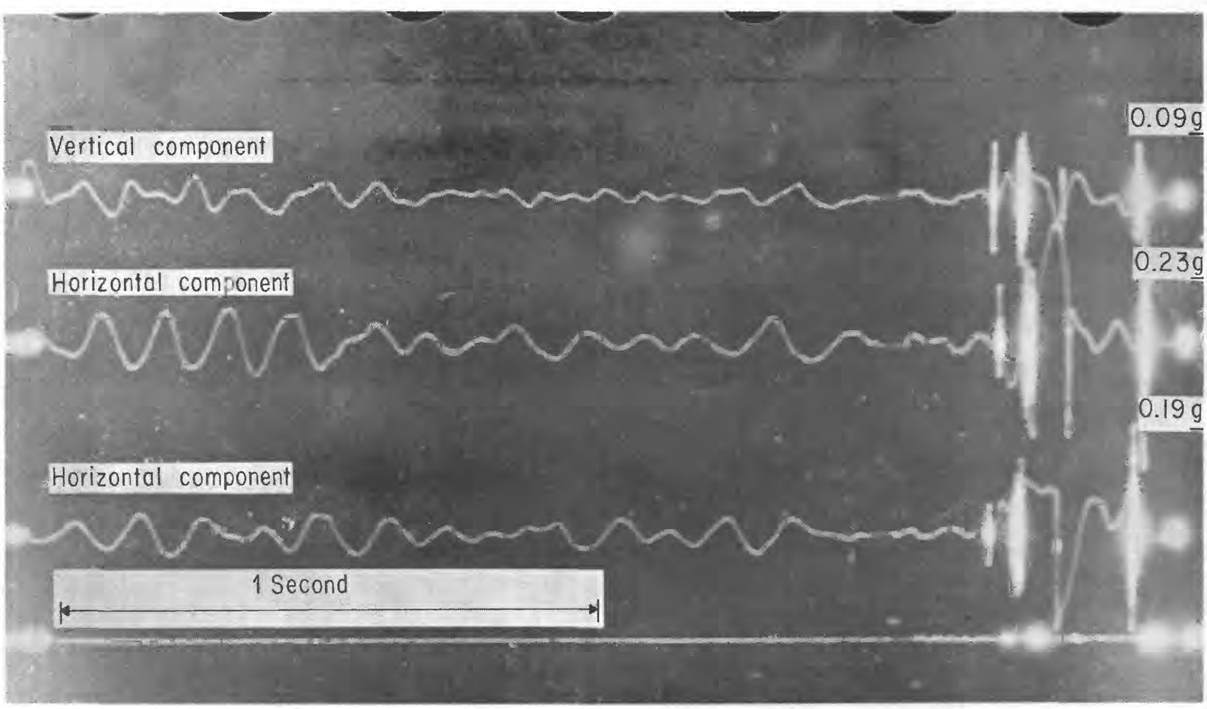
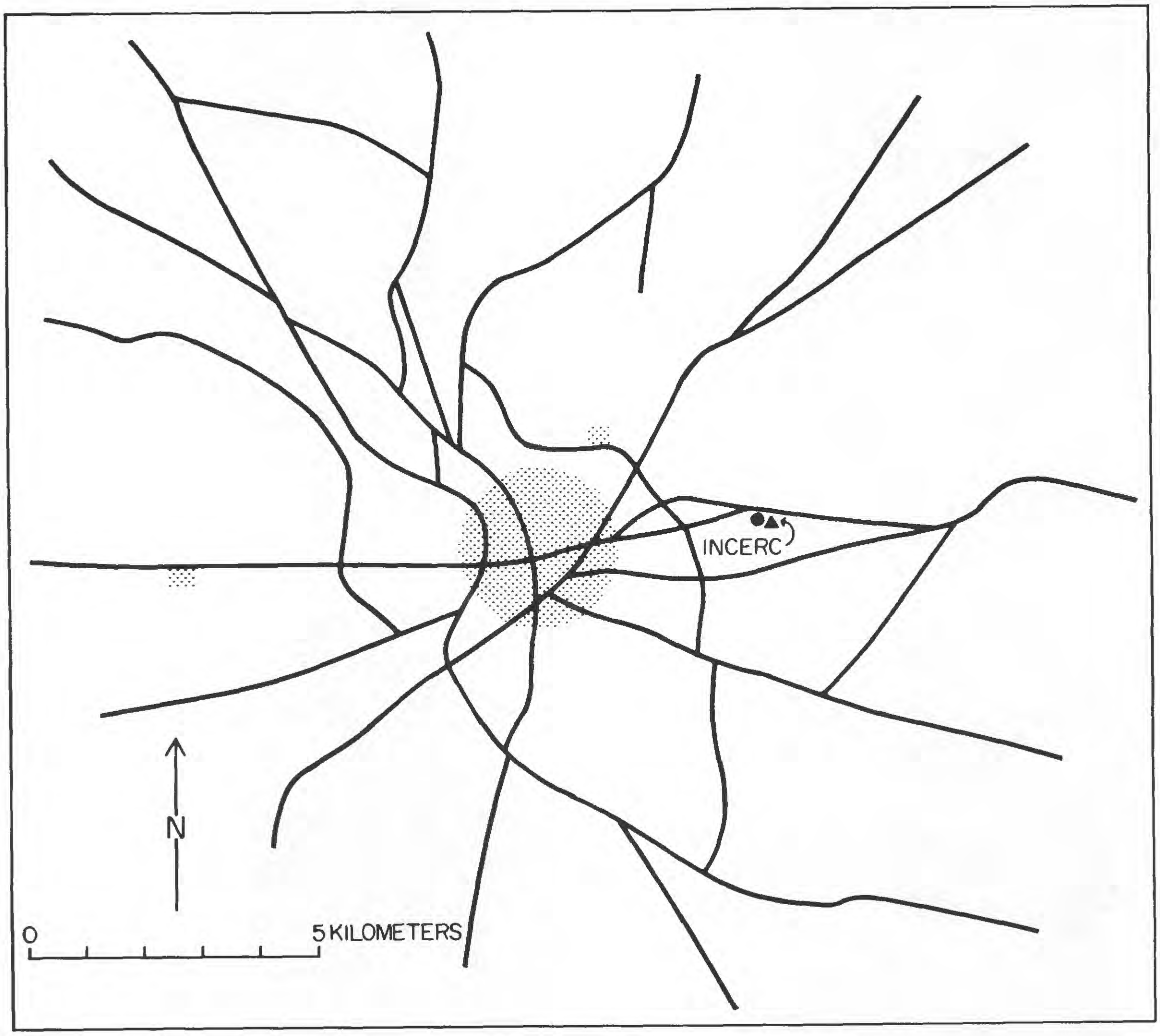


Figure 4.- MO-2 strong-motion accelerogram recorded on March 4, 1977 in the seismic station of Vrincioaia, 2 km west of the epicenter. Record is distorted in time because the film drive mechanism did not operate continuously during the earthquake. Maximum acceleration values and time scale are based on known instrument characteristics and the assumption that the dark dots at the top of the record define sprocket holes at standard spacing on 35-mm film. Record provided by G. Serbanescu of INCERC.



EXPLANATION

- ● Ground level accelerograph
- ▲ Ground level seismoscope
- ░ Area where greatest damage occurred

Figure 5.- Map of Bucharest showing area where greatest destruction occurred and location of INCERC strong-motion station.

Figure 6.- Typical one-story adobe/wood-wall dwelling in Vrincioaia, 2 km west of the epicenter. With the exception of minor hairline cracks at several locations on the exterior walls, the building was undamaged by the earthquake.

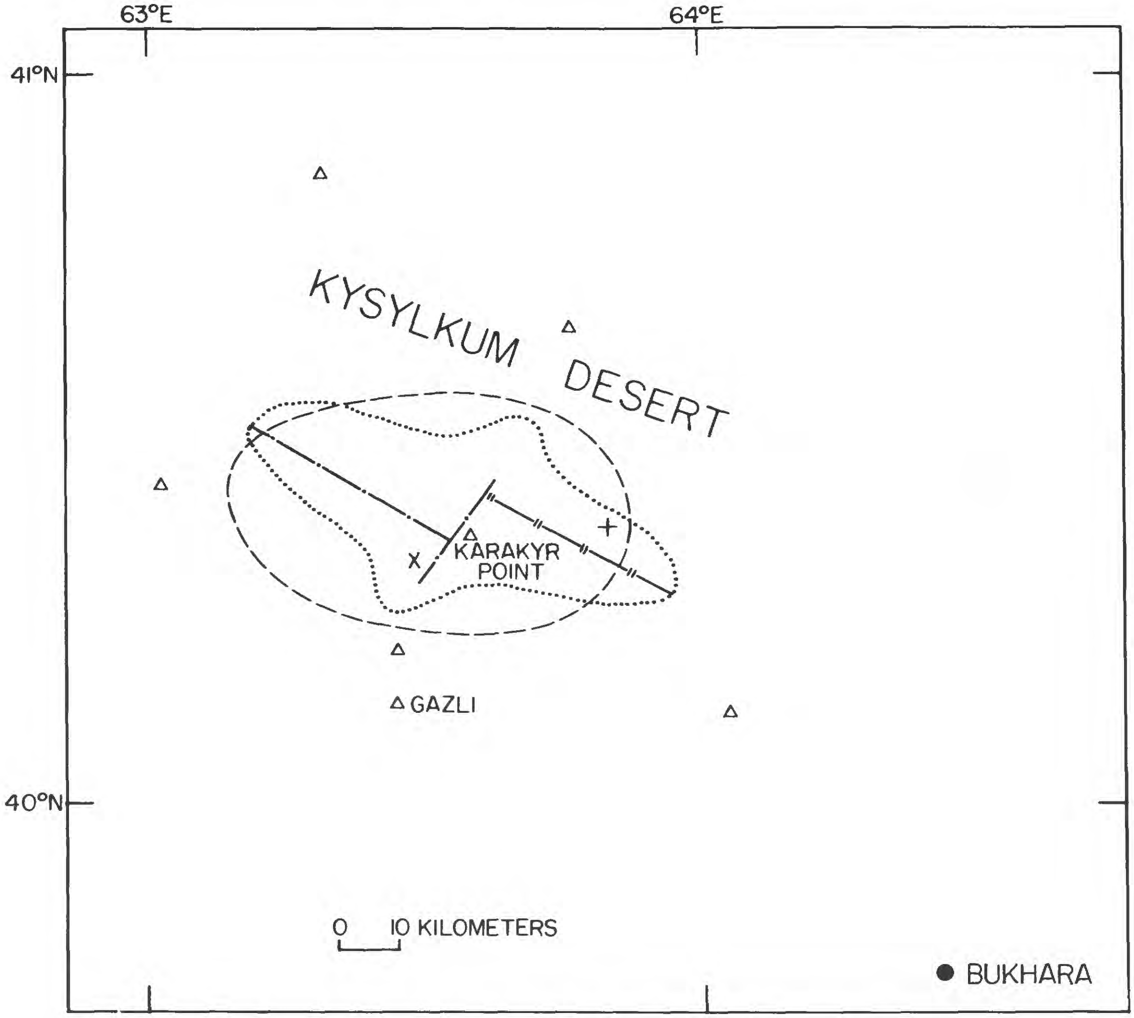
Figure 7.- Main boulevard in the center of Bucharest. Most of the buildings shown here were built prior to the 1940 earthquake (before lateral force building code provisions were adopted), and most sustained severe structural and nonstructural damage. The tall building in the distance (center of photograph is the Intercontinental Hotel, built in 1970. It sustained nonstructural damage in the form of heavily cracked interior masonry walls.

Figure 8.- Partially collapsed reinforced concrete frame and masonry-wall office and apartment building built prior to the 1940 earthquake. Building was located in the center of Bucharest, and extent of damage is similar to that sustained by 31 other older buildings.

Figure 9.- Computer Center of Ministry of Transportation and Telecommunications, Bucharest. Center part of this three-story reinforced concrete flat-slab building collapsed; service towers at each end remained intact. Three persons died in the collapse.

Figure 10.- Typical older two-story unreinforced masonry wall dwelling, Bucharest. Note collapsed exterior wall between second floor and roof.

Figure 11.- Typical undamaged reinforced concrete large-panel building on the outskirts of Bucharest. The city is surrounded by several thousand of these buildings and few (based on initial investigations) were damaged by the earthquake.



EXPLANATION

△ Seismic station

\+ April 8, 1976 earthquake epicenter

x May 17, 1976 earthquake epicenter

Probable fault plane of April 8, 1976 earthquake

Probable fault plane of May 17, 1976 earthquake

Aftershock area

Intensity IX isoseismal (approximate)

Figure 12.- Epicentral zone of 1976 Gazli earthquakes, observation points and hypothetical source model. No villages exist in the epicentral area.

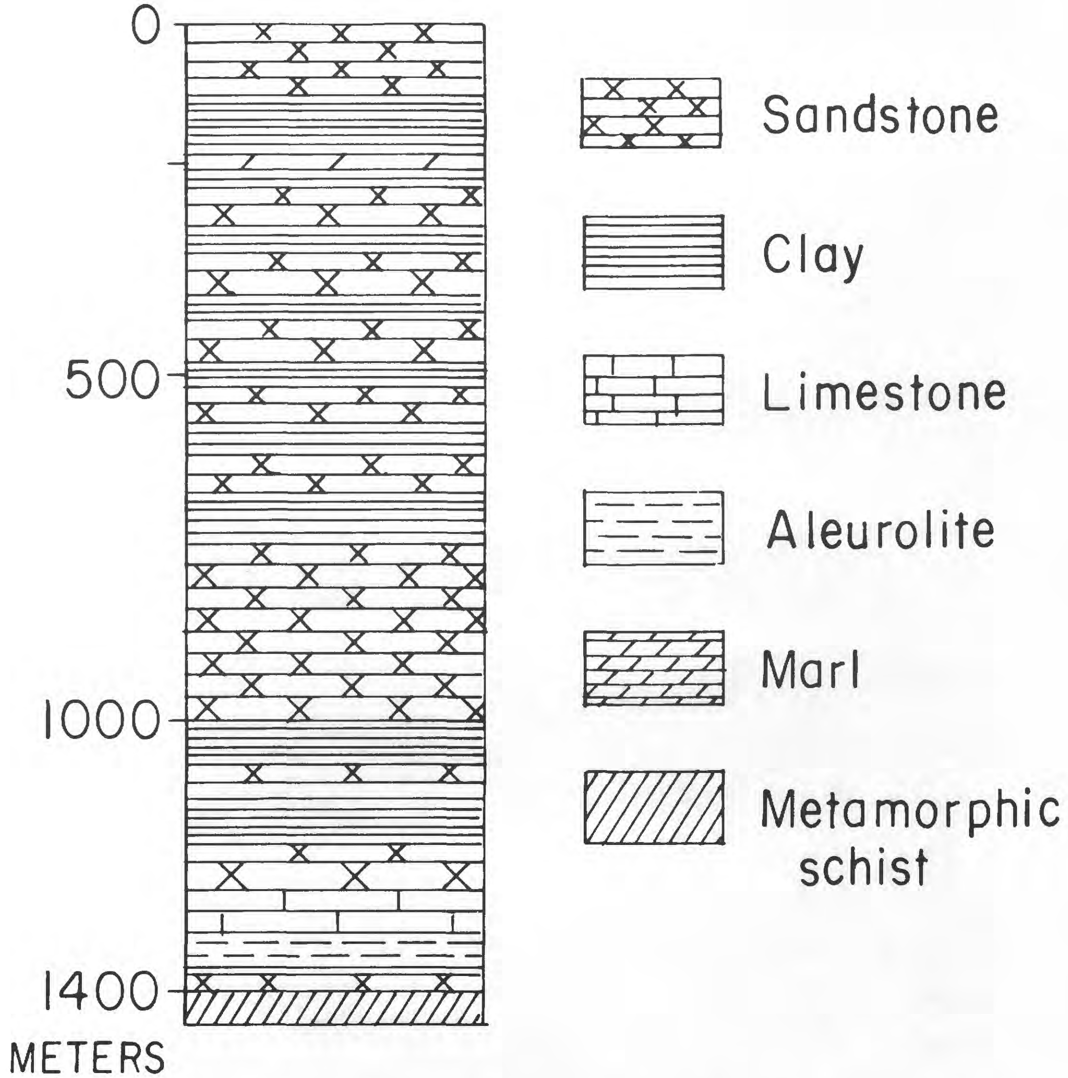


Figure 13.- Geologic profile at SSRZ accelerograph site, Karakyr Point.

Figure 14.- Partially collapsed two-story unreinforced brick-wall building with precast concrete floor slabs, Gazli, U.S.S.R. Building was damaged by both the April 8, 1976 and May 17, 1976 earthquakes; it was not designed to resist earthquakes (A. A. Lunyov, oral commun., October, 1976.) Photograph by P. Mork.

Figure 15.- Partially collapsed two-story large-panel building, Gazli, U.S.S.R. End-wall precast panels, interconnected with two steel rods at each panel corner, separated at construction joint (between panels) and collapsed. Building was damaged by both the April 8, 1976 and May 17, 1976 earthquakes; it was not designed to resist earthquakes (A. A. Lynyov, oral commun., October, 1976). Photograph by P. Mork.

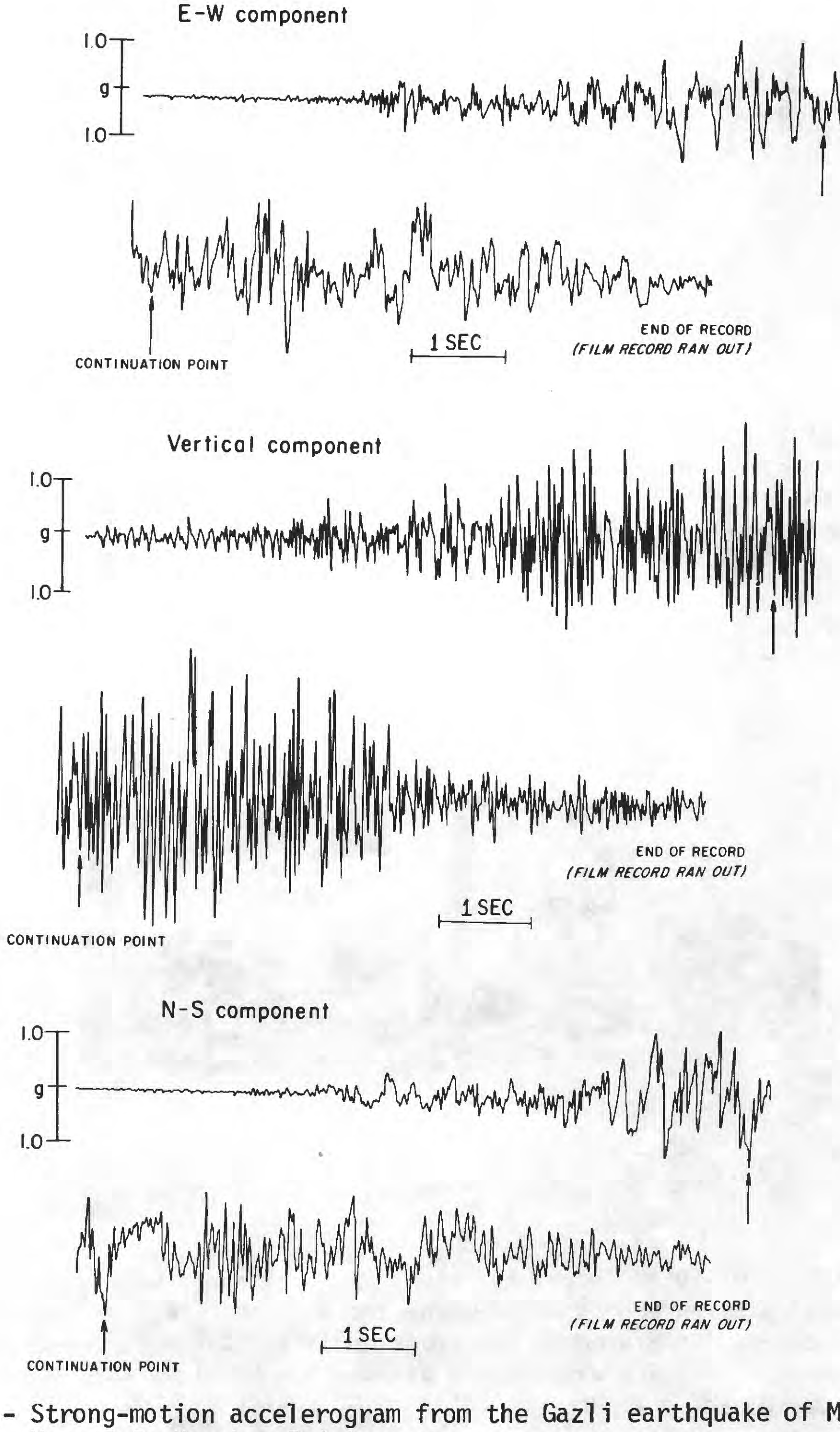


Figure 16.- Strong-motion accelerogram from the Gazli earthquake of May 17, 1976, M_S = 7.2, Karakyr Point.

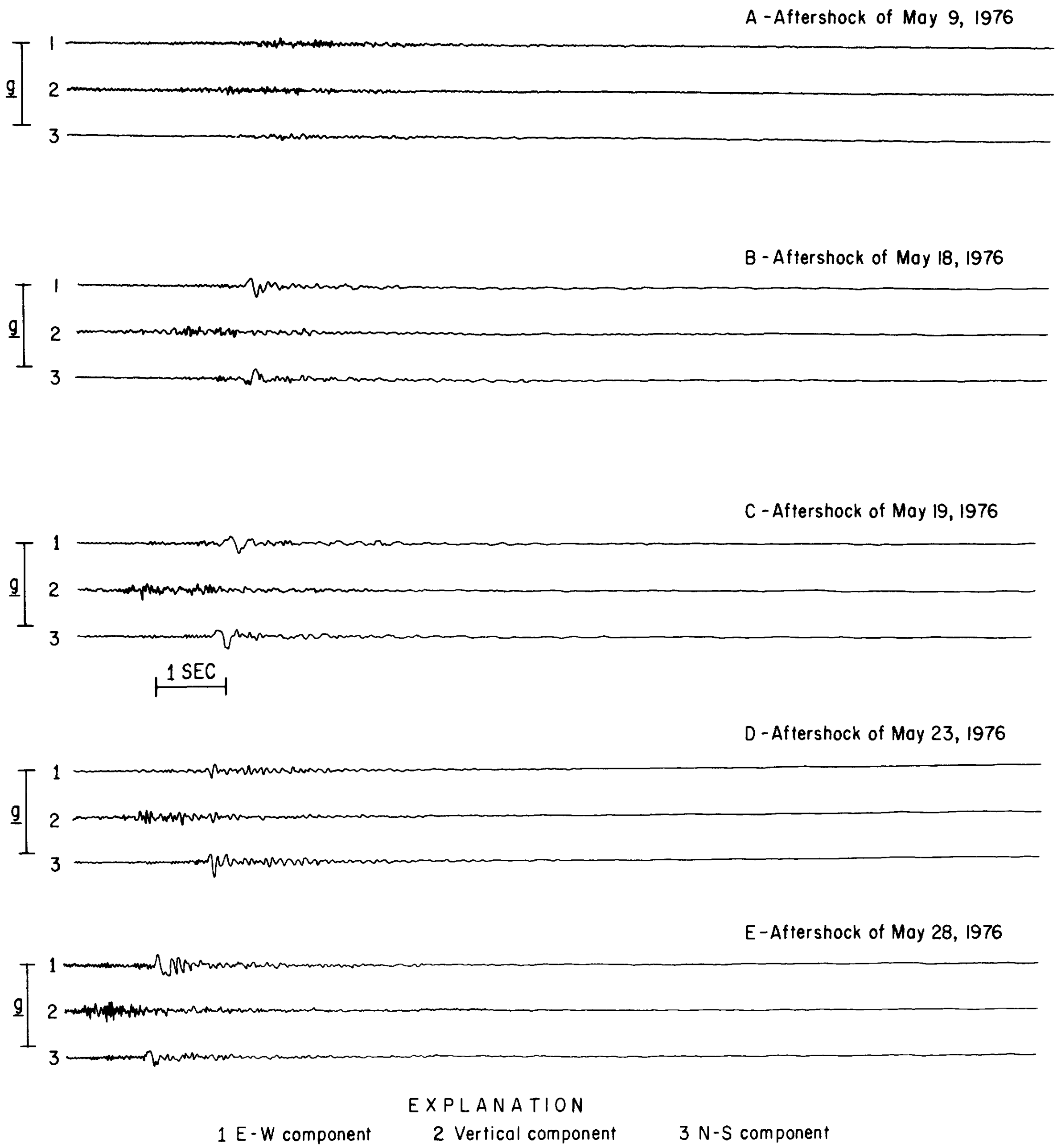


Figure 17.- Strong-motion accelerogram from the aftershocks of May 1976, Karakyr Point.

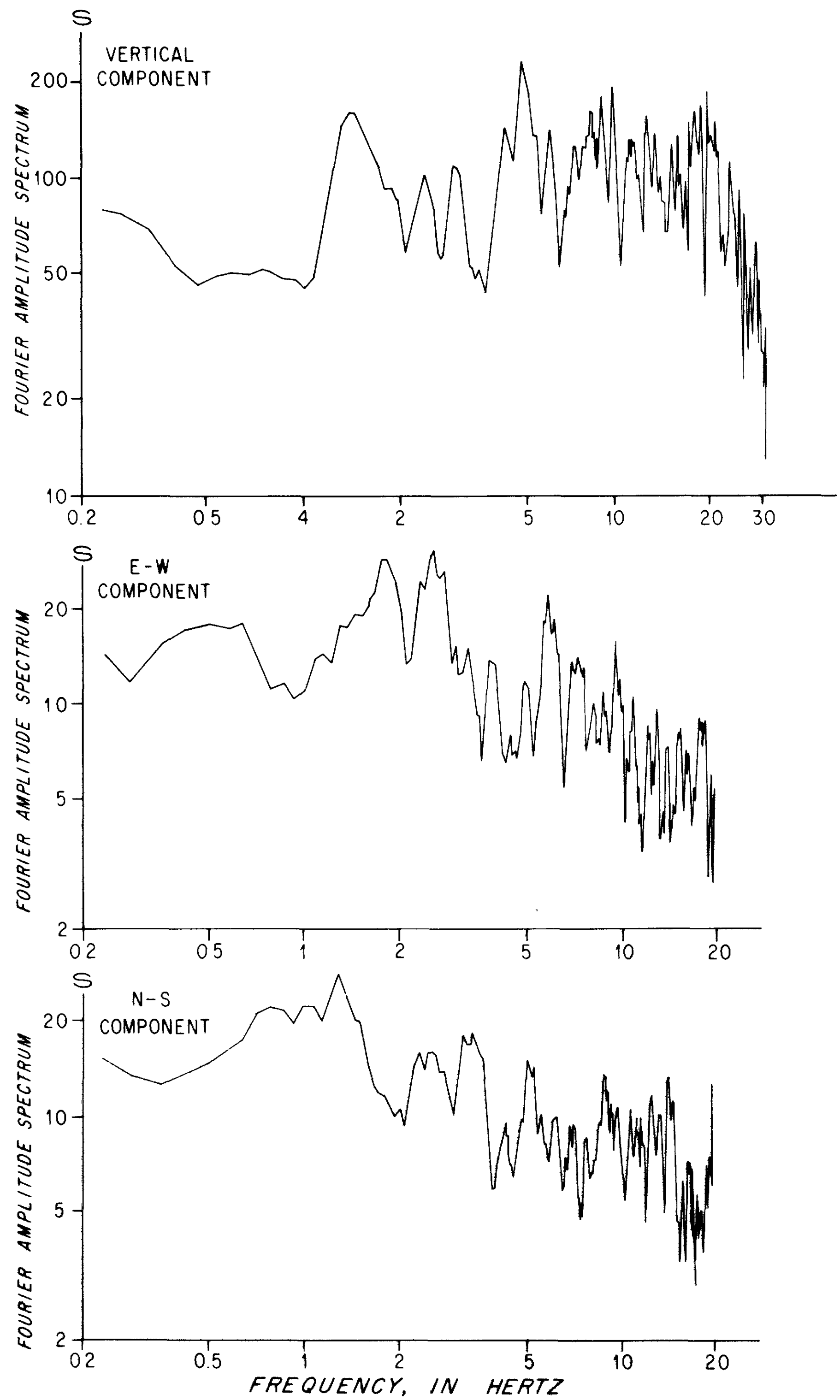


Figure 18.- Fourier amplitude spectra from strong-motion record of May 17, 1976, Karakyr Point.