PROGRESS REPORT ON SELECTED GEOPHYSICAL ACTIVITIES OF THE UNITED STATES, 1973–76

A QUADRENNIUM OF COOPERATION AND PROGRESS

INSTITUTO PANAMERICANO DE GEOGRAFIA E HISTORIA
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

GEOLOGICAL SURVEY CIRCULAR 763

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Edited by James N. Jordan, U.S. Geological Survey, and Kendall L. Svendsen, National Oceanic and Atmospheric Administration

GEOLOGICAL SURVEY CIRCULAR 763

FOR PRESENTATION TO THE III PAN-AMERICAN CONSULTATION ON GEO-PHYSICS, QUITO, ECUADOR, AUGUST 15–20, 1977

SUBMITTED BY THE UNITED STATES MEMBER OF THE COMMISSION ON GEO-PHYSICS OF THE PANAMERICAN INSTI-TUTE OF GEOGRAPHY AND HISTORY, A SPECIALIZED AGENCY OF THE ORGANI-ZATION OF THE AMERICAN STATES

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United States Department of the Interior
CECIL D. ANDRUS, *Secretary*

Geological Survey
V. E. McKelvey, *Director*

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Preface

This report contains information on some of the United States activities of interest to the Commission on Geophysics and its committees. More detailed information may be obtained from the journals of the various professional societies concerned with the areas that are of interest to the Commission--both those activities solely within the United States and those joint projects that involve U.S. and Latin colleagues in the hemisphere. In particular, refer to the U.S. National Report (1971-74) to the International Union of Geodesy and Geophysics in Reviews of Geophysics and Space Physics, American Geophysical Union, v. 13, no. 3, July 1976.[1] Of special note among the many contributors to this report, we would like to cite the following: Margaret Ann Shea of AFGL; George W. Wetherill, L. Tom Aldrich of CIW/DTM; Ellis Krinitzsky of USA/COE; Stephen E. Patchett, Roman Geller of DMA/IAGS; George P. Woollard of HIG; Gilbert D. Mead, Richard J. Allenby of NASA; Boyd E. Olson, Robert H. Higgs of NAVOCEANO; Rutlage J. Brazee, Kendall L. Svendsen, Paul J. Grim, J. Bruce Grant, Harris B. Stewart, Jr., Jerry L. Coffman, Jeffrey P. Calebaugh, Mark G. Spaeth, Raymond O. Conkright of NOAA; Lauriston R. King of NSF; Tom Simkin of SI; John S. Derr, Waverly Person, Carl W. Stover, Albert M. Rogers, Jr., Stanley Brockman, Charles Knudsen, Walt W. Hays, M. Dean Kleinkopf, Eugene B. Fabiano, John D. Wood, James Jordan of USGS.

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[1]Use of brand names in this report does not constitute endorsement by the U.S. Geological Survey.

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A number of damaging earthquakes struck the United States in this quadrennium. Some of these appear to have been rare events, causing minor damage in Minnesota, Florida, Pennsylvania, New Jersey, Tennessee, Georgia, Nebraska, Alabama, and Kentucky. Damaging earthquakes also struck Alaska, Hawaii, California, Idaho, Illinois, South Carolina, Montana, Wyoming, New York, New Mexico, Arizona, and Oregon. The most significant events are listed in table 1.

National Earthquake Information Service

This activity was transferred to USGS (U.S. Geological Survey) in September 1973 from NOAA (National Oceanic and Atmospheric Administration), where it had been known as NEIC (National Earthquake Information Center). In August 1974 the office was moved from Boulder about 32 km south to Golden, Colo. The PDE (Preliminary Determination of Epicenters) and WWSSN (Worldwide Standardized Seismograph Network) programs are now under USGS; historical data services are provided by NOAA EDS (Environmental Data Service). Thus, hypocenters are computed and published by NEIS, but hypocenter data-file services such as searches and selective listings are provided by EDS. Likewise, the WWSSN is administered and serviced and its quality controlled by USGS, but the network seismograms are are microfilmed and copies are provided to the users by EDS. James F. Lander is now responsible for the EDS seismic data services; his former position with NEIS in now filled by Waverly Person.

Many of the tsunami-warning observatories have also changed authority. Guam, Mariana Islands, Newport, Wash., and San Juan, P.R., are now in USGS, while Honolulu, Hawaii, and Adak and Palmer, Alaska, are still in NOAA. All of these observatories still cooperate closely in the tsunami program. Nine stations in the U.S. Network are telemetered to Newport Observatory, Wash., providing rapid data at Newport and for the Tsunami Warning System in Honolulu, from an area covering the 48 contiguous United States. The specific stations, in addition to Newport Observatory, are Albuquerque, N.M., Dugway, Utah, Kanaka Peak, Calif., Glamis, Calif., Large Aperture Seismic Array stations (Montana), Gold Mountain, Wash., Liberty all, S.C., Potsdam, N.Y., and Glen Canyon, Ariz.

The U.S. Network of seismographic stations has expanded to both coasts in the past 4 years. Figure 1 shows the participating stations that are now telemetered to Golden and recorded in real time on develocorders and helicorders. The stations that cooperate by sending readings by telephone for significant events are also shown. This network is still expanding, and state-of-the-art digital telemetry units are gradually replacing the older FM systems.

The NEIS continues to publish the PDE, EDR (Earthquake Data Report), and PDE Monthly Listing. Other publications are an annual report (Coffman and Stover, 1976) and quarterly reports on U.S. earthquakes (Stover and others, 1976a, b, c; Simon and others, 1976, 1977). The service was interrupted temporarily in 1975 during a change to a new and very different computer. Some recovery in schedule has since been made, but the computer has just recently been changed again. USGS is now utilizing a commercial computer service while the entire system is being rewritten for the new Honeywell Multics computer. PDE monthly listings are now (June 30, 1977) published through July 1976 and the publishing program is being accelerated. More up-to-date PDE's are available through a bi-weekly series of publications. When the new system is completely operational, events should be published within 2 weeks of their occurrence.

Over the last 4 years, the amount of data coming to NEIS by both telegrams and air mail has increased significantly. In addition, another mode of data input has been initiated: direct computer link. At present, data from Canada and some other countries are obtained by having NEIS call the remote host computer and copy a data file to a cassette tape in the standard telegraphic format. Another mode, to be initiated this year, is to have observatories in the United States call the NEIS computer using a toll-free WATS line and enter the data directly. Advantages of this latter system are that the contributing observatories can check their data to assure accuracy, locate hypocenters and determine magnitudes using USGS computer programs, and search current and historical files, all at no cost to the observatory. As hemisphere telephone service improves, it may become practical for neighboring countries to use such services.

In the meantime, hemisphere nations that do not report to NEIS are encouraged to work out arrangements for contribution of data telegraphically over the U.S. State Department AUTODIN circuit.

Table 1.--*Significant Earthquakes of the United States, 1973-1976*

[Leaders (---) indicate no data. PAS, Pasadena; BRK, Berkeley; SLM, St. Louis University; BLA, Blacksburg; TUL, Tulsa; SHA, Spring Hill]

Date	Origin time (UTC) Hr Min S	Lat	Long	Location	Depth (km)	Magnitude[1] USGS	Magnitude[1] Other	Remarks
1973								
Feb. 21	14 45 57.3	34.1 N.	119.0 W.	Southern California--	8	5.2	5.9 PAS	Several persons injured; approximately $1 million damage reported in the Oxnard area. Felt from San Diego to San Luis Obispo.
Apr. 26	20 26 28.0	19.9 N.	155.1 W.	Hawaii--------------	50	6.1 6.2 ML	6.3 PAS	Eleven persons injured; $5.6 million damage. Felt throughout islands.
June 15	01 09 04.2	45.32 N.	70.91 W.	Maine---------------	12	4.8 mb	---	Maximum intensity V. Felt in New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine; and Ontario and Quebec Provinces, Canada. Mag. 5.2 mb (Nuttli).
July 1	13 33 34.6	57.8 N.	137.3 W.	Off coast of south-eastern Alaska.	33	6.7 6.1 mb	6.7 PAS	Minor damage at Sitka. Felt in Yakutat and Juneau areas.
Nov. 30	07 48 41.2	35.80 N.	83.96 W.	Tennessee-----------	3	5.6 mb	---	Minor damage (VI) in Maryville area. Felt in Alabama, Georgia, Kentucky, North Carolina, South Carolina, Virginia, and West Virginia. Mag. 4.6 MbLg (BLA, TUL), 4.6-4.7 mbLg (SLM).
1974								
Feb. 15	13 33 49.2	36.5 N.	100.7 W.	Texas Panhandle region.	24	4.5	---	Maximum intensity V. Felt in Kansas, Oklahoma, and Texas. Depth was determined by using depth phase recorded at College, Alaska. Mag. 4.6 mbLg (SLM).
Apr. 20	03 00 09.3	46.76 N.	121.52 W.	Washington----------	5	4.8 mb 4.9 ML	---	Felt (V) in Lewis County.
Aug. 2	08 52 09.8	33.87 N.	82.49 W.	Georgia-------------	1	4.3 mb	---	Slight damage (VI) in Bobby Brown State Park. Felt in Georgia, North Carolina, and South Carolina. Mag. 4.8 mbLg (SLM), 4.9 mbLg (USGS) from SHA gram.
Nov. 11	05 17 51.0	51.6 N.	178.1 W.	Andreanof Islands, Aleutian Islands.	68	5.8 mb	---	Minor damage (VI) on Adak.

1975								
Feb. 2	08 43 39.1	53.1 N.	173.5 E.	Near Islands, Aleutian Islands.	10	7.6 6.1 mb	7.5 PAS 7.4 BRK	Fifteen injured and damage on Shemya (IX). Minor damage on Attu. Felt on Adak.
Feb. 4	01 32 52.1	48.2 N.	114.1 W.	Montana---------------	8	4.6 mb 5.0 ML	---	Minor damage (VI) in Creston-Kalispell area. Felt (V) at Trego, Columbia Falls, Swan Lake, and Big Arm.
Feb. 22	08 36 07.4	51.4 N.	179.4 W.	Andreanof Islands, Aleutian Islands.	48	6.5 6.3 mb	6.4 BRK 6.0 PAS	Felt (VI) at Adak.
Mar. 28	02 31 05.7	42.06 N.	112.55 W.	Idaho-----------------	5	6.0- 6.1 ML	6.2 PAS	$1 million damage.
May 18	15 42 59.1	63.17 N.	150.26 W.	Alaska----------------	106	5.4 mb	---	Felt.
June 7	08 46 22.4	40.57 N.	124.14 W.	Near coast of northern California.	21	5.7 5.4 mb	5.2 ML BRK	Damage (VIII) in Ferndale-Rio Dell area.
June 30	18 54 13.4	44.75 N.	110.61 W.	Yellowstone National Park, Wyo.	7	5.9	6.1 BRK	Felt. Minor damage.
July 8	09 37 27.3	29.46 N.	113.35 W.	Gulf of California----	33	6.5	---	Felt.
July 9	14 54 15.1	45.67 N.	96.04 W.	Near Morris, Minn.----	10	4.6 mb	---	Felt. Minor damage.
Aug. 1	20 20 12.9	39.44 N.	121.53 W.	Oroville, Calif.------	15	5.6	5.7 ML BRK	Damage in Oroville area.
Aug. 2	10 18 17.9	53.39 N.	161.49 W.	South of Alaska-------	33	6.0 6.2 mb	5.7 BRK	Felt (IV) at Cold Bay.
Sept. 24	17 19 37.2	25.15 N.	109.26 W.	Gulf of California----	33	5.7	5.8 BRK	---
Nov. 29	14 47 40.4	19.3 N.	155.0 W.	Hawaii----------------	5	7.1	7.2 PAS	Tsunami; damage estimated $4 million. Two killed.
1976								
Jan. 5	06 23 32.9	35.84 N.	108.34 W.	New Mexico------------	25	5.0 mb 4.6 ML	---	Slight damage (VI) in the Gallup area. Felt in Arizona, New Mexico, Colorado, and Utah.
Feb. 4	00 04 58.1	34.66 N.	112.50 W.	Western Arizona-------	12	4.9 mb 5.1 ML	5.2 ML PAS	Slight damage (VI) at Prescott, Paulden, Cottonwood, and Chino Valley. Also felt in Maricopa, Mohave, Yuma, Coconino, and Pinal Counties and at Parker dam, California.
Mar. 25	00 41 20.5	35.60 N.	90.48 W.	Arkansas--------------	15	4.9 mb	5.0 mb SLM	Slight damage in epicentral area. Felt in Alabama, Arkansas, Illinois, Kentucky, Mississippi, Missouri, and Tennessee.
Apr. 13	00 47 17.1	45.22 N.	120.77 W.	Washington-Oregon border region.	15	3.3 4.5 mb 4.8 ML	---	Slight damage (VI) in Wasco County, Oreg. Felt sharply from The Dalles to Bend, Oreg. Also felt in some areas of southern Washington.
Nov. 26	11 19 23.1	41.35 N.	125.77 W.	Off coast of northern California.	33	6.8	6.1 ML BRK	Felt along the coast of Humboldt.

[1]All magnitudes MS unless otherwise stated.

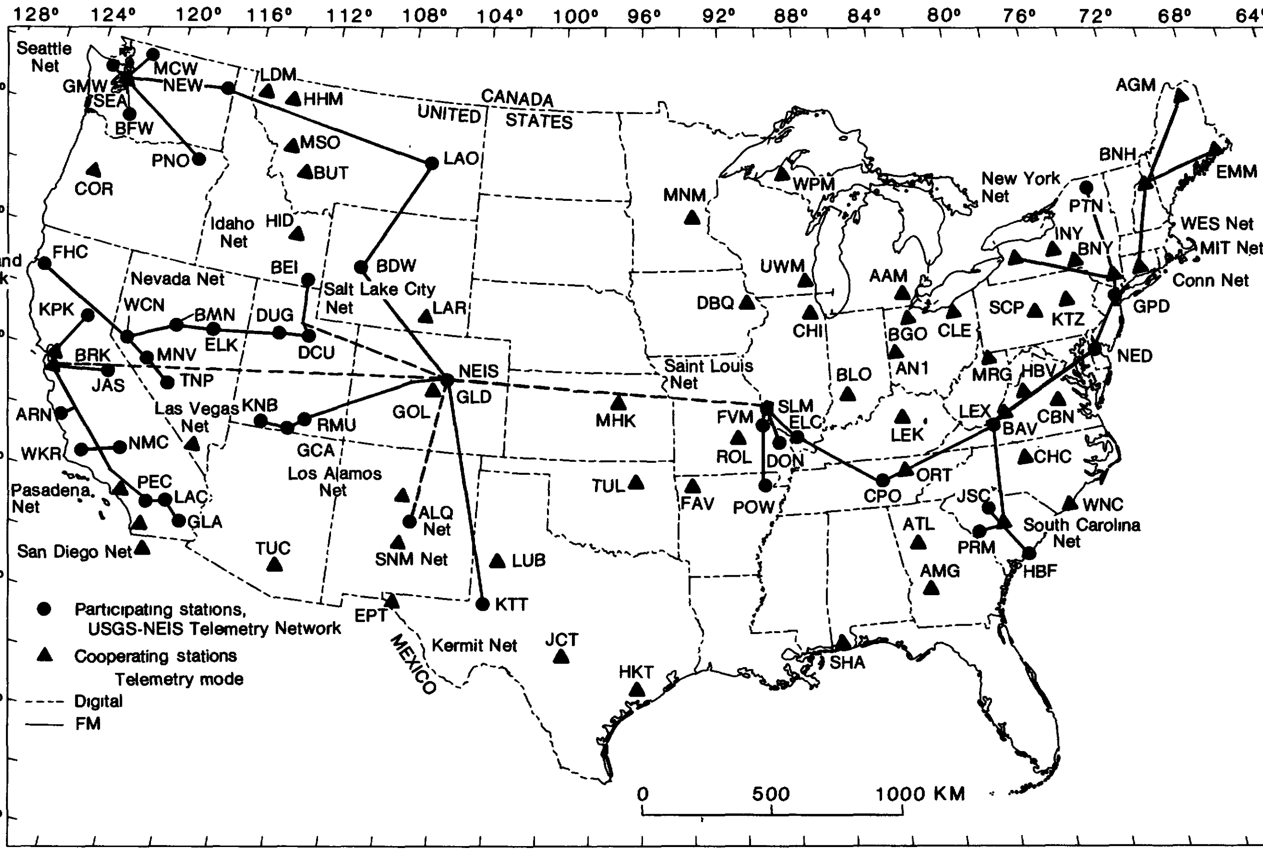


FIGURE 1.--NEIS seismograph network; abbreviations as in Covington (1974). Networks cited indicate a central recording station from which one or more stations may be used by the NEIS network. AAM, Ann Arbor, Mich.; AGM, Allagash, Maine; ALG, Albuquerque, N. Mex.; AMG, Americus, Ga.; AN1, Anna, Ohio; ARN, Arnold Ranch, Calif.; ATL, Atlanta, Ga.; BAV, Blackburg, Va.; BDW, Boulder, Wyo.; BEI, Bear River Range, Idaho; BFW, Baw Faw Mountain, Wash.; BGO, Bowling Green, Ohio; BLO, Bloomington, Ind.; BMN, Battle Mountain, Nev.; BNH, Berlin, N.H.; BNY, Binghamton, N.Y.; BRK, Berkeley, Calif.; BUT, Butte, Mont.; CBN, Corbin, Va.; CHC, Chapel Hill, N.C.; CHI, Chicago-Loyola, Ill.; CLE, Cleveland, Ohio; COR, Corvallis, Oreg.; CPO, Cumberland Plateau, Tenn.; DBQ, Dubuque, Iowa; DCU, Deer Creek, Utah; DON, Dongola, Mo.; DUG, Dugway, Utah; ELC, Elco, Ill.; ELK, Elko, Nev.; EMM, East Machias, Maine; EPT, El Paso, Tex.; FAV, Fayetteville, Ark.; FHC, Fickle Hill, Calif.; FVM, French Village, Mo.; GCA, Glen Canyon, Ariz.; GLA, Glamis, Calif.; GLD, Golden, Colo.; GMW, Gold Mountain, Wash.; GOL, Golden, Colo.; GPD, Green Pond, N.J.; HBF, Harts Bluff, S.C.; HBV, Harrisonburg, Va.; HHM, Hungry Horse, Mont.; HID, Hammer Butte, Idaho; HKT, Hockley, Tex.; INY, Ithaca, N.Y.; JAS, Jamestown, Calif.; JCT, Junction City, Tex.; JSC, Jenkinsville, S.C.; KNB, Kanab, Utah; KPK, Kanaka Peak, Calif.; KTT, Kermit, Tex.; KTZ, Kutztown, Pa.; LAC, Landers, Calif.; LAO, LASA array, Mont.; LAR, Laramie, Wyo.; LDM, Libby dam, Montana; LEK, Lexington, Va.; LEX, Lexington, Va.; LUB, Lubbock, Tex.; MCW, Mt. Constitution, Wash.; MHK, Manhattan, Kans.; MNM, Minneapolis, Minn.; MNV, Mina, Nev.; MRG, Morgantown, W. Va.; MSO, Missoula, Mont.; NED, Newark, Del.; NEW, Newport, Wash.; NMC, Nine Mile Canyon, Calif.; ORT, Oak Ridge, Tenn.; PEC, Perris, Calif.; PNO, Pendleton, Oreg.; POW, Powhatan, Ark.; PRM, Parsons Mountain, S.C.; RMU, Rainbow Monument, Vt.; ROL, Rolla, Mo.; SCP, State College, Pa.; SEA, Seattle, Wash.; SHA, Spring Hill, Ala.; SLM, St. Louis, Mo.; SNM, Socorro, N. Mex.; TNP, Tonopah, Nev.; TUC, Tucson, Ariz.; TUL, Tulsa, Okla.; UWM, Milwaukee, Wis.; WCN, Washoe City, Nev.; WES, Weston, Mass.; WKR, Work Ranch, Calif.; WNC, Wilmington, N.C.; WPM, White Pine, Mich. NETWORKS: Berkeley and Menlo Park, Calif.; Connecticut; Idaho; Kermit, Tex.; Las Vegas, Nev.; Los Alamos, N. Mex.; Massachusetts Institute of Technology; Nevada; New York; Pasadena, Calif.; St. Louis, Mo.; Salt Lake City, Utah; San Diego, Calif.; Seattle, Wash.; South Carolina; Weston, Mass.

Intensity surveys

The intensity and (or) damage data for U.S. earthquakes are collected, in general, by means of a mail canvass using the "Earthquake Report" questionnaire (fig. 2). The canvass is made using a computer file of addresses of postmasters, government employees, police headquarters, and so forth, which is searched for the addresses located in the area affected by the earthquake. The line printer used this list to address the questionnaires; they are then mailed. When the size of the earthquake warrants it, a field survey of damage is made by a geophysicist and (or) engineer, and the data are incorporated with the mail canvass and used in compiling the intensity report. Figure 2 is the questionnaire now in use by USGS. It is designed for computer evaluation and for use in automated isoseismal mapping.

The intensity data collected by the method described above are published in the report on U.S. earthquakes (Stover and others, 1976a, b, c; Simon and others, 1976, 1977), which consists primarily of two sections. The first is a tabular listing of earthquakes, in chronological order by State, consisting of the following basic information: date, origin time, hypocenter, magnitude, maximum intensity, and the computation source of the hypocenter. The second sections consists of seismicity maps, isoseismal maps, and detailed descriptions of damage and feld data. These data, along with strong-motion, tsunami, and water-well-fluctuation data, are also included in the annual publication "United States Earthquakes," published jointly by USGS and NOAA. In addition to the 50 States, this publication contains data from the Panama Canal Zone, Puerto Rico, and the Virgin Islands (Coffman and Stover, 1976).

Seismological data services of National Geophysical and Solar-Terrestrial Data Center

As part of the 1973 agreement under which most of the seismological activities of NOAA were transferred to USGS, many of the seismological data services were retained in NOAA's EDS (Environmental Data Service), more specifically NGSDC (National Geophysical and Solar-Terrestrial Data Center). In addition to their traditional responsibility for collecting, microfilming, archiving, and disseminating copies of the seismograms from the WWSSN, NOAA (via NGSDC) retained responsibility for maintenance of the historical earthquake data files and the dependent data services. Furthermore, operation of World Data Center A for Solid Earth Geophysics was implemented, with the present chief task being collection of worldwide seismograms for selected major earthquake events.

The efforts to date have resulted in two important magnetic tape files, one containing the hypocenter locations, magnitudes, and other coded information on 130,000 earthquakes of historical record derived from NEIS, ISC (International Seismological Centre), and many local sources; and the other, a catalog of all intensity reports for U.S. earthquakes that have been collected for the years from 1928 to 1974. Both files are continuously updated and expanded by the addition of earlier information gathered from older sources. The tapes are in a multi-access format, by which investigators may acquire information based on 15-20 single parameters such as area, time interval, magnitude, and maximum intensity, or on multiple combinations of these factors. A microfilm file of all strong-motion seismograms written by instruments of the Seismological Field Survey of Menlo Park, Calif., and a file of tsunami mareograms are also available. Digitized tapes of the more significant of the strong-motion seismograms (currently about 350) are also on file. They were produced, for the most part, by the Earthquake Engineering Research Laboratory of the California Institute of Technology, with some additions digitized by NGSDC in Boulder. Investigative work during the period has been confined to search out and editing source materials and a detailed analysis of the Modified Mercalli Scale.

The newest activity of NGSDC is collecting very long period digital seismic recordings from the IDA (International Deployment of Accelerometers) program and making them available to users. The IDA is a worldwide network of digitally recording La Coste-Romberg gravimeters, operated by the University of California at San Diego in cooperation with many foreign institutions and with support from the Cecil and Ida Green Foundation and the National Science Foundation. Of the projected 20 stations, seven are already in operation, including the Western Hemisphere stations of Halifax, Nova Scotia; Pinon Flat, Calif.; and Nana, Peru. These data are unique in providing very long-period digital recordings of Earth tides and of free oscillations of the Earth. They have applications in the analysis of the Q of the free oscillations, elasticity, and density of Earth; earthquake source mechaism; and Earth and regional structure models.

For further information refer to NGSDC's "Earthquake Data Services and Publications" and "Earthquake Data File Summary, Key to Geophysical Records Documentation No. 5."

Engineering applications

Induced seismicity

Seismicity studies in the United States are under way at Auburn dam, California; New Melones dam, California; and Teton dam, Idaho. The Auburn dam network comprises 19 seismograph stations covering an area from Oroville on the north to New Melones on the south. These stations monitor the Foothills fault zone. Eight seismograph stations are located in the vicinity of the New Melones damsite. A three-station seismograph unit is operating at Teton dam.

Post-impoundment studies are continuing at Lake Oroville, Calif., where a 24-station seismograph array is operating. A cause-and-effect relationship between the seismicity observed at Lake Oroville and the lake impoundment is not clearly defined. No earthquakes were observed for the first 6 years after the lake was filled in 1969. The seismicity, which began in 1975 and included a magnitude 5.9

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
EARTHQUAKE REPORT

Form Approved
OMB No. 42–R1700

Please answer this questionnaire carefully and return as soon as possible.

1. Was an earthquake felt by anyone in your town or zip code area recently?
   ☐ Not felt: Please refold and tape for return mail.
   ☐ Felt: Date________ Time________ ☐ AM ☐ PM ☐ Standard time ☐ Daylight time

Name of person filling out form ________________
Address________________
City__________ County__________
State__________ Zip code__________

If you felt the earthquake, complete the following section. If others felt the earthquake but you did not, skip the personal report and complete the community report.

PERSONAL REPORT

2a. Did you personally feel the earthquake? 1☐ Yes ☐ No
b. Were you awakened by the earthquake? 2☐ Yes ☐ No
c. Were you frightened by the earthquake? 3☐ Yes ☐ No
d. Were you at 4☐ Home 5☐ Work 6☐ Other?
e. Town and zip code of your location at time of earthquake __________

f. Check your activity when the earthquake occurred:
   7☐ Walking 8☐ Sleeping 9☐ Lying down 10☐ Standing
   11☐ Driving (car in motion) 12☐ Sitting 13☐ Other
g. Were you 14☐ Inside or 15☐ Outside?
h. If inside, on what floor were you? 16☐☐

Continue on to next section which should include personal as well as reported observations.

COMMUNITY REPORT

Check one box for each question that is applicable.

3a. The earthquake was felt by ☐ No one 17☐ Few 18☐ Several 19☐ Many 20☐ All?
b. This earthquake awakened ☐ No one 21☐ Few 22☐ Several 23☐ Many 24☐ All?
c. This earthquake frightened ☐ No one 25☐ Few 26☐ Several 27☐ Many 28☐ All?

4. What outdoor physical effects were noted in your community?

Parapets or cornices fallen	29☐ Yes	☐ No	
Trees and bushes shaken	30☐ Slightly	31☐ Moderately	32☐ Strongly
Standing vehicles rocked	33☐ Slightly	34☐ Moderately	35☐ Strongly
Moving vehicles rocked	36☐ Slightly	37☐ Moderately	38☐ Strongly
Ground cracks	39☐ Wet ground	40☐ Steep slopes	41☐ Dry and level ground
Landslides	42☐ Small	43☐ Large	
Underground pipes	44☐ Broken	45☐ Out of service	
Water splashed onto sides of lakes, ponds, swimming pools	46☐ Yes	☐ No	
Elevated water tanks	47☐ Cracked	48☐ Twisted	49☐ Fallen (thrown down)
Air coolers	50☐ Displaced	51☐ Rotated	52☐ Fallen
Railroad tracks bent	53☐ Slightly	54☐ Greatly	
Stone or brick fences	55☐ Cracked	56☐ Fallen	57☐ Destroyed
Tombstones	58☐ Displaced 61☐ Fallen	59☐ Cracked	60☐ Rotated
Chimneys	62☐ Cracked 65☐ Broken at roof line	63☐ Twisted	64☐ Fallen 66☐ Bricks fallen
Highways or streets	67☐ Cracked slightly	68☐ Large cracks	69☐ Displaced
Sidewalks	70☐ Cracked slightly	71☐ Large cracks	72☐ Displaced

Continued on the reverse side

5. What indoor physical effects were noted in your community?

Windows, doors, dishes rattled	73☐ Yes	☐ No	
Buildings creaked	74☐ Yes	☐ No	
Building trembled (shook)	75☐ Yes	☐ No	
Hanging pictures	76☐ Swung	77☐ Out of place	78☐ Fallen
Water in small containers	79☐ Spilled	80☐ Slightly disturbed	
Windows	81☐ Few cracked	82☐ Some broken	83☐ Many broken

6a. Did hanging objects, doors swing? ☐ No 84☐ Slightly 86☐ Violently 85☐ Moderately
b. Can you estimate direction? ☐ No 87☐ North/South 88☐ East/West 89☐ Other

7a. Were small objects (dishes, knick-knacks, pictures) ☐ Unmoved 90☐ Shifted 91☐ Overturned 92☐ Fallen, not broken 93☐ Broken?
b. Was light furniture ☐ Unmoved 94☐ Shifted 95☐ Overturned 96☐ Fallen, not broken 97☐ Broken?
c. Were heavy furniture or appliances ☐ Unmoved 98☐ Overturned 99☐ Shifted 100☐ Broken?

8. Indicate effects of the following types to interior walls if any:

Plaster	101☐ Cracked	102☐ Fell
Dry wall	103☐ Cracked	104☐ Fell
Ceiling tiles	105☐ Cracked	106☐ Fell

9a. Check below any damage to buildings or structures.

Foundation	107☐ Cracked	108☐ Destroyed	
Interior walls	109☐ Split 110☐ Fallen	111☐ Separated from ceiling or floor	
Exterior walls	112☐ Hairline cracks 115☐ Partial collapse	113☐ Large cracks 116☐ Total collapse	114☐ Bulged outward
Building	117☐ Moved on foundation	118☐ Shifted off foundation	

b. What type of construction was the building that showed this damage?
   119☐ Wood 120☐ Stone 121☐ Brick veneer 122☐ Other
   123☐ Brick 124☐ Cinderblock 125☐ Reinforced concrete
c. What was the type of ground under the building?
   126☐ Don't know 127☐ Sandy soil 128☐ Marshy 129☐ Fill
   130☐ Hard rock 131☐ Clay soil 132☐ Sandstone, limestone, shale
d. Was the ground: 133☐ Level 134☐ Sloping 135☐ Steep?
e. Check the approximate age of the building:
   136☐ Built before 1935 137☐ Built 1935–65 138☐ Built after 1965

10a. What percentage of buildings were damaged?
   Within 2 city blocks of your location ☐ None 139☐ Few (about 5%) 140☐ Many (about 50%) 141☐ Most (about 75%)
b. In area covered by your zip code ☐ None 142☐ Few (about 5%) 143☐ Many (about 50%) 144☐ Most (about 75%)

11a. Were springs or well water disturbed? 145☐ Level changed 146☐ Flow disturbed 147☐ Muddied ☐ Don't know
b. Were rivers or lakes changed? 148☐ Yes ☐ No ☐ Don't know

12a. Was there earth noise? ☐ No 149☐ Faint 150☐ Moderate 151☐ Loud
b. Direction of noise 152☐ North 153☐ South 154☐ East 155☐ West
c. Estimated duration of shaking 156☐ Sudden, sharp (less than 10 secs) 157☐ Long (30–60 secs) 158☐ Short (10–30 secs) 159☐ Other

13. What is the approximate population of your city/town? 160☐ Less than 1,000 161☐ 10,000 to 100,000 162☐ 1,000 to 10,000 163☐ Over 100,000
Or are you in a 164☐ Rural area?

This community report is associated with what town or zip code? __________

Thank you for your time and information. Refold this card and tape for return mail.

(m_b) event in the same year, has shown no correlation with lake level and occurred as much as 18 km south of the lake. Study of the lake-induced stresses indicates that it is unlikely that they triggered the main shock; however, a pore-pressure increase along the fault zone has not been eliminated as the cause of the seismicity.

Post-impoundment studies are also under way at Lake Jocassee, S.C., where about five portable seismograph stations are operating. This area was one of low natural seismicity, but seismic events have increased since impoundment and seem correlated with the lake level in a complicated way.

A recently completed 1½-year study at Lake Mead, Nevada-Arizona, found lower levels of seismicity than in the past; strike-slip orientation and tension axes were in agreement with those for tectonic earthquakes in other parts of the Basin and Range province. No correlation was noted between lake level and seismic rates.

An induced seismicity study has been initiated in the last year in the vicinity of the Central Basin Platform in west Texas. This area overlies several major oil and gas fields that have been operated under secondary-recovery water-injection programs for many years. A low level of seismicity has been recorded in the area; however, since the array was installed, three felt earthquakes have occurred. No relation has been established between the water injection and the seismicity.

Figure 3 shows U.S. Army Corps of Engineers facilities, some of which are currently being studied for induced seismic effects (Johnson and others, 1977). The U.S. Bureau of Reclamation and various State agencies are also concerned with the problem and have active programs.

Seismological and geological review of nuclear reactor sites

The seismic review of about 27 nuclear reactor sites has been undertaken by USGS since the beginning of 1974. Of these reviews, about 20 have been completed. Current status is shown in figure 4.

The procedures that a power company must follow in order to obtain a license to build--and eventually operate--a nuclear powerplant are complicated and comprehensive; they involve aspects of demography and environmental impact, in addition to seismology and geology. The power company compiles a large summary report of its investigations--a PSAR (Preliminary Safety Analysis Report)--to suport its conclusions. The

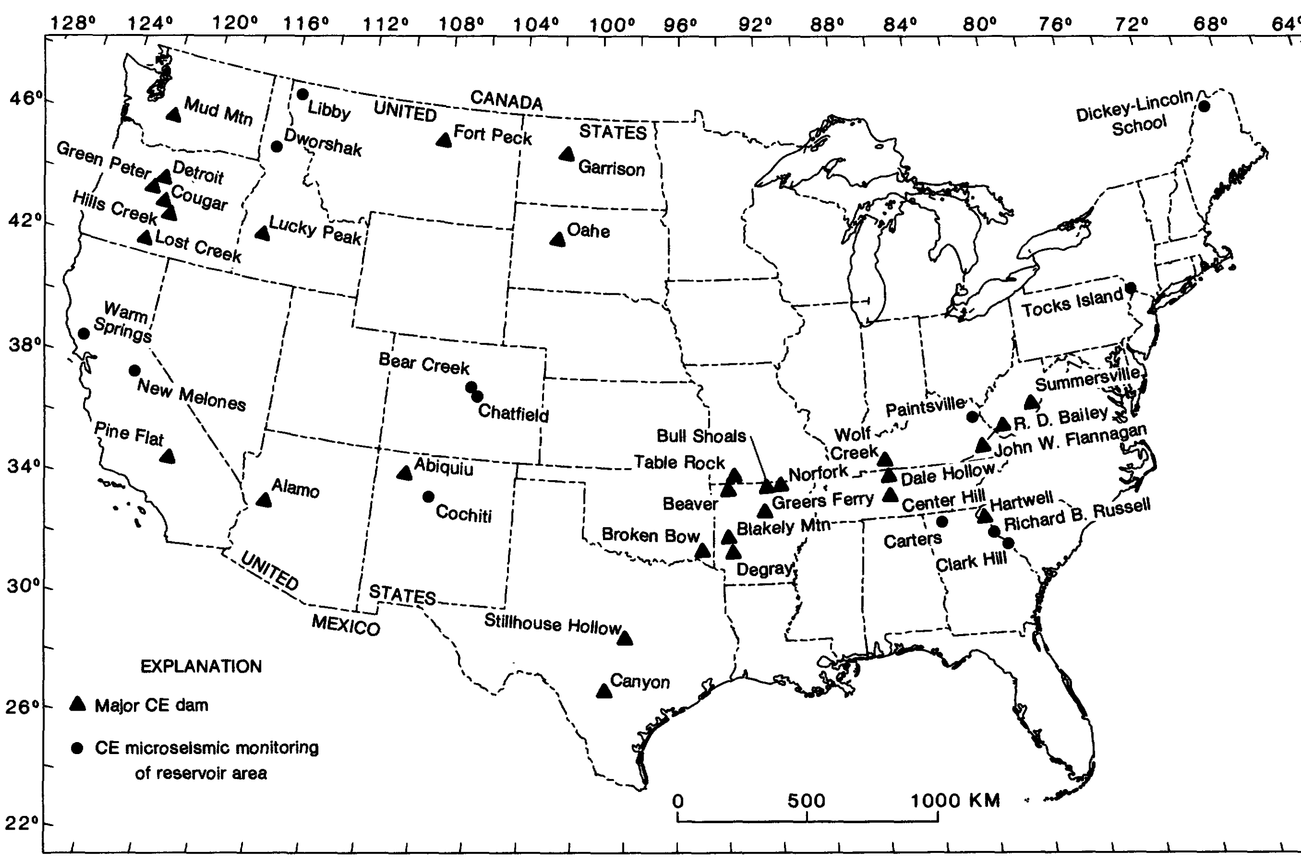
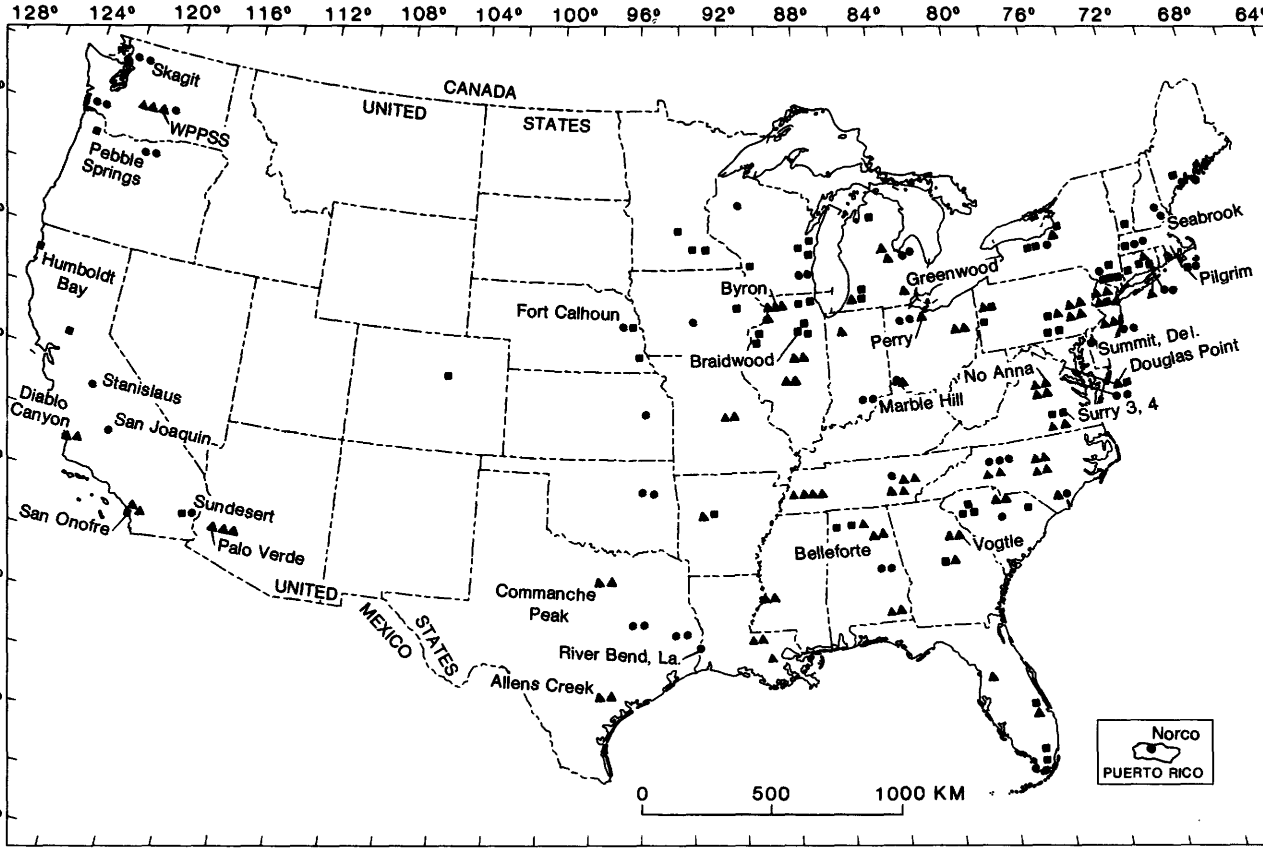


FIGURE 3.--Location of major Corps of Engineers projects and of reservoirs instrumented for microearthquake monitoring (modified from Johnson and others, 1977).



NUCLEAR GENERATING UNIT CAPACITY	kilowatts
■ Operable	
58 licensed by NRC to operate	40,317,400
2 others authorized to operate (ERDA-owned)	940,000
▲ Being Built	
74 construction permits	76,931,200
19 site work authorized	20,490,000
• Planned	
61 reactora ordered	69,394,000
24 reactors not ordered*	28,900,000
238	236,972,600

*There are no symbols for units planned but not sited.

FIGURE 4.--Nuclear power reactors in the United States. Reactor reviews completed, with involvement of the U.S. Geological Survey: River Bend, La.; Allens Creek, Tex.; Commanche Peak, Tex.; Bellefonte, Ala.; Summit, Del.; Douglas Point, Md.; Seabrook, N.H.; Perry, Ohio; Greenwood, Mich.; Byron, Ill.; Braidwood, Ill.; Fort Calhoun, Nebr.; Palo Verde, Ariz.; WPPSS 1, 2, 4, Wash. (USGS not involved in 3,5); San Onofre, Calif.; Diablo Canyon, Calif.; Marble Hill, Ind. (USGS involved in early work but not in final at NRC request); Surry 3, 4, Va.; Vogtle, Ga.; No. Ànna, Va. Reactor reviews in progress: Diablo Canyon, Calif. (review recently reactivated); Pilgrim, Mass.; Skagit, Wash.; Pebble Springs, Oreg.; San Joaquin, Calif.; NORCO, P.R.; Humboldt Bay, Calif.; Sundesert, Calif. Reactor review to be undertaken soon (1978?): Stanislaus, Calif. From ERDA press release (June 30, 1976).

seismic and geologic sections of the PSAR are written in compliance with the criteria in the Congressional Federal Register, v. 38, no. 218, p. 31279-31285, "Seismic and Geologic Siting Criteria," which sets forth the definitions and required investigations.

USGS, as a consultant to the Nuclear Regulatory Commission, reviews the geologic and seismic data and conclusions presented in the seismology and geology sections of the PSAR for technical content and validity. USGS personnel having expertise in given areas that are appropriate to the site being considered are normally consulted.

Much of the investigative work performed by the power companies and USGS is state-of-the-art in nature and has contributed to the knowledge of seismology. For example, errors in earthquake catalogs have been corrected, maximum intensities have been reevaluated, and epicentral locations have been redefined.

Strong-motion program

The U.S. accelerograph network has grown rapidly in the last few years. As of September 1976, a total of 1,739 accelerographs were installed and in operating order throughout the United States. Figure 5 indicates the number of accelerographs in each of the 50 States plus Puerto Rico. More than 80 different organizations have purchased or required the purchase and installation of these accelerographs. Table 2 lists 18 instrument owners who have made an initial purchase of more than 10 accelerographs. Only 10 States are now without strong-motion instruments. These 10 States are in seismic risk zones 0 or 1, and there is little possibility that these States will be instrumented in the future.

Figure 6 is a map of Central America; it includes a table indicating the number of accelerographs and seismoscopes that were in place during 1976. Figure 7 is a map of the Latin American and Caribbean countries, showing the number of accelerographs installed in each country.

Digitization and analysis of the five significant 1971 records subsequent to the February 9, 1971, San Fernando earthquake have been published (U.S. Geological Survey, 1976). Table 3 lists those accelerograph records for the period 1973-76 that are considered significant (arecord with a peak amplitude of 10 percent g or more). Digitization and analysis of these significant records are being carried out by the USGS Office of Earthquake Studies.

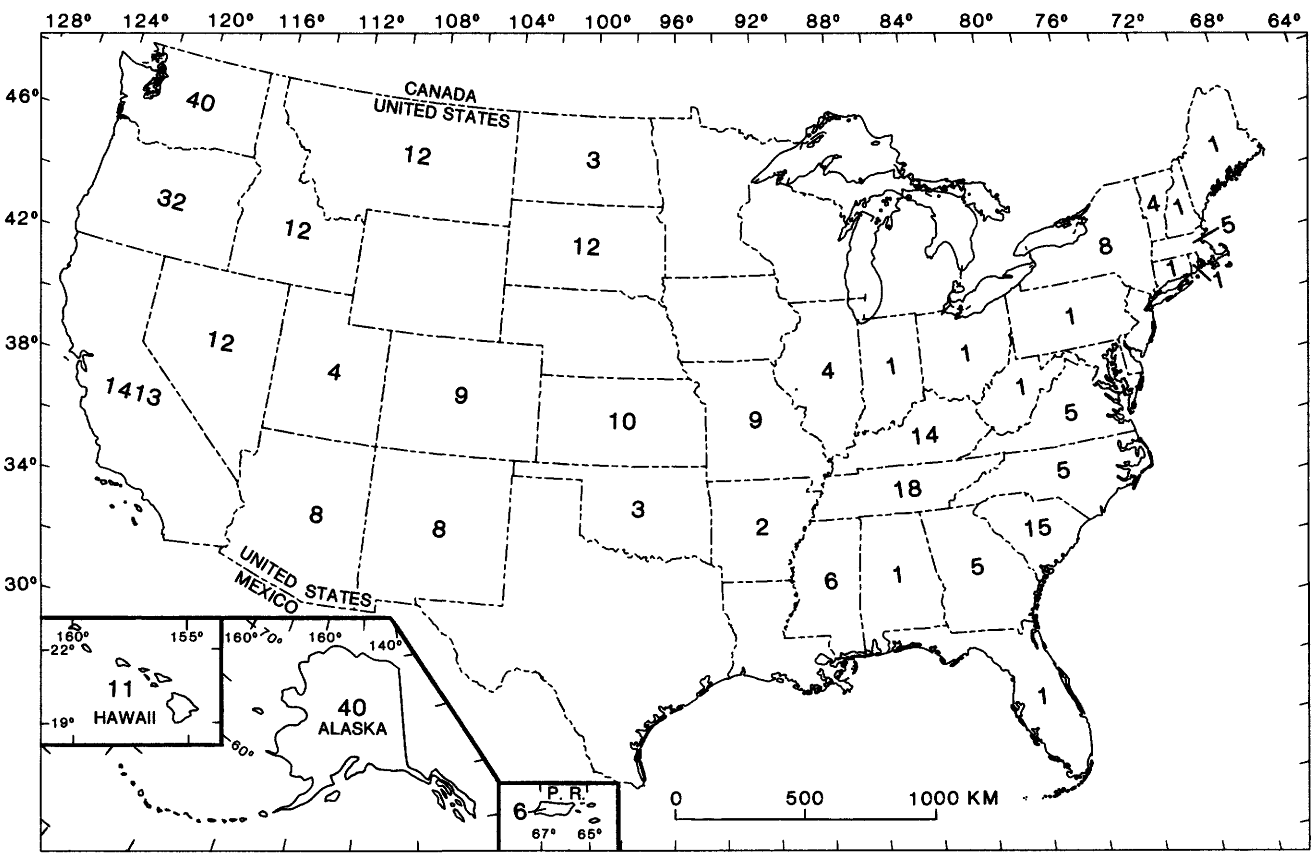


FIGURE 5.--U.S. accelerograph network, September 1976. (Number indicates total number of accelerographs in State.) Total accelerographs 1,739 (modified from Mathiesen, 1974).

Table 2.--*Agencies in the United States with 10 or More Strong-Motion Instruments*

Instrument owners	Accelerographs
Los Angeles City Ordinance------------------------	469
California Division of Mines and Geology----------	263
Corps of Engineers, U.S. Army---------------------	222
Seismic Engineering, USGS-------------------------	163
California Institute of Technology----------------	73
California Dept. of Water Resources COOP Project--	65
U.S. Veterans Administration----------------------	61
Beverly Hills City Ordinance----------------------	48
Coronado City Ordinance---------------------------	24
Metropolitan Water District-----------------------	23
Newport Beach City Ordinance----------------------	21
U.S. Bureau of Reclamation------------------------	20
Santa Ana City Ordinance--------------------------	18
El Segundo City Ordinance-------------------------	15
Santa Rosa City Ordinance-------------------------	12
Inglewood City Ordinance--------------------------	12
Pacific Telephone & Telegraph Co.-----------------	11
Palo Alto City Ordinance--------------------------	11

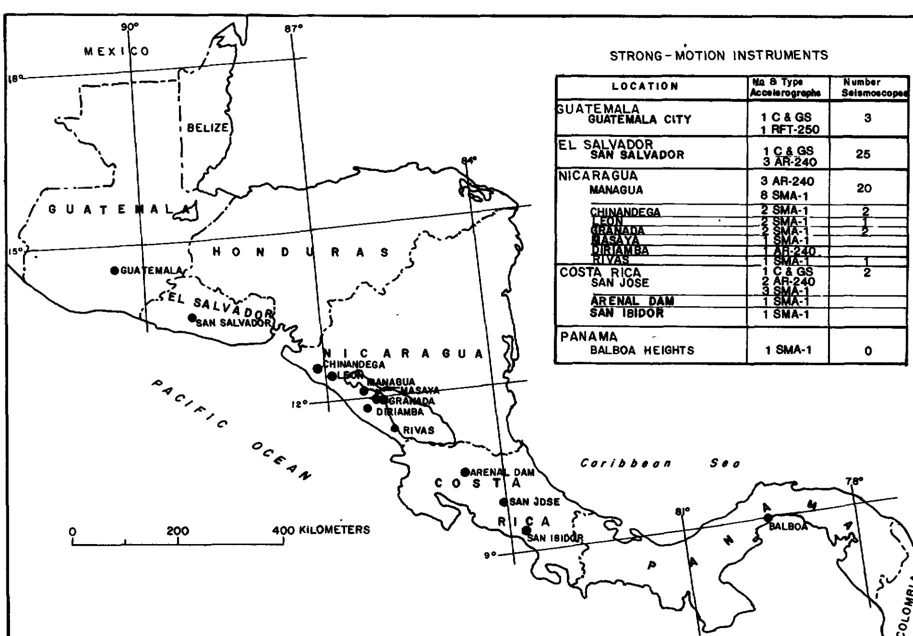


FIGURE 6.--Central America strong-motion stations. Modified from Knudson (1975).

FIGURE 7.--Latin America and Caribbean strong-motion accelerographs. Number in parentheses, number of accelerographs in country. Modified from Knudson (1975).

Table 3.--*Significant Accelerograph Records, 1973-1976*

Date of event	Station location	Maximum accel.[1] (g)
	1973	
Feb. 21	Port Hueneme, Calif.; U.S. Naval Laboratory------------	0.13
Mar. 31	Managua, Nicaragua; National University----------------	.60
Apr. 26	Kilauea, Hawaii; Namakani Paio campground--------------	.17
Aug. 8	Ferndale, Calif.; Old City Hall------------------------	.14
Sept. 16	Berryessa, Calif.; CDF Fire Station--------------------	.18

Table 3.--*Significant Accelerograph Records, 1973-1976* --Continued

Date of event	Station location	Maximum accel.[1] (g)
	1974	
Jan. 5	Lima, Peru; Zarate Station------------------------------	0.16
	Lima, Peru; Geophysical Institute-----------------------	.11
Jan. 31	Gilroy, Calif.; Gavilan College, Building 10------------	.16
Feb. 11	Los Angeles, Calif.; 420 S. Grand[2]----------------------	.10
	Los Angeles, Calif.; 525 S. Flower, North Tower[2]--------	.13
	Los Angeles, Calif.; 700 W. 7th[2]------------------------	.18
	Los Angeles, Calif.; 533 S. Fremont[2]--------------------	.25
	Los Angeles, Calif.; 420 S. Grand[2]----------------------	.10
Aug. 14	Pacoima dam, California; abutment----------------------	.12
	Vasquez Rocks Park, Calif.------------------------------	.10
Oct. 3	Lima, Peru; Dr. Huaco's residence-----------------------	.18
	Lima, Peru; Geophysical Institute-----------------------	.21
Nov. 9	Lima, Peru; La Molina Station---------------------------	.14
Nov. 28	Hollister, Calif.; City Hall----------------------------	.17
	San Juan Bautista, Calif.; 24 Polk Street---------------	.12
	Gilroy, Calif.; Gavilan College, Building 10------------	.14
Dec. 6	Imperial, Calif.; Imperial Valley College Adm. Building-	.11
	1975	
Jan. 11	Petrolia, Calif.; general store-------------------------	0.10
	Cape Mendocino, Calif.; Petrolia------------------------	.19
Jan. 23	Imperial, Calif.; Imperial Valley College Adm. Building-	.11
Mar. 6	Bear Valley, Calif.; Melendy Ranch East-----------------	.18
May 6	Shelter Cove, Calif.; Station 2 power plant yard--------	.18
June 7	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	El Centro Array, Calif.; Station 6, 551 Huston Road-----	.10
June 20	El Centro Array, Calif.; Station 6, 551 Huston Road-----	.13
	Holtville, Calif.---------------------------------------	.15
Aug. 1	Oroville dam, California; crest-------------------------	.13
	Oroville dam, California; seismograph station-----------	.11
Aug. 2	Pleasant Valley, Calif.; pumping plant------------------	.08
	Pleasant Valley, Calif.; switchyard---------------------	.13
Sept. 13	Parkfield Grade, Calif.; Jack Varian Ranch--------------	.14
	Vineyard Canyon, Calif.---------------------------------	.18
Nov. 14	Ferndale, Calif.; Old City Hall-------------------------	.18
	Cape Mendocino, Calif.; Petrolia------------------------	.13
	Petrolia, Calif.; general store-------------------------	.10
Nov. 29 0335 (local time)	Hilo, Hawaii; University of Hawaii Cloud Physics Laboratory.	.15
Nov. 29 0447 (local time)	Honokaa, Hawaii; Central Service building---------------	.11
	1976	
Jan. 1	Brea dam, California; crest-----------------------------	0.13
	Brea dam, California; downstream------------------------	.10
	Carbon Canyon dam, California; crest--------------------	.12
	Carbon Canyon dam, California; right abutment-----------	.14
	Carbon Canyon dam, California, left abutment------------	.14
	Santa Ana, Calif.; Orange County Reservoir, abutment----	.18
	Whittier, Calif.; 7215 Bright Avenue--------------------	.28
Feb. 18	Guatemala City, Guatemala; IBM building-----------------	.10
Apr. 14	El Centro Array, Calif.; Station 6, 551 Huston Road-----	.14
Nov. 4	Brawley Airport, Calif.; Transformer building-----------	.11

[1]Maximum acceleration at ground level.

[2]The records from the upper levels of these buildings are being digitized.

Figure 8 shows important earthquakes (large magnitude or destructive) that have occurred in Central America and parts of northern South America since 1898. Preliminary efforts are under way to increase the number of strong-motion instruments in the region. The operation of these instruments should be useful for all concerned with earthquake risk studies.

Earthquake hazards

Earthquake-hazards research in the USGS has the long-range objective of quantifying earthquake hazards throughout the United States. The principal research efforts are focused on (1) locating the zones where potentially damaging earthquakes might occur; (2) identifying the areas that have a high potential for rupture of the ground surface by faulting; (3) identifying the potential for damaging levels of ground shaking on different geologic units at various distances from the earthquake source; (4) specifying the areas that are susceptible to ground shaking, causing induced ground failures such as landslides and liquefaction; and (5) delineating the areas that are susceptible to flooding from dam failures, tsunamis, seiches, and tectonic changes of sea level.

A seismic-risk map (fig. 9) was a major product of the earthquake-hazards research program during 1976 (Algermissen and Perkins, 1976). It depicts the peak ground acceleration expected at a rock site in the contiguous United States in a 50-year period, at the 90-percent probability level. This map, unlike past seismic-risk maps, provides quantitative data needed for many engineering applications.

A team of scientists went to Guatemala following the February 4, 1976, earthquake to examine the geologic and hydrologic effects, to inspect areas of damage and nondamage to buildings and city lifeline systems, and to record aftershocks of the earthquake. Working cooperatively with Guatemalan scientists, engineers, and government officials, the scientists were able tolearn a great deal about earthquake effects, and the research findings have been published (Espinosa, 1976).

The present near-term objectives of earthquake-hazards research in the United States are twofold: (1) to obtain information needed for improved national seismic-risk assessment, and (2) to establish a framework for undertaking regional and local hazards assessment to aid regional, State, and local governments.

Examples of research projects that are designed to meet these objectives include (1) ground response, Los Angeles, Calif., region; (2) ground respon, Salt Lake City, Utah, region; (3) relation of seismicity to regional geology; (4) active faults and recent tectonic deformation, southern California; (5) assessment of seismic hazards, northern Mississippi embayment; (6) seismic attenuation, United States; and (7) U.S. seismogenic zones.

Prediction of seismic and volcanic activity

The following description is excerpted from the Federal Register, v. 42, no. 70, April 12, 1977:

"Geologic processes and conditions that could result in harm to people and property include earthquakes, volcanic eruptions, landslides, mudflows, subsidence, faulting and fissuring of the

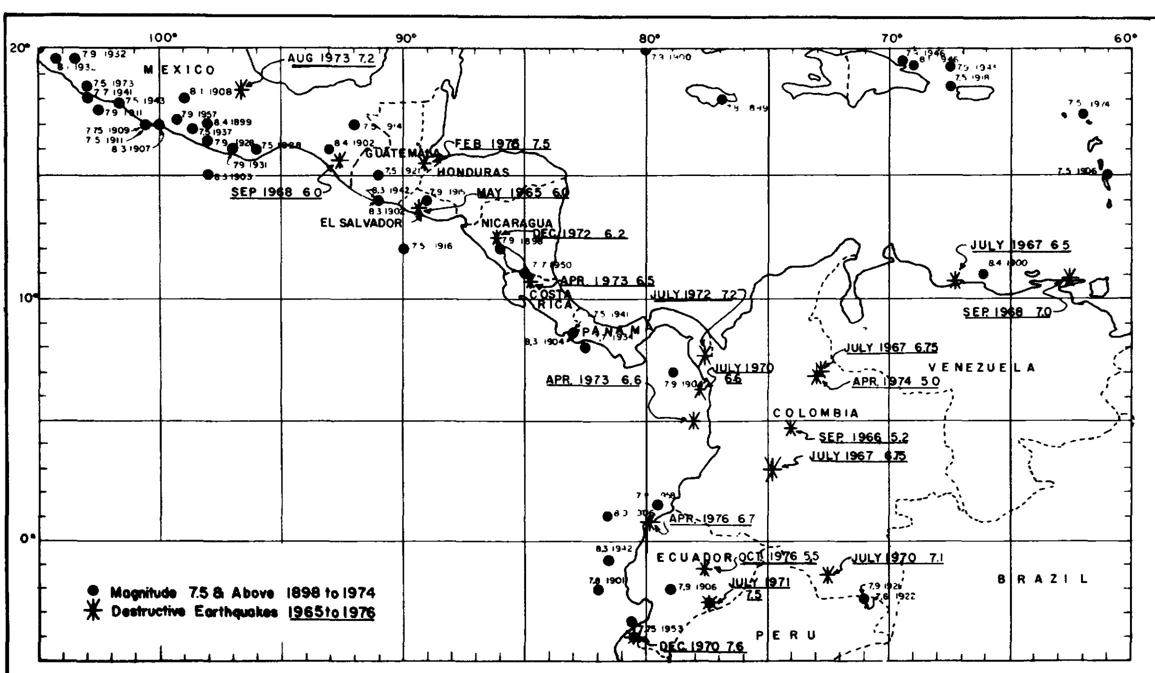


FIGURE 8.--Large-magnitude and destructive earthquakes in Middle America.

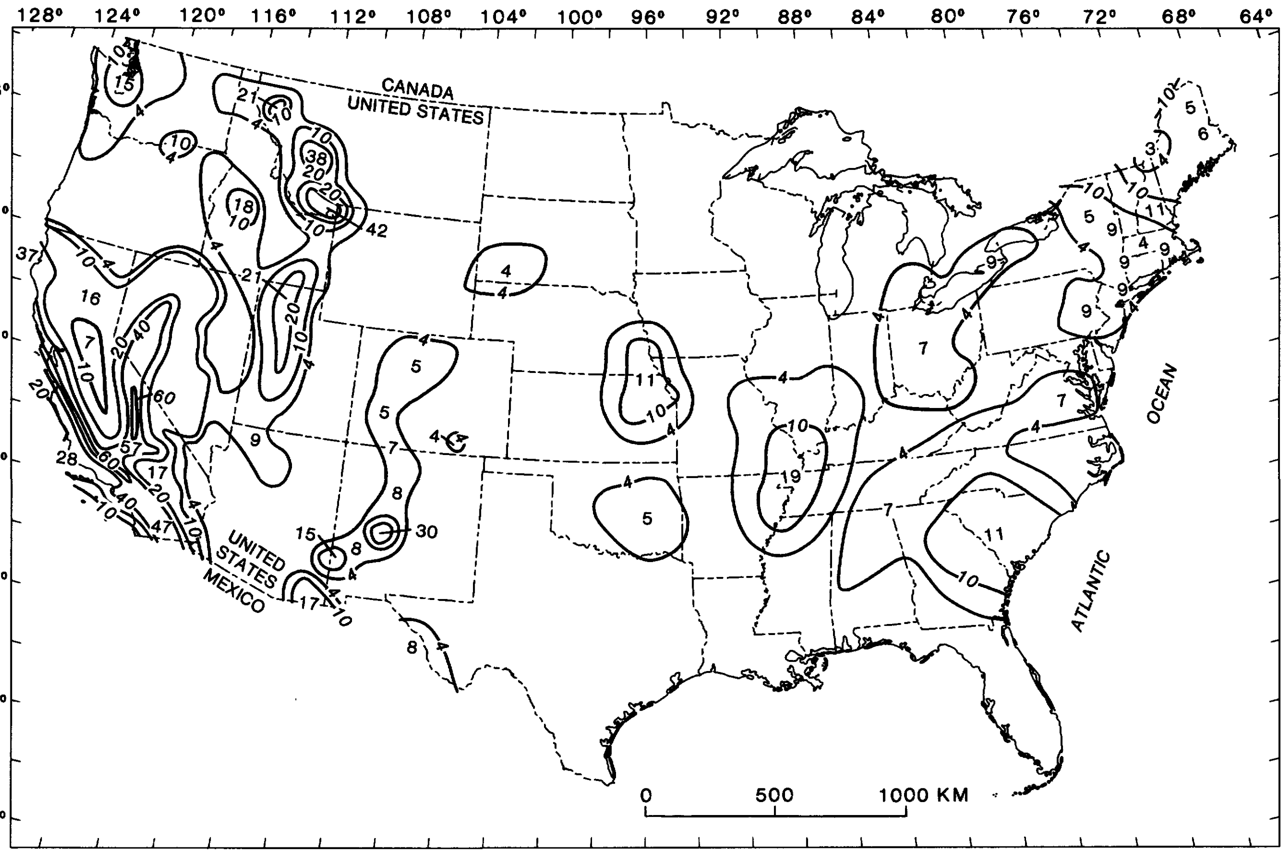


FIGURE 9.--Horizontal acceleration (percent of gravity) in rock with 90 percent probability of not being exceeded in 50 years. Maximum acceleration within the 60 percent contour along the San Andreas and Garlock faults in California is 80 percent of g (using the attenuation curves of Schnabel and Seed, 1973). From Algermissen and Perkins (1976).

ground surface, and glacier-related phenomena such as release of glacier-dammed lakes and rapid ice surges or retreats. Under certain conditions, these events may occur suddenly and affect large numbers of people and property over a wide area; in other instances, however, the processes involved occur slowly or affect very limited areas so that few if any people are endangered. The present capability of scientists to predict hazardous events varies greatly as to the type of event and knowledge of its time, place, and magnitude of effects."

Earthquakes

Much of the United States is subject to some degree of earthquake hazard. The western States of Alaska, California, Hawaii, Idaho, Montana, Nevada, New Mexico, Utah, Washington, and Wyoming are particularly susceptible, but major earthquakes have also struck the eastern and central parts of the United States (Hadley and Devine, 1974), particularly Arkansas, Georgia, Kentucky, Indiana, Illinois, Massachusetts, Mississippi, Missouri, New York, North Carolina, South Carolina, and Tennessee.

In many instances, earthquake-generated ground shaking causes the most widespread earthquake damage, principally through failure of buildings. Earthquakes also give rise to various geologic processes that may cause injuries and property damage, including surface faulting, landsliding and associated ground failures, generation of large waves in water bodies, and regional vertical movements (downwarping and upwarping).

The surface effects of earthquakes have been evaluated on the basis of geologic and seismologic studies in parts of Alaska (Page and others, 1972), California (Borcherdt, 1975), Idaho (Witkind, 1972), Nevada (Bingler, 1974), Utah (U.S. Geological Survey, 1976), Washington (Pitt, 1972; U.S. Geological Survey, 1975), and the Eastern United States (Dutton, 1889). The results of regional studies under way in these and other States will be published as they are completed.

Predictions of the precise location, time, and magnitude of specific earthquakes cannot generally be made now. Certain precursors, such as ground tilting and changes in water levels in wells, the magnetic field, and seismic-wave-velocity characteristics in rock, may be useful in predicting earthquakes. Experimental instrumental arrays have been installed in a few research areas, such as near Hollister, Calif., to evaluate these precursors and to help develop an earthquake-prediction capability.

Locations of faults that may be the sources of future damaging earthquakes have been determined in some regions of the country, particularly in parts of Alaska, California, Nevada, Idaho, Montana, and Utah. Geologic and seismologic studies in these regions, however, are not adequate to assure that all such faults have been delineated. Geologic studies of recurrence intervals of earthquakes have been made on only a few faults, principally in California. Some of these studies provide a basis for estimating the magnitudes of earthquakes that are likely to be generated by movement along a particular fault. Broad-scale estimates of the susceptibility of the various regions of the United States to earthquake hazards have been made and are published in earthquake-hazard maps and reports (Algermissen and Perkins, 1976), which will be updated as new information is acquired. These maps, and the more detailed studies on which they are based, identify those regions known to be highly susceptible to earthquakes, even though they may not identify all faults along which movement may take place.

Regional earthquake-hazard assessments are also under way in parts of New Mexico, New York, South Carolina, and Washington, and in the lower Mississippi Valley.

Volcanic eruptions

At the present time, volcanoes are active in Alaska and Hawaii; volcanoes in California, Oregon, and Washington are dormant, but have erupted within the last 150 years. The likelihood of future eruptions that will be damaging to man is greatest in the vicinity of volcanoes in these States. Geologic evidence indicates that volcanic activity could occur in other areas, such as Arizona, Nevada, New Mexico, Wyoming, and Idaho (Mullineaux, 1976), where eruptions have occurred as recently as 350 years ago; no current evidence, however, suggests that volcanic activity may occur in these areas in the near future. Broad estimates have been made of regional susceptibility and types of volcanic hazards in the conterminous United States and Hawaii (Crandell, 1976; Crandell and Mullineaux, 1975; Mullineaux, 1976; and Powers, 1948); these will be updated as new information is acquired.

Volcanic eruptions produce a wide variety of primary and secondary hazards to life and property, stemming mainly from hot avalanches, mud flows, ash falls, lava flows, volcanic gases, hot-particle and gas clouds, and floods.

Studies of the products of past volcanic activity in the Cascade Range, including lava flows, ash falls, mud flows, and hot avalanches, have been completed on the volcanoes of Mt. Baker (Hyde and Crandell, 1975), Lassen Peak (Crandell and others, 1974), Mt. Rainier (Crandell, 1973), and Mount St. Helens (Crandell and Mullineaux, 1976; Crandell and others, 1975); similar studies are planned or in progress for other major volcanoes in the Cascade Range, such as Mt. Hood and Mt. Shasta, and for Augustine Volcano in Alaska.

Detailed studies at Kilauea and Mauna Loa Volcanoes in Hawaii show that the products of most historic and prehistoric eruptions are lava flows; subordinate products include ash falls and hot-particle and gas clouds. Eruptions issue from fissures and vents both in the summit areas and along rift zones on the flanks of the volcanoes. Assessments of hazard-susceptible areas have been made for the islands of Hawaii (Mullineaux and Peterson, 1974) and Oahu (Crandell, 1975).

Kilauea and Mauna Loa Volcanoes are monitored by an array of instruments and by systematic measurements that permit assessment of the likelihood of impending activity (Waesche and Peck, 1966; Kinoshita and others, 1974). Physical precursors often permit predictions to be made within time frames of weeks or days, and sometimes highly specific signals precede eruptions by one to several hours (Swanson and others, 1971; Fiske and Kinoshita, 1969).

A study of the historic cycles of activity on Mauna Loa indicates the possibility of long-term prediction of the general locality and the general time frame (months or years) of the next eruptive event (Lockwood and others, 1976).

Predictive capability has not been achieved for volcanoes in the Cascade Range or in Alaska, although it is possible that the methods developed in Hawaii can be modified and adapted to be useful in these regions. Detailed estimates of hazard-susceptible areas surrounding some of these and other volcanoes have been made, as indicated earlier. Other studies are under way and will be published as completed.

Geophysical exploration

Exploration geophysics is the application of the principles of physics to the search for minerals, including metals, coal, oil, gas, and water, that occur in Earth's subsurface. Most geophysical work is done using sophisticated electronic equipment that has been calibrated to detect contrasts in such physical properties as density, electrical conductivity, heat conductivity, seismic velocity, and magnetic susceptibility. The common techniques used are the gravity, magnetic, electrical, electromagnetic, seismic, and radioactivity methods. Measurements may be made from aircraft, at Earth's surface, or in boreholes. The discussions here will be limited to geophysics as applied to evaluations of metallic mineral resources.

USGS is active in several aspects of geophysical research that have applications in mineral resource evaluations. A combination of geophysical techniques, including both direct and indirect, is often applied to a particular problem in order to obtain a more diagnostic evaluation of an area. The objectives of USGS programs have been to define areas that seem likely to contain mineral deposits and not specifically to explore for discrete ore bodies. It has been left for the private sector to discover, develop, and mine ore deposits.

The aeromagnetic and gravity methods are used singly or in combination and have proven to be among the most useful methods for analyzing regional geologic framework and for identifying intrusives or other major rock types that may be useful in mineral resource evaluation. The truck-borne magnetometer has been effective as a rapid and economical means of examining the magnetic signature of an area. This information may be used in planning aeromagnetic work; or, in a more detailed evaluation of specific anomalies, it may denote unmapped or blind intrusives that have associated mineralization, such as the porphyry copper deposits at Ruth, Nev. Conversely, it may directly reflect iron ore deposits as at Marmora, Ontario. Negative anomalies also may be significant for cases in which the magnetite content of the host rock has been greatly reduced by hydrothermal alteration associated with ore emplacement, as at Cripple Creek, Colo.

Electrical-resistivity and electromagnetic surveys are well suited for follow-up to provide additional information about target areas delineated using gravity and magnetic surveys; they are particularly useful in the identification of buried conductors indicative of massive sulfide deposits. In studies of lateral variations in stratigraphy in sedimentary and highly foliated crystalline rocks, these methods can be used in investigating stratabound ore deposits and locating buried channels that may control uranium deposits.

In uranium and thorium studies, radioactivity surveys will be used by USGS directly to detect radioactive minerals and to correlate rock units in geologic mapping. Gamma-ray spectrometers are used to discriminate radiation from uranium, thorium, and potassium sources on the basis of the identification of energy levels in the total-count radiation spectrum. In other exploration research, gamma-ray spectrometers are used to study radioactive potassium associated with hydrothermal alteration that may have occurred during mineralization.

In geothermal exploration, a number of mineral prospecting techniques have been adapted, and developments offer promise for improved mineral exploration techniques for the future. Large self-potential anomalies have been observed over geothermal systems. In measurements of natural earth currents, telluric current, audio-magnetotelluric and conventional magnetotelluric methods have proven useful as economical reconnaissance techniques in exploring for conductive anomalies that may be associated with geothermal systems. As a follow-up, resistivity and transient electromagnetic measurements are used for detailed studies of suspected geothermal anomalies.

In remote sensing, USGS is conducting experiments in flying a multi-spectral four-band camera and thermal IR (infrared) scanner over areas of known base-metal and uranium mineralization to study resolution of subtle surface-alteration patterns. In studies of the Virginia City, Nev., area, a combination of digital computer processing and color compositing of ERTS (Earth Resources Technology Satellite; now called Landsat) MSS (Multi-Spectral Scanner) images was used to enhance spectral-reflectance differences; the result was detection and mapping of hydrothermally altered areas associated with the mineral deposits.

The anticipated increased demand for metal in the near future portends an urgent need to accelerate research and development of improved field measurements, streamlined data handling, and computer modeling of results to achieve more accurate interpretations of geophysical data in terms of identifying blind mineral deposits.

A number of developments are under way by USGS in electrical methods as applied to mining geophysics. The techniques of total-field resistivity mapping promise to be a rapid, yet good-resolution reconnaissance approach for deep resistivity studies. The method consists of grounding a long current bipole and calculating the total electrical field at various field stations. An improved electromagnetic technique, designated as ELF (extra low frequency), is being developed, which uses a ground transmitter as a multiple-frequency source and an aircraft to carry the receiver. The system has the advantages of providing a reliable signal along with rapid, systematic coverage possible only by using aircraft. The depth of penetration for large targets is about 500 m in areas of resistive country rock.

Progress is being made in interpretation of geophysical data using electronic computers. Highly effective computer programs for automatic interpretation of two- and three-dimensional models based on both d.c.-resistivity and electromagnetic data are being developed. Of most interest using the magnetic method are new computer techniques for making automatic depth determinations and for calculating the pseudogravity field from magnetic data. More rigorous mathematical treatment of filtering, such as recursive filtering, is being applied to magnetic data in attempts to effectively separate superimposed magnetic anomalies whose sources are at different depths in the subsurface. This treatment is particularly significant in detecting buried stocks that may be mineralizers in areas of surface volcanics and offers promise for a more rapid and economical evaluation of mineral resource potential using magnetic data. USGS has developed computer techniques for removing the terrain effects from magnetic data gathered in high-relief mountainous areas.

For a broader in-depth discussion of state-of-the-art geophysics, see Campbell (1977) and Espey (1977).

USGS conducts research in coordinated programs with other countries. High priority is given to training, generally on a one-to-one basis, of a USGS scientist working with a counterpart scientist both in the field and in interpretation of the data. In northern Mexico, for example, in cooperation with the CRM (Consejo de Recursos Minerales), USGS is engaged in an experimental studies program to develop new geochemical, geophysical, and geological exploration techniques useful in the search for mineral deposits, especially porphyry systems, in the Sonoran environment.

This program is an international, multiphase, and interdisciplinary evaluation of mineral exploration methods. Phase one, about 75 percent completed, is a regional evaluation of a belt having high mineral potentials; it is a belt of about 15,000 km^2 in the State of Sonora, extending from west of Nogales, through Cananea, Nacozari, and Oputo. The ongoing regional stream-sediment, gravity, and aeromagnetic surveys; structural and alteration studies; and the revision of geologic maps provide the framework for phase-two investigations. In phase two, regional studies will continue for the purpose of comparing the effectiveness of additional techniques at this scale; however, emphasis will be on interdisciplinary investigations of selected smaller areas of highest priority, as established by evaluation of phase-one data.

A variety of geological, geochemical, geophysical, and remote-sensing field and interpretive techniques are to be tested in the different physiographic, geologic, and climatic zones of the study areas. In the large areas of pediment gravels, which probably cover existing mineral deposits, combined geophysical techniques such as gravity, geoelectrical, and (or) seismic methods; geochemical techniques using element- and compound-concentration variation in soil gases, vegetation, and ground water; and remote-sensing techniques using luminescence and reflectance measurements will be evaluated. In areas of thin soil cover and outcrop, geologic studies of rock-unit relationships, structure, and alteration furnish guides to the type of geochemical and geophysical techniques to be applied.

Geomagnetism

Operations

The Project MAGNET RP-3D aircraft of the U.S. Naval Oceanographic Office has surveyed 1,337,000 line-kilometers of geomagnetic data in this quadrennium. Area coverage was worldwide, and both high-level (7,600-m) vector survey missions and low-level (150-m) scalar survey missions were flown.

Survey coverage in the PAIGH area included approximately 322,000 line-kilometers of vector data collected at the 7,600-m flight level. Survey lines are shown on the accompanying chart (fig. 10). The survey data will be used to improve the mathematical model of Earth's main geomagnetic field. Vector magnetic data points at various intervals (usually at 37 nautical-kilometer intervals) are available at the Geomagnetic Data Library, Magnetics Division, U.S. Naval Oceanographic Office, Bay St. Louis, Miss. 39522.

GASS (Geomagnetic Airborne Survey System) has been improved and expanded to provide a greater computer capacity and to upgrade positional accuracy. Both 16K capacity computers now have an auxiliary 16K memory unit. This allows the survey team to increase the sampling rate for a particular parameter. An electrostatic suspended gyro inertial system was added to GASS to provide more accurate references for the vector magnetometer and more accurate dead-reckoning information between navigational satellite fixes. More reliable synchro-to-digital converters were procured and integrated into GASS.

GASS accuracies that were realized are as follows: variation of compass, ±0.1 degree; inclination, ±0.1 degree; vertical intensity, ±5 nanoteslas; horizontal intensity, ±7 nanoteslas; total magnetic intensity, ±1 nanotesla; and position, ±0.5 kilometer.

In 1973, most of the magnetic observatories that had been operated by NOAA were transferred to USGS. These observatories were located at Barrow, College, and Sitka, Alaska; Fredericksburg, Va.; Boulder, Colo.; Dallas, Tex.; Newport, Wash.; Tucson, Ariz.; Castle Rock, Calif.; San Juan, P.R.; Guam, Mariana Is.; and the South Pole. The NOAA National Weather Service continued operation of the Honolulu Observatory in Honolulu, Hawaii. The South Pole station was closed at the end of 1974. Dallas Observatory terminated operations in April 1975, Castle Rock Observatory in May 1976. Digital magnetometer systems recording declination and horizontal and vertical intensities using fluxgate magnetometers, and total intensity using a proton magnetometer were installed at College, Sitka, Barrow, Newport, Tucson, and Boulder. Similar systems are planned for eventual installation at all USGS observatories.

In 1974 a USGS geophysicist visited magnetic observatories in Mexico, Colombia, Peru, Bolivia, and Brazil to make comparative measurements between the absolute instruments used in these countries and the instruments used in the United States. These measurements permit establishment of a common baseline or international standard of magnetic measurements. This cooperative work was funded primarily by PAIGH. In 1976 PAIGH approved funding for USGS geophysicists (1) to visit Brazil and Argentina (in 1977) to continue these comparative measurements, and (2) to visit the University of Costa Rica to advise and assist in the establishment of a magnetic observatory in Costa Rica, for which USGS will provide most of the instrumentation. (For more information on these PAIGH projects, see the section entitled "Special Projects of the PAIGH involving the U.S. Commission on Geophysics.")

USGS conducted a magnetic measurements program at more than 100 repeat-survey field sites to provide data for the 1975 magnetic charts. The measurements were made at these sites utilizing a fluxgate magnetometer mounted on a theodolite for measuring declination and inclination. Total field measurments were made with a proton magnetometer, permiting calculation of the horzontal and vertical components. A three-component fluxgate recording system was operated at these sites to provide information for removing tranient and diurnal variations from the observations.

Data services

In cooperation with the U.S. Naval Oceanographic Office, USGS produced a new world model of Earth's magnetic field for epoch 1975.0, which was used to create the world magnetic charts subsequently published by the Defense Mapping Agency. The model, consisting of 168 coefficients derived using a spherical harmonic analysis, utilized an initial set of 600,000 worldwide measurements of the geomagnetic field made from 1939 to 1974. The models of secular variation, also derived by spherical harmonic analysis, used the annual means from 140 worldwide magnetic observatories to produce a series of 80 coefficients. World maps were published for declination, inclination, horizontal intensity, vertical intensity, and total intensity. USGS also published a series of five magnetic charts of the United States for epoch 1975.0 in cooperation with NOAA. The new U.S. charts, for all five components, were derived by polynomial analyses using more than 60,000 regional observations collected since 1900. The declination chart for the conterminous 48

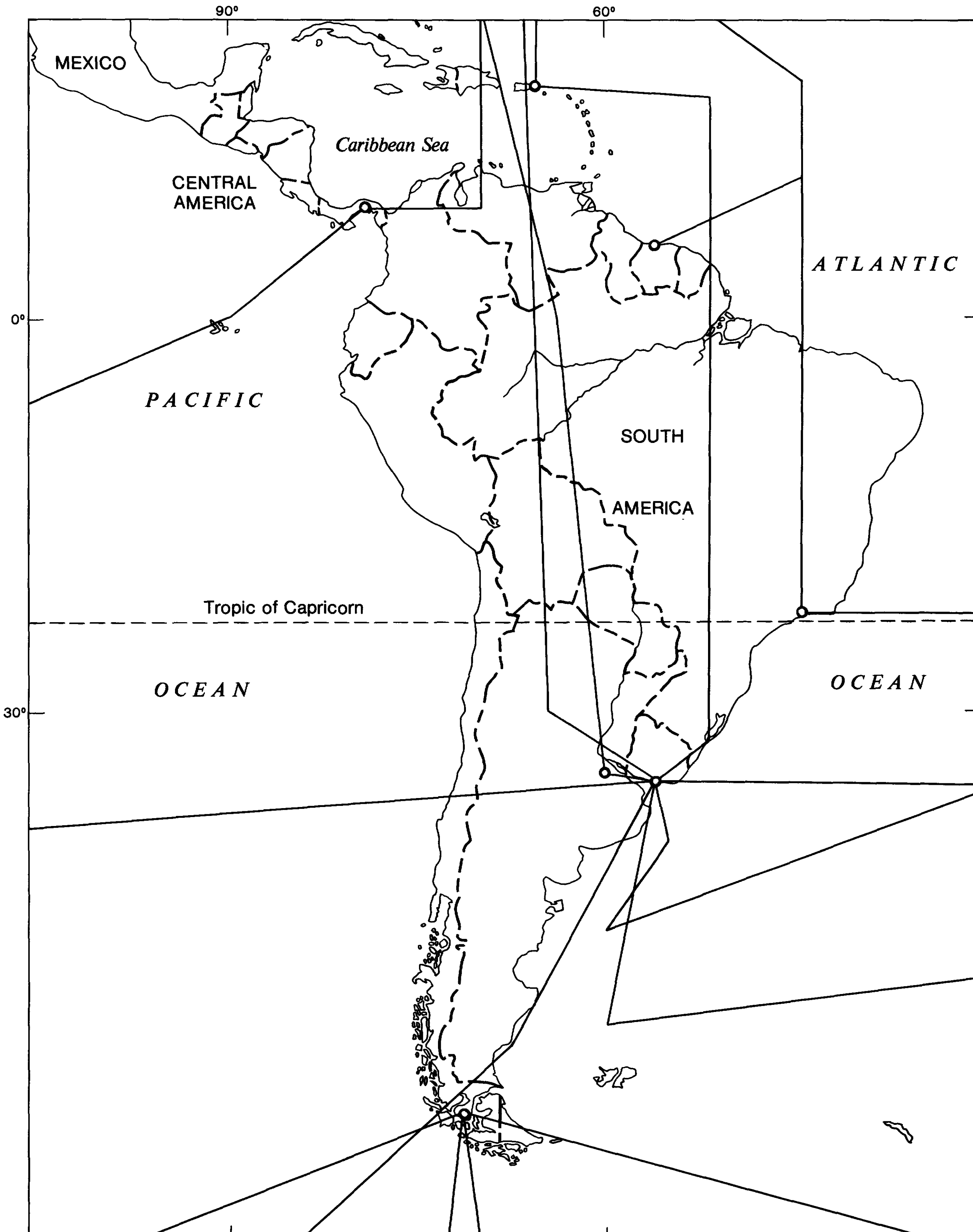


FIGURE 10.--Project MAGNET surveys, southern PAIGH area, 1973-76. Lines, flight lines; circles, base stations. Data from: Geomagnetic Data Library, Magnetics Division, Bay St. Louis, Miss. 39522.

States was derived by partitioning the region into five 12° X 12° longitudinal bands having 2° overlap and performing a degree-7 analysis, yielding 36 coefficients for each partition. The other components are represented by single degree-7 models. For the lines of equal annual change, data from regional magnetic observatories and more than 100 U.S. repeat stations were analyzed to produce models of annual change, each consisting of 28 coefficients. All models, both of the main field and its annual change, were used directly on the CDC6400 computer to contour the required isolines.

NOAA's EDS in Boulder, Colo., continued its WDC (World Data Center) operations in geomagnetism via WDC-A for Solar-Terrestrial Physics and WDC-A for Solid Earth Geophysics. The normal flow of data input was enhanced by the visit of a WDC-A representative to the Latin American institutions that operate magnetic observatories. Using a portable microfilming camera, this representative filmed all available magnetograms and tables of hourly values that were not already in the WDC collection. Requests for copies of data from WDC-A, mostly from geophysical researchers, have continued to increase, and it is expected that the present augmented collection will result in an even greater number of data requests. WDC-A has continued to collect all forms of worldwide geomagnetic data, maintaining the data bases that are used by the other U.S. Government agencies in their analyses. In addition, WDC-A has digitized magnetograms from 11 polar observatories for the years 1966-75, obtaining values for every 2.5 minutes, for the purpose of computing indices of AE (auroral electrojet) activity. Most of this work has been accomplished using semiautomatic digitizers, but a new automatic digitizer was acquired in 1974 and some of the magnetically quiet intervals were processed using this new machine. Other new hardware provided for a system for the review of results and correction of errors by interactive graphics.

Heat flow

WDC-A for Solid Earth Geophysics published a unique heat-flow map of the world. The first of its kind, the map shows the amount of heat flowing outward from the interior of Earth and indicates where heat-flow measurements have been made and the approximate value of heat flow at each site. Heat-flow measurements are shown by one of five different colors, each indicating a different range of heat-flow values. Measurements number about 5,500 for the entire globe. The map also shows the locations of all known active volcanoes, along with earthquake epicenters for the years from 1961-73. These areas of volcanic and seismic activity delineate regions of Earth where the litospheric plates are interacting. The data for this map were compiled under the auspices of the International Heat Flow Commission IASPEI/IUGG (International Association of Seismology and Physics of the Earth's Interior/International Union of Geodesy and Geophysics) by A. Jessop, M. Hobart, and J. Sclater. The map was prepared by P. Grim of WDC-A for Solid Earth Geophysics.

Volcanology

Since 1973 the National Museum of Natural History, Smithsonian Institution, has been engaged in a collaborative program with the Escuela Politecnica Nacional in Quito, Ecuador, to study Volcan Reventador in Ecuador. This study was accelerated following the January 1976 eruption of Reventador. Principal investigators are Minard Hall of the Escuela Politecnica Nacional and Tom Simkin of the National Museum.

A larger project has been the study of three volcanoes, Fernandina, Marchena, and Cape Berkeley, in the Galapagos Islands. This study began in mid-1968 after the major eruption and caldera collapse of Fernandina, and several investigators are continuing to collaborate. Principal investigator is Tom Simkin of the National Museum (Simkin and others, 1972; Case and others, 1973; Simkin, 1972; Filson and others, 1973; and Simkin and Howard, 1970).

The National Museum has also compiled a computerized volcano data file and is preparing a publication to summarize much of the physical and chronological information that has been compiled on the volcanism of the last few thousand years (Simkin, 1976).

Marine geophysics

International Decade of Ocean Exploration and International Phase of Ocean Drilling

Marine geophysical activities in the United States flourished during the 1973-76 quadrennium. The IDOE (International Decade of Ocean Exploration), begun in 1971, gained further momentum. Detailed geophysical surveys under the IDOE-funded Seabed Assessment Program were conducted along the Atlantic Continental Margins of both Africa and South America. In the Pacific, the IDOE marine geophysical programs concentrated on the Nazca Plate in the first half of the quadrennium; since that time a program has been initiated to explore the geophysical characteristics of East and Southeast Asia in conjunction with the IOC (Intergovernmental Oceanographic Commission). Additional details follow on the Nazca Plate study. (See section entitled "IDOE" for a summary of the IDOE-CUEA program.)

Cooperative Investigation of the Caribbean and Adjacent Regions and Intergovernmental Oceanographic Commission Association for the Caribbean and Adjacent Regions

NOAA's Atlantic Oceanographic and Meteorological Laboratory in Miami, Fla., participated in the CICAR II (Cooperative Investigation of the Caribbean and Adjacent Regions) Symposium held at Caracas, Venezuela, July 12-16, 1976. The group agreed to continue the marine studies in the Caribbean area and welcomes any other group or individual to join in the study. Objectives of the study are described in the following recommendation (Intragovernmental Oceanographic Commission/IOCARIBE-I/3, 1976):

"Environmental Geology of the Caribbean Coastal Area

The IOC Association for the Caribbean and adjacent regions,
Recognizing that the coastal area of islands and mainlands is most strongly affected by man's activities and is therefore the immediate concern of coastal zone management,
Proposes a systematic and time-progressive geological programme of investigation collectively referred to as Environmental Geology of the Coastal Area within the IOCARIBE area - the term "coastal area" being defined as those contiguous marine and land areas characterized by direct interaction (typically the coastal plains and submerged continental and insular shelves) - and being guided in the formulation of this programme by information contained in Programme 10 of the ad hoc Group of Experts (Puerto Rico, March 1976) and the draft programme "Morpho- and Lithogenesis of the Mexico-Caribbean Coastal Shelf Zones," presented by the delegation of the Soviet Union;
Recommends that one of the products of this investigation will be a series of folios (quadrangular maps) of these coastal areas.
Recognizing further that various countries do not have the capability to produce such folios,
Decides that two pilot programmes should be developed,
Suggests that areas which might be considered for these pilot studies include all the coastal areas of the region but in particular the Lesser Antilles, Central America, and portions of the Greater Antilles,
Recommends that a workshop be convened to:
i) define the content of the above folios
ii) identify investigative procedures and methods
iii) develop a co-ordinative scheme for existing national programmes which could produce such folios
iv) identify areas for the two IOCARIBE pilot studies mentioned above
v) select Project Managers and Assistant Project Managers as needed;
Appoints Dr. John P. Scott of Trinidad and Tobago as Chairman of a Steering Committee to convene this Workshop and empowers him, in consultation with the Chairman of IOCARIBE, to select the remaining members of the Steering Committee."

Nazca Plate

The Nazca Plate project was initiated in 1971 as a joint research effort by HIG (Hawaii Institute of Geophysics) of the University of Hawaii and the School of Oceanography of OSU (Oregon State University), with supporting collaboration from both individual scientists and various agencies in Colombia, Ecuador, Peru, and Chile. NOAA's POL (Pacific Oceanographic Laboratory) was involved in the program in its initial phases. The investigation employed a wide range of marine geophysical, geological, and geochemical experimental techniques directed at determining the interrelationship of an oceanic crustal-plate tectonic cycle to metallogenesis and eventual ore emplacement. This tectonic cycle has been considered in terms of (1) the primary locus of metallogenesis at a divergent crustal-plate boundary, where new oceanic crust is being generated (the East Pacific Rise); (2) the transport, and accumulation of sediment on the moving plate and interaction of the crust with seawater; and (3) the zone of continental plate collision (Peru-Chile Trench) where the oceanic plate is subducted, loses its identity and is assimilated beneath the continent, with consequent mountain building, seismicity, volcanism, and intrusion into the overlying crust to create zones of mineralization.

During 1972-74, the participating institutions conducted extensive and comprehensive research cruises on the Nazca Plate, with emphasis on the divergent and convergent boundaries. OSU was involved in the data collection in 1972 and 1974 with the R/V YAQUINA and participated in one leg of the POL (NOAA) cruise in 1973. During April-May 1975, OSU also obtained dredge samples on the R/V MELVILLE from the basaltic crust of the Peru-Chile Trench.

Since the termination of field work in 1975, Nazca Plate scientists have been analyzing data and collected samples. During 1977 and early 1978, these analyses and interpretations will be completed. Publication of this work will occur in standard scientific journals. A special synthesis volume of papers will also be prepared to relate the various scientific tasks of the program to their metallogenesis theme. A series of maps accompanying this volume will depict various geological, geochemical, and geophysical data across the plate. Principal investigator for this project is LaVerne D. Kulm of OSU.

Other activities

The 1973-76 period saw the development and growth of a national marine geophysical data center at NOAA's EDS. This center, NGSDC (National Geophysical and Solar-Terrestrial Data Center), located in Boulder, Colo., presently serves major U.S. marine-oriented universities, Federal and State agencies, and many international organizations as a secure data archive and a source for all types of marine geophysical data in variable format. Its data collections already number some millions of track-kilometers of bathymetric, seismic, magnetic, and gravity data.

The U.S. Naval Oceanographic Office conducts multi-purpose surveys to obtain information in oceanic areas to support U.S. Navy requirements for oceanographic information, and in addition, where feasible, to contribute information to the scientific and economic community. This information is made available to the user through NGSDC. Oceanographic and geophysical data are collected from three civilian-manned oceanographic ships under the operational control of the Oceanographer of the Navy. During the past quadrennium (1973-76), USNS SILAS BENT (T-AGS 26) operated in the North Pacific Ocean, while USNS KANE (T-AGS 27) and USNS WILKES (T-AGS 33) were operating in the North Atlantic Ocean. These ships are equipped to collect oceanographic information on station and geophysical information while under way. Geophysical data are collected from a variety of sensors including magnetometer, seismic subbottom profiler, 3.5-kHz shallow profiler, and narrow-beam 12-kHz echo sounder. These systems are briefly described below:

1. Magnetic System--A proton precession-type magnetometer having a±0.1 nanotesla sensitivity is towed 180-240 m astern of the ship to measure Earth's total magnetic intensity. Data are recorded in both digital and analog form.
2. Bathymetry System--A Harris Model 853D, NBES (Narrow Beam Echo Sounder), operating at a 12-kHz frequency, is the system primarily used for bathymetry data acquisition; data are recorded digitally and in analog form. Selection of separate elements, within independent hull-mounted receiver and transmitter arrays, is gyro-controlled to always "look" vertically. Combined transmitter and receiver beams cross in a pattern that effectively produces a nominal 3° beam width. Data are recorded in sonic meters with a ±2-m accuracy at a depth of 8,000 m (system specifications).
3. 3.5-kHz Shallow Subbottom Profile System--Continuous profiles showing shallow subbottom reflectors are collected using an Edo 240 system employing a hull-mounted transducon array operated at a 3.5-kHz frequency. Output power is variable up to 5,000 watts. Data are collected in graphic analog form only, generally using a 1- or 2- ms pulse width at a 1-second recorder sweep rate.
4. Seismic System--A Teledyne SSP sparker seismic system, capable of energy outputs to as much as 90,000 joules, is used to produce continuous reflection profiles of the ocean-bottom sediment section. Arcer cables and a multielement dual-channel hydrophone streamer are towed behind the ship. Received signals are processed through an amplifier system that provides the filter control required to optimize the quality of data recorded on graphic-chart recorders. Records are generally collected using a 10-second recorder sweep rate and a slave recorder at a delayed 4-second sweep rate.

Navigation is provided by Satellite, LORAN-C, and LORAN-A systems. Magnetometer and echo-sounder data are acquired and processed on Digital Equipment Corporation PDP-9 computers onboard ship; navigation data are processed on the computer, while subbottom profiling data are acquired on analog recorders.

Automated data are returned to the U.S. Naval Oceanographic Office where they are stored in digital form in a UNIVAC 1108 computer data bank; analog data are microfilmed and original records are preserved. These data are analyzed and reported to various U.S. Navy users.

During the period from 1973-76, the following geophysical data were collected in the Geophysical Surveying Project in the Northern Hemisphere: magnetic, 178,503 km; narrow beam ES, 282,115 km; seismic, 221,867 km; and 3.5-kHz SSP, 429,808 km. Differences in distance arise because not all parameters are necessarily collected on every track. When processing is completed, copies of 3.5-kHz and seismic subbottom profiling data are forwarded to NGSDC; NBES data are sent to the Defense Mapping Agency Hydrographic Center, and magnetic data are deposited in the Magnetics Library of the U.S. Naval Oceanographic Office. Cruises made by the USNS SILAS BENT (in conjunction with USNS DESTEIGUER, T-AGOR 12) off the Pacific coast of Latin America, and cruises by USNS KANE and WILKES in the Caribbean Sea may be of interest. The data from the Caribbean Sea have been combined with other data in a publication entitled "Regional Geological/Geophysical Study of the Caribbean Sea" (Matthews and Holcombe, 1976). The study consists of seven geophysical maps and three track-control maps that have been compiled for the eastern Caribbean Sea. These maps are based upon bathymetric, magnetic, and seismic data from all available sources; they are estimated to contain between 90 and 95 percent of all data in existence for the Venezuela Basin. A comparison of the seismic maps with the bathymetric map indicates that eastern Caribbean bathymetry is primarily controlled by structure. Sedimentary processes have tended to subdue the structural expression by partially filling depressions. The geomagnetic map shows generally low relief resulting from the low magnetic latitude of the mapped area. High-amplitude, short-wavelength anomalies are associated with igneous activity along the island chains and the Aves Ridge. Interpretations are limited, with emphasis placed on criteria used for compilation of the maps.

Brief descriptions of the surveys conducted by USNS SILAS BENT and USNS DESTEIGUER off the west coast of Latin America are contained in U.S. Naval Oceanographic Office, 1973a and 1973b. The point of contact for this project is James L. Carroll, Code 3430, U.S. Naval Oceanographic Office, Washington, D.C. 20373.

Scientific Event Alert Network (SEAN)

In 1975, the Smithsonian Institution reassessed the performance of the SCSLP (Smithsonian Center for Short-Lived Phenomena) and concluded that the scientific community, as well as other interested correspondents, needed more timely and thorough reporting of natural scientific events. Accordingly, in October 1975 the Institution transferred three SCSLP employees from Massachusetts to the National Museum of Natural History in Washington, D.C., and formed SEAN (Scientific Event Alert Network). The objectives of SEAN are (1) to act as a communications hub for transient natural events--gathering information on events and passing it rapidly (via telephone or telex) to scientists immediately concerned with such events; (2) to distribute this information at no cost to a broader group of interested scientists and correspondents via a monthly bulletin; (3) to prepare follow-up reports in subsequent monthly bulletins on events of longer duration; (4) to concentrate on natural scientific events (man-made pollution events are normally not reported); and (5) to guarantee the close involvement of Smithsonian scientists with SEAN's communications activities.

Also in October 1975, the remaining members of SCSLP (Director Robert Citron and one part-time employee) formed a private corporation. This corporation, known as CSLP (Center for Short-Lived Phenomena), is no longer affiliated with the Smithsonian Institution. CSLP continues to serve its paid subscribers via postcard reports.

There are many correspondents in Latin America; in the last year they have reported nine volcanic eruptions and one fireball event. It is hoped that an even wider network of correspondents in Latin America will give better coverage and, in turn, stimulate more work on the transient geophysical events of that part of the world.

Earth-structure studies by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and various groups in Latin America

During the period 1973-76, the DTM/CIW (Department of Terrestrial Magnetism of the Carnegie Institution of Washington) has been involved in a variety of cooperative geophysical studies in Latin America. Several of these are continuing in nature; others represent efforts in new localities or with new groups. In summary, these studies are concerned with the region of the west coast of South America where it interacts with the Nazca Plate. The attempt has been made to delineate the nature of this interaction through studies of seismic structure from seismicity, studies of attenuation of seismic energy, surface-wave and refraction studies using earthquake and artificial sources, and studies of electrical-conductivity structure using magnetic storms as probes. The emphasis of DTM/CIW has been on the collaborative aspects of geophysical observations, continuing a long history of helping graduate students undertake their studies in North America. In this report period, for example, two students were Carnegie predoctoral fellows at Canadian universities. Several investigations will be briefly discussed, and resulting publications listed. Added support needed for this work has come primarily from the National Science Foundation, the A. L. Day Fund, and the H. O. Wood Fund. Important contributions in transporting equipment to and from the United States and South America and between various countries in South America have been helpfully provided by the Interamerican Geodetic Survey, Fort Clayton, Canal Zone. The Center for Research in Seismology in Lima, A. A. Geisecke, Director, has also provided invaluable contributions in support of these studies.

Anelasticity

This study was undertaken in Chile from 1966 to 1970 and in Peru from 1966 to the present. Broad frequency range (0.01-Hz), large dynamic range (2 cm-ground noise) tape recording seismographs were installed at three sites: Toconce in northern Chile, Cuzco in central Peru, and Trujillo in northwest Peru (Sacks, 1966). Using a technique equivalent to reversed refraction in explosion seismology, spectral ratio data derived from earthquakes at different depths are analyzed to determine Q structure (Sacks, 1969; Sacks and Okada, 1974). The broadband seismographs also have been used for source spectral studies of South American earthquakes (Linde and Sacks, 1972; Linde, 1974).

The lithosphere beneath South America has been shown to be very much thicker than was expected from the earlier, simple plate-tectonic models. A technique using shear-to-compressional wave conversion has been developed, which allows a fairly precise determination of the base of the lithosphere (James, 1971a; Sacks and Okada, 1974; Sacks and Snoke, 1977).

Evidence based on converted phases shows that the angle of subduction of the Nazca Plate under central Peru is about 30° instead of about 10° as proposed by others on the basis of seismicity (Okada, 1974; Snoke and others, 1977).

Seismicity

A number of high-sensitivity short-period seismographs were sited and operated to give good control of hypocenter determinations, in collaboration with A. Rodriguez B., Universidad Nacional de San Agustin, Arequipa, Peru; F. Volponi, Cuyo Universidad, San Juan, Argentina; Ramon Cabre, S.J., San Calixto Universidad, La Paz, Bolivia; German Saa, S.J., deceased, Universidad del Norte, Arica, Chile; and L. Ocola, IGP (Instituto de Geofisica del Peru, Lima, Peru) (James and others, 1969; Sacks and others, 1976). I. Selwyn Sacks was the principal investigator.

A discovery has been made of the interrelationship between the anelasticity structure (Q), the seismicity, and the volcanoes (Sacks, 1977).

Explosion seismology

This study was made in collaboration with L. Ocola, Lima, Peru; Ramon Cabre, S.J., La Paz, Bolivia; E. Ramirez, S.J., Bogota, Colombia; and A. Rodriguez B., Arequipa, Peru. The experience in southern Peru and northern Chile during the IGY, in which the Carnegie group led by H. Tatel and M. Tuve found large attenuation of seismic energy normal to the Andean Chain and little evidence for a refracted wave from the upper mantle, has led to continued efforts to learn the structure in southern Peru and central Bolivia. The latest of these observations was completed in July 1976, at which time colleagues from the University of Washington, Seattle (B. Lewis); University of Wisconsin (R. Meyer); and the University of Texas at Dallas (C. Helsley) joined in an offshore-onshore study with Carnegie and South American collaborators.

Explosion studies, which were also a major effort in 1973, include a study in southern Colombia and northern Ecuador that was carried out in collaboration with J. E. Ramirez of the Instituto Geofisico de los Andes Colombianos and J. Egred of the Universidad Politecnica, Quito, Ecuador. In addition to three papers already published (Ocola and others, 1971; Ramirez and Aldrich, 1973; and Ocola and others, 1975), a monograph is currently in preparation summarizing the entire experiment and giving a number of results obtained. In addition to the university collaboration mentioned above, the University of Hawaii and its ship, the KANA KEOKI, made important contributions (E. Berg and D. Hussong). The principal investigator was L. T. Aldrich.

Electrical conductivity structure in the Andes

Several areas have been studied from 1962 to the present. The bulk of the data has been obtained in central and southern Peru and in western Bolivia. Reconnaissance studies have also been made in northern Chile and central Colombia. A concentrated study using 15 temporary variograph stations included observations across the Andes in the region from lat 30° to 33° S. The Latin American collaborators include M. Casaverde R., IGP, Lima; A. Rodriguez B. and L. Tamayo, Universidad Nacional de San Agustin; R. Salgueiro P. and S. del Pozo in Bolivia; J. Bannister P., Universidad de Chile, Santiago; E. Triep, Cuyo Universidad, San Juan, Argentina; C. Garavito, Planetario Bogota; and J. S. Ramirez, S.J., Colombia. L. T. Aldrich is the principal investigator.

An early reconnaissance study of about 15 sites by Schmucker (1969) showed the existence of an anomalously high conductivity region paralleling the eastern Cordillera in Peru and central Bolivia. The data of Schmucker have been augmented by another set of over 75 stations in this region that extends into northern Chile and northern Peru. The structure appears to be complex, and analysis of the data is currently in progress.

The Defense Mapping Agency--Inter-American Geodetic Survey geophysical activities in Latin America

The DMA/IAGS (Defense Mapping Agency--Inter-American Geodetic Survey) contribution to geophysical activities in Latin America included support of regional reconnaissance gravity mapping and collection of geomagnetic data for revision of magnetic charts. Occasional coordination and reimbursable logistic support were provided for a variety of geophysical projects of significant international interest. Support for gravity mapping was provided in the form of instrument and equipment loans, occasional direct financial support, and regional coordination of planning and field activities. Through the international cooperation of cartographic and geophysical agencies in all Latin American countries, good progress was made toward reduction of existing gravity data to world standards and the preparation of national gravity anomaly maps at a scale of 1:500,000 and 1:1,000,000.

DMA/IAGS contributed to a Latin American geomagnetic program consisting of vector-component field observations used in compilation of magnetic charts and sufficient reoccupations for periodic revision of these charts. Instruments, planning coordination, and limited logistic support were provided. Permanent magnetic observatories were upgraded instrumentally, and minor items and expendable supplies were provided. Coordination of data collections from the observatories to WDC-A was improved.

DMA/IAGS, through its logistical, communications, and administrative systems, furthered the extent and feasibility of international geophysical projects to minimize effects of earthquakes and other natural disasters and to promote development of Earth resources.

Other related geophysical activities of DMA/IAGS are described in the U.S. report to the Commission on Cartography.

National Aeronautics and Space Administration geophysical projects in Latin America

One NASA (National Aeronautics and Space Administration) project is under way and another is in the planning stage. The former is the Cotopaxi Volcano Monitoring System; its purpose is to look for unusual tilts or seismic activity that might precede possible eruption. Hardware has been installed. The system is based on USGS designs and consists of two vertical borehole tiltmeters and one single-axis, vertical, short-period (1-Hz) seismometer. It is now installed on the side of Cotopaxi, and the data are radio-relayed to the NASA STDN (Spaceflight Tracking and Data Network) Tracking Station about 20 km away. Data are recorded in analog form and made available immediately to interested Ecuadorian geophysicists. Planned duration of the project is 5 to 10 years. Local contacts are C. Shaddeau, NASA STDN station director, Quito; and M. Hall, Escuela Politecnica Nacional, Quito.

The other project being planned is the South American Seismic Data Relay System. This would be a cooperative experiment between NASA and CERESIS (Centro Regional de Sismologia para la America del Sur) to establish a system of 10 to 20 seismic stations in South America that would utilize data-collection platforms and a synchronous satellite to relay, in near real time, seismic data to a central receiving station, probably located in Peru. Implementation would begin in the 1979-80 period. Local contact is A. Giesecke, Director of CERESIS, Instituto Geofisico del Peru, Lima.

Oceans and atmospheres

International Decade of Ocean Exploration (IDOE)

Living resources program

The long-term goal of the CUEA (Coastal Upwelling Ecosystems Analysis) program is to understand coastal upwelling ecosystems sufficiently to predict their response far enough in advance to be useful to mankind. This goal, when achieved, provides the basis for protecting the long-term productivity of fisheries in these ecosystems. There are 20 multi-disciplinary projects. To achieve its goal, CUEA has four objectives:

1. To describe and understand the mesoscale distributions that define coastal upwelling ecosystems in space and time, including such variables as radiation, winds, currents, density, nutrients, phytoplankton, zooplankton, nekton, and benthos, as well as analyses of the spectral characteristics of each.
2. To understand the dynamic processes that affect the total behavior of these ecosystems and to derive quantitative values of wind-induced upper oceanic circulation, mesoscale flow fields, uptake of nutrients by phytoplankton, and other processes that can limit grazing, predation, excretion, respiration, and remineralization.
3. To learn more about the physical, chemical, and biological interactions that increase

the production of coastal upwelling ecosystems by an order of magnitude over that of open-ocean areas.

4. To develop models that will simulate the northwest African and Peruvian upwelling ecosystems and that will provide the basis for predicting the response of these ecosystems to variabilities in scales and rates of processes, or to different fishery management strategies.

Five field programs are complete: MESCAL-I and -II, CUE-I and -II, and JOINT-I.[1] The sixth, JOINT-II, began in March 1976. The methods developed and experience gained in the first four field programs were brought together in JOINT-I, the first major CUEA interdisciplinary expedition. Cooperation with scientists in the CINECA (Cooperative Investigations of the Northern Part of the Eastern Central Atlantic) program made possible an international experiment involving ships, aircraft, equipment, and personnel from 11 countries. The field programs have provided comprehensive and detailed descriptions of the physical, chemical, and biological processes that influence the productivity or potential economic yield of each upwelling ecosystem. The usefulness of the data and findings obtained through the observational phases and theoretical research in the field was confirmed at the meeting of the UNESCO SCOR (Scientific Committee on Ocean Research) Working Group 36 in June 1974, at which meeting results from other laboratories and from cruises to the northwest African and Peruvian upwelling regions were compared.

CUEA tested newly gained knowledge of upwelling processes in JOINT-II, an intensive collaborative study of the Peruvian upwelling region ecosystem from March 1976 to May 1977. Most JOINT-II investigations were in an area about 100 by 100 km, centered at lat 15° S. between Pisco and San Juan, Peru (fig. 11), during three intensive phases: March-May 1976 (MAM 76), July-

[1]MESCAL-I and -II were primarily biological studies off the coast of Baja California during March 1972 and March and April 1973. CUE-I and -II were physical oceanographic studies off the Oregon coast from April-October 1972 and the summer of 1973. JOINT-I was the first integrated biological and physical field study; it was located off the northwest coast of Africa during February-May 1974.

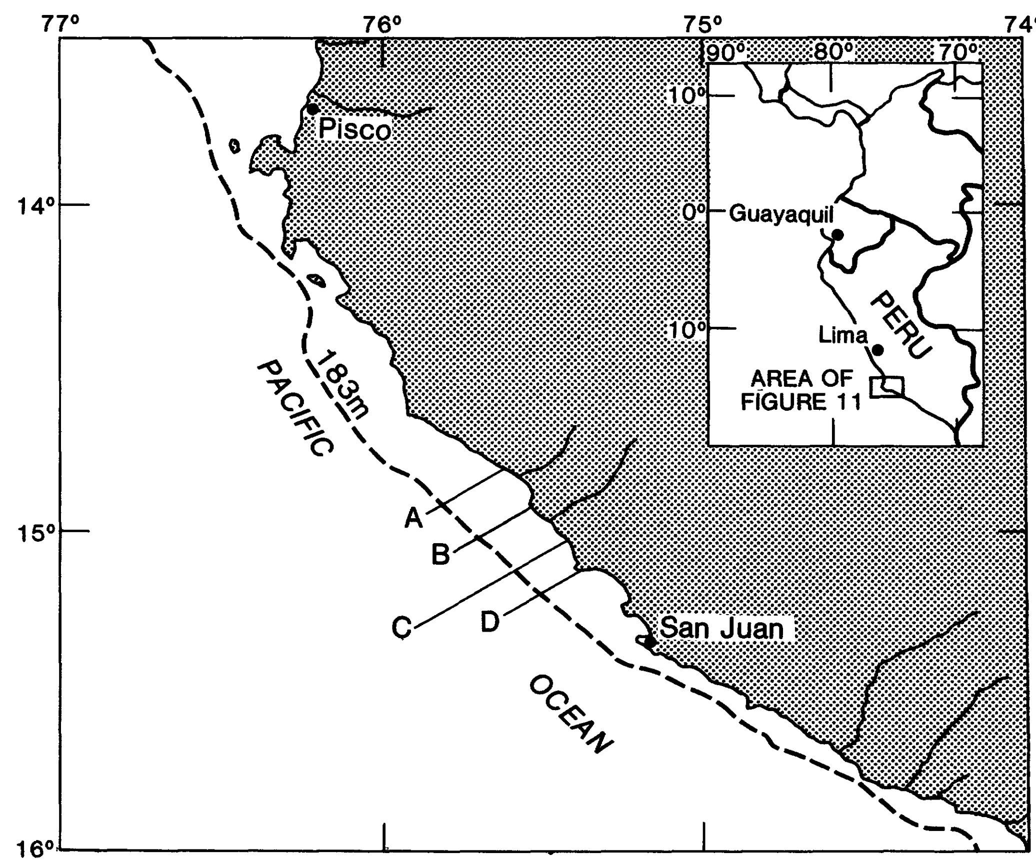


FIGURE 11.--JOINT-II area and hydrography lines A-D, which form the JOINT-II research grid. Modified from Holt (1976).

November 1976 (JASON 76), and March-May 1977 (MAM 77). Observations were made from seven U.S. research vessels, Peruvian research vessels, aircraft, moored current meters, coastal meteorological stations, and satellites. The conceptual framework includes four areas of investigation: (1) physical mesoscale studies, (2) frontal studies, (3) biological mesoscale studies of the circulation, and (4) phytoplankton processes.

At the beginning of the CUEA program in 1972, the Peruvian upwelling region was selected as the site for JOINT-II. This selection now appears appropriate for the following reasons:

1. Concepts have been developed concerning processes that enhance the biological productivity off Peru as opposed to the other major upwelling regions of the world. These now can be tested.
2. The Peruvian research institutions--IMARPE (Instituto del Mar del Peru), SENAMHI (National Meteorological and Hydrological Service), DHNM (Naval Hydrographic and Navigational Directorate), IGP (Peruvian Geophysical Institution)--have initiated a program titled "A Study of the Coastal Upwelling System off Peru." The Peruvian program includes coast and detailed studies in four important achoveta fishery regions. These studies will complement the intensive mesoscale studies of CUEA in JOINT-II.
3. IMARPE is participating in the scientific program of JOINT-II through collaboration of IMARPE scientists with various CUEA components; by contributing one complete scientific component (Component 19, Zooplankton Fields); and by contributing the use of IMARPE space, facilities, and services for the JOINT-II investigation. This collaboration has made it possible to compare the complex IMARPE fish stock models with CUEA ecosystem models. IMARPE and the Food and Agriculture Organization of the United Nations have developed an assessment and prediction system using five independent determinations of abundance and catch. This program provides monthly predictions of anchoveta stocks. The opportunity exists to combine both IMARPE and CUEA capabilities into a tool for understanding and managing the protein resources of upwelling regions. In June 1975, a formal agreement was reached between CUEA and IMARPE on the areas of participation and collaboration.
4. The Latin American countries along the Pacific coast have initiated a study entitled ERFEN (Estudio Regional del Fenomeno El Nino). This program will monitor the oceanic and atmospheric environment from about lat 10^{o} N. to lat 35^{o}S. and from the Pacific coast of South America to 500 km west. It will document the large-scale climatic and oceanographic features within the JOINT-II study area. JOINT-II results will increase understanding of the El Nino phenomenon by identifying mesoscale processes that are driven by the large-scale disturbance and that cause the productivity of the region to collapse.

Seabed Assessment Program

Activities are described in the section "Nazca Plate."

Tsunami Warning System

The Tsunami Warning System is operated by NOAA's National Weather Service in cooperation with other U.S. and foreign informational groups; it functions in concert with the Intergovernmental Oceanographic Commission and member states.

An agreement of major importance was reached during December 2-7, 1974, when U.S. and USSR tsunami experts met in Silver Spring, Md., and signed a Bilateral Agreement on the Integration of the Tsunami Warning Systems of the two countries. In 1975 the United States and the Union of Soviet Socialist Republics participated in a 2-month Kuril Tsunami Experiment; they met again in September 1976 in Novosibirsk for a second meeting of tsunami experts.

The Tsunami Warning System in the Pacific has continued to expand and improve its services; it now distributes watch and warning information to 15 countries and territories throughout the Pacific and receives reports from 31 seismic and 54 tide stations. Seismograph stations at Yuzhno-Sakhalinsk and Petropavlovsk, USSR; Albuquerque, N.M.; Dugway, Utah; Glamis, Calif.; Blacksburg, Va.; and Fort Yukon and Yakutat, Alaska, now report data to the system. New tide stations participating in the warning system are located at Kushiro, Japan; Langara Island, Canada; Socorro Island, Colima, Mexico; Sand Point, Alaska; and San Francisco and San Diego, Calif.

A major improvement in the warning system occurred when facilities for automated message preparation and data-handling were provided to the warning unit at Honolulu Observatory. The time involved in composing, verifying, and transmitting a watch or warning message has been cut from approximately 45 minutes to less than 5 minutes.

Work continues on the development of automated tide and seismic platforms that can be interrogated through a GEOS (geostationary satellite). Prototype platforms have been undergoing testing for a year, and second-generation platforms will begin operational testing in 1977.

One of the main tsunami research activities within the United States is focused on instrumentation systems and the development of a real-time mid-ocean tsunami reporting system. The research objectives are to obtain data on the untransformed wave in deep ocean and to measure and study the changes that occur as the wave interacts with the shoreline. The mid-ocean tsunami reporting systems, when operational, will make possible a quantitative warning. A numerical hydro-dynamic study of tsunami runup serves to outline areas of potential inundation and to limit the type of structures that may be put in any particular place. Nonlinear studies of runup have continued, but almost without exception are in the realm of nonoperational and nonapplied research.

The WDC-A for Tsunamis was relocated from Honolulu to Boulder, Colo., in December 1974 to take advantage of the data-processing capability and staff available in WDC-A for Solid Earth Geophysics. WDC-A is in the process of microfilming the large file of mareographic data in NOS. (National Ocean Survey). When completed, WDC-A will have on 35-mm microfilm approximately 1,000 tide records from more than 100 tsunami events worldwide. WDC-A will then proceed to complete its holdings, as called for in the ICSU (International Council of Scientific Unions) Guide to International Data Exchange, by requesting records through the International Tsunami Information Service from the participating stations.

Table 4 gives a summary of tsunami activity, 1973-76. Reporting stations are shown in figure 12.

Solar-terrestrial physics

Data bases

One of the requirements necessary for the study of the phenomena of solar-terrestrial physics is the availability of an adequate data base. To accumulate such a base, contributions must be made from a worldwide network of ground-based observatories and from observations monitored from satellites in the magnetosphere and the interplanetary medium. In many cases these observations need to extend through several solar cycles in order to delineate and to make comprehensible the complex time variation.

Table 4.--*Tsunami Activity, 1973-1976*

Earthquake epicenter						Maximum tsunami			Remarks[1]
Mo	D	Hr	Min	Lat	Long	Ht (m)	Mag (ms)	Location	
								1973	
01	30	21	01	18.5 N.	103.0 W.	1.16	7.3	Manzanillo, Mexico------	Minor tsunami.
02	28	06	38	50.5 N.	156.6 E.	1.50	7.1	Shumshu Island----------	---
06	17	03	55	43.2 N.	145.8 E.	3.04	7.7	Nemuro, Japan-----------	Several fishing boats sunk.
06	24	02	43	43.3 N.	146.4 E.	1.22	7.1	Hokkaido, Japan---------	---
10	05	05	45	33.0 S.	071.9 W.	.40	6.3	Valparaiso, Chile-------	---
								1974	
01	31	23	30	07.5 S.	155.9 E.	1.52	6.9	Shortland Island--------	Flooded Korovu police station.
02	01	03	12	07.4 S.	155.6 E.	4.60	6.8	Choiseul Island, Shortland Island.	Minor damage on Choiseul Island.
09	27	05	47	43.2 N.	146.7 E.	.38	6.7	Hanasaki, Japan---------	---
10	03	14	22	12.3 S.	077.8 W.	1.83	7.5	Callao, Peru------------	---
								1975	
05	26	09	12	36.0 N.	017.7 W.	2.13	8.0	Ponta Delgada, Azores Islands.	---
06	10	13	47	43.0 N.	147.7 E.	3-5	7.1	Kanashir, Kuril Islands-	---
07	20	14	38	06.6 S.	155.1 E.	∿ 2	7.8	Near Bougainville-------	Minor damage at Torokina.
10	31	08	28	12.5 N.	126.0 E.	.50	7.2	Chosi, Japan------------	One death; 30 houses lost on east coast of Samar Island.
11	29	14	48	19.3 N.	155.0 W.	7.91	7.2	Halape, Hawaii Island---	One death; one missing; $1.5 million damage on Hawaii Island; $2 thousand damage on Santa Catalina Island, Calif.
12	26	15	57	16.3 S.	172.5 W.	.75	7.8	Pago Pago, American Samoa.	---
								1976	
01	14	16	48	28.4 S.	177.7 W.	.90	8.0	Suva, Fiji--------------	---
01	21	10	05	44.9 N.	149.2 E.	.13	7.0	Burevestnik, USSR-------	---
02	04	09	02	15.3 N.	089.1 W.	.24	7.5	Puerto Cortez, Honduras-	---
08	16	16	11	06.3 N.	124.0 E.	4.57	7.9	Moro Gulf---------------	Five to eight thousand killed or missing due to tsunami and earthquake; extensive damage on Moro Gulf.

[1]Information was extracted from *U.S. Earthquakes* and *ITIC Newsletters*. Leaders (---) indicate small, local events causing no deaths and little, if any, damage.

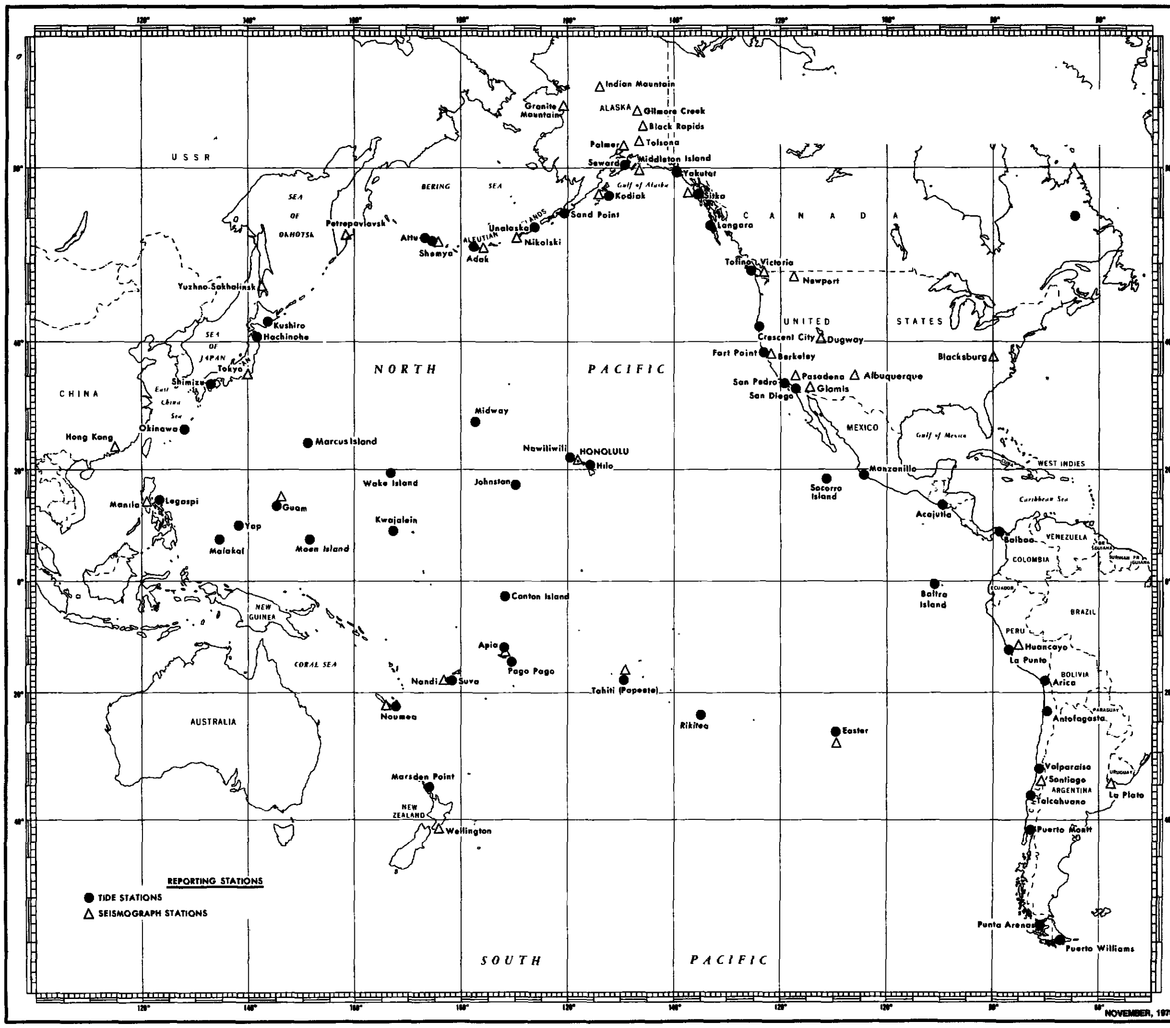


FIGURE 12.--Reporting stations of the Tsunami Warning System.

NSSDC (National Space Science Data Center) and NGSDC (National Geophysical and Solar-Terrestrial Data Center) were established to acquire, archive, and disseminate data throughout the scientific community. Consequently, these centers have developed an enormous data information system that can be utilized by anyone in the world.

NSSDC is located at the Goddard Space Flight Center of NASA, Greenbelt, Md., and is collocated with WDC-A for Rockets and Satellites. Because it is not practical to archive the large amount of satellite data acquired from every scientific experiment on every satellite, NSSDC does not normally maintain complete files of raw or calibrated data, but does assist scientists in obtaining copies of data either held by experimenters or available through national archives. This data center is also responsible for maintaining records on sounding rockets, satellites, and space-probe launchings. During the past four years, NSSDC has responded to many data requests received from Latin American scientists. For example, during 1974 the data center processed 163 individual requests from scientists in Argentina, Bolivia, Brazil, Chile, Mexico, and Venezuela.

NGSDC is located at EDS, NOAA, Boulder, Colo. This center, collocated with WDC-A for Solar-Terrestrial Physics, acquires, archives, and provides data in the following areas of solar-terrestrial physics: ionosphere, solar and interplanetary phenomena, geomagnetic variations, aurora, cosmic rays, and airglow. Atmospheric-ozone data are not the primary responsibility of this data center; they are available through the National Climatic Center, Asheville, N.C.

WDC-A for Solar-Terrestrial Physics (or NGSDC) maintains a record of all locations where solar-terrestrial physics observations are being conducted throughout the world. See Buhmann and others (1974) for a list of stations currently in operation; the geographic coordinates of each station; the type of observation identified by discipline; and, for those stations where observations have terminated, a record of the time period during which the experiment was operating. Figure 13 illustrates the locations where solar-terrestrial physics observations are presently being conducted in the Western Hemisphere.

Many requests for solar-terrestrial physics data acquired at Latin American stations are received by WDC-A for Solar-Terrestrial Physics each year. For example, in the period from July 1975 to July 1976, the data center received 34 individual requests for ionospheric vertical sounding data acquired in South America. These requests represented 899 station-months of data.

Catalog of possible collaborators

A catalog containing the names of scientists in the United States and Canada who are engaged in various experimental and theoretical investigations in solar-terrestrial physics and who also are willing to collaborate with Latin American scientists is currently being prepared by M. A. Shea of the Air Force Geophysics Laboratory. With the cooperation of WDC-A for Solar-Terrestrial Physics and AGU (American Geophysical Union), a list of approximately 1,500 people

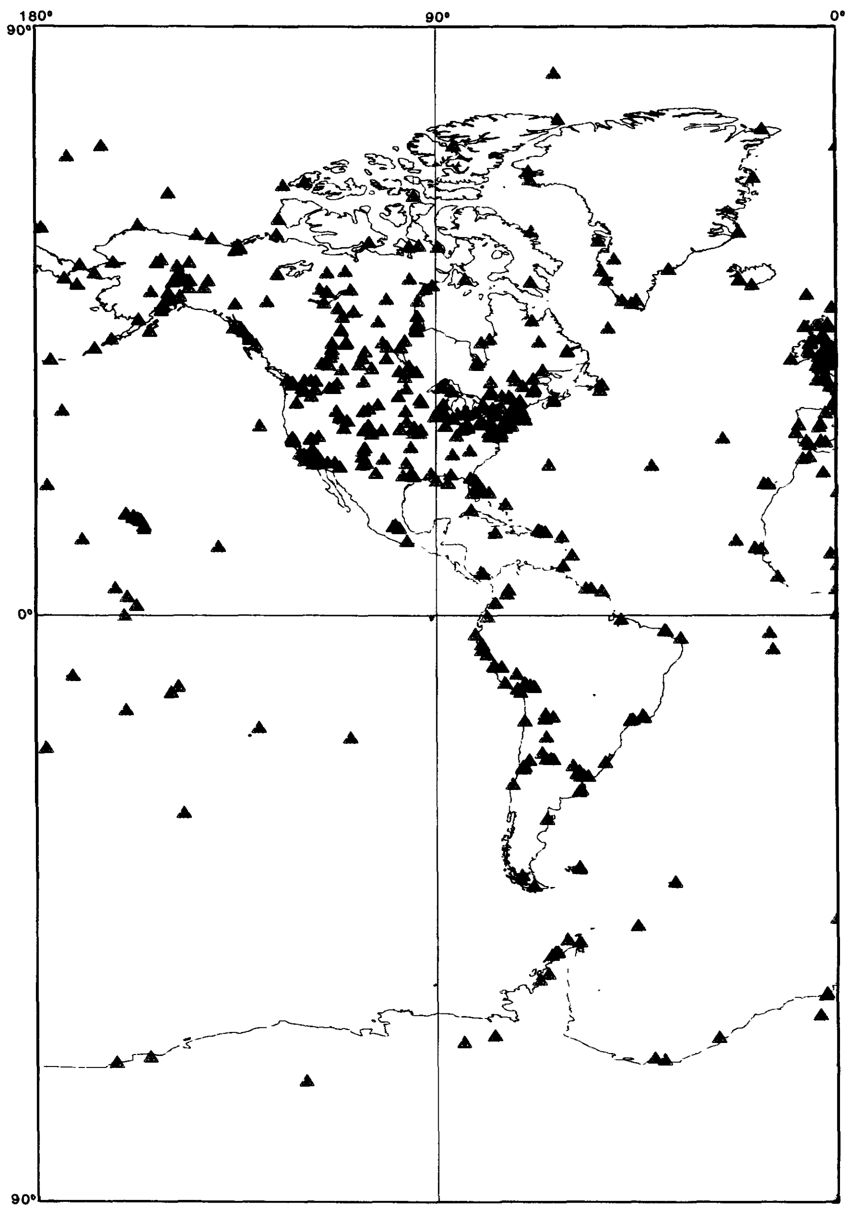


FIGURE 13.--Solar-terrestrial physics stations (triangles) in the Western Hemisphere. Data from NOAA/EDS.

interested in solar-terrestrial physics was compiled. A letter with questionnaire was sent to each of these people asking whether he was willing to collaborate with Latin American scientists in various projects.

Approximately 150 people responded to this questionnaire. These replies are being compiled into a format that will list the name and address of each scientist; the area of interest; the type and location of experimental equipment in operation (if applicable); and whether the respondent's group or institution can accept a scientist, technician, or student for a specified period of time in a cooperative and (or) training endeavor. Respondents indicating that some financial support might be available for various projects are also identified.

The text of this report will be prepared in English and Spanish, and copies will be sent to each scientist and principal investigator listed in the report. Additional copies will be sent to the PAIGH executive office. This publication will also include names and addresses of the people listed in the STP catalog (Comision de Geofisica del IPGH, 1975).

Other activities

Other formal and informal programs of a cooperative nature between scientists in the United States and Latin America have been undertaken.

Since 1973 studies of transionospheric radio propagation have been made, in collaboration with the Air Force Geophysics Laboratory, through observations of ionospheric scintillation and total electronic content at Huancayo, Peru, and Natal, Brazil. These observations are made by monitoring radio signals transmitted by satellites equipped with radio beacons. The measurements are being used to develop global models of ionospheric scintillation and total electron content. In order to gain information on the formation of scintillation-causing mechanisms the scintillation measurements at Huancayo recently have been supplemented with measurements made by the incoherent scatter radar located at Jicamarca, Peru. (See Mullen and others, 1976.) Principal investigator is Jules Aarons of the Air Force Geophysics Laboratory (PHP).

Also in collaboration with the Air Force Geophysics Laboratory, observations of the total intensity and circular polarization of quiet-sun and burst emission have been carried out since 1972 at 9.4 GHz at the Huancayo Observatory of the Instituto Geofisico del Peru and at 7 GHz at the Itapetinga Observatory of Mackenzie University, Sao Paulo, Brazil. Data from these observations, and similar ones at 5 GHz at the Air Force Geophysics Laboratory's Sagamore Hill Radio Observatory, Hamilton, Mass., have been used to obtain centimeter wavelength circular-polarization spectra of a number of radio bursts. These spectra are used to investigate burst-region properties (magnetic field, electron density, and energy distribution) and solar emission-mechanism theories. Principal investigator is D. Guidice, Air Force Geophysics Laboratory (PHP).

Studies of ionospheric irregularities using VHF radars were made in Peru and Brazil. Approximately 12 trips to take experimental measurements at various locations in South America were made, with each trip taking 3-4 weeks. The locations include Jicamarca Radar Observatory near Lima, Peru; Geophysical Observatory at Huancayo, Peru; and Brazilian Rocket Launch Facility near Natal, Brazil. The following scientists participated in one or more of these trips: B. B. Balsley, W. L. Ecklund, D. A. Carter, and P. E. Johnston, all of NOAA. The purpose of these trips varied considerably. Data on equatorial spread F in conjunction with a chemical release of barium by an instrumented rocket were acquired in Brazil; neutral wind measurements at E-region heights were made in a recent experiment between Huancayo and Jicamarea; and a series of experiments designed to measure various aspects of equatorial sporadic E, equatorial spread F, neutral winds in the E-region, as well as specific parameters of mesospheric, stratospheric, and tropospheric wind fields was conducted at Jicamarca. Pertinent publications include the following: Balsley and Farley (1973); Balsley, Carter, and Woodman (1976); Balsley and Farley (1975); Balsley, Fejer, and Farley (1976); Balsley, Rey, and Woodman (1976); Farley and Balsley (1973); Fejer, Farley, Balsley, and Woodman (1975a; 1975b, 1976a, 1976b); Kelley and others (1976). Principal investigator is Ben B. Balsley, Aeronomy Laboratory of NOAA, Boulder, Colo.

Another cooperative program between NOAA and Huancayo is the Dobson Spectrophotometer Observations of Atmospheric Total Ozone at Huancayo. Measurements of total ozone have been made three times per day since 1964. Processing of the data by computer is accomplished at the NOAA/ERL Air Resources Laboratory, Boulder, Colo. Final results are archived routinely at the World Ozone Data Center by the Canadian Atmospheric Environment Service, Department of the Environment, in cooperation with the World Meteorological Organization. One important finding has emerged from these measurements: In a study of global trends in total ozone during the 1960's, it was found that the rate of increase in total ozone for Huancayo is 6.0 ± 0.4 percent per decade (Komhyr and others, 1971). Principal investigator is W. D. Komhyr of the NOAA/ERL Air Resources Laboratory.

Cooperative projects concerning equatorial ionospheric irregularities and upper-lower atmospheric coupling have been conducted between scientists at the Jicamarca Radar Observatory in Peru and the Aerospace Corporation in California. One of the projects was the building of the Chilca rocket range to launch the EQUION rocket probe. Additional rocket and radar projects, and possibly a balloon and radar project, are being planned. Principal investigators are F. A. Morse and C. J. Rice of the Space Sciences Laboratory, Aerospace Corporation, Calif.

A cooperative program to study equatorial airglow and dayglow emissions is being conducted between scientists at the University of Texas at Dallas and Huancayo, Peru. The equatorial emissions are made using a 1-m grille spectrometer and filter photometers. Principal investigator is A. B. Christensen of the Center for Space Science at the University of Texas at Dallas.

Observations of radiowave scintillation produced by electron-density irregularities in the ionosphere are being studied. Radio signals from a coherent beacon aboard a polar orbiting satellite are being received at Ancon, Peru, Stanford, Calif., and Poker Flat, Alaska. Analyses of these data are then made in comparison with other ionospheric and geomagnetic phenomena. Principal investigator is E. J. Fremouw of the Radio Physics Laboratory of Stanford Research Institute.

The phase and amplitude of VLF signals are being measured in a joint project between scientists at the USAECOM (U.S. Army Electronics Command), Fort Monmouth, N. J., and the Centro de Radio-Astronomia e Astrofisica, Sao Paulo, Brazil. The purpose of this experiment is to observe solar-induced changes in the lower ionosphere by monitoring the VLF signals emitted by Omega transmitters. The ground-based equipment is located at Fort Monmouth and Sao Paulo. Principal investigator is F. M. Reder of USAECOM in Fort Monmouth.

Since 1974 there has been an informal cooperative program between scientists at the Air Force Geophysics Laboratory and the Instituto de Pesquisas Espaciais, Sao Jose dos Campos, Brazil, involving the calculation of cosmic-ray geomagnetic cutoff rigidities and the utilization of these values for the analyses of cosmic-radiation data acquired from balloon measurements over Brazil. Initial results of this study are given in Shea, Smart, and Palmeira (1976). Principal investigators are M. A. Shea and D. F. Smart of the Air Force Geophysics Laboratory (PHG), Hanscom Field, Mass.

Other cooperative projects also exist: Magnetic field measurements are being conducted at Eusebiom, Brazil, with principal investigator Paul J. Coleman, Jr., of the Department of Geophysics and Space Physics of the University of California at Los Angeles; electric field measurements are being conducted at Jicamarca, Peru, using the Jicamarca radar with principal investigator Michael C. Kelley of the School of Electrical Engineering, Cornell University; and an electric field mill is in operation at Cerro Tololo, Chile, with principal investigator Chung G. Park of the Radioscience Laboratory of Stanford University.

Progress in the science

Although past emphasis in solar-terrestrial physics has been largely on research leading to an understanding of the processes in the upper atmosphere and on the physical mechanisms of the effect of solar-interplanetary phenomena on this atmosphere, some phases of the work have been directed toward more practical applications. For example, ionospheric measurements have been and continue to be used to improve the planning and operation of radio telecommunications using the high-frequency band on which long-distance, point-to-point communication is made possible by radio-wave reflections from the ionosphere. Interruptions caused by ionospheric disturbances to such telecommunications circuits can often be traced to specific solar phenomena such as the emission of solar X-rays. Other types of ionospheric disturbances associated with geomagnetic storms can be forecast in some cases; prompt warnings of the onset of these storms enable telecommunication services to take action to minimize the effect of the disruptions.

As our measurement techniques became more sophisticated and our technology more advanced, additional areas of solar-terrestrial physics were found to have direct application to ordinary daily activities. When it became known that the occurrence of a major solar flare on the sun had both immediate and delayed effects on communication systems, scientists found it necessary to acquire enough data of these phenomena to describe, model, and predict the disturbances of our environment that could be expected after a solar flare was visually observed. In the past few years, although neither direct nor indirect relationships are clearly evident from the data, increasing evidence has accumulated that many of the climatic changes over the decades may be related to solar activity. Certainly, economic benefits would be associated with the ability to predict from the observations of solar activity, long-term changes in the weather patterns in specific areas of the world.

During the next four years, research in solar-terrestrial physics is expected to increase, particularly in magnetospheric and geomagnetic studies. Scientists will be participating in the International Magnetospheric Study project in an attempt to gain a better understanding of Earth's magnetosphere, the interplanetary medium, and the interaction between the two. A large and comprehensive Middle Atmosphere Program on atmospheric studies, including the possibility of solar effects on the weather, is tentatively planned for the period 1978-85. The exchange of scientific information and data, plus the cooperative efforts of various scientists participating in projects such as the International Magnetospheric Study and the Middle Atmosphere Program, should prove most fruitful, not only for the scientists participating in these programs, but also for those who gain increased understanding of the environment in which we live and the subsequent benefit for mankind.

Special projects of the PAIGH involving The U.S. Member of the Commission on Geophysics

Geomagnetism projects

Latin American-United States cooperative work in geomagnetism

This refers to PAIGH Special Project No. 3.4.1.14. COMGEOFIS (Commission on Geophysics) resolution no. 4 of the X General Assembly of PAIGH recommended that the United

States send a geophysicist to Central and South American magnetic observatories for the purpose of standardizing and comparing magnetic instruments used in the network of observatories. There were three primary objectives: (1) to use instruments calibrated against the magnetic standards of Fredericksburg Observatory for making comparative observations about observatory standards in each country; (2) to establish mutual consultation on problems with magnetographs, magnetometers, data processing, and so forth; (3) to exchange information on the development of new instrumentation and recording techniques being utilized in geomagnetic data collection.

Travel funds and living expenses were provided by PAIGH, and in 1974 A. H. Travis, a geophysicist of the U.S. Geological Survey who is Chief of the Fredericksburg Geomagnetic Center in Fredericksburg, Va., went to Latin America to accomplish this mission. Offices and observatories visted were:

Instituto de Geofisica
Ciudad Universitaria
Mexico, D. F.

Teoloyucan Observatory
Teoloyucan, Mexico

Instituto Geografico
Bogota, Colombia

Fuquene Observatory
Fuquene, Colombia

Instituto Geofisico del Peru
Lima, Peru

Huancayo Observatory
Huancayo, Peru

Instituto Geofisico
Univ. Nac. de San Agustin
Arequipa, Peru

Arequipa Observatory
Arequipa, Peru

Instituto Investigaciones Fisicas
Universidad Mayor San Andres
La Paz, Bolivia

La Paz Observatory
La Paz, Bolivia

Oficina Meteorologica de Chile
Santiago, Chile

Isla de Pascua Observatory
Easter Island

Observatorio Nacional
Rio de Janeiro, Brazil

Vassouras Observatory
Vassouras, Brazil

Tatuoca Observatory
Tatuoca, Brazil

Mr. Travis also intended to visit Argentine observatories, but he was able to visit only the Buenos Aires office of the Servicio Meteorologico Nacional.

At each station the instruments were inspected, technical discussions were held, and, where possible, preliminary comparative results were determined and furnished to the staff during the visit. Final results were sent from Fredericksburg following completion of computations. Details of Mr. Travis's findings are given in his trip report.

As part of this cooperative project, William Paulishak of WDC-A visited the same offices (except for Santiago) in January-March 1976, using a portable microfilming camera to film magnetograms and tables of hourly values that were not already in the data center collection. About 100 observatory-years of records and data were copied. Salary and travel expenses were borne by WDC-A (NOAA). Considerable logistical assistance was provided by IAGS, and coordinated by Roman Geller. A letter signed by Jose Saenz explaining the informational and scientific nature of the project expedited customs formalitie in the various countries. The excellent cooperation by the institutions visited was invaluable in making this project a success.

Site planning for geomagnetic facility in Costa Rica

This refers to PAIGH Special Project No. 76-058-22. At the request of the University of Costa Rica, J. D. Wood, a geophysicist of the U.S. Geological Survey in Denver, Colo., traveled to Costa Rica in February 1977 for the purpose of assisting and advising in the selection of a site for the future magnetic observatory to be operated by the University. Mr. Wood carried a proton magnetometer for the purpose of making magnetic observations at the various sites. Sites considered were Turrialba, Ochomogo, Jardin Lancaster, Finca Baudrit, and San Ramon. On the basis of the observations and other considerations, San Ramon was determined to be the best site. Details of Mr. Wood's findings are contained in his report to the Director of the Department of Physics at the University (Wood, 1977). When the University completes the buildings and facilities required for the proposed observatory, Mr. Wood plans to return to Costa Rica to assist and advise on the installation of the observatory instrumentation. The Instituto Geografico Nacional, also interested in establishment of this observatory offered considerable assistance to Mr. Wood during his visit.

Latin American-United States cooperative work in phase two geomagnetism

In a continuation of the project entitled Latin American-United States Cooperative Work in Geomagnetism, A. H. Travis returned to Brazil and Argentina early in 1977. He visited the following offices and observatories:

Observatorio Nacional
Rio de Janeiro, Brazil

Vassouras Observatory
Vassouras, Brazil

Instituto de Geofisica
Servicio Meteorologico Nacional
Buenos Aires, Argentina

Pilar Observatory
Pilar, Argentina

Observatorio Astronomico
La Plata, Argentina

Las Acacias Observatory
La Plata, Argentina

In Brazil he assisted in checking orientation of magnetograph magnets, installation of a new magnetometer, and other instrumental matters; in Argentina he accomplished the instrumental comparisons scheduled earlier.

This mission was a complete success. Corrections to International Magnetic Standard are now known with certainty for all Latin American observatories visited, and this standard may be carried by the institutions to the observatories not visited directly by Mr. Travis.

Preparation of a catalog of principal facts for gravity stations and gravity anomaly maps on a common scale for Latin America.

This refers to PAIGH Special Project No. 74-033-11. The proposal submitted under this project had as its ultimate aim, as expressed in its title, the preparation of catalogs of principal facts on gravity observations and gravity anomaly maps on a country-by-country basis for each of the Latin American countries. These were to be based on a common scale and the IGSN 1970 gravity standard adopted at the Moscow meetings of the International Union of Geodesy and Geophysics. A critical step in meeting the objectives was to obtain releases in each country of the data available, as well as to determine whether the data had been reduced and put on the national datum for each country, and whether auxiliary information (position and elevation values) was available for anomaly reductions. Because this, as well as a commitment for cooperation on the project by all of the principals working in gravity, could be determined only at a joint meeting of the principals, the proposal submitted to PAIGH was only for funds to cover the cost of such a meeting. It was this proposal that was approved by PAIGH, and the meeting was held in Panama City, Panama, in November 1975. Twenty-five attendees came from 14 countries, and the meeting was declared "one of the most successful working group meetings that has ever been held." All attendees were active in gravity investigations, all had full appreciation of the problems involved, and all came fully prepared with information on the status of gravity investigations in their countries. They were enthusiastic about the objectives and were prepared to work to achieve success.

The formal accomplishments of the Panama meeting are summarized in the following:
"Considering:

1. That (this) meeting constituted a technical working group in gravimetry of the Latin American countries.
2. That the presentations and technical discussions have evidenced the notable quality and quantity of gravimetric information existing at this time.
3. That in the light of the problems of scientific and practical kinds, the necessity of establishing a uniform reference system of gravimetry was appraised.
4. That the assembly recognized the socio-economic importance that gravimetric studies have in the problems of the community.

The working group on gravimetry adopted the following recommendations:

No. 1: That the group here constituted acquire a permanent character and officialize the representation of its members before the respective national sections of PAIGH in the corresponding countries.

No. 2: That the PAIGH sponsor a special training course of observation, maintenance and primary reduction of gravimetric data; at the same time, as a product of the development of the said course, the publication of a manual of gravimetric observations is recommended.

No. 3 That the Latin American countries continue lending their support and collaboration with SILAG (Sistema Latin Americana de Gravimetria). That each country effect a critical evaluation of existing gravimetric information in accordance with SILAG standards. This evaluation should be communicated to SILAG before the first of June 1976.

No. 4: To solicit to the COMGEOFIS of PAIGH and to the chairman of the SILAG working group that they study alternatives concerning the future location of SILAG in a Latin American country.

No. 5: To establish by the first of June 1976 the necessary gravimetric ties between the countries contained in Annex 3, in order to improve the Latin American Net (Annex 2). At the same time it is recommended to establish gravimetric stations in the areas presently lacking observations, such as the Amazonian Basin, the Strait of Magellan, and forested regions of Central America and southern Mexico, observing simultaneously with the Geoceiver system.

No. 6: It is recommended to incorporate the marine gravity survey into the Latin American Net.

No. 7: It is recommended to maintain a permanent relationship with the working groups of the Committee on Geodesy of PAIGH.

No. 8: It is recommended to exhort IAGS that it continue lending its valuable collaborations through its technical support and infra-structure of communications, to this working group and to SILAG.

No. 9: To support all the expanding efforts: a) Prompt publication of national gravimetric maps and catalogs; b) Reobservation of ancient gravimetric stations; c) Integration of gravimetric data at a regional level by the publication of a gravimetric map of Latin America.

No. 10: To utilize the Boletin Aereo of PAIGH to regularly inform the scientific community of the advances and needs of the gravimetric work.

No. 11: To hold the second meeting of this technical group in Ottawa in September 1976, in conjunction with the meeting of COMGEOFIS of PAIGH, organized by the National Section of Canada."

Since the Panama meeting, the following has been accomplished:

1. Using two La Coste gravimeters, J. Monges C. (Mexico) has interconnected most of the primary national gravity bases, as well as other key gravity sites in South America, Central America, and Mexico, to the primary Western South American standard sites.
2. J. Tanner (Canada) agreed to have IGSN 1970 values determined for some 1,500 gravity bases distributed throughout Latin America, and these values are now essentially ready.
3. R. Geller (IAGS) completed the three secular change traverses in Chile, as well as made the Santiago-Buenos Aires connection that J. Monges could not do earlier because of political considerations.
4. G. Woollard (USA) submitted a proposal to the U.S. National Science Foundation (now funded) for support in adjusting and compiling all existing data in Latin America on the IGSN 1970 standard; he has been assured of computer support by the DMA-AC (Aerospace Center) Gravity Library (formerly Aeronautical Charts Information Center) on a no-cost basis for computing anomaly values as a first step in preparing catalogs of principal facts on each country and preparing gravity anomaly maps.
5. There were unexpended funds from the Panama meeting in the amount of about $6,500, owing in large part to saving on hotel accommodations. These funds were used to support travel expenses of Latin American participants to the meeting in Ottawa in September 1976.
6. Since 1972 and since initiation of coordination in the gravity program, catalogs of gravity values on a nationwide basis have been published for Uruguay, Colombia, Chile, northern Venezuela, Bolivia, Ecuador, El Salvador, areal segments of Brazil, and regional base values for Argentina. New free-air and Bouguer gravity anomaly maps based on observed and predicted values have been published by DMA-AC (St. Louis). Over 4,000 observations have been compiled and adjusted for Peru and should be ready for publication, along with regional coverage for Argentina, in late 1977. Several thousand observations are now being adjusted for Mexico, and field work is in progress to complete the regional coverage of gravity values in Mexico. Over 10,000 observations are now in various stages of reduction and adjustment for the various countries in Central America. A considerable body of oil-company gravity exploration data has been obtained, as well as anomaly maps; and, with the exception of Paraguay and major segments of Brazil, significant progress in turning out complete catalogs of principal facts for gravity sites as well as anomaly maps for each country can be expected over the next 2-year period.

The support supplied through PAIGH for the Panama meeting was the key action necessary to bring into being the coordination of effort and focus on problems and standards required to put all gravity in Latin America on a uniform high-quality basis. It further resulted in the establishment of a program that will allow the objectives of the proposal to be met in a reasonable time frame, and the organization of what is now a team effort of all principals in each country working together to produce what promises to be an exceptionally well coordinated international effort in the geophysical study of any continent.

Seminar on seismic and volcanological risk

This refers to a joint undertaking of PAIGH (Special Project No. 74-031, Seminar and Workshop on Seismic Risk and Other Natural Hazards in Central America and Adjacent Regions) and the OAS (Organization of American States).

This seminar was held at the ECG (Escuela Centroamericano de Geologia) of the University of Costa Rica in San Jose, July 13-18, 1975. Chairman of the local committee was César Dóndoli. Organizers of the technical program were S. T. Algermissen (USA), Gabriel Dengo (Guatemala), and J. E. Ramirez, S. J. (Colombia). Coordinators were James N. Jordan for the PAIGH and Antonio Quesada for the OAS. There were 103 attendees from 22 countries. Travel expenses were paid for 31 and per diem expenses for 36. Forty-nine formal papers were presented, the majority of which were published in *Revista Geofísica*, no. 5.

The purpose of the seminar was to summarize progress in the investigation of earthquake and volcanic risks in Central America. It also included reviews of current programs in the United States, the Caribbean area, and other parts of Latin America, together with discussions of recent earthquake and volcanic studies. A forum was provided, both formally and informally, for the discussion of programs funded and likely to be funded by the OAS, UNESCO, PAIGH, and others.

Most of the investigators felt that the assessment of seismic and volcanic risk is in the infancy stage. Relating these studies to the socio-economic conditions within a viable framework is a challenge for all concerned. The seminar afforded the chance to discuss data systems, analysis methodologies, and some of the possible products. Engineers, geologists, seismologists, planners, and others related to the seminar theme. The assessment of seismic and volcanic risk is multi-disciplinary, and most realized the importance of understanding the requirements and work of the others. It is felt that the seminar helped to create this dialogue and understanding.

Ionogram scaling course

This refers to PAIGH Special Project No. 76-039-12. The United States actively participated in an effort to unify the ionogram data-interpretation and data-reduction work throughout the Americas. R. O. Conkright, from

NOAA's WDC-A for Solar-Terrestrial Physics and an expert in ionospheric data interpretation and reduction, conducted a 2-week ionogram scaling course in Buenos Aires, Argentina, in November 1976.

This course, held at the Ionospheric Laboratory of the Navy of the Republic of Argentina, was attended by 24 scientists and technicians from Argentina, Bolivia, Chile, and Peru. The first week was devoted to ionospheric physics, the formation and variation of the undisturbed ionosphere, and data-reduction techniques. Because the group represented a vast range in geographic latitude, and because the problems encountered in equatorial, mid-latitude, and polar-region ionograms are quite different, most of the second week was devoted to questions on specific ionograms that had been difficult for the scalers to interpret confidently. At the end of the course, the participants decided to formulate a simple set of local rules for the scaling procedures that gave them the most difficulty. Mr. Conkright was asked to guide them in preparing this document, so that their local rules would conform with the international rules as much as possible. This set of rules will be sent to the Ionospheric Network Advisory Group when finalized. The techniques learned during this course will provide the scientific community with more uniform and accurately reduced data from the Latin American chain of vertical ionospheric sounding stations.

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