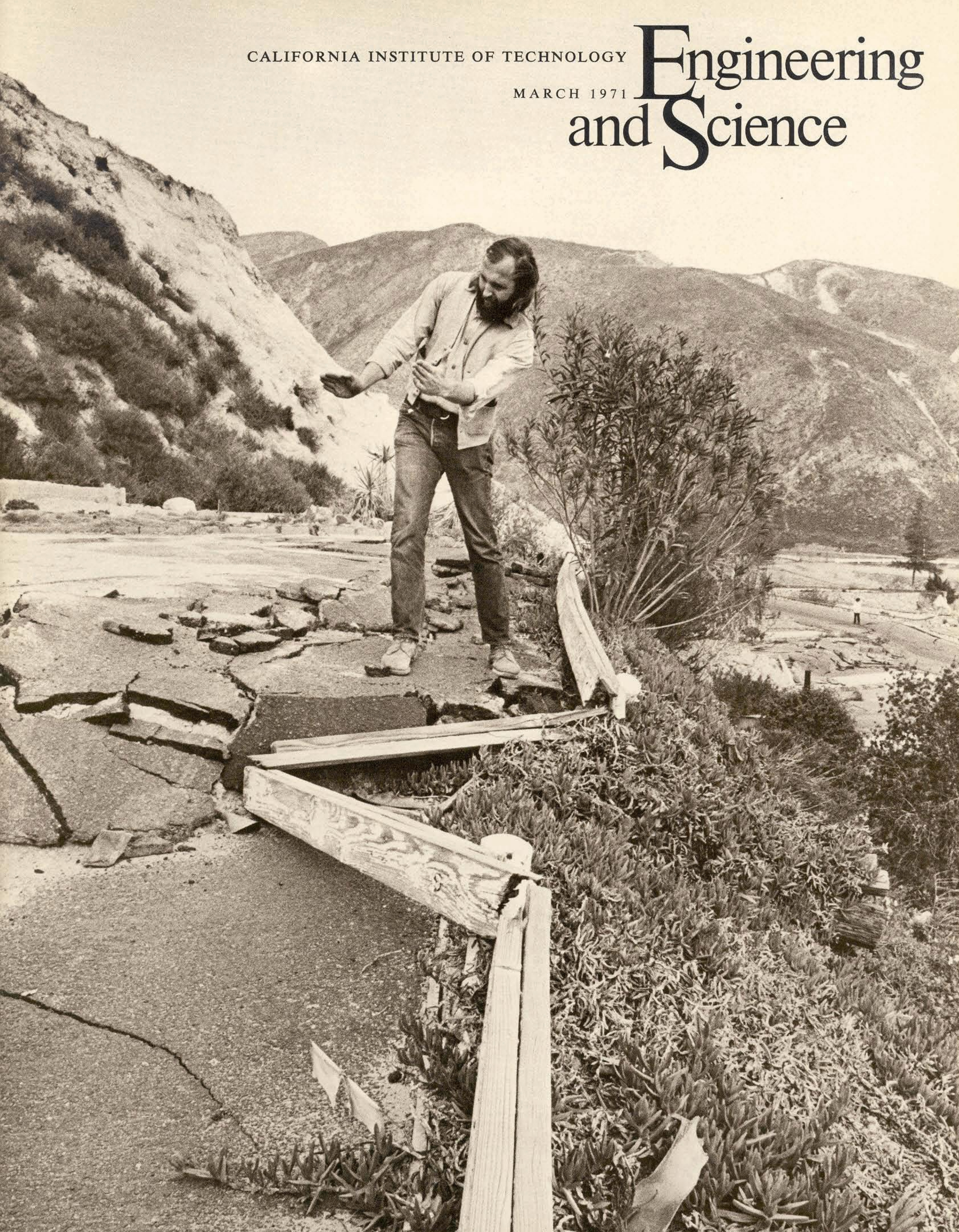
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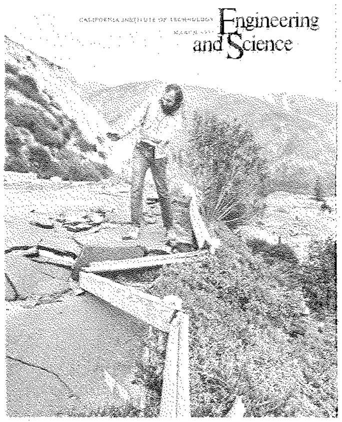

Engineering and Science

In this issue

The Earthquake

On the cover—graduate student Wayne Thatcher, one of the team of Caltech geologists that swarmed into the field after the San Fernando earthquake of February 9. Thatcher is investigating a fault trace at the mouth of Lopez Canyon where the far side of the fault not only moved *upward* during the quake—shattering the asphalt paving—but moved *forward,* shortening the ground so that the wooden road railing snapped into a sharp V.

Beginning on page 5, *Engineering and Science* tells about the San Fernando earthquake—one of the most important quakes in history because it was better recorded than any previous quake has ever been. Though it came as no surprise(southern California is no stranger to earthquakes), it was surprising to earthquake engineers because of the amount of damage for a shock of this size (6.6) and to geologists because of the amount of surface faulting.

Earthquake engineering has been an active program at Caltech for nearly 50 years, and the 45-year-old Seismological Laboratory is one of the world's leading centers for earthquake research. After this quake, the staffs of these two groups performed invaluable educational services for official bodies and the curious and frightened public as well. They made written reports; held news conferences and television and radio interviews; and were hosts to hundreds of colleagues from all over the world who rushed here to study the quake. Caltech also supplied about half the members to a newly formed Los Angeles County Earthquake Commission, of which President Brown was named chairman. Joining him were engineer George Housner and seismologist Charles Richter; and—as a special consultant—the Institute's president emeritus, Lee DuBridge.

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1971

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THE SAN FERNANDO EARTHQUAKE

What It Did to Structures

A report by Caltech's earthquake engineers

At 6 a.m. Tuesday, February 9, 1971, the strongest earthquake to strike metropolitan Los Angeles in this century occurred in the northern San Fernando Valley. The magnitude 6.6 earthquake was not a large earthquake in the seismological sense; earthquakes of this magnitude occur at an average rate of 30-40 per year on the earth, and on the average of about once every four years in the southern California area. From the engineering point of view, however, the earthquake was a very large and important one because it was located at the edge of a densely populated urban area, and the region of heaviest ground motion contained an unusually large number of such critical installations as hospitals, dams, electrical switching and converter stations, and freeway interchanges. Some 400,000 people were subjected to very strong ground shaking, and an additional 2,000,000 to moderately strong motion. Furthermore, the particular

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An aerial view of the Veterans Administration Hospital in Sylmar on the morning of the earthquake. The collapsed structures in the center were built in 1926, before earthquake-resistant design procedures were reflected in the building codes. The adjacent major structures, built in 1937 and 1947, received no significant structural damage.

– One of the Most Important in History

What It Did to the Earth

A report from Caltech's seismologists

Until 1971, seismic activity in the San Fernando Valley area had been low to moderate—as it was in many other parts of California. Certainly there was nothing in very recent seismic history to suggest that this area was more likely than any other to experience a magnitude 6.6 earthquake. Caltech has kept track of the epicentral locations of southern California earthquakes since 1934—the epicenter of an earthquake is the point on the surface of the earth above the subsurface point where the initial breaking occurs. In the last 34 years only about 10 earthquakes of magnitude 3.0 or greater have occurred in the epicentral region of the San Fernando earthquake. None of these tremors was considered large, although a few were felt locally, such as the magnitude 4.0 shock on August 30, 1964, that was centered under southern San Fernando.

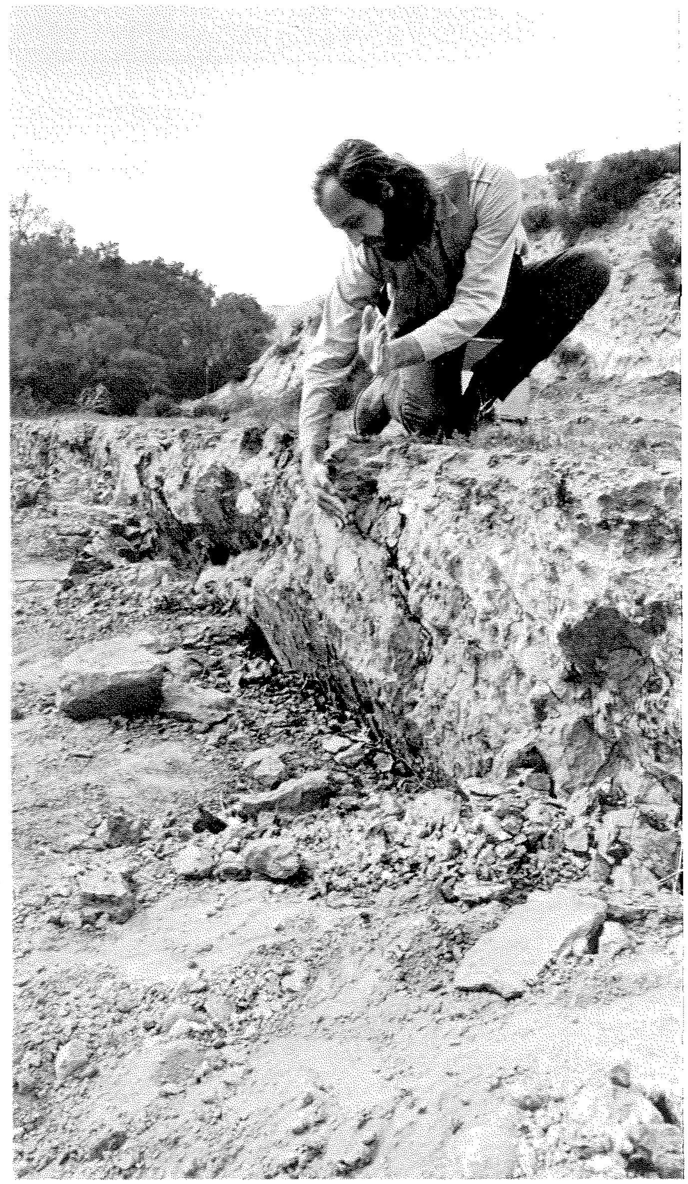
Previous to 1934, two shocks in this vicinity are of particular interest. One—with a magnitude of 5.2—occurred on August 30, 1930. It was probably much closer to the San Fernando area than the original epicentral assignment in the Santa Monica Bay suggests, and it is significant because it caused some very minor damage to the lower Van Norman dam, which was severely damaged by the 1971 event.

Of much greater significance, in terms of its similarity to the recent San Fernando earthquake, is the Pico Canyon earthquake of 1893. Pico Canyon is just three miles west of Newhall, which was heavily shaken by both the 1893 and the 1971 quakes. The Pico Canyon temblor probably originated slightly west of the epicenter of the 1971 earthquake, and it certainly indicates that moderate earthquake activity is not new to the region. Nevertheless, it is clear that the 1893 event was smaller than that of 1971.

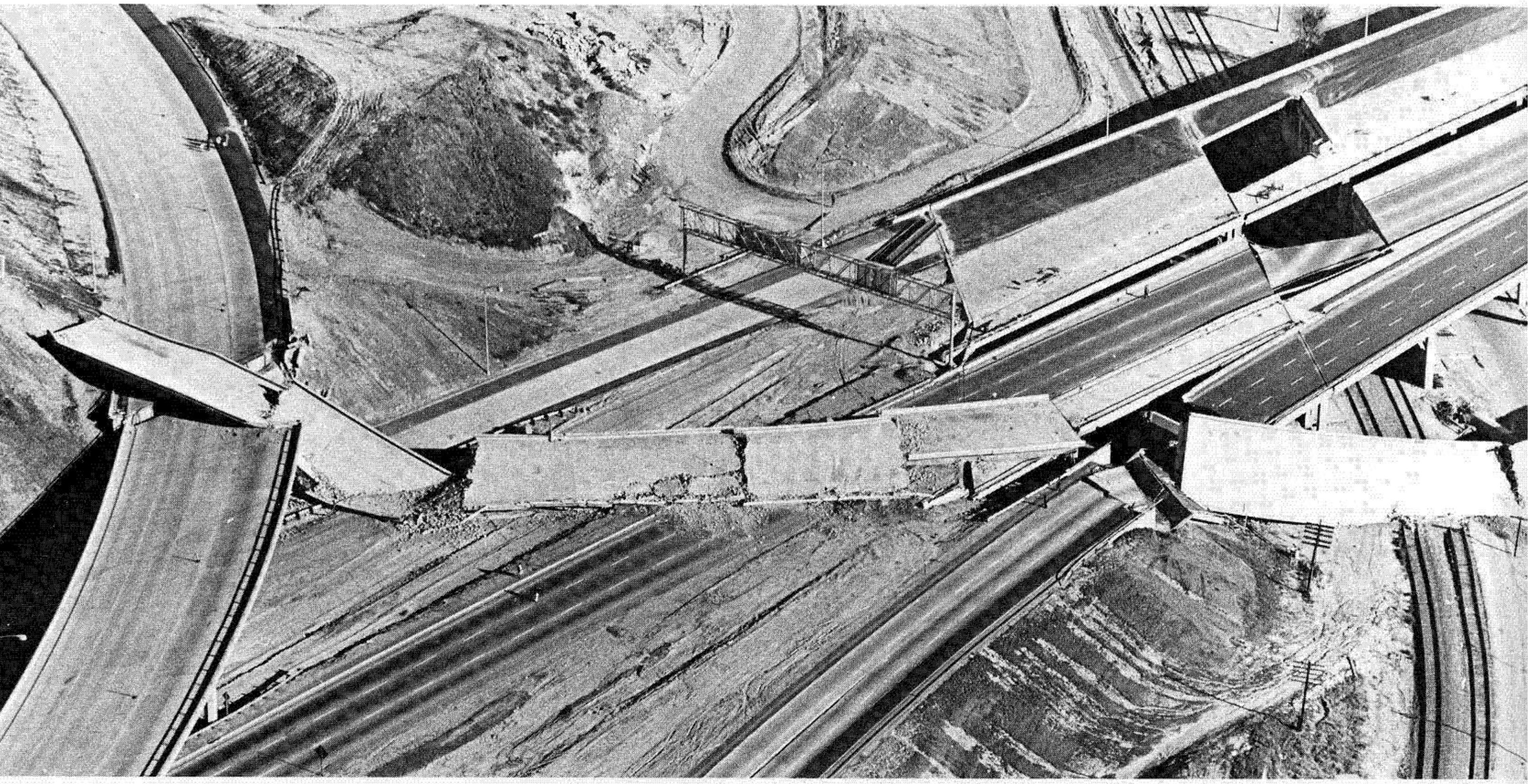
In the light of these past events, the San Fernando quake emphasizes the fallacy of assuming that the largest shock experienced in the past in any given area is necessarily typical of the largest shock to be expected there in the future. Since an earthquake of at least the magnitude of this one (6.6) occurs somewhere in southern California about once every four years, the February 9 earthquake was no great surprise. An earthquake of about this same magnitude occurred in 1968 in the Borrego Mountain area about 137 miles southeast of Los Angeles, but damage was small because—unlike the 1971 event—it took place in a sparsely settled area.

A reasonable geologic model developed by Caltech for the San Fernando earthquake reveals ground displace-

Continued on page 12



Wayne Thatcher, geology graduate student, examines a fault scarp in Lopez Canyon after the quake. It was this displacement —in which the right-hand or north side of the fault moved up about 3 feet—that caused the quake.



This is one good reason why earthquake engineers feel there are many improvements that can be made in highway structures. Nearly every bridge and overpass structure in the interchange between the Foothill and Golden State freeways was seriously damaged by the earthquake.

type of overthrust faulting that occurred resulted in a release of earthquake energy at an unusually shallow depth. Many of the heavily damaged facilities were virtually on top of the earthquake and were subjected to severe shaking.

The estimated cost of the damage caused by the earthquake is in the vicinity of one-half billion dollars.

The major loss of life occurred at the Veterans Hospital in Sylmar where a concrete frame, tile-wall, pre-earthquake code hospital building collapsed, killing 44 people. Another 11 were killed elsewhere, including 2 crushed by a collapsed freeway overpass, and an additional 9 were reported to have died from heart attacks.

Four major facilities in the central region of the shock suffered severe damage: the new Olive View Hospital (initial cost $27 million); the Sylmar Converter Station of the Pacific Intertie (this large electrical switching and rectifying station had an initial cost of about $110 million); the Metropolitan Water District's new, large underground reservoir; and two earth dams at the Van Norman reservoir site (constructed in 1915 and 1928).

There was also severe damage from ground movements to the $6.5 million San Fernando juvenile facility, and vibrational and ground-movement damage to numerous one- and two-story industrial and commercial buildings in the San Fernando Valley. Some buildings in the eight- to fifteen-story range in North Hollywood suffered structural damage. In addition to the Veterans Hospital at Sylmar and the Olive View Hospital, the Pacoima

Lutheran Hospital, the Holy Cross Hospital, and the nearby Indian Hills Medical Center (an office building) all received serious structural damage. The most severe industrial damage occurred near Newhall where a glass factory suffered approximately $10 million damage. Nonstructural damage, including broken glass, fallen light fixtures and ceilings, and plaster cracking occurred throughout the San Fernando Valley and also in the adjoining areas of Glendale, Pasadena, Los Angeles, and to the north at Newhall and Saugus.

An estimated $30 million damage was done to bridges and overpass structures on the Golden State, Foothill, San Diego, and Antelope Valley freeways. Particularly hard hit were the interchange between the Golden State and Antelope Valley freeways and the interchange between the Foothill Freeway and the Golden State Freeway. Bridges on the Antelope Valley and Foothill freeways in the epicentral area also received serious damage.

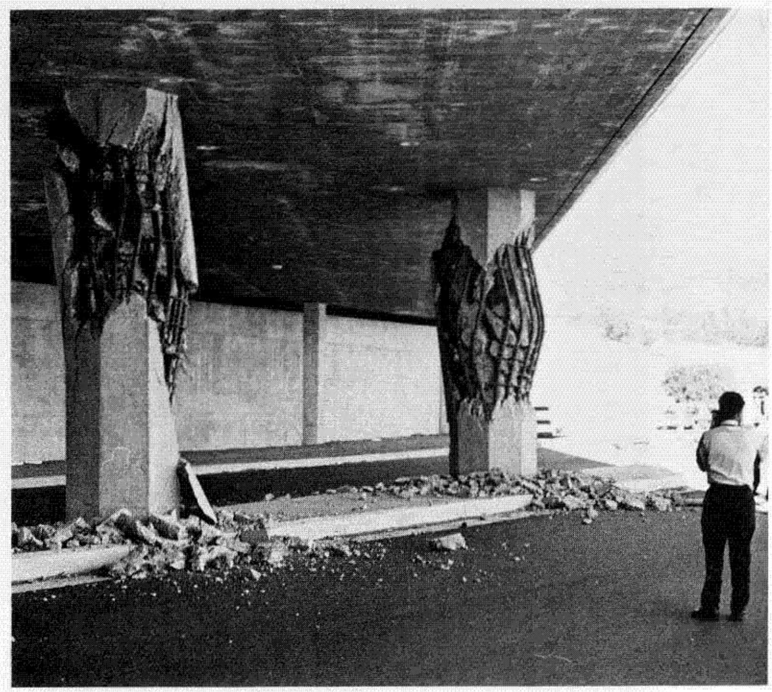
Permanent ground displacements caused extensive disruption to underground utilities in parts of the San Fernando Valley, especially where surface faulting occurred. Gas lines were ruptured in several areas, and water and sewer lines also were fractured, affecting service to thousands of homes. Telephone service was lost to ten to twenty thousand customers in the epicentral area from approximately $4.5 million damage to General Telephone's central facility in Sylmar. Emergency communications were hampered by a power outage at police headquarters and by destruction of the radio facility at the Veterans Hospital.

The faulting and the ground movement, combined with the shaking, damaged thousands of homes, and hundreds were damaged to the point where they no longer could be occupied. Chimney damage was the most common vibrational damage and occurred as far away as Pasadena.

Old, weak buildings in downtown San Fernando and as far away as Pasadena, Los Angeles, and Santa Ana suffered significant damage, usually in the form of falling masonry. Two people were killed by failure of old buildings in downtown Los Angeles. Caltech's oldest building, Throop Hall, suffered extensive cracking to the nonstructural tile filler walls and to the exterior facing. No structural damage to it occurred in this earthquake, but Throop Hall falls well below modern standards, and its eventual fate has not yet been decided.

Although the earthquake damage was severe, there were several factors which limited the disaster the earthquake might have caused. First, the area subjected to the most damaging shaking was of small size, and it was immediately adjacent to a relatively undamaged urban area containing extensive fire, police, medical, and other service facilities. These services were adequate to cope with the situation without becoming seriously overloaded.

A second fortunate factor was that most people were



Columns on the Foothill Boulevard overcrossing of the Foothill Freeway were severely damaged. The complex failure of the bridge was aggravated by the inadequacy of the ½-inch horizontal ties that were supposed to confine the 2¼-inch-diameter vertical reinforcing steel.

in their homes at the time of the earthquake, and the type of residential construction common here is highly resistant to earthquake destruction. The typical light and strong wood frame house may be seriously cracked and damaged, but it seldom collapses completely with a major threat to life and limb. Only a very few, perhaps two or three, people were killed in their homes during this earthquake. If the shock had occurred just three hours later, the collapsed Psychiatric Day Care Center at the Olive View Hospital would have been occupied, the freeway overpasses would have collapsed on lanes of traffic, and the falling debris from old buildings in San Fernando and Los Angeles would have pelted busy sidewalks. The resulting casualty toll would have been much more severe.

Another favorable factor was the lack of major landslides in densely populated areas. Such slides were a major source of damage in the Alaskan earthquake of 1964 and in the 1970 Peruvian earthquake, in which one major rock and ice avalanche buried two towns, with an estimated 20,000 deaths. Fortunately, the possibility of such slides in the Los Angeles area seems small.

By far the most fortunate escape from disaster was the survival of the two Van Norman dams which were both

The luckiest feature of this earthquake was the survival of the lower Van Norman dam—which looked like this on the morning of the quake. A major section of the dam slid into the reservoir, leaving a scarp of about five feet between the water level and the top of the remaining portion of the dam.

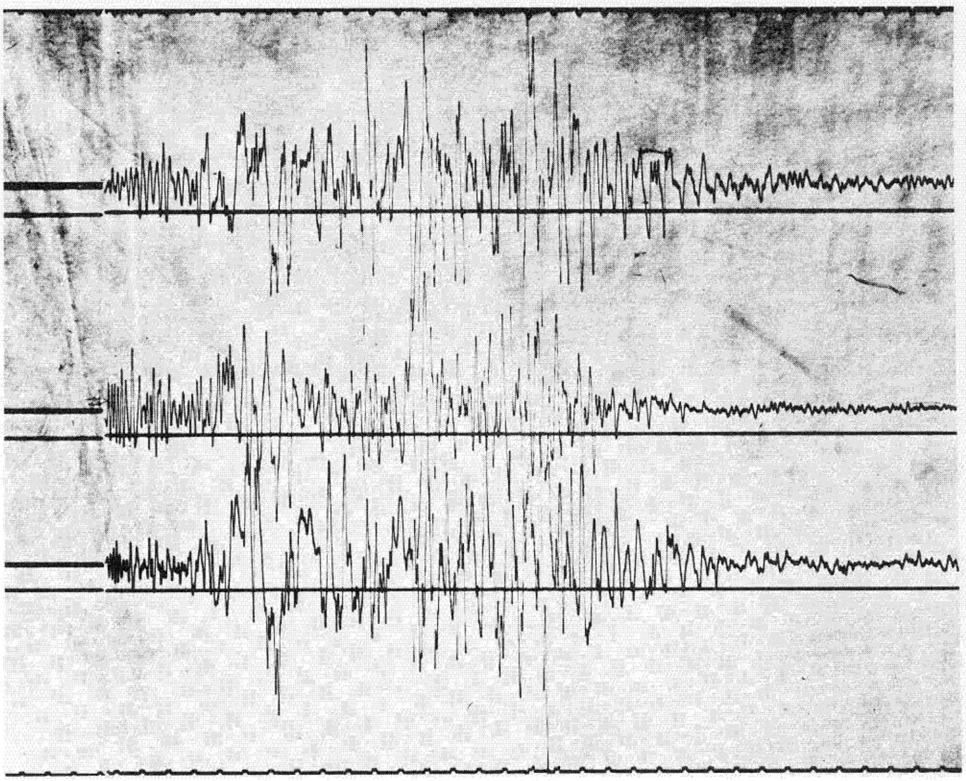
severely damaged by the earthquake. The dams very nearly failed, and had the ground shaking lasted a little longer or had it been a little stronger, a catastrophic flood would have swept through a densely populated region before the inhabitants could have been evacuated. This is perhaps the most frightening aspect of this earthquake.

On the positive side, the earthquake provided a large amount of valuable data on ground and building motions that will notably increase engineering knowledge of earthquakes. Some 200 accelerographs recorded earthquake motions at various locations—on the ground, in buildings, on dams, for example. These accelerographs, maintained by the National Oceanographic and Atmospheric Administration's National Ocean Survey and Caltech's Earthquake Engineering Research Laboratory, provided by far the greatest amount of strong-motion data so far recorded in any earthquake. Included in these results is the strongest ground shaking ever recorded. The record was obtained in the middle of the epicentral region on a steep rock ridge near the south abutment of Pacoima Dam. The concrete arch dam was not damaged.

The large collection of records obtained in the earthquake is extremely valuable from the point of view of research. For the first time there is enough data on the character of the ground motion and the response of structures to strong shaking to begin to answer some of the fundamental questions in earthquake engineering research. Such questions include how much the local geology affects ground motion, and what level of energy dissipation occurs in buildings under strong shaking.

The information gained from the San Fernando earthquake will aid greatly in efforts to reduce the disaster potential of future strong earthquakes. Many detailed studies are now under way to clarify particular features of the earthquake damage and to recommend ways to avoid damage in future shocks. Detailed recommendations and conclusions must await the results of careful study, but some general lessons of the earthquake are already apparent:

(1) A striking consequence of the earthquake was the fact that four hospitals in the San Fernando area were damaged so severely that they were no longer operational just when they could have been needed most. Critical structures such as these should be designed so that they remain functional after experiencing the most severe ground shaking. Included are hospitals, schools, high-occupancy buildings, and buildings housing police and fire departments and other agencies relied upon to cope with disasters. In addition to the structures, the emergency communication systems of these agencies must receive special care so they will not be damaged. Basic utilities that must be depended upon for the life of the community must also receive an extra measure of protection.



This accelerogram retrieved from the Pacoima Dam represents the strongest earth motion ever recorded. The single largest deflection in each band represents an acceleration of one full g, and several deflections indicate 60-70 percent g.

Ordinary building codes cannot be depended upon to preserve these functions, and special code provisions are necessary.

(2) This earthquake has provided the first really comprehensive practical test of U.S. earthquake codes. Modern structures designed according to earthquake requirements of the building code performed well in the regions of moderately strong ground shaking. In the region of very strong ground motion, however, some modern buildings were severely damaged, and the few that collapsed would have caused many additional deaths had they been occupied at the time. If the duration of strong ground shaking had been appreciably longer, as it would be in a great earthquake, some of the severely damaged structures would almost certainly have collapsed. It is clear that existing building codes do not always provide adequate safety against collapse, and such codes should be reviewed in detail and updated to include the latest practical developments in earthquake engineering.

(3) Many old, weak buildings in the regions of strong and moderately strong shaking suffered severe damage, and the major loss of life occurred in one old building designed before the adoption of modern building codes. There are many thousands of such old buildings in California that will collapse if subjected to strong ground shaking. Programs should be undertaken to render such buildings safe, or to raze them, over a reasonable period of time. A successful effort of this type has been under way for some time in the city of Long Beach, and in the city of Los Angeles especially hazardous parapet walls

on several thousand buildings have been removed or strengthened. The San Fernando earthquake dramatically demonstrated the value of such procedures. A much more extensive program to eliminate the major hazards of old buildings is needed.

(4) The near catastrophic failure of the lower Van Norman dam endangered the lives of tens of thousands of people. Such risks are clearly unacceptable. Inasmuch as many existing dams in all parts of the country have not been designed to resist earthquake forces, a program for bringing older dams up to modern safety standards is imperative. Such structures should be thoroughly examined and measures taken to reduce such hazards to an acceptable level. The successful performance of a new earth-fill dam at the Van Norman site shows that modern earth-fill construction can withstand the earthquake forces that damaged the older dams.

(5) A number of freeway overpass bridges collapsed, causing two deaths and resulting in major disruptions of traffic. In a great earthquake, such interruptions of transportation could greatly magnify the disastrous effects of the earthquake. Freeway bridges, and important highway bridges, should be designed for adequate safety

The damage to the new Olive View Hospital was the most significant feature—from the structural engineering point of view—in this quake. The damage here was not caused by faulting under the structure (as has been suggested), but by ground shaking.

against collapse. Present standard code requirements for earthquake design of highway bridges are inadequate and should be revised in conformity with the current state of knowledge in earthquake engineering.

(6) It is noteworthy that, in the region of strong shaking, school buildings designed and constructed under the Field Act of the California State Legislature did not suffer structural damage that would have been dangerous to the occupants had the schools been in session. This demonstrates that one- and two-story school buildings can indeed be made safe by practicable code requirements even when such buildings are subjected to very strong shaking combined with appreciable ground deformations beneath the structures. On the other hand, older school buildings that did not meet the requirements of the Field Act suffered potentially hazardous damage in regions of only moderately strong ground shaking. The lesson is clear that such hazardous school buildings must be eliminated or strengthened.

(7) None of the tall buildings in Los Angeles was seriously damaged by the earthquake, but it should be emphasized that this earthquake was too far away from downtown Los Angeles to be a good test of the strength of these structures. Tall buildings, like other buildings, can be made to resist the strongest shaking without collapse, but this does not occur automatically. Unless the special care devoted to the design of recent tall buildings is continued in the design of others, tall buildings, too, can be a hazard in the event of strong shaking.

(8) The extensive damage to electrical transmission facilities shows that the earthquake-resistant design of these facilities must be markedly improved. It has been estimated that it will be at least a year before repairs are completed at the Sylmar Converter Station, which suffered approximately $30 million damage.

(9) The approximate damage cost of $500 million and the effects on vital services from a moderate earthquake occurring on the fringe of the Los Angeles metropolitan area point out the large disaster potential of major earthquakes. If the shock had occurred near the center of the city, or if a great earthquake should occur on the San Andreas fault, it would seem that the damage could approach three or four billion dollars, and essential services would be severely crippled. The rapid recovery from the San Fernando earthquake showed that the disaster was not too large for the recuperative powers of the metropolitan area to overcome; the utilities, medical, and protective systems handled the increased burden very well; and relative normalcy has been approached in a matter of days or weeks. It is not expected, however, that such systems could overcome the consequences of a great earthquake without major assistance from outside the metropolitan area.

(10) The San Fernando earthquake again demonstrated that the most practical approach to the problem of safety in earthquakes is earthquake-resistant design.

Nearly all the bookshelves collapsed on the upper stories of Caltech's Millikan Library, and about 75,000 books spilled to the floor. The accelerograph at the base of the library recorded a maximum acceleration of 15 percent g, and the instrument at the top of the building showed about 35 percent g.

Structures can be designed to withstand safely the most severe earthquakes, but this cannot be done without an increase in cost. For many buildings and other structures, this increase in cost is a modest one; for others it may represent a significant increase in over-all investment. Once essential function and safety of life and limb have been assured, the problem of earthquake-resistant design becomes an economic problem; the initial cost must be balanced against the possible cost of repair to earthquake damage over the expected lifetime of a structure.

The San Fernando earthquake, though a disaster to many, has provided a unique opportunity to learn about the effects of strong earthquake motion. The results of the many engineering studies now under way, and the actions and regulations prompted by this earthquake, should reduce significantly the hazard from earthquakes of the future.

This article was written by the staff of Caltech's Earthquake Engineering Research Laboratory in the Division of Engineering and Applied Science. Contributors include George W. Housner, Donald E. Hudson, Paul C. Jennings, Ronald F. Scott, Wilfred D. Iwan, Mihailo D. Trifunac, Gerald A. Frazier, Arthur G. Brady, and John Wood.

The San Fernando Earthquake – What It Did to the Earth

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ment that began at a depth of about eight miles beneath the epicenter (located about 7½ miles east of Newhall). It then moved southward and upward along a fault plane that slanted at an average angle of 45 degrees, and actually broke the surface of the ground in the Sylmar-San Fernando area. This kind of a fracture, known as a thrust fault, is typical of the faults that had been mapped by geologists in this area prior to the earthquake. However, the particular fault that broke on February 9 had not been recognized as being especially active, and there was no obvious reason to consider it more dangerous than the many other similar-appearing faults throughout the Los Angeles region.

Investigations of the earthquake area indicate the presence of a combination of land movements. Some was of the strike-slip variety, in which the northern block moved to the west relative to the southern block. Combined with the strike-slip movement—and probably dominant over it—was the overthrust movement in which one block went up and over the opposite block.

In the San Fernando earthquake, the San Gabriel Mountains (the northern block) moved in a thrust-like motion southwestward over the San Fernando Valley floor (the southern block) along a fault plane that slants shallowly back underneath the mountain range. Preliminary estimates indicate that the mountain block rose up at least three feet in relation to the valley floor and moved at least three feet to the south.

When the fault met the surface, it produced a great deal of ground shortening. As much as six feet of shortening took place across the Sylmar fault trace—the fault trace is the line where the fault surface outcrops on the surface of the earth. Such ground displacement extended over a wide zone, buckling streets and sidewalks and causing heavy damage to many structures.

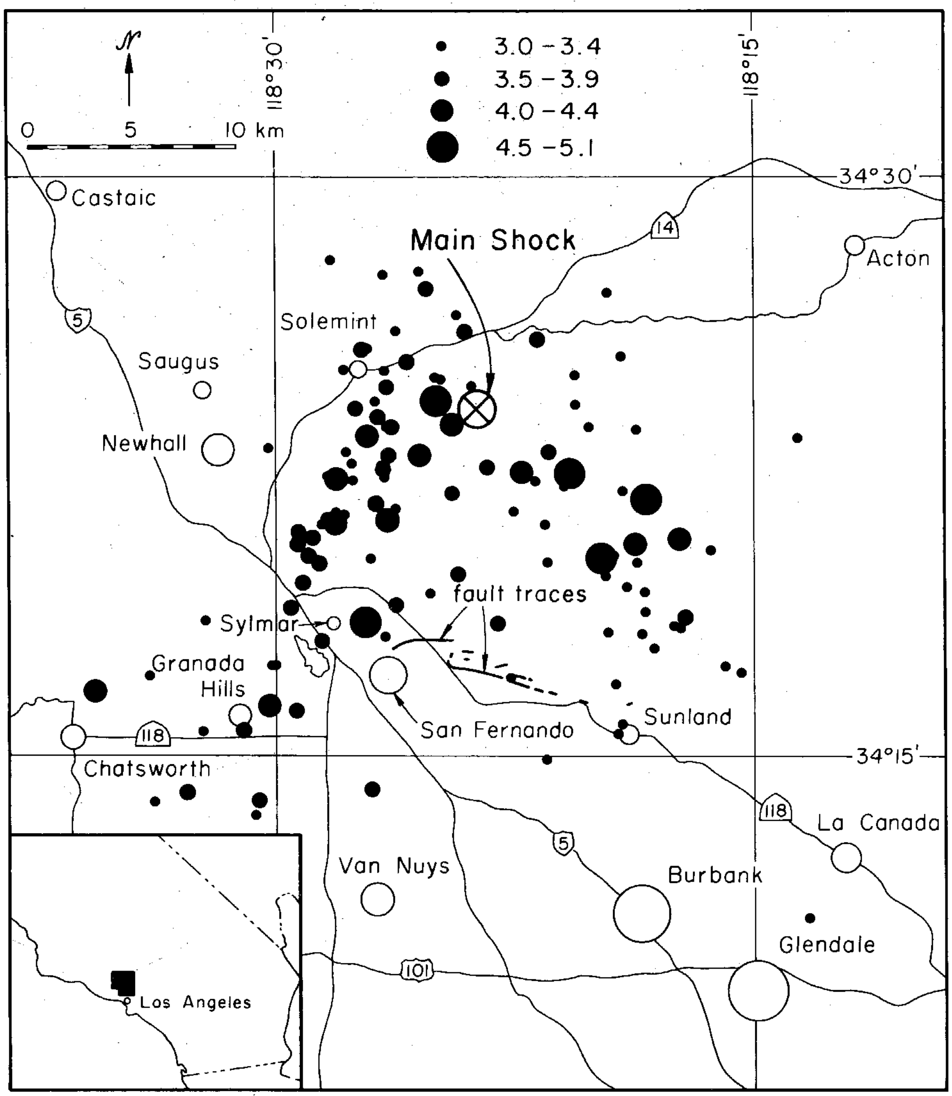
The first large shock to be so thoroughly monitored and recorded, this earthquake is expected to produce more significant and more detailed data than any other earthquake in history, because it occurred very near the center of the southern California seismographic recording network. Caltech's Seismological Laboratory operates an array of 20 permanent recording stations extending from the Owens Valley to the Mexican border and comprising both conventional and special purpose instruments. Seismic records produced at eight of the stations, six of which are operated directly by Caltech and two by the State Department of Water Resources, were relayed by microwave to the Seismological Laboratory in Pasadena where instantaneous readings were made. The records from the remaining 12 stations are made photographically and are mailed to the lab once a week for processing and evaluation. Since February 9, this network has detected and recorded over 200 aftershocks of magnitude 3.0 or greater.

Aftershocks of earthquakes are usually distributed over a wide area that is more or less centered on the area of the fault that originally breaks. The aftershock sequence following the San Fernando earthquake seems to be a normal one, and Caltech seismographic records taken before the quake show no indication of identifiable foreshocks. A careful examination of records from the Mt. Wilson seismic station indicates that no shocks exceeding magnitude 1.5 had occurred in the area in the preceding eight days. No shock exceeding magnitude 2.5 had been identified in the area during the preceding four months, and it appears that the most recent identifiable event within the area of subsequent activity was a shock of magnitude 2.6 that occurred north of Sylmar on September 28, 1970.

The greatest concentration of aftershock activity appears to lie roughly in the shape of an inverted U symmetrically disposed with respect to the epicenter of the main shock and to the pattern of the surface faulting. The epicenters of the aftershocks tend to delineate the boundaries of the thrust displacement that caused the quake, although many of the shocks along the western limb seem to represent deeper strike-slip events whose relationship to the main thrust fault is very complex and not yet understood.

Very accurate hypocentral locations have been determined for some 25 of the aftershocks. Hypocenters are the points beneath the earth's surface where the first motion occurs. The deepest of these hypocenters is about eight miles, and the average depth is close to three miles. As has been observed in other aftershock distributions associated with thrust faults, the bulk of the aftershocks following the San Fernando earthquake occurred predominantly in the upper plate of the earth, leaving it more broken up and shattered than the underlying rock.

Since the San Fernando earthquake, many questions have been asked about its possible effect on the "big" earthquake that has long been forecast for the southern portion of the San Andreas fault. These are extremely difficult questions to answer. Southern California is an area with a very complex series of faults that have different directional trends and different styles of



A seismological map of the epicenters of the main shock and aftershocks of magnitude 3.0 or greater that occurred in the month following the February 9 earthquake. The aftershocks occurred in a peculiar inverted U-shape. The hypothesis is that the segment of the fault that broke has this same U-shape. Aftershocks may represent the points where the displacement on the fault actually stopped.

movements, though they fall, essentially, into two major fault systems. One of these systems is composed of the east-west trending ranges like the San Gabriel Mountains and particularly the mountains near Santa Barbara. These mountains are characterized by east-west trending faults that tend to exhibit thrusting of the type observed in the San Fernando Valley earthquake.

The other system is directly related to the San Andreas fault that slices through western California for more than 600 miles, extending in a straight line southeasterly from the Mendocino County coast to the southern San Joaquin Valley; there it bends to the west and then continues southeast along the north flank of the San Gabriel Mountains. Branches of it eventually reach the Gulf of California.

The San Fernando quake occurred within the first system, and its effect on the San Andreas system is still unclear to geologists. But it is believed that the compression along the 50-mile stretch where the San Andreas bends westward may have had some direct relationship with the February 9 earthquake, even though there was apparently no movement along the big fault.

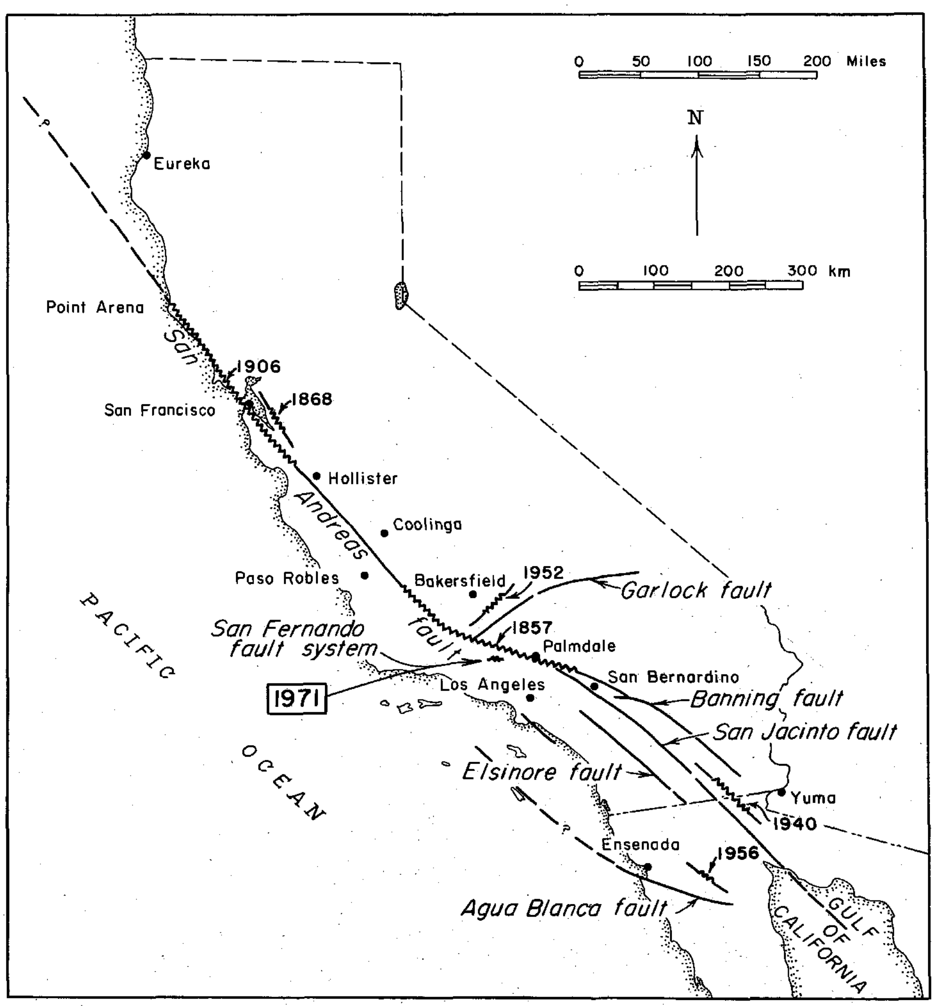
"The bend," says Don Anderson, director of Caltech's Seismological Laboratory, "tends to block and jam the general northwesterly movement (at the rate of about two inches a year) of that part of California that lies west of the San Andreas fault in relation to the rest of the state east of the fault. The fault runs in virtually a straight line both north and south of the bend. In those areas this general northwesterly movement is punctuated by occasional horizontal slipping along the San Andreas and its associated faults, accompanied by earthquakes.

"But near the bend the horizontal slipping gets hung up. The compression builds up, and instead of horizontal movement there is overthrust faulting in that region, with land thrusting over land along fault breaks, triggering earthquakes like the one in San Fernando."

Will the Los Angeles area experience another major quake—this time along the San Andreas? Clarence Allen, professor of geology and geophysics, says, "We know something about the rates at which movements are taking place along the San Andreas fault. We have geodetic observations from surveying in the Imperial Valley and in northern California that give us some clue to the rate at which the shape of California is changing, and if our computations are correct—and there are many assumptions in this—it leads us to believe that an earthquake along the San Andreas fault should occur at an interval of once every 100 to 200 years.

"We last had a break down here in 1857, and consequently our feeling is that a major quake on this, the southern portion of the San Andreas fault, say tomorrow, wouldn't be any surprise. The stresses relieved

Some historic earthquakes on the San Andreas and its associated faults in California and northern Mexico. The zigzag lines show where the ground surface was broken in various earthquakes. The bend in the San Andreas, just north of Los Angeles, may have played an important role in triggering the San Fernando quake.



at the time of the 1857 earthquake have again built up to the point where they deserve attention."

The recent San Fernando earthquake and the continuing discussion about possible quakes along the San Andreas fault have focused new interest on an old question: Can earthquakes be predicted? Among the world's experts there is not much agreement on the subject. Some say precise earthquake prediction is impossible; others say it is possible but will take a long time and a lot of money.

Charles Richter, the inventor of the Richter Scale and Caltech professor of seismology, emeritus, says flatly that it can't be done. Clarence Allen and Don Anderson both agree that predicting earthquakes is an impossible business at the present time, but it is an objective worth working toward. According to Allen, precise prediction is "not something we'll do in the immediate future, but even if we are never able to predict earthquakes in terms of exact time and place, we may be able to reach another objective of great value. That is, through geological and geophysical studies, we may be able to ascertain which areas are likely to have more earthquakes than other areas and what the average frequencies of any given magnitude in those areas will be. This is what the engineers need in order to design buildings safely and economically."

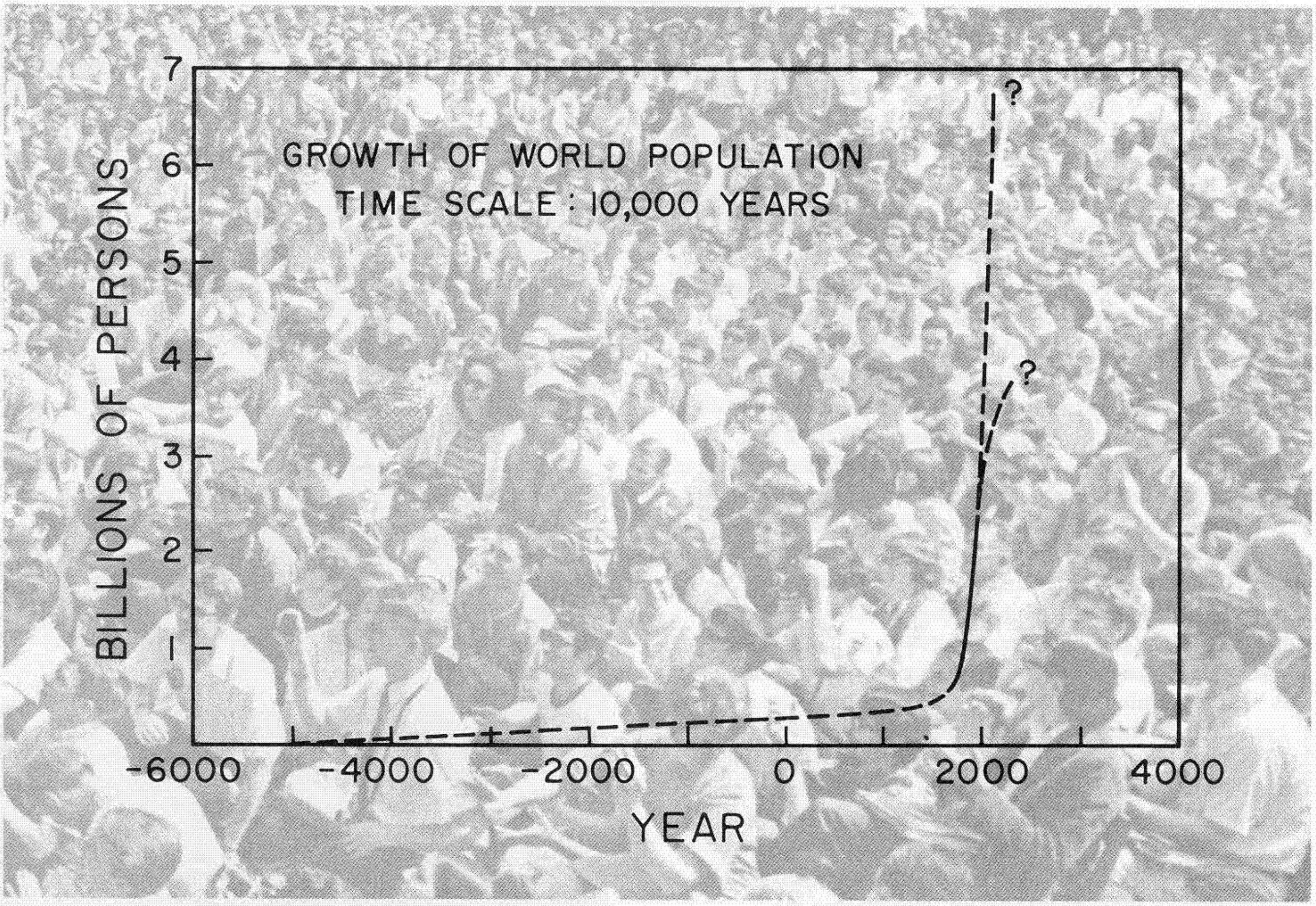
Anderson says that we can't predict earthquakes now except in the sense that we know there have been and will continue to be a lot of them. He feels it is not a problem you can successfully tackle with statistics because the records just don't go back far enough in time.

The primary technical obstacle to achieving a relative prediction capability is a lack of instrumentation. Currently, southern California has only about 30 seismic stations, and they are located about 12 miles apart. Ideally, a grid of many seismographic stations not less than six miles apart would be necessary to keep accurate tabs on the seismic activity in most areas. More importantly, special purpose instruments such as strain gages and tiltmeters are required to monitor the strains before an earthquake.

While the problem of earthquake prediction is still unresolved, it is clear—as everyone was reminded on February 9—that California will continue to have hundreds of earthquakes every year. And some of them will be big ones.

This article is a summary of the early findings from the San Fernando earthquake by the Division of Geological and Planetary Sciences.

Among the many fortunate people who survived the earthquake with a bare margin of safety was Dee Barr, graduate secretary in Caltech's chemistry division. She and her husband, who is the caretaker of the Pacoima Dam, awoke February 9 to find that their bedroom wall had come very close to being crushed by a boulder fallen from the mountain behind their house.



The Crowded Earth

The Caltech Population Program is proceeding on the assumption that all the countries of the world have much to gain by slowing their rates of population growth.

The Caltech Population Program is a long-range plan for studying the world's population problems and making its findings available to population scholars and policy-makers. Headed by Harrison Brown, professor of geochemistry and of science and government, the program is examining how different social and cultural patterns and varying governmental policies affect population. The ultimate objective, of course, is to help man control his own numbers.

Assisting Brown as deputy program director is Alan Sweezy, professor of economics, and an advisory board consisting of Edwin Munger, professor of geography; James Bonner, professor of biology; Thayer Scudder, professor of anthropology; David Elliot, professor of history; and Kenneth Frederick, assistant professor of economics.

For its first three years the program is being supported by an $800,000 contract with the Agency for International Development (AID) and will concentrate on under-developed countries, where population growth and the resulting socioeconomic pressures are greatest. Later, a separate phase of the program might consider the population question in the United States. This phase would clearly be related to many of the environmental concerns of Caltech's new Environmental Quality Laboratory (*E&S*–January 1971).

Though the program will remain based at Caltech, a large part of the work will be done by the American

Universities Field Staff (AUFS)—an international research organization supported by a consortium of American universities, including Caltech, which has for the last 20 years done field studies on a broad range of topics and countries. Providing the program with a worldwide deployment of population researchers, AUFS has agreed to do a total of 60 studies during the initial three-year period. In each country to be studied, specialists will probe the population policies and programs of individual governments, AID, and other international and private organizations working in the field. Local studies by foreign scholars will also be supported. All this data will become part of a special collection of books, papers, statistical surveys, and other material which Caltech is assembling as a body of source information for scholars and policymakers.

The results of the first year's efforts were presented recently to a group of Caltech scholars, visiting demographers, and AUFS specialists at the first annual conference of the program. Reports on a total of 12 countries were given by as many AUFS population experts: Jon McLin (Belgium), Dennison Rusinow (Yugoslavia), F. Roy Lockheimer (Japan), Loren Fessler (Hong Kong), Willard Hanna (Indonesia), Albert Ravenholt (the Philippines), Louis Dupree (Afghanistan), Thomas Sanders (Brazil), Richard Patch (Bolivia), Victor DuBois (Ivory Coast), James Hooker (Malawi), and Norman Miller (Kenya). The papers illustrated what is unique about the Caltech program because they cut "diagonally" across the problem, dealing with the political, economic, social, cultural, and historical backgrounds of the population policies operating in each country.

One of the most dramatic developments covered by the conference is the discovery of prostaglandins, a group of hormone-like chemicals found throughout the body but mostly in seminal fluid. These substances, described by R. T. Ravenholt, director of AID's Population Office, may prove to be a major breakthrough in birth control technology.

Of the 16 prostaglandins identified so far, two appear to be most promising as birth control agents. They have already been used successfully by a Ugandan doctor in inducing labor in full-term pregnancies, and by a researcher in Sweden, where the chemicals were shown to be effective in emptying the uterus at *any* time after conception. The substances, which are apparently involved in the natural mechanism that triggers labor, operate by causing muscular contractions in the uterus.

If subsequent tests prove successful, prostaglandins may truly be the ideal birth control device: a non-toxic, completely effective substance which, administered on a single occasion at any time after intercourse, terminates pregnancy. If a means of self-administration is developed, prostaglandins could end the "clinical bottleneck"—the shortage of trained medical personnel and available clinics—which hampers present birth control programs. Of course, the substances may also introduce a new set of problems. For if women can use the chemicals to administer their own abortions, this may conflict with local laws. And if it becomes necessary to regulate the distribution of the chemicals through trained medical personnel, that may re-introduce the clinical bottleneck.

Encouraging as the new research seems, the key is motivation and education, not technology. The "perfect" birth control device, even if we get it, may not have great impact because of other obstacles.

This notion seems to be borne out by the experience of Belgium, where fertility is low—but not because of sophisticated birth control agents such as prostaglandins. Recent research indicates that most Belgians still use *coitus interruptus* and the rhythm method.

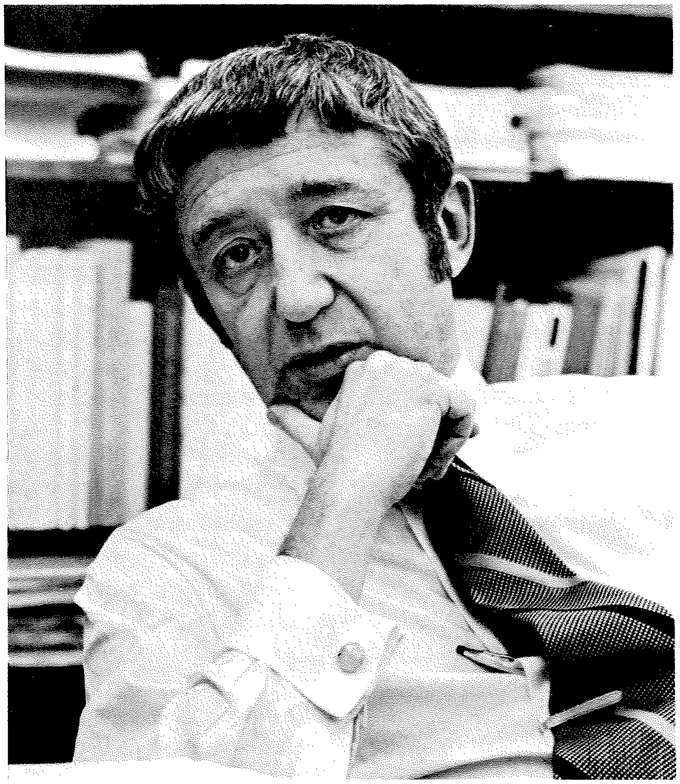
Belgium is fairly typical of Western Europe, where the great decline in fertility which occurred in the 19th and early 20th centuries came about without extensive use of modern contraceptives. The pill and IUD (intrauterine device) were unknown until after the decline had reached its low point. In fact, the real cause of declines in birth rates in these industrialized countries appears instead to have been related to spontaneous forces such as rising affluence and aspirations, or changes in the economic role played by the family.

Large-scale, conscious attempts at family planning are a new phenomenon. The U.S., the U.N., and a growing list of other countries and international organizations are pursuing family planning programs. It is still too early to judge the success of most of these efforts. Taiwan and South Korea, where planned programs of fertility control have been undertaken, exhibit declining birth rates, but there is considerable disagreement as to how much of the decline is due to the program and how much to economic growth, urbanization, and other socioeconomic changes.

Throughout most of history, both birth and death rates have been high and approximately in balance. The success of modern science and technology—progress in medicine and public sanitation—have destroyed the balance. Falling birth rates have eased, though not eliminated, population pressure in the industrialized countries. But when modern public health measures were extended to underdeveloped countries—mostly within the past 20 or 30 years—these countries experienced a sharp decline in death rates without a corresponding decline in birth rates.

Most people in the poorer countries—which are still largely agricultural, where supporting children is cheap, and where children are the only old-age security a subsistence farmer can ever hope to have—kept on having as many children as they could.

Modern public health techniques can be applied on a vast scale without requiring the education of large numbers of people, but birth control techniques obviously



Harrison Brown, principal investigator for the population program.

cannot. This theme—the critical necessity of individual education and motivation, regardless of the technology available—was repeatedly underscored at the conference.

Many reports also made it clear that the required education should not be directed exclusively at the masses; the governing elites also need persuading that their countries face a real population crisis which demands resources and governmental action.

A variety of official attitudes exists among the nations discussed; some actually favor increased population growth. They see it as a means of achieving international stature (more people = more importance in international affairs; more people = bigger armies). They also equate population growth with economic growth—a notion only recently challenged in this country.

Some countries favor decreased population growth, although practically none of these have taken effective action or allocated sufficient resources to family planning programs.

Some countries have no policy at all.

In Malawi (a small country in southeast Africa), few people are very much excited about population problems, though Malawi has an alarmingly high annual growth rate of 3.3 percent and one of Africa's highest densities. Since they are concentrating on agricultural rather than industrial development, Malawians feel that they, unlike Americans, are increasing rather than wasting the earth's resources. So, from their point of view, American arguments against population growth are merely old-style racism tricked out in new garb.

What happens in tiny Malawi may not do much to impede the worldwide momentum of family planning, but the situation in a country as big as Brazil certainly can. Brazil is one of the countries that officially *favors* population growth. Currently increasing at 3 percent per year, its population will double in 23 years. The advocates of rapid growth believe it will hasten Brazil's emergence as a great world power. They are also convinced that Brazil's huge uninhabited interior contains vast resources which can be developed to support the rapidly growing population.

Indonesia is a country which is belatedly committed to population control, but so far has been frustrated in achieving it. For Sukarno's Indonesia, escape from colonial domination signaled a single-minded lunge for international prestige, with little thought for the costs of uncontrolled population growth. To Sukarno, population growth was only another monument to the national glory of a country that already ranked fifth in the world in numbers of people. But after the fall of Sukarno in 1966, there came a sobering realization that over-population was closely related to practically every other ill that beset the nation.

Today, Indonesia is experiencing one of the most rapid —and tragic—processes of urbanization in the world. Not only the major cities but also former villages now classified as urban are being packed by migrants attracted by the illusory prospect of employment, housing, and education. In parts of Java, Madura, and Bali, these villages now stretch out almost continuously along the pathways and waterways, so that the residents seem almost to be spilling back into the fields from which they recently migrated.

Statistics in developing countries are often fanciful, but in Indonesia the published numbers bear out what can be seen by any observer: Individual shares of national income, already among the world's lowest per capita figures, are shrinking—even though the national income is rising. The reason is a 2.5 to 3 percent annual rate of population increase.

So far, the country's ponderous, overstaffed, and underpaid bureaucracy has been ineffectual in its attempts to launch a birth control program. In fact, the Indonesian project to date has probably been one of the least effiicent and most expensive ever undertaken. The 1969 figures indicated that it cost $60 to reach each of the 50,000 persons served by the program.

The gloomy inventory goes on: If Kenya's present rate of population growth continues, the potentially productive acres per person will sink from 4.2 in 1965 to 2.6 in 1980 and 1.3 in 2000. Yet, the opposition leaders in Kenya criticize the government's support of family planning on the grounds that neighboring Uganda may get ahead in numbers and power.

Nor should it be assumed that sentiments like these prevail only in relations among nation-states. In the wake of tribal tensions that accompanied the assassination of Tom Mboya in 1969, members of the Kikuyu tribe in Kenya took oaths to avoid any family planning so as to increase their numbers vis-à-vis other tribes in the country.

What is the prospect for increasing the productivity of people, land, and factories to provide for the added population? Rapid population growth acts as a serious drag on economic development, and it means one of two things: (1) Either a part of current production must be used merely to maintain the existing standard of living, or (2) some people must be left out and all the resources concentrated on improving the lot of the in-group.

This gives rise to what social scientists call a "dualistic society": one sector with jobs and a rising standard of living; the other unemployed or underemployed, scraping along on bare subsistence, and looking forward to nothing better.

It is not that there is an ideal population for each country. This surely is a function of technology, social organization, natural resources, and other factors. The problem is capital formation—saving something back from present consumption to invest in greater output of material and social goods in the future.

Critics of Brazil's present policy would undoubtedly grant that this richly endowed land could eventually support 200 million people at a satisfactory standard of living, but they would insist that it makes a great deal of difference how soon that population level is reached.

It is obvious that Indonesia, another vast and potentially rich country, theoretically could support her population at the standard of living enjoyed by Japan, which has a similar population (more than 110 million) but only a fraction of the land and resources. However, in the late 19th century when Japan was beginning to industrialize, her population was only about 30 million. Population grew rapidly *during* the course of economic development—but not before it. Thus, the resources Indonesia needs to *both* sustain her present population *and* invest in the future are enormously greater than those Japan needed to launch her "economic miracle."

Traditionally, most nations have viewed their population problems in economic terms. To some extent this attitude remains prevalent today, with most discussions centering around the question of whether a nation's population can produce enough goods to sustain itself, or how population growth will affect its gross national product. Only recently has the scope of concern broadened to include the effects of population on the overall quality of life, and this awareness has largely been confined to the most industrialized countries. Japan, for example, a country whose economic growth has been spectacular by any standards, today faces problems of industrial pollution and urban congestion at least as severe as those encountered in the U.S. Japan's GNP is

Alan Sweezy, the program's associate investigator.

now the third largest in the world, and there is no question of that country's ability to feed its own people. But this very prosperity has brought her up squarely against a whole new set of problems: Her atmosphere, countryside, rivers, and coastal seas are polluted; and her cities are plagued by inadequate housing, increasing congestion, and uncontrolled urban sprawl.

Environmental pollution and urban problems are not confined to industrialized nations. Brazil, for example, which is still a relatively undeveloped country, is already experiencing problems of smog and deficient urban services such as transportation, health, education, and sanitation. Some of these problems, in fact, like inadequate health, sanitation, and housing, are actually worse in the less developed countries, where the resources to cope with them are scarcer than in the industrialized countries. However, people in the undeveloped countries place a higher priority on improving their material standard of living than on preserving their environment or solving their urban problems.

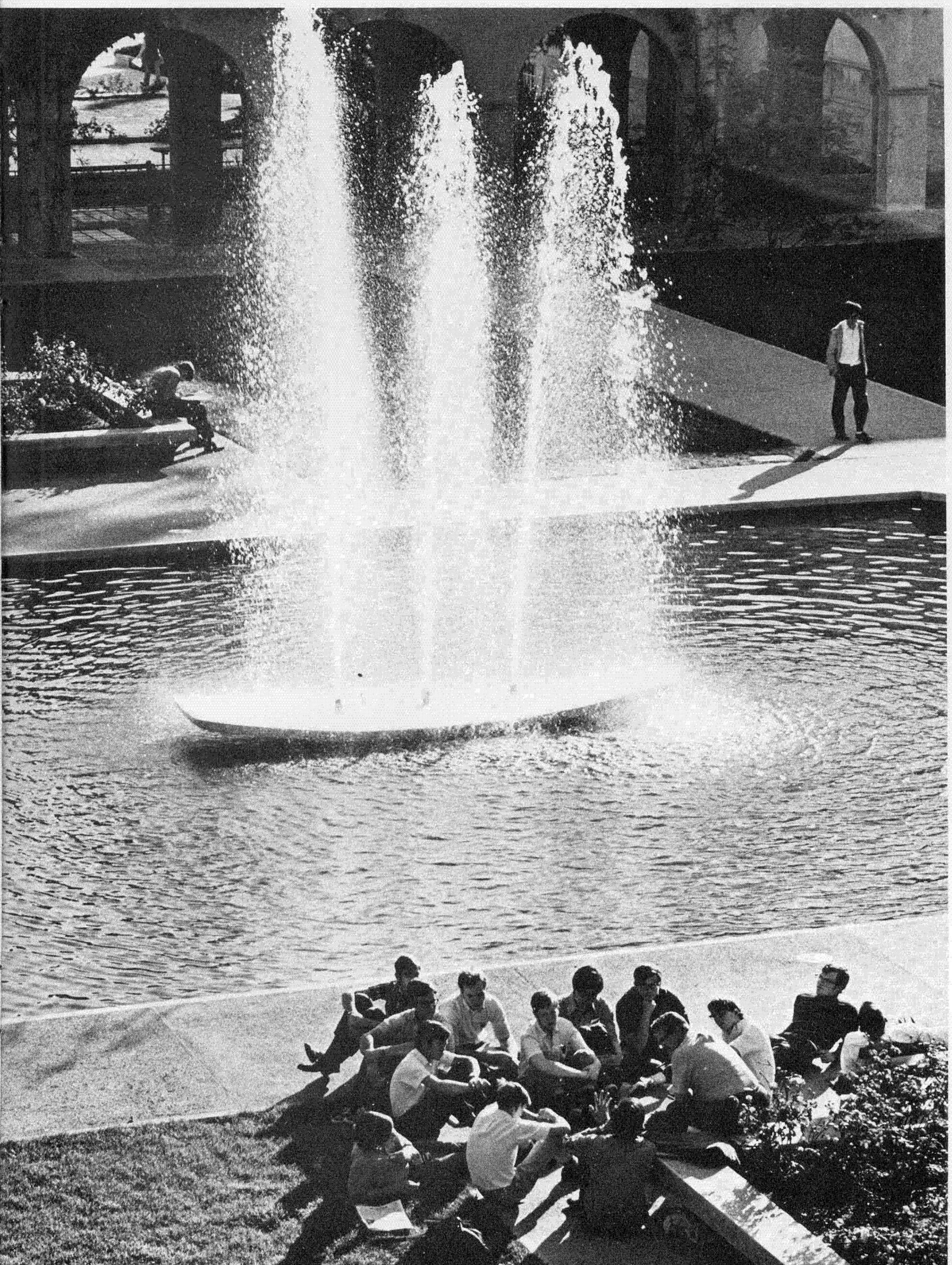
Clearly, rapid population growth not only hampers capital formation—and therefore economic growth; it can degrade the quality of life as well. For this reason the Caltech Population Program is proceeding on the assumption that all the countries of the world—whose individual circumstances and problems it will be examining in detail in the next few years—have much to gain by slowing their rates of population growth.

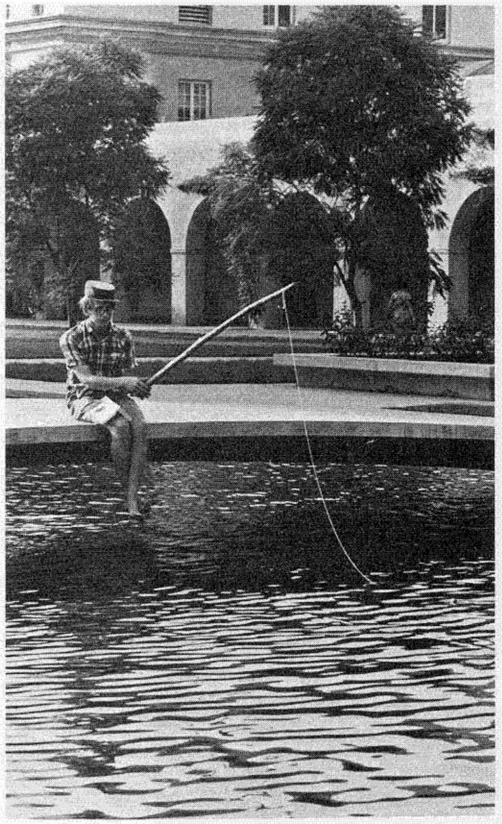
JUST ADD WATER—

and you add a whole new dimension to campus life

When the architects (Flewelling and Moody) drew up their plans for Caltech's Millikan Library more than five years ago, they made special provision for a reflecting pool and a fountain. As a landscaping element, the pool was intended to give a greater sense of open space to the quadrangle formed by Millikan, Gates, Dabney, Throop, Sloan, and Bridge. Architecturally, it was meant to achieve harmony between the new and the old buildings. Most of all, the architects hoped that the sound of the fountain and the patterns on the water's surface would "divert attention from other activities" and that the water would be "conducive to reverie and study." As the pictures on these pages show, it's been conducive to all that and a lot more.

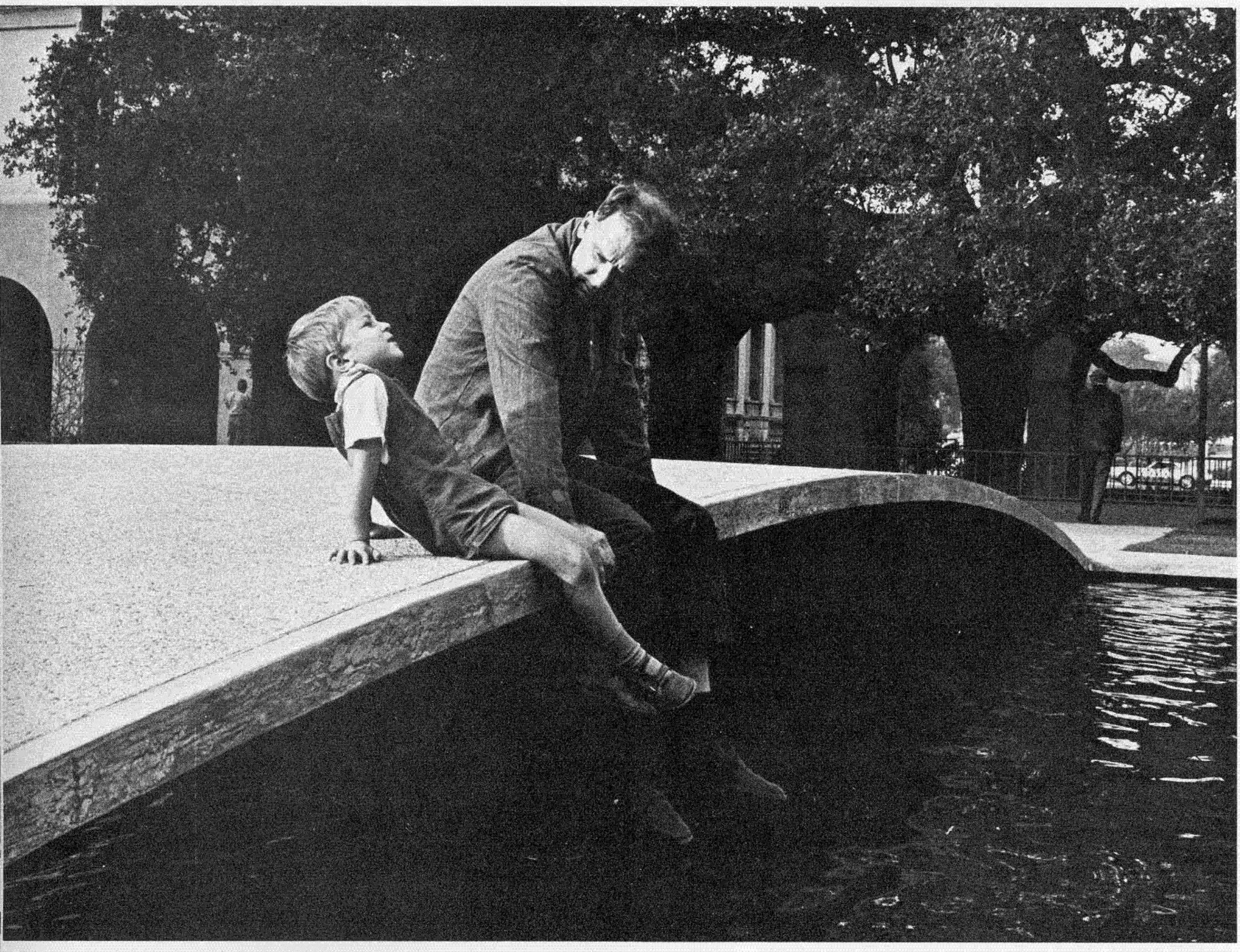
On a clear day you can usually see at least one class in session on the edge of Millikan Pond.

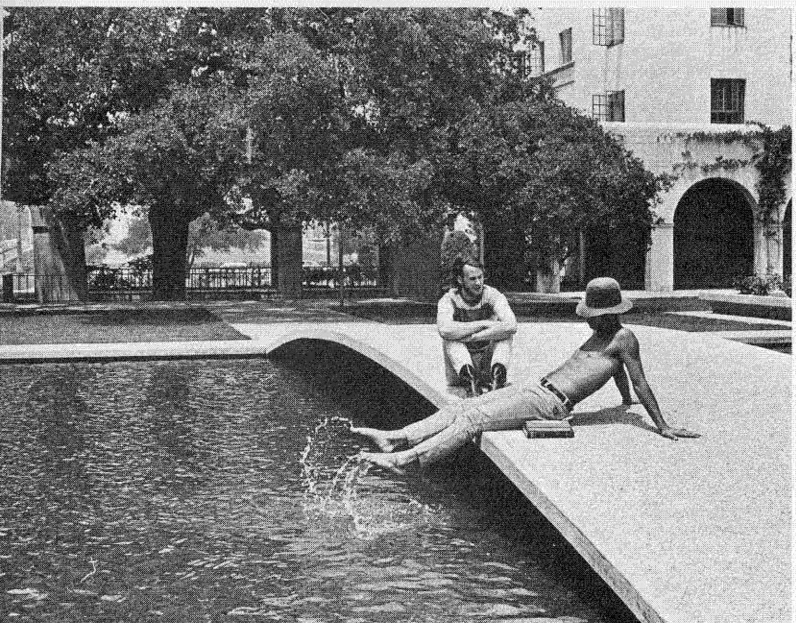




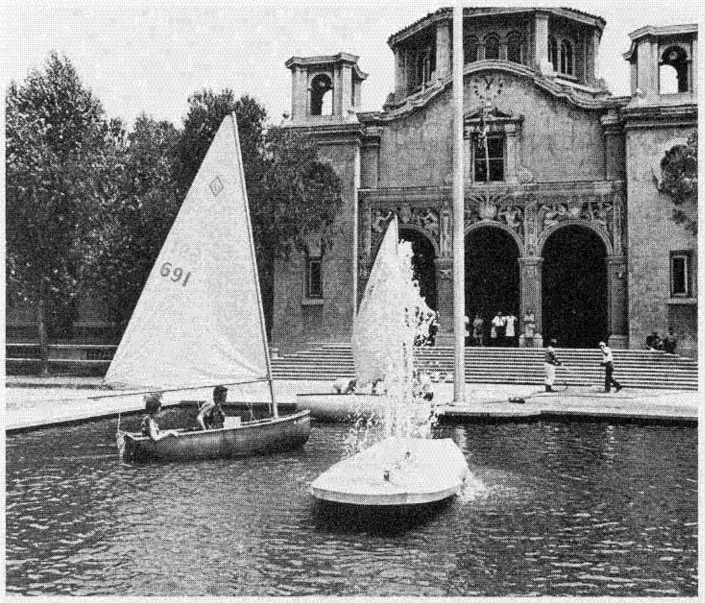
The fishing may not be good —but it's certainly convenient. (The book on his knee? Moby Dick, *of course.)*

Sometimes a girl's got to go all the way to the middle of the campus to get a little privacy.

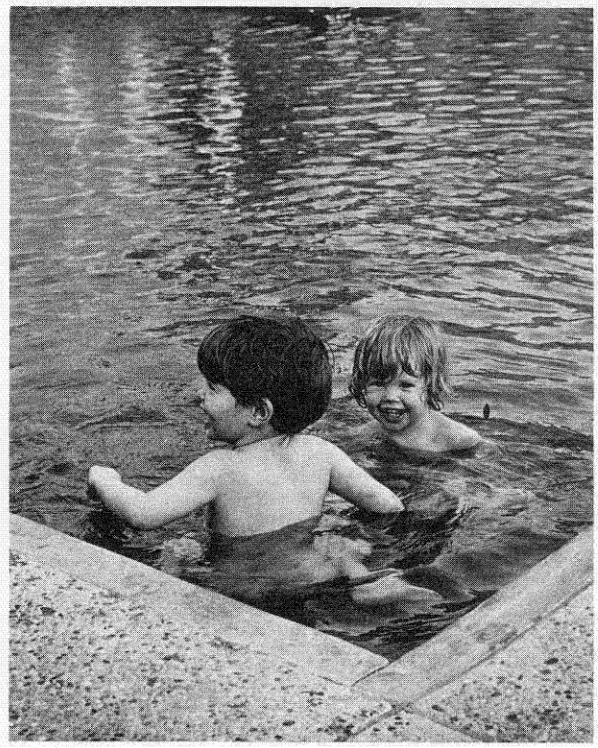


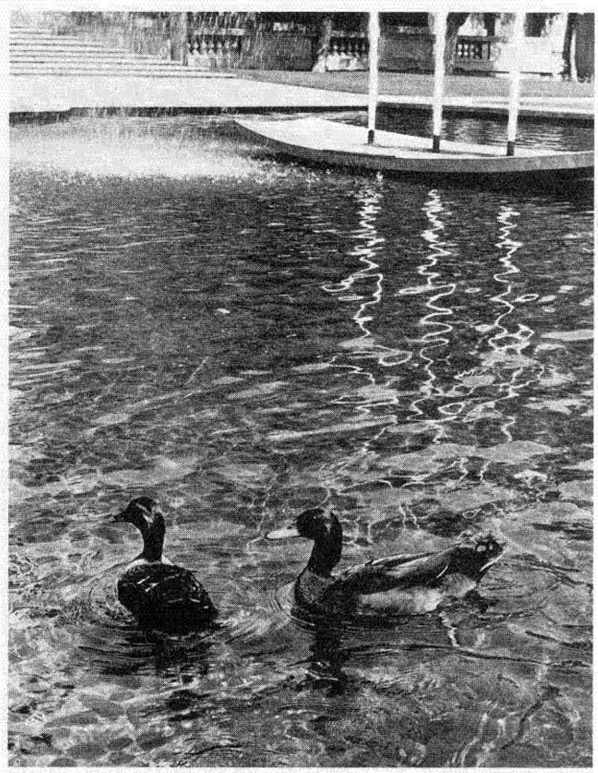


There must be something about a bridge that just naturally makes you reflective.



When the weather gets really hot, of course, you're liable to find almost anything *in the water.*





Retiring This Year

Sterling H. Emerson

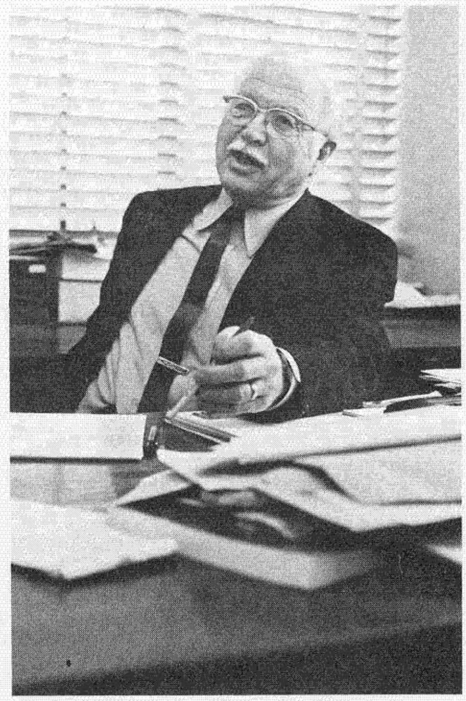
Sterling H. Emerson is a native of Lincoln, Nebraska, with a BS from Cornell University, and an AM and a PhD from the University of Michigan. His first position after he received his doctorate in 1928 was as an assistant professor of genetics at Caltech. Now, 43 years later, he has been named professor of genetics, emeritus, at the Institute. In the interim he has investigated and unraveled complex genetic phenomena in a number of organisms—the evening primrose, fruit flies, and fungi.

A major theme of Emerson's research has been to understand how genes recombine with one another to generate the seemingly endless diversity of types which characterize many living forms. In spite of the tremendous strides made in understanding the chemistry of genes, little is known about the actual events at the chemical level which go on when two like chromosomes, one from the father and one from the mother, come together and recombine with one another. This process, known as crossing over, is one of the major ways in which nature is able to generate a large number of new kinds of animals and plants from pre-existing hereditary variations.

Emerson began his studies on crossing over using the fruit fly, Drosophila. He and a number of other investigators at Caltech showed that properties of gene recombination, or crossing over, can be deduced by elaborate kinds of breeding experiments using multiply marked chromosomes. More recently, Emerson has turned to a study of genetic recombination in fungi where not only crossing over but another related process of gene recombination known as gene conversion occurs. Gene conversion is a process in which tiny bits of one gene molecule exchange with tiny bits from another gene according, again, to certain rules which Emerson has been elaborating. Emerson is building mathematical models to help explain the gene conversion patterns which he and others have studied in a number of fungi.

In another kind of investigation Emerson has been concerned with how organisms are able to build up a hereditary resistance to drugs or other toxic agents. For these studies he chose the bread mold, Neurospora—since its genetics is very well understood—and the drug sulfanilimide because it is toxic to Neurospora as well as to many microorganisms, especially bacteria. Emerson was able to breed a strain of Neurospora which was not only resistant to this drug but actually required it to survive. With Marko Zalokar, at that time a Gosney research fellow at Caltech, he then was able to work out why this was so: The sulfanilimide interferes with the action of an essential vitamin, p-aminobenzoic acid. When a strain of the mold developed a requirement for sulfanilimide before it would grow, Emerson was able to show that a new mutation had arisen which caused the mold strain to be inhibited by a metabolic product of p-aminobenzoic acid. In the absence of the drug, the mold was literally dying of too much of the vitamin. When the drug was added, it brought the level back down to normal levels so that the mold could again grow in a normal way.

These elegant experiments of Emerson's were some of the first to clarify the way in which living organisms are able to build up resistance to drugs or antibiotics. The practical significance of such work is immense, since in medicine a continual battle must be waged to control bacterial infection by developing new drugs to which the bacteria are not yet resistant. Emerson's work has contributed to the development of a multiple drug or multiple antibiotic attack, which has become an important mode of therapy in controlling infectious diseases.



Sterling Emerson

In 1951 Emerson received a Fulbright award and a Guggenheim fellowship that enabled him to spend an academic year studying at the Botany School of the University of Cambridge in England and a summer in the department of genetics at the University of Paris. From August 1955 to September 1957 he was on leave from Caltech to serve as geneticist in the biology branch of the Division of Biology and Medicine of the Atomic Energy Commission in Washington, D.C. He has represented the AEC at several international conferences on the genetic effects of radiation.

Emerson's favorite way of relaxing is walking, which gets less and less rewarding in southern California. That drawback plus the eastward pull of family ties—his son lives in Philadelphia and his daughter in England—have Emerson and his wife considering a move. Meanwhile, he is working up old data and trying to write about it, and he is pursuing his other hobbies—plant breeding and drawing.

A. J. Haagen-Smit

Caltech's pioneer crusader for clean air, Arie Jan Haagen-Smit, is one of a notable group of distinguished scientists who have left their laboratories to go to work in areas of public concern. After 34 years at Caltech—the last 22 of them at the beck and call of a growing environmental problem—he has now become professor of bio-organic chemistry, emeritus.

Haagen-Smit was born in Utrecht, Holland, in 1900. He received three degrees—his AB, AM, and PhD—from the university there and then joined its faculty. His work on the isolation and synthesis of plant hormones gave him an international reputation among other plant physiologists. It also brought him an invitation, in 1936, to lecture for a year at Harvard, and another invitation, from Caltech's famous geneticist Thomas Hunt Morgan, to join the Caltech biology division in 1937.

At Caltech Haagen-Smit continued his investigations of the structure, determination, and synthesis of naturally occurring compounds by returning to a project he had begun while working on his doctorate: the analysis of essential oils. From that work he moved to flavor studies, in the course of which he developed microanalytical techniques for separating compounds in order to obtain basic information about the chemical constituents of the flavor of food materials such as onion, pineapple, and grape. In 1950 he was given the Fritzsche Award of the American Chemical Society in recognition of his work on oils and flavors.

In 1948 Haagen-Smit decided to apply the techniques he had evolved in the flavor studies to finding out what was in the irritating air people were beginning to complain about. Starting with several hundred cubic feet of air (an equivalent of the amount a person breathes in one day), he collected a few ounces of condensed smog. This liquid was found to be mostly water containing a number of evil smelling chemicals—aldehydes, acids, and organic peroxides. Although these substances were known to be products of incomplete combustion and known to cause eye irritation, they had never before been reported as significant air pollutants. Their discovery in smog opened up a new field of investigation into the problem.

A. J. Haagen-Smit

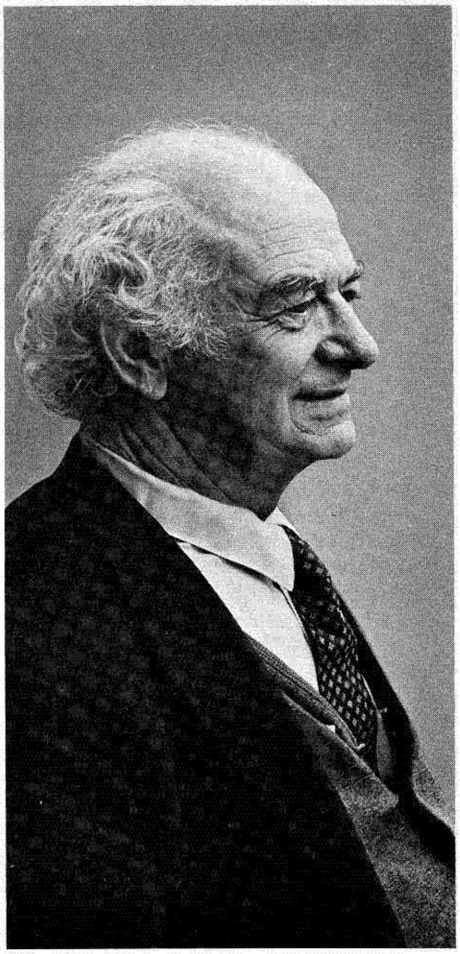
In 1949, Haagen-Smit published his conclusion that the organic material released into the air—mostly hydrocarbons—was oxidized through the combined actions of oxides of nitrogen and sunlight to become photochemical smog. He named the automobile and such industries as petroleum refineries, power plants, and steel factories as the major sources of air pollution. While the industries involved protested at first, eventually they cooperated in the effort to reduce smog. Today, in fact, California refineries are the best controlled in the world, and most of the automobile plants have impressive projects devoted to the study and control of auto exhaust.

Now, after years of serving on smog control bodies both for the state and the nation (and delivering innumerable speeches to interpret his findings), Haagen-Smit feels that pollution control will at best be only marginal as long as the public insists on all the goods and services it is accustomed to, and continues to regard such things as automobile emission inspections and curbs on electric power as inconvenient rather than imperative.

Haagen-Smit looks with some satisfaction on the accomplishments of the California State legislature and the Air Resources Board, of which he has been chairman for the past three years. California has set standards for the nation in air pollution control; the refineries have long since cleaned up their operations and, he believes, by the end of the 1970's the internal combustion engine will no longer be the number one smog producer.

Retirement will still mean a full speaking schedule for Haagen-Smit, and continuing activity on a variety of committees. He acts, for example, in an advisory capacity to the Atomic Energy Commission; the Department of Health, Education and Welfare; various California state organizations; the Los Angeles County Air Pollution Control District; and the County Tuberculosis Association. He is a member of the editorial boards of two air pollution journals, and—most pleasurable of all—he is a member of the board of trustees of the Los Angeles County Arboretum Foundation. Even with all this, as a dedicated gardener he is looking forward to a little more time for growing orchids and fighting crab grass.

Linus Pauling



Linus Pauling

Caltech's only winner of two Nobel Prizes, Linus Pauling, has now been named professor of chemistry, emeritus. Winner of the Nobel Prize in chemistry in 1954 and the Peace Prize in 1962—and recipient of nearly countless other awards, medals, and honorary degrees—Pauling has been on either the student or the faculty rosters at the Institute almost continuously since 1922.

Pauling was born in Portland, Oregon, in 1901 and, after receiving his BS in chemical engineering from Oregon State College in 1922, came to Caltech to do graduate work under Arthur Amos Noyes. He received his PhD in 1925, and then spent a year and a half in Europe doing research on the application of quantum mechanics to the problems of the structure of molecules and crystals He returned to Caltech in 1927 as assistant professor of chemistry. In 1931 at the age of 30 he became full professor; and in that same year he was named the first winner of the American Chemical Society's Award in Pure Chemistry, given for the most distinguished research of the year by a young man not over 30.

After the death of Noyes in 1937, Pauling succeeded him as chairman of Caltech's Division of Chemistry and Chemical Engineering and director of the Gates and Crellin Laboratories—positions he held until 1958. He continued his research and teaching at Caltech until 1964, when he became Research Associate in Chemistry. Since then he has also held positions as a member of the staff of the Center for Democratic Institutions in Santa Barbara and as professor of chemistry, first at the University of California at San Diego and then at Stanford.

Pauling's fields of interest have covered all branches of chemistry—extending into experimental and theoretical physics in one direction, and into biology and medicine in the other. Up to 1933 his experimental work comprised the determination of the structures of crystals and of gas molecules by the diffraction of X rays and electrons, respectively, and his theoretical work included the discovery of basic principles concerning the nature of the chemical bond and the structure of molecules. (His book *The Nature of the Chemical Bond,* published in 1939, is a classic and still a standard reference in the field.)

After 1933, Pauling applied himself to the problem of the structure of proteins. Instead of trying to study proteins directly, he and his co-workers studied the structure of the amino acids of simple peptides, and of other simple substances related to proteins. By using the information obtained in this way, they were able to predict the detailed structure of several proteins, including those found in bone, muscle, and red blood cells. One of the outcomes was that he and his associates were the first to demonstrate that sickle cell anemia is a molecular disease.

At least as important as his experimental work in biological chemistry was the style of thinking he brought to the field. For the most part, scientists had been inclined to think of the large molecules of biology—such as enzymes, other proteins, and nucleic acids—as amorphous blobs of matter. Pauling realized the value of thinking of them as structural atomic systems, and he expressed those thoughts in terms of the topological complementarity between molecules in biochemical reactions and the helical structure of many proteins.

Pauling is the author or co-author of a number of textbooks in chemistry, several hundred scientific papers, and of *No More War!*—a vigorous statement of his stance in regard to nuclear testing, published in 1958. In December 1970 he published *Vitamin C and the Common Cold.*

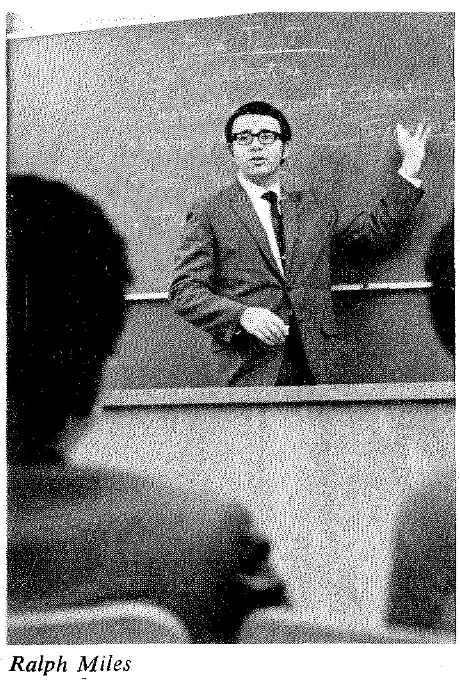
At present, during the academic year, home for Pauling and his wife is Portola Valley, near Palo Alto and the Stanford campus; for vacations they have a ranch in the Big Sur area. The four Pauling children—and 14 grandchildren—are scattered across half the globe: Linus Jr is a psychiatrist in Honolulu; Peter is professor of chemistry at the University College in London; Crellin is associate professor of biology at U.C. Riverside; and Linda is Mrs. Barclay Kamb of Pasadena. Kamb, professor of geology and geophysics at Caltech, is responsible for one further honor for Pauling: In 1960 he discovered a new mineral—one with the largest known basic structural unit of any inorganic material (nearly 3,000 atoms)—and named it after his father-in-law, "Paulingite."

The Month at Caltech

Systems Engineering

Ralph Miles is one of those "total" Techers; he got his BS here in 1955, his MS in 1960, and his PhD in 1963—all in physics. Now he is back on campus as a visiting assistant professor of aeronautics and environmental engineering science, on loan from JPL where he is a member of the technical staff.

The main reason for his return is to teach a course in spacecraft engineering, Ae 250. He is also the moving spirit behind a current seminar in systems engineering, "Systems Concepts for the Private and Public Sectors," which will consist of ten public subscription lectures on the theory and application of systems concepts. The lectures are given by authorities in fields that utilize systems concepts, and are held on Tuesday evenings at 7:30 in Ramo Hall in the new Baxter Hall of the Humanities. The first meeting of the seminar was held on March 30.



Ralph Miles

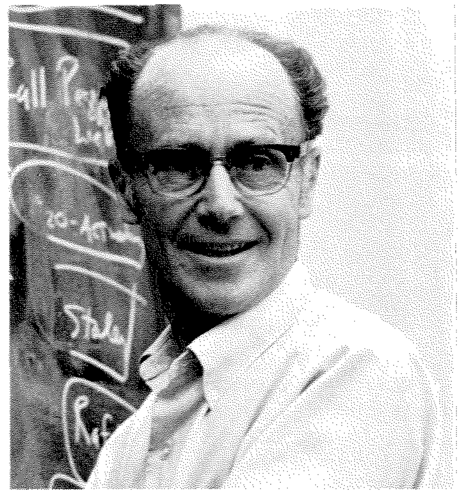
Simon Ramo, another Caltech alumnus, opened the series with a discussion of both the potential and the limitations of the systems approach. Ramo, a TRW Inc. executive and a member of Caltech's board of trustees, is known for his provocative ideas, and he has recently published two books on the application of science to social problems: *Cure for Chaos* and *A Century of Mismatch.*

In addition to being open to the public, the series will be the basis for a class Miles will teach during third term: Ae 241—Systems Engineering. One requirement of the course will be for the students to carry out systems analyses of two problems developed by the Harvard Graduate School of Business—one concerning helium conservation in the U.S., and one on how to transport passengers to and from Washington, D.C., airports more efficiently than is now possible.

The idea behind the seminar is one that Francis Clauser, chairman of the division of engineering and applied science, is interested in pursuing vigorously. He is urging that men of vitality and vision from industry and other universities be invited to campus frequently to keep engineering students and faculty up to date on new developments. The Miles seminar fits neatly into this program.

Miles sees the need for the systems approach as calling more for a change in emphasis than in content in dealing with some troublesome aspects of our society. He feels there should be more stress on defining goals, considering systems in their totality, and developing workable alternatives.

"Much of the effort of systems research today," he says, "is being directed toward civil and social systems, which now lie on the frontiers of systems engineering. The optimal design and operation of civil and social systems will require further research at the discipline and basic science level. To a large extent this is going to involve the 'hardening' of the soft sciences such as psychology, sociology, and political science."



Norman Davidson

ACS Award

Norman Davidson, professor of chemistry, is the 1971 winner of the American Chemical Society's $2,000 Peter Debye Award, established in 1960 to reward outstanding research in physical chemistry. He received the award at the 161st national meeting of the society in Los Angeles this month.

Davidson is responsible for fundamental advances in nucleic acid chemistry and for the development of new methods for solving problems in molecular biology. His recent use of the electron microscope to study the arrangements of genes in DNA molecules has provided the most accurate genetic map known to date.

A member of the Caltech faculty since 1949, Davidson is the executive officer for chemistry and has served as chairman of the Faculty Board.

Buwalda Room

The favorite lecture room of John Peter Buwalda, the founder of the Division of Geological Sciences at Caltech and its first chairman (1926-1947), was Room 151 Arms Laboratory. For years this room has not only been used for classes but for seminars, Geology Club meetings, and press conferences as well. Recently, at the suggestion of Eugene Shoemaker, the current chairman of the division, the room was refurbished and renamed. It is now the John Peter Buwalda Room, and it is decked out with a new carpet, a projection and public address system, a gallery of newly framed historic photographs of former students and faculty of the division, and a portrait of Buwalda painted by Ferdinand van Aken.

A formal dedication of the room was held on Sunday afternoon, February 14, and Mrs. Imra Buwalda was presented with another Van Aken portrait of her husband. Three of his former students and colleagues took part in the ceremonies. C. Hewitt Dix, '27, professor of geophysics, spoke about the period during which the division was founded; Richard Jahns, '35, PhD '43, a former Caltech faculty member and now dean and professor of geology at Stanford, reminisced about the division during the 1930's; and Leon Silver, PhD '55, professor of geology, showed slides and recalled a field trip that he and other geologists took with Buwalda after the Arvin-Tehachapi earthquake in 1952.

This honor for Buwalda came, coincidentally, in the wake of the earthquake in the San Fernando Valley area on February 9—a seismological event that would have interested him professionally. Buwalda's interest in recent crustal deformations and current geological processes was a primary factor in causing the U.S. Coast and Geodetic Survey to set up a triangulation system across fault lines in southern California to measure the drift on opposite sides of faults.

Marjorie Caserio comes back to Caltech to tell women students what to expect professionally. Orchids may be few, but they are worth trying for.

A Woman in Science—Marjorie Caserio, Chemist

Back in 1956 Marjorie Beckett, a young Englishwoman with a brand-new PhD in chemistry from Bryn Mawr, arrived at Caltech as a postdoctoral fellow. In her ensuing eight-year stay here she became a senior research fellow in the division of chemistry and chemical engineering, married Fred Caserio (a postdoctoral fellow in the same division), and co-authored a book, *Modern Organic Chemistry,* with John Roberts, who was then chairman of the division.

Marjorie Caserio is now an associate professor of chemistry at the University of California at Irvine, and the department's only woman faculty member. She came back to Caltech this month to take part in a "Women in Science" seminar, one of a series of talks by women scientists about their problems and satisfactions. The series was originated by Nancy Beakel, one of Caltech's psychologists, and is sponsored by the Caltech YMCA.

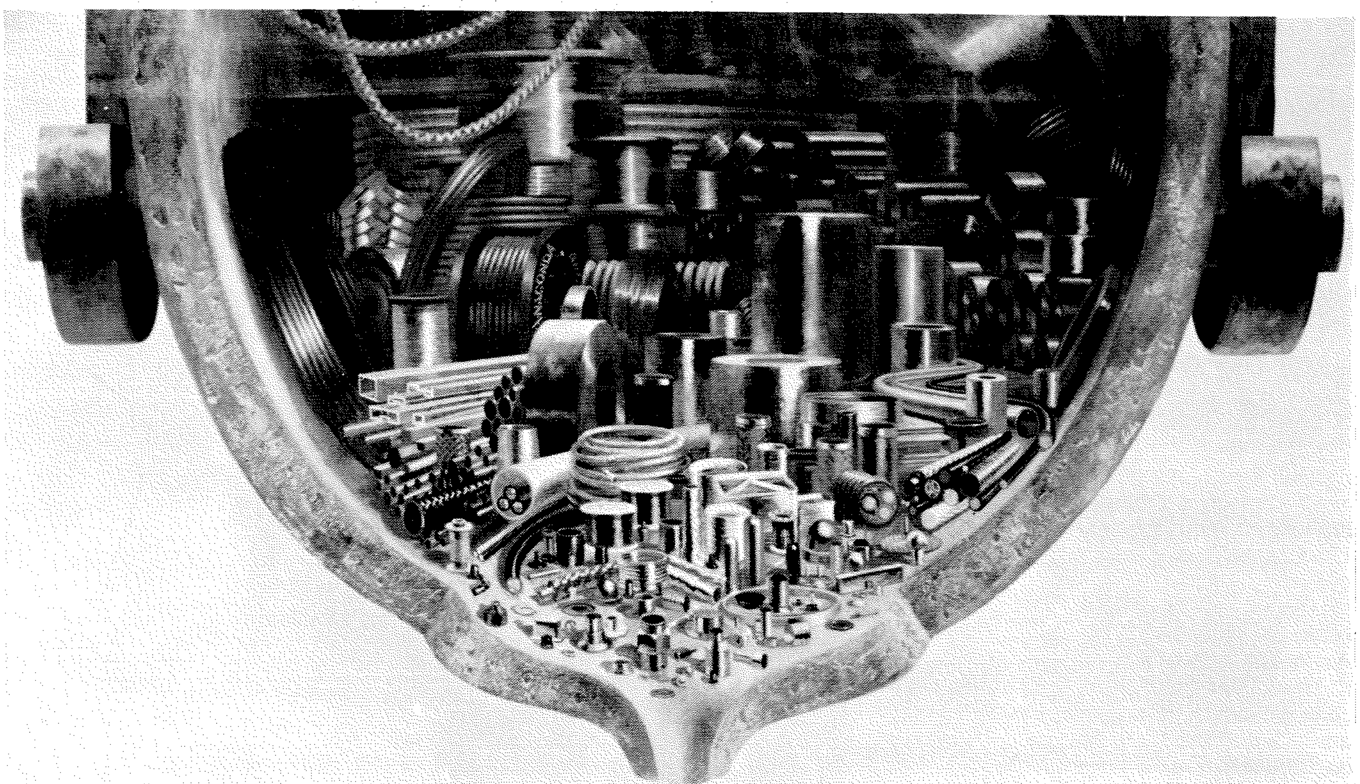
Brought up in an environment in which *nice* girls didn't go into science, she compromised by attending Chelsea College in London and studying chiropody—the least arduous and most remunerative field she could find. She soon realized that she would much rather come to grips with the tougher elements of a career in chemistry, and became the only woman in the college making that her major. Most of the others were pushing toward degrees in home economics or nursing.

Before she arrived at Caltech, Marjorie Caserio viewed herself as a second-class citizen, and as a result she didn't take advantage of the opportunities she now feels were available to her academically. But at Caltech she finally attained a feeling of professional self-respect, because she was accepted as a member of the academic community and received "recognition, opportunity, and courtesy." Paradoxically, though, there came the time when she saw no future for herself here and accepted the post at Irvine.

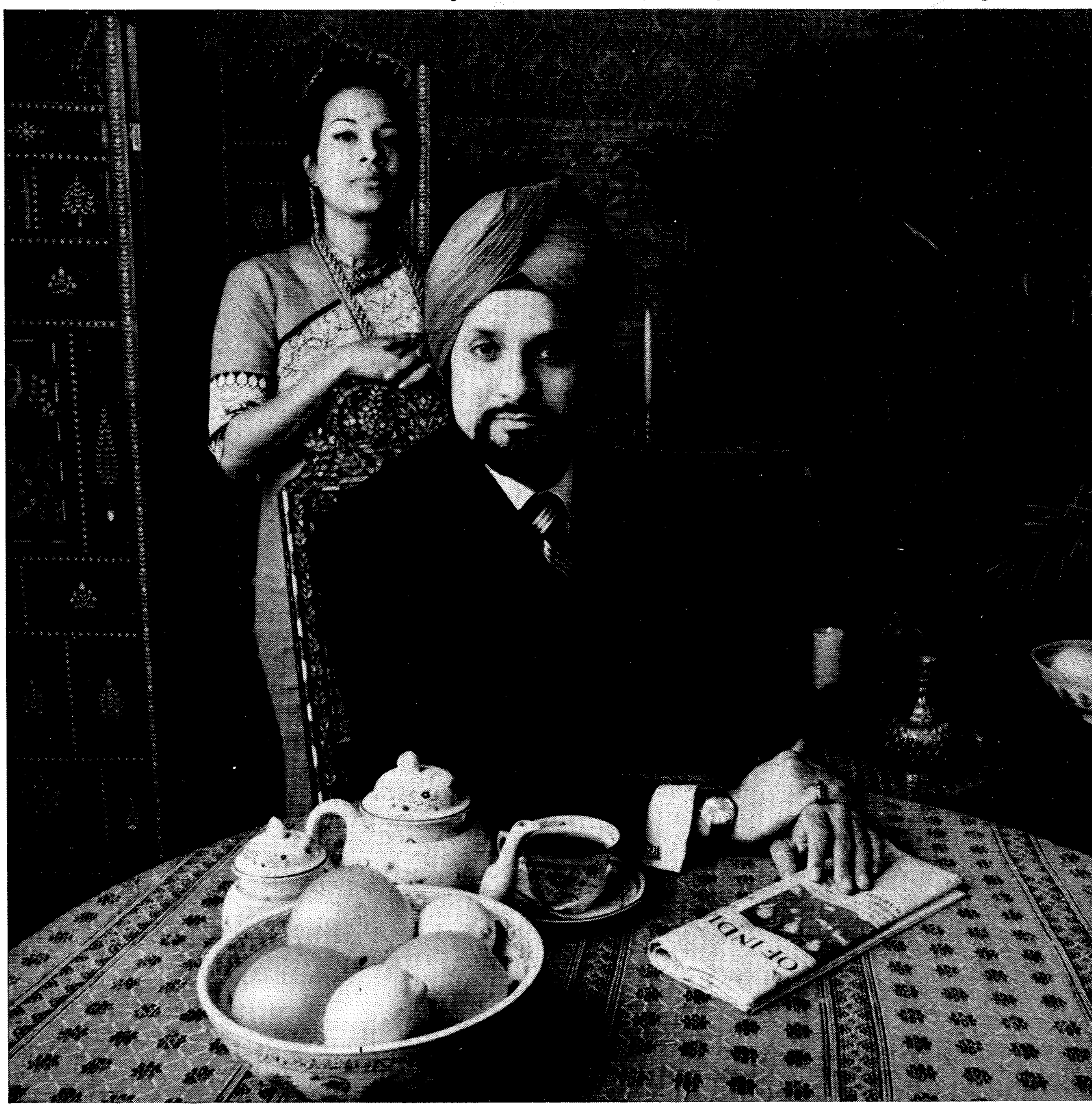
Dr. Caserio's research interests are primarily in physical organic chemistry with emphasis on organic reaction mechanisms, but she doubts that, as a woman scientist, she will ever be able to interest very many graduate students in working for her.

Has Marjorie Caserio's career ever conflicted with that of her husband? Fortunately, no. Such conflicts generally arise when one of the duo gets a good job offer that involves a move and the other has to take whatever is available. Neither of the Caserios cares to leave southern California (he is a chemist with the Union Oil Company), and Fred Caserio endorses his wife's wish to do as effective a job as possible in teaching and research.

In spite of the drawbacks Marjorie Caserio describes for women scientists, she recognizes that her present career beats being a London chiropodist.



When they look at us, they see a little of you.



When Union Carbide sends its people to Asia, Africa, South America and even Europe, they represent a country as well as a company.

So while we're out to make money abroad, we're also out to make friends abroad.

Sometimes, it's as simple as knowing local customs.

In Singapore, our Eveready battery plant has a cafeteria that serves three different menus. To meet the dietary, ethnic and religious needs of our Indian, Chinese and Malaysian employees.

Othertimes, making friends and making money is a little more complex.

To mine huge manganese deposits in Ghana, we built a whole town. From the ground up. Later, we put a plastics plant in Ghana. And then a battery plant. And made even more friends.

None of this is our newest idea. It's something Union Carbide discovered long before international business was fashionable.

And it's all quite simple.

Overseas, we're you.

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IS NEW YORK REALLY NECESSARY?

Or, for that matter, is Los Angeles? Or Chicago? Or Philadelphia? Or Dallas?

Or any other city groping its way to an uninhabitable anachronism.

A curious situation has developed in America. Eighty per cent of the people in this country live on less than ten per cent of the land area.

There used to be a good reason for this.

At the time of the industrial revolution, we congregated in cities because that's where the sources of energy were. Coal. Water. Electricity.

And our communications network was so limited that we had to be in close proximity to each other for business and social purposes.

No more.

There are no longer any good reasons to continue this hopelessly outmoded life style.

With the advent of the whole spectrum of new communications available to us (wide-band communications, laser beams), we will have the opportunity to live in significantly less dense population centers.

This is no idle prophecy.

The concept is quite realistic and well within the bounds of engineering capabilities which we already have.

Not only do we have the tools to provide the means for new styles in human settlements, but also to rebuild, in a sociological sense, the crowded inner core of our major cities.

The combination of international satellites and cable will provide the means of bringing individuals all the information they need or want without interference or control.

And without the need to be in any specific place.

(Think for a moment about the Apollo 11 moon landing in July, 1969. 500 million people around the world saw, via television, *precisely the same thing at the same time.* Being in New York or Los Angeles held no advantage over being in Keokuk or Harrisburg.)

Historically, we've been preoccupied with moving people and objects. Thus, our intricate network of highways and railroads and airlines — all of which have become enormously inefficient (not inherently, but in application).

The future will see us moving *information,* not, by necessity, people and things.

Your home will be the absolute center of your life.

You will work from home, shop from home, "visit" with family and friends from home, receive in your home any intellectual or cultural achievement known to man.

Fantastic, yes. Fantasy, no.

It is quite within reason to expect these changes by the 1980's.

If we want them.

If we want to change. If we want a better life for ourselves.

Technology has advanced to such an extent, that man is now, literally, capable of changing his world.

Yet, today, a certain gap has developed between the potential of technology and its use by mankind.

There is an obvious contradiction in a method which can land a man on the moon, yet tolerates, perhaps even accepts as inevitable, poverty and ignorance here on earth.

There is a contradiction in a method which affords the best of everything for some, and next to nothing for others.

So we must, in a sense, catch up with the technological potential and apply it for the benefit of all mankind.

All we need sacrifice are the antiquated work practices and our anachronistic traditions.

At RCA, through research and product development, we are committed to closing the technology gap and cancelling the contradictions.

This is the age of the engineer. Nobody understands this better than RCA.

If you're an engineer, scientist or systems programmer, and want to be part of RCA's vision of the future, we invite inquiries.

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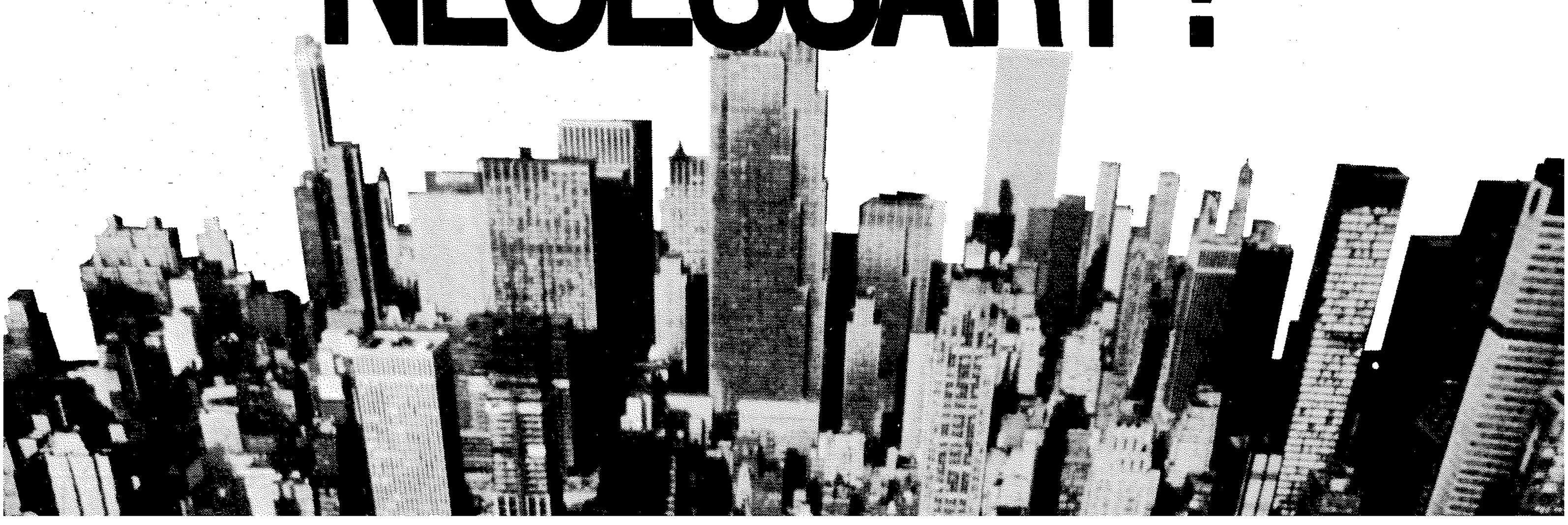

An engineer can cut crime as well as any cop. Maybe better.

Last year, murder was up 7%. Rape was up 17%. Robbery was up 14%.

It's getting to the point where a woman can't show her face on a dark street. And grown men are running scared. Sadly, crime has become a part of our everyday lives.

Where do we turn for help? To police, of course. But why not also to engineers?

Engineers at General Electric set out to develop a more efficient streetlight. And they came up with one of the most efficient crime fighters ever invented.

It's called the Lucalox® lamp. It puts twice as much light on a street as any other lamp without any extra operating cost. And wherever Lucalox has gone up, crime has gone down. By 50% or more in city after city.

But that's not all an engineer can do. He might design communications equipment that enables one patrolman to do the job of two. Or a complex of traffic monitors that puts twenty cops back on the beat. Or even a patrol car to do its special jobs in a better way.

It's sometimes hard for people to realize that engineers, with their technology, can solve social problems. But, in fact, some social problems can't be solved any other way.

So if you're an engineer who's bothered by social problems, you're in a unique position to help.

General Electric could use your help. We see more problems around us than we know how to solve. So what we need is more engineers.

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