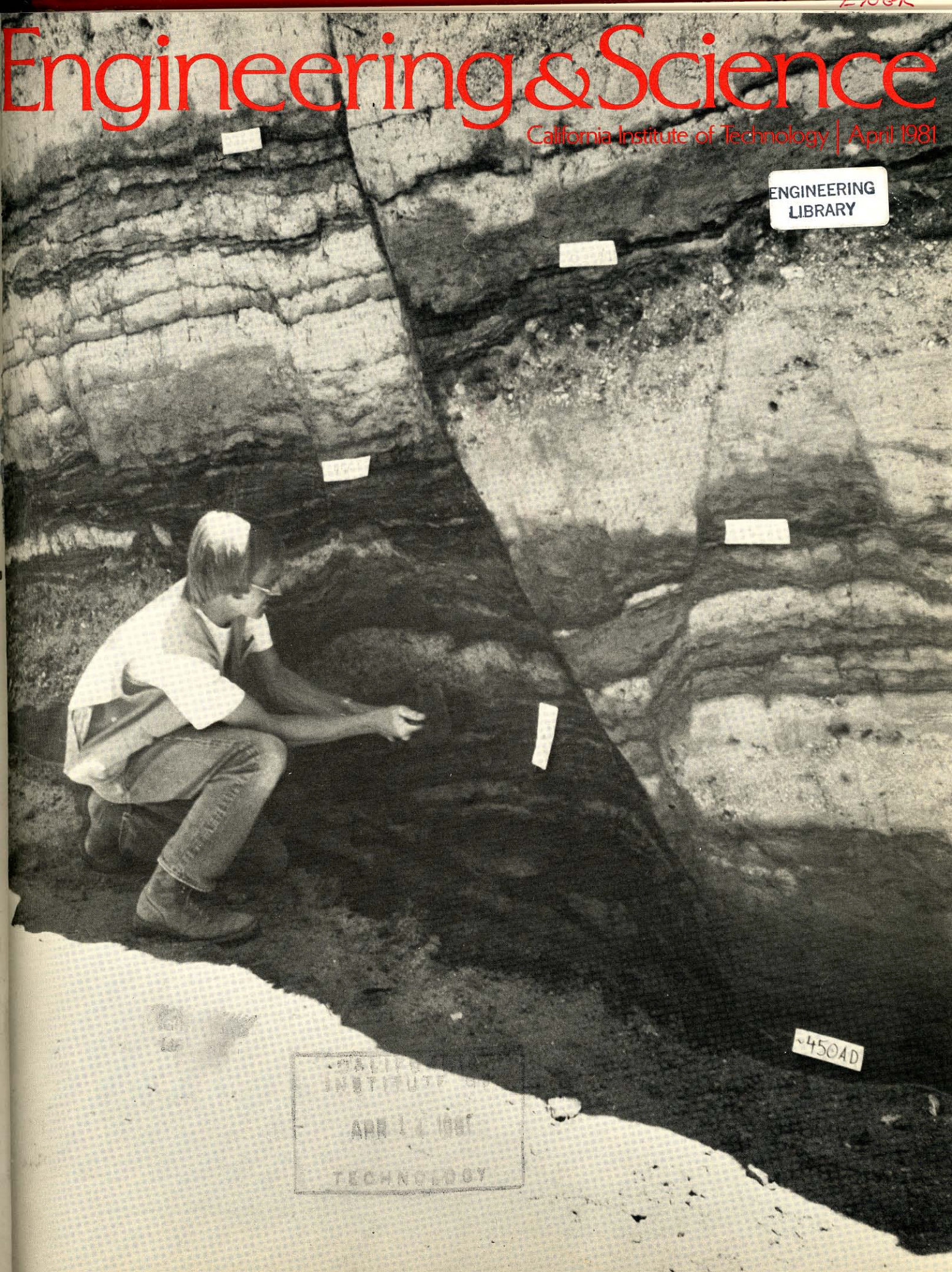
Engineering & Science

California Institute of Technology | April 1981



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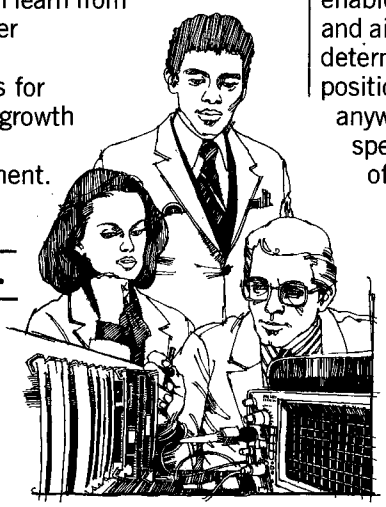

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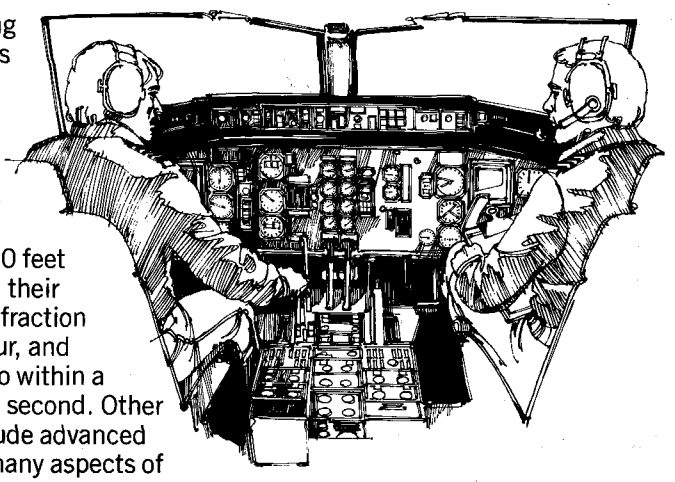

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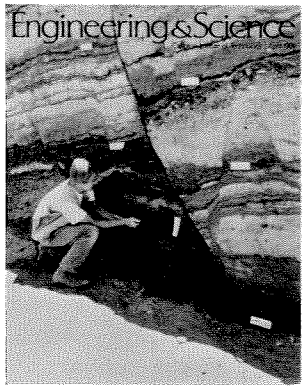
In This Issue

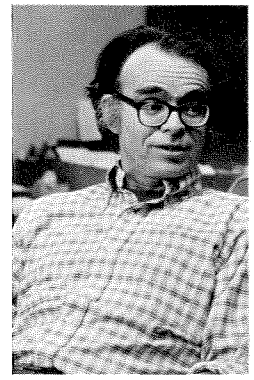


Time Line

On the cover — Kerry Sieh at work on the exposed sediments of a cut at Pallett Creek near Palmdale, California. Sieh is an expert in neotectonics, a relatively new science that involves the study of currently active movements of the earth, particularly faulting. He applies his expertise to determining what has happened on a particular segment of a fault in the course of repeated earthquakes, with emphasis on those that have occurred during the last few thousand years. He hopes eventually to be able to forecast when similar phenomena will recur. In "Is California 'Overdue' for a Great Earthquake?" on page 4, he reports on his methods and progress, and his prognosis for our future. The article is adapted from a recent Watson Lecture.

A native of Iowa, Sieh received his AB from UC Riverside in 1972. He did his graduate work at Stanford under former Caltech professor of geology Richard Jahns and received his PhD in 1977. He then came to the Institute as assistant professor of geology.

Thayer Scudder



Dam-nation

When some 55,000 Gwembe Tonga people in Zambia had to be relocated because of the construction of the Kariba Dam between 1957 and 1959, the resulting dislocation of their lives was severe. It was so severe, in fact, that Thayer Scudder, professor of anthropology at Caltech, has been doing research into those effects ever since. A couple of years ago he gave an overview of what he has observed, in a Watson Lecture on "What It Means to be Dammed: Local Impacts of River Basin Development in Africa."

Since that time he has expanded his research to include a wider variety of large-scale development projects in rural areas of Africa and Asia. In "What it Means to be Dammed: The Anthropology of Large-Scale Development Projects in the Tropics and Subtropics" on page 9, he discusses a development model he has worked out generally over the last 25 years and specifically in the last 2.

Scudder, whose AB and PhD are both from Harvard, came to Caltech in 1964 after doing research and teaching for several years in Northern Rhodesia and Egypt. He hasn't spent all the subsequent time in California, of course. His many trips for field work, meetings, and consultations in Africa and Asia add up to a total of more than five years — almost a third of his time with the Institute.

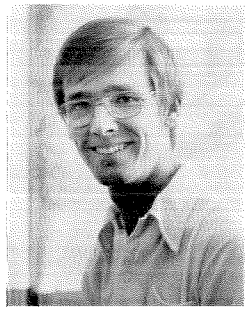
Eleanor Searle

Historic Rights

"The real source of female self-confidence in the Western world has thousand-year-old roots," says Eleanor Searle in "Women and Marriage in Medieval Society" on page 16. As a specialist in medieval history, with particular interest in the institutions of marriage and the family, Searle speaks with some authority. She has been delving into the subject throughout her professional life, which began when — with her brand-new LMA degree (Licentia Medaevorum Studiorum) from Toronto's Pontifical Institute of Medieval Studies — she was a visiting research fellow at Oxford in 1961.

Searle spent the following year at Caltech as a lecturer in history and then the next five years at the Australian National University. She returned to California in 1969 as professor of history at UCLA, and in 1979 came back to Caltech as professor of history, having been awarded a papal doctorate in 1972. Her research has been based largely on the Huntington Library's great medieval collections. She is the author of three books on the medieval period and has one in progress — on women's property rights, family inheritance, and the functioning of feudal society. She has recently been awarded a fellowship for independent study and research from the National Endowment for the Humanities and will use it to continue her research next year in London and at Cambridge University in England.

Kerry Sieh



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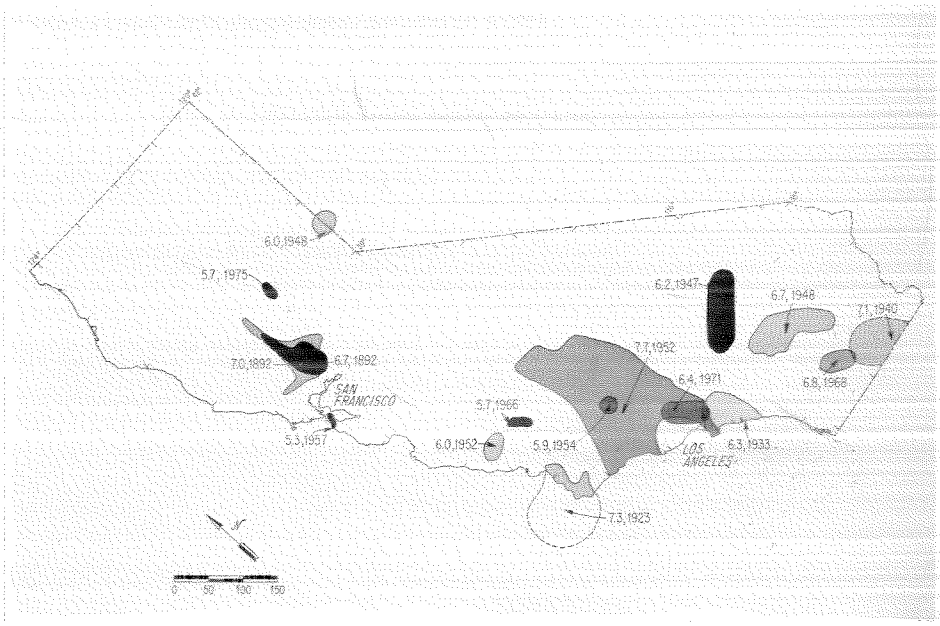
Is California "Overdue" for a Great Earthquake?

by KERRY SIEH

If a great earthquake is defined as one with a magnitude exceeding 8.0, the latest to rock California occurred in the central part of the state in 1906 — the San Francisco earthquake, whose magnitude is estimated to have been 8¼. Recent government estimates are that if that quake were to occur again, 11,000 lives could be lost and $38 billion of material damage could result. Forty-nine years prior to 1906, in 1857, southern California was racked by a similarly great earthquake. A repeat of this quake today could kill 13,000 or more people, leave 100,000 families homeless, and produce $15 billion worth of damage. The anticipated death toll is many times higher than that of any national calamity to date, and each of the latter two figures is about five times greater than the results of Hurricane Agnes in 1972, the greatest natural catastrophe so far in the history of the United States.

These kinds of facts and figures make Californians understandably sensitive to suggestions that the state is "overdue" for another great earthquake, and they react in various ways. When even a moderate-size jolt occurs somewhere in the state, scientists and laymen alike wonder if it is a forerunner or precursor of the big quake we have been anticipating for the last 70 years. Scientists are constantly scrambling over the state measuring bulges and gases and creakings of the earth's crust in the hope that they will be the predictors of the big event. The predictions of non-scientists that a great quake will devastate California on some January 4th or March 10th or November 30 have all-too-often commanded prominent positions in our newspapers and on our television broadcasts. Thrill-seekers seem to want to believe it will be soon, and they vicariously experience the seismic destruction of Los



One of the major differences between a great earthquake and a large-to-moderate earthquake is the size of the area over which destructive intensities may be felt. Each shaded patch on this map of California represents an area that has experienced destructive intensities during one of California's lesser earthquakes.

If we can expect another great earthquake in California, when will it happen—in 1000 days or 1000 years?

Angeles in their movie theater seats. Investors and home owners, on the other hand, hope and pray that it is at least 100 years in the offing.

Are we *really* overdue for a great earthquake? Can we actually expect a repeat of a 1906 or 1857 earthquake? If so, will it be in 1000 days or in 1000 years?

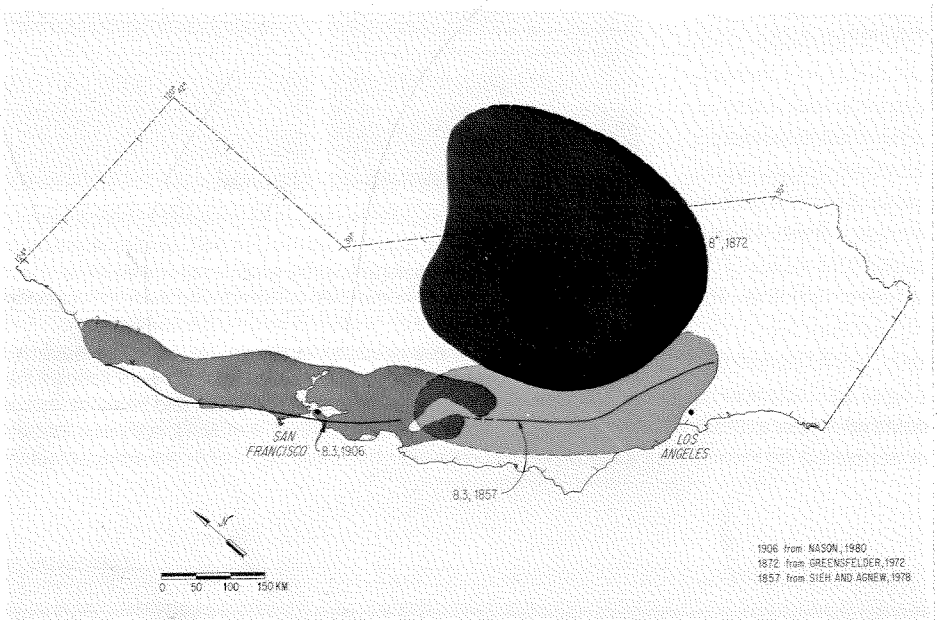
To come up with any sort of answer to those questions, we need first to sort out the great earthquakes from the lesser ones. A random sampling of moderate quakes would include the 1971 San Fernando quake, the Long Beach earthquake of 1933, and the 1952 Tehachapi earthquake. Many of us in southern California remember the shaking that February morning in 1971, which resulted in about 60 deaths and $500 million in property loss. Older Californians will recall that hundreds of lives were lost in the Long Beach event. If schools had been in session when it struck, thousands of children would have perished in the ruins of the numerous collapsed school buildings. The 1952 earthquake was widely felt, but it really produced severe damage only in the agricultural regions south of Bakersfield. We must expect that relatively local earthquakes like these will continue to occur frequently throughout California; and though each will affect a relatively small area, some of them will be far from inconsequential. A moderate event in a heavily populated area could actually produce damage and casualties comparable to a more remote great earthquake.

The three great California earthquakes about which we have eyewitness reports — those of 1906, 1872, and 1857 — were much more extensively felt than any moderate earthquake. Events of this size have the potential of severely affecting very large portions of the state, partly because they last longer than moderate quakes. Most of us who experienced the 1971 earthquake report between 10 and 30 seconds of shaking, but most Californians who felt and reported the 1857 earthquake estimated a duration of one to three minutes. The long duration and low frequencies associated with these events make them much more capable of seriously damaging large buildings than are moderate earthquakes.

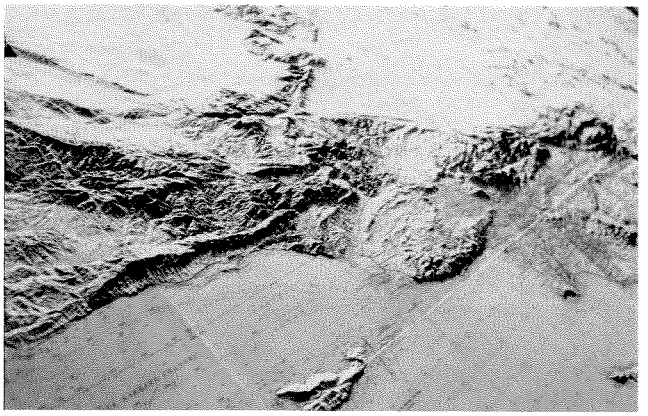
Many of us in the business of estimating how frequently earthquakes are likely to strike a given region talk about the average "recurrence interval" (R.I.). In south central Chile, for example, a 100-kilometer-long section of the coast has experienced four great earthquakes in the historical period — one each in 1575, 1737, 1837, and 1960. The repeat time, or recurrence interval, between quakes has varied from 100 to 162 years. The average of these values is 128 years, but the actual values have deviated by as much as 22 percent. Similarly, a 1300-year-long historical record for a 400-kilometer-long section of coastal Japan reveals repetition of great earthquakes every 90 to 260 years. The average R.I. is 180 years, but individual intervals have varied as much as 50 percent from this value.

In both of these regions, the period of dormancy since the latest great event is only a few decades, which is much less than the average or even the shortest recurrence interval. So we do not expect a repeat of great earthquakes in these areas for at least the next half century. We can expect that great earthquakes in southern California also occur with an average R.I., and much of my work has focused on determining what that interval is. We can also expect that actual, individual intervals will deviate several percent or tens of percent from that average, as they do elsewhere in the world.

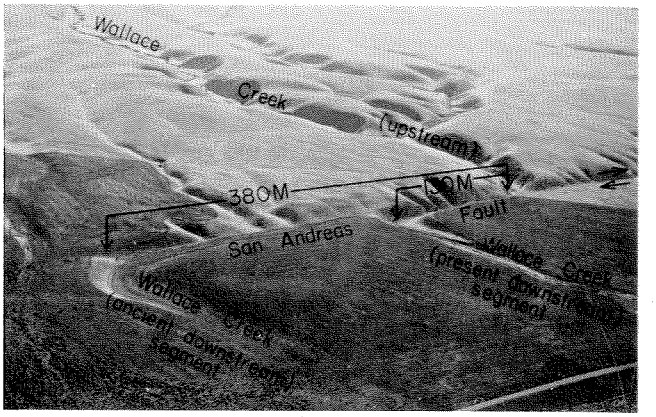
Our understanding of how and why earthquakes recur in California begins with the geological concept of plate tec-



In contrast to the map on the opposite page, this one shows the area of heavy shaking for the three great historic California earthquakes. On each map the date of the tremor and its magnitude appear next to the shaded patch, and (except for the 1872 earthquake) an arrow points to the epicenter.



A relief map of a section of southern California clearly delineates the San Andreas fault as a series of aligned linear valleys and escarpments stretching across the photo above between the arrows. The Garlock fault drops almost vertically to meet the San Andreas.



This aerial view of Wallace Creek (taken by Robert Wallace of the United States Geological Survey) is labeled to show the effects of repeated earthquakes on a piece of ground that straddles the San Andreas fault.

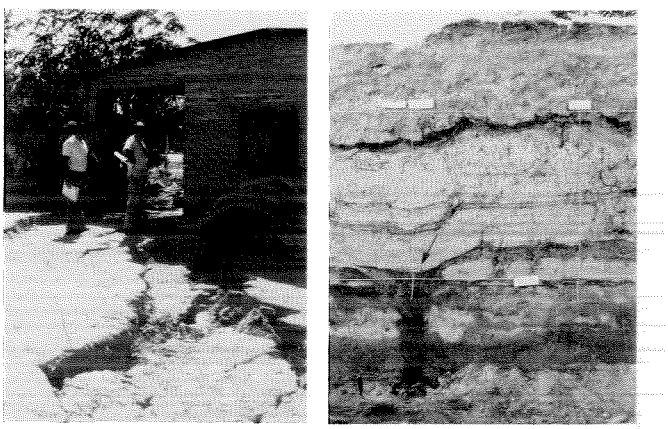
tonics — a model of the earth in which a number of rigid plates move independently over the surface, floating on a viscous layer of the earth's mantle. It is at the boundaries of those plates, where they interact with each other, that most seismic and volcanic events occur. Most of California is on the North American Plate, which is moving with respect to the Pacific Plate (on which much of southern California sits) at about 5.5 centimeters per year. The boundary between the two plates is marked by the San Andreas fault. This fault is the main actor in the plate tectonic drama in California, and it is the culprit that produced two of the three great historical earthquakes.

We can't, of course, know exactly what the San Andreas fault has in store for us, but geologists can make informed guesses about it because they believe that events and processes occurring in modern times are governed by the same laws that controlled them in the geological past. In short, the behavior of the San Andreas fault in the past is a clue to its future behavior. With this in mind, in the past five years I have become very well acquainted with two small pieces of ground that straddle the San Andreas fault — one at Wallace Creek west of Bakersfield, and one at Pallett Creek near Palmdale. In them resides the record of prehistoric earthquakes, their sizes, and their dates.

At Wallace Creek, the San Andreas fault has been offsetting small stream channels for millennia — 9 meters of offset occurred in 1857. Faint evidence for still older gully segments indicates that similar offsets were associated with earlier great earthquakes. The downstream and upstream segments of Wallace Creek now show a separation of 130 meters. If 9 meters is an average offset, 14 or 15 earthquakes might be represented in the 130-meter offset. An older channel is offset 380 meters, which by the same standards might represent about 42 earthquakes.

Studying the geology of these channels, with the aid of a tractor and a backhoe, revealed their ages and history. Several deposits of sediment were uncovered in excavated trenches — the oldest is an alluvial fan deposited by floodwaters flowing out of the mountains. A radiocarbon date indicated it was being laid down 19,000 years ago. The channel that is offset 380 meters was cut into the alluvial fan before new deposits were laid down in it between 4000 and 6000 years ago. Finally, radiocarbon analyses show that the gully offset 130 meters is less than 4000 years old. Since, according to our average of 9 meters per quake, 14 or 15 earthquakes have produced the 130-meter offset, which we now know is less than 4000 years old, the average R.I. is 285 years or less. Similarly, 42 earthquakes in 6000 years gives an average R.I. of 145 years or more. So the average R.I. at Wallace Creek seems to be between 1½ and 3 centuries.

At Pallett Creek, however, we can now see evidence for prehistoric earthquakes in much finer detail than at Wal-



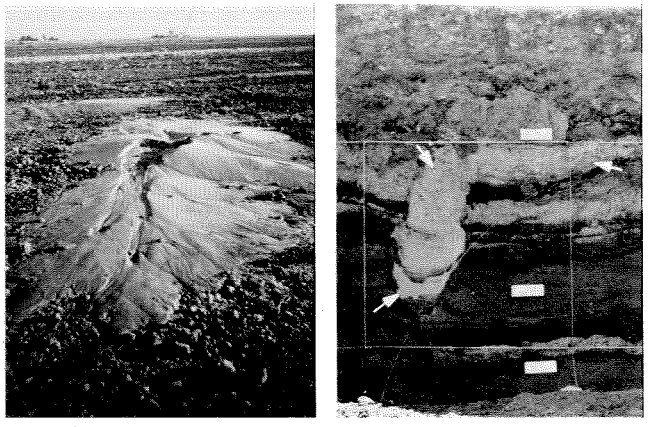
An earthquake in Baja California last June created the fissure running through the yard and beneath the house (left above). Excavation would show that layers of ground beneath it are also broken. Eventually, evidence of this earthquake will be buried beneath unbroken layers of sediments. If a geologist excavates the area after that happens, he will find something similar to the cut at Pallett Creek (right). A 16th-century earthquake caused the fissure (arrow) that cuts downward through various layers of peat. The fact that none of the overlying layers is broken by this fissure is evidence that the earthquake occurred after the lower sediments were deposited.

lace Creek. Until about 1910 Pallett Creek was a swamp in which black peats were formed and periodically buried by sand and gravel borne by the creek's floodwaters, leaving a layer cake of the peats, clays, sands, and gravels. Dissecting the cake layer by layer has led to unraveling the seismic history of the past 2000 years. About a dozen earthquakes have occurred in that period. Radiocarbon dating shows that the deepest layer was deposited about the year 0 A.D., and old planks and bottles in the uppermost layers indicate that the youngest deposits were laid down in the late 1800s or early 1900s.

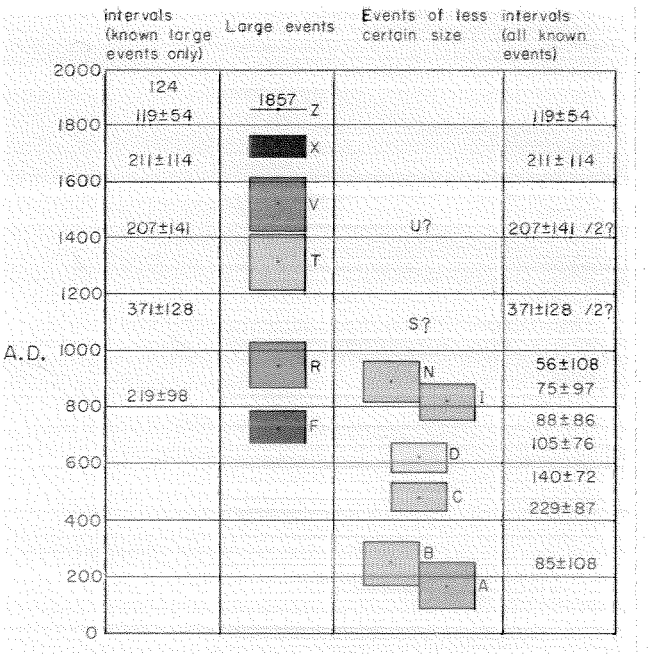
In the Pallett Creek excavations we have found several features similar to those formed during recent earthquakes elsewhere. There are fissures, for example, overlain by unbroken layers of sediment. The layers beneath these fissures (which were on the surface at the time of a given earthquake) are broken. This means that the earthquake that produced each fissure occurred after the lower layers were deposited, but before the unfissured layers above were laid down.

Another familiar feature is the sandblow or sand volcano. The strong shaking of an earthquake results in the eruption of small fountains of sand and water from the earth, leaving a little cone of sand that will eventually be covered and preserved by further layers of sediment. This has happened repeatedly at Pallett Creek. Small scarps resulting from fault slip have also repeatedly been formed, buried, and preserved.

I don't know how large each of the earthquakes at Pallett Creek was, but I have made some progress in assessing the sizes of some of them. What I try to do is to reconstruct a deformation pattern associated with each event and compare them with each other. The 1857 earthquake evi-



. . . and before the unfissured layers were laid down. Sandblows or sand volcanoes like the one at the left above, which was found in the Imperial Valley after a recent earthquake, are features formed during many earthquakes. In the late 17th or early 18th century, a similar small fountain of sand (arrows on photo at the right) erupted during an earthquake on the San Andreas fault. Its profile was revealed nearly three centuries later in the course of Kerry Sieh's geological research at Pallett Creek near Palmdale. In each of the photos of the Pallett Creek cuts, the area that is enclosed by the string is a one-meter square.



dence is now buried by a half meter or so of sand and gravel, and the modern ground surface is fairly level. The ground surface in 1857 was also nearly flat — until the earthquake deformed it. The unit of sediment overlying the 1857 deformation is a mold of the topography produced by the earthquake, showing fissures, sandblows, and scarps. I try to make maps that indicate not only the style but the amount of deformation produced by each earthquake. A map of the 16th-century earthquake at Pallett Creek shows deformations similar in size to those produced by the 1857 earthquake — which I know was a great earthquake. Thus I can assume that the 16th-century event was probably as big as that of 1857.

Above is a summary of the evidence for earthquakes at Pallett Creek, together with their R.I. averages. Recognized earthquakes are represented by rectangles; the position of the rectangle on the vertical time scale indicates the date, the earliest being at the bottom and the latest at the top. The height of the rectangle represents the uncertainty in the date of the earthquake, the lower and upper lines indicating the earliest and latest limits. (It has nothing to do with the size of the event.) For example, the time of the 1857 event is known very precisely, so it is shown as a very narrow line. All the events in the left center column have deformations, offsets, and scarps at least as large as those of the 1857 event, so they can be categorized as large — probably great — earthquakes. The events in the right center column have not been *demonstrated* to be large events, though they may well have been. And the occurrence of events "U" and "S" is suspected but not yet proven.

The R.I. between each event is shown in both the far left- and the far right-hand columns. Those on the left are calculated assuming that only the confirmed large events occurred. Those intervals, with one exception, are refreshingly long — 225 years, on the average. On the right are the intervals calculated assuming that all recognized events are large. Some of these intervals are frighteningly

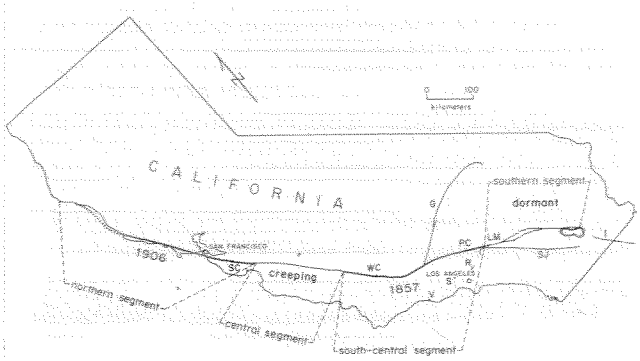
short. In fact, if events "U" and "S" did occur, the average recurrence intervals would be a mere 123 years.

The problem is that the Pallett Creek data are frustratingly ambiguous at exactly the level of most significance. On the one hand, the average R.I. may be 225 years. Alternatively, it may be less than 150 years, and only a few very long R.I.s are more than the current 124-year-long period of dormancy. And there is certainly the possibility that the average R.I. is only 123 years, with the current 124-year period of dormancy being greater than all but one of the past 9 recurrence intervals.

Now, how does all this fit into a regional picture of the San Andreas fault? First, we can break the fault down into four segments according to what we know about its activity — northern, central, south central, and southern. The 1857 earthquake may be characteristic of all great earthquakes along the south central segment if the average R.I. at Wallace Creek is identical to that at Pallett Creek. This is most likely if the average R.I. is between 150 and 225 years, since this is the range of overlap in the R.I. determined at the two sites. If the average R.I. at Pallett Creek is about 125 years, earthquakes must be more frequent there than at Wallace Creek, where the shortest average R.I. appears to be about 150 years.

Two large earthquakes have been produced historically along the northern segment — one in 1838 and the other in 1906. We suspect that the recurrence intervals are similar to those along the south central segment of the fault, but geologic studies like those I have described have only just begun there.

The 170-kilometer-long central stretch of the fault has historically slipped at rates as high as 30 millimeters per year. Some geologists have speculated that this stretch will not be involved in a future great earthquake because the strain accumulation is being relieved by this annual fault slip, or creep. Others have suggested that, since this creeping section separates the two segments that have produced great earthquakes, it is unlikely that a "superquake" that ruptured all three sections could occur at one time. I would like to point out, however, that the 30 mm/yr of slip in the creeping zone is only a fraction of the long-term slip rate, which at Wallace Creek is between 33 and 64 mm/yr. Thus it is quite plausible that a great event could rupture the south central section, propagate through the creeping central segment with a few meters of offset, and rupture the northern segment too. Our civil preparedness programs should allow for the possibility that both San Francisco and Los Angeles could be severely damaged simultaneously by such a superquake.



The San Andreas fault can be broken down into four segments in terms of its historic activity. Studies at Wallace Creek (WC), Pallett Creek (PC), and at a site near Indio (LM) are revealing much of the record of its behavior. Three other major southern California faults are also shown — the Garlock (G), the San Jacinto (SJ), and the Imperial (I).

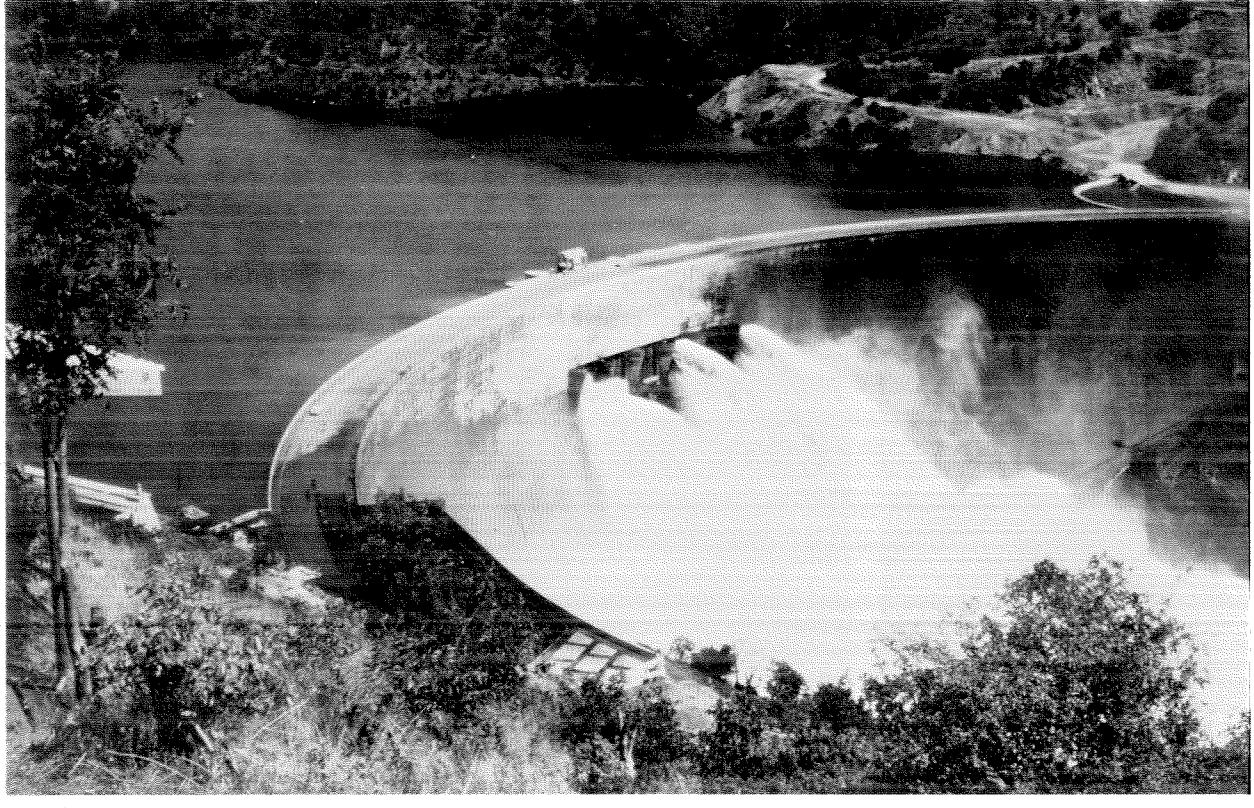
The southern segment of the San Andreas fault has historically been dormant — it has not produced a great event in the 210-year-long historical period. I have been working at a site just east of Indio in an attempt to determine its potential. Studies there are far from complete, but the preliminary findings indicate that the latest great earthquake in this area may have been over 350 to 600 years ago. Two or three great earthquakes have occurred within this same period of time at Pallett Creek.

It is possible to argue that such a long period of dormancy means either that this segment is the next to go or that it is less of a risk than the segment that broke in 1857. My opinion is that no one (including myself) has enough information at this time to make a meaningful statement about its possibilities.

What conclusions can we draw for the south central section of the fault if the data at Wallace Creek suggest that great earthquakes recur every 1½ to 3 centuries on the average, and the data at Pallett Creek yield evidence that the average recurrence interval is somewhere between 125 and 225 years? If the interpretations at Wallace Creek can be believed, the current dormant period will not equal the average R.I. until at least the beginning of the 21st century. Before we let this reassure us, however, let me remind you that great earthquakes don't tend to adhere rigorously to their average R.I. when making individual appointments. Just recall the 20 to 50 percent variations for Chile and Japan.

The Pallett Creek data allow that we could just be reaching the average R.I., which means that the next great earthquake in southern California would not break millennial tradition if it occurred within the next decade. Neither would the prehistoric record be contradicted if that event failed to occur within the lifetime of most readers of this article.

We are almost certainly not "overdue" for a repeat of the great 1857 earthquake, but we are clearly well along in the process. We are much too far along, in fact, to neglect serious preparations for the eventuality. Geologists will continue to work toward more precise forecasts and predictions of great earthquakes, but the data we have already assembled should press upon all of us the immediate need for civic action toward preparedness. The economic and human risks are just too great to gamble with the odds. The future of all of us depends on such preparedness. □



One of Africa's great dams, the Kariba on the Zambesi River, was built mainly for hydropower generation.

What It Means to be Dammed

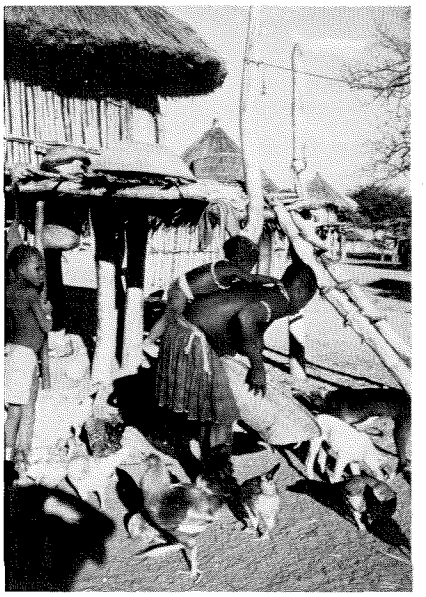
The Anthropology of Large-Scale Development Projects in the Tropics and Subtropics

by THAYER SCUDDER

Since 1956 my research has been concentrated on the local impacts of river basin development in the tropics and subtropics. In particular, I have been studying what it means to local residents to adjust to the effects of the damming of the rivers whose banks have been their ancestral homes and whose waters have provided much of their families' livelihoods. Recently, however, I have expanded that research to include a wider variety of large-scale development projects in the rural areas of Africa, the Middle East, and Asia, including new lands settlement projects as well as river basin and irrigation projects. This research is of special interest because of its policy implications—both locally and nationally, and to both late-developing and industrial nations throughout the world.

To date, the big-project approach to rural development in the tropics and subtropics has largely failed to achieve the benefits intended—both for local citizens who live in the project area and for the nations involved. In the case of river basin development, the big-project approach has failed to tap to the extent possible the development potential of local resources. And since many countries in the tropics and subtropics have access to only one major river system, which is often the heartland of these countries, clearly they cannot afford such underutilization.

I believe that this failure can be attributed more to policy, planning, and implementation inadequacies at the national level than to inadequate responses to new opportunities on the part of local citizens living within the



Tonga villages like the one above are relatively resilient because they are relatively self-sufficient. But often big projects replace such resiliency with dependency.

The photograph above shows a Tonga village that has been flooded out by water backed up from the Zambesi River in Central Africa.

project area. Combining what are called "development from below strategies" with "development from above strategies," an alternative development approach starts from a better knowledge of an area's human, land, and water resources than is usually the case. And in advocating the integrated development of those resources, it focuses from the start on the people living in the area — the assumption being that they and subsequent immigrants are the major resources. Any project that tries to release the development potential of these people and their land and water resources must pass through four stages, taking a full generation, before it can be considered successful both from the point of view of the local people and of the project planners and managers. My four-stage framework is at this point tentative; it needs further empirical testing in the field.

From a policy point of view, the deck is stacked against most rural areas of the old world tropics and subtropics because national development policies not only favor the urban industrial sector, but do so at the expense of the rural sector. (The best general source on this topic is Michael Lipton's *Why Poor People Stay Poor: Urban Bias in World Development.)* With only a few exceptions (including Egypt's High Dam — probably the most integrated and successful of the various large dam projects though, ironically, also the most condemned), big dams are a classic example of this bias. Though located in rural areas, their main purpose is to generate hydroelectric power for the urban-industrial sector. Not only do rural areas not benefit through, for example, rural electrification from the transmission lines that pass overhead, but local residents realize this and follow those transmission lines to the cities where they know the opportunities lie — hence accelerating the rural-to-urban influx that is such a global feature of our time.

In terms of what rural development is carried on within river basins, there are other policy and planning inadequacies. The overemphasis on the management of water resources, for example, precludes the integrated development through time of human, land, and water resources. In such African projects as Kariba (Zambia-Zimbabwe), Volta (Ghana), and Kainji (Nigeria) — all giant projects producing the first mainstream dams on the Zambesi, Volta, and Niger rivers, respectively — the primary emphasis was on water management for hydropower generation to the exclusion even of irrigation. But even where irrigation does occur, the emphasis in both Africa and Asia is on the production of one or two crops, often for export, rather than on the creation of diversified farming systems that can catalyze the development of the regions in which they exist. They catalyze development by raising net incomes of the farming community (hence increasing their purchasing power for local goods and services) and by meeting the food needs of the nonfarm sector as well as providing produce for agro-industrial development.

Another policy-planning inadequacy I have labeled "the development from above syndrome coupled with the myth of the conservative or lazy peasant." Espoused by politicians, planners, and decisionmakers who think they know what is best for local populations (about whom they actually know very little), "the development from above" approach can be best visualized as an economic laying on of hands, backed up by international expertise and finance. The planners superimpose development strategies on local

people who have virtually no say in any aspect of the project — planning, implementation, management, or evaluation — in spite of the rather obvious fact that these local people are the primary risk takers.

As for the myth of the conservative peasant, that portrays the local people as so conservative that the only way to "jolt" them into the 20th century is to restructure their societies according to the national priorities of the day. This approach has four very pernicious effects. First, it ignores the fact that the closed traditional peasant society is today the exception; most rural societies in the tropics and subtropics are increasingly dynamic and open-ended systems in which citizens are both aware of and want better education for their children, better medical facilities, and better economic opportunities. Indeed, it can be convincingly argued that the developmental strategies of the members of such societies are more dynamic than those of the planners and decisionmakers who manipulate them! Second, it ignores the fact that local people are willing to work for these benefits. Third, it ignores the voluminous recent literature on the "rationality" of local farming and other production systems. For example, Robert Bates, professor of political science at Caltech, has written in detail on this topic. This literature suggests that development plans should start with these systems, enhancing their very real strengths and offsetting their weaknesses through a process that combines "development from below" with "development from above." Fourth, it provides an effective mechanism for blaming project failure on the supposed beneficiaries rather than on the more responsible planners.

In believing that they know how to create new and better farming and production systems for rural peoples, planners forget that such systems are imbedded in far more complicated sociocultural systems that they do not have the ability to create. The cultural arrogance of this position has two major defects. First, it does not tap the potential of existing production systems. (In this sense, planners are ignoring the private sector and its involvement in development. Though I am stressing here the involvement of small- and medium-sized private sector operators — the family firm whether farm or business — the same applies to larger businesses.) Second, it can and does lead to the extinction of existing sociocultural systems, especially in the case of the societies of small-scale host populations.

Inevitably, the construction of big dams like Kariba opens up isolated areas by incorporating them within a national or regional framework.

Another inadequacy is an institutional one. Frequently governments establish a highly centralized special area or national development agency — called parastatal agencies in Africa — to implement and manage large development projects. Well capitalized, at least at the start, such agencies, it is argued, can best implement and manage development. They also allow international donors to more carefully monitor how their funds are spent, hence giving them greater control over what the economist Judith Tendler calls their "external environment" in an intriguing little book titled *Inside Foreign Aid*. It may well be true that such parastatals are more efficient (and possibly more effective) during the initial years of project development than decentralized administrative arrangements whereby one agency is responsible for coordinating the activities of a range of government departments with existing responsibilities within the project area. But there is also increasing evidence that such agencies may also become a major — if not the major — constraint to subsequent development both because of increasing operational inefficiencies and because of their inability to decentralize and to devolve responsibilities to the relevant government departments, local municipal and rural councils, and local participatory action groups of farmers and other producers.

In making this critique, I do not wish to give the impression that I am necessarily anti big project — a perspective that is becoming quite fashionable in certain quarters. On the contrary, in some countries major river basin development and area development projects are essential if current living standards and rural productivity are to be raised. Though more emphasis should be placed on articulating a series of small- and medium-sized projects into a larger regional context, it is not necessarily bigness as such that should be under attack; rather, it is the approach to project planning and implementation.

My own work with large-scale river basin development projects, irrigation projects, and new lands settlements has convinced me that planning for such projects must start with a far better knowledge of the human, land, and water resources of the development area. As I see it, the purpose of area or regional development is to start a process of integrated development of an area's human, land, and water resources in terms of production for local consumption and export, employment generation, rising standards of living, social equity, natural resource enhancement, and resiliency.

All of these goals are straightforward except for the last. By resiliency, all I mean is the capacity of an area to stand on its own to some extent in the event that the external

Started by the Dutch in the 1930s, this irrigation project in Sulawesi, Indonesia, is currently being rehabilitated through a cooperative Indonesia-Dutch aid program.

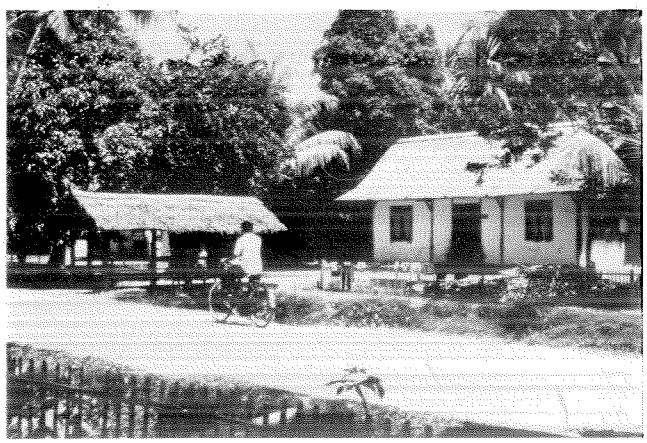
Rice fields, ducks, and settler-owned tree crops on another Sulawesi irrigation project, which is currently being renovated through a cooperative Indonesia-US AID program.

political economy (both national and international) destabilizes (as, for example, in the recent case of Uganda), so that government commitments to the area cannot be met. Though decisionmakers take the initiative in opting for a policy that advocates area development, the starting point should be the existing production systems of the local peoples and the sociocultural contexts in which they are imbedded. This priority makes sense not just because the local people are the main risktakers, but also because evaluatory studies indicate that their active involvement increases the chances for project success. (This was pointed out in a 1975 evaluation for the U.S. Agency for International Development by Development Alternatives, Inc., of 36 rural development projects in 11 countries in Africa and Latin America.) The local people include both current residents (irrespective of length of residency) and future immigrants. Both need to be integrated into project planning and implementation since ignoring the hosts is an assured way of exacerbating conflicts over land, economic opportunities, and social services, while ignoring immigrants will reduce the capability of any large-scale project to catalyze a process of area development.

During the past two years I have spent most of my time carrying out a global evaluation of both government-sponsored and spontaneous settlement of new lands in the tropics and subtropics. Though most new lands will have been settled by the end of the present century, in such areas as the humid tropical lowlands of Latin America (including, of course, the Amazon basin), Africa (including the Congo basin), and Asia (including Malaysia and Indonesia) large relatively unutilized areas remain. I say relatively unutilized because such areas are frequently used by gatherer-hunters, and shifting cultivators who constitute a host population whose land and other rights tend to be ignored by governments more often than they are observed. (For a blatant example of government inhumanity to host populations — in this case local tribal societies who have lived in the Amazon Basin for millennia — I suggest reading *The Geological Imperative: Anthropology and Development in the Amazon Basin of South America* by Shelton H. Davis and Robert O. Mathews.) The same applies to certain savanna, semi-arid and arid lands, the development of which requires improved irrigation, provision of domestic water supplies, and, often, disease control for both people and livestock. Examples include much of the Sudano-Sahelian zone of West Africa, large parts of the Sudan, the basin of the Mahaweli Ganga (which covers approximately two-fifths of Sri Lanka), and other monsoonal areas of Asia characterized by seasonal rainfall.

Large-scale development projects are already under way or on the drawing boards for many of these areas, most of which continue to illustrate the deficiencies that I have briefly mentioned. Ironically, while many of these projects tend to have unreasonably high expectations for the initial five years, they also tend to underestimate project benefits and especially multiplier effects that could occur over the longer term. A major reason for this incongruity relates to the short time horizons of many planners and planning agencies, and especially to their failure to visualize a development project as a dynamic process that must pass through a succession of stages in order to be considered successful.

I have found a four-stage development framework very useful in explaining the relative success or failure of a number of new lands settlement projects that have been in existence for 15 or more years. Influenced by the African research of Robert Chambers, this framework not only "explains" why planners' expectations for rapid early returns are unrealistic, but it also illuminates a range of other issues that have plagued new lands settlement projects — issues that are of critical importance though there is insufficient space to explore them in this article. While the model was developed specifically for new lands settlement projects, I believe, with some modifications, that it is also applicable to populations of refugees, and to river basin and other types of area development that are not focused



A typical irrigation-settler household plot in the Luwu District of Sulawesi has a relatively comfortable residence surrounded by fruit trees.

so much on the settlement of new lands by an immigrant population.

The four stages are as follows. *One;* Planning, Infrastructure, and Settler Recruitment; *Two:* Transition; *Three:* Economic and Social Development; and *Four:* Handing Over and Incorporation. To meet my criteria for success, a new lands settlement project must pass through all four stages, though not necessarily as sequenced. Since the fourth stage includes handing over to a new generation of settlers, at least a generation must pass before success is insured, although a considerably longer period may be involved if the third and fourth stages are reversed. Both stages are crucial if living standards and productivity are to rise and if continuity and development are to continue. In many government-sponsored new lands settlements, the third stage is omitted entirely. Consequently, handing over to the next generation tends to perpetuate a pioneering situation characterized by a subsistence mode of agriculture based on extensive agriculture, a low level of community services, community instability, a low level of employment and production outside of the agricultural sector, and often environmental degradation (a characterization paraphrased from Michael Nelson's 1973 book, *The Development of Tropical Lands: Policy Issues in Latin America).* As time goes by, living standards and productivity are apt to drop as degraded holdings are subdivided — and the potential for new lands settlement to catalyze a process of regional development lessens rather than grows.

Ideally, the four stages should occur in sequence, thus realizing the development potential of new lands settlement in the shortest time period possible. But as indicated in the previous paragraph, the last two stages may be reversed in some successful settlements. Analytically, the situation is made even more complicated for a number of reasons. First, the different stages, and substages within them, frequently overlap. Second, the boundaries between the stages are often fuzzy, partly because of measurement difficulties (relating to whether or not certain indices apply) and partly because some settlers progress more rapidly through the second stage than do others. The possibility of settlers being pulled back from Stage Three into a more extensive and subsistence-oriented mode of production is an ever-present one, new lands settlements being vulnerable to ecological setbacks, changes in government policies, and increasing managerial inefficiencies. A third difficulty of applying an ideal model to actual settlement areas arises from the fact that particular settlements may attract new settlers over a considerable time period.

In spite of such analytical difficulties, it has been relatively easy to place different settlements in a particular stage. Furthermore, the very concept of stages draws attention not only to the fact that new lands settlements have histories, but also that these histories are remarkably similar.

STAGE ONE: PLANNING, INFRASTRUCTURE, AND SETTLER RECRUITMENT

This stage lends itself to further division into two substages — the first relating to feasibility studies, planning, and design and the second to settler recruitment and the construction of such initial infrastructure as roads and irrigation facilities.

1. *Feasibility Studies, Planning, and Design.* Ideally, the feasibility studies that are carried out during this substage should consider a wider range of alternatives before the decision is made whether or not to proceed with a particular type of settlement project. Should a positive decision result, then a whole range of planning and design activities follow. Under planning, a wide range of issues need to be considered, including the scope and scale of the intended farming systems and the settlement as a whole in relation to regional development. Weitz and his colleagues assume, for example, that multiplier effects are correlated with diversification of the farming system, farm family income, and settlement scale. (See R. Weitz, D. Pelley, and L. Applebaum, "Employment and Income Generation in New Settlement Projects," International Labour Office, World Employment Programme Research, Working Paper 3.)

2. *Construction of Initial Infrastructure and Settler Recruitment.* The wording "initial" infrastructure suggests that infrastructural development should be phased, with planners establishing priorities for timing the construction of different types of infrastructure for settler families, administrators, and other nonfarm families. A major problem with many settlement projects is the inadequacy of all infrastructure, the authorities failing in their attempt to introduce "instant" facilities from the start. The logical corrective is to construct only essential items like access roads and irrigation structures during Stage One. As for settler recruitment, far too much emphasis in the past has been paid to the recruitment of individual men as opposed to settler families where attention is paid to both spouses.

STAGE TWO: THE TRANSITION STAGE

The word "transition" is used to emphasize two points. First, that this is a stage of transition for settlers who in many cases are moving from one habitat to another; and second, that this transitional period must come to an end before settler families can be expected to take the risks that may increase significantly their productivity. While the duration of the transition stage may be less than a year for a minority of families in settlements that subsequently reach Stage Three, for the majority it would appear to last for at least two years and more often for five to ten years.

During the transition stage the large majority of settlers are risk-averse, which explains why they are reluctant to adopt major technical, organizational, and sociopolitical innovations at this time. Risk-aversion appears to be a coping response to the stress and uncertainty associated with moving into a new habitat — where settler families need not only come to grips with a new physical and biotic environment, but also with new neighbors, an increased government presence, and frequently with a new host population. While "learning the ropes," most settlers adopt a conservative stance, their first priority being to meet their subsistence needs. They favor continuity over change; and where change is necessary, they favor incremental change over transformational change. They cling to the familiar by moving into new settlements with relatives, former neighbors, and co-ethnics, if possible.

During the earliest days of the transition stage, settler behavior is family and neighbor oriented, while community activities (including the formation of and participation in economic, social, political, and religious groupings) are deemphasized. In this sense, the context of social behavior is simplified.

The transition stage comes to an end when enough settler families shift from a conservative stance to a dynamic open-ended one, hence initiating the third stage of economic and social development. This shift is most apt to occur after settler security is increased through the production of sufficient food to meet family needs and the settlers begin to feel "at home" in their new habitat. Economic self-sufficiency can be measured by calculating agricultural yields and family incomes, while feeling at home can be assessed through the use of a wide range of indices. One set relates, for example, to increasing familiarity with the new habitat, "taming" it, for example, by referring to it in songs and other narrative forms.

Another set of indices relates to the reestablishment of community-wide religious organizations and the formation of such new organizations as farmers' unions, water-user associations, women's groups, cooperatives, and rural and municipal councils that can represent the interests of the settlers vis-a-vis the hosts, the government, and the outside world at large.

Granted the security-oriented and conservative stance of the settlers during the transition stage, it is unreasonable for planners to expect rapid increases in productivity through agricultural intensification during the first five years.

STAGE THREE: ECONOMIC AND SOCIAL DEVELOPMENT

The contrast between Stage Two and Stage Three is dramatic: the first characterized by a population of risk-averse settlers and the second by a population of risk-taking settlers. Since the same people are involved, a dramatic change occurs during which settler communities become dynamic and open-ended, with the potential of catalyzing a process of development both within and without the settlement area. There is something of a paradox here since some of the variables creating stress during Stage Two facilitate development during Stage Three. A case in point is the simplifications of the sociocultural system immediately following settlement. While departure from an old sociocultural setting — with extended ties of kinship, patron-client and other nonkin relationships, and a pervasive community and religious organization — can be initially stressful, subsequently individual households and groups of neighbors may be more able to show initiative. They may also be more innovative within the settlement area than if they had stayed "at home" simply because their behavior is no longer constrained by the preceding relationships and institutions.

Though settlers previously concentrated on a domestic mode of production involving extensive agriculture (with investments largely restricted to education for children), during Stage Three I have observed them develop a wide range of investment strategies designed to achieve higher levels of labor productivity through diversification of the family estate. While more data analysis is necessary, it would appear that settlers follow the same sequencing of investment activities in different parts of the world. Initially they invest in education for their children, indicating a willingness from the start to forego returns from the labor of those children in agriculture in exchange for possible remittances and other support ten or more years later. Subsequently additional farm land is sharecropped, leased, and/or purchased, and the farming system is expanded into cash crops (including labor-intensive, high-risk crops). The crop component itself is expanded to cover livestock and nonfarm activities. Nonfarm activities tend to start on the farm homestead, taking the form of small business enterprises, such as crafts, baking, and tailoring, which are located within the home. The home itself may be extended, with rooms rented out to laborers and officials — and in some cases a separate house is built for rental income. Subsequently investment expands to nonfarm activities off the homestead but within the settlement area, with these including small general stores and transport for hire in the form of two- and four-wheel tractors, trucks, taxis, and mini and other buses. Still later, as observed in Egypt and the Sudan, investments are made in urban real estate (both land and housing) and businesses.

Local farming systems in South Asia are often diversified as here in Sri Lanka where rice cultivation and livestock are combined with off-farm employment; but big projects often reduce such resiliency by over-emphasis on one or two major export crops.

A thriving regional center on the large-scale Uda Walawe irrigation project in Sri Lanka uses two-wheel tractors. This is one of the few cases in the tropics and subtropics where development planning included both rural and urban components.

As incomes go up, many settlers prefer to hire laborers for an increasing proportion of agricultural tasks, using family labor for more remunerative activities both on and off the settlement allotment.

Farm diversification and increasing net income among settlers also facilitate the development of commercial and service centers that consume and process the produce and serve farm and nonfarm family needs. Before the settlement can realize its potential for catalyzing a broad-based process of regional development, however, a wide range of settler organizations need to develop. These make a number of vital contributions to the emergence of economically and socially viable settlements. First, they contribute to community and settlement integration, altering the atomistic nature of social organization during the transition stage. Second, their existence is correlated with higher productivity since members can personally deal with matters that directly concern their economic welfare. Third, strong local organizations enable settlers to influence policy and to compete at the regional and national level for scarce resources.

STAGE FOUR: HANDING OVER AND INCORPORATION

1. *Handing Over*. Because of the observed inefficiency of long-established national and special project settlement agencies and because of the frequently negative impact of educational systems on the willingness of settler children to continue farming, I do not consider any settlement to be a success until a degree of handing over control to settlers and other local institutions by the agencies has occurred — and until a second generation of settlers has taken over. Handing over activities to departmental, local government and settler organizations is a tricky business that can proceed both too rapidly and too slowly. On the whole, however, the problem in the postcolonial era is that centralized and hierarchically organized settlement agencies retain for too long a period a wide range of activities that could be more efficiently carried out under a policy of devolution to local organizations. This delay indicates a need for a reexamination of the relative merits of centralized versus decentralized management strategies for project development.

2. *Incorporation*. Incorporation refers to the process whereby a new lands settlement becomes an integrated part (rather than a special enclave) of the region within which it is situated. To an extent, incorporation is the result of a successful process of handing over to locally based government departments and to rural and municipal councils. But physical handing over alone is not sufficient. The incorporating agencies must have the personnel and capital resources and the will to take over essential settlement services so these services do not subsequently break down. Resources and will both require emphasis. Where new lands settlements are in isolated areas, departments of public works, for example, may not have the resources to maintain access roads, bridges, and other essential structures even if they have the will. And because of the tensions that so often exist between specialized development authorities and the technical ministries, this will may be absent — local officials in public works and other departments often preferring to allocate resources to communities and projects that they have been serving for longer periods of time and where they are themselves part of a network of social and political relationships. Part of the problem here is political incorporation, since settlement organizations will not be able to compete for regional resources after handing over unless they are integrated within the political economy of the region. So incorporation has a number of aspects that extend beyond the process of handing over. Furthermore, if larger and more diversified new lands settlements are to realize their potential for catalyzing a process of regional development, incorporation must enable the settlement area to play a major role in influencing regional policies and the implementation of those policies. □

Women and Marriage in Medieval Society

by ELEANOR M. SEARLE

The feudal world was a face-to-face society in which women participated in important activities and were expected to submit to social discipline like their men

We in the 20th century live in a world of separate families. Their welfare, I suppose, is dependent upon the activities of dominant family members, and upon the activities of governments that are overwhelmingly powerful and exceedingly distant. We are proletarians in the real sense that we are, by and large, dependent upon wages paid us for our labors, rather than being stewards of a family resource that supports us and that we hope will support our children and grandchildren.

The property we have acquired, we own, and we inherit under rules that are prescribed and knowable. The bank may be able to repossess, but we need not be dependent upon our neighbors' opinions of our worth to be able to buy, inherit, or continue in possession. One or both parents in a family may bring home the bacon and pay the school fees, but their dominance would quickly end if they expected a child's acquiescence in an arranged marriage; and the idea of our colleagues or neighbors being involved is unthinkable. We may be concerned citizens, but we are not concerned in one another's family business. As far as government goes, we do not have to be personally, constantly active for it to work. Government is the formative background to our lives, but our direct relation to it tends to be slight: April 15, being audited, drafted, or applying for a grant — and the nightmare vision of it is Kafka's labyrinth of incomprehensible menace.

All this is laboring the obvious. At least I hope so, for we will then agree about the shape of modern society in the most general sense. And our own society must color our expectations of the normal and desirable; it is from our own time that we peer back uncertainly into the past.

This is particularly necessary in analyzing family structure and the position of women in the formative years of our institutions — the European Middle Ages. For most certainly the institutions of marriage and the family that we can see then could not possibly have the slightest utility or moral justification in the social configuration of today. Medieval children were often, perhaps normally, betrothed in infancy in a union that was binding unless repudiated by one or other of them at about the age of 14. Such betrothal contracts commonly contained very specific nominations of second-, third-, and fourth-choice partners, supposing death should occur.

Such contracts have been castigated by Professor Lawrence Stone of Princeton as ones "by which children were bartered like cattle." The father who could do such things to his babies, Stone proposes, not only arrogated to himself an absolute right of disposal over them, but had at best an "emotional detachment" from them. If a father died, the marriages of his unbetrothed children fell to his landlord, who had a moral (and by the 13th century, a legal) right to arrange their marriages. Lords often sold the right of marriage, which could then be resold, and which might pass through the hands of several buyers in a rising market.

Children were not the only individuals so at the disposal of others. Women with property were particularly so. A widow "fell into her lord's hands," as medieval records put it, and her remarriage to a man chosen by him was at his discretion. Henry II of England in the late 12th century once accepted a large bribe from a 93-year-old countess "that she not be made to marry any more," as his account rolls blandly put it. When the countess of Warwick, a young widow who was the holder of an important castle in her own right, dared to remarry without license, the sheriff was commanded to confiscate all her lands and to keep the couple from cohabiting. Wicked King John was first married to a great heiress, subsequently divorced her, and then sold her marriage to a favorite friend of his. But men thought he had gone too far, I must admit.

Every king's and every manorial lord's financial records are full of fines paid by women at all levels of society to be allowed to choose their own husbands or to stay single. And, to be fair, I have found one record of a fine paid by a village man to avoid marriage with a particular widow of the village. The marriages of children and girls were also subject to the permission of the father's lord and peers, whether his fellow vassals at the upper levels of society, or his fellow villagers at the lower. The lawyer Glanvill, writing in the 1180s the first collection of English "customs," as he called them (which became the basis of English common law), declares that it is the custom that any father who arranges a marriage for his heiress without his lord's permission is subject to the confiscation of all his land by the lord.

The assumptions about these arrangements vary a good

deal today, now that the women's movement and a current interest in the history of the family have coincided. But more than one of these assumptions need challenging: first, that the family in Europe has always been "patriarchal" until the present — that is, ruled by an authoritarian father; and second, that it hadn't in the Middle Ages dawned upon men and women that all this represented an outrageous tyranny, and that better institutions could have been adopted whenever they liked. This last is particularly dangerous, I think, because it provides a false historiography to women of their traditional treatment, and that is not healthy for a political movement. And it provides an excuse for not thinking hard, for not trying to understand the men and women of the past in their own terms.

My own particular research has brought me to this uneasiness, for it centers upon the interplay of economics, political institutions, and the law in medieval England. The 1970s was certainly the most exciting decade in nearly a century in the history of law. Brilliant theoretical work on the nature of medieval land law turned upside down our preconceptions about land ownership, the very basis of medieval power, and about land conveyancing, the very basis of family control. Working, as I am, in the social and political implications of this new legal theory, I am challenging a view of society that sees autonomous patriarchal families whose heads are able to allocate family resources as they see fit. And I am attempting to work out a new politics of feudal groups.

Let me offer, then, a picture of tenure and inheritance in the feudal world as I see it — as a beginning to understanding why such strict control over women and their marriages might have been acceptable even to families who loved their daughters.

The seignorial world I propose to you is not one of individual families operating within a loose network of patronage. On the contrary, patronage relationships were the very organizing principle of medieval society. It is a world of lords and their vassals assembled in courts, in which the disciplinary, equitable, and civil jurisdictions were exercised in constant political maneuvering. The seignorial court served the interest of the lord, and at the same time it served as the meeting place where the interests of lord, family, individual, and community were talked out, adjusted, and finally compromised. The rules of these courts were flexible, and their decisions were political in their very nature, for upon them rested local peace. Recorded descriptions of their customs cannot be assumed to be statements of right. Rather, they were the normal rules by which the reconciliation of conflicting interests was effected.

Medieval tenure begins in interdependence, and the assumptions of inheritance and admittance cluster around recruitment — the addition of a tenant acceptable to the lord and a peer acceptable to the lord's men. In this world a newcomer does not buy land from a lord; it is the lord who buys a man to perform certain services, and he pays the man in land. If the tenant stops doing the service, the lord may oust him, but the ousting will happen publicly, with the restraining influence, the advice, and at last the aid of the vassal's peers.

The lord's court, then, could not be a disinterested tribunal that might conceivably award an occupied tenement to a claimant who appeared with a so-called better right. The group had in common accepted the holder, had judged him, and no other title could exist. They had *recruited* the tenant to their number. It is clear that courts held strongly to the general principle of family claim, but the very existence of the group might dictate that the *right* young person — the effective, the trusted — should inherit or be accepted rather than the eldest son, for example.

It is in this setting that the control of women's marriages can be seen to perform a function vital to the group. The medieval marriage involved the transfer of property to the new couple by their parents; it involved an act of inheritance. And in courts that sought merit as the criterion of acceptability, strong property rights for women were an important asset. Any medieval girl thus was a potential heiress as well as the recipient of a dowry at her marriage. These strong principles of property rights played an important part in recruitment to the group.

Marriages functioned as strengtheners of the bonds between a lord and his vassals. Endogamy (marriage within a group) and lordship go together. No lord would want to permit his lands to go with a girl into another man's lordship without compensation. It might be useful to both the vassal group and to the lord that *his* daughters (or some of them) marry his vassals. In the royal enquiry of 1166 into men who owed the king service, one reply told the king that the sender felt himself responsible for more military service than he could perform, so "I gave two of my daughters to two of my knights with enough land from my wife's dowry to perform a half-knight's service, and the three of us perform the whole service together." This was a father, but he was more importantly here a lord.

The solidarity of the male group was surely more assured by the intermingling of their lands and by their mutual dependence for security of tenure than by feudal "palship." They called their women "peace-weavers" not in sentimentality but because their women's property rights wove the group together with yet greater strength and complexity, whether they acted as heiresses of dead tenants or received dowries that might be as large.

In this way it could, and frequently did, happen that women acted as the channel of family inheritance, even when they had living brothers. Nor was this perceived as tyranny, either on the part of a father or of a lord, because agreements that clearly disinherit boys are specifically done by the lord "at the request and with the advice" of his court. A striking example is the marriage contract in 1153 between two troublesome lords, Robert Fitzharding and Roger of Berkeley, made in their lord's presence, at his request, and with the agreement of his vassals, their

peers. By it, at least one son and one daughter of each family was to marry, the Berkeley daughter carrying to the Fitzharding son as her dowry essentially her father's entire fief, and the daughter of Fitzharding conveying back again about half to her Berkeley husband, with a bit of Fitzharding land added. The two fathers were in essence ousted in the name of their grandchildren, and in fact the complexities of relationship and tenures created in this contract also created great stability.

An able girl, too, might be outfitted with an able husband and preferred to an untrusted or insignificant brother. The formidable girl Amabel of Bellême in Normandy inherited in preference to two brothers. She was then given in marriage to the great war leader Robert of Montgomery. But she herself, besides having nine children, rode always with 100 armed retainers, made war, and died at last, age 29, by the sword. There was not only a certain roughness but a rough equality about these feudal couples. They were in business together, whether or not they were in love romantically. Loyalty to one another appears to be the quality they most prized. And loyalty was needed, for the men were on the whole the offensive warriors, putting their strength behind lance, sword, or battleaxe. Their women were skilled keepers of fort or castle, and the crossbow was their weapon.

An account of the rebellion of Eustace of Breteuil against the duke of Normandy about the year 1100 shows Eustace guarding one castle and his wife another that had been her dowry. After a long siege, during which she used the crossbow to great effect from the castle walls, she was forced to surrender. But though she negotiated terms for her several hundred men, she scorned them for herself. "She lept from the walls and fell, though somewhat shamefully, with bare buttocks, into the depths of the moat. This happened in the third week of February . . ." But she had arranged secretly for a horse, and while the army laughed, she surprised them by scrambling out and galloping safely off to join Eustace, "to give him a first-hand account," as the chronicler tells us.

If these formidable women were to be included in the group's property, then their marriages had of necessity to be matters of group interest and control. Arranging their marriages fell to the lord in his court if their fathers died before having his hopes for them publicly accepted. The lord thus had access again to what was *his* and acted as guardian. Child marriage and infant betrothal insured that the girl's father would at least have a say in the matter, and also that the girl would inherit even if her father died young and her brother was the one left to deal with the lord.

Marriage arrangements whereby the girl was pre-contracted to marry one boy and — if he died — to wed another, and so on, far from bartering children like cattle were the ultimate in the group's care for children. They were insurance, with contingency clauses, that the girl would inherit. Widows with property, particularly if they were too old to manage it, were married to men who could. The alternative was being parted from one's property. The 93-year-old countess who "would marry no more" could have retired earlier. Her great-grandson simply took over all her property when she did. Until 93 she preferred to be in the fray.

In medieval society there was in fact a way out of control if one wished to risk it — simply *not* having property. For however much I speak about marriage being controlled (and that was the way *they* spoke of it), in fact nothing was easier than to contract a valid marriage. All a man and woman were required to do, when they had reached 14, was to say the words of consent (you are my husband/you are my wife) and to have sexual intercourse; they were married, even if the consent were given in perfect secrecy. Romeo and Juliet, as the audience knew, were perfectly validly married, and they would have been so without the blessing of Friar Lawrence. In a society of strict marriage controls, marriage itself was a safety valve of thorough anarchy for the unconforming individual.

But there was a price: the property that went with the marriage. Nothing was guaranteed — not dowry, not inheritance. Free marriage was the prerogative of the foolish and the penniless. A claimant to a holding in Devon, in a curious case about 1200, says that he is married to the girl who has the closest claim to inherit. "By whose authorization did you marry her?" the justice asked. "By no one's," answered the husband, "for I found her destitute." Only in such circumstances could one conceive of marrying without public authorization.

This was no golden age for men or for women. The feudal world was a face-to-face society where men and women knew and intensely cared about one another's abilities, character — and property. Their private arrangements were subject to public scrutiny and public control to an extent we find virtually impossible to imagine. But it was not a society in which women were thought inferior in intellect, or in which they were kept guarded from experience of the world. In fact, they were little if any more controlled than their brothers. They participated in important activities and were expected to submit to social discipline like their men.

And however true it is (and it is) that early modern society denied these hardships and opportunities to its women, an unprejudiced look at the feudal world may make us less uncritical than we might otherwise be in condemning the past wholesale. History is not a one-way path ascending to our perfection. Nor need women complain of a tradition of semi-slavery.

Modern western woman is not the troublesome and upright figure she is because of *modern* notions. The real source of the female self-confidence of the western world lies in these thousand-year-old roots of comradeship with men. We cannot expect the descendents of the crossbow experts to be undifficult or the descendents of the peace-weavers to be satisfied with anything less than equality. □

The Fairchild Scholars Program

A program to promote scholarship through interaction is alive and well at Caltech. How does it work?

Fifteen Fairchild Scholars are now in residence at Caltech — two each in the divisions of Chemistry and Chemical Engineering and Geological and Planetary Sciences, three each in Engineering and Applied Science and Humanities and Social Sciences, and five in Physics, Mathematics and Astronomy. They bring to almost 170 the grand total of such guests of the Institute in the approximately eight years of the existence of the Sherman Fairchild Distinguished Scholars Program at Caltech.

This program was established back in 1973 by the gift of $7.5 million from the Sherman Fairchild Foundation. It was named in honor of the founder of the Fairchild Camera and Instrument Corporation and of Fairchild Industries, a man who would himself have been an ideal Fairchild Scholar. He was a pioneer — and an indefatigable inventor — in the fields of photography, aviation, and sound engineering.

Under the terms of the grant, the money was to be used over a period of ten years to underwrite the costs of visits to the Caltech campus of distinguished scholars or of young persons of outstanding promise from the worlds of academia, industry, and government. The appointments were to be made for periods ranging from a term to a year. Francis Clauser, Clark Blanchard Millikan Professor of Engineering, Emeritus, who originally suggested the idea, pointed out how much the members of the Caltech community would benefit from the opportunity to interact with the world's intellectual leaders. And, of course, the sharing of wisdom and ideas would go both ways. Since the board of the Fairchild Foundation has recently renewed the grant for an additional five years, the program has obviously worked out. But how? A large amount of money and a considerable number of people have been involved. Who has done what to make the whole thing so effective? What have been the necessary mechanics of the operation? Has it been useful to the participants on both sides?

Many people all over the Institute have been involved in making the program work — faculty, division chairmen, administrators, and staff — but the director from the first has been C. J. Pings, who is also vice provost, dean of graduate studies, and professor of chemical engineering and chemical physics. Working with him at the administrative level, Lea Sterrett, assistant provost, has maintained liaison with the Scholars between the academic preliminaries of nomination, approval, and invitation and the practical logistics of taking care of the visitors once they have arrived. And Carol Cooper, executive secretary in the office of the provost, has been keeper of the records and Jill-of-all-trades in the day-to-day operation.

With this as background, here is the scenario for the mechanics of the visit of a hypothetical Fairchild Scholar. We are using a male in this case, because most of the Scholars so far have been men, but distinguished women are also sought and welcomed. Albert E. Murray, PhD, DSc (several times), Thomas Hunt Feyn-Mann Professor of Theoretical Physics, is doing exciting research in his field at Bohr Institute of Technology. Several of his fellow scientists at CIT know about the work and the scientist and would like to know both better. At least, they'd like to exchange ideas with him over a longer period than an occasional professional meeting. They also hope he wouldn't be averse to spending a little time at Caltech, where he can interact with our people in the same field. After some informal discussion among those people, one of them presents Murray's name to the divisional committee charged with recommending Fairchild

Excerpts from letters written by some recent Fairchild Scholars about their stay at Caltech:

In the past I have been a visiting professor in many countries. I know about the problems arising at the beginning of a visit. One needs weeks to settle down, to take care of housing and transportation. The Fairchild Program is absolutely different. All is taken care of. You enter your house or apartment just like coming home from short vacations. You find a car in the garage and you can drive to the next supermarket to complete your half-filled refrigerator. And the next morning you can start your work at the Institute.

What does a Fairchild Scholar really do during his time at the Institute? Sometimes I heard this question. In my case I used the time being here intensively to do science without any restriction or obligaton. I used the time to write a number of papers for publication, to discuss with colleagues and to participate in many seminars and research conferennes. . . . The eight months as a Sherman Fairchild Distinguished Scholar at Caltech were so far the best months of my entire academic life.

HORST HOFFMANN
Professor and Head of the Physics Department
University of Regensburg
West Germany

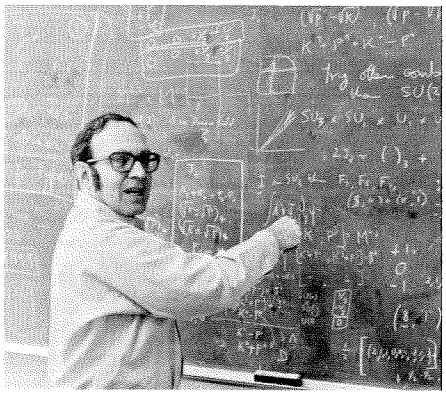
Scholars. That committee discusses and evaluates Murray's name along with other divisional nominations.

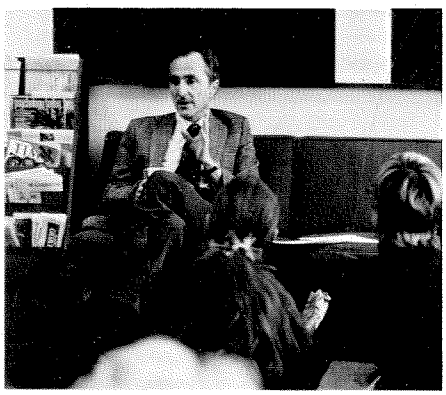
Dr. Murray passes this first test with flying colors, and his name is sent along to the division chairman, who assembles all the relevant data he can find about Murray, fills out a nomination form, and sends the package to the Institute Administrative Council (IAC). At that point a ten-day-long countdown begins, and if no one has expressed objections to Murray's nomination at the end of that period, the nomination is considered approved. The division chairman is notified, and he is then free to write Murray a letter offering a Fairchild appointment.

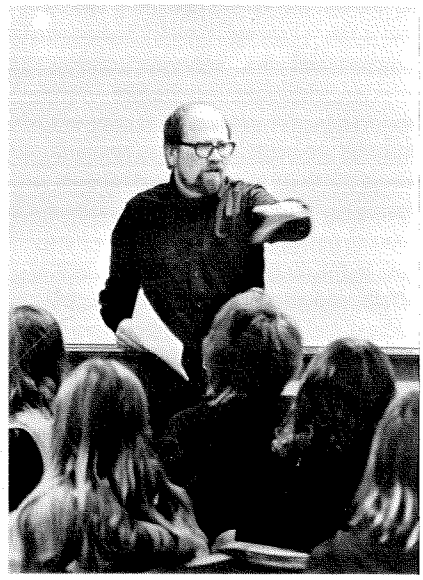
A division chairman is always happy when that time comes, mostly because, as Harry Gray, chairman of the division of Chemistry and Chemical Engineering, says, "There's no way of overestimating the value of these visitors. The interaction between them and all members of our division is immediately enriching; the Scholars affect in a very positive way both our teaching and our research programs."

More specifically, Fairchild Scholars for the division of Humanities and Social Sciences are selected in part because of the extent to which their research interests intersect the activities either under way or contemplated within the division. Because the disciplinary groups in Humanities and Social Sciences at Caltech are very small, a steady stream of visitors is an important source of information about activities in the profession at large and a significant increment to the number of colleagues with whom to consult and collaborate on research. This is especially true for graduate students, who during the normal four years of study at Caltech will have the opportunity to interact with as many Fairchild Scholars as there are permanent faculty in social sciences.

In addition, says Roger Noll, chairman of the division, "the Fairchild program has been invaluable to the social scientists in spreading the reputation of the Institute as a place where high-quality research in social science is taking place, and where first-rate graduate students are being trained. The Caltech social science program achieved national recognition very soon after it was introduced, in large part because a flow of outstanding scholars from major universities came through as Fairchild Scholars. Then, when they returned to their home institutions, they spread the word about the program. They have subsequently been instrumental in







Three former Fairchild Scholars in interaction at Caltech: physicist Yuval Ne'eman (top left), who came to the Institute from Tel Aviv University; psychiatrist David Hamburg (bottom left), from Stanford University; and Norbert Bischof, a behavioral scientist from the Max Planck Institute at Seewiesen, Germany.

For relatively short visits to institutitons (a few months) I have found in the past that too much time is wasted on organizational matters. However, when these details are taken care of, as in the Fairchild program, I now know that a change of environment can be scientifically stimulating and personally rewarding.

LENNOX L. COWIE
Research Staff Member
Princeton University Observatory

In looking back on the time I spent at Caltech, I regret that the pressure of other commitments made it impossible for me to stay longer, and that perhaps is the most appropriate measure of the value I put on my experience. The opportunity to interact with the Caltech faculty, the freedom from day-to-day routine cares, and the support level provided by the Institute, all combined to make my stay both profitable and enjoyable. For the record, I was able to complete a long review of the properties of water which I had not had the time or opportunity to think about deeply at the University of Chicago and which I had been trying to complete for a year. In addition, I believe I planted the seeds for collaborative work with Ahmed Zewail and with Professor Cohen in applied mathematics. It will take some time to determine if those seeds will germinate, but I think there is a good chance they will.

STUART A. RICE
Frank P. Hixon Distinguished Service Professor of Chemistry
The James Franck Institute
The University of Chicago

helping us place our graduate students in major research universities."

Occasionally, of course, there are objections to a nomination, and this brings about a discussion and eventual resolution by the IAC. But everyone thinks Murray will make an excellent Fairchild Scholar, so all the division (in this case, Physics, Mathematics and Astronomy) has to do is figure out if and when it is going to have available office and/or lab space and secretarial help. Also, Murray is a busy man with many commitments, and his time is hard to come by. Getting final agreement on the exact dates, duration, and working conditions of his visit to the Institute will probably take several letters.

Once all this is worked out, Murray receives a letter inquiring what he will need in the way of other perquisites that may go with being a Fairchild Scholar — transportation to and from Pasadena, housing, stipend, and medical insurance, for example. Not everybody needs all of these things, but they are all available to some degree, and there's a sound philosophy behind providing them. "The needs of the Fairchild Scholars and their families are as diverse as the people themselves," says Lea Sterrett. "Our job is to eliminate for them — as much as we possibly can — the frustrations of getting settled in a new place, so they can take advantage of their visits without delay and without distractions."

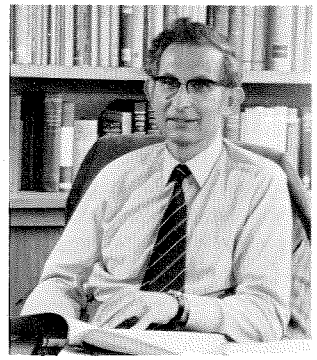
Housing, for instance, is almost always needed, and every effort is made to make what is available acceptable to its temporary occupants. A number of houses and apartments of various sizes are leased and are completely furnished and kept for the Scholars. These include everything from a four-bedroom house on a large lot to a small apartment, and the supervision of these residences gives this part of the program a decidedly hotel-management aspect. Over the past seven years, never less than 18 units of housing at a time have been under the care of Lea Sterrett and Carol Cooper, aided by a single housecleaning person. This hotel-management service, incidentally, is provided at no cost to the Fairchild Program, being paid for by the Institute.

Murray informs Caltech that he doesn't care whether he has a house or an apartment as long as he doesn't have to do any gardening and that his family will need a minimum of two bedrooms. He wants to be within walking distance of the campus. These requests are filled — all the dwellings on the housing list fit comfortably into these slots.

Bohr Tech allows professors on leave only 50 percent of their normal salaries, so Murray will need a stipend to make up the difference in his income. He will also need supplemental medical insurance. He recognizes that he is going to have to do some driving, and his wife may take some classes at UCLA, so a car should be rented or leased for him, preferably something compact. He would also like some help in getting his 12-year-old son enrolled in a nearby school.

Once all of these details have been settled, President Marvin Goldberger writes a formal letter of appointment to Dr. Murray and his name and the dates he is expected begin to appear on the list of appointees. This list is circulated regularly to key people on campus to let them know that these special guests will be here and that plans for taking advantage of the fact may be put in motion. The accounting department gets the list so it can get its books ready for a new name. And the board of the Fairchild Foundation gets the list as well, along with the supporting material on each new scholar.

Suppose Dr. and Mrs. Murray and their son are going to arrive next week. The apartment chosen for them will be cleaned and double-checked for having all the equipment the annual inventory shows that it has — sheets, towels, dishes, silver, pots and pans, vacuum cleaner, TV, working telephone, and the like. Airline reservations for getting the family to Los Angeles are made, as well as arrangements for them to be met and brought to Pasadena. Murray will be informed as soon as possible how to get to the campus, to his division, and to the Fairchild office, and also of his new residence address and telephone number. The division is where he will work, of course, and that is very important to him; but the Sterrett-Cooper area on the third floor of Millikan is very important too. That is where he will go for help with solving problems of daily living in Pasadena — to find out the name of a local dentist, for example, or how to get a plumber.
Academically, Murray is in the hands of his division, and each division has its own way of welcoming visitors and fitting them into the life of the community. In Chemistry and Chemical Engineering, for example, selected members of the faculty make sure that the Scholar is introduced around the division and taken to lunch at



After years of living in Cambridge and working in London, it has been almost blissful to be able to walk to work in a few minutes and to lunch or dine or play tennis at the Athenaeum nearby.

The most important and profound effect that my year had and will continue to have on me is to reinforce my enthusiasm for science, and my belief that there is no substitute for first-rate science in any successful modern engineering project. The current emphasis on "relevant" and very applied work has, to my mind, already had serious ill-effects on the health of academic life in many parts of the world, and so it was most encouraging to witness a successful marriage of long-term fundamental objectives and useful consideration of short-term problems such as has been achieved at Caltech.

J. R. ANTHONY PEARSON
Professor of Chemical Engineering
Imperial College
University of London

I was in residence at Caltech from December 1978 to July 1979. This was one of the most productive periods of my professional life. During this period we used the presence of David Cass (also a Fairchild Scholar) and Lionel McKenzie (a visiting professor) and myself, as well as the Caltech faculty, to organize a seminar series that attracted scholars from all over the LA area. Even though the seminars were held at night, we had regular visitors from UCLA, USC, and UC Riverside. . . . I used my time to formulate and study the problem of self-fulfilling speculative bubbles that never burst even though the classical perfect information postulates of economic theory are satisfied. . . . Since

the Athenaeum. Very often the Scholars become involved in collaborative research with one or more groups in the division.

In Humanities and Social Sciences, the committee that operates the Fairchild program also selects the Scholars who are to be nominated for a Fairchild appointment. A necessary part of the nomination is that a member of the faculty of the division—usually the one proposing the Scholar — takes the responsibility of integrating him or her into the life of the division. There are no formal requirements for this because different Scholars have different interests and different amounts of prior contact with Caltech faculty. Usually the sponsoring faculty member will at a minimum invite the Scholar to relevant seminars and arrange early social events to make it possible for the Scholar's family to meet Caltech people.

Each Scholar has his own idea of what he wants to do here too, so it is difficult to generalize about what happens in the course of visits. Some Fairchild Scholars have become so deeply involved in what is going on in their part of Caltech's academic environment that it is hard to tell them from members of the faculty. (Recruitment, however, is definitely not a part of the program, although two former Scholars are now members of the Caltech-JPL family.) A few have used the period of the visit to disappear into an office or lab as much as possible to get work done that for various reasons would be impossible to accomplish in their home institutions—and have been reluctant to emerge. Most have found a comfortable niche somewhere between these two extremes.

Scholars also frequently cross disciplinary lines. For example, Rutherford Aris of the University of Minnesota is currently a Fairchild Scholar in chemical engineering at Caltech. But he also has an amateur interest in Latin paleography and is doing some research and writing in this area. In this connection he benefits greatly from contacts and discussions with John Benton and Eleanor Searle, who are notable historians and authorities on the Middle Ages.

During his stay here our man Murray gets a lot of research done. He and one of our physicists have a paper coming out in the prestigious *Journal of the American Association of Theoretical Physics*, and he has some ideas for new lines of research back at Bohr Tech. Some of our physicists have gotten some new research ideas from him too. One of the Caltech graduate students will be coming to him as a postdoc-

Rutherford Aris

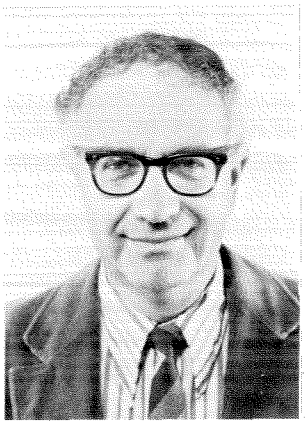
toral fellow as soon as he gets his PhD. Murray is an outgoing person as well as an outstanding scientist, so he lunches at the Athenaeum, gives seminars, makes a talk on the Watson Lecture series, and meets with students. By the time his visit is at an end, he is on a first-name basis with a lot of people at the Institute. And he enjoys spending a year in southern California; he considers a few days of smog a reasonable trade-off for the few days of snowstorms he is used to dealing with each year.

So, after a mutually profitable and pleasant year, the Murrays and Caltech officially part company. As a windup, he is asked by Pings to think about his experience a bit and then write a letter summing it up. The people involved in the visit, both at Caltech and at the Fairchild Foundation, really want to know what he did here and how he feels about it, so these letters are important. The actual letters received have varied considerably. There have been step-by-step summaries of research, bread-and-butter thanks for hospitality, lively reminiscences, and mixtures of all three.

Even laudatory and light-hearted verse has turned up, and at least one book has a dedication that is a result of the Fairchild Program: "To my friends at the California Institute of Technology, than whom there are no hosts more gracious nor colleagues more stimulating" appears in the front of a volume by Aris, who is obviously no mean practitioner of graciousness himself. Professor Murray hasn't sent in his letter yet, but more than 150 others have—all testifying to the value of promoting scholarship through interaction. □

"noise" in the data makes it extremely difficult to test historical episodes for the presence of bubbles, laboratory experiments are even more essential here than in other branches of economics. . . . Needless to say, having access to Caltech's group of experimental social scientists (the finest such group in the world) was essential for this part of my research.

WILLIAM A. BROCK
Professor of Economics
University of Chicago



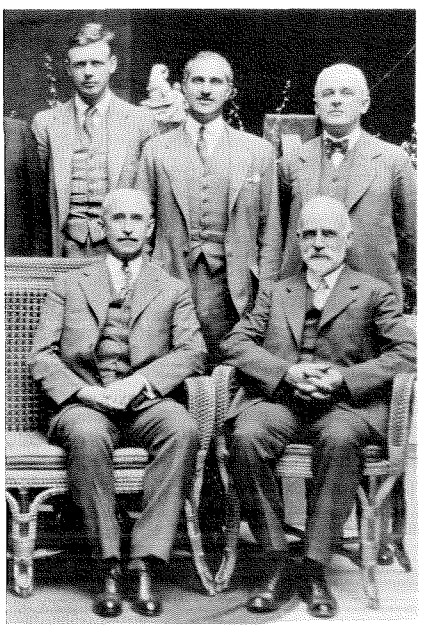
During the six-month period of my stay, I was able to accomplish several things. In the first place, as a small gesture of my gratitude for the appointment, I presented four regular seminar lectures during the spring quarter. I also persuaded several of the faculty of the chemistry and biology departments interested in membrane research to meet with their students at regular intervals for seminar-discussions. With regard to my own work, aside from the preparation and submission of some eight research publications that were in various states of disrepair at the time I arrived, my major achievement was the development of a new and comprehensive theory about the molecular mechanisms of cell-cell recognition in immune systems. I can confidently state that this work would never have been done during my regular activities at home, and was made possible only by the free and uninterrupted time I could spend on it as a Fairchild Scholar.

S. JONATHAN SINGER
Professor of Biology
University of California
San Diego

The Triple Alliance

Millikan, Guggenheim, and von Kármán

The 100th anniversary of the birth of Theodore von Kármán will be observed this spring, and one of the ways he will be honored is by a dinner to be held at the Athenaeum on April 21. Von Kármán's is one of the most honored names at Caltech, as it should be. He led aeronautics at the Institute – and the country – to preeminence in the world. How he was lured here in the first place is a tribute to the wisdom and drive of Robert A. Millikan, who was tireless and ingenious in his efforts to recruit a superb faculty for the school he headed. Fortunately, much of the correspondence that led to von Kármán's becoming a part of the Institute survives in the Archives of the Robert A. Millikan Memorial Library. These papers have been organized by the archival staff, in particular Archivist Judith Goodstein, who provided ideas for this article and invaluable guidance through the collections. Some of the letters are on display in the conference room in Kármán Laboratory.



Among the board members of the Daniel Guggenheim Foundation for the Promotion of Aeronautics (ca. 1927) were (seated) Orville Wright, W. F. Durand of Stanford, and (standing) Charles A. Lindbergh, Harry F. Guggenheim, and Robert A. Millikan.

Theodore von Kármán, director of the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT) from 1930 to 1949, was recognized at the time of his death in 1963 as having contributed more to the fundamental understanding of atmospheric and space flight than any single person in this century. He was also perhaps Robert Millikan's greatest catch, being already distinguished in the infant field of aeronautics (pioneered by his teacher, the mathematical physicist Ludwig Prandtl at the University of Göttingen in Germany) when Millikan lured him here for the first time in 1926.

Born May 11, 1881, von Kármán studied mechanical engineering at the Budapest Royal Technical University and mathematics, physics, and mechanics at Göttingen, receiving his PhD in 1908. He lectured there for three years, waiting for a regular faculty appointment, before finally accepting a post as professor of aeronautics and mechanics at the Technical University of Aachen, which soon became recognized as the foremost school of aeronautics in the world.

Millikan first met von Kármán (according to von Kármán's autobiography *The Wind and Beyond,* written with Lee Edson) sometime in the 1920s, possibly on the same European trip in 1921 during which Millikan recruited theoretical physicist Paul Epstein at Leiden. But this meeting remained an isolated incident until a few years later when other fortunate circumstances (though Millikan probably had more to do with them than fortune) arose.

The Daniel Guggenheim Fund for the Promotion of Aeronautics was established in January 1926, devoting $2,500,000 to education and scientific research in aeronautics and to the development and application of aircraft to commerce and industry. Von Kármán states in *The Wind and Beyond* that Millikan read about the fund and its grants to New York University, MIT, and the University of Michigan in the Pasadena *Star-News*. *The Autobiography of Robert A. Millikan* reports that the fund gave subsidies to four institutions in January 1926, but had neglected southern California — an oversight he hastened to correct.

Actually Millikan was even quicker on the trigger than that. On Christmas Eve, 1925, while arrangements for the fund were still being concluded in Washington, Millikan wrote to Harry Guggenheim, Daniel's son, whose interest in aviation had stimulated formation of the fund, proposing establishment of a research center at Caltech to advance the science and art of aeronautics — and an endowment of half a million dollars. On January 6, two weeks before the fund was formally announced, Millikan was meeting with Guggenheim in New York and presenting his arguments — Caltech's outstanding faculty in mathematical physics (Epstein and Richard Tolman), the work already being done here in aeronautics (Harry Bateman and Albert Merrill), the proximity of the Santa Monica airplane plant of Donald Douglas (who had dashed off a supportive letter also on Christmas Eve), and the advantageous climate and

topography of southern California.

At this point, despite von Kármán's and Millikan's versions of the chronology, southern California had not yet been overlooked. Only NYU had received a subsidy for a school of aeronautics, and that was back in June 1925 before the fund itself had been established or even thought of. Millikan, however, was not waiting to give California a chance to be slighted and vigorously pressed his case, tempering it to fit the charitable winds. In a letter to his friend and fellow physicist, Frank Jewett, on January 18, Millikan wrote:

"Unfortunately, Harry Guggenheim has shied away a bit from the word 'research,' and it is possible, too, that the word is over-abundant in my vocabulary. The net result is that his first reaction is not to establish through endowment a real center out here of the kind that is herein proposed, but has asked me to make request to the new foundation for certain installations and for certain assistance for a period of say five years in the way of helpers, apparatus, etc. I am going to do this in a detailed way just as soon as possible. . . ."

"As soon as possible" turned out to be by the end of January, and in an accompanying letter to Harry Guggenheim, Millikan offered to assist him in meeting important people on his fact-finding trip to Europe. Von Kármán's name first came up in this letter of January 29:

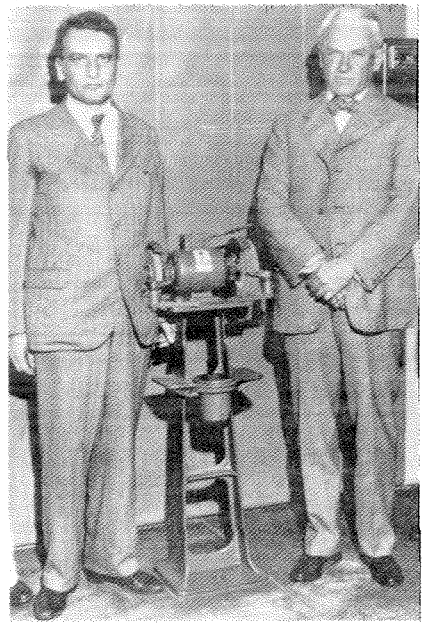
"One of our ablest young mathematical physicists is now in Göttingen and might be of much use in connection with the visit to Prandtl's laboratory, while the association of our group with Kármán at Aachen [presumably the Epstein connection] would also open a door which might otherwise remain closed."

(Apparently Guggenheim did not avail himself of this opportunity. In his autobiography von Kármán recalls being met at the pier in New York on his first visit by Admiral H. I. Cone, vice president of the fund, possibly, it seemed to von Kármán, checking him over to see if he were presentable enough for a visit to the Guggenheims.)

Millikan again traveled to New York on April 30 to talk to Harry Guggenheim and was asked to make a formal proposal to the board of directors. By this time Stanford University was also in the running in the California stakes, but Millikan's confidence remained unshaken. He wrote on May 17 to General J. J. Carty, who had originally leaked the news of the fund to him way back in December of 1925:

"As a matter of fact, the case is so exceedingly strong for the Institute that I myself can't see how any other claims that may be urged are in any way comparable with those that we are putting forth, but how thoroughly informed the Board is or can be made as to the actual situation, I do not know."

On June 2, 1926, the fund's board of directors met; on June 7 Harry Guggenheim wrote to Millikan that "there was approved in principle an appropriation



Theodore von Kármán and Robert A. Millikan in 1930.

of funds for the establishment of a school of aeronautics at the California Institute of Technology, in accordance with the general purposes of your proposals." He suggested that Millikan submit to the executive committee budget proposals of $180,000 for building and equipment, $100,000 for salaries at $10,000 per year for 10 years, and $25,000 for 5 years of research at $5,000 annually. The Caltech and Stanford grants were announced simultaneously, the first two, after NYU, of a total of seven (MIT, the Universities of Michigan and Washington, and Georgia School of Technology).

The Caltech board of trustees met on July 8 to accept this aeronautical program, but Millikan, with characteristic self-assurance, hadn't waited that long to get the ball rolling. A day earlier he had already written to Guggenheim about his choice of an adviser for the initial construction of GALCIT:

"With respect to the suggestion which you made as I left your house that we try to get Prandtl over here for a short time, I have talked the matter over at length with Epstein and Bateman. Both of them think that in view of Prandtl's advanced age and his somewhat unpractical personality he would be far less useful to us than v. Kármán, head of the aerodynamical laboratories at Aachen, and unquestionably the foremost of the younger aeronautical engineers of Germany; or G. I. Taylor, who occupies a similar position in Great Britain. Bateman and I both know Taylor fairly well personally, and Epstein is well acquainted with v. Kármán (who, by the way, is a Hungarian in nationality). We have between us reached the conclusion, partially because of v. Kármán's nationality and because of his representing in a special way the aeronautical developments on the European continent, that it would be well to try first to see if we cannot get him."

(Apparently Millikan never told von Kármán that he was their first choice; in his autobiography von Kármán assumes that he was asked only because Prandtl was unavailable.)

In addition to not waiting for official approval of the whole program from the Caltech board of trustees, Millikan also did not dawdle around waiting for Guggenheim's reply to his suggestion. Already on July 5, two days before Millikan mentioned von Kármán to Guggenheim, Epstein had written von Kármán at Millikan's direction "to sound out whether you might possibly be inclined to spend a few months with us in Pasadena this fall." In fact, Epstein's letter offers von Kármán Millikan's suggested $4,000 for the trip and writes that "it is probable, almost certain, that it will be approved."

Millikan does get around to admitting in the July 7 letter to Guggenheim that Epstein has actually already written because there would be a better chance "of getting v. Kármán over here . . . if we can proceed at once than if we delay until after the next school year gets into full swing." He hopes that Guggenheim will not think he has acted precipitously in the matter, and thinks that it will be no problem rearranging things if Guggenheim doesn't fancy the idea:

"In case your Board wishes to get behind the enterprise and prefers Prandtl or

G. I. Taylor, or indeed any one else, let me know and we will simply fit into your plan but cable v. Kármán to the effect that it has been impossible to make the arrangements tentatively suggested in Epstein's letter, and we can then cable or write to Taylor or Prandtl or the other chosen person, whoever he may be, and start the negotiations de novo.''

Fortunately for all concerned, Harry Guggenheim was also not the type to worry about such niceties as official approvals and wrote back on July 14:

''I think it a splendid suggestion to try to get Professor v. Kármán to come to America . . . Dr. Prandtl of course stands alone in the aeronautical world, but I heartily agree with you that for a practical visit such as you have in mind and which will fit in very nicely with our plans, Professor v. Kármán is the right man. I do not think for one moment that you acted precipitously; on the contrary, I congratulate you on your initiative.''

All this initiative was perhaps not necessary after all. Von Kármán, on vacation in Belgium, was unaware that such impatient forces in Pasadena and New York were shaping his destiny. Epstein's warm (and practical) letter telling him how comfortable visiting German scientists felt in Pasadena and that he could save a nice portion of the $4,000 since living here wouldn't cost much (''Actually we are paying H. A. Lorentz, who is lecturing here the following trimester, only $3,500. Of course, he is lecturing in Ithaca till Christmas and is saving a lot that way.'') didn't reach him right away. Von Kármán relates in *The Wind and Beyond* that his first inkling of the whole business was a mysterious cable from Millikan forwarded from Aachen:

''Proposals suggested Epstein's letter confirmed Cable answer giving earliest sailing''

This was dated July 20 after all approvals really had been granted. However, Millikan had apparently forgotten that this was originally supposed to be tentative — his copy of the cable shows that ''Arrangements'' was written first before being crossed out and ''Proposals'' substituted.

Von Kármán wrote later in his autobiography that ''this odd cable'' caught him completely by surprise. ''What did he want of me?'' Although von Kármán states that he remained in the dark until Epstein's letter arrived 10 days later, he must have found out somewhat sooner than that what Millikan wanted of him. On July 26 he cabled Millikan from Ostende:

''Accept with thanks Some difficulty about proposed time Cable my proposals within a few days.''

Von Kármán apparently didn't allow the matter to disturb his vacation, however, and let Millikan stew in his impatience — he was hoping to get von Kármán to Pasadena by August 15. (Millikan to Guggenheim on August 5: ''. . . I have been awaiting anxiously another cablegram telling exactly when he will appear, but it has not arrived.'')

But on August 14 von Kármán wrote Professor Mellikan (with an i handwritten over the e):

''Professor Epstein's letter and your kind telegramm have given me great pleasure; the idea of spending some months in your circle is the most delightful thing I can imagine. I hope to be able to be of assistance to you in the development of your institute for aerodynamics.''

He wouldn't be able to arrive until the end of September because of difficulties arranging the time and passage. Replying to Epstein at the same time, he wrote that he hoped to learn a lot of theoretical physics from him during his stay and particularly looked forward to discussing the Born-Heisenberg theory — ''I hope the matter will eventually become simpler.''

Von Kármán had also been invited to Japan to help establish the first aeronautical research laboratory there, so he took a year's leave of absence to accept the two invitations. He states in his autobiography that he wasn't thinking of any permanent change at the time; however, it is possible that the thought may at least have crossed his mind in 1926.

Growing German militarism and anti-Semitism were factors in von Kármán's decision three years later (with intensive coaxing from Millikan and Guggenheim) to accept the directorship of GALCIT. Actually anti-Semitism had already affected his career in 1922, when Ludwig Prandtl considered a post in Munich, which would have left open his prestigious chair in Göttingen. To many, von Kármán was the obvious successor, but he was not offered the position. Von Kármán does not mention the incident, but two apologetic letters in the von Kármán papers — from physicist Max Born and mathematician Richard Courant, both members of the natural sciences faculty in Göttingen and friends of von Kármán's — tell the tale. When objections to von Kármán arose with doubts about the ''ethnic composition'' of the faculty, Born and Courant, also both Jewish, did not have the courage (or energy, wrote Born) to support his candidacy, even though they had the backing of noted mathematician David Hilbert. Born, in particular, felt miserable about his own disloyalty and weakness, he wrote von Kármán, but after fighting to bring James Franck with him when he accepted his own appointment at Göttingen (two Jews instead of just one!), he had no more strength left for battle.

Both Born and Courant excuse themselves for being pushed to act quickly and unanimously with the rest of the faculty, since the agricultural engineering faculty was eager to snatch the position for themselves; and Born doubts that von Kármán, with his technological leanings, would have wanted to come back to Göttingen anyway. It is, of course, unclear whether he would have accepted, and it turned out that Prandtl did not leave, in any case, but the fact that he was denied the honor of being asked to succeed his former teacher because of his Jewishness could not have failed to sound some sort of signal to von Kármán.

He was lucky after all. Courant still thought von Kármán was making a mistake to come to Caltech permanently in 1930, ut when things started to get difficult under the Nazis only a very few years later, both Born and Courant, along with many others, wrote to von Kármán, now safely installed in California, for help in finding positions outside of Germany.

Von Kármán did arrive as promised in September 1926, redesigned GALCIT's wind tunnel with eventual extraordinary scientific results, lectured to large audiences at Caltech and in Washington, and visited several other universities before traveling on to Japan. Although he was appalled by ''the complete dearth'' of applied mathematicians in the U.S. (he wrote to Courant that he found this particularly remarkable in such a highly industrialized country), he returned in 1928 for an exchange semester (Epstein went to Aachen). He declined the directorship of GALCIT at that time, but in 1929 Millikan's persistence (and $15,000 more in the promised budget) paid off, and von Kármán finally accepted. In the years at Caltech, from 1930 onward, von Kármán presided over the emergence of American aviation and rocket propulsion into a position of world dominance. □

Research in Progress

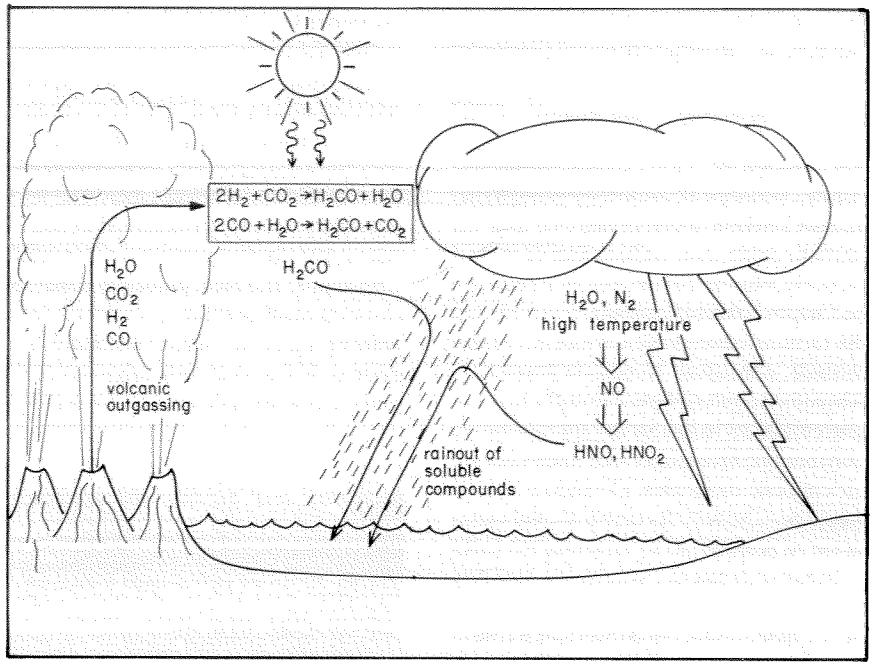
Pre-Life Amendment

Life emerged from an organic soup, the classical assumption says. Theories vary, however, on how the organic compounds got into the soup in the first place because life has neatly consumed the clues to its own origins and added products of its own to the biosphere and the atmosphere. Scientists can only guess at the original ingredients and the processes that cooked them up.

All that may change now that various Mariners, Vikings, Voyagers, and other space missions have sent back information giving hints about how other planets and their atmospheres could have been formed, and some scientists are suggesting new theories that differ sharply from the older ones on how Earth's atmosphere, and eventually life, might have evolved. Using modeling studies of hydrocarbons in other planetary atmospheres, Yuk Yung, assistant professor of planetary science, and graduate student Randall Gladstone (along with Joseph Pinto of the Goddard Institute for Space Studies) suggest that photochemical reactions in Earth's primitive atmosphere could have created organic compounds, specifically formaldehyde (H_2CO).

Yung, Gladstone, and Pinto think that Earth's primitive atmosphere was much the same as it is now—minus the oxygen, which was added later by biological processes. Its composition would *not* have been determined by the primordial solar nebula, the cloud of gas and dust out of which all the objects in the solar system were originally formed, which is responsible for the massive atmospheres of the giant planets. Instead, like Venus, Mars, Io, and Titan, Earth's atmosphere was probably created out of the volcanic release of gases from the planet's interior—*after* the core had already been formed and iron had been removed from the upper mantle. The absence of iron would preclude the previously theorized hydrogen-rich, highly reducing atmosphere. Yung, Gladstone, and Pinto propose a mildly reducing atmosphere with as its major constituents molecular hydrogen, nitrogen, water vapor, and carbon dioxide with small amounts (but larger than those observed today) of reduced gases—molecular hydrogen and carbon monoxide.

Assuming these constituents, they set out to determine whether the atmosphere could have been the chemical engine to generate organic compounds (such as for-



A new scenario for the formation of life on Earth postulates an atmosphere of hydrocarbons released from the planet's interior through volcanoes. Photochemical reactions could produce organic compounds (such as formaldehyde), and reactions between nitrogen and water around lightning discharges could generate nitrite and nitrate. Sufficient concentrations of these ingredients rained into the oceans would provide conditions very favorable for life.

maldehyde) out of inorganic ones. This reaction is quite easy in the photochemical reaction of photosynthesis, where organic compounds result from carbon dioxide and water; but could it have been managed without pre-existing reduced organic compounds around to help out?

By adding together in a computer model all the known reactions of the theorized hydrocarbons in the atmosphere, including a couple of reactions only recently studied in the laboratory, the planetary scientists derived two possible photochemical pathways to formaldehyde. These pathways result in the net reactions:

$$2CO + H_2O \longrightarrow H_2CO + CO_2$$

$$2H_2 + CO_2 \longrightarrow H_2CO + H_2O$$

Even though 99 percent of this formaldehyde would be destroyed by photolysis, enough could be incorporated into raindrops to dump three million tons of it annually into the oceans, where it would be "happy" (that is, not exactly stable but forming other stable compounds). At this rate, after about 10 million years, formaldehyde would exist in sufficient concentrations in the oceans for it to be polymerized by sunlight into more complex organic molecules. Conditions would then be very favorable for the evolution of life.

In earlier research (with M. B. McElroy of Harvard) Yung also modeled an analogous situation for the delivery of nitrite and nitrate to the oceans by reactions between nitrogen and water in the air surrounding lightning discharges. Large amounts of nitrogen and organic carbon create conditions so favorable that the emergence of life would be "nearly inevitable." Gladstone and Yung also plan to construct a similar model for the atmospheric generation of hydrogen cyanide (HCN), a key compound that can form important amino acids. Their studies of inorganic-to-organic reactions are not limited to those on primordial Earth—Saturn's moon Titan has an atmosphere rich in methane, another likely candidate for producing more complex organic molecules and in older theories thought to be the precursor of life on Earth. □

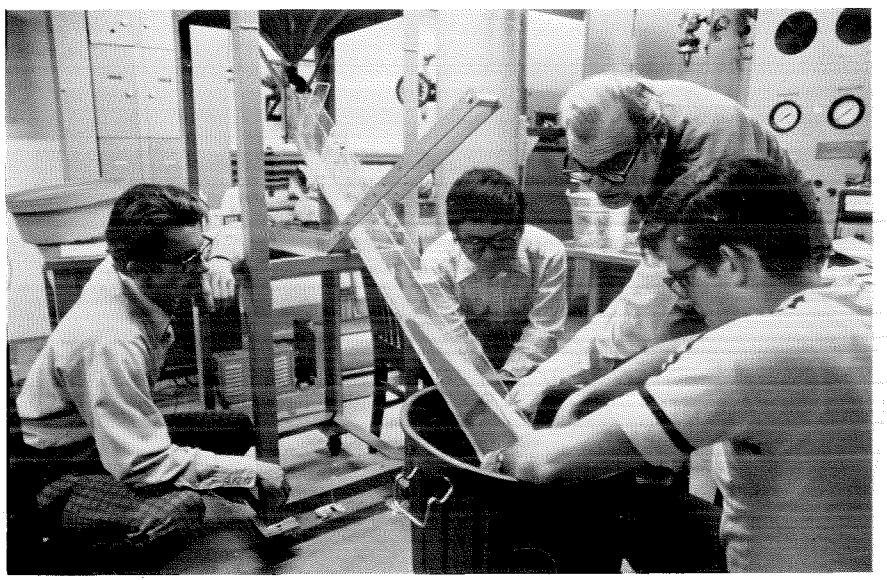
Going Against the Grain

Granular materials flow somewhat like fluids — but with enough differences to flow right into the cracks between the traditional disciplines of classical fluid mechanics, kinetic theory, and soil mechanics. While the flow of liquids and gases has been studied for centuries, the properties of granular flow are not well understood.

Rolf Sabersky, professor of mechanical engineering, stumbled onto this surprising interdisciplinary crack several years ago when he heard about a heat exchanger in which hot soap granules were cooled by pouring them over water pipes. The interesting problems encountered in this seemingly simple operation led him and Christopher Brennen, associate professor of mechanical engineering, to begin a research project on granular materials in general. Many such materials — coal, gravel, ores and grains of all kinds, fertilizers, even plastic stock — are transported and handled in enormous bulk quantities.

Heretofore, the rather simple transport contraptions — hoppers, chutes, conveyors — as well as more complex processing machinery have been designed by trial and error with very little scientific knowledge of how the material moved through them. As energy and construction costs increased, however, the benefits that might be derived from more effective designs have also become more apparent. In addition, many of the suggested solutions to the energy situation involved transporting and processing even greater quantities of bulk material, such as coal and shale.

Nature also presents problems of granular flow — mud and rock slides and avalanches. Scientists are interested in how the sand patterns recently discovered on Mars and Venus might have been formed

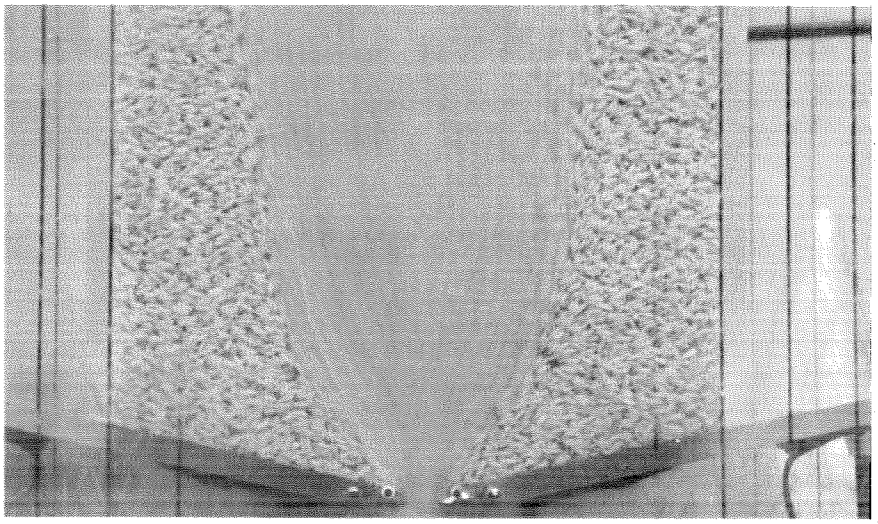


As sand flows down the chute, it is partially backed up behind a gate while a layer of sand continues flowing over the top, a phenomenon known as a hydraulic jump when it occurs in water. Rolf Sabersky points out an element of the flow to students Henry King (center) and Bill Ledeboer. Christopher Brennen observes at left.

and in how the soil of the Los Angeles basin might behave during a great earthquake.

Brennen and Sabersky's research, which has been funded by Union Carbide and the National Science Foundation, deals with both the theoretical and experimental aspects of these flows, which are two-phase flows, that is, a mixture of solid and fluid (air or water). In very low concentrations, such as dust in wind, the mixture behaves as a normal fluid with stresses determined by the suspending medium (air). But as concentration of the solid increases to the point where particles collide with sufficient frequency, the stress communicated by the collisions may increase to the point where it dominates that transmitted by the suspending medium. Of course, many granular flows are determined by both of these effects — collisions and the viscous forces in the suspending medium.

These particle collisions have an analogy in kinetic, or molecular, theory but with two problems that make granular materials more difficult to deal with than gases: their high density, or solids fraction, and the inelasticity of the collisions; that is, energy is dissipated every time a particle collides with another. (Energy is conserved in collisions of atoms or molecules.) The flow behavior involves the relationship between the stresses, or pressure, on the one hand and the solids fraction and the random motion of particles (analogous to temperature in molecular theory) on the other.

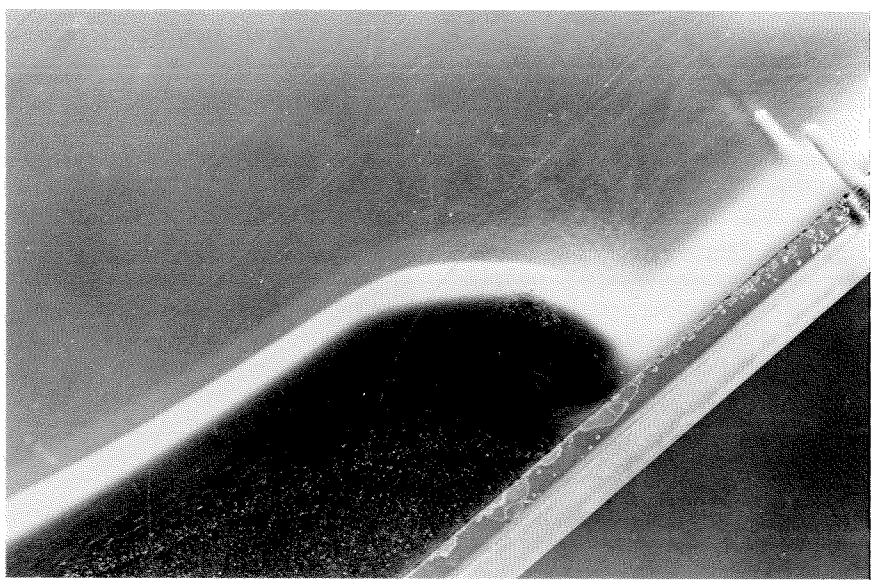


Rice grains remain stagnant at the sides of this hopper, while only the center moves as a "funnel flow." Most hoppers are designed to avoid stagnant regions.

Work in Sabersky and Brennen's groups (currently including graduate students Charles Campbell, Scott Patton, and Karel Spelt) involves postulating certain of these relationships, putting them in the equations of motions, solving for certain flows, and then comparing them with experimental results from relatively simple flows in hoppers and chutes. They are developing new instrumentation and techniques to get inside these flows in order to measure velocity and density at particular points. They also have simulated flows on a computer. One of the problems they have encountered in the experiments is the buildup of electrostatic charge. Friction between particles can turn a hopper into a Van de Graaff machine, creating substantial voltage differences. This phenomenon may in fact be involved in some of the explosions in grain elevators.

Substantial progress has already been made in a specific engineering problem — designing hoppers to avoid "funnel flow," which leaves stagnant regions along the sides. To achieve the desired mass flow, Brennen and Sabersky investigated the geometry of the hopper; its height and width, the shape of its parts, and the shape of the particles intended to flow through the hopper (for example, the elongated grains of rice) are all factors that needed to be considered.

Experimenting with granular flow means carrying a lot of sand around (or rice, mustard seed, glass beads, or plastic granules), and this has generated some transport problems of a local nature. Bucket brigades from the bottom of the chute to the top of the hopper are one solution, but it becomes more complicated when the stuff must be trucked to another floor so it can descend steeper chutes. A hole in the basement of Spalding to accommodate the lower end of the chute will soon solve that problem. Students researchers carrying buckets, however, will probably continue to joke about majoring in sandbox. □



The backed up stationary layer of sand can be seen in this cross-sectional view of the "hydraulic jump" experiment. There is another very interesting spot of stationary granules near the top of the curve, where a vortex is created adjacent to the main flow. Lighting from above makes the top surface appear light.

The Great Solar Blackout of 1980

by PETER DEWEES

As the train lurched to a halt, I looked out the window to verify that I had at last arrived in Puri. In the two months since I had left California, I had come halfway around the world to get to this spot on the eastern coast of India. Why Puri? Because on that February afternoon there was to be a total eclipse of the sun, and Puri lay directly in the path of totality.

It would be misleading to suggest that I had undertaken this trip with the express purpose of catching an eclipse in India. I had been wandering through the South Pacific and Southeast Asia, and Puri was only my next stop — chosen because back at Caltech I had read about the coming eclipse and realized that I could watch it in Puri if I stopped there on my way to Nepal to go trekking in the Himalayas.

Trying in Calcutta to arrange to make the Puri stop had introduced me to the bureaucratic hassles and piles of red tape that bog down every process in India that requires paperwork. It took me the better part of a day to track down a train ticket. First, I had to get an allocated seat from the "tourist quota." Then I had to make a reservation, buy a ticket, and confirm the reservation. All of this may sound like standard tourist trouble, but each step required going to different windows in different buildings in different parts of a very large city. And in front of each window was a queue of at least ten people trying to do the same things as I.

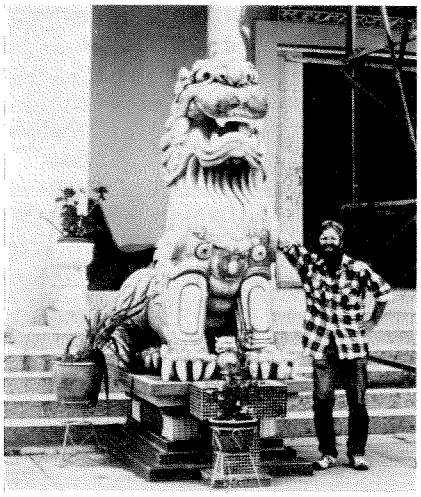
The train left on schedule in the early evening, and 12 hours later I woke up in the chill of the early February morning, shaking a layer of soot off my blanket. The coal-powered locomotive sent clouds of the stuff billowing out of its stacks, and half of it seemed to have ended up in my compartment.

At the Puri station, which we reached about 10 A.M., everything was relatively subdued. The ticket office was conveniently located right there, making it possible to book passage easily for the next leg of the trip. Getting something to eat turned out to be not as easy as I'd hoped, and by that time I was hungry. Indian train stations usually have restaurants of sorts, offering food of reasonable quality and variety. I sat down at a table in the restaurant adjacent to the Puri station and glanced over the menu printed on a sign in Hindi and English. I decided on *masala dosa*, a wonderfully spiced vegetable mix wrapped in a thin bread shell. But, my waiter informed me, they had no *dosa*. Okay, I would have *dalbaht*, a thick lentil soup poured over a bed of rice. No *dalbaht* either. Several suggestions later I asked the waiter what they did have. Eggs. I could have anything made out of eggs — scrambled, hard-boiled, or omelets. Most food, it seems, would be poisonous during the lunar passage, but for some reason eggs were safe, perhaps because their shells protected them. In Puri, the restaurants were taking no chances.

I was aware that the coming eclipse had caused quite a stir throughout the country. The Calcutta newspaper, for example, had been filled with warnings about some of the very real dangers of watching it, referring specifically to retinal damage that could be caused by staring directly at the sun. But there were other articles too that reflected some widely held beliefs about actually nonexistent dangers (to Western minds). Not only would food be tainted, but one might even die from the effects of the eclipse. Pregnant women would later give birth to infants with birth defects. In the 20th century, these were very real fears for people who had never gotten out of the Dark Ages. The *Hindustan Times* of February 14 had an article that said:

> "The sun will be in great agony during the coming eclipse, and all our prayers will be for its health," said a sadhu [a holy man] today in a temple on the Yamuna bank. Most of the sadhus and Brahmins have decided to go to Kurukshetva and stand in the holy waters there for the duration of the eclipse.

The people were quite intent in their fears. The country had come to a standstill while its 620 million inhabitants waited for the outcome of that afternoon's celestial happening.

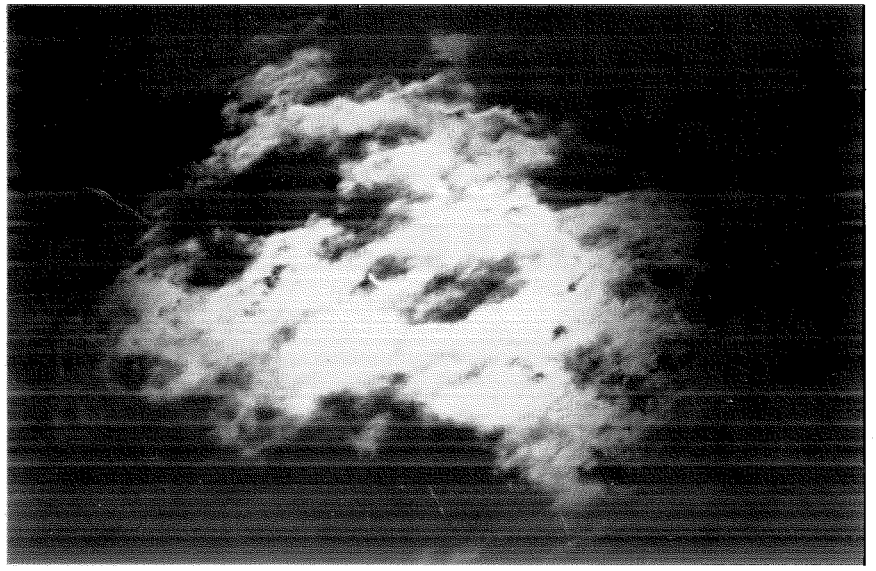


Peter Dewees outside a Buddhist temple in the Cameron Highlands, Malaysia, which was one stop in his travels during the year after he graduated from Caltech in 1979. Another stop is described in this article. Dewees is currently a graduate student in biology at Dartmouth College.

Since the eclipse obviously had such great religious and mythological importance, I later made an effort to identify some of the common themes. In Hindu solar mythology, Surya, the Sun god, is manifested in 12 solar divinities, each of whom serves all sorts of useful functions. Puchan provides food for all living things. Indra, the Lord of the Gods, is the destroyer of their enemies. Varuna dwells in the heart of the waters and gives life to the universe. Vivasvan causes good digestion.

Vishnu is the manifestation of Surya who rides about the sky in his solar chariot, not unlike the Apollo of the Greeks. In eclipse mythology, a demon, Svarbhanu, once drank some of the nectar of immortality, and in retaliation Vishnu lopped off the demon's head with his sword. But because the demon had become immortal, his head goes flying about the heavens for all eternity. Whenever Svarbhanu's head catches up with Vishnu, it devours him, thus causing darkness to fall upon the earth. Indra then frees Vishnu from Svarbhanu and restores light to the earth.

This mythology helps to make it clear why Hindus so greatly fear eclipses. Vishnu, the preserver and bringer of all good things, is no longer manifest. Minor demons have free reign over the earth while Vishnu is hidden by Svarbhanu. Mere mortals must hide for their lives from the



A tiny sliver of solar crescent shows through the broken clouds as the eclipse of the sun nears totality. Puri, India, February 16, 1980.

demons who will wreak havoc upon the earth during the period of totality.

Even though the mythology also explains why eclipses take place, there has long been an understanding in India that such events do not occur randomly. There are reports that Indian astronomers from the 15th century could predict the coming, the length, and the path of totality of eclipses to an amazing degree of accuracy. But in spite of the scientific knowledge, the mythology — and the fears — remain.

As everyone waited for this eclipse, Puri was like a ghost town, with the shops boarded up tight and few people on the streets. One exception was at the famous Jagganath Temple, which seemed to be the only place where people were congregated in any numbers — perhaps just because it was a religious edifice.

As a young American traveling alone in India, I was an object of curiosity. People would approach me on the street, in train stations, in museums and parks, and ask, "Please, what is the purpose of your visit?" In Puri it was difficult to persuade anyone that I was just an interested tourist, not a European scientist there to observe the eclipse. As far as I could tell, there were no Western scientists in town, but I understood there was a scientific expedition from an Indian institution. When I tried to track them down, I got the impression they were trying to avoid the throngs of the curious who were pestering them. I was just one of the throng.

Totality was to take place around 3:30 P.M., and with a few hours to kill I wandered down to the beach on the shore of the Bay of Bengal to write a few letters and update my journal. Even there my presence attracted a small crowd of people, among whom was an Indian university student who introduced himself and asked me if I would go with him to meet some of his friends and watch the eclipse with them.

I followed him to a three-story brick structure that turned out to be a dormitory, and there I at once became the uneasy center of attention for about 30 of those friends. Most of them just stared at me and smiled. I figured it was going to be a really long afternoon if I just stared at them and smiled back, so I started telling them about myself and what I was doing there. Only a few of them really spoke English, but a torrent of questions followed — about my Levis, for instance; did everyone in America wear them? Who was going to arrange my marriage? What did I study? The answer, "cell biology," only drew blank looks. The only types of biology these students seemed to recognize were botany and zoology.

I didn't get the impression that the students I met reacted differently to the eclipse than the rest of the population. In answer to my questions about food, they said (perhaps in deference to me) that they didn't think the eclipse would really have any effect on it, but that the holy men had told them dire consequences would come from eating, and they thought it best to listen to their holy men. I was left with the feeling that the ban on food was an attempt to purify the body and spirit so that the people would be strengthened in their ability to prevail against any evil that might come to them during the eclipse. The concept of a fast in Christian countries seems to me to be quite similar.

As totality approached, we went to the rooftop. High clouds had threatened to obscure the view, but they broke in the last minutes before darkness. The sequence of events leading to totality was no different here than in an eclipse anywhere else. Twilight began to fall by midday. Birds took off in flight. Shadows became distorted by the crescent sun. Dogs started barking. Suddenly it became like night. The stars came out. A pink glow extended around the horizon. What I didn't expect were the cries, the wails, the moaning that rose from the town. Horns were blown and drums were beaten, presumably to ward off the darkness or the evils that might come from it.

Then, as quickly as it had come, the darkness was gone. Bright beads of light first glimmered as the sun peeked through the valleys of the moon's profile. The beads gave way to a sliver of a solar crescent. Within an hour, the sun was restored to fullness.

Svarbhanu had once again been vanquished by Indra. Vishnu's fiery chariot could continue its celestial journey, bringing light and good to the hearts of men. And the world did not come to an end — this time. □

Indian astronomers have predicted eclipses since the 15h century. This observatory in New Delhi was constructed by the Maharajah Jai Singh II about 1730.

Indian university students adopted Dewees for the afternoon of the eclipse, which they all watched from the roof of the student dormitory.

Trevor Byer's software takes a hard look at telephone traffic.

As a result, calls flow more smoothly through the nationwide network.

Shortly after Trevor Byer came to Bell Labs in 1976, we asked him to join a design team tackling a big job. Their task: find a way to determine the accuracy, completeness and timeliness of the hundreds of millions of traffic measurements collected weekly in the Bell System. The job was important because engineers and managers at each Bell telephone company use the measurements to assure that enough equipment and circuits are available to meet customer demands.

The solution that Trevor Byer's team came up with was the Centralized System for Analysis and Reporting, or CSAR. Trevor focused on determining how much information telephone company managers needed, and how that information could best be reported to them. His responsibilities ranged from software design and systems engineering to field testing of reports and training of CSAR users. With a BS and MS in Electrical Engineering from the University of Illinois, Trevor was prepared for the job.

Here's how CSAR works. Once a week all the Bell telephone companies transmit performance data from their computers to a central computer in Piscataway, N. J. Overnight, CSAR analyzes the information, organizes it for use in many ways, including management reports designed by Trevor, and stores it for retrieval the next day.

From their own computer terminals, CSAR users in the telephone companies request a variety of reports: from summaries of switching system performance for an entire company to detailed performance of individual switching systems. The reports can be displayed graphically to summarize performance trends over weeks, months, or longer.

CSAR is one of more than a hundred computer-based systems used by the Bell System to provide better network performance and better service to customers.

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From Science: Service

ALUMNI FLIGHTS ABROAD
1980-1981

This program of tours, originally planned for alumni of Harvard, Yale, Princeton, and M.I.T., is now open to alumni of California Institute of Technology as well as certain other distinguished colleges and universities. Begun in 1965 and now in its sixteenth year, it is designed for educated and intelligent travelers and planned for persons who might normally prefer to travel independently, visiting distant lands and regions where it is advantageous to travel as a group.

The program offers a wide choice of journeys to some of the most interesting and unusual parts of the world, including Japan and the Far East; Central Asia, from the Khyber Pass to the Taj Mahal and the Himalayas of Nepal; the surprising world of South India; the islands of the East, from Java and Sumatra to Borneo and Ceylon; the treasures of ancient Egypt, the world of antiquity in Greece and Asia Minor; East Africa and Islands of the Seychelles; New Guinea; the South Pacific; the Galapagos and South America; and more.

REALMS OF ANTIQUITY: A newly- expanded program of itineraries, ranging from 15 to 35 days, offers an even wider range of the archaeological treasures of classical antiquity in Greece, Asia Minor and the Aegean, as well as the ancient Greek cities on the island of Sicily, the ruins of Carthage and Roman cities of North Africa, and a comprehensive and authoritative survey of the civilization of ancient Egypt, along the Nile Valley from Cairo and Meidum as far as Abu Simbel near the border of the Sudan. This is one of the most complete and far-ranging programs ever offered to the civilizations and cities of the ancient world, including sites such as Aphrodisias, Didyma, Aspendos, Miletus and the Hittite citadel of Hattusas, as well as Athens, Troy, Mycenae, Pergamum, Crete and a host of other cities and islands of classical antiquity. The programs in Egypt offer an unusually comprehensive and perceptive view of the civilization of ancient Egypt and the antiquities of the Nile Valley, and include as well a visit to the collection of Egyptian antiquities in the British Museum in London, with the Rosetta Stone.

SOUTH AMERICA and THE GALAPAGOS: A choice of itineraries of from 12 to 29 days, including a cruise among the islands of the Galapagos, the jungle of the Amazon, the Nazca Lines and the desert of southern Peru, the ancient civilizations of the Andes from Machu Picchu to Tiahuanaco near Lake Titicaca, the great colonial cities of the conquistadores, the futuristic city of Brasilia, Iguassu Falls, the snow-capped peaks of the Andes and other sights of unusual interest.

EAST AFRICA—KENYA, TANZANIA AND THE SEYCHELLES: A distinctive program of 5 outstanding safaris, ranging in length from 16 to 32 days, to the great wilderness areas of Kenya and Tanzania and to the beautiful islands of the Seychelles. The safari programs are carefully planned and comprehensive and are led by experts on East African wildlife, offering an exceptional opportunity to see and photograph the wildlife of Africa.

THE SOUTH PACIFIC and NEW GUINEA: A primitive and beautiful land unfolds in the 22-day EXPEDITION TO NEW GUINEA, a rare glimpse into a vanishing world of Stone Age tribes and customs. Includes the famous Highlands of New Guinea, with Sing Sings and tribal cultures and customs, and an exploration of the remote tribal villages of the Sepik and Karawari Rivers and the vast Sepik Plain, as well as the North Coast at Madang and Wewak and the beautiful volcanic island of New Britain with the Baining Fire Dancers. To the south, the island continent of Australia and the islands of New Zealand are covered by the SOUTH PACIFIC, 28 days, unfolding a world of Maori villages, boiling geysers, fiords and snow-capped mountains, ski plane flights over glacier snows, jet boat rides, sheep ranches, penguins, the Australian "outback," historic convict settlements from the days of Charles Dickens, and the Great Barrier Reef. Optional visits can also be made to other islands of the southern Pacific, such as Fiji and Tahiti.

CENTRAL ASIA and THE HIMALAYAS: An expanded program of three itineraries, from 24 to 29 days, explores north and central India and the romantic world of the Moghul Empire, the interesting and surprising world of south India, the remote mountain kingdom of Nepal, and the untamed Northwest Frontier at Peshawar and the Punjab in Pakistan. Includes the Khyber Pass, towering Moghul forts, intricately sculptured temples, lavish palaces, historic gardens, the teeming banks of the Ganges, holy cities and picturesque villages, and the splendor of the Taj Mahal, as well as tropical lagoons and canals, ancient Portuguese churches, the snow-capped peaks of the Himalayas along the roof of the world, and hotels which once were palaces of maharajas.

THE FAR EAST: Itineraries which offer a penetrating insight into the lands and islands of the East. THE ORIENT, 30 days, surveys the treasures of ancient and modern Japan, with Kyoto, Nara, Ise-Shima, Kamakura, Nikko, the Fuji-Hakone National Park, and Tokyo. Also included are the important cities of Southeast Asia, from Singapore and Hong Kong to the temples of Bangkok and the island of Bali. A different and unusual perspective is offered in BEYOND THE JAVA SEA, 34 days, a journey through the tropics of the Far East from Manila and the island fortress of Corregidor to headhunter villages in the jungle of Borneo, the ancient civilizations of Ceylon, Batak tribal villages in Sumatra, the tropical island of Penang, and ancient temples in Java and Bali.

Prices range from $2,350 to $4,500 from U.S. points of departure. Air travel is on regularly scheduled flights of major airlines, utilizing reduced fares which save up to $600.00 and more over normal fares. Fully descriptive brochures are available, giving itineraries in detail and listing departure dates, hotels, individual tour rates and other information. For full details contact:

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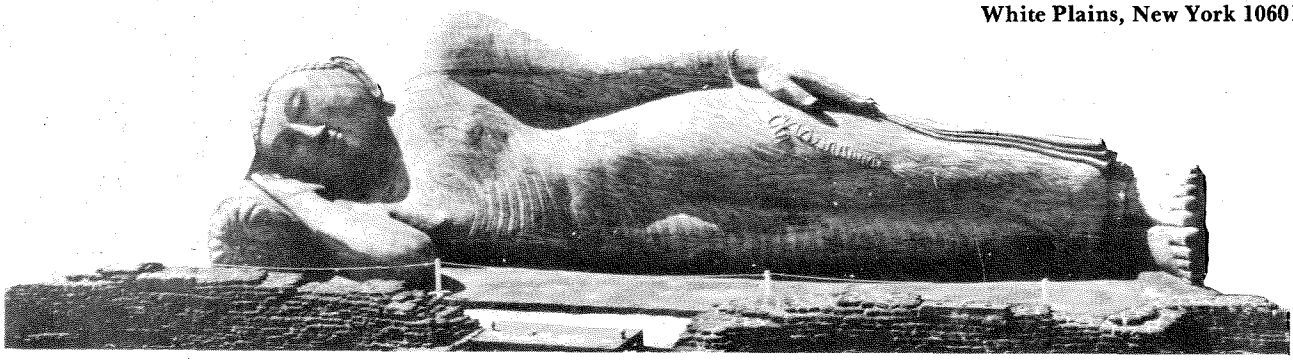
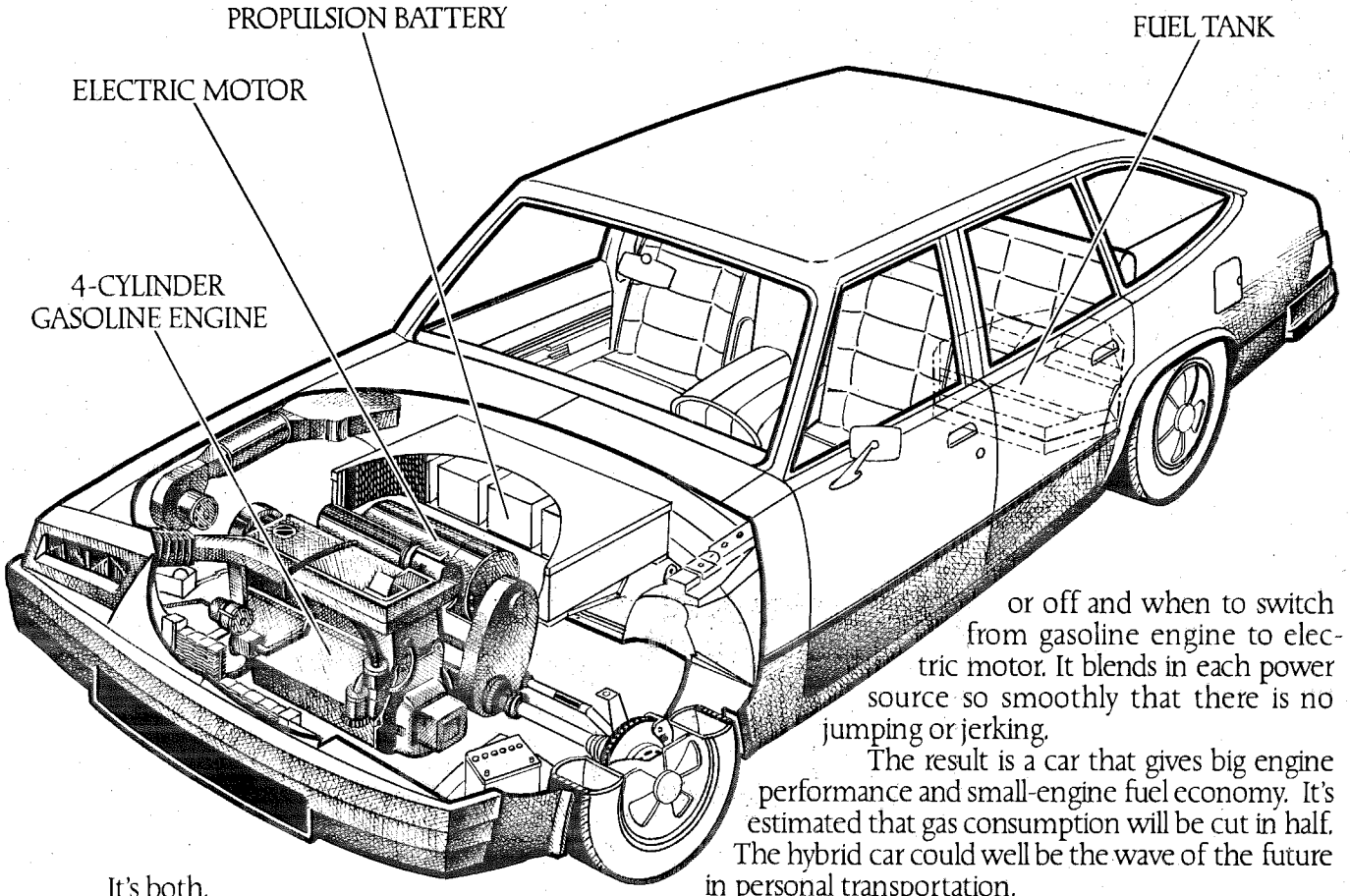


Is it an electric car that runs on gasoline, or a gasoline car that runs on electricity?



It's both.

It's a hybrid car being developed by General Electric for the Department of Energy. It's powered by both a gasoline engine and an electric motor.

This car runs part of the time on gasoline, part of the time on batteries, and combines both power sources when needed.

The electric motor will be used primarily for speeds from zero to 30 mph, and the gasoline engine for most highway driving. When you need extra power for passing, the electric motor automatically kicks in to boost the power.

The key to the operation of this vehicle is a GE-designed microcomputer. This computer, about the size of a cigar box, continually receives signals from more than three dozen sensors, measuring all the functions of the vehicle.

The microcomputer takes this information and determines the amount of power needed to meet the driver's command when he presses on the accelerator or brake pedal. It then decides when to turn power on or off and when to switch from gasoline engine to electric motor. It blends in each power source so smoothly that there is no jumping or jerking.

The result is a car that gives big engine performance and small-engine fuel economy. It's estimated that gas consumption will be cut in half. The hybrid car could well be the wave of the future in personal transportation.

Looking for new and practical solutions to transportation problems is just one example of research in progress at GE. We're constantly investigating new technologies, new materials, and innovative applications for existing technologies—in such areas as energy sources, motors and drives, aerospace systems.

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