

VOLUME XCVIII

NUMBER FOUR

THE NATIONAL GEOGRAPHIC MAGAZINE

OCTOBER, 1950

New Map of South America

Peru, Homeland of the Warlike Inca

With 40 Illustrations
29 in Natural Colors

KIP ROSS

Puya, the Pineapple's Andean Ancestor

With 18 Illustrations
13 in Natural Colors

MULFORD B. FOSTER

Sky-high Bolivia

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Strife-torn Indochina

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ORGANIZED FOR "THE INCREASE AND DIFFUSION OF GEOGRAPHIC KNOWLEDGE"

To carry out the purposes for which it was founded sixty-two years ago, the National Geographic Society publishes this Magazine monthly. All receipts are invested in The Magazine itself or expended directly to promote geographic knowledge.

Articles and photographs are desired. For material The Magazine uses, generous remuneration is made.

In addition to the editorial and photographic surveys constantly being made, The Society has sponsored more than 100 scientific expeditions, some of which required years of field work to achieve their objectives.

The Society's notable expeditions have pushed back the historic horizons of the southwestern United States to a period nearly eight centuries before Columbus crossed the Atlantic. By dating the ruins of the vast communal dwellings in that region, The Society's researches solved secrets that had puzzled historians for three hundred years.

In Mexico, The Society and the Smithsonian Institution, January 16, 1939, discovered the oldest work of man in the Americas for which we have a date. This slab of stone is engraved in Mayan characters with a date which means November 4, 291 B. C. (Spinden Correlation). It antedates by 200 years anything heretofore dated in America, and reveals a great center of early American culture, previously unknown.

On November 11, 1935, in a flight sponsored jointly by the National Geographic Society and the U. S. Army Air Corps, the world's largest balloon, *Explorer II*, ascended to the world altitude record of 72,305 feet. Capt. Albert W. Stevens and Capt. Orvil A. Anderson took aloft in the gondola nearly a ton of scientific instruments, and obtained results of extraordinary value.

The National Geographic Society-U. S. Army Air Forces Expedition, from a camp in southern Brazil, photographed and observed the solar eclipse of 1947. This was the seventh expedition of The Society to observe a total eclipse of the sun.

The Society cooperated with Dr. William Beebe in deep-sea explorations off Bermuda, during which a world record depth of 3,028 feet was attained.

The Society granted \$25,000, and in addition \$75,000 was given by individual members, to the Government when the congressional appropriation for the purpose was insufficient, and the finest of the giant sequoia trees in the Giant Forest of Sequoia National Park of California were thereby saved for the American people.

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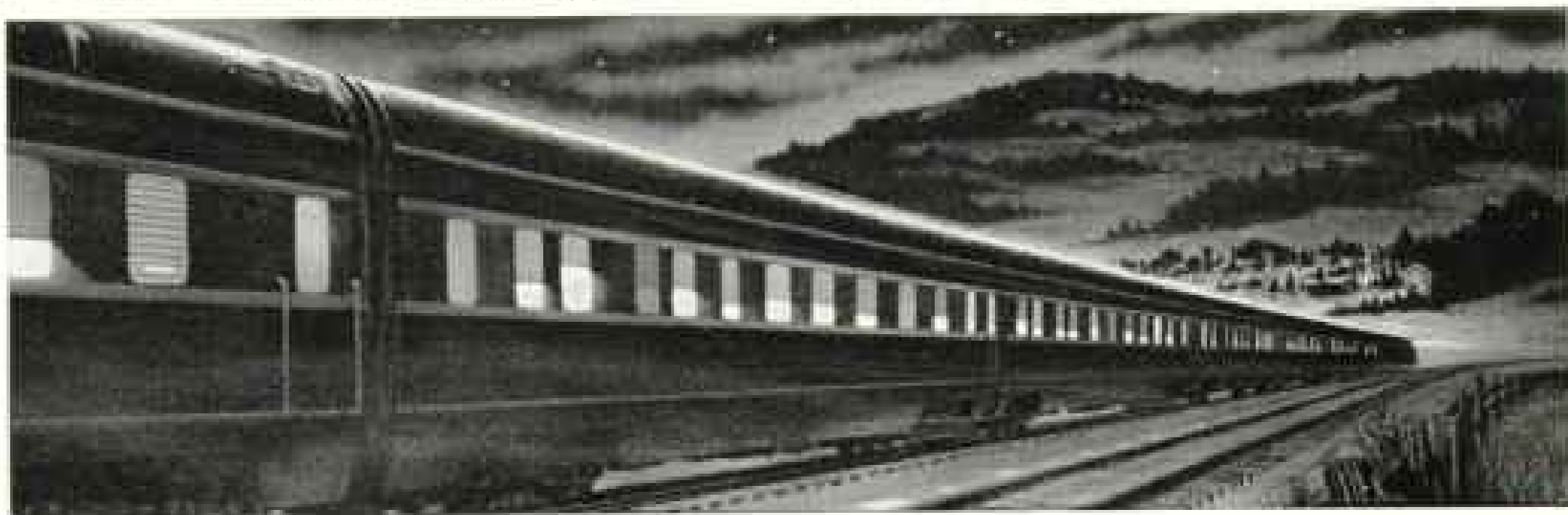
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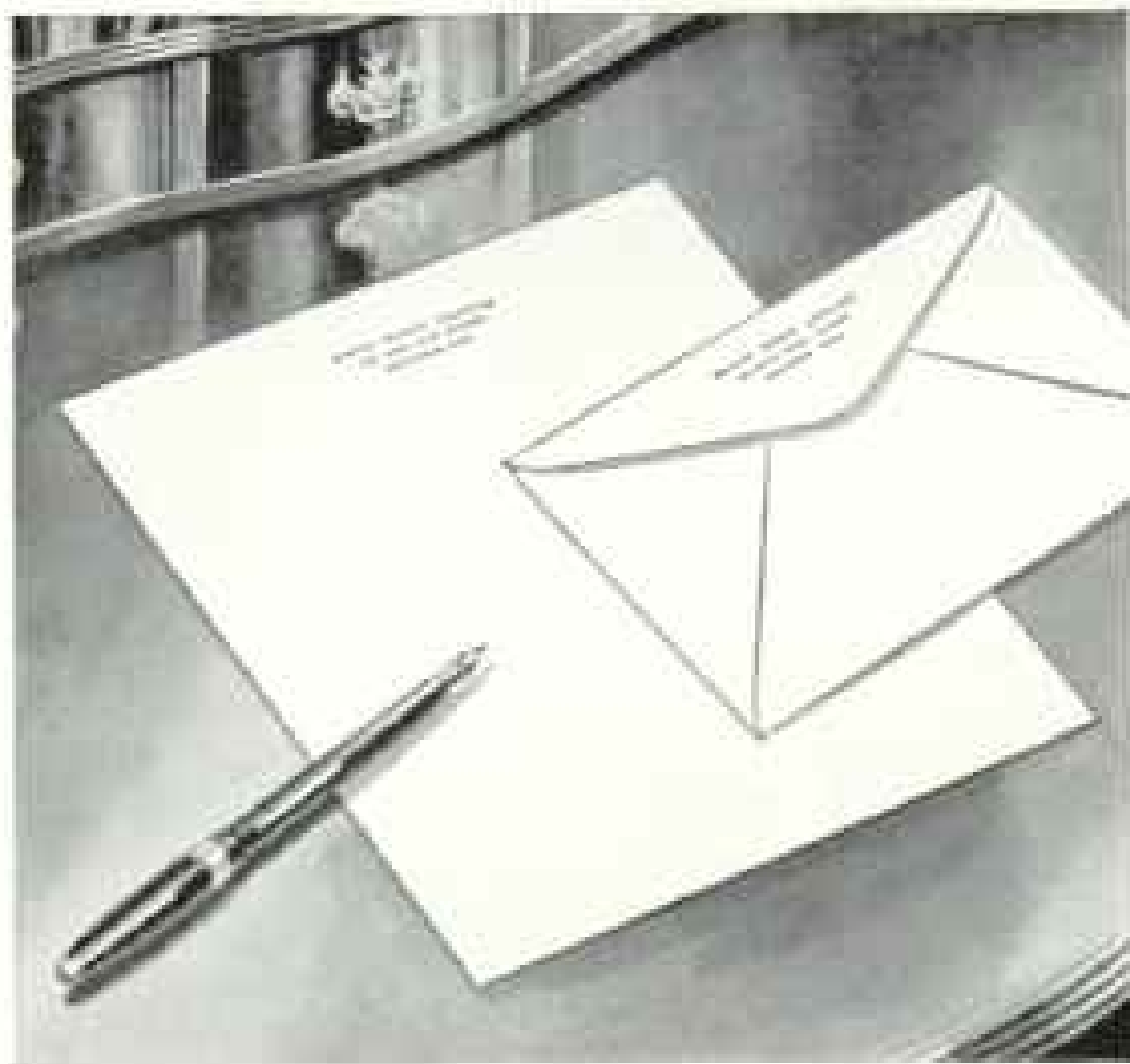
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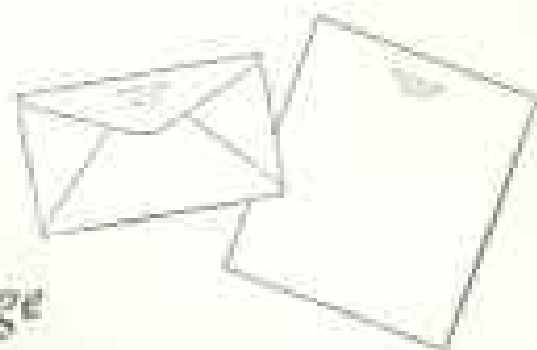
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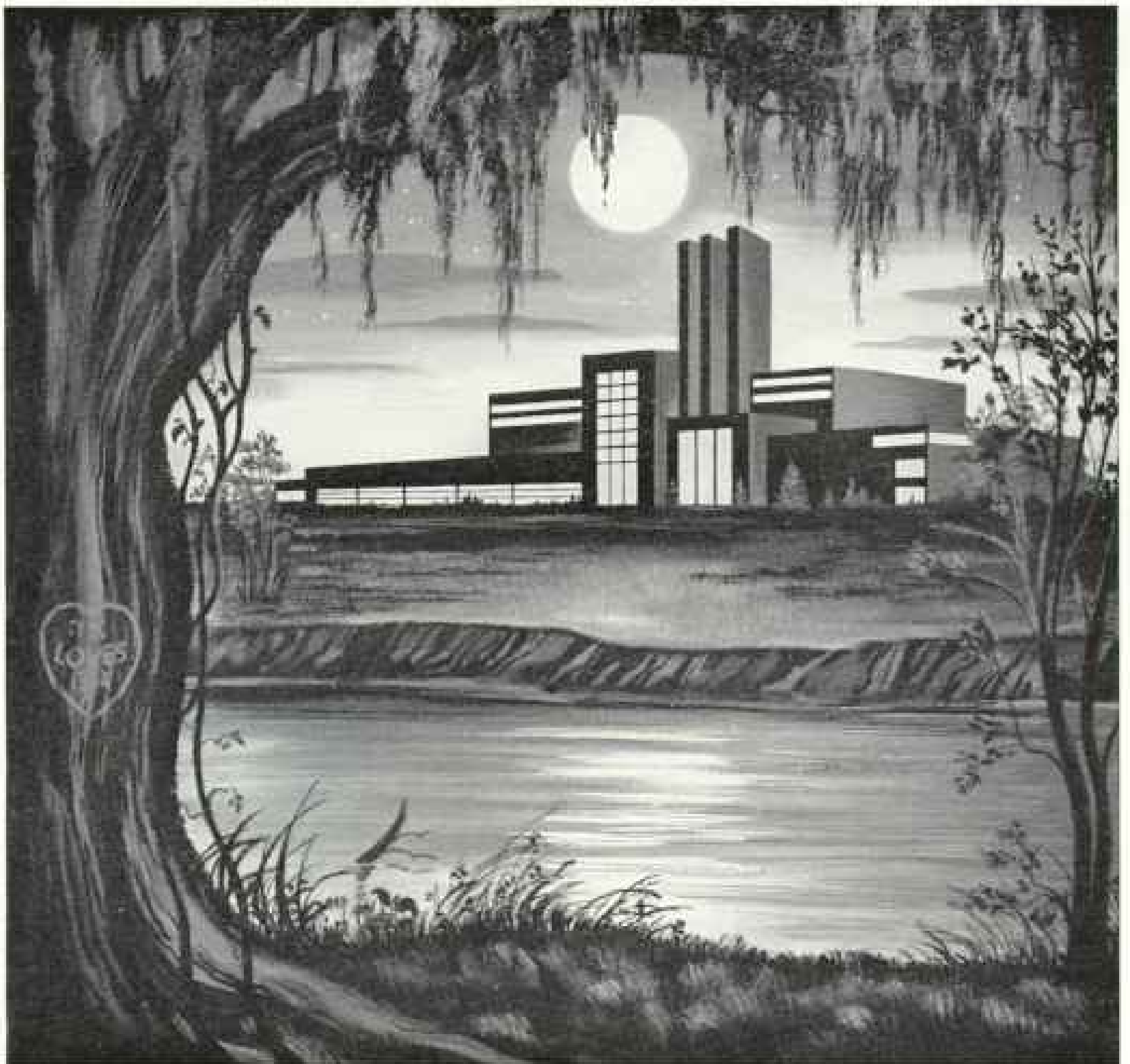
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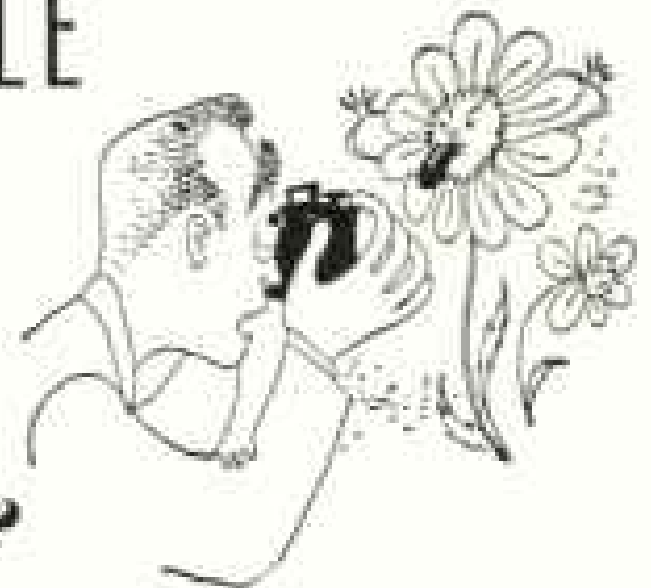
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Surprise! Surprise! I wonder whether
This card foretells uncertain weather?
Stormy skies, roads drenched with rain
Not a fit night out for car or plane!



9 Diamonds—Good Luck

But look at this... the lucky nine!
Your trip is certain to be fine.
You're traveling (it's plain as plain)
Aboard a New York Central train!



8 Clubs—Pleasure

The eight of clubs betokens pleasure.
I see you dining at your leisure,
Or finding time for conversation
With new friends in the observation.



Three Tens—All Fine

Three tens mean everything's okay
For you to dream the miles away.
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10 Spades—Another Town

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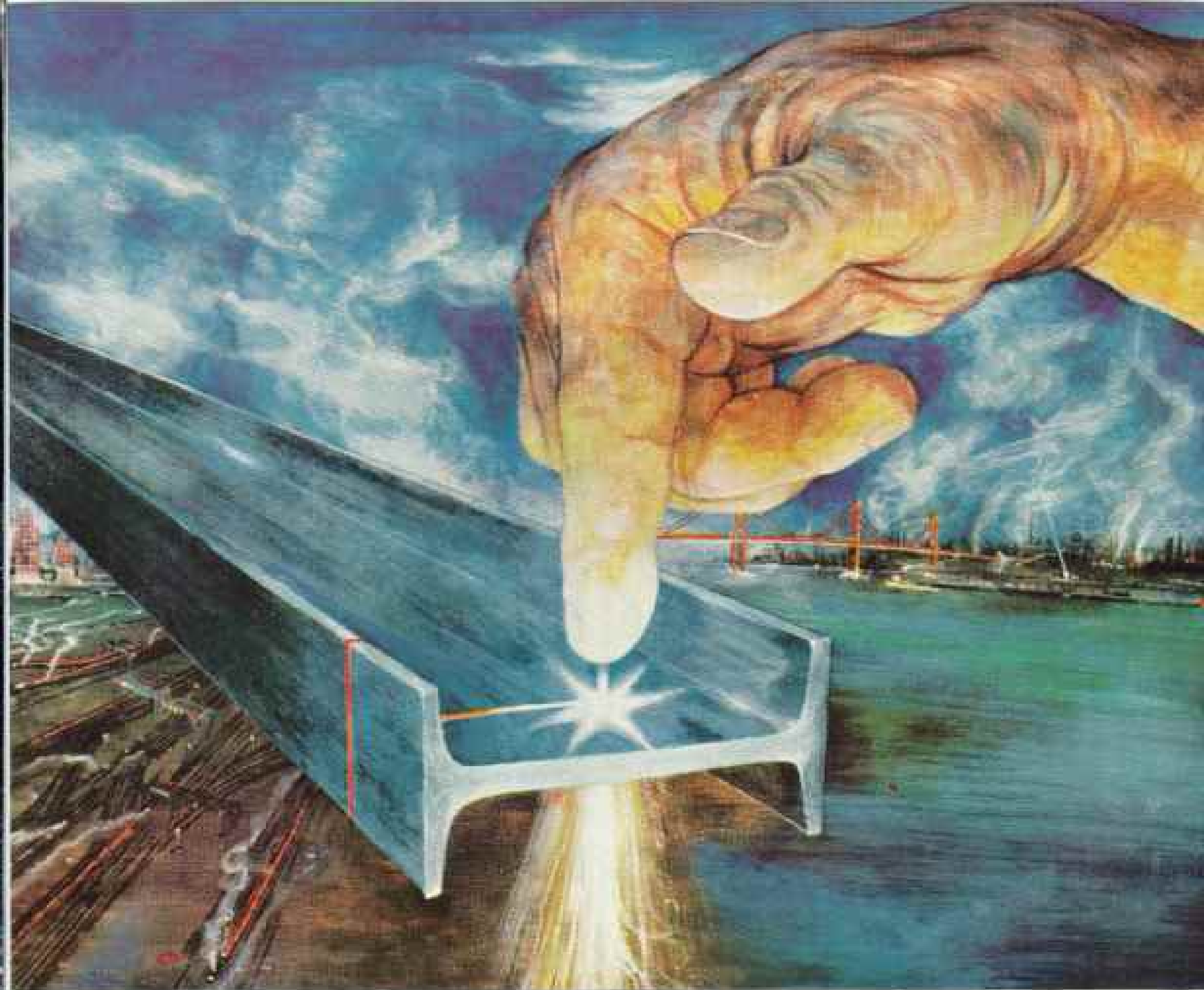
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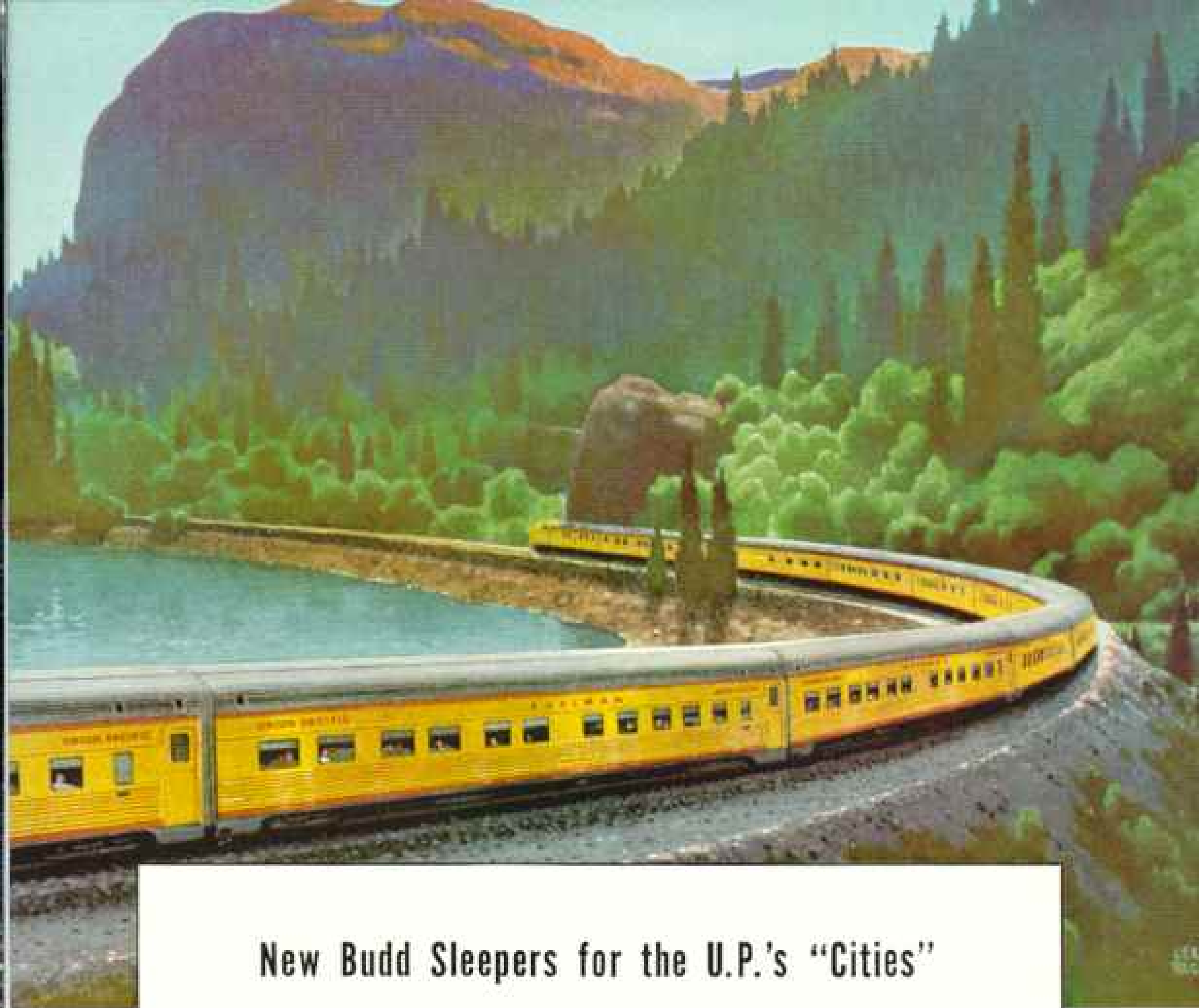
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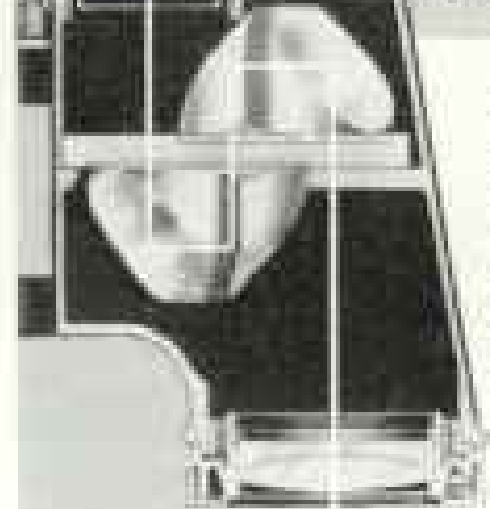
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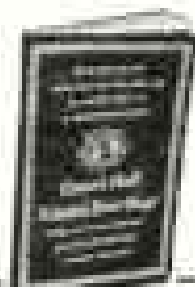
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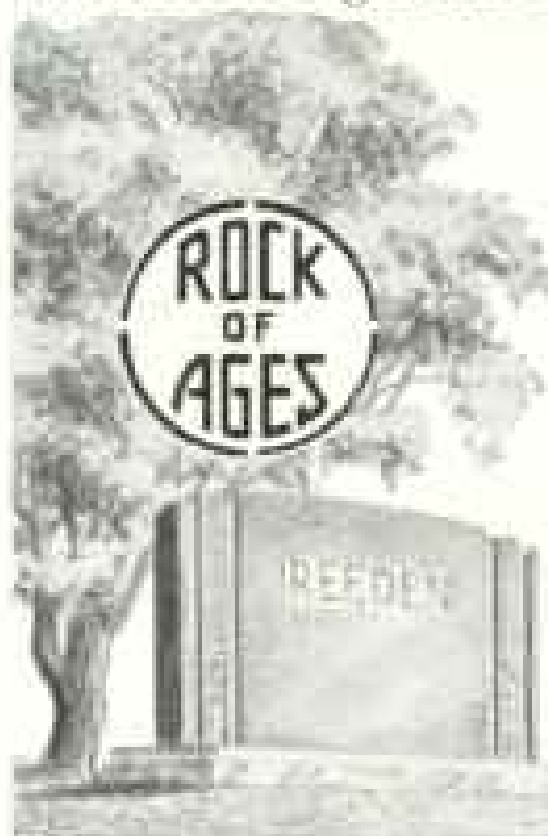
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New weapons help fight ARTHRITIS

MEDICAL SCIENCE is definitely on the march against arthritis. For example, experiments with many new substances have shown great promise in test cases, even though they have not as yet been completely verified on a broad scale. These substances, however, are very scarce and at present are available only



for research purposes and for limited use in treatment in certain hospitals.

Even without such substances, doctors today know more than ever before about arthritis and how to treat it. They also know that one of the big problems is to get people to have prompt medical attention in the early stages of the disease.



Too often those with arthritis rely on so-called "sure cures" which may temporarily relieve pain but generally do little or nothing to correct the fundamental situation. According to the Arthritis and Rheumatism Foundation, *if proper treatment is started early, about 60 percent of the arthritis patients can*

be greatly helped and in some cases completely relieved.

There are many different forms of arthritis. The two most common are rheumatoid arthritis which usually begins before age 40, and osteoarthritis which is found most often in people past middle age. Using approved diagnostic methods, including a complete physical examination, the doctor can usually determine what type of arthritis is present and prescribe the treatment best suited to the patient's *individual* needs.

Among other things, the doctor may recommend bringing the weight down to normal.



Even as little as 10 or 15 pounds of extra weight may appreciably increase the pain of arthritis, especially in the weight-bearing joints. He may also suggest following a nutritious but moderate daily diet, maintaining proper posture, and paying careful attention to daily hygiene.

While great strides have been made in treating the disease, medical research is continuing its efforts to develop more effective weapons against the many forms of arthritis. Today, doctors believe that the future holds real hope for the millions of people with this condition.

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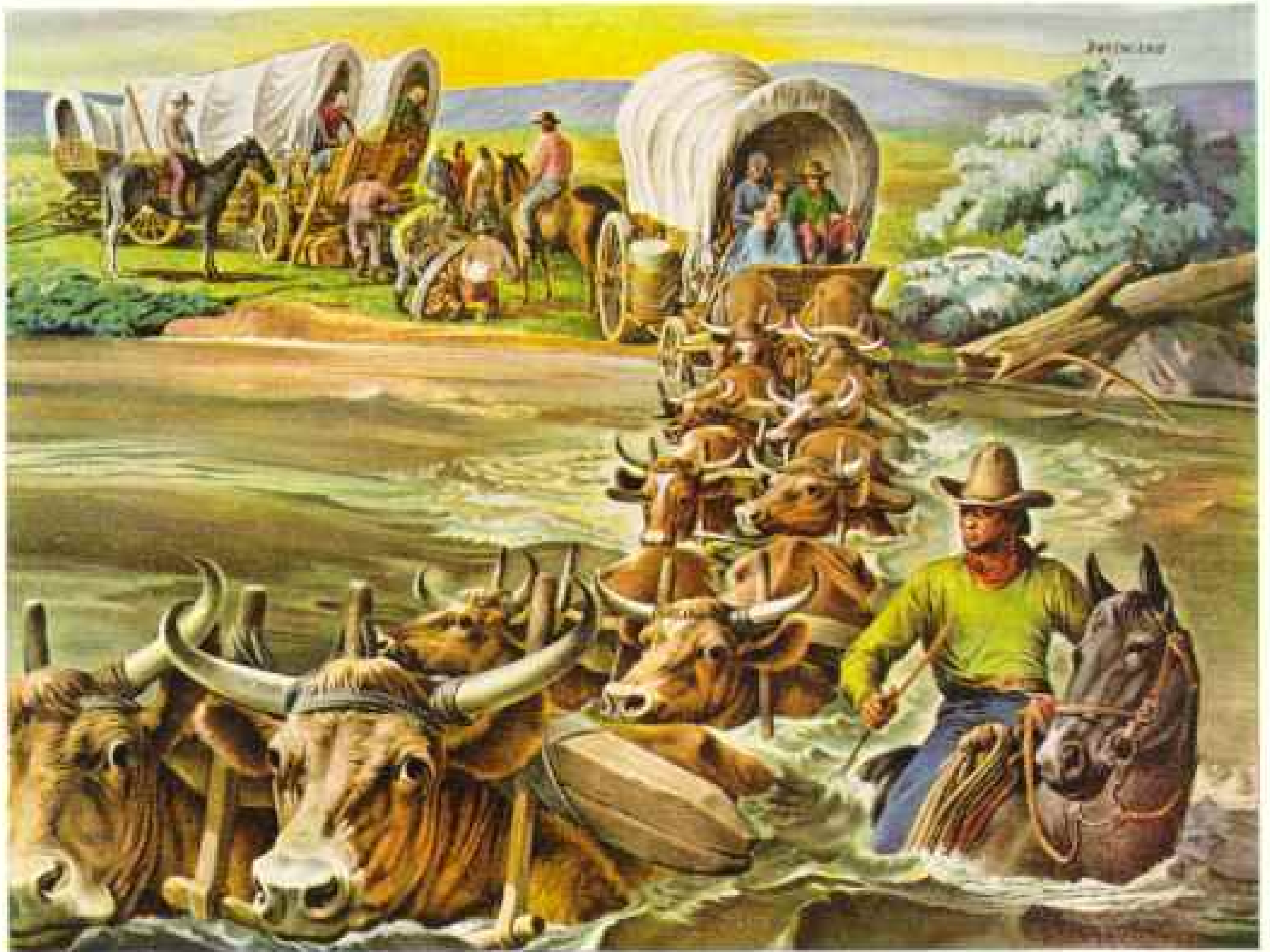
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This idea put them across the Platte

LEADERS of the covered wagon trains heading West in the 1860's dreaded the fording of the Platte.

The river acquired its ominous reputation because even experienced scouts could never tell where the pockets of quicksand and the potholes lay—so changeable was the strong current of the broad and muddy stream.

When an ox-team bogged down, stalling a wagon, the prairie schooner was usually overturned—dumping family and possessions into the river.

Pioneers soon learned from scouts, who had crossed the river before, how to tackle the Platte.

When a number of wagons had arrived at the river, the oxen from all of them were hitched together to pull each of the families across. Even though one team in the long string floundered, enough were on *sure footing* to keep the wagon on the move.

Maybe you've never thought of it, but every family today—just as the pioneers crossing the Platte—is faced by dangers it cannot cope with alone.

A fire or windstorm may damage the home. An accident or death may stop the salary the family lives on—and cost its life savings in hospital and doctor bills.

In facing such dangers as these, no man need stand alone. Through insurance, you combine your resources with others who face the same kind of danger (as the pioneers did their wagon teams) and make sure *no one suffers financial loss*.

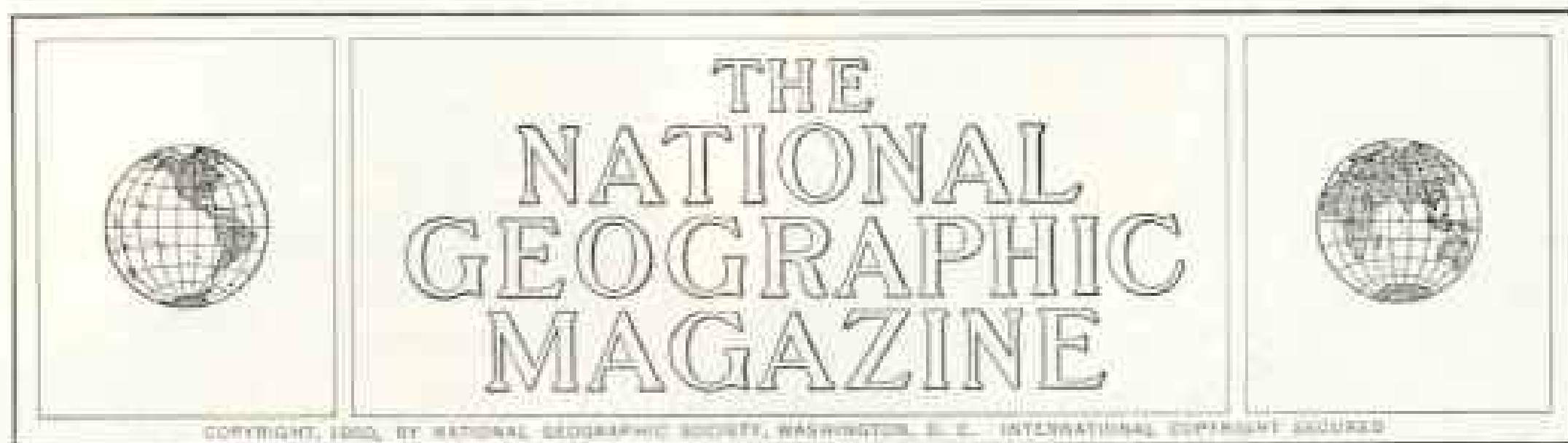
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Peru, Homeland of the Warlike Inca

By KIP ROSS

With Illustrations from Photographs by the Author

MOST of all on my last visit to Cusco I think I missed the sound of church bells. The earthquake had silenced them.

First reports of the disaster in Peru on May 21, 1950, received at National Geographic Society headquarters, indicated that the whole of this venerable city was in ruins.

Since I was then writing this article about Peru, I had to learn at once the extent of the damage. Accordingly, I packed my cameras and took off from Miami on the famed Pan American "Interamericano" plane for Lima. Two days later I was in Cusco to see things for myself.

First glimpse of the city from the air was deceiving. Superficially, it appeared the same pink-roofed jewel of the Andes as shown on page 442. At the airport I was greeted by Dr. Albert A. Giesecke, Civil Attaché of the U. S. Embassy staff in Lima, who had come to Cusco to coordinate relief and reconstruction work. From his jeep, on our way to the hotel, I saw the earthquake's shocking devastation (pages 422, 423).

Inca Walls Stood Firm

Towers of many of Cusco's famous Spanish colonial churches were fallen or shattered. Walls of the narrow old streets had caved in, blocking passage entirely in many instances. Some had been propped up with long poles to prevent collapse.

Every plaza, every available open space, was dotted with tents, temporary shelters, and medical dispensaries. Our driver constantly sounded his horn to clear homeless children and confused oldsters from our path (pages 427, 447).

Yet the ancient Inca walls stood firm! Earthquakes were not new to them.

Some 500 years before the Spanish conquest, the Incas, without knowledge of the wheel or of steel, raised these massive granite structures. How they shaped and dressed the stone, so hard that it will cut glass; how they notched the blocks to fit snugly together without mortar; and how they hoisted them, one on the other, sometimes to a height of 15 feet, are achievements which amaze all who see them (pages 424, 425, 426).

The conquering Spaniards destroyed the Inca temples and palaces, but they did not completely raze their walls. They used them as foundations upon which to erect their own buildings of stone and mortar masonry.

These newer structures tottered and collapsed in the quake. Adobe houses, many with walls three feet thick, were badly damaged. Some 90 percent of all the homes in Cusco were considered more or less unsafe for occupancy. Ninety people were killed.

But, unlike the walls of Jericho, those of the Incas refused to come tumbling down.

Chaos had followed in the wake of the disaster. Relief came quickly to the stricken community from the Peruvian Government and from the Peruvian, American, and International Red Cross. Building materials, medicines, clothing, and blankets were rushed in by plane in a confused jumble. Hourly the disorder grew worse. Then Dr. Giesecke arrived from Lima and, with the aid of other tireless workers, brought order.

This remarkable gentleman, known as "first citizen of Cusco," had lived in the community for many years, although he is a citizen of the United States. For 12 years he had



Crumbled Tower and Buttressed Cloisters Proclaim the Ruinous Cusco Earthquake

To the Incas, gold was the "tears wept by the sun," their deity. They made his temple a veritable gold mine, its walls sheeted with gold, its gardens filled with golden flowers and trees. Rumors of this treasure led Francisco Pizarro to conquer and loot the city in 1533. Spaniards, trying to erase Inca memory, converted palaces into dwellings, temples into churches. Here Monastery of Santo Domingo rises above the Temple of the Sun. Struck by earthquake, May 21, 1950, its Spanish superstructure cracked, its Inca walls endured.

headed the University of Cusco; for three he served as the city's mayor.

The Cusqueños for the most part accepted the disaster philosophically, and I found them cheerfully tackling the job of cleaning up the wreckage. The Peruvians are among the most gracious of all Latin Americans. The Cusqueños particularly possess a charm all their own, as distinct as their Inca heritage and the unusual city which is their home. But the tragic aspects of the quake were always present.

As I was strolling in San Agustín Street, for example, I came to a corner where an adobe house had collapsed into a heap of rubble. Atop a section of an adjoining wall sat the owner, an elderly woman. Men were clearing away the debris. At intervals one of the workers would pause, hold up a tattered remnant of household equipment or a damaged trinket.

"Shall we save this?" he would ask.

"No, it's of no use now. Throw it away

with the rest," she would respond in a voice of resignation.

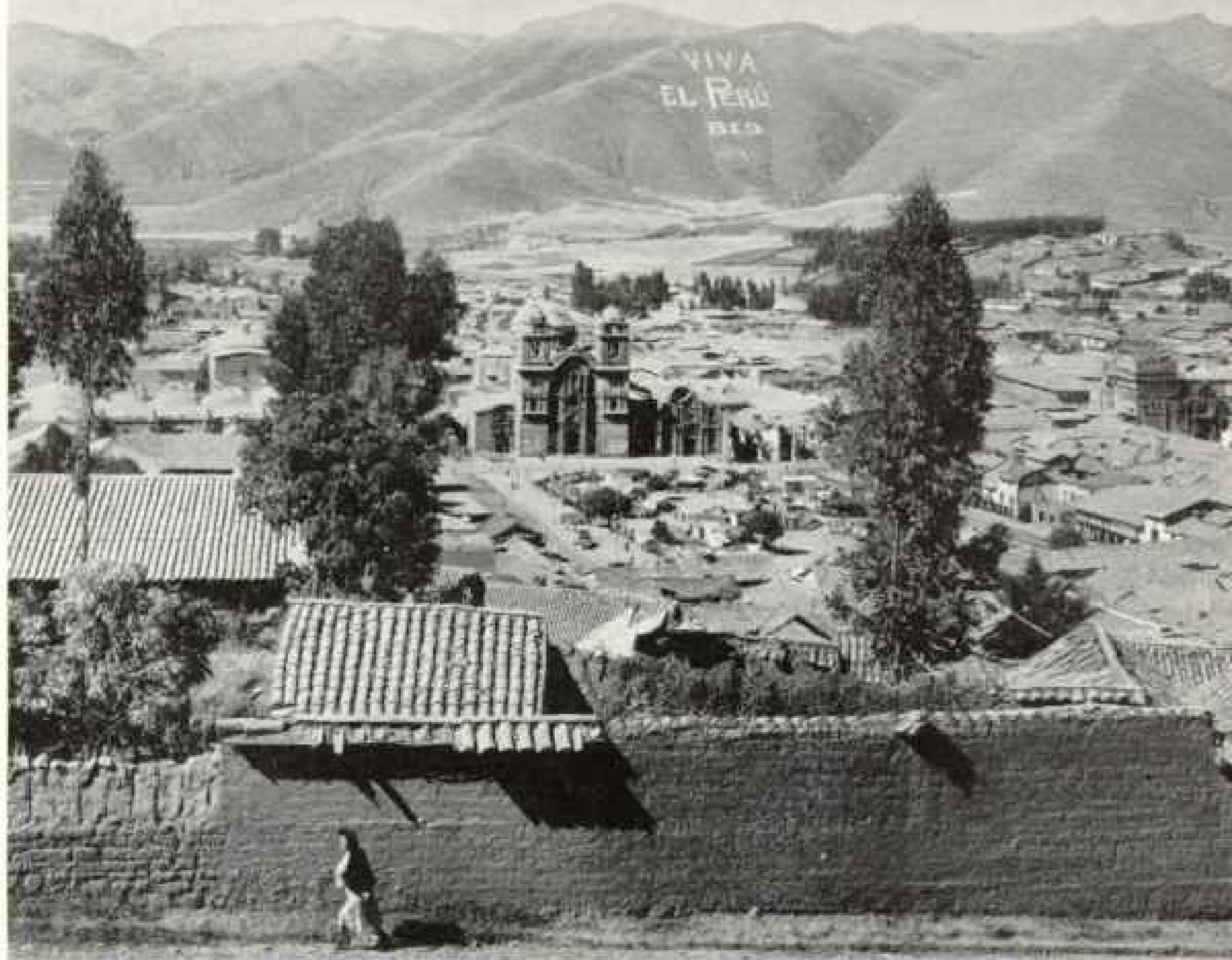
To return and see old friends and familiar surroundings under such circumstances was sad.

Restoration will require several years. However, if plans materialize, the city eventually will be even more interesting than before, since a distinguished group of scientists and archeologists is studying plans to make restoration as accurate as possible.

Recalls First Visit to Peru

My return to Cusco recalled some of my first contacts with the fascinating people of the Peruvian Andes.

With Rosita, my Spanish-American wife, I had taken an air tour around South America. We first touched Peruvian soil at Lima, but because we were eager to see the mountain country—most of all, Machu Picchu—we took off next morning for the short hop to Arequipa.



423

Cusco's Upright Appearance Is Deceiving; the Earthquake Damaged 90 Percent of Its Homes

A general view taken a month after the quake shows the Plaza de Armas crowded with refugees' tents (page 447). Twin-towered La Compañía (center), erected by the Company of Jesus on the ruins of an Inca palace, suffered such injury that visitors were barred. La Merced (right), founded in 1536 and damaged by both the 1650 and 1950 quakes, sheathes its tower in scaffolding. "Viva el Perú" was boldly chalked on the mountainside by patriots of Battalion 19, Peruvian Army, who destroyed a Communist sign there.

From our flying classroom the geology and geography of the region unrolled below us.

The coastal area of Peru is a desert, one of the world's driest places. It stretches between South America's highest mountain range on one side and the Pacific Ocean on the other.

The earth beneath us skimmed past in wide stretches of Saharalike sands, blown into frozen wave patterns or crescent-shaped dunes by the ceaseless march of the winds.

There were no oases such as those of the Sahara. Instead, this desert is veined by many Niles. In comparatively recent geological times the narrow land shelf was elevated to its present height, and rivers, draining from the mountains, cut deep trenches to the sea.

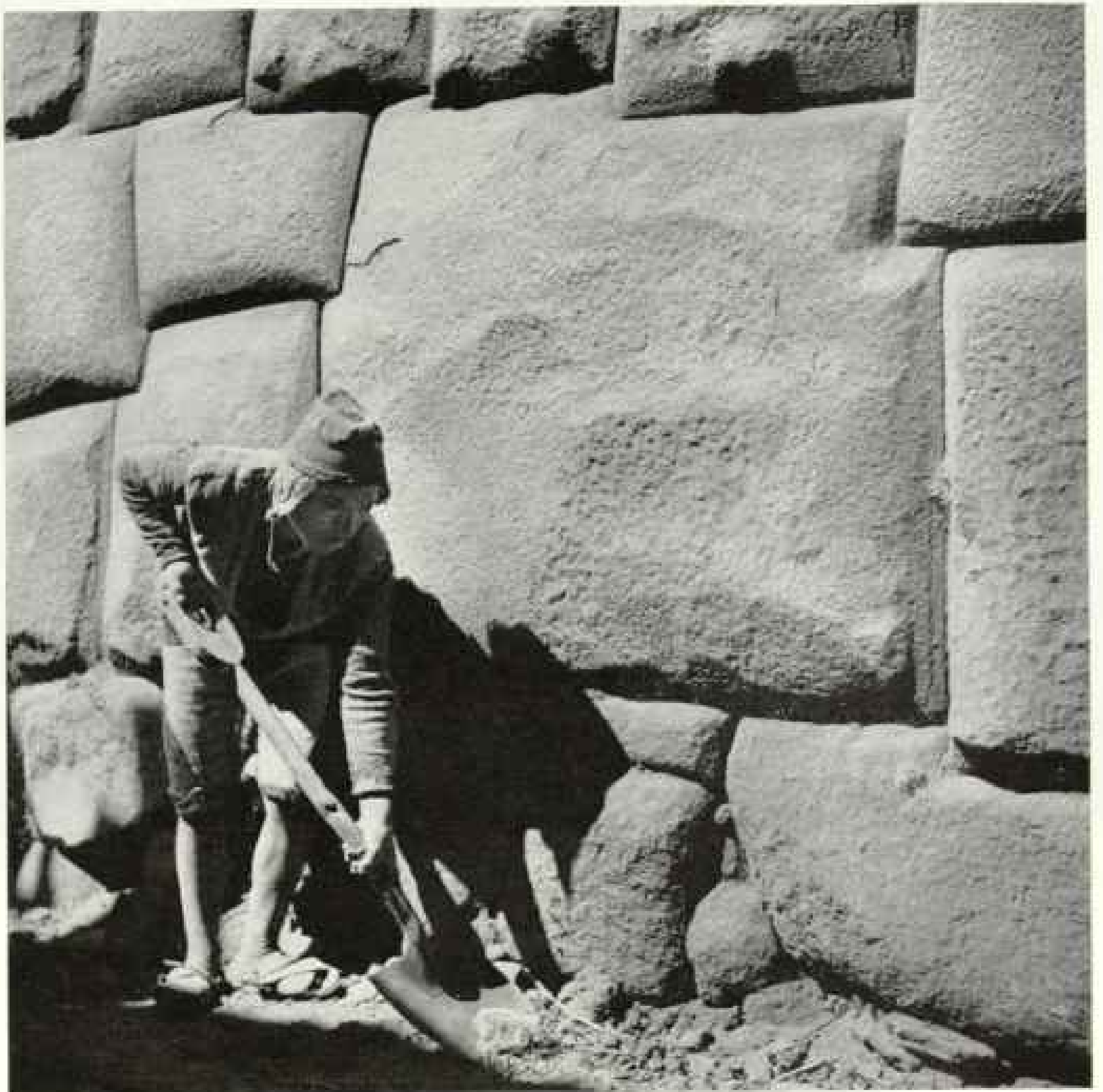
From one side of the plane we could look down into these valleys, each with a strip of brilliant green along the banks of its central river. Red-tiled roofs of tiny farmhouses gave a homey touch. From the other windows we looked east to the peaks of the sky-reaching Andes, silhouetted in the early-morning light.

From the air we looked down upon a giant relief map, for along the flat, dry surfaces of these uplifted areas we saw patterns of ancient river systems, complete with tributaries which tapered off into branches fine as ferns. They had not held water for years.

Suddenly something caught my eye. In contrast to the curving, irregular lines of rivers, the straight line I saw seemed strangely out of place. Then other lines came into view, some parallel, some intersecting, some fanning out like radio beacon marks. Mostly they ran east and west. Although they looked man-made, I saw no signs of habitation (page 448).

An Ancient Farmers' Almanac

Later, back in Lima, I met Miss María Reiche, astronomer and engineer, who explained the mysterious lines. That area was once the territory of the Nasca civilization, which preceded that of the Incas. Astronomers of this ancient world probably laid out



Cusco's Mortarless, 12-angled Stone Fits Its Neighbors Like a Jigsaw-puzzle Piece

Lacking steel tools and blasting powder, ancient quarrymen cut monoliths, some weighing hundreds of tons, and moved them, without cranes or horses, across mountains. Then masons, working without cement, ground and fitted the blocks, some of irregular shape, so perfectly that, centuries and earthquakes later, razor blades cannot find a chink in many joints. Engineers can only guess at the ancients' secret methods.

these lines to aid their observations of the sun, moon, stars, and planets. Here indeed was an old farmers' almanac on a grand scale!

From the other side of the plane beautiful snow peaks beckoned. There was El Misti, 19,031 feet high, between his two less famous brothers, Chachani and Pichu-pichu, 19,077 and 18,054 feet, respectively. Then we started dropping down to land at Arequipa.

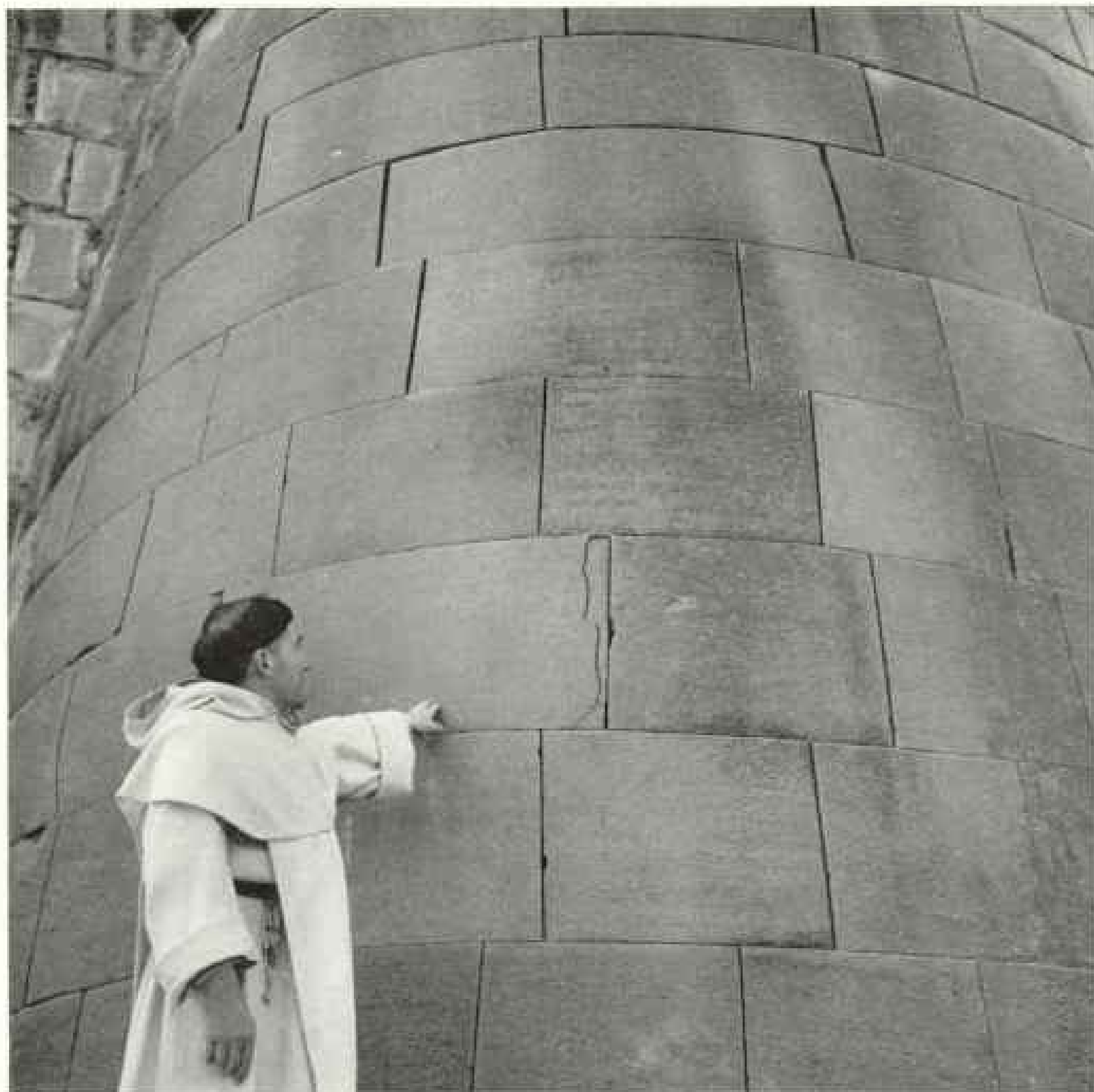
This lovely city lies in the lap of the Andes at an altitude of 7,500 feet, where average day-time temperature is 74° F. and average temperature after sundown is 58°. It has little rain and almost always clear, sunny skies. We found

this second city of Peru busy and modern.

Beneath electric light and telephone wires boys herd sheep or cattle along paved streets lined with walls of brilliant white and pink *sillar*, a volcanic substance which is a principal building material. Barefooted Indians trot over the cobblestones to market, and proud llamas mince daintily along the street-car tracks.

I had been told that llamas, alpacas, guanacos, and vicuñas were timid. The alpaca I met was not.*

* See "Camels of the Clouds," by W. H. Hodgr, NATIONAL GEOGRAPHIC MAGAZINE, May, 1946.



Solid Granite Splits (Center), but the Inca Joint an Inch Away Holds Fast

Ancient Peruvians, using rough, many-sided stones, constructed walls of amazing strength. Later, in the Inca period, they ground down smooth, rectangular blocks to build walls of exquisite grace. Indian architects planned this curving wall with a precise mathematical formula; yet they never attained the true arch. Father Calderón Sadoc's hand rests on the Temple of the Sun, foundation of his Church of Santo Domingo. Upper stones, yielding to earth shocks, have separated slightly. (pages 422, 426).

In the new Hotel Turista we sat at a neat table beside a wide casement window. Beyond lush green grass and eucalyptus trees spread a matchless view of El Misti.

Through the open window a shaggy black head reached suddenly for the top roll on our plate. Just outside stood a full-grown alpaca! The waiter explained that this friendly fellow liked to vary his diet of grass with hot buttered rolls from guests' tables (page 462).

Four days of sight-seeing in this important city gave us time to get our breath before pushing farther into the Andes.

The train from Mollendo on the Pacific coast to Puno on Lake Titicaca ran only on Mondays, Wednesdays, and Fridays, and was already panting from its preliminary climb.

How short, I wondered, will our own breath be when we get to the high valley floor?

Two Days of Ups and Downs from Arequipa to Cusco

The salon car was early-American, equipped with leather-upholstered chairs. At one end of the car stood two men in uniform, one tall, the other slight, both neat in appearance. In



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Inca Walls, Built for Eternity, Defy Time and Quake; Spanish Frosting Topples

What must Cusco Indians think as they compare their ancestors' mortarless stones with the conquerors' cemented works? To picture Santo Domingo's former glory, see the NATIONAL GEOGRAPHIC MAGAZINE, August, 1941, page 168.



A Cloud of DDT Safeguards an Indian Against Vermin-borne Typhus

Following the earthquake, health authorities set up road blocks and stopped everyone entering Cusco. They vaccinated many against smallpox; they sprayed DDT above and beneath garments. Ticked by the hoses, most women screamed or giggled, but this one remained impassive.

other seats were a few Peruvian civilians.

The Southern Railway train took us steadily upward in a series of sweeping curves through rich green areas of alfalfa, wheat, and other irrigated fields bordered by varieties of cedar, cypress, and lovely eucalyptus. Soon most of the vegetation petered out, and our train twisted, swayed, and creaked through barren hills.

The taller of the two uniformed men introduced himself as Lt. Álvaro Lunati Revoredo, of the Guardia Civil of the Cusco Department. He was about six feet, broad-shouldered and husky, with friendly brown eyes.

The Civil Guard is a body of national police, all picked men especially trained for their work. They must have a knowledge of law, geography, history, mathematics, and native languages. Lunati was returning from headquarters at Lima, the capital, to his post at Urubamba, north of Cusco.

The other man was Capt. Victor Rosas Ramírez of the Peruvian Army, also bound for an isolated station in the interior.

Soon he and his friend were telling us of that little-known land among the mountain peaks which is the home of one of America's oldest civilizations,

"Archeologists have only scratched the surface of the highlands," said Lunati. "You will see Cusco, the capital of the Inca Empire of 500 years ago, but you must also see Machu Picchu, a lofty city in the sky whose origins still are mysterious."

Mystery People of the High Mountains

"What are the people like?" I asked.

"Indians of the high mountain country are unlike other Peruvians," replied Rosas. "They have the usual Mongoloid characteristics, but they are short and stocky, with a peculiar ruddy complexion. We of the lowlands find the mountain air extremely thin; they thrive on it.

"The Quechua they speak is a dialect of an ancient language which once was spoken throughout most of the Andes region."

Both men spoke Quechua, and soon we were learning new words in that language. *Runa* means "man," *huarmi*, "woman," *rucana*, "finger," *cocha*, "lake," *yana*, "black." The sound of some words was descriptive, such as *cullcu*, "pigeon," and *huahua*, pronounced "wawa," meaning "baby."

At Pampa de Arrieros, a town at 12,303 feet above sea level, the train stopped for lunch.

Only those in the salon car had meals served on the train. From our window we saw other passengers pile out onto the platform where tables and chairs were set up in the open air.

The Top Higher than Pikes Peak

On station platforms I noted the increasing elevation—Pampa de Arrieros, 3,750 meters, Canaguas, 4,078 meters, Sumbay, 4,127 meters, Vincocaya, 4,377 meters. Every additional thousand meters meant approximately 3,000 feet of altitude.

"Here's a salute to the top!" said Lunati.

There, outside our window, bleak and gray in the clouds, stood the station of Crucero Alto, with the equivalent of 14,665 feet lettered in meters on the front. We were more than 500 feet higher than Pikes Peak (14,114), but as casual and gay as if we were back home on the Pennsylvania Railroad going from Washington to New York for a week end. No *soroche*, or mountain sickness, troubled us.

Soon after we crossed the divide, the country changed. Here among the perpetual clouds more moisture permitted vegetation. The slopes were covered with a tawny grass. Woolly flocks of llamas, alpacas, and occasionally the shy and gentle vicuñas grazed.

Now going downhill the train rattled and swayed. The air grew chilly, for the sun was setting. We saw more people and more farms. We were now in the midst of the *puno*, the higher section of the *altiplano*. This immense pampa of southern Peru lies between the two highest cordilleras of the Western Hemisphere* and averages more than 12,000 feet above the sea.

The sun had set behind the Western Range and it was dark as we left the train at Juliaca.

Our hotel room was on a rickety balcony overlooking a patio. There were no windows, but the cracks around the door provided plenty of ventilation.

Previous occupants had penciled their names and the dates on the walls—a sort of Spanish "Kilroy was here" covering many years.

Water was in an enameled pitcher beside a metal basin.

"Look, running water!" exclaimed Rosita.

We had it all right, for there was a half-inch hole in the bottom of the basin!

It was cold, too, for the lack of oxygen at 12,550 feet means less fuel for the blood, and we went to bed with everything but the linoleum piled on us!

Next morning Rosita, Lunati, and I took the train for Cusco. Until nearly noon we rode north and west across the vast puna.

The short, tufted grass reminded me of our

western plains. In the background rose crests of the mountains. For mile after mile these two mighty ranges paralleled the tracks.

We passed through tiny villages of adobe huts where loafers watched the train go by and women at doorways held up chunky brown babies to see the Indian equivalent of the choo-choo.

We waved to one man with an impassive Mongoloid face. He was in modern store clothes, his feet were bare, and he wore the age-old Indian *chullo*, a knitted skullcap with ear flaps. On top of this an American-style snap-brim felt hat fitted snugly. Suddenly he grinned and waved courteous good-bye.

At Chuquibambilla the train passed between neat wire fences, and in the distance we saw a tractor pulling a gang plow.

"That is the Peruvian Government's experimental farm," explained the lieutenant. "Here the modern heirs of ancient Peru are taught 20th-century agricultural methods.

"Once our people ranked among the greatest farmers in the world. Other ancient peoples knew about irrigation and the use of fertilizers, but centuries before Columbus we used methods which even your own experts have studied.

"Most farms of ancient Peru were terraced. All the earth in those thousands of terraces was put there by hand, sometimes after being carried for miles from some other place. Moreover, that soil was carefully selected for its composition and fertility and placed on terrace surfaces to form 'artificial' topsoil.†

"Now your experts learn from our ancients, and our moderns learn how to drive a tractor made in U.S.A."

At La Raya, once more over 14,000 feet, we passed out of the Titicaca basin and started down again. Although the change is almost imperceptible at this point, we had crossed an important watershed. A stream which had paralleled the track now was running with the train instead of against it.

"Now you are in the Amazon drainage," another passenger said. "That tiny trickle you see there eventually reaches the Atlantic, 4,000 miles away."

Grains Grow at High Altitude

Barley, maize (called *choclo*), and a pig-weed (*Chenopodium quinoa*) known as *quinoa*, which is another cereal, grow here at altitudes above 13,000 feet, watered by ice-cold streams from the mountain peaks.

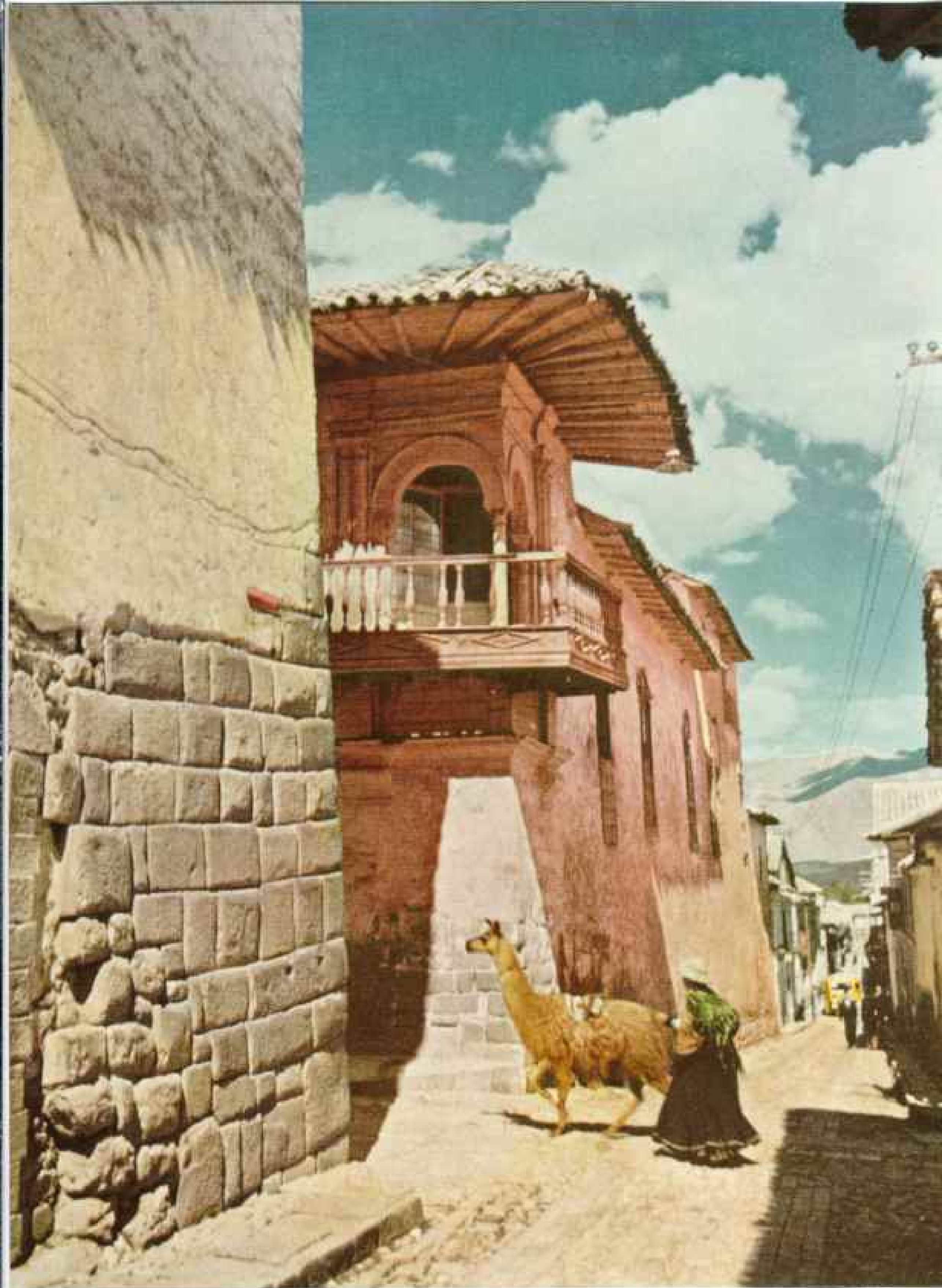
* See "High Lights in the Peruvian and Bolivian Andes," 18 ills. in color by W. Robert Moore, NATIONAL GEOGRAPHIC MAGAZINE, February, 1927.

† See "Staircase Farms of the Ancients," by O. F. Cook, NATIONAL GEOGRAPHIC MAGAZINE, May, 1916.



Indian and Llama, Partners in Peru's High Places, Thrive in the Thin Andean Air

This Quechua possesses the huge lungs that highlanders develop to withstand altitudes where airmen use breathing aids. His blood system, laden with extra hemoglobin to absorb oxygen, has more red cells than normal.



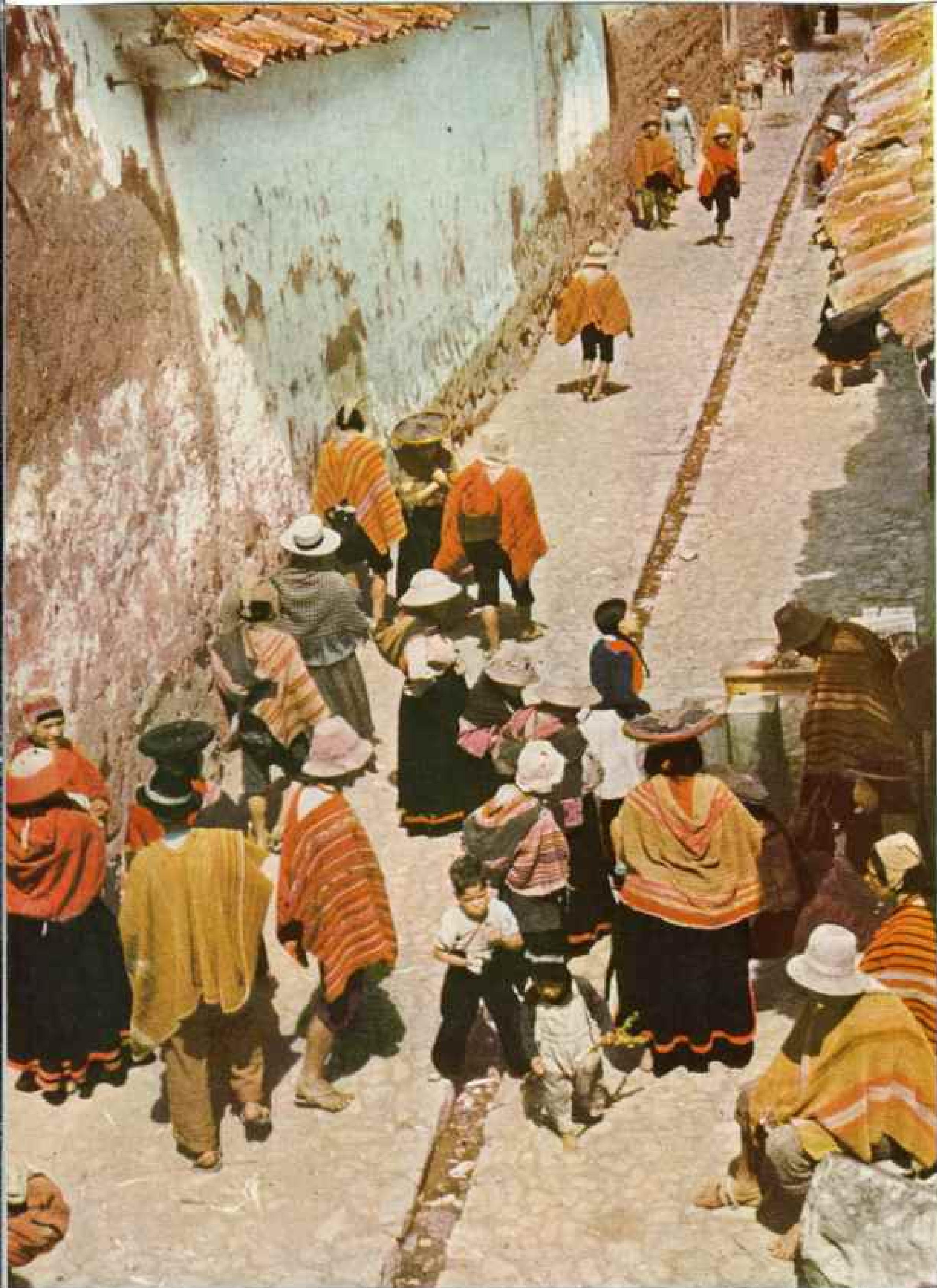
Cusco's Walls, Inca below and Spanish above, Blend Two Cultures in Stone and Stucco

These stout Inca walls, built without mortar, suffered no serious damage in the earthquake of May, 1950. The balconied home of a 17th-century Spanish nobleman stands on the site of the Emperor Roca's palace.



Lacy Spanish Balconies Overhang Narrow Streets Laid Out for Cusco's Llama Traffic

Today trucks flash by corners which never saw a wheel until Spaniards rolled in. Police try to keep llamas off the main streets. Portaled arcades (left) make convenient shelters during rains.



Pisac's Open Gutter Comes Down from the Incas, Who Lacked Underground Sewers.

Sunday market draws Indian women in flat hats and *cholar* (racial mixtures) in straws. They wear layer upon layer of skirts. A cap with ear flaps (right) suggests the Tibetan ear muffs of equivalent altitudes.



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Kodachromes by Kip Hoss

♣ Indian Dancers at Fiesta Shuffle along a Road near Pisac

Indians have always had to do Peru's heavy labor. Religious processions and folk dances of fiestas enliven their existence. Here, with mincing steps, they dance to antique music.

♣ A Dancer's Mask (Center) Pokes Fun at Spanish Mustaches

Facial hair is sparse among Peruvian Indians. Whiskers therefore mark a man as Spanish or *cholo*. Drummers and dancers at the gayest fiestas frequently wear mournful expressions. Grin (right) is rare.





Snow-capped Volcano, Green Trees, Tawny Cattle, and Evening Shadows Compose a Picture of Suburban Arequipa

Waters from 19,000-foot El Misti, the city's barren but imposing backdrop, help irrigate an area growing three crops of alfalfa a year.

An Indian Herds His Llamas Off the Calen Road to Let a Truck Pass. He Waits in Boredom; His Beasts Seem to Express Annoyance.

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Illustration by Keith Hunt





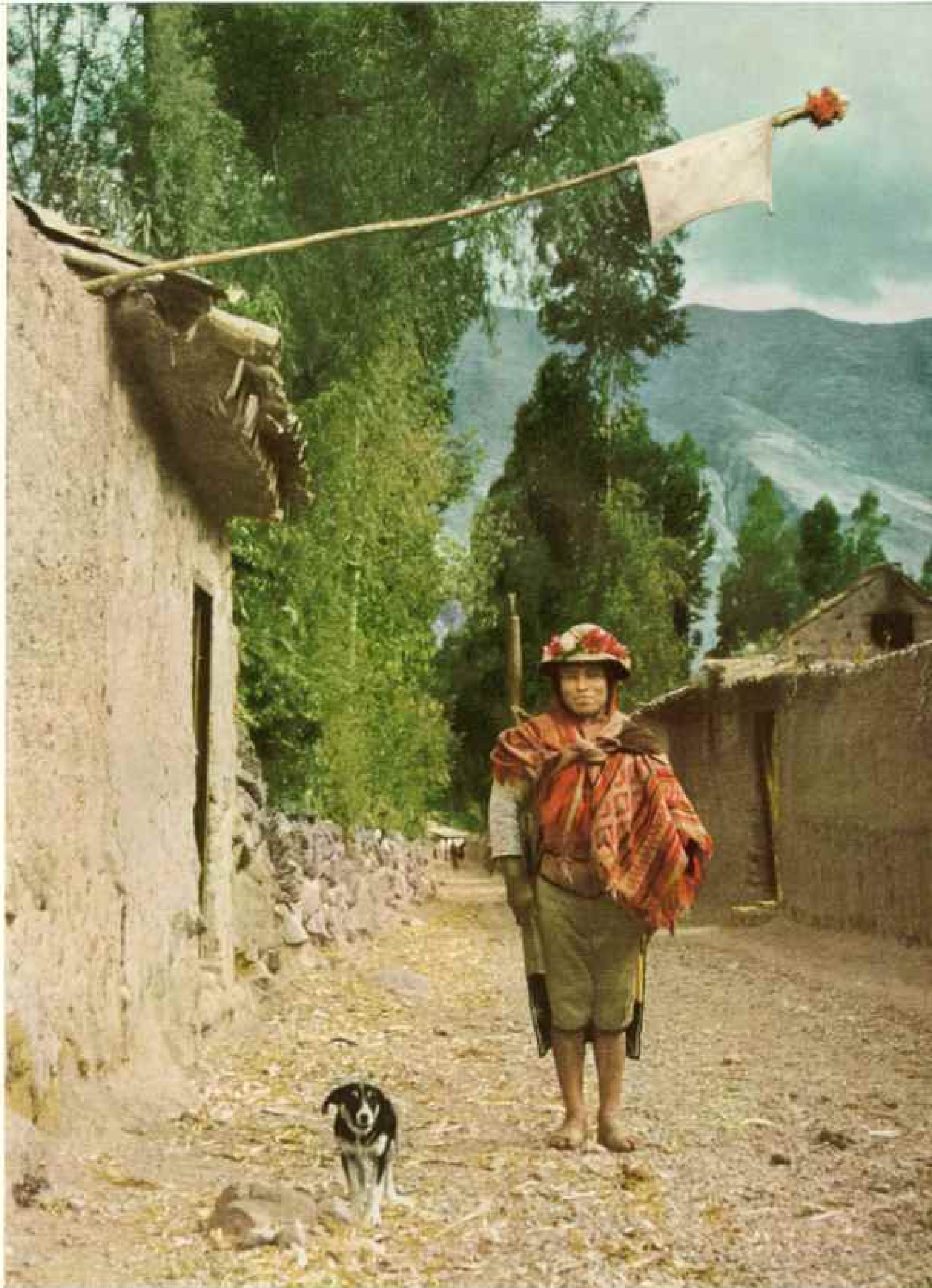
▲ **Juliacca, a Railway Junction, Gives Travelers a Free Fashion Show**

Derbied, shawled women meet every train and hawk caps, dance masks, and food. The younger generation (right) defies convention with pigtails and bobby sox; she sells lottery tickets. Train is bound for Cusco.

▼ **A Motorbus on Flanged Wheels Runs Between Cusco and Machu Picchu**

Forty years ago Hiram Bingham and his fellow explorers spent 2½ days negotiating the 70 miles by muleback. The yellow *autocarril* delivered the author in six hours. This stop, Ollanta, is named for an Inca hero.





A Policeman near Cacha Advertises for a Wife with the Flowers on His Hat

A liquor shop's flowers on staff announce *chicha*, the Incas' corn beer (page 439). White flag proclaims aguardiente, a sugar-cane firewater introduced by Spaniards. This drink, often poisonous, is the Indians' ruin.



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Illustrations by Rita Bates

▲ **High, Stylish Shoes Pinch the Toes;
Off They Come for Indian Sandals**

An Arequipa woman removes American-made foot-gear of World War I vintage. Sandal vendor carries baby on her back. Stripes (left) decorate candles. Volcanic wall stone was sawed from Misti's slopes (p. 434).

▼ **Andean Looms Have Changed Not at All
Since Inca Women Used Them**

This Indian might have been one of the convent guardians who taught the Virgins of the Sun to weave for the emperors. Her alpaca wool is an Inca heritage. Aniline dyes have replaced fine old vegetable colors.





♣ Indian Women in Cacha Drink *Chicha*,
the Incas' Sprouted-corn Beer

Some native beer is still made the Inca way. The women chew corn; spit it out, let it start to ferment, then add water. Pie-pan hats may be reversed in rainy weather. These are worn "sunny side up."

♣ Sales Are Measured, Not with a Scale
but by the Pile: Pisac

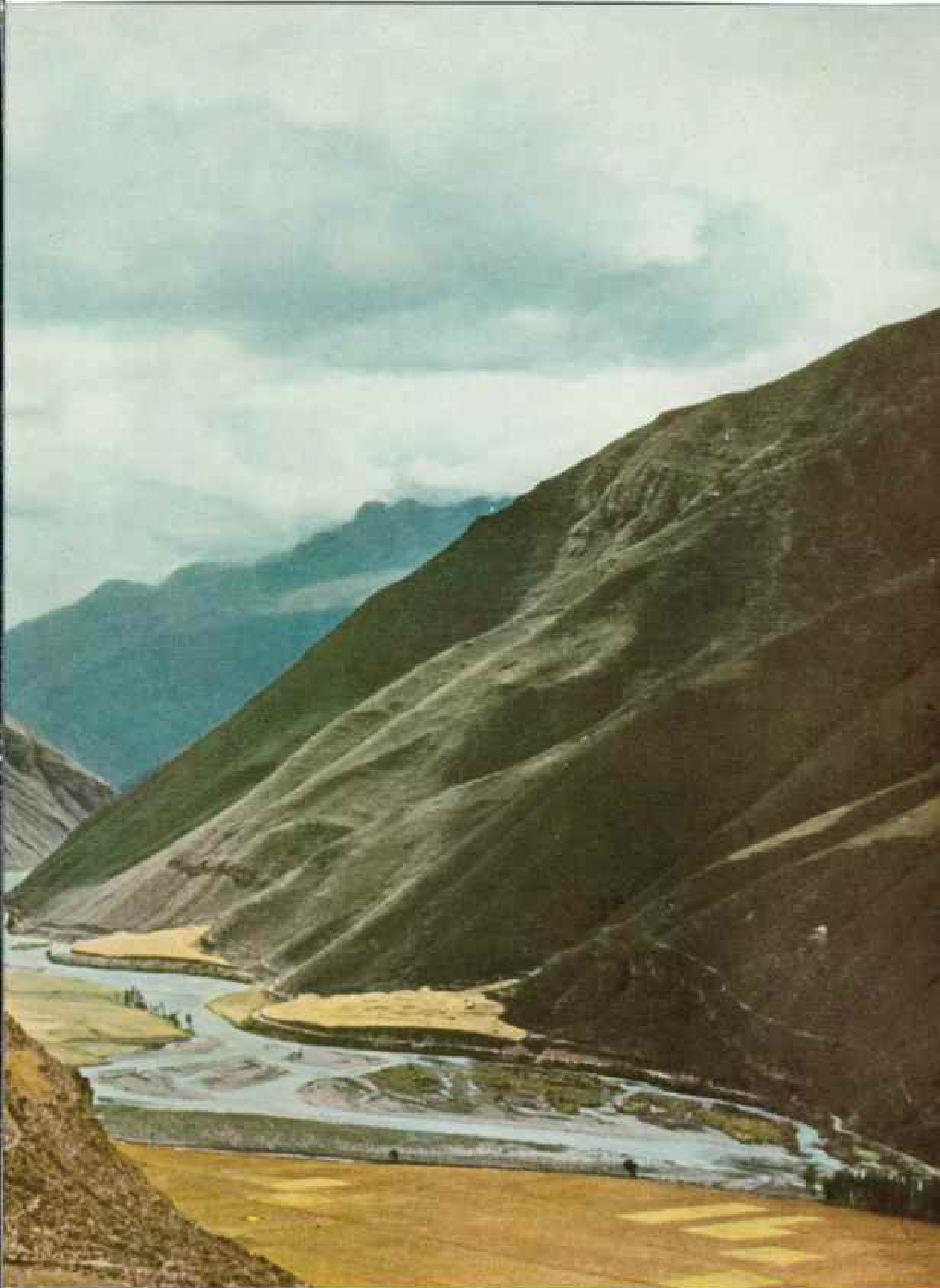
These vegetables call to mind that ancient Peruvians domesticated more food and medicinal plants than any other early people. Corn, potatoes, and quinine represent three of their many contributions.





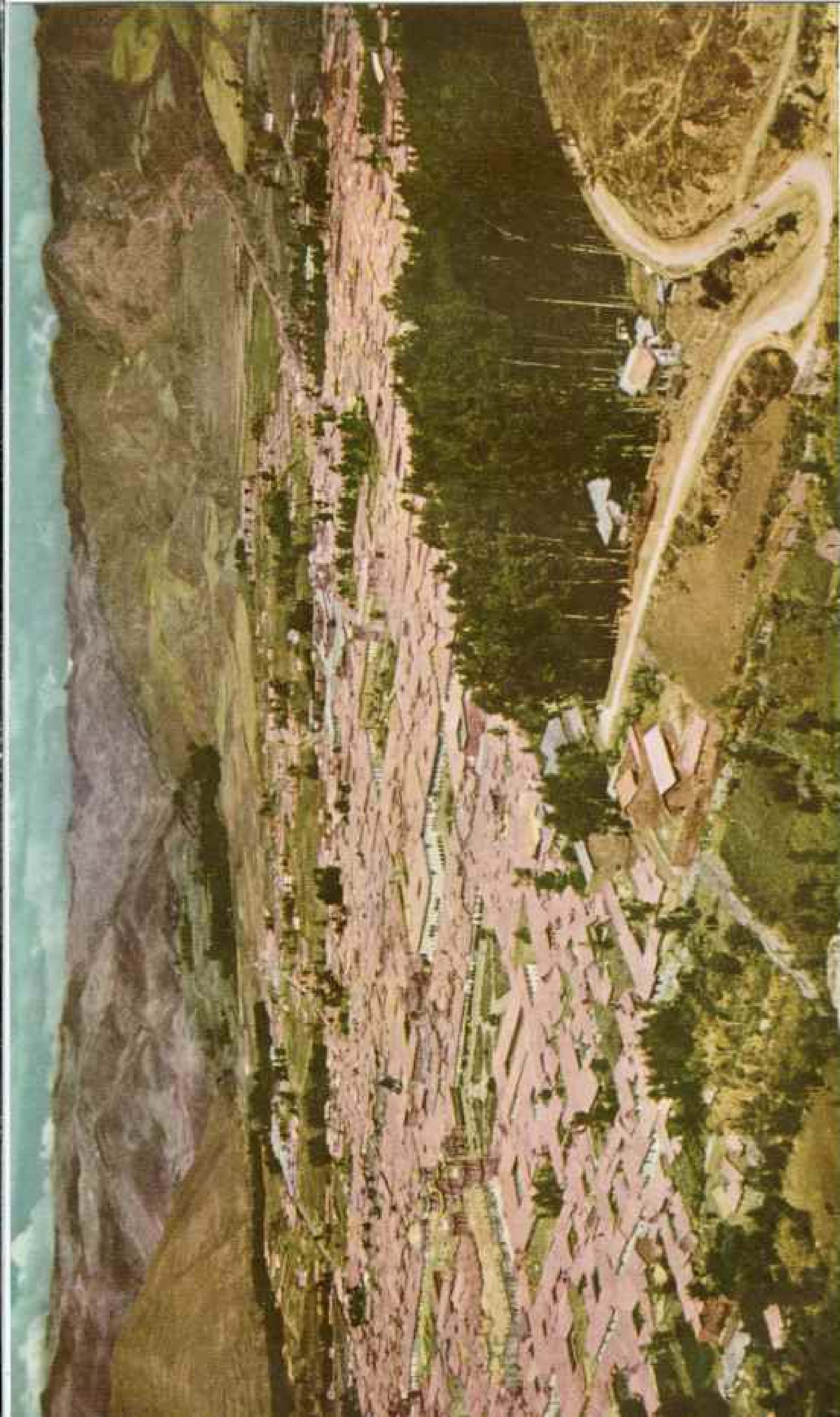
Indian Farmers' Sloping Fields Overhang the Vilcanota, the Incas' Sacred River

In this pleasant climate Cusco's Indian nobles maintained country estates and luxurious baths. Fruit trees and flowers filled their gardens. Forests rang with the songs of tropical birds (pages 443 and 460).



Ripening Grain of Pisac Farmers Transforms the Broad, Level Valley into a Golden Sheet

Travelers, comparing this spot with Switzerland's vales and Norway's fjords, find it no less enchanting. Later in its course the Vilcanota changes its name to Urubamba, the torrent flowing past Machu Picchu (page 454).



Cusco's Pink-tile Roofs Are Spanish, Its Eucalyptus Groves Australian, but Its Sun Is the Old Inca Deity

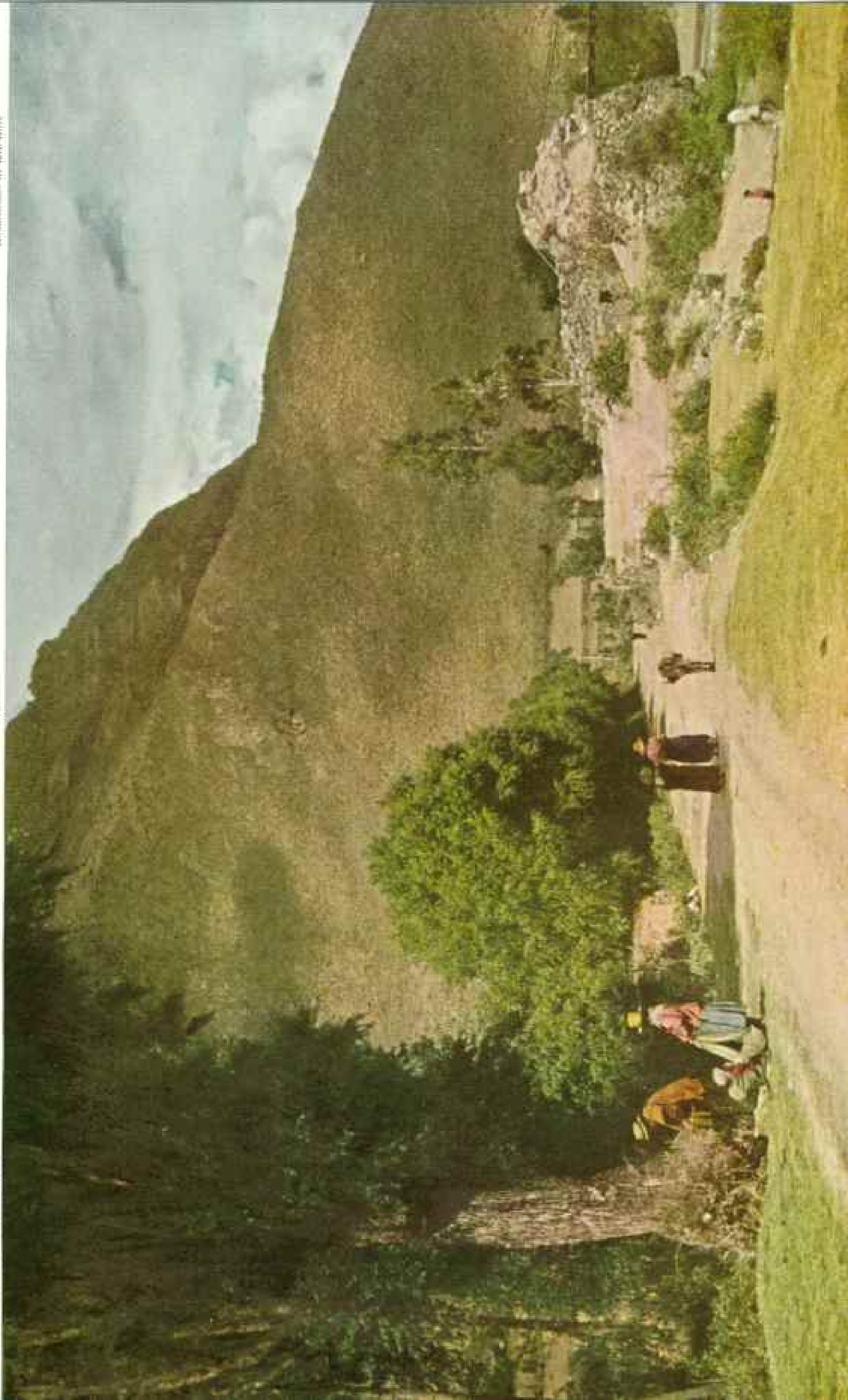
Legend says that a solid-gold chain once enclosed the main plaza. Indians, hiding it from Spaniards, threw it into a lake. Treasure hunters never found it.

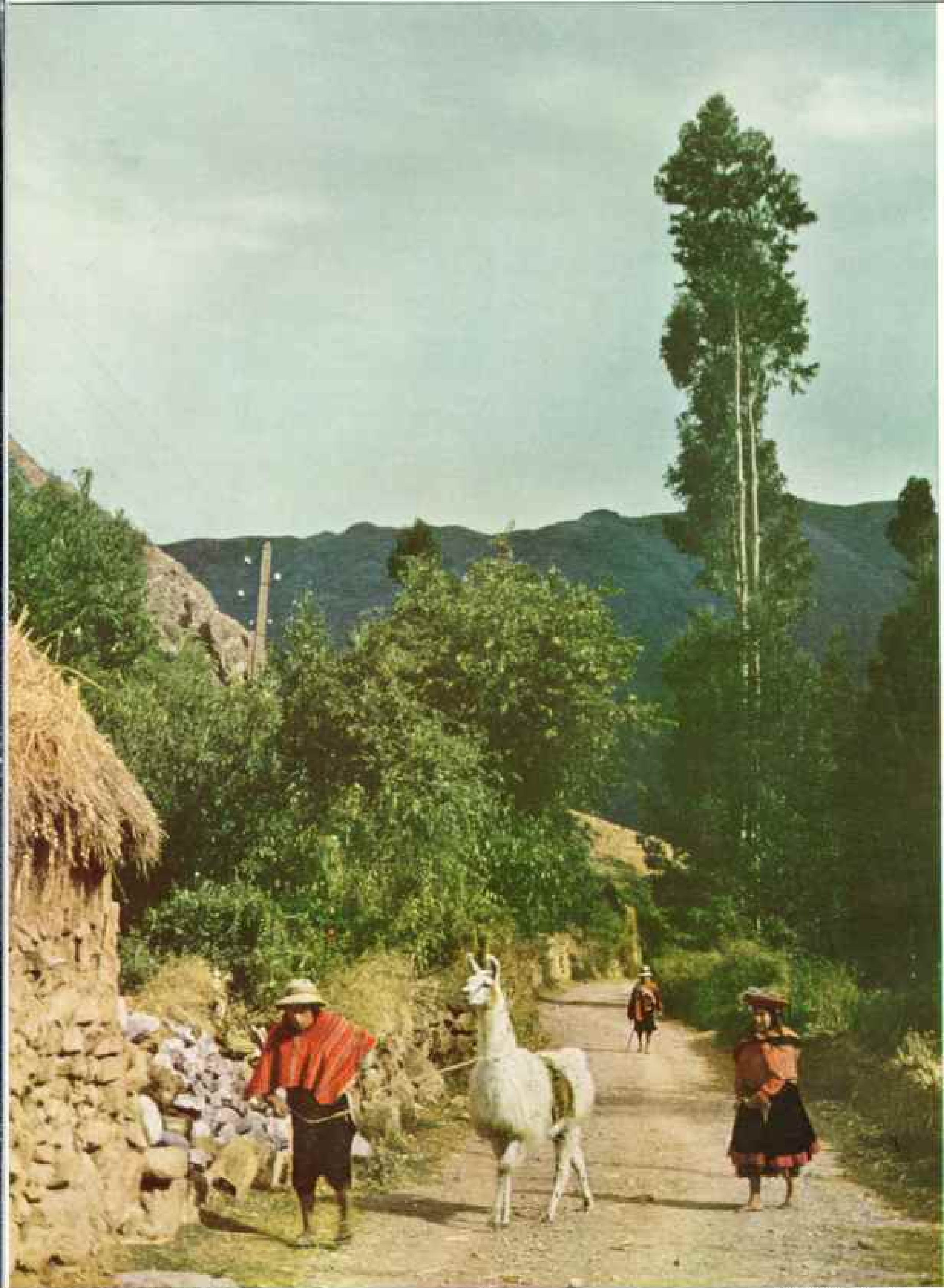
Holidaymakers Picnic in the Vilcanota Valley. An Inca Stone Pier (Right) Supports a Modern Bridge

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Reproduction by K. L. B. B. B.





Llama, the Camel of the Andes, Remains the Impoverished Indian's Faithful Friend

Source of hides, meat, wool, and labor, llamas are a Quechua's most precious possession. He stables them next to his hut; sometimes feeds them by hand. They recognize his voice. This scene is near Yucay.

Pink adobe houses with blue doors and white houses with pink doors stood amid golden grain. Some houses even had red Spanish tile roofs instead of thatch or corrugated iron.

At Chactuyoc a huge yard vibrated with vividly dyed wools laid out in the sun to dry. Near by was a modern basketball court.

As we left Sicuani, Lunati pulled his broad shoulders back through the window.

"Here is a treat for you," he beamed. From a vendor on the platform he had bought three *anticuchos*.

These were small wire spits about six inches long, strung with pieces of beef heart highly seasoned with garlic and oregano and topped with a chunk of potato. Fresh from an open fire, they were sizzling hot and aromatic.

We whiffed other fragrant odors as the day passed. Finally smoke began to curl from huts along the way, and it grew dark. We were down to about 11,500 feet now and 200 miles nearer the Equator. Trees had appeared again. We got off the train at Cusco in an atmosphere fragrant with the unforgettable perfume of burning eucalyptus.

"The Navel of the World"

To the Incas, Cusco was the "Navel of the World." Even today Indians of the Andes mutter a prayer upon coming in sight of the "Sacred City." As I looked down upon its red-tile roofs and green groves, the narrow, hill-climbing streets and numerous bell towers betokened the antiquity of the city (page 442).

Even in the modern and comfortable Hotel Cusco the venerable feel of the city is strong. Step outside and you are in a strange land.

The city lies at an altitude of 11,155 feet, in a little valley of the Huatanay River, a tributary of the Vilcanota. Its population is about 53,000, mostly of Indian descent.

The place is a happy hunting ground for historians. Recently many new ruins have been discovered.

Narrow streets, many of them less than 15 feet wide, make one-way traffic imperative. Uneven cobblestones have been replaced by two thin paths of smoother stones to provide easier riding for automobiles (pages 430, 431). Other streets have never known a wheel, for on the steep hillsides they are stair-stepped.

Most interesting of all are the walls which line these historic passageways. The Incas were master stonemasons, and Cusco, their capital, contains excellent examples of their art.*

Oscar Gonzales, an English-speaking student at the University of Cusco, showed us

around the city. Like 90 percent of the population of Cusco, he also spoke Quechua.

Llamas in flocks of from two or three to a dozen or more were frequent. With haughty heads and seemingly disdainful air their tiny two-toed feet apparently scorned the cobbles. They were never led. On the contrary, they always preceded their owner and stopped or started, turned to left or right as they pleased.

Llamas Obey Indians' Signals

"Do the Indians just follow the llamas?" I asked Oscar.

He laughed. Up the street came another group.

"See if you can hear the sounds the man is making," Oscar suggested. "He is telling them what to do."

The llamas passed us with the Indian trotting along behind. He seemed to be wheezing.

"That hissing noise is understood by the llamas," said Oscar. "You can't tell the difference in the sounds, but they can, and he keeps talking to them as they go along."

"Ask him to stop them," I requested.

Oscar shouted in Quechua, the man gave a sharp hiss, and the llamas, already 30 yards down the street, stopped in their tracks!

"Now ask him to turn them around and come back," I suggested.

The Indian hissed again. The llamas executed a perfect right turn and came trotting directly toward us. When they got to within about 10 feet, the man made a sound like a soft sigh and the beasts slowed to a stop!

That night we sat with Lunati and other guests before the big open fireplace of the Hotel Cusco. Instead of a tame alpaca, two tame deer had the run of the building. A package of cigarettes left carelessly on the coffee table disappeared down their throats, cellophane and all, before you could say "Machu Picchu."

Neatest trick, however, was the way they inserted their slender noses into glasses of fiery-hot *pisco*, a Peruvian brandy someone offered them, and lapped up the stuff to the last drop. It did not seem to affect them.

Cusco a City of Many Bells

Outside, the air was full of the sound of bells, but today, after the earthquake, most of them are silent. Cusco has more churches, convents, and monasteries than most other South American cities of its size, and their bells seemed to be chiming most of the time.

* See "Incas: Empire Builders of the Andes," by Philip Ainsworth Means, NATIONAL GEOGRAPHIC MAGAZINE, February, 1938.

Early the next morning, with Lunati and Oscar, we took the road to Pisac, north out of Cusco, past the cyclopean fortress of Sacsahuaman. On the ancient Inca parade ground before the megalithic main wall we saw modern descendants of the Incas playing football.

"Basketball, baseball, and tennis, all those games, were introduced here by your countryman, Dr. Giesecke," said Oscar (page 421). "In addition, he was one of the first to recognize the importance of the archeology of this region, and through his efforts many important discoveries have been made. All phases of our Peruvian culture have been enriched by this remarkable *Vanqui*."

The road to Pisac is narrow and winding. It was unpaved. Available rock had been used in places to form a stone retaining wall against the side of the mountain rather than for road surface. We commented on this.

"*Upa-anca*," said our monosyllabic driver.

"That explains everything," I commented.

"It does," said Oscar. "That one Quechua word means the silent swoop of an eagle upon its prey, and refers to a peculiar form of landslide we have in this region. Without warning, and without a sound, the land suddenly lets go and envelops everything in its path. It is not a pleasant death."

But there was gaiety upon the highway, too. Rounding a sharp corner, we came upon an early fiesta.

Masked dancers in fantastic costumes performed a kind of double shuffle in the middle of the road (page 433).

Only men were dancing. Smiling women watched, dogs barked excitedly, and the orchestra did some solid "sending" on a few monotonous notes. Then the band stopped to wet its whistle.

Literally, the whistle was the leader, for the "orchestra" consisted of a flute, a snare and a bass drum, all homemade. During the intermission I exchanged a few cigarettes for good will and made a few pictures (page 453).

"Sacred Valley" Gem of Inca Land

Another turn in the road and before us spread the Valley of the Vilcanota, sometimes called the Vilcamayu (Sacred River), because its waters and the Vale of Vilcanota were sacred to the Incas (page 460).

Below and to our right lay the village of Pisac, with ancient agricultural terraces on the mountainside above it. Lunati pointed to the river running past the town.

"The river flows between stone walls so fields may be built right out to the river banks without danger of erosion," he said. "There

is an example of the reclamation agriculture of the Incas."

A winding road led us down the mountain and across a modern suspension bridge into the center of town (page 432).

Pisac is one of the oldest centers in the valley. An attraction is the colorful Sunday market and the strange Mass said in the primitive church of the Indians. *Varayocs*, or leaders of the surrounding clans, come to town to form an official escort for the priest. They accompany him from his residence to the church for the services and afterwards conduct him home again. They and their sons also take part in the Mass (pp. 455, 459).

As we entered the gloomy interior of the church, devoted Indians in strange attire surrounded us, their faces rapt with feeling as parts of the ritual were intoned in Latin, Spanish, and Quechua. Weird notes wheezed from an antique homemade pipe organ. A lusty, barrel-chested Indian worked frantically at the bellows. At one point in the ceremony the sons of the clan leaders startled us by blowing mournful tones on conch shells.

On an altar near us rested a human skull with a faded red flower stuck into an eye socket. It had formerly belonged to a man of the neighborhood who had done much good for the church. This was a sincere tribute from these simple

Cleanup Week in Pisac

Following the Mass, an Indian in modern dress mounted the steps to the foot of the cross in the plaza and shouted for attention. Soon a crowd of citizens stood beneath him. From a paper he translated into Quechua as he read:

"Citizens of Pisac, our city is becoming more and more a center of trade and tourism. We have become famous! From all over the world people come to Pisac. But we do not take enough pride in our city. Streets must be cleaned up, gutters cleared, cobbles replaced, and walls whitewashed. This must be done immediately. Anyone who has not cleaned up his house and the street in front of it within 10 days from this date will be fined. This is an order!"

Farther down the valley we passed a young Indian carrying a toy wooden gun and followed by a black pup. At my request he posed for a picture beneath a *chicha* (native beer) sign.

As a member of the Rural Guard he wore his toy gun proudly as a symbol of his importance, but gay flowers in his hat struck a strangely festive note (page 437).

"Why the flowers?" I asked.



'Tents and Shacks of Refugees Litter the Proud Plaza de Armas, Heart of Cusco

During Inca festivals this sacred square saw the mummies of departed emperors seated in honor beside their successors. In colonial times it witnessed the execution of rebellious Spaniards and Indians. Atahualpa, the Inca slain after he had filled a room with ransom gold, stands atop the fountain. Cast in the United States, he resembles a North American Indian more than an Inca. La Compañía (left), erected in 1661-89, stands with the support of long props. Cusco University (center) was damaged by the earthquake.

"Because I am a *solterón*, a bachelor, and they indicate that I am looking for a mate."

We drove through beautiful country by back roads lined with eucalyptus, willow, and poplars. The air was soft and fragrant with flowers.

Among the willows which overhung an irrigation ditch small green parakeets flitted, and tiny hummingbirds darted among red lilies and passionflowers. As the sun sank lower, we heard the coo of pigeons.

Back in Cusco we prepared for the climax of our entire journey, the trip to Machu Picchu. That ancient citadel of the Incas was unearthed in 1912 by a National Geo-

graphic Society-Yale University expedition under the leadership of Dr. Hiram Bingham (page 451).*

Our friend Lunati dined with us that evening, along with Fra Conrado Juárez, a Franciscan friar we had met on the train.

"I have never eaten such wonderful potatoes!" exclaimed Rosita.

"Why not?" Lunati asked. "The potato originated here. When the conquistadores

* See, in the NATIONAL GEOGRAPHIC MAGAZINE: "Further Explorations in the Land of the Incas," May, 1916; "Story of Machu Picchu," February, 1915; and "In the Wonderland of Peru," April, 1913, all by Hiram Bingham; and "Pith of Peru," by Henry Albert Phillips, August, 1942.

Mysterious Figures Resembling Airstrips Mark the Ancients' Gigantic Calendar

These strange lines intrigued the author while flying from Lima to Arequipa (page 423). Near Nasca, some 50 miles from the Pacific, he saw raincloud-robbing mountains dividing an arid plateau (left) from fertile valleys bordered by trees (black clumps).

Nature marked the plateau with the irregular fernlike lines of long-dead streams. Later, Indians of the pre-Inca Nascan civilization carved their own marks—airfieldlike trapezoids, enormous triangles, and long lines, all laid out with geometrical accuracy. To the same terrain they transferred pottery designs (not shown)—divinities, fish, birds.

Nascan engineers treated the desert, worthless in their time as now, as a gigantic drawing board. Using no surveying instrument other than their telescopic vision, they traced straight lines scores of miles. Then they excavated designs in black and white, uncovering a layer of black stones and exposing the desert's white heart. For possibly 1,500 years these shallow depressions remained visible, because ruin never fell to wash them away.

Indians long ago forgot the lines' meaning. White men, motoring across, dismissed them as farmers' abandoned furrows. The air age, revealing their true dimensions, brought to light an astonishing engineering feat, evidently of astronomical significance.

A reliable calendar was necessary to the coast-dwelling Nascan planters; for, to anticipate sowing time, they had to know when corn-producing rains in the Andes would swell their dry irrigation channels. Feast or famine was the gamble.

One can imagine the aboriginal astronomers peering down the long, straight lines watching for a calendar star to spring above the horizon at dawn and fix the date. More than likely, the coincidence of constellation and rainy season gave rise to star worship.



American Boys Survey Muchu Picchu from Huayna Picchu's Awesome Brink. The Inca Citadel Sits on a Mountain Saddle

Peru's new Hiram Bingham Highway runs past the white guesthouse (left). The old mule trail zigzags below it.

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John Bayle, Jr.



brought the potato to Europe, they gave the world a gift far more valuable than all the gold of the Incas."

After dinner we said good-bye to him, as he had to return to his post at Urubamba. We did not see him again.

Early next morning Rosita and I, with six other passengers, crowded into the tiny yellow *autocarril* at Cusco station. The vehicle was a small autobus with an automobile motor, designed to run on the narrow-gauge railroad track which extends from Cusco to Machu Picchu (page 436).

We made several switchbacks to surmount the steep mountainsides which enclose Cusco. Soon we started on a downgrade which would continue all the way to the foot of the citadel, from the high, chill plateau above Cusco to the edge of the tropical area.

The Anta plain spread out before us like a big rug. On it fed sleek brown cattle. Indians in red ponchos trotted along paths or roads which led to feudal-looking haciendas surrounded by stately groves. Here and there a dashing caballero on a white horse rode by like a grandee of old.

Vertical Landscape Is Startling

Then we were in a canyon. The sudden transition from horizontal to vertical landscape was exciting. Almost vertical cliffs had been cut back for the railroad track along a narrow stream of rushing white water. Yellow flowers like black-eyed Susans and graceful fronds of pampa grass bordered the way.

In a few moments our narrow canyon suddenly ran head on into another slash in the mountains, and we turned almost at right angles to follow the canyon of the Urubamba. Through it flows the river we had seen at Pisac (page 446), there known as the Vilcanota.

Unfortunately we could not stop long at Ollantaitambo (Ollanta), another famous Inca city and fortress near the river. It formed one of a chain of Inca citadels which extended from Machu Picchu to Cusco.

Farther on we passed the ruins of other Inca centers—Runcaraccay, Wiñay-huayna, Choquesuysuy, Qquente. At Salapunco remains of another fortress marked the entrance to the Torontoy canyon, narrowest stretch of the Grand Canyon of the Urubamba.

Here the walls of the canyon close in. Daylight fades. Rising sheer for as much as 2,000 feet in a single step, the granite sides extend upward like the windowless walls of gigantic skyscrapers. The confined waters of the river roil and foam, casting white spray high into the air.

Orchids, ferns, and other tropical foliage covered the lower faces of the cliffs, for we had now passed through the temperate zone and were on the edge of the tropical area. More than two miles above us towered the great snow peaks of the Andes.

Machu Picchu station is just that—a tiny railroad station located on the floor of the canyon, about 6,500 feet above sea level, with telephone, telegraph, and a cramped side track for switching. At present it is the practical end of the railroad, although the rails extend a short distance down the canyon to the foot of the ridge on which the ruins stand. We coasted on down the track.

Machu Picchu at Last

"All out for Machu Picchu!" Oscar called.

After crossing the dizzying torrent on a sturdy bridge, we came face to face with several mules. Although we knew from the beginning that we should have to ride mules up to the ruins, our meeting was not one of mutual pleasure. We started upward.

The old city lies along a narrow ridge between 10,300-foot Machu Picchu (Old Peak) and 9,060-foot Huayna Picchu (Young Peak), which sticks up sharply to the north. The altitude of the city itself is about 8,000 feet above sea level, with many variations in level among the various parts of the ruins. Everything is up or down, and we came to think in terms of vertical rather than horizontal distances (pages 456-7).

At the top we found the Machu Picchu guesthouse, installed by the Peruvian Government. This was our home for three days and nights while we explored the city.

The site is especially valuable because it is the largest and most complete Inca city which still remains just as it was in Inca days. From the time of the death of the last inhabitant, sometime in the 16th century, it remained indeed a lost city of the dead, soon covered by the fast-growing vegetation. So hidden in the sky was Machu Picchu that colonial Spaniards never found it. Here lived the last four independent Incas, the emperors and living gods of their people, the Quechuas.

Chosen Women Secluded in Convents

In all the Andes the Inca sun god could not have chosen a more awesome setting for his temples. The city looked up at two towering peaks; it gazed down into the Grand Canyon of the Urubamba, a 2,000-foot drop.

In this stupendous setting the Incas' Virgins of the Sun, or Chosen Women, passed away one by one, leaving no sons or daughters to give the world the story of their sky-top city.



A. Ogden Plarrot

Hiram Bingham, Discoverer of Machu Picchu, Dedicates Its New Road, His Namesake

Professor Bingham toiled through mountains and jungles, following history's faint clues, until he revealed the Incas' lost city in 1911. He led three National Geographic Society-Yale University expeditions uncovering the ruins from the jungle's green grip. World War I called him away from his archeological labors; later he became a United States Senator. In 1948 he was invited to inaugurate the *Carretera Hiram Bingham*, a motor highway which climbs the backbreaking approach (page 452).

Polygamy was the rule among the Inca nobles, who usually selected their brides from national convents called Houses of the Chosen Women of the Sun.

These institutions, consecrated to the sun god, also trained ancient Peru's vestal virgins, the Chosen Women, to be handmaidens of the Inca. They wove his finest textiles and brewed his *chicha* beer. Such a convent city was Machu Picchu.

Many people do not realize that the Inca Empire, though reduced to a shadow, sustained its independence in a mountain retreat for 39 years after Cusco fell to Spain.

Vitcos, built in haste, was the Incas' military headquarters. Vilcapampa, long established, was their sacred, templed city. According to Senator Bingham, Vilcapampa was the Inca

name for Machu Picchu, a title which he gave to the ruined city in 1911 because he did not know then what else to call it.

Nature's Formidable Fortress

To Vilcapampa the Inca Manco took flight from conquered Cusco with his three sons, his bravest troops, his Chosen Women, and the mummies of his ancestors.

The lower Urubamba Valley gave the Incas a fortress defended by some of Nature's most impregnable ramparts. The road to their kingdom crossed passes 15,000 feet high and canyons 5,000 feet deep. However, Spanish invaders finally penetrated the kingdom-in-exile. They captured the last Inca, somewhere near Vitcos, bore him in triumph to Cusco, and put him to death, in 1572.

The victorious Spaniards did not settle the lower Urubamba. Not inquisitive about Vilcabamba, they seem never to have searched it out. Spaniard and Indian alike forgot the city; the jungle took over.

Senator Bingham rediscovered the lost city in 1911 after a long search through canyons and mountaintops. He was exploring Machu Picchu, the mountain, expecting to find only insignificant ruins, when he suddenly faced a surprising sight—"a flight of 100 walled terraces."

Full of wonder, Senator Bingham wrote:

"I saw beautiful walls of stone houses built in the most exquisite Inca style. Moss, bamboo thickets, and even trees burdened the ruins, but I could discern granite ashlar still fitting together as perfectly as though they had been laid the day before.

"I stared at moss-hung ruins—temple after temple, surprise upon surprise. The sight fairly took my breath away.

"Machu Picchu was a tremendous natural fortress. A handful of men could have guarded the approaches. Signal stations stood on the twin peaks. Man-made walls, reinforced by a dry moat, enclosed the city limits. Only the Inca, his nobles, priests, and the Chosen Women were permitted to pass these barriers.

Stairways Connect City Terraces

"Completing preliminary explorations, we returned to the United States. That winter (1911-12) the National Geographic Society and Yale University agreed to back an extensive survey.

"The next season we completed the spade work and examined Machu Picchu in detail.

"The city was built on the saddle of a mountain ridge and the steep slopes immediately below.

"Space was so limited that houses were crowded together on narrow streets.

"Terraced city levels were linked by 100 or more stairways. The longest of all, with about 200 steps, divided the city in half and served as its principal thoroughfare. This precipitous main street we called the Stairway of the Fountains because it was the site of a series of basins.

"The finest staircase of all led to a little hilltop commanding the city.

"Here our expedition found a fine stone *intihuatana*, a sanctuary where the Inca priests 'reversed' the solar deity and 'tied' him down. One can picture the nobles, priests, and Chosen Virgins ascending the granite steps on festive days and blowing kisses to their fiery deity.

"One windowless, gabled compound of beautifully built houses appeared so palatial that we called it the King's Group. We can imagine the palaces furnished with vicuña-wool rugs and other soft textiles woven by the Chosen Women.

"One small building we named the Semi-circular Temple because its outer wall was bonded to a curving rock. So closely fitted were the mortarless granite ashlar that they seemed to have grown together. They held by friction, not unlike the glass stopper in a bottle.

Where Incas' Mummies Were Worshipped

"On a spot which I called the Sacred Plaza we found two fine structures which were left completely open on one side so that the sun might shine in.

"The larger structure, which we named the Principal Temple, contained a 14-foot-long block, which appeared to have been a ceremonial throne where mummies of departed Incas were brought out at regular intervals to be aired and worshiped.

"Our Indian workmen, spurred by bonuses, discovered more than 50 caves and tombs. Not one of these gave up any gold or other common 'treasure.' A solitary green glass bead was the only indication of previous contact with Europeans.

"Cemetery caves yielded 173 skeletons. Of these, females predominated in a ratio of 10 to 1. This significant discovery showed beyond doubt that Machu Picchu had indeed sheltered the Virgins of the Sun.

Tomb Yields Bones of a *Mamacuna*

"One day we unearthed the burial place of a *mamacuna*, or high priestess, the superior of a convent. Her calling was identified by a concave bronze mirror such as *mamacunas* used to ignite tinder by focusing with it the sun's rays, to the mystification of the superstitious laity.

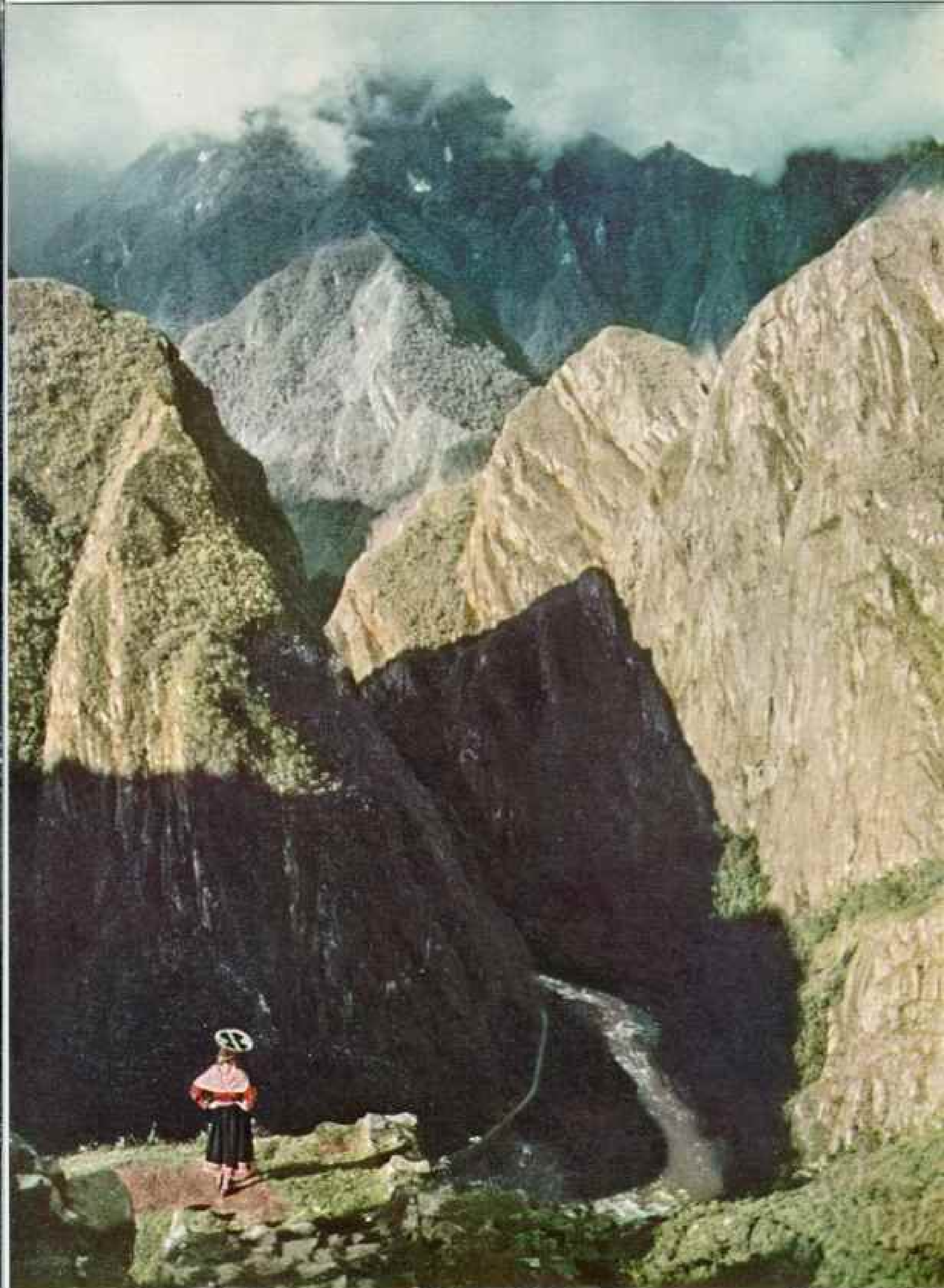
"The exciting discoveries of 1911 and 1912 led me to undertake further studies of Machu Picchu in 1914-15, which were financed chiefly by the National Geographic Society, but World War I stopped our visitations. I did not return until recently, when the Peruvian Government invited me to attend on October 17, 1948, the opening of the *Carretera Hiram Bingham*, the new five-mile motor road which mounts the slopes some 1,250 feet to Machu Picchu" (page 451).

There is nothing spooky about the place today, we found. Several families of laborers live among the ruins, keeping the underbrush cleared away.



A Pisac Musician Inherits His Flute from Incas, His Costume from Colonial Spaniards

Andean styles seldom change. Incas favored loose robes and wrap-around skirts. Sixteenth-century Spaniards forced the Indians into short trousers. The poncho, sleeveless, hand-dyed, and home-spun, came later.

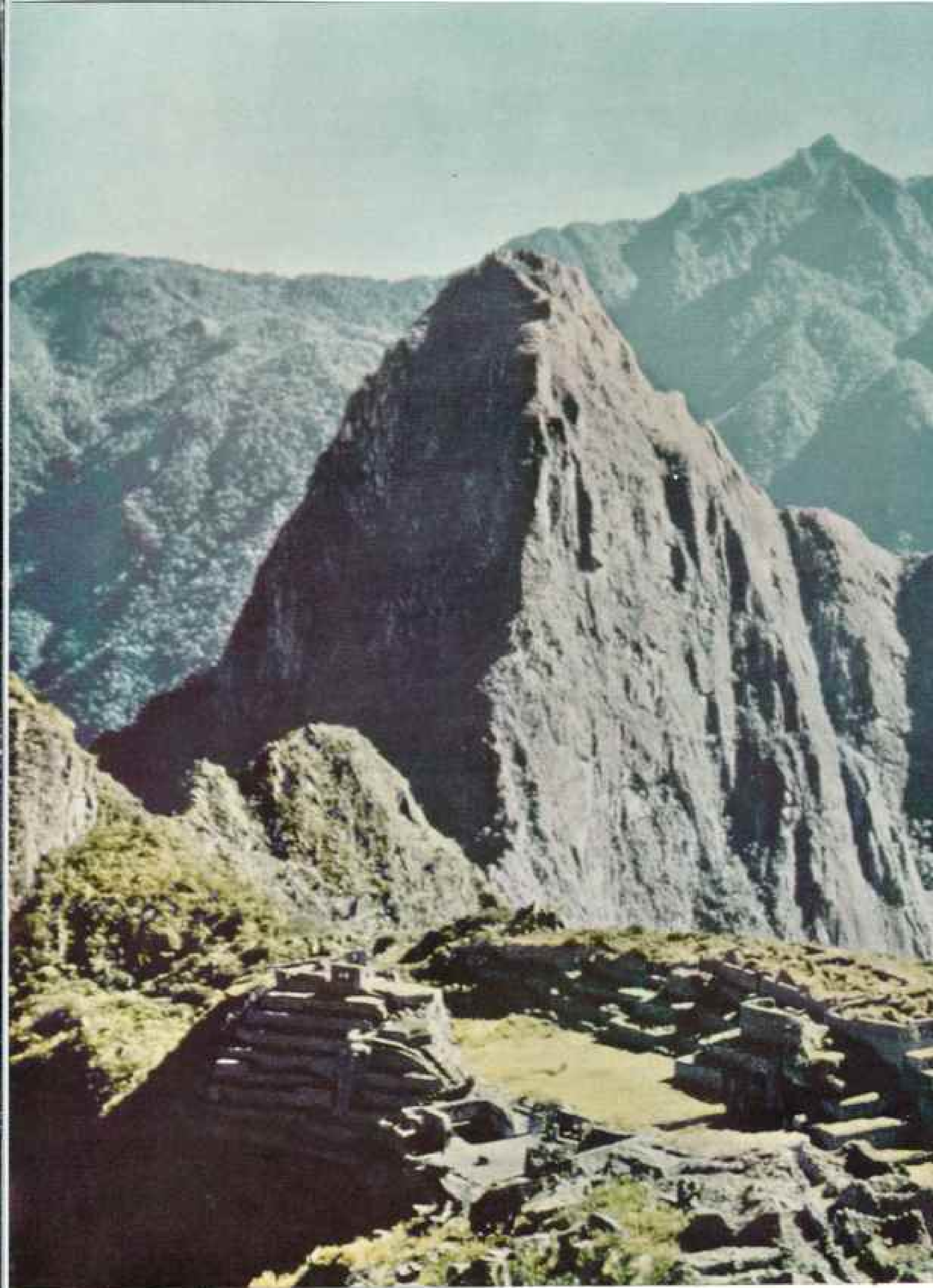


Machu Picchu, the Incas' Lost Citadel, Looks Down 2,000 Feet into the Roaring Urubamba
Here Indians built a sacred city. Their empire collapsing, they abandoned it to the jungle. Lost three centuries, Machu Picchu was rediscovered by Hiram Bingham, leader of three Yale-National Geographic Society expeditions.

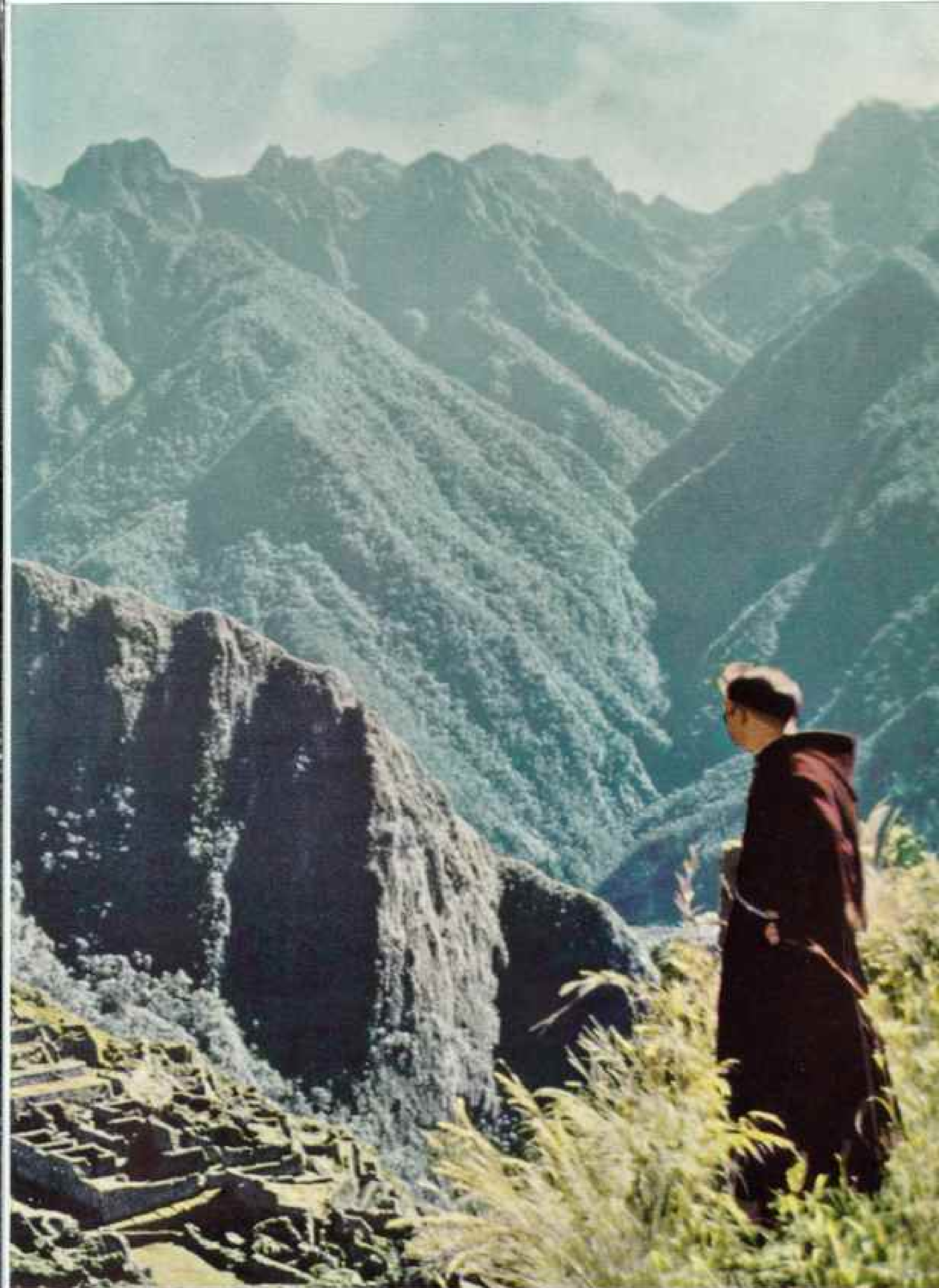


Vileanota Valley Mayors and Adjutants Carry Silvered Staves as Symbols of Office

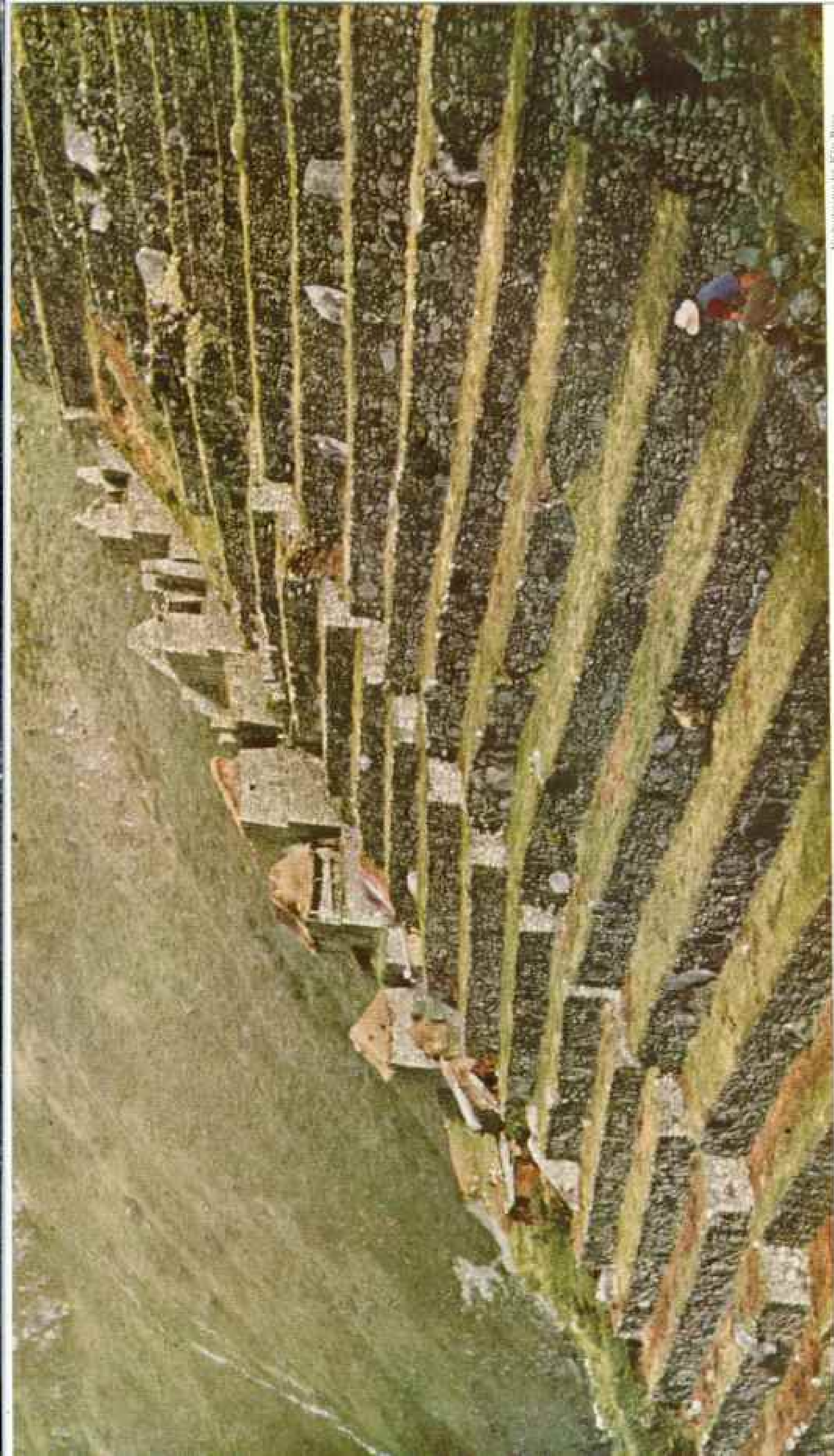
Cane beaters in ceremonial attire stand before Pisac's market cross (page 459). They neglect their ancestors' terraces (background). These marvelous gardens were gradually abandoned after Spain's stunning triumph.



Machu Picchu, Sanctuary of the Virgins of the Sun, Clings to a Ridge 8,000 Feet in the Sky
Here the Inca kingdom endured 39 years after Spain took Cusco. Ancient temples adjoin the small Sacred Plaza (left). The terraced eminence leads to an *intiknatana* stone, to which astronomer-priests "tied" the sun.



Empty Temples Stare Through Thatchless Roofs at a Sun Worshipped by the City's Builders
Terraces and lookout towers scar the peak of Huayna Picchu, which overlooks the city. From such lofty stations unlettered Indian sentries flashed "wireless" messages with beacon fires.



With Giant Strides the Ancients' Hanging Gardens March Up to Machu Picchu in a Hundred Rock-walled Steps

These green terraces, scientifically constructed for drainage, gave Hiram Bingham his first surprised look at the lost capital. Rethatched Inca houses (left), which formerly sheltered men not allowed within the sacred city, now lodge Machu Picchu's repair force.

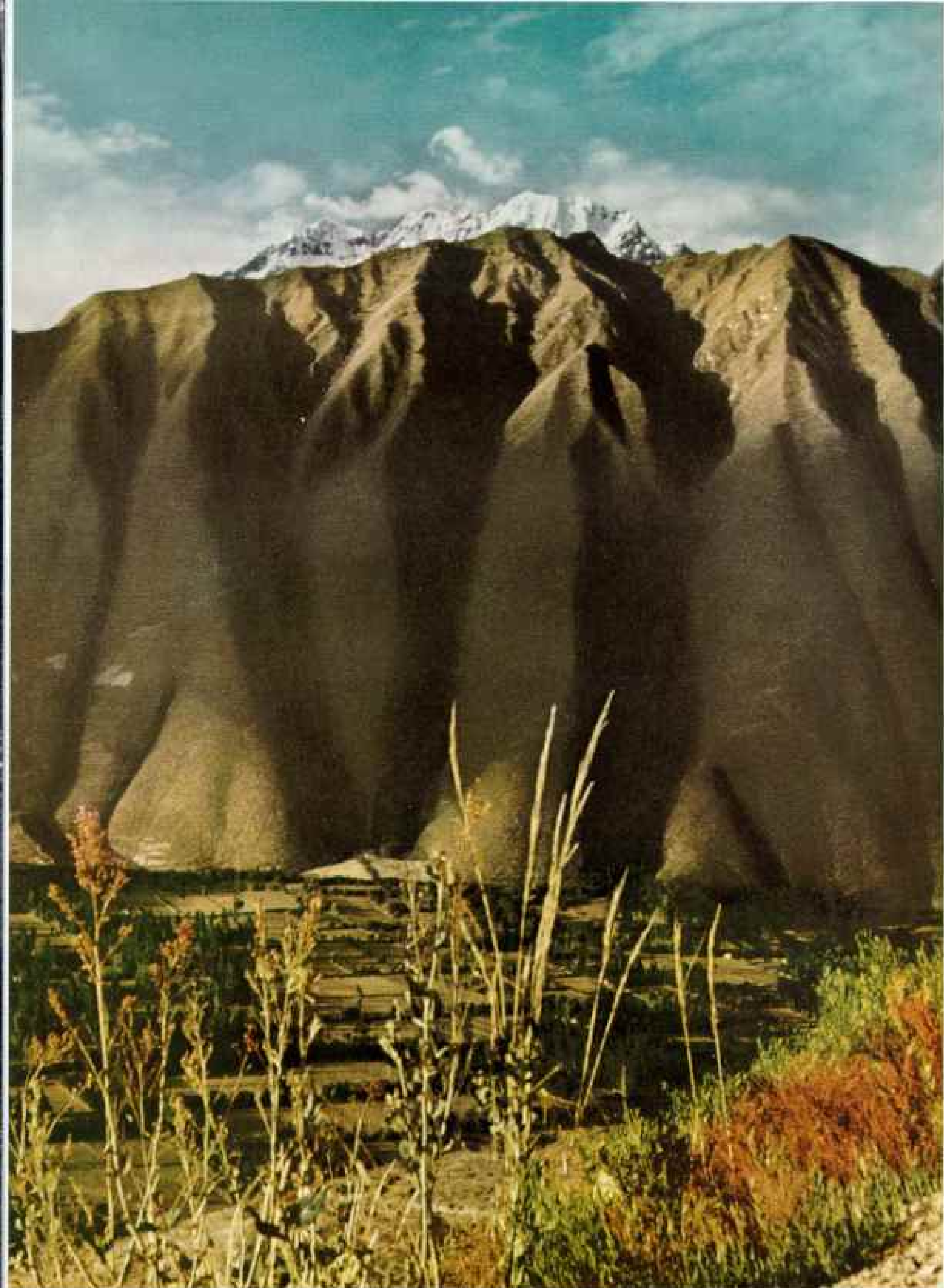
Staff Bearers in Their Sunday Finest Meet after Mass in Pissac to Form an Honor Guard for the Priest

© National Geographic Society

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Photographs by Elyse Ross





Eternal Snows of Cordillera Vilcabamba Overlook a Semitropical Valley at Urubamba

Here the vertical landscape of southern Peru is dramatically depicted. Fertile fields a mile and a half above sea level glow with autumn grain. Higher by another mile and a half stands the white peak of Pitu Ciday.

At the guesthouse the food prepared by Letitia Pinedo, the cook, was delicious, although we were told she was "not feeling well."

Next day we learned the reason.

About 2 o'clock in the morning a subdued commotion overhead roused us briefly, but we soon went to sleep again. At breakfast the manager was smiling.

"Last night the cook had a baby girl," he announced. "The first baby of modern times to be born on Machu Picchu! Her name is Domitila Estanislao Incacahui Pinedo."

After breakfast the next day Fra Juániz, who had rejoined us, Oscar Gonzales, and I climbed several hundred feet above the city and surveyed the ruins from high up the slope of Machu Picchu Peak. From an ancient cemetery we had an impressive view of the entire city (pages 456-7).

Machu Picchu is famous for lighting effects. Because of peculiar climatic location on the edge of the tropical zone, the city might be said to stick up into the Temperate Zone, while the lower slopes are in the Tropics.

A Night on the Mountains

A night on Machu Picchu is never to be forgotten.

As the huge red sun rushes down beyond the rim of western peaks, the ancient granite gables and towers fade from gold to black, and clouds brush the tips of neighboring mountaintops. Unfamiliar night smells of tropical vegetation float upward from the canyon, and, as the skies clear, the world is filled with strange stars unseen in North American latitudes. Beyond the black saw-toothed outline of the Inca citadel blazes the Southern Cross.

In the morning the cooler air above the canyon is warmed by the rising sun and lifts to make way for the humid air below. As this moisture-laden air ascends, it cools and condenses, so that observers at Machu Picchu look out horizontally upon mysteriously forming clouds which take shape before their eyes, shift, rise, and disappear above the airy peaks.

Literally, the acme of a visit to Machu Picchu is the climb to the tip of Huayna Picchu, the sharp peak which dominates the city. I was determined to stand on the very tiptop. Oscar had climbed it once before, so he led the way.

Beyond the main part of the city and the base of the peak lies an area of junglelike growth through which we had to fight our way to the narrow ridge between the two. Here we stumbled over more ruins still uncovered and unsuspected by the average visitor.

Among the scattered stones grew tall grasses which hid sudden pitfalls. Vicious-looking red and black millepedes more than six inches long were everywhere underfoot.

Afterwards I learned that this area is a favorite of the dreaded fer-de-lance and bush-master, as well as the lethal coral snake, all of which strike without warning. Luckily I saw nothing of them.

Orchids of many varieties were always just out of reach.

Stout Wire Aids Climbers

Some unknown but considerate person had rigged a stout wire along the sharpest edge of the narrow knife edge to Huayna Picchu. Without this the way would be almost impassable. A drop of hundreds of feet is on either side.

From there on, however, the climb is just hard work. From any distance the clifflike sides of the peak look sheer, but a tiny trail has been there since Inca times. This narrow path zigzags upward so steeply that in some places a rock, dislodged from the bend above, will clear the trail below and fall clean for hundreds of feet.

The trail was so overgrown with grasses and ferns that often we had to feel our way. Several times it narrowed to a foot in width while climbing steeply. Even this scant foothold was sometimes lacking where small cave-ins had caused V-shaped apertures fringed with long grasses. We cut long sticks and prodded before us like blind men.

During frequent stops for breath I saw many forms of bird life. I recognized tanagers and flycatchers and numerous swifts. One soft gray fellow with a black head Oscar identified as a grosbeak.

"The fertile Urubamba Valley is a natural habitat for birds," said Oscar. "Even from North America they fly over Machu Picchu."

Dangling at 1,500 Feet

The trail higher up was bare and moist. Suddenly I slipped. Strangely enough, I wasn't scared. Somehow, as I started over the edge I grasped a thick tendril and found myself sitting with feet dangling out over nothing. Beneath my soles swirled empty space for at least 1,500 feet. Far below curved the Urubamba. I looked up into Oscar's pasty face, and it was then that I felt fear. After I cautiously regained my feet and paused to overcome my shakiness, we went on.

Two hundred feet from the top came a surprise. Here, at one of the steepest parts of the climb, just when I wondered where the



A Woolly Window-side Beggar Thrusts In His Head and Gobbles a Hot Buttered Roll

This alpaca, penned beside an Arequipa hotel, is as spoiled as a pampered dog. He startles many guests by leaning into the dining room and fastening soft, demanding eyes on a bun. These girls enjoy a breakfast view of El Misti volcano. (page 434).

next foothold could be found, we stumbled on a flight of stairs! The steps were narrow and almost vertical, but obviously made by man. Each block was a carefully hand-worked piece of granite.

A little more and we rounded the sharp corner of a man-made granite wall, the face of the lowest stage of terraces. One more steep little climb, a few more stairs, and we were at the top.

Huge granite boulders capped the tip. The highest rested at an angle so that one edge ran across the rock like a comb. Below the boulders caves had been hollowed out to form a dwelling place.

An Inca Sentry Post

Slightly lower among thick grass Oscar indicated a point of rock at the very edge of the cliff. It had been worked smooth to form a tiny platform just large enough for one person, and was worn slightly hollow on top,

Here had stood the lookouts of the Incas, shuffling restless feet while guarding the ancient city.

Below and to the right I could look southwest and see the Urubamba with a tiny motor truck crawling along the road near San Miguel bridge. I felt that, if I swung my arms, a good jump would sail me clear into the river 3,000 feet below (page 449).

Off to the left was Machu Picchu. From this height the enduring buildings were dwarfed and lost. Only a general area of brown marked the ancient city and the terraces near by. Farther to the left white scratches in the mountainside identified the roadway to the top named for Dr. Bingham. Overhead a condor sailed. I felt like a condor myself. This moment was a fitting climax to our Peruvian pilgrimage.*

* For additional articles on Peru, see "NATIONAL GEOGRAPHIC MAGAZINE Cumulative Index, 1899 to 1949."

Puya, the Pineapple's Andean Ancestor

BY MULFORD B. FOSTER

TO WITNESS the dramatic flowering of the most colossal of all the herbs, an Andean ancestor of the pineapple, I flew 6,000 miles from Florida to the heart of Bolivia. There, high in the Andes, a mile and a half above the sea, I found a giant herb of fantastic proportions, the *Puya raimondii*, largest of all the bromeliads in the world.

When the layman thinks of herbs, he probably has in mind such familiar aids to cooking as thyme, mustard, or marjoram.*

Botanically, however, herbs are classed as seed-producing plants which do not have a central woody structure, as do our trees and shrubs.

This herb was a towering specimen standing in solitary grandeur, with its feet in the rocks and its head in the clouds.

Where else but in a dream could one expect to find an herb more than 30 feet high? The flower stalk alone is some 20 feet long, with a circumference of 8 feet. My mind had difficulty in accepting what the eye and camera recorded (page 469).

When Giant Puya Blooms, It Dies

My previous knowledge of *Puya raimondii* was limited to a botanical description and a photograph published in 1911 in a German work. I had long felt the urge to go see such a curiosity. Now the dream was a pilgrimage.

Fortunately, after correspondence with Dr. Martín Cárdenas, I had been able to time my visit with the flowering period of the only survivor in this vast locality, many miles from the other three known groups of these plants, one in Bolivia and two in Peru.

Not in the memory of anyone in the vicinity of Cochabamba had *raimondii* bloomed before.

The flowering period is its swan song, because, when *raimondii* shoots its great compact columnar flower head 30 feet or more into the air, it is the first and only time it will bloom. And it takes nearly 150 years to reach that climax.

Three days after arrival in Bolivia we finished preparations for the trip to Cuesta de Huakaquí, which means in Quechua the "Slope of Going to Cry." Early in the morning of November 13, 1948, Dr. Cárdenas and I with three local helpers started out from Cochabamba on that memorable trip.

Dr. Cárdenas is the outstanding botanist

* See "Spices, the Essence of Geography," by Stuart E. Jones, NATIONAL GEOGRAPHIC MAGAZINE, March, 1949.

in Bolivia. He knows the high Andes, its plants, its Spanish and Indian peoples. Having part Quechua Indian blood, he speaks that language besides several others. He was a fellow at Cambridge University, England, before he became president of the University of Cochabamba.

Cochabamba nestles on the eastern side of the Bolivian Andes, the broadest part of the Andean range. *Cocha* means "lake" in Spanish; *bamba* is a corrupt form of the Indian *pampa*, meaning "plain"; thus the name implies a "lake of plains." This situation makes Cochabamba an agricultural center.

The mountain Huakaquí rises to about 8,000 feet. It is rocky and dry, with very little vegetation.

Fire Ladder Borrowed to Climb an Herb

An hour or so before reaching our destination we stopped in a village and went to the local fire department. I supposed the visit was for some ordinary permit, but it proved to be for a very special permission. We desired the loan of the firemen's longest ladder. Dr. Cárdenas facetiously suggested that they postpone all fires until our return, possibly the following day.

The firemen allowed us to take the ladder, and we proceeded on our climb high on those parched and brown rocky slopes, wondering all the while how it was possible that so arid an area could sustain such a giant plant.

The last few miles were a strain on the old truck which transported us wearily over the last hill and around the last curve till we were startled by the sight of an imposing isolated sentinel, the great *chuqui kjora* ("strong puya"), as the Indians called it. To us it was a noble specimen of *Puya raimondii*.

For miles there was little vegetation to be seen in those great stretches of barren rocky wastes: yet there on the mountain Huakaquí was a solitary "candlestick" to celebrate my 60th birthday.

First to Photograph Giant Puya in Color

This plant had sprouted from a small winged seed nearly a century before I was born. It had withstood high winds, shifting of rocks, rarefied air, and blistering sun. Its charred trunk gave evidence that it had survived the fires which Indians frequently set.

I was humbled before the dignified giant. I was to be the first to photograph in color and record on motion-picture film this mammoth of all the herbs at its blooming period.



Malcolm D. Foster

A 35-foot Puya Shares a Bleak Domain with a 1-inch Cousin Clinging Mosslike to a Rock

Largest and smallest of bromeliads are these two. Its very prominence makes *Puya raimondii* vulnerable to man's destructive whims; its neighbor, an unnamed tillandsia, is too small to be noticed. Like rootless Spanish moss, the tillandsia draws food from the air, but it grasps the bare granite with tiny rootlets (page 480).

Only four previous botanical records had been made since its original discovery in 1870 by Antonio Raimondi, an able Italian botanist (1825-90).

Imagine a trunk 10 feet high topped with a thick rosette of narrow, heavily spined leaves 4 feet long, from the center of which rose a flowering stalk 8 feet in circumference and over 20 feet long, covered with thousands of waxy white flowers. The over-all height of the plant was more than 30 feet.

30-foot Giant Bears 8,000 Flowers

The 20-foot center cluster contained hundreds of 18-inch branches radiating from it like the spokes of a wheel. In turn, each branch contained numerous chaste white 3-inch blossoms radiating in a similar manner but extending to the end. In all, there were more than 8,000 flowers (page 470).

The tip of each flower branch is barren and serves as a convenient resting place for hummingbirds after they have supped on its nectar.

Although I had tried to picture the dimensions of this monstrous bromeliad, the experience of standing at the foot of one in full bloom was so overwhelming that I could think only of such whimsical tales as *Alice in Wonderland*. The miracle here was all the greater when I realized that the tallest growth of other plant life in this area as far as we could see was not over two feet.

After much effort we managed to place the ladder to reach above the spiny foliage, and from there on up it was really a Jack-and-the-beanstalk climb. It was lucky we had brought a ladder, for otherwise we should have had to ruin the plant to procure some of the flowers.

With shoes off, one of our Indian helpers climbed up the huge column, flower by flower, gingerly stepping on and grasping the flower stems until he reached the freshest blooms near the top.

We did not solve the mystery of the location of this solitary plant, for it was far from the known present range of this species. Not another plant of any age or size was to be found on that mountain of Going to Cry. And now, this plant with its flowering period nearly over, was soon to return to the earth.

Mystery of a Wandering Plant

Was this lone plant a survivor of a former large colony here, or had the wind carried the seed from a group on a far-off mountain? Neither surmise seemed plausible. The rocks here are Devonian instead of the granitic formation in which the other puyas of this species thrive. Furthermore, the spot is some

300 miles from the nearest existing group of *Puya raimondii*.

Perhaps an Indian had brought the puya there as a small plant to serve as a torch for his grandchildren to fire on some fiesta day. Unfortunately, this practice of burning the dry plant and flower stalk, full of seeds, has destroyed many of these noble bromeliads (page 479). To celebrate a fiesta with flames shooting 50 feet into the air is a temptation not to be resisted!

Several months after our visit, Dr. Cárdenas sent a helper there to procure seeds for me. It was too late. The giant had crumpled to the ground, having been burned before the seeds had ripened.

Most of the other species of puyas grow in big groups; thus a single plant produces many flowering heads on creeping trunks. These send forth new offshoots each year, creating a massed group often covering a large area.

I have found a few species in the bromeliad family, such as *Puya raimondii*, which are true monocarps—plants which develop no offshoots either before or after their maturity.

Puya Seeds Have Little Chance

These particular species bloom but once, then die after their seeds have matured; their propagation depends entirely upon the few seeds which germinate from the millions dispersed by the wind. Just a few might find a protected crevice where a bit of humus has been caught.

Not even one chance in a million do these seeds have of surviving and becoming a mature plant, for survival means a never-ceasing endurance test, a fight for life which starts from the tiny seed, little more than a quarter of an inch long, and culminates in the 150-year-old plant which we had come to admire.

Fire, frost, wind, relentless sun, some snow, and almost no rain—these are the handicaps this plant meets when trying to grow on a soilless, almost barren mountainside.

Lower on the side of the mountain grew another puya of a different species, *Puya tunarensis*, a dwarf (rarely over 18 inches) compared with the lofty *raimondii*. This small one grew in profusion among the rocks. It might have been camouflaged from view, so nearly rocklike was its coloring, had it not been for the brilliant little red flowers appearing upright and sparkling like birthday candles over the bronzed head.

The genus *Puya* is primarily an Andean group, with a few outlying species found near Santa María de Dota, Costa Rica, in the Sierra



Stanford D. Foster

From *Puya hamata's* Sugary Heart Comes an Indian Drink Called "Juice of Red Water"

Ecuadorians eat tender shoots of the plant's stiff foliage. Its best-known relative, the pineapple, bears many small fruits, all fused into one luscious berry, or "apple," in which it houses seeds. Brazilian Indians for centuries have woven a cloth, stronger than sisal and softer than linen, from the fibers of *Neoglaziaria variegata*, another useful bromeliad. Curving leaf spines of *Puya chilensis* are sometimes used as fishhooks.

Nevada de Santa Marta, Colombia, and on Mount Roraima, British Guiana.

More than 100 species have been found by plant explorers in the past hundred years, most of them growing in bleak, barren areas. In Costa Rica the endemic *Puya dasylirioides* grows at 10,000 feet in wet, swampy areas—in fact, often even in water. This condition is not common among puyas, which are generally known as dry land plant life.

Also, while botanizing in Colombia, I found puyas seemingly out of place. On the heights of the Sierra Nevada de Santa Marta, that majestic and very old South American range, much older than the Andes, we found several species of puyas growing in wet, moist areas, their roots submerged in deep beds of sphagnum moss. On the high *paramo*, mostly grasslands, where wild horses have roamed for many years, the puyas mark their water holes, just below the glittering glaciers.

The puyas, oldest genus of the bromeliad family, were, I am convinced, originally swamp plants growing along the western coast of South America, and were gradually lifted up when the lofty Andean range rose in one of the most extensive face-lifting operations of recent geologic times.

Flowers Clothed to Resist Cold

In spite of the heights to which these mountains have risen, the puyas have kept pace. With pure Andean tenacity they have adapted themselves to elevations as much as 14,650 feet above sea level; there I found *Puya fosteriana*, a new species (pages 474 and 477).

Up there the plants are prepared for cold weather; their gorgeous turquoise or teal-colored flowers are generally embedded in tufts of rich brown wool. Like the llama, the Andean beast of burden, these puyas enjoy

those high snow-blustered mountainsides and are similarly clothed to endure it.*

In all my extensive exploration for bromeliads I have found no puya that lives at any elevation below 7,000 feet.

As one of the bromeliads, the puya belongs to a large plant family, the Bromeliaceae, containing nearly 50 genera and more than 1,600 known species, most of them tropical. All but one are native to the New World; 19 live in the United States.

Pineapple and Spanish Moss Cousins

Inured to hardships, the bromeliads flourish in sun or shade; in deserts, on oceansides, in swamps or jungles; on rocks, bark, or palms. Airy clouds of bromeliads beard our southern forests and dangle from telephone wires with no visible means of sustenance.

This great family usually goes unrecognized by the nonbotanist, who refers to its spiny-leaved members as "cacti." But, whether he recognizes it or not, the layman sinks his teeth into a juicy bromeliad whenever he eats pineapple, the globe-trotting *Ananas comosus*. When he rests on a cushion, he may sink into another bromeliad, *Tillandsia usneoides*, Dixie's Spanish moss.

These two represent the extremes—the terrestrial pineapple, rooted in earth; and the epiphytic Spanish moss, a rootless air plant. Most bromeliads have roots, but in many species these serve not as mouths but as props for the upright plant, which absorbs food through its leaves.

Bromeliads developed their air-feeding habits, it is presumed, when, encountering dark, choking jungles, they took to treetops for survival, not as sap-sucking parasites but as self-providers. One tree-borne species, *Aeckmea conifera*, weighs up to 125 pounds.

A Puya Eaten Like Celery

After returning from Huakaqui to Cochabamba, we made a hurried trip to the near-by mountain Tunari to collect other puyas, and especially the *horka*, a bromeliad (*Tillandsia rubella*) the heart of which is eaten by the natives as we eat celery.

After crossing the pass at the foot of the snowcaps, we reached 14,000 feet. Here the snows are frequent but light. The peaks above are continuously sheathed in white.

Settlements are scarce. Except on a few scattered, privately owned huge ranches, there is no human habitation. Though domesticated llamas often wander far from habitation, they return to their shelters at night.

A person from other lands shivers in this high, cool, thin air, while the llama and the

Indian are well adjusted. The atmosphere is so clear that the visitor sunburns easily.

The largest vegetation in most of these areas consists of the strictly Andean puyas or low-growing cacti, which, strangely, are related to those found in Argentina and Mexico.

Starting our descent, we reached a small, glittering lake formed by melting snow. We tested the temperature of the amazingly clear water where we saw swiftly darting trout.

Within a few hours we had gone steadily down to Morochata, a town of over a thousand people. All were housed in mud, stone, and grass-thatched houses.

After a night here we dropped down into a valley 3,000 feet below where a moist and more fertile area greeted us. Here avocados thrived; flowers, vegetables, and grains were encouraged. This was a welcome change from the cold *puna*, the name for the higher, bleaker parts of the Bolivian plateau, where we slept under five coarse ruglike blankets.

Descending Ladder of Vegetation

To experience even greater changes in vegetation, we crossed over the Eastern Cordillera for a collecting trip down into the tropical rain forest area in the deep valleys far below Cochabamba to the east. Much of the way was slippery for a truck; it was dangerous to travel without chains on the tires. For a sightseer it would be a most uncomfortable trip, but for a botanist it is paradise.

Every few hundred feet down from the cold, foggy, windy crest brought new plants. The trees were higher, the growth denser, the greatest change in plant families being from the low-growing plants resembling the huckleberries, at the top, to tropical growth below.

Here, on just one slope of the Eastern Cordillera, could be seen the whole range of floral families covering the coastal area of North America. Starting with plants typical of the cold States of Maine and Vermont, one can get down into Pennsylvania, Maryland, North Carolina, and Florida-type plant life by vegetational changes within a few hours' travel.

As we approached the Florida temperature zone and subtropical growth, we encountered small avalanches. Things began to look discouraging: each avalanche was larger than the last one, and a mean drizzle was falling.

Just ahead, a recent avalanche had piled a mass of rocks, soil, trees, and shrubbery 15 feet high, shutting off the only possible way of travel. The road was barely wide enough for a truck, and the sheer drop of 2,000 feet to our right was not inviting.

* See "Camels of the Clouds" by W. H. Hodge, NATIONAL GEOGRAPHIC MAGAZINE, May, 1946.

What to do with the truck? There was no turning around. How the driver managed to back the truck up the mountain around hairpin turn after turn, until we reached a space large enough in which to turn around, I shall never know. Under such dangerous circumstances the South American driver seems to be at his best. In spite of a terrifying experience, we arrived safe in Cochabamba late that night.

A Thrilling Flight Across High Plains

For my second experience with *Puya raimondii* I flew from Cochabamba to La Paz, capital of Bolivia. The flight across the high plains northwest of Cochabamba was thrilling.

With letters of introduction to Bolivian Government officials, I was able to arrange a trip to the ancient granite mountain called Comanche. Since the authorities were interested in my suggestion to add more native flora such as puyas and cacti to the new botanical garden, they gave me every assistance.

For miles as we crossed the desolate *puna*, we traveled due west in the direction of Peru, then turned south. In the distance we could see the hazy blue of earth's highest steam-navigated mountain lake, Titicaca, lying at an elevation of 12,500 feet. Here the sun and the moon were born, according to Aymará legends.

More than 110 miles long, 50 miles wide at its greatest width, and 1,000 feet deep, Titicaca is surrounded by mountains. Within its perimeter are several sizable islands, Coati and Titicaca being the most important. The water remains so cold that a man who capsize from his fragile balsa craft would have no chance to swim far before being paralyzed (pages 483, 494, 495, 496).

Cold and Depressing Is the Puna

Dismal monotony in the vegetation of the landscape greets the eye in this *puna* area. I saw no tree. Very short yellow-brown *ichu* grass covers the ground without the usual sparkling green. Sparsely scattered, a few bulbous amaryllids seem to survive, although they remain underground most of the year.

Here and there we spotted a few low mounds of "mosses," which are not mosses but relatives of our sunflower. These are miniature compact shrubs covered with thousands of tiny white flowers. They form mounds tighter than ordinary mosses, hugging the earth to keep out of the drying cold winds.

A salt-lined river, the Desaguadero, courses slowly over the flat land from Titicaca to Lake Poopó. It is a lazy, thirsty, shallow river that looks as if it had never had a really good drink. Often wide but rarely deep, it looks

more like the wet trail of some prehistoric giant reptile.

The climate is just as cheerless and monotonous as the landscape. A constant raw, chill wind and meager dung fires in a poorly built shelter are hardly conducive to a cheerful soul. Undoubtedly this cheerlessness has influenced the Aymará Indian's taciturn character (page 480).

Sources of food and water are meager. Dried roots and manure are used as fuel.

The lowly Indian who shares these lonely, bleak spaces with puyas and llamas would find it difficult to accept lower altitudes with fertile soil and easy living conditions.

Everything up here seemed either the driest or the longest, the hardest or the coldest, the smallest or the loneliest.

It was hard to understand how our Indian helpers, clad in scanty attire and barefoot, could tolerate the cold of this early morning as they rode in the back of the truck where the only windbreak was provided by the bodies of their fellows.

Although warmly clothed in red flannels, woolen shirt, heavy suit, extra coat, sweater, and a rubber raincoat over all, I was hugging myself to keep my teeth from chattering. And I was up front beside the driver with a hot engine to keep my feet warm!

40 Giant Puyas All in Bloom

At long last in the distance we saw our objective, Comanche. Out of the vast plain extending far beyond vision jutted this time-hewn granite mountain in splendid isolation, covering a square mile amid the miles of barren vastness. It appears to be out of place, for there is nothing else like it as far as the eye can see—and you can see far up there.

That ancient mountain gradually revealed an amazing picture. Grouped here and there among the giant granite boulders were nearly 400 plants of the *Puya raimondii* in varying sizes. I counted 40 in bloom!

What a sight! The solitary, isolated specimen near Cochabamba had been a thrill. Now 40 times that! I was overwhelmed. No Indian hand had planted this colony (pages 464 and 478).

How could these mammoths of the plant world survive where there was so little sustenance? No other plant on this mountain, with the exception of one lovely golden columnar cactus, *Trichocereus bertramianus*, grew to be over three feet high (page 475).

Surrounding some of these gold-spined cacti were clusters of blue and violet lupine set off artistically by the orange-petaled, daisy-like senecio.



Indian Jack Climbs the Puya Beanstalk. It Blooms Only Once in 150 Years, Then Dies

A year earlier this plant looked like a 10-foot edition of the pineapple, its kinaman. Then on maturity a pillar of blossoms shot up 20 feet above its leafy base. With a borrowed fire-department ladder, these men gather flower specimens from a solitary *Puya raimondii* in the Bolivian Andes.



Climax of 150 Years of Growth—Puya's Huge Flower Head

No man living remembered when *Puya raimondii* was born, for the event took place a century and a half ago. No one could have seen it bloom before, for it does so but once in a lifetime. No one would see it flower again, for blossoming signals its death.

Largest of all bromeliads is *P. raimondii*, the discovery of Antonio Raimondi, an Italian botanist. A giant among the herbs, it dwarfs in age even the largest of Mexico's agaves, popularly called century plants.

Author Foster found this solitary specimen, the only one of its kind within 300 miles, on Bolivia's Mount Huakaqui, which to Indians means Going to Cry Mountain. He could only guess how it grew so far from its parent colony.

At fruiting time the flower head rose swiftly out of the trunk (page 469). Eight feet in circumference, it easily supported a man. It bore more than 8,000 flowers on branches like the one shown below.

Puya's tiny seeds number millions, but any one of them has less than a chance in a million of taking root in the stony mountainside and surviving the Andes' frost, snow, wind, and drought.

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Kodachromes by Mufford B. Foster

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The Botanizing Author Collects a Bromeliad Specimen in the Bolivian Andes

Puya herzogii bears no edible fruit, yet it belongs to the pineapple family (Bromeliaceae). Though the plant is rooted to earth, it derives part of its food from the atmosphere. Spanish moss, its rootless cousin, feeds entirely on air. Mr. Foster, a plant explorer, has discovered 100 species of bromeliads, amaryllids, orchids, and cacti. He has led many plant-hunting expeditions into Latin America. The world's largest collection of living bromeliads grows in his Orlando, Florida, garden.

Thoughtless Enemies of the Giant Puya Are the Indians

Flames shooting up 50 feet from a dry plant in seed make magnificent fiesta fireworks for a people too poor to afford explosives. Bolivia's highland Indians, knowing the puya has no economic importance, apply the torch, never dreaming that botanists esteem the plant for its rarity and beauty.

Such a fate befell Mount Huakaqui's solitary *P. patinozii* (page 409). After its flowers had withered, author Foster sent back assistants to gather seeds. They arrived too late. Festive Indians had already applied fire.

These women are Quechuas, descendants of the tribe predominant in Inca times. Photographers appreciate their white hats and colorful skirts. So accustomed have the women become to cameras that they ignored the *Fengui* author and his picture box.

The expected arrival of a train at Sacabamba station called this circle together. If no business develops with passengers, the women will trade with one another.

Native trees are scarce on Bolivia's high plateau, but the eucalyptus grove (back ground) thrives as if it were at home in low, sunny Australia.

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Illustration by Sanford H. Foster



A Bromeliad Arch Marks the Home of a Chief

Wife and son are two of the 2,000 Sibundoyos, who live in the Colombian Andes not far from the Ecuadorian border.

Unlike the Quechuas and Aymaras, some of whom have received admixtures of Spanish blood, the Sibundoyos remain a pure Indian strain. They form part of a large tribal group called the Quillacinas, meaning Moon in the Nasa, a name derived from their former custom of wearing golden crescents as ritual ornaments.

Like their llamas, Andean Indians are perfectly adjusted to the cold, thin mountain air. While the heavily clad author chattered and shivered, his barefoot helpers uncomplainingly accepted hardships they had known all their lives.

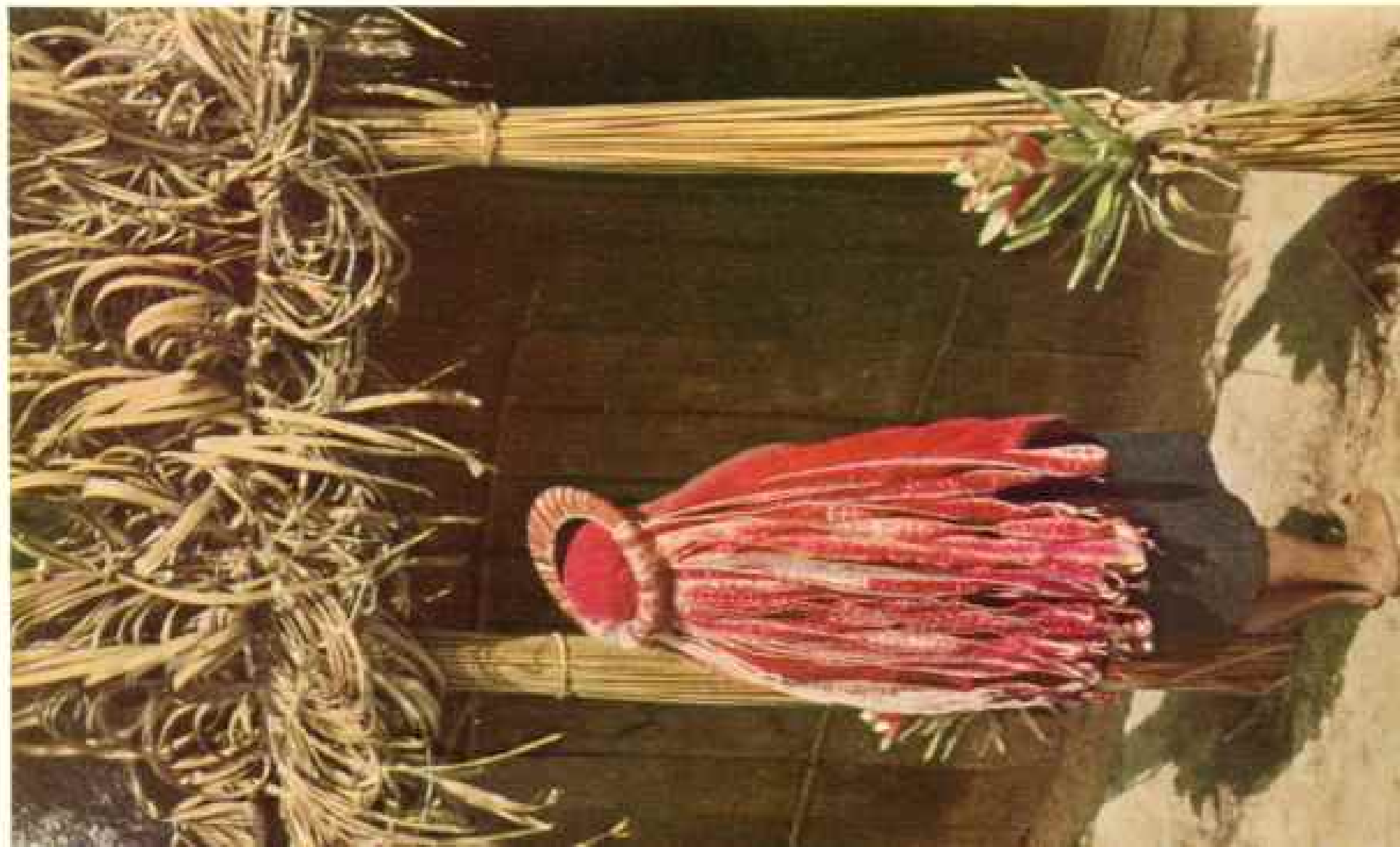
Left: the chief's wife wears her dazzling crown on important occasions. Each streamer tells an ancient tribal legend.

The arch, which designates the home of the chief, is fashioned of reeds and palm fronds and decorated with colorful *bromelios* (bromeliads).

Right: the chief's 14-year-old son produces bassoonlike tones with his 3-foot flute, which he plays at festivals, funerals, and religious ceremonies. Its varied tonalities result in some interesting musical combinations.

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Illustrations by Milton B. Post



← Author's Discovery
Blooms in Triumph
at 14,650 Feet

Puyas, Mr. Foster is convinced, began their existence as swamp dwellers and gradually adjusted themselves to altitude as the Andes were uplifted. Even in the mountains, some species retain their fondness for boggy areas, though they derive moisture from the air.

Left: *Puya fosteriana* bears the name of the author, who identified it as a new species. At fourteen and a half thousand feet it accepts the highest altitude known to bromeliads. Constantly struggling against cruel winds, it stands ever ready for snow. Brown, woolly bracts clothe its blue flowers against cold.

Here on the eastern slopes of the Eastern Cordillera the elements are so severe that the puya and a few clumps of grass appear to be the only living things. The old llama trail in the distance carried the author across the pusa, which, at 15,500 feet, lacks 271 feet of topping Mont Blanc, highest of the Alps.

Right: ferns, vines, shrubs, and giant begonias clog the 11,000-foot plateau north of Bogotá, Colombia. This decaying stump shines with the red flowers of *Bomarea*, a vine. *Tillandsia decorensis*, a cousin of the pineapple, grows at its base.

© Norman Conant/John Foster

Illustrations by Clifford B. Foster



Armored, Drought-resisting Companions to the Puyas Are the Wild Cacti Blooming in Andean Rock Gardens

Cactus is as American as pumpkin pie or tortillas; all but a few species are native to the New World. Since discovery days, however, man has carried the cacti to arid sections of Australia and the Mediterranean shore. Here *Trichocereus bertramianus* (right) grows in spiny columns on Mount Comanche, *Lobivia corymbosa* (left) flowers on Mount Tunari, sometimes among the snows. It takes its generic name, *Lobivia*, from an anagram of Bolivia.

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Reproduced by Matthew B. Fisher



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Illustrations by Maudslayi B. Foster

▲ *Guzmania cryptantha* Hides Flowers
in the Crypts of Its Bracts

This strange cousin of the puyas lives on rocks, trees, or ground. Though it grows a root for maintaining posture, the plant takes nourishment from the air, not from the soil. Only one bromeliad, Africa's lone species of *Pitcairnia*, is native to the Old World.

✦ *Bromelia balansae*, Armed with Daggers,
Outbursts a Barbed-wire Fence

Certain bromeliads arm themselves so formidably that they are frequently mistaken for cacti. Just as Mexicans use the organ cactus as a living fence, South Americans employ *B. balansae* as a property-line marker. A tasty beverage is made from its fruit.





National Geographic Photographer R. Arthur Stewart

Practical Botanists, Like Sentimental Damsels, Preserve Faded Flowers Between Pages

Dr. Lyman B. Smith, in the National Herbarium, Smithsonian Institution, examines puya specimens forwarded by the author from Bolivia to Washington, D. C. Here he measures the petals of altitude-loving *Puya fosteriana*, whose Andean portrait (left) is an enlargement of the color plate on page 474. Such made-in-the-field photographs give laboratory scientists a complete story in recording new species.

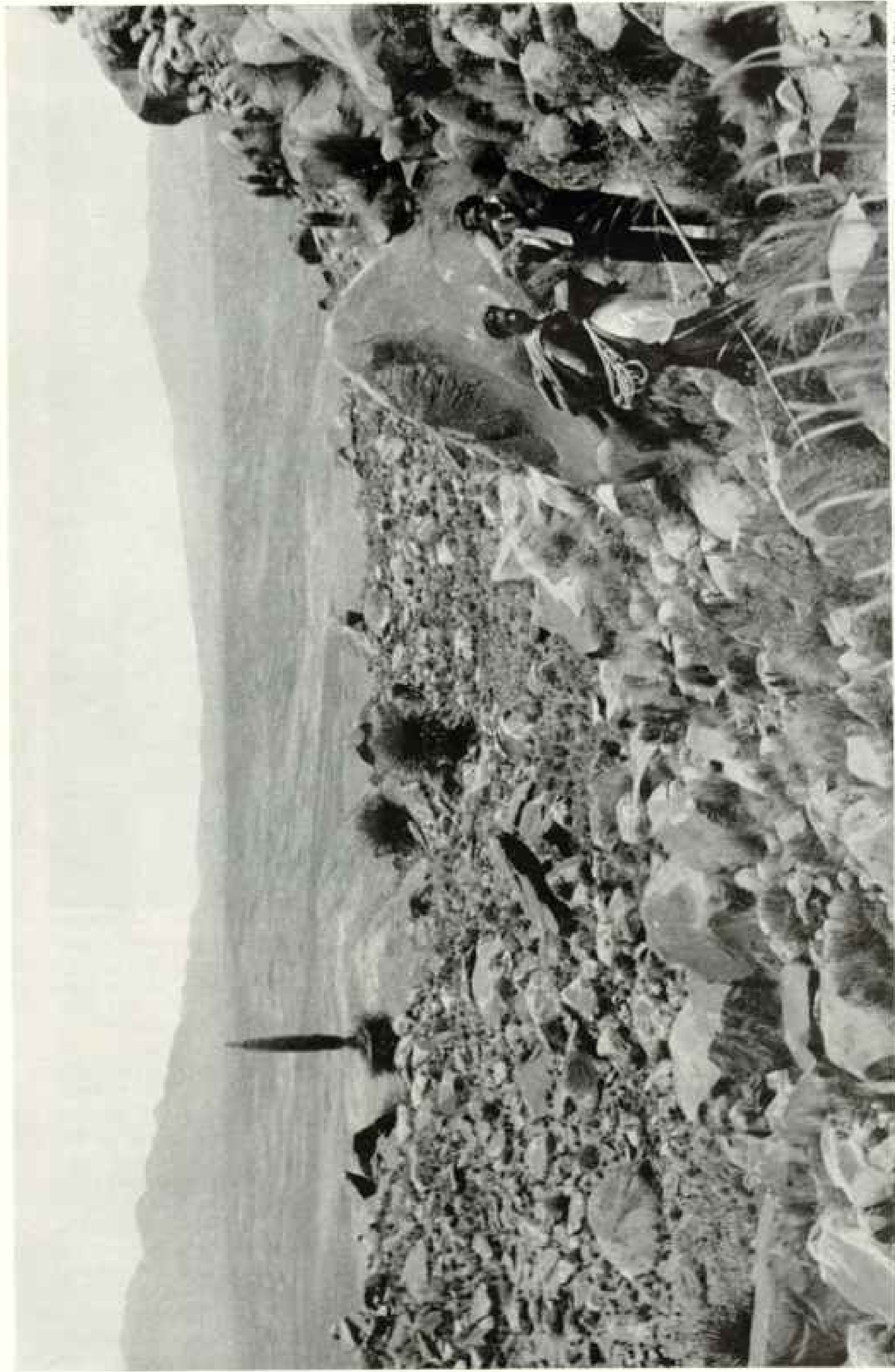
The few Aymarás living at the base of the mountain told us that the sight of 40 puyas blooming simultaneously happened but once in 25 to 50 years. I counted only three or four specimens that might flower within the next few years.

Only one was found that gave any evidence of being past the blooming period, and that was a huge charred and fallen trunk, a victim of past ravages by Indians. Nine feet in circumference, it may well have lain there several years even though partially burned. On it I counted more than 300 rings of leaf scars, assuring me that 150 years would be a

conservative estimate of its age (page 479).

Several attempts have been made to transplant *Puya raimondii* to other locations, even to Argentina, but none has succeeded. We hope, however, that we shall have success in our efforts on this botanical mission, because we carried several medium-sized plants back to the botanical garden in La Paz, where every effort will be made to give them a happy home not far from their birthplace.

My herbarium specimens formed the most extensive collection of these flowers ever to be brought to the United States. I presented them to the Smithsonian Institution in Wash-

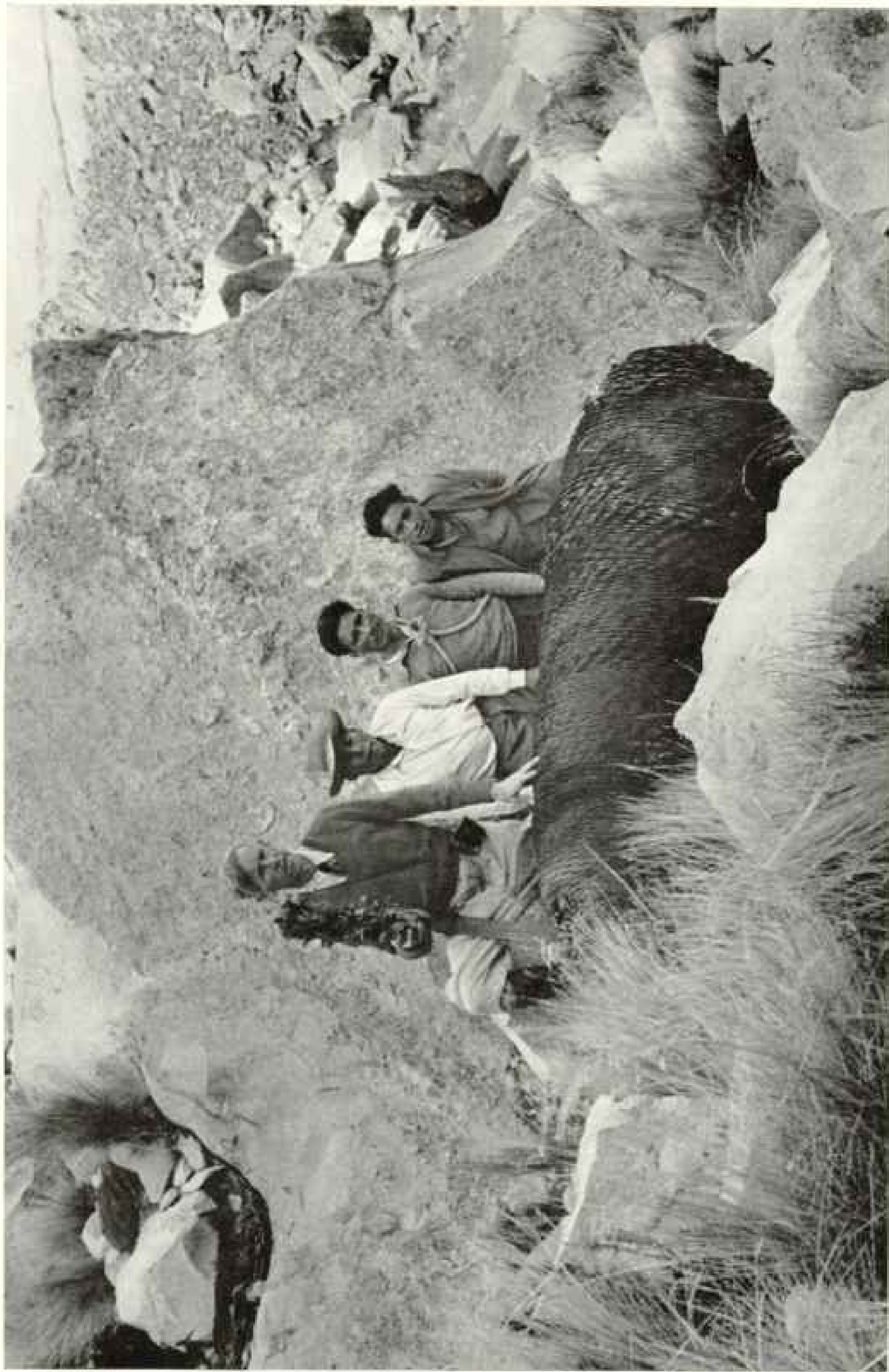


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Mount Comanche's Granite Wastes Reduce Most Plants to Pygmy Size. *Raimondii's* Once-in-a-lifetime Bloom Soars 35 Feet

The climate, as dismal as the landscape, suits Indians, llamas, and bromeliads. Here the author found 400 *Puya raimondii* specimens growing in one of the world's three known surviving colonies. His Bolivian helpers gather living puyas for their capital's botanical garden. All previous transplantations failed (page 468).

Sheldon H. Foster



This Fire-blackened Giant Measured the Puya's Life Span. Its 300 Semiannual Growth Rings Revealed at Least 150 Years

Just as this noble plant bore its seeds, Indians applied the torch to create a fireworks spectacle. As flames shot into the air, the fruits of a lifetime perished (page 477). Dry, cold air enables the trunk to resist decay. The author holds a charred branch.

ington, D. C., and to the Gray Herbarium at Harvard.

Herbarium specimens are difficult to prepare, except for the simplest ferns or grasses; those of a puya are a real challenge. Nevertheless, from the first *Puya raimondii* which I visited, flowers, flower bracts, leaves, and even trunk scrapings were pressed between blotters, descriptive notes recorded, and photographs made.

Giant and Pygmy Side by Side

The photographs are still the most conclusive and valuable proof of our efforts, as neither herbarium sheets nor words alone could possibly delineate the structure of noble *Puya raimondii*. My records of the one Huakaqui specimen had to be complete, since the difficulties and complications of getting to the large colony of them near Comanche might have been insurmountable.

In this highland of the clouds one can always expect extreme contrasts, and in so far as comparison of size of plants is concerned, I certainly found the extreme in contrasts.

Here, only a few feet from the huge puyas, I found the smallest member of the bromeliad family clinging tenaciously to granite boulders. It was a miniature tillandsia, barely an inch high, growing in close mat clusters. It had no soil for its sustenance, just a bare rock for its roots to cling to and only the elements in the air for food (page 464).

Both species of bromeliads, largest and smallest of their family, living side by side, were here long before the Inca civilization started. Like two tribal representatives of that empire, the Quechua and Aymará, they still hold forth with tenacity.

These two tribes of Indians who people the Bolivian highlands are distinct in their attitudes. Rarely do the two groups intermarry, even to this day.

Two Tribes of the Bolivian Highlands

The Aymará, who lives on the higher levels, seems to have an utter lack of sense or taste for the beautiful or picturesque. His only reaction to Nature seems to be toward the elements that cause him to fear for his person or his few possessions.

At Comanche the few Aymarás toiled day after day cutting by hand the blocks of granite rock used for years to pave the streets of La Paz miles away.* They were as silent and stolid as the rock they hewed.

These Aymarás predominate in the high region of La Paz, Oruro, and Potosí.

The Quechuas are more widely distributed, being found in all the Andean countries from

Ecuador to Chile. They are far more approachable than the Aymarás.

The women are known for their voluminous skirts, colorful shawls, and high white hats. They love their colorful attire as much as do the Mexican or Guatemalan Indians. It seems to compensate for their drab homes and surroundings.

The men work in the fields, mines, or factories, but the women have their own fruit and vegetable market or dress goods shop. They carry their entire stock for the day upon their backs in colorful shawls. At a moment's notice they can "set up store" anywhere.

Alone, sitting on curb or doorstep, in groups in the market or at the railroad station, Quechua women are quick to place their goods on display; if there are no other buyers around, they start selling to one another. Their skirts of brilliant coloring, often hand-decorated, contain more than three yards of heavy hand-woven woolen fabric and form a comfortable mass to sit upon, whether on the ground, curbstone, or market floor (page 472).

There are still thousands of pureblood Quechuas and Aymarás, but there is no longer a pure Quechua or Aymará culture in the sense that it existed before the Spaniards came. The culture of the present-day Indians is mixed with that of the white man, and, although the Quechua and Aymará languages continue to be spoken, both have borrowed many words and some constructions from the Spanish.

Huge Herb Threatened with Extinction

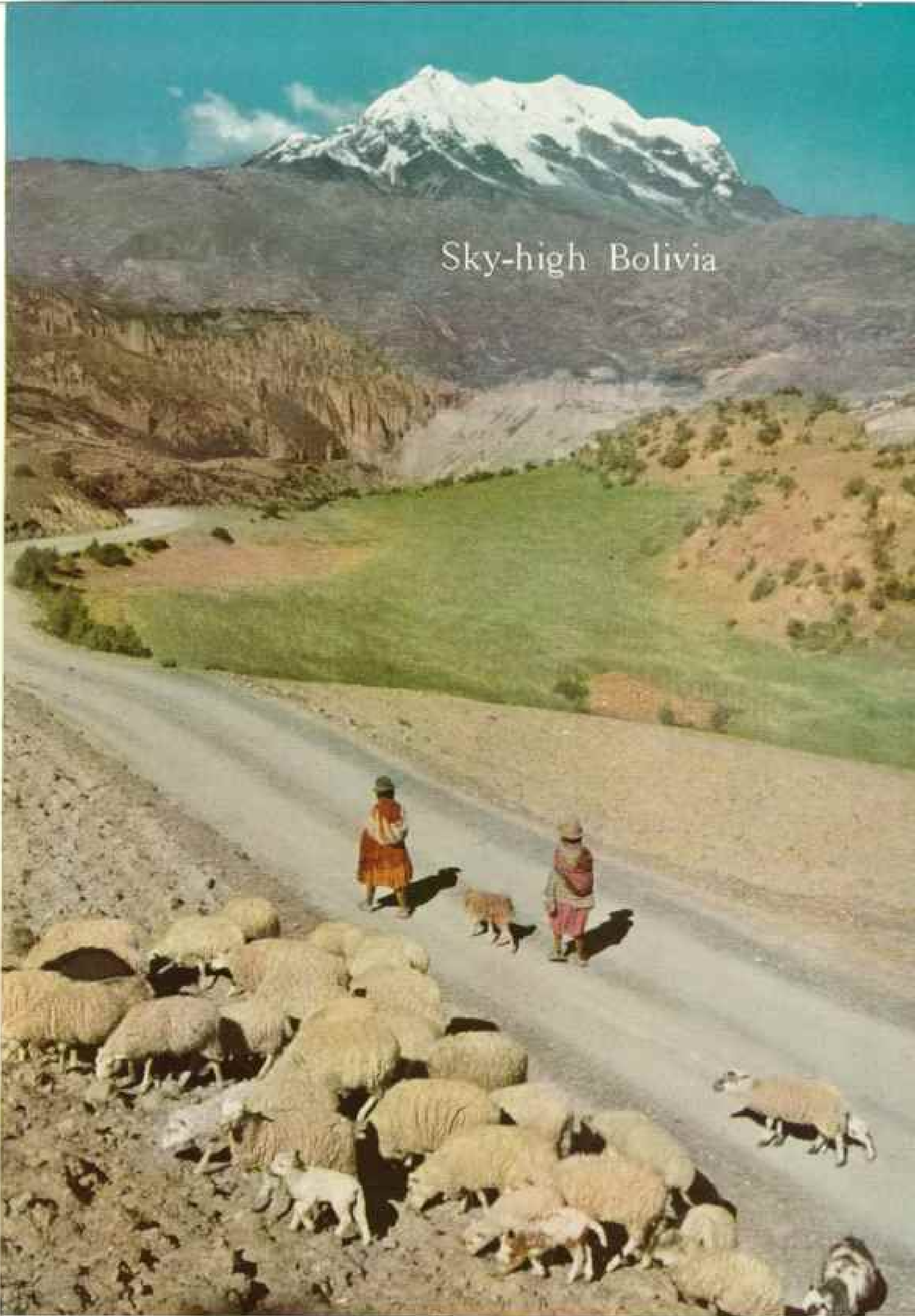
We left the land of the puyas and that amazing display of phenomenal plant growth with deep impressions. Not the least was the sad thought that this royal colony of puyas would gradually fall victim to the whims of a people who, to break the monotony of an otherwise colorless night, would thoughtlessly destroy them.

This 35-foot puya, living side by side with its inch-high tillandsia relative, should be protected by law. A national park, such as those in the United States, would give these rare plants the protection they deserve.

Of these two extremes, the pygmy tillandsia, independent of soil conditions and too insignificant to be noticed by anyone except a botanist, needs no protection.

But *Puya raimondii* is vulnerable in its majesty. Before it is too late, we hope that something may be done to preserve it.

* See, in the NATIONAL GEOGRAPHIC MAGAZINE: "Bolivia—Tin Roof of the Andes," by Henry Albert Phillips, March, 1943; "Heart of Aymará Land," by Stewart E. McMillin, February, 1927.



Sky-high Bolivia

Indian Shepherdesses Stolidly Ignore Illimani's Glittering Glaciers

As Tibet perches in the Himalayas, so Bolivia sits on its Andean throne. La Paz, its 11,900-foot capital, rivals Lhasa. Most Bolivians, lungs enormously developed, live two miles above sea level. A few dwell at 16,000 feet.



Huayna Potosí Lifts Its Frosty Head among the Clouds. It Stands in the Cordillera Real, Crowning Range of the Andes

Aymará legend says an Inca with a slingshot created this peak by shooting off the tip of flat-topped Mururata (page 485). He called it Huayna (Young) Potosí.

Unsinkable Bulrush Boats Driven by Rush Sails and Gusty Winds Ply Lake Titicaca

These graceful craft, their prows curving up like the heads of snails, duplicate the bulrush boats found by the first Spaniards to see Titicaca, the sky-high lake cupped among the Andes. Spaniards, remembering the coast's light balsawood rafts, called the boats *balsa*, an enduring misnomer.

No wood or other stiffening is used in the *balsa* save in the collapseable mast. Hull and sail are constructed of rushes.

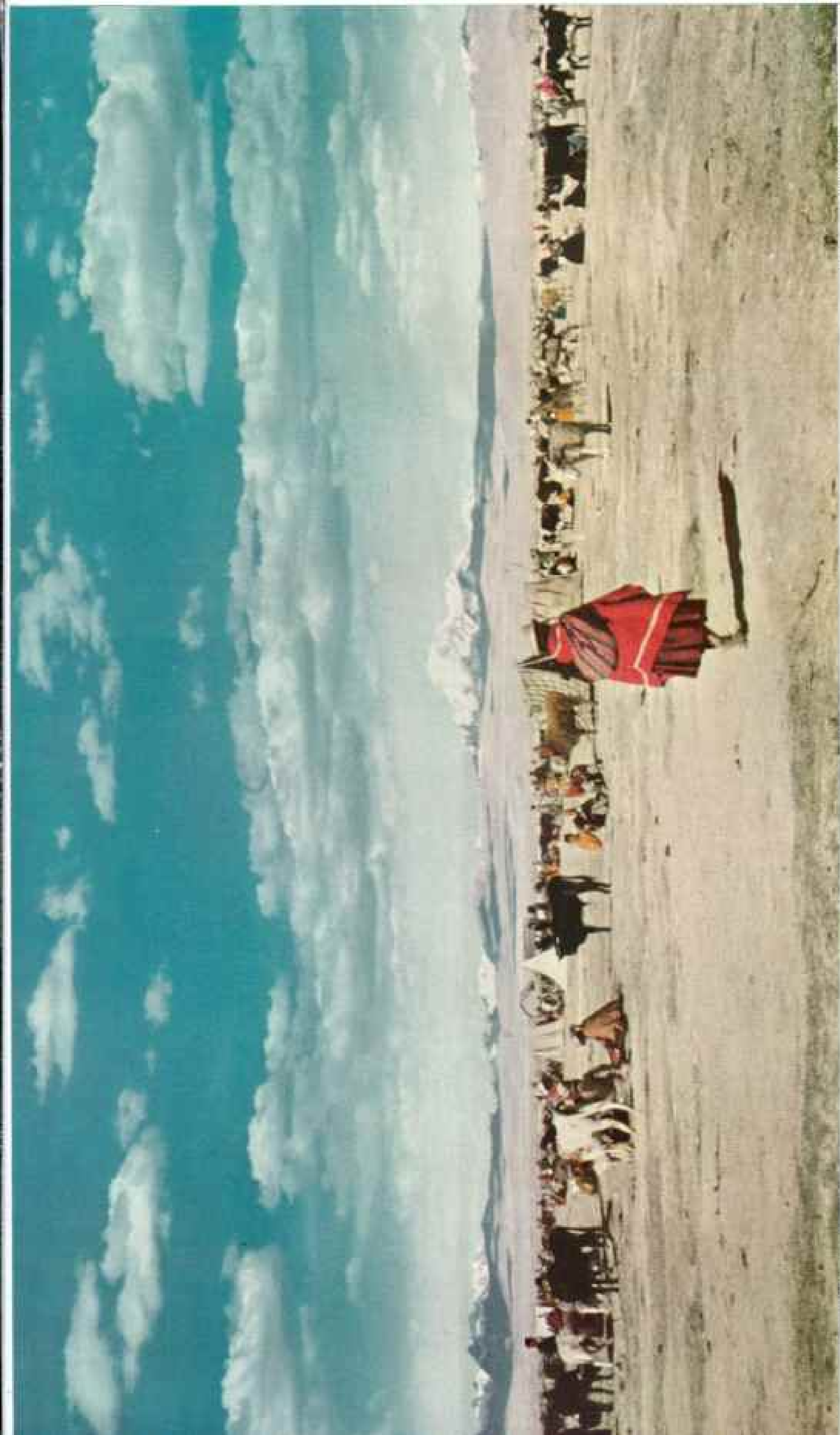
Indians cut rushes and dry them in cornstalklike sheaves. Then, using grass twine, they bind them into bundles. These lashed together form keel and hull. Smaller segments, lapping the gunwales, turn back waves.

A cork-light pith with cellular air spaces makes the rushes unsinkable, even in the lake's sudden squalls. Once waterlogged, the craft is dragged ashore and dried. Under a stiff wind the *balsa* may sail at six miles an hour. Punted through the shallows, it can do no better than half a mile. Larger balsas carry a dozen passengers; some transport llamas.

Titicaca's rush (*totoro*) is as important to its Indians as bamboo is to Chinese. Fishermen thatch houses with rushes, fashion rush raincoats, and eat young rush roots like asparagus tips.

Millions of waterfowl hide in the rushy marches. Ducks are so thick that Indians sometimes bat young ones down with poles.





Once a Year Indians Pitch Tents, Tether Cattle, and Hold a Livestock Fair on the Broad, Wind-swept *Altiplano*

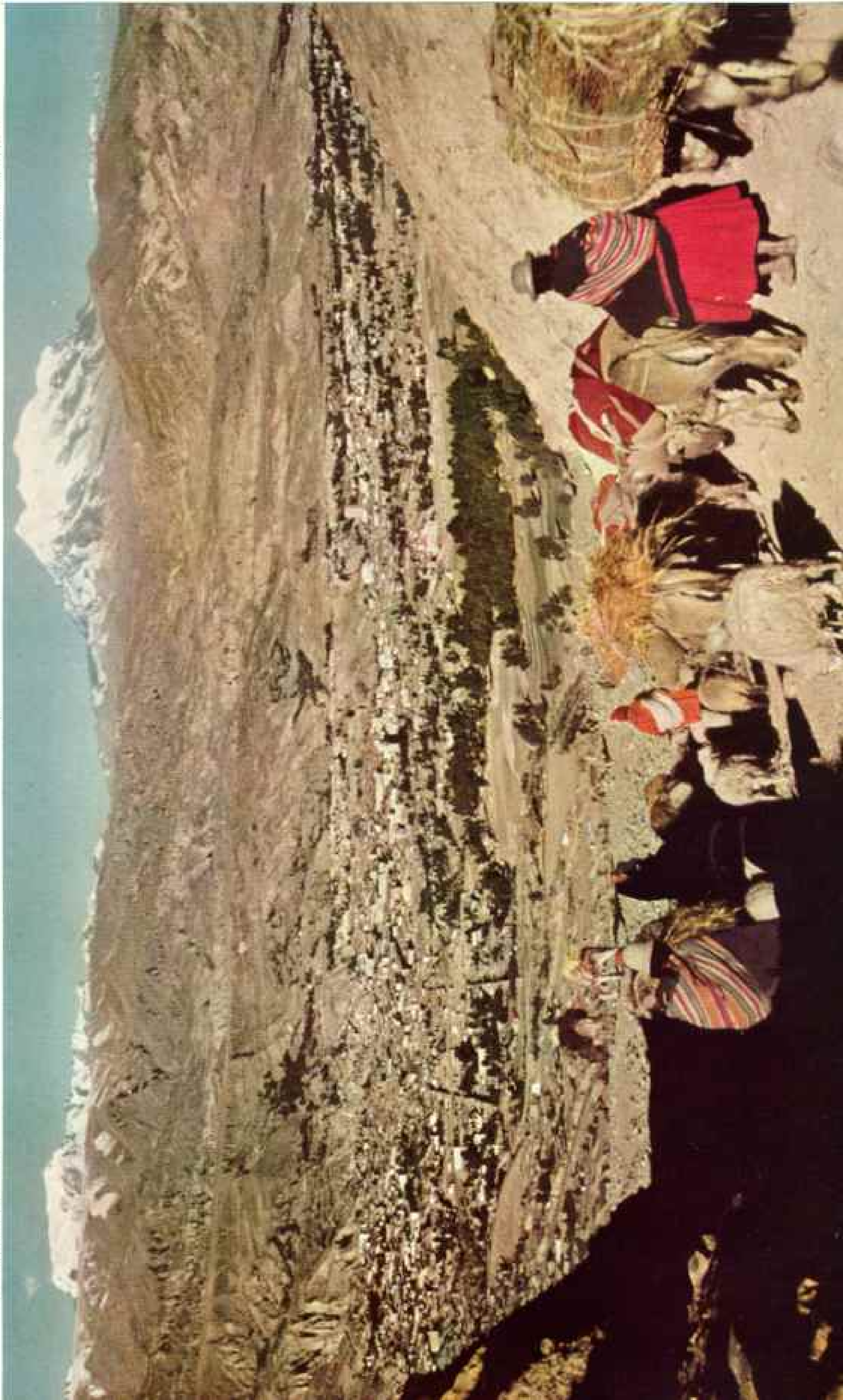
Guided by distant Huayna Potosí (page 482), many have tramped vast distances beside their animals. Here, near Pujaráni, they exchange the plateau's cows, leather, cheese, and frozen potatoes for the lowlands' corn, fruit, and bamboo, and factories' clothes, dyes, and gadgets. Such fairs are hailed down from Inca times.

Market-bound Indians Enter La Paz by an Old Llama Trail. Illimani (Right) and Mururata Stand Eternal Guard

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Illustration by T. Harlow





As Regularly as Sunday Mass, Derbyed Indian Saleswomen Squat Beside the Church in La Paz, Where La Paz Was Founded in 1548

Here the *adriplano* proved so cold and barren that the city was transferred to its sheltered valley (page 485). When La Paz celebrated its fourth centennial in 1946, the old church was restored. Pulpit and main altar are of solid silver.

Indian Women Spin Yarn Sitting, Walking, Sometimes Dancing. Distaffs Whirl Whenever Hands Are Free

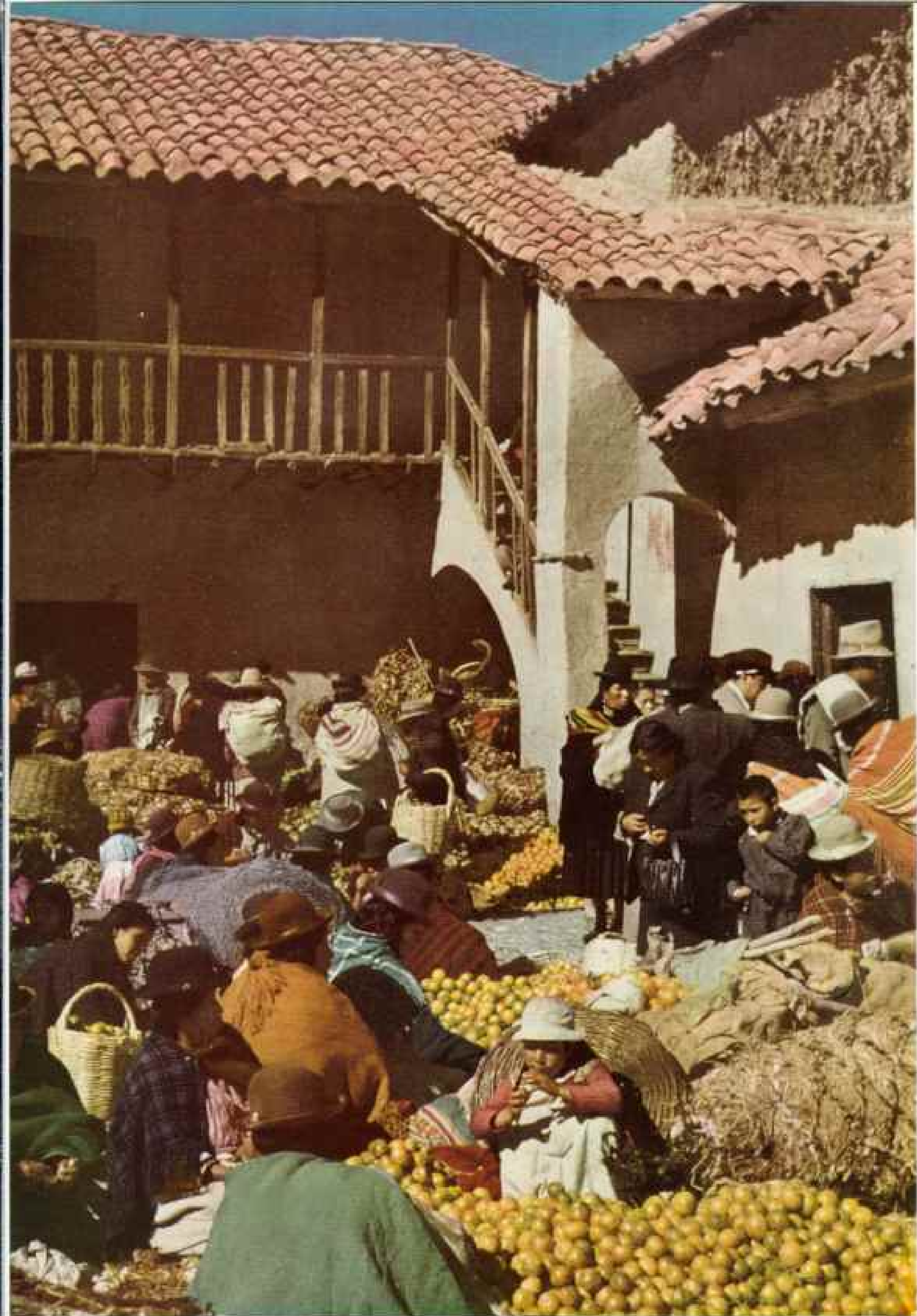
Right: Ekeoko, the plaster doll, is the Aymará god of abundance. His dwarfish figure is commonly decked in miniatures such as boats, houses, even automobiles. Indians, *Chólos*, and a few whites all pay respect to this pagan deity. L. A. Pat honors him at January's *Ahasñas* ("Boy") fair by publishing tiny newspapers.

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Illustrations by Carl J. Bell





Merchants and Merchandise Share the Hard Ground: Sunday Market in La Paz

Colors, from dark felt derbies to bright shawls, flash in the welcome sun. Babies' cries break through the cackle of bargaining. Sales are measured by the eye—a pinch of salt, a handful of flour, a few oranges.



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Rotations by Carl S. Bell

† Barefoot Indian Dancers Spin Like Tops. Skirts Balloon, Colors Flash

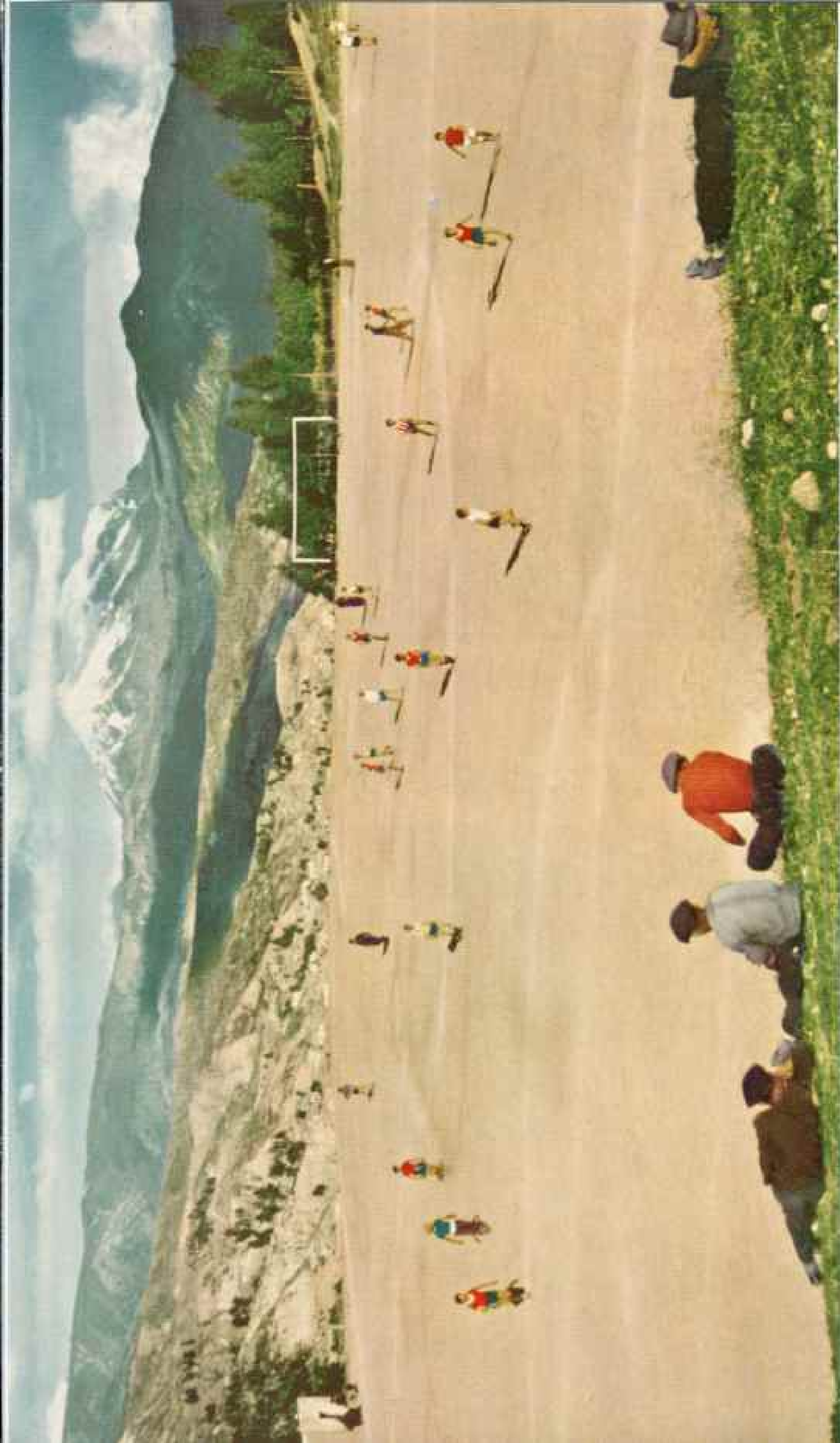
Fiesta celebrators, feasting, drinking, and whirling, dance themselves dizzy in the Tiquina area. The more skirts they wear, the greater prestige they boast. If oranges, purples, and greens clash, so much the better.

‡ Carnival Whips La Paz into a Frenzy; Dance Teams Dress in Matching Costumes

Crowds toss confetti and perfumed water; masked youths slap passers-by with cardboard batons. This team, with its little *mascota*, competes in National Stadium. The silver fish parodies a popular ornamental pin.

Rotations by T. The Blues





La Paz Factory Teams Play Soccer in Thin Air with Never Time Out for Gasping. Distant Illimani Seems to Overhang the Field. American boys, arriving from sea level, may suffer mountain sickness; but, once adjusted to the altitude, they play softball and tennis vigorously. The Bolivian capital claims the world's highest golf course at suburban El Alto. Its mountain-ski run starts down from nearly 17,000 feet.

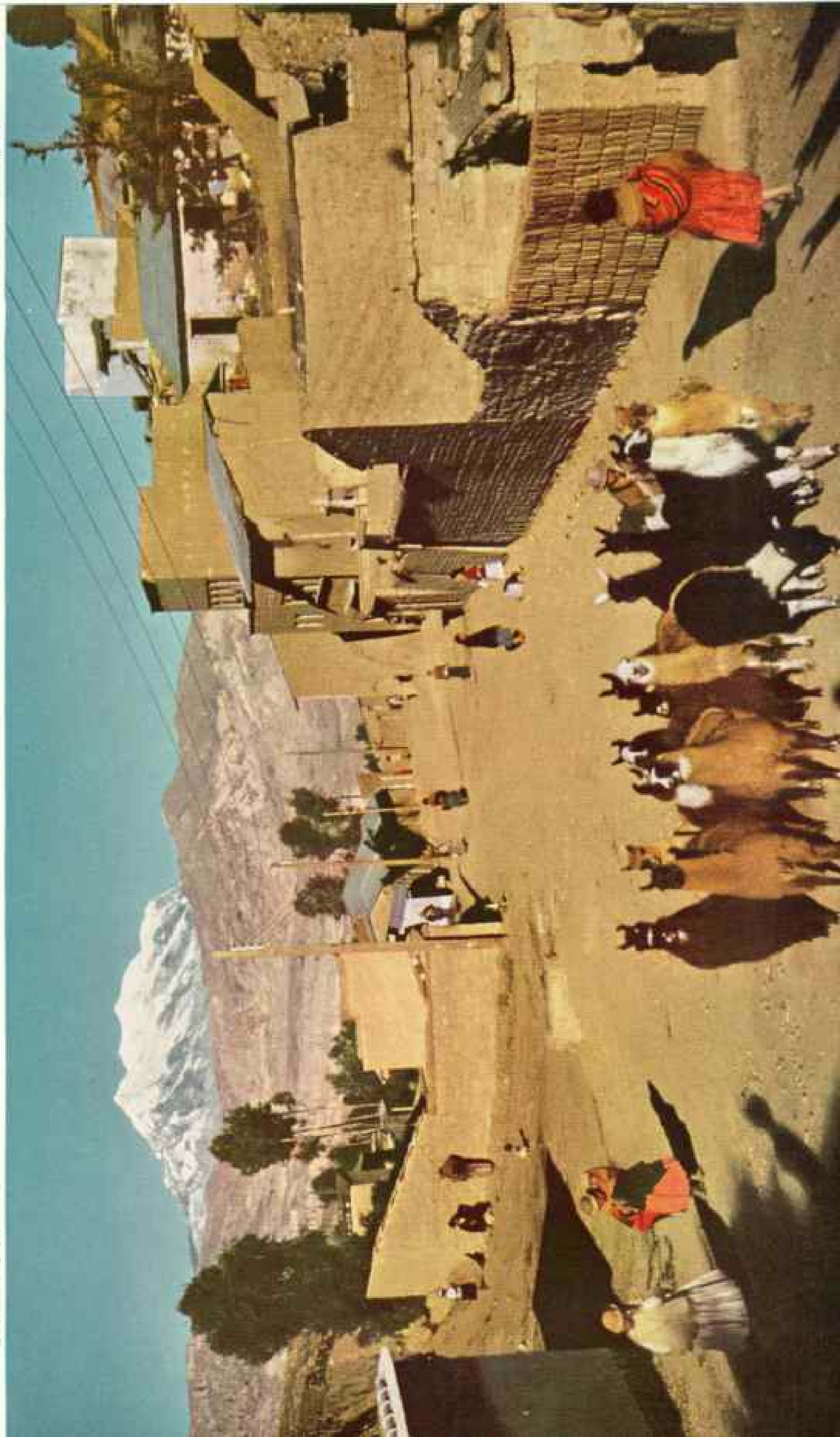
Llamas, Sternly Excluded from the City Limits of La Paz, Pick Their Way Through Indian Town as if They Owned It

Babies ride mothers' backs; men lounge in the sun. Odors of food and corn beer drift past adobe walls and hang over the dirt street.

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Photographs by T. Roy Rapp





Fashionable La Paz Loves to Stroll the Mosaic Walks of the Prado on Bright Sunday Mornings

Newspaper office, skyscraper home of a university (both left), hotel, Protestant church, and clubs (right) line this booming thoroughfare.

Winged Angel with Crooked Sword and Hubcap Shield Battles a Demon. Seven Deadly Sins with Horns and Wigs Watch the Fray

Bolivian Indians' fiesta dances are as bewildering and grotesque as those of Tibetan lamas. This team, which calls itself La Diablada, spends most of its evenings on costumes. Here it performs in the prefect's mansion in Oruro. Before the dance, angels and devils kneel side by side in church. Right: close-up of an Indian devil with jagged teeth, popping eyes, and horns. One may buy his mask in miniature at the *Masitas* fair (page 487).

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Illustrations by Carl W. Hoff



From Inca Times down Through the Christian Years, Copacabana Has Drawn Pilgrims to Titicaca's Shores

Inca centuries ago embarked from the promontory for the Island of the Sun (Titicaca), their founders' legendary birthplace. Nowadays multitudes arrive each August to adore the Virgin of the Lake, a miraculous image reportedly carved by an Indian in 1576.

Primitive Square Sails of Indian Ferries Zip Across Lake Titicaca

Could Mount Fuji, Japan's highest peak, be moved across the Pacific, its cone would look up more than 100 feet to this 17,500-foot lake in the clouds.

Titicaca's 3,300 square miles make it half the size of Lake Ontario. In places it is too deep for anchors. It is so cold that native Indians, like Arctic Eskimos, rarely learn to swim.

This lake's waters, like the Dead Sea's, do not reach the ocean. Flowing into bitter Lake Poopó, they disappear in salt marshes.

Nowhere else is steam navigation carried on at so great a height. Little steamers regularly carry passengers and freight between railroad terminals in Peru and Bolivia. Built in Scotland, they were transported in sections across the Andes and assembled on the lake. Before trains arrived to do the job, one ancient steamer went up the mountains piece by piece on muleback.

At its widest the lake stretches some 50 miles, but here the Strait of Tiquina narrows it to about a mile, making a convenient ferry crossing.

Indians ply these craft between the peninsula of Copacabana (opposite page) and Tiquina (shown ahead). Sails are so clumsy that ferrymen reach their goals only by dint of skill and toil. Often toward evening they are plagued by fierce winds.

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Illustrations by Carl F. Bell





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Illustration by Carl E. Hill

★ **Titicaca's Tattered Ferry Pilot Poles
His Craft to a Landing**

Like many Aymará men, he wears his work clothes until they are ready to fall off. Though poor, he is proud and self-reliant. Hardships he endures without complaint. His face reflects his race's reserve and habitual melancholy.

✧ **Lake Mirrors Illampu's 23,000-foot Snows;
Indians Drag Titicaca for Fish**

These waters, ideally cool for trout, lacked game fish until a decade ago, when Bolivia and Peru planted Great Lakes trout. These have grown so large that many Bolivian sportsmen lack gear to take them. Rainbows, too, now thrive in Titicaca.

Illustration by T. Orr Bell



New National Geographic South America Map Shows a Continent Coming of Age

WHEN Francisco Pizarro was faced with mutiny on his southward expedition to find the Incas in the 16th century, he drew a line in the sand from east to west.

Pointing to the line, the conquistador said: "On this side are toil, hunger, nakedness, drenching rains and storm, desertion and death; on the other side, ease and pleasure. There lies Peru with its riches; here, Panama in its poverty. Let each man choose his own destiny. For my part, I go to the south."

Today South America is finding itself heir to riches Pizarro never suspected, notably mountains of iron and subterranean lakes of oil.

To provide a timely picture of the vast southern half of our hemisphere, the National Geographic Society has prepared the new 10-color map, "South America," issued as a supplement to this October number of its NATIONAL GEOGRAPHIC MAGAZINE. More than 1,950,000 copies have been printed to supply The Society's world-wide membership.*

The map shows a continent coming of age. Red stars indicating airports spangle even the deep interior. New towns linked to the outside by air have sprouted in the heart of the continent in areas only a few years ago as little known as any on earth outside of Antarctica.

Venezuela bristles with oil-well symbols, and now the life fluid of the machine age pours also from fields in Argentina, Peru, and half a dozen other countries.

"Newly Delivered Mother" Yields Iron

Seeking new sources of iron to supplement dwindling deposits at home, United States Steel Corporation men struck it rich in Venezuela. Some 50 miles south of Ciudad Bolívar they found a mile-wide, 11-mile-long mountain named La Parida ("Newly Delivered Mother"). More than half of it turned out to be solid iron ore. La Parida, renamed Cerro Bolívar, rivals immense resources of iron already known in Brazil.

From the huge Urucum manganese deposits near Corumbá in southwestern Mato Grosso, Brazil, the same company expects to get an annual 100,000 tons of this vital steel-making mineral. Other large manganese sources have been found on the Amapari River in Brazil's newly created Territory of Amapá.

As industries develop in South America, the old pattern of life is changing. At the big U. S.-built Volta Redonda steel plant in the

Brazilian State of Rio de Janeiro, one initial problem was the employees' habit of blithely departing for a three-day fiesta, leaving furnaces to cool.

Despite the growth of industry, much of the continent is still in the pioneering stage. South America contains only 14.7 persons to the square mile, compared with 145.3 for Europe, 77 for Asia, 21.3 for North America, 15.1 for Africa, and 2.6 for Australia.

Pioneering in Reverse

In the United States, when people began to find out about their country, they started on foot or with canoe or horse and gradually worked up to the airplane. South Americans reverse the process. When Brazilians recently mapped their nation, they started with an aerial survey, followed it up with automobiles, and finally, in isolated spots, with oxcarts and dugout canoes.

The 1950 picture reflects the enormous increase in geographic knowledge brought about by the extensive governmental, military, and private surveying that resulted from World War II and the search for new sources of petroleum by oil companies.

Fourth in the National Geographic's post-war continent series, the new South America map contains more changes in physical details than any of the others, including Africa.† Even the dense, silent jungles have been yielding the secrets of their geography to men riding the mighty rivers or flying above with cameras clicking.

On the new map the veinlike pattern of the Amazon, which drains an area nearly as large as the United States, is greatly changed. Courses of major rivers such as the Xingu, Tapajós, and Madre de Dios are so altered in the light of this new information that they are hardly recognizable.

So barbarous are some of these jungle lands that when U. S. Air Force mapping planes dipped low, savage Indians launched futile spears and arrows at them.

Poisoned spears greeted men exploring for

* Members may obtain additional copies of the new map of South America (and of all standard maps published by The Society) by writing to the National Geographic Society, Washington 6, D. C. Prices, in United States and Possessions, 50¢ each on paper; \$1 on linen; Index, 25¢. Outside United States and Possessions, 75¢ on paper; \$1.25 on linen; Index, 50¢. All remittances payable in U. S. funds. Postage prepaid.

† Previous maps of continents in this postwar series were: Africa and the Arabian Peninsula, March, 1950; Europe and the Near East, June, 1949; and Australia, March, 1948. All are still obtainable.

petroleum around Shell Mera in Ecuador. These were the calling cards of primitive, much-feared Indians known as *aucas*, which means "enemy" or "rebellious."

In contrast with the wild hinterland stand a few large cities of long and proud lineage. What is the third biggest city in the Americas? The answer is Buenos Aires, capital of Argentina. With 3,000,371 inhabitants, it ranks behind New York and Chicago and ahead of Philadelphia.

Though smaller than North America, the neighbor continent is immense. The world's fourth largest land mass, it would stretch from the Panama Canal to Thule in northern Greenland. Its width, from Punta Pariñas, Peru, to João Pessoa, Brazil, is 17 percent greater than the maximum width of the United States.

All this tremendous area is shown on a 28-by-39½-inch sheet at a scale of 126.3 miles to the inch. For the first time South America is mapped on the National Geographic's new Chamberlin Trimetric Projection, which gives the truest over-all picture of the continent.*

The map shows both old and new—pre-Columbian ruins and oil pipe lines, roads and railways existing and under construction.

Far down in Chilean Tierra del Fuego a pipe line connects the new port of Caleta Clarencia with a newly found petroleum field near Cerro Manantiales which Chile hopes will make it self-sufficient in this important product. A new pipe line in southern Bolivia from the fields at Camiri is pouring out about 70 percent of that country's domestic requirements.

In Brazil's mineral-rich State of Goiás a road is being pushed north from the railhead at Anápolis to help open its treasure-trove of nickel, quartz crystals, and diamonds and to aid the influx of farmers.

Highway of the Hemisphere

A heavy red line on the map, with some sections marked "Under Construction," shows progress on the great Pan American Highway system. Most ambitious road project in history, the highway will some day stretch from Fairbanks, Alaska, to Patagonia.

South American branches take the traveler through Venezuela and Colombia and on to Ecuador, where he can straddle the Equator, stand with a foot in each hemisphere, and shiver in an overcoat because of the altitude.

Down through Peru runs the part called the Franklin D. Roosevelt Highway. At Lima the motorist-adventurer can branch off and cross the main range of the Andes at 15,889 feet. In no other place in the world can one drive a passenger car to such an altitude.

Of the 6,942 names on the map, most are Spanish or Portuguese. Others are Indian, such as Llanquihue and Titicaca.

Anglo-Saxon voyagers around the Horn have left place names on that stormy route. Staten Island, Lennox Island, and Nassau Bay might well make the reader think of New York City and vicinity. Londonderry Island and Cornish Bay could easily be part of the British Isles. But these places, spelled in the Spanish manner, are found on the southernmost tip of South America, along with such other incongruities as Bahía Cook and Isla Duque de York.

All of the place names in Brazil have been recently revised in accordance with the officially adopted simplified spelling of the Portuguese language there, and these appear on the National Geographic map for the first time. Brazil has also launched a nationwide program which will largely eliminate duplication of names. Many have been shortened, too. For instance, Vitória do Alto Parnaíba is now simply Alto Parnaíba.

One of the newest towns anywhere appears on the South America map. Near Argentina's Ushuaia, southernmost town in the world, Empresa Borsari mushroomed almost overnight. Here live several hundred Italian colonists brought over in 1948 to further the Argentine project of making Ushuaia into a naval base and tourist port.

Towns Wiped from Map by Measles

Among the deletions are many towns and villages in the Madre de Dios and Loreto Departments of Peru. Most maps still show these towns, but their inhabitants have virtually disappeared in the wake of a deadly epidemic of measles. Those who survived moved out of the area or settled in such places as Piquen, which now appears on the map.

The new map has ten interesting and important insets. One gives a close-up of the Panama Canal. Another shows the position of South America in the Western World. A third emphasizes the continent's physical geography, from low green jungles to icy-white Andean heights; blue stars mark sources of major rivers. Seven of these insets show island groups belonging to South American countries but lying beyond the map's borders.

* For a fascinating description of how maps are made and a graphic explanation of this and other projections used by cartographers, see the National Geographic Society publication, *The Round Earth on Flat Paper*, by Wellman Chamberlin. The new edition is illustrated with 117 drawings by Charles E. Riddiford, photographs, and maps. Copies may be obtained from the National Geographic Society, Washington 6, D. C., upon remittance of 75 cents each in U. S. funds.

Strife-torn Indochina

BY W. ROBERT MOORE



ON THE MAP Indochina bears a striking cartographic resemblance to a magnified Korea. It abuts the south border of Communist China in almost the same way as the Korean peninsula hangs southward from Manchuria (map, page 501). Like Korea, too, it has been a political hot spot of Asia since the close of World War II.

Only a little larger than Texas, Indochina is made up of three States—Cambodia, Laos, and Viet Nam. The sparsely populated Kingdoms of Cambodia and Laos, which comprise more than half the country's land area, have remained relatively quiet, but the turbulent new State of Viet Nam has been in the news so often that its name is now more familiar than were those of the prewar provinces—Tonkin, Annam, and the French colony of Cochin China—from which it was created.

Two Leaders Gain Recognition

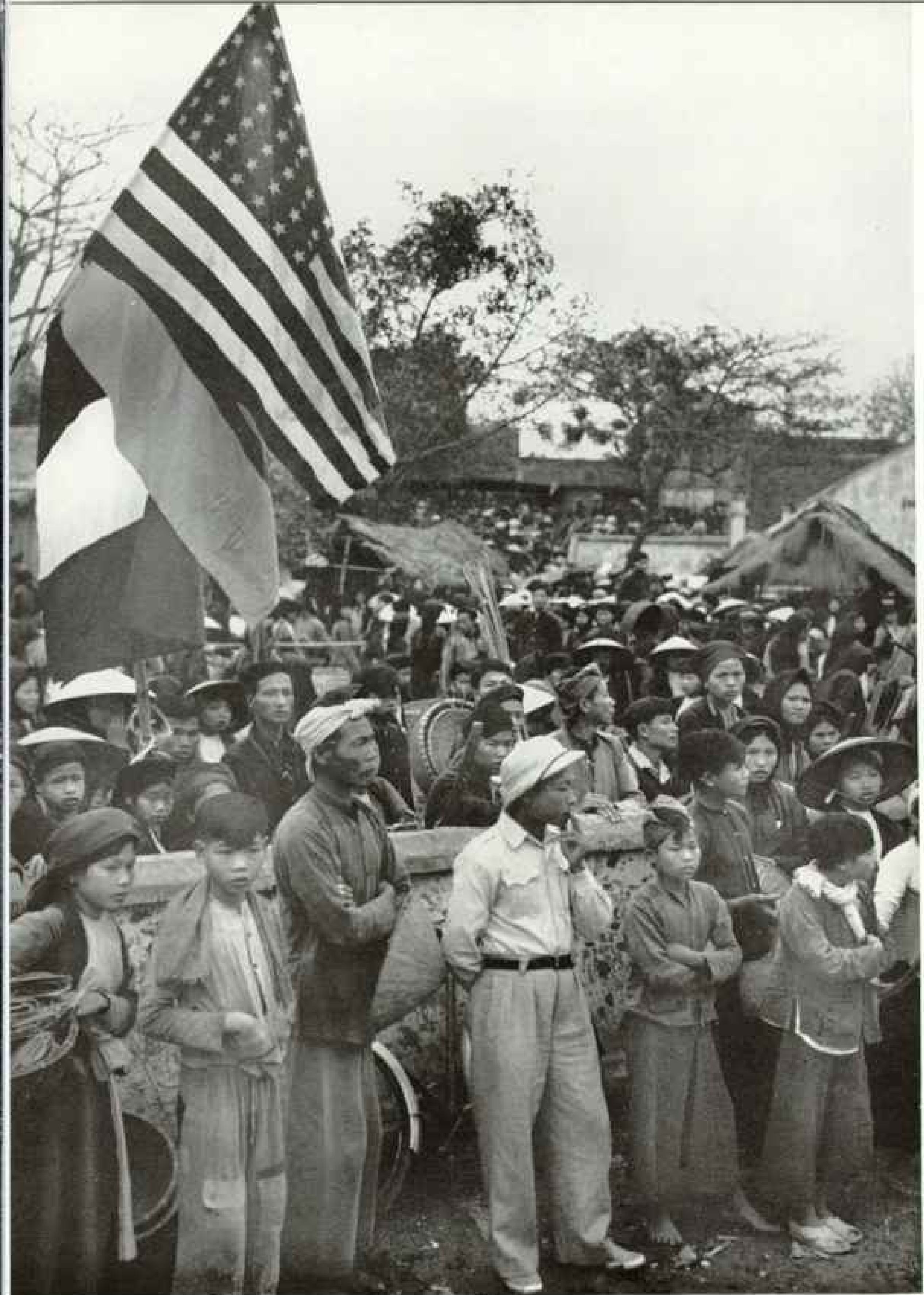
Born as a puppet state under Japanese occupation and reviving its ancient name, meaning "People of the South," Viet Nam has been in conflict with French forces and involved in long negotiations aimed at self-government.

Early this year Viet Nam reached the point of having two recognized leaders, not one! Soviet Russia and her satellites announced recognition of Moscow-trained Ho Chi Minh, key figure in earlier negotiations with the French. The United States, Great Britain, and several other nations acknowledged the government headed by Bao Dai, ex-emperor of Annam, who was cooperating with the French in establishing organized independent rule (page 508).

Here was created no artificial boundary division such as Korea's 38° parallel, which cut the country in two. Instead, Ho Chi Minh's followers, now known as Viet Minh, have gone underground and are waging a vigorous hit-and-hide guerrilla campaign against French forces and against Viet Nam villages guarded by local militia (above).

Every night when I was in Saigon in April this year I could hear the dull boom of mortars in the marshy river margins at the outskirts of the city. Machine guns often popped in the distance like strings of firecrackers set off at a Chinese festival.

Saigon itself, however, had been cleared, so that grenades no longer were tossed into



Villagers Near Hanoi Welcome Visiting Americans with U. S., Viet Nam, and French Flags
America, joining Indochina's struggle against Communism, has come to its aid with advisers and arms.



Indochina, Key to Southeast Asia, Is a Vital War Front. Like Korea, It Borders Red China

When President Truman last June 27 intervened in Korea, he similarly directed the acceleration of military assistance to French forces fighting a four-year war in Indochina. Burma, Thailand, and the Malay States, with their tin, rubber, and oil, appeared to be the stake. France, the protecting power, held Indochina's cities and valleys. Rebels led by Moscow-trained Ho Chi Minh controlled mountains and jungles from China to Gulf of Siam. Fighting centered in Viet Nam (meaning "People of the South"), home of 22 of Indochina's 27 millions. Cambodia and Laos, other partners in the union, were relatively peaceful.

French street cafes, and the early curfew had been lifted on traffic between Saigon and the adjacent Chinese town of Cholon (page 508). Cholon's night clubs and casinos again were busy.

Along roads and at railway bridges high watchtowers had been built to guard against marauders. Prize targets for the guerrillas were the military convoys moving between towns.

"What part of the country is Viet Nam and what Viet Minh?" I asked in Saigon, Dalat, and Hanoi.

"It all depends upon the time; much of the country is Viet Nam by day, but Viet Minh by night," was the gist of many answers.

French troops have cleared out many pockets of resistance, so that Viet Nam police have been able to take control. Rebel forces have been driven from much of the rich rice areas of south Viet Nam (formerly Cochin China) and the broad Red (Rouge) River delta in the north. Crops now can be planted and harvested to feed Viet Nam's 22,000,000 people.

From Saigon I flew to Dalat, resort hill town 150 air miles to the northeast. Homes sprawl in the midst of pine woods beside a

lake at nearly 5,000 feet elevation. Bao Dai spends much of his time here, rather than in steamy Saigon, provisional capital of Viet Nam.

Big Game in the Hills

In the hills roundabout Banmethuot, 80 jeep miles away, Bao Dai and his guests often go tiger hunting. Tigers have been unusually plentiful in the region of late. In the hills, uninhabited save for a few villages of primitive Moi tribesmen, hunters find wild cattle, elephants, and other big game.

Today it is not possible to drive an automobile the length of the old Mandarin Road (Route Coloniale No. 1) from Saigon to the China border as I did 20 years ago.* Consequently, I missed revisiting the coast towns and spectacular land- and sea-scapes where the mountains crowd down to the coast.

Nor is it easy to get to Hué, old capital of Annam. Here, until war swept them away, survived the ancient court customs and costumes patterned after those that once existed in Imperial China.

* See "Along the Old Mandarin Road of Indo-China," by W. Robert Moore, NATIONAL GEOGRAPHIC MAGAZINE, August, 1931.



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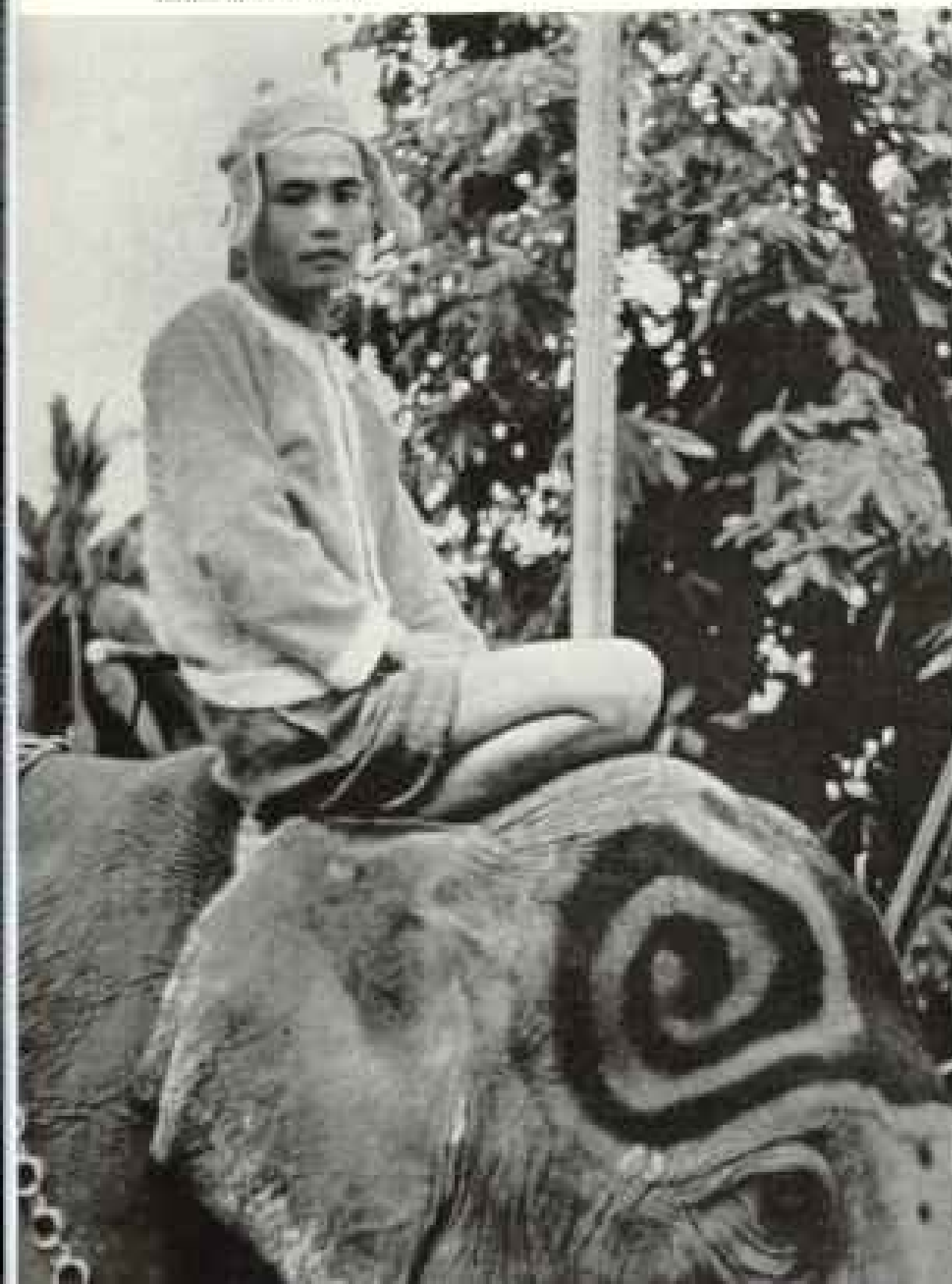
♣ Archers, Lancers, and War Elephants
March Across Angkor Walls

Here the ancient Khmers, whose imperial elephants bore golden tusks, erected classic Hindu temples and carved lifelike sculptures. Ruined by wars, they abandoned Angkor five centuries ago. In 1860 a French botanist rediscovered it in the jungle's green grip.

Kenneth P. Landolt

♣ Indochinese Vase and Royal Elephant
Are Painted by Hand

Rehearsing for the April New Year's festival, the King's herd marched to a temple in Luangprabang for ritual hay and priestly incantations whispered in their ears. Potters, taught by the French to re-create ancient designs, work in a school near Saigon.





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"Communism, No; Colonialism, Never!" Cry the Slogan-conscious People of Da Phuc

Viet Nam's ancient banners flew up front, France's Tricolor in the rear. The author counted 49 stars in homemade American flags waved by the children. Other slogans said: "Welcome Truman's Point 4" and "We beg immediate and direct aid." World events impress these Annamites.

Here, in 1942, Emperor Bao Dai performed the age-old rites of Sacrifice to Heaven and Earth in the same manner as those once offered at the Altar of Heaven at Peiping.

Architecture of the palaces at Hué was as rigidly Chinese in style as were its ceremonies. Some palace buildings have since been damaged and their wealth looted.

With several other Americans I flew straight to Hanoi, chief city of Tonkin and former seat of the Governor General of French Indochina.

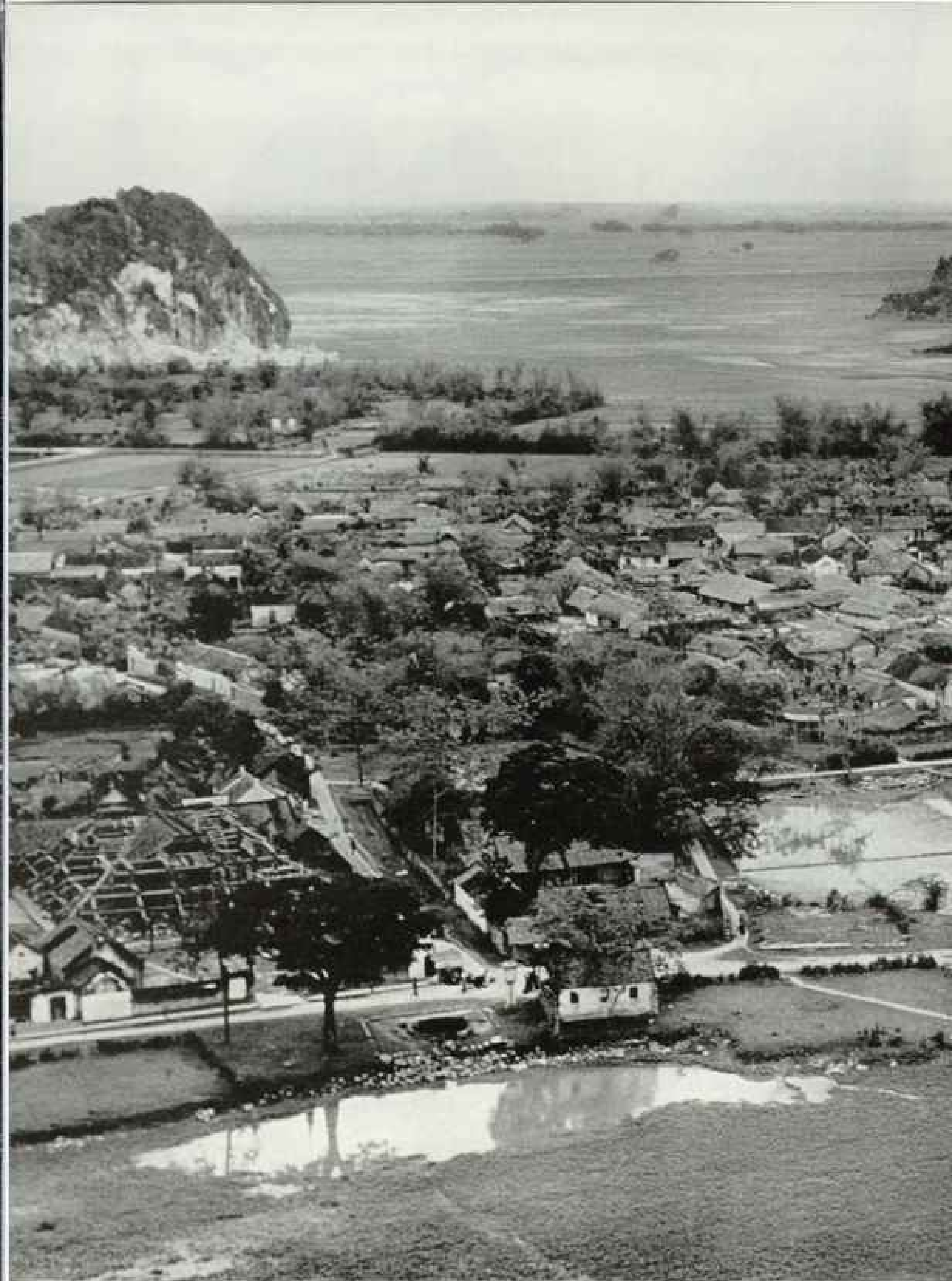
During our visit there the Governor of northern Viet Nam and members of his staff took us on a tour of the surrounding districts to see towns and villages destroyed in recent fighting. Hostilities exploded an armistice in

December, 1946, while negotiations were under way over Viet Nam's becoming "a free state having its government, its parliament, its army, and its finances within the framework of the Indo-Chinese federation and the French Union."

Some towns, such as Sontay northwest of Hanoi, were completely demolished. Other settlements, partly wrecked, still afforded shelter for farmer folk who till the rice lands of the flat, lush Red River delta.

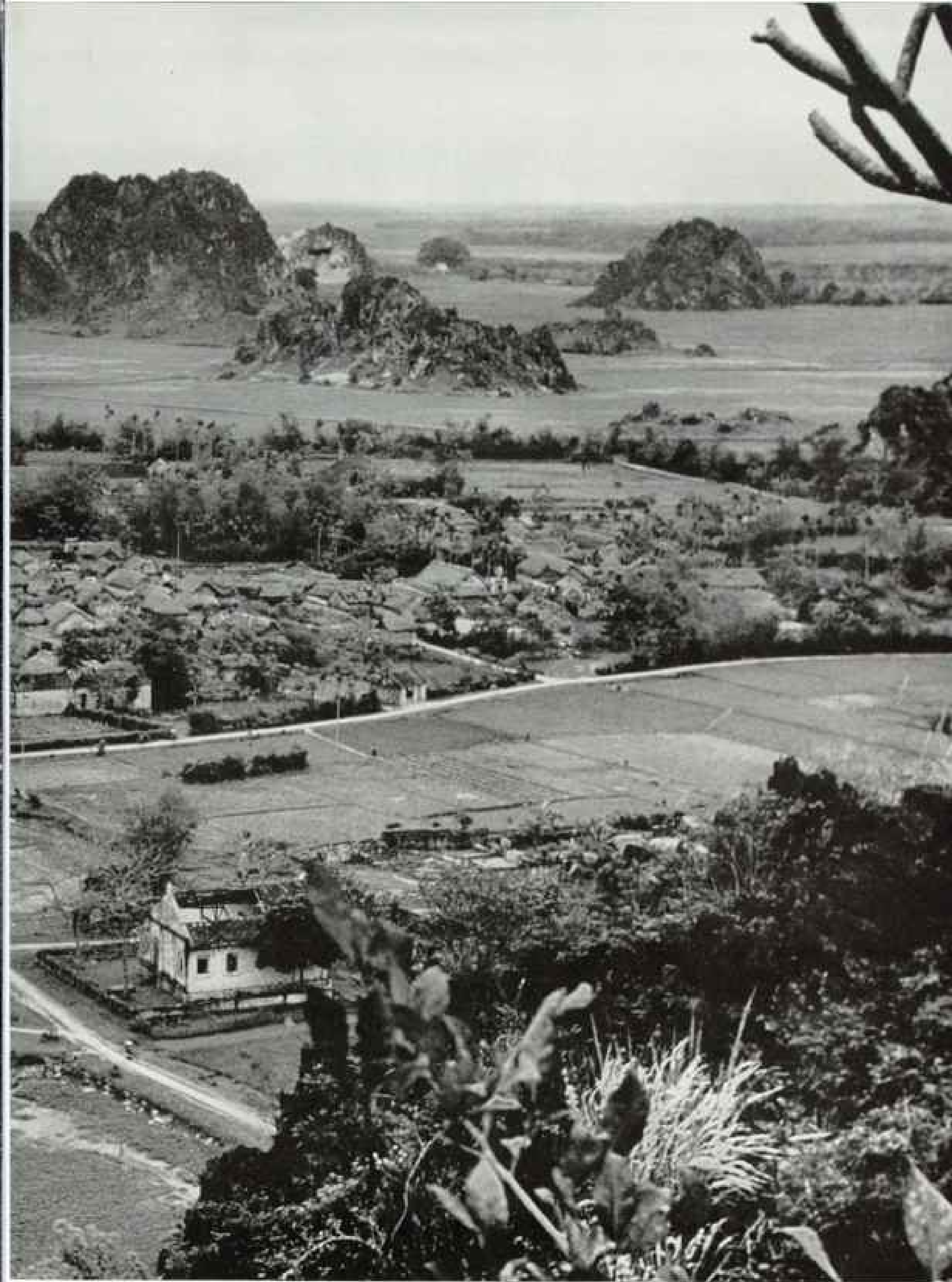
Much of the destruction, officials said, was a deliberate scorched-earth policy adopted by the Ho Chi Minh forces when they were forced to retreat before the French.

One village we visited had apparently remained intact only by the sheer length of



Burned-out Roofs in Da Phuc Proclaim the Scorched-earth Tactics of Retreating Reds

France, which once lost control of Viet Nam except in the cities, has recaptured two rich river valleys. Now, sentries in roadside towers rule the country by day, but Communist guerrillas still strike by night.



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Red River Delta's Limestone Outcroppings Rise Like Alps from a Billiard-table Plain
Once Indochina's rice helped feed the East; civil war cut production in half. Possession of these rich fields enables the French to feed their allies and cut off provisions to their enemies.



As Real as Life, a Stuffed Tiger Fastens Glassy Eyes on a Ceremony at Saigon

Southern Viet Nam's Governor (in turban and silk robe) attends a memorial to Le-van-duyet, a national hero. The audience faces an altar which held bullock, goat, and pig as sacrifices. Tigers, elephants, deer, and wild cattle, teeming in Indochina's hills and jungles, make big-game hunting a popular sport.

argument. The people themselves had refused to help destroy it, said the headman, and had argued right up to the moment the troops were forced to flee.

Greeted by American Flags

At villages and along the roads we met clusters of people. Men and women dressed in long black tunics and trousers stood in separate groups. Youngsters waved printed American flags. Over hastily built bamboo arches hung the red-striped yellow flag of Viet Nam, the Stars and Stripes, and the Tricolor of France, together with ancient banners and slogans (pages 500 and 503).

War here has also caused a shortage of draft water buffaloes and cattle. Despite their lack, most of the rice fields were planted and stood vivid green with a new crop.

From Hanoi I crossed to Vientiane, in the Kingdom of Laos. This main commercial town and seat of the government perches on the banks of the broad Mekong north of the big eastern bulge of Thailand (Siam). Because of its position, much of its trade is with Thailand, as is that of all Laos.

Here and at Luangprabang, where the King resides, the people seemed happy and care-free. I saw no serious-faced youngsters; I had seen many in Viet Nam.

The Laotians belong to the same race as the Thai, and their speech enabled me to make myself understood with my halting, half-forgotten Siamese.

It takes about 12 days to ride upstream from Vientiane to Luangprabang by the motor-propelled dugout canoes that ply the river. We reached there in an hour by plane. The six-months rainy season and the fogs that often hang over the valley keep Luangprabang in isolation much of the time.

Nestled amid mountains, the town seems a Shangri la. Its numerous Buddhist temples and the King's palace have the same picturesque architecture as those in Thailand (page 509).

The Crown Prince Entertains

King Sisavang Vong is now aged and crippled. Many of the government duties fall on the Crown Prince, Tiao Savang Vattana.

The Prince and his princess entertained us one evening at the palace. After dinner we looked at the King's priceless collection of Buddhist images. One is the historic treasured gold statue called Phra Bang. From this palladiumlike figure the city gets its name.

One day, during the recent Japanese occupation, a Japanese soldier came in, and against the palace guards' protest that the



Sidewalk Vendors' Stands in Phnompenh Move with the Sun, Seeking the Street's Shady Side

Rubber balls and clothing catch the eye; store signs are in Chinese. One shorts- and bathcloth-clad customer browses at a bookshop; those narrow strips of palm leaf contain Buddhist scriptures. By afternoon every open-air merchant will be on the opposite side of the street.

statue was sacred, picked it up and started to carry it away. Before he reached the bottom of the steps, he fell and, as the Prince expressed it, "his blood all ran out."

Other Japanese soldiers waiting outside became frightened. Their officer ordered that none should touch the Buddha. A palace attendant then rescued the Phra Bang and restored it to its proper place.

Later we moved to the front terrace and watched ancient dances. Some of the acts were drawn from local folk tales, others from the classical *Ramayana*.*

From the darkness of huge palms bordering the central path leading to the terrace actors emerged and wove rhythmic patterns as they danced slowly toward us. An orchestra of drums, gongs, and xylophonelike instruments played in the shadows.

The epic fight of Rama and his ally, the monkey god Hanuman, against the evil multiple-headed King of Lanka was the only struggle I saw in this portion of Indochina.

But Laos does watch its frontier bordering on China.

It was April, Cambodian New Year, when we arrived at Phnompenh. To offer a greet-

*See "Pageantry of the Siamese Stage," by D. Sonakul, NATIONAL GEOGRAPHIC MAGAZINE, February, 1947.

ing, we called on French-educated 28-year-old King Norodom Sihanouk. Afterward we watched his court dancers perform ancient classical plays.

Cambodia is rich in traditions. From the 6th to the 13th centuries the country built some of the most elaborate structures known to man. The majestic ruins of Angkor, near the large lake, Tonle Sap, 150 miles northwest of Phnompenh, attest that fact (p. 502).

But the proud civilization of Angkor was reduced by frequent assaults of Siamese armies. The political association that has since taken place and the Buddhist religion which both countries share have contributed toward their similarity. The royal palace and many of the temples today are of Siamese architectural style.

A Spick-and-span Town

Phnompenh is a spick-and-span town, half European, half Oriental in appearance. It gains its name from the temple-crowned hill of Penh, which stands in midtown.

On one side of the hill, too, is a monument showing the late King Sisowath flanked on one side by three Cambodian women bearing offerings and on the other by a soldier beside a plaque. It commemorates the return to Cambodia of three provinces—Siemréap,



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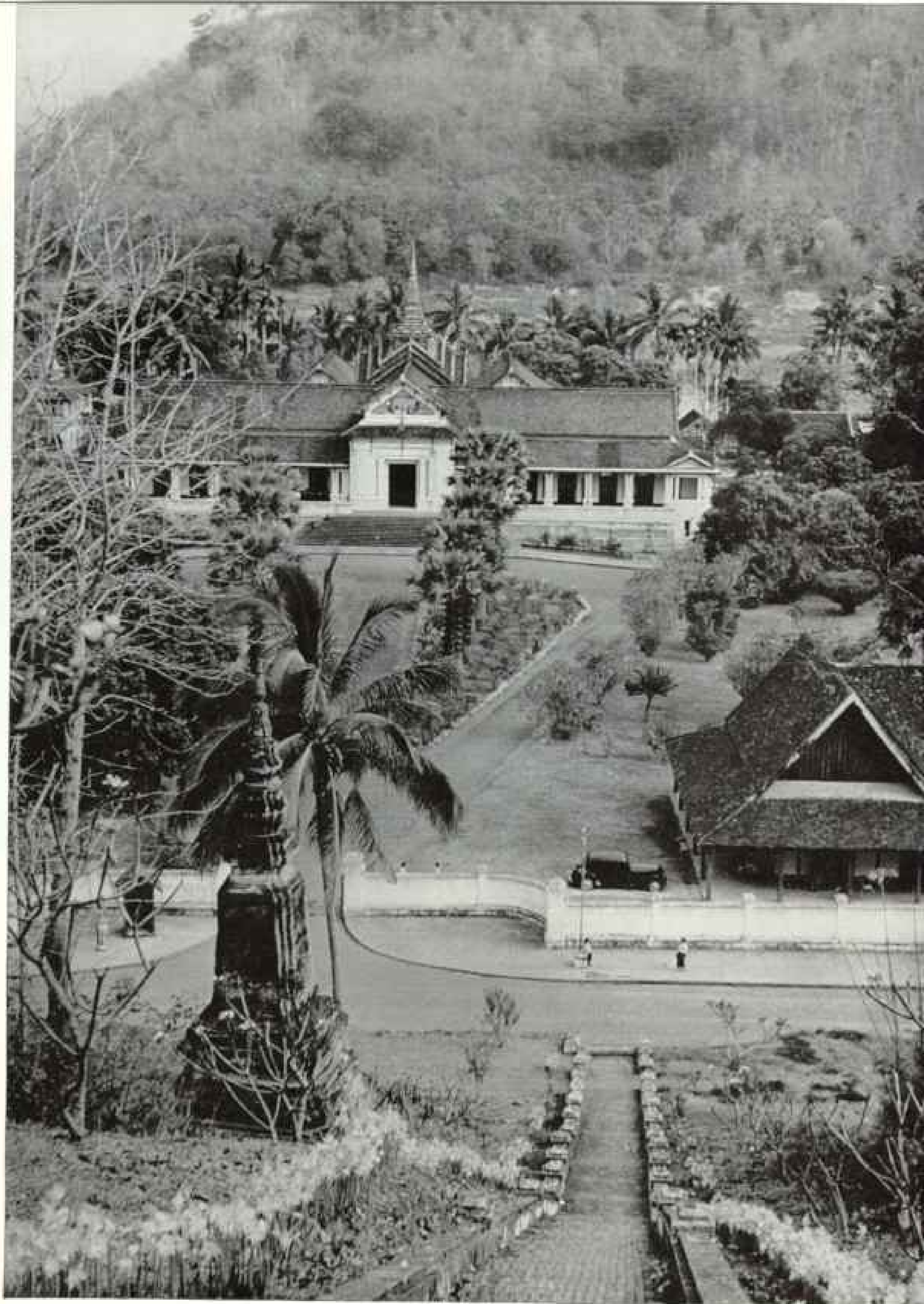
★ **Bao Dai, Viet Nam's Chief of State,
Accepts Mr. Truman's Signed Gift**

The White House recognizes Bao Dai, who hunts tigers, just as the Kremlin acknowledges Ho Chi Minh, who hunts men. Former emperor of Annam, Bao Dai spent years of exile in France. State Department's Kenneth P. Landon makes the presentation.

✧ **Cholon Market's Bread Is French;
Its Saleswomen Are Chinese**

Keen traders, Indochina's 500,000 Chinese dominate many businesses. Thousands live in Cholon, Saigon's Chinese neighbor, where they have seen the terrors of civil war. These palm-leaf hats serve equally as sunshades or umbrellas.





Laos's Royal Palace, Free of War's Hate and Violence, Wears a Misty, Dreamy Look.
Mekong River, born in western China's icy mountains, sweeps between palace and hill in tropical Luangprabang.



Twin Dugouts, Lightly Bridged, Ferry Cars Across an Arm of the Mekong at Luangprabang

On the far bank grow areca palms, whose chewy fruit, the betel nut, blackens Southeast Asia's teeth.

Sisophon, and Battambang—obtained from Thailand by French treaty in 1907.

In 1941 a new boundary dispute was arbitrated by Japan and, with some modifications of boundary, the three provinces were awarded to Thailand. After World War II they were again returned to Cambodia.

Outstanding geographical feature of Cambodia is Tonle Sap, the "Sea of Sweet Water." It is a colossal reservoir linked by a long channel to the Mekong River at Pnompenh.

During the rainy season part of the flood rushing down the Mekong pours through the channel into the lake. When the Mekong drops, the action is reversed and the lake begins discharging its pent-up waters.

As I motored over the roads of Cambodia, the countryside seemed quiet. In a few places, however, we had to travel in a convoy of cars. It was a reminder that parts of this normally peaceful kingdom had been pene-

trated by the men and the ideas of Viet Minh.

Members of the National Geographic Society are able to follow fighting in Korea and news of other areas in the Far East by consulting recent issues of their NATIONAL GEOGRAPHIC MAGAZINE, in which Korea, Japan, Formosa, and other regions are described, mapped, and pictured. Timely articles of recent date follow:

"Roaming Korea South of the Iron Curtain," by Enzo de Chetelat, June, 1950; "Japan Tries Freedom's Road," by Frederick G. Vosburgh, May, 1950; "Okinawa, Pacific Outpost," 20 illus., April, 1950; "Trawling the China Seas," 18 illus., March, 1950; "Formosa—Hot Spot of the East," by Frederick G. Vosburgh, February, 1950; "A Woman Palms the Tibetans," by Lafugie, May, 1949; "Power Comes Back to Peiping," by Nelson T. Johnson and W. Robert Moore, September, 1949; "With the U. S. Army in Korea," by Lt. Gen. John R. Hodge, June, 1947; and "Backwoods Japan During American Occupation," by M. A. Huberman, April, 1947.

For earlier presentations giving backgrounds of many countries and areas now in the news, see "NATIONAL GEOGRAPHIC MAGAZINE Cumulative Index, 1899-1949."

Seeing the Earth from 80 Miles Up

BY CLYDE T. HOLLIDAY

A WARNING siren screamed and a red star shell soared high over the sun-drenched desert. They signaled that in just two minutes another V-2 rocket would go roaring skyward from White Sands Proving Ground, New Mexico.

Soldiers and scientists already had taken shelter in the massive concrete blockhouse from which the rockets are fired by remote control (page 515).

Nerves were tense, for on this flight we were sending aloft a camera which it was hoped would photograph the earth from more than 80 miles up.

"X minus one," announced a voice from a loud-speaker, meaning one minute to go. Then it started counting seconds: "Twenty, nineteen . . . twelve . . . seven . . . three, two, one, fire!"

A brilliant whitish-orange flame burst from the rocket's tail (page 516). With a thundering roar it started to rise, almost imperceptibly at first, then gathering tremendous speed.

Out of Sight in 30 Seconds

In less than 30 seconds the V-2 was practically out of sight of the naked eye. Riding with it, besides our camera, were instruments to make rapid measurements of cosmic rays, the earth's magnetism, temperature, atmospheric pressure, and other things during the brief two or three minutes that the rocket would spend in the little-known reaches of the upper air.*

Trailing invisibly behind the rising rocket was a stream of telemeter signals radioed back automatically by the instruments, telling what they were finding up there aloft. These signals, recorded on the ground, would provide almost the only record of the results of the flight, since most of the instruments would be smashed when the rocket crashed in the desert a few minutes later.

Designed by the Germans as a terror weapon, the V-2's traveled faster than sound and gave no warning of their approach. They caused heavy damage and many casualties in and near both London and Antwerp in 1944-45.

Actually, however, the V-2's have been far more valuable in exploring the upper atmosphere in this country than they were as weapons of war for the Germans. Because so many skilled engineers were diverted from other projects to work on the V-2, its development handicapped Germany's war potential

more than the rockets' destruction interrupted the war effort of the Allies.

In 1945 the United States Army captured 100 V-2's and brought them to White Sands. Since then they have helped gather much useful knowledge of the almost unexplored ocean of air that extends more than 300 miles above the earth's surface.

One of the most spectacular results of the flights has been high-altitude photographs of the earth taken from heights no camera ever had reached before.

Photographs Show Earth's Curvature

Within 15 minutes after our camera soared aloft on the V-2, a search plane had located the crumpled remains of the rocket in the desert and then returned to guide the recovery party to the spot. The camera was wrecked, but the film, protected by a heavy steel cassette, was unharmed despite crashing into the ground at a speed of 500 feet per second (pages 518-520, 527).

A truly dramatic spectacle unfolded when the film was developed. The camera had taken photographs every one and a half seconds from the moment of take-off up to an altitude of 83 miles, then back down again to about 40 miles above the earth.

On these photographs we saw what a passenger on a V-2 would see if he could stay alive on the zooming ride up to that height and back again, and how our earth would look to visitors from another planet coming in on a space ship.

Curvature of the earth was plainly visible on the horizon of these tremendous panoramas. Great mountain ranges, long river courses, and broad plains were mere details in the breath-taking sweep of the pictures. Single views covered more than 100,000 square miles.

The highest of these photographs were made from altitudes six times as high as the 13.71-mile ceiling of the National Geographic Society-Army Air Corps stratosphere balloon flight in 1935.†

* Army, Navy, and Air Force, and many universities and industrial firms participated in the V-2 research program. The author is a member of the staff of the Applied Physics Laboratory of the Johns Hopkins University, which took part under a Navy contract.

† See, in the NATIONAL GEOGRAPHIC MAGAZINE: "Man's Farthest Aloft," January, 1936, and "Scientific Results of the World-Record Stratosphere Flight," May, 1936, with photographic supplement showing the lateral curvature of the earth as photographed from 72,295 feet. Both articles are by Capt. Albert W. Stevens.

The rocket penetrated far above the stratosphere, into the lower layers of the rarefied ionosphere, where long-range radio signals are reflected back to earth, where meteors are seen, and where the aurora borealis flames. This is on the border of outer space itself, for the air here is so thin that it is almost a vacuum. In fact, 95 percent of the earth's atmosphere is left behind after a rocket passes an altitude of only about 14 miles.

Composite photographs made from several of the high-altitude pictures, placed side by side, include nearly a million square miles, the area of Mexico and Texas combined (pages 524-525). Only three or four such composites would cover the entire United States, and nine or ten would include all of North America. To do this, however, we should have to send up rockets from various locations.

Scouting with Guided Missiles

Results of these tests now are pointing to a time when cameras may be mounted on guided missiles for scouting enemy territory in war, mapping inaccessible regions of the earth in peacetime, and even photographing cloud formations, storm fronts, and overcast areas over an entire continent in a few hours, which would be of great benefit to weather forecasters.

Amazingly small details can be picked out on these pictures despite the heights from which they are taken, though the nature of such details is a military secret. It can be said, however, that even from 100 miles aloft a good camera, equipped with a telephoto lens and mounted on a steady-flying missile, probably could detect troop movements.

Cameras mounted on guided missiles might be shot out over enemy territory and brought back with a photographic record of troop concentrations, fortifications, and airfields.

If the missile were equipped with television, it could send back a running report of what the camera "saw" as it flew. In such a case the missile could be sent out twice as far on the same amount of fuel, and there would still be a record of what it photographed, even if it did not return.

Camouflage would hide little from such an all-seeing flying eye if the pictures were taken in color, for the varying wave lengths of light recorded by color film penetrate almost any kind of artificial concealment.*

Aerial mapping of country difficult to penetrate on foot, such as rugged mountain areas, jungle, desert, or swampy territory, or the

interior of the Antarctic Continent, might also be done with cameras carried by guided missiles. In fact, the entire land area of the globe might be mapped in this way.

For wartime reconnaissance, missiles probably would be flown high, so that the enemy would not even know of their presence, though in any case their supersonic speed would make it difficult to detect them with radar and almost impossible to shoot them down.

All this, of course, lies in the future.

Useful in Weather Forecasting

Already, however, the pictures have proved useful to the U. S. Weather Bureau. With the aid of the photographs, weathermen for the first time have been able to look down from above on cloud formations over great areas of country and confirm some theories about clouds which never could be checked as well before.

The pictures show how cumulus clouds form where "bubbles" of warm air rise above heated ground areas, carrying up moisture that condenses in the colder regions above. Around these warm air bubbles, where cooler air is sinking, no clouds appear. Clouds that form above the rising bubbles often make striking cellular or honeycomb patterns (page 522).

How clouds are related to the topography of the ground below also is revealed by the pictures. During the daytime clouds are most frequent over mountaintops and high plateaus, where warm air moving up the slopes has carried moisture aloft to condense; but over valleys and low-lying areas clouds form less often.

Cloud "streets," long lines of vapor with gaps between, sometimes fairly straight but occasionally curved, show in the photographs. These are dependent on the winds and temperatures aloft, and perhaps also on the contours of the earth below, though in just what way is not yet known.

To make the best forecasts, weathermen need to know what conditions prevail at any given moment over a wide area. If guided missiles carrying cameras could be sent out criss-cross over the entire continent of North America every day, photographing in a few hours all the cloud banks, storm fronts, and overcasts, weather forecasts could be made more accurately than now.

How Cameras Aid Cosmic-ray Study

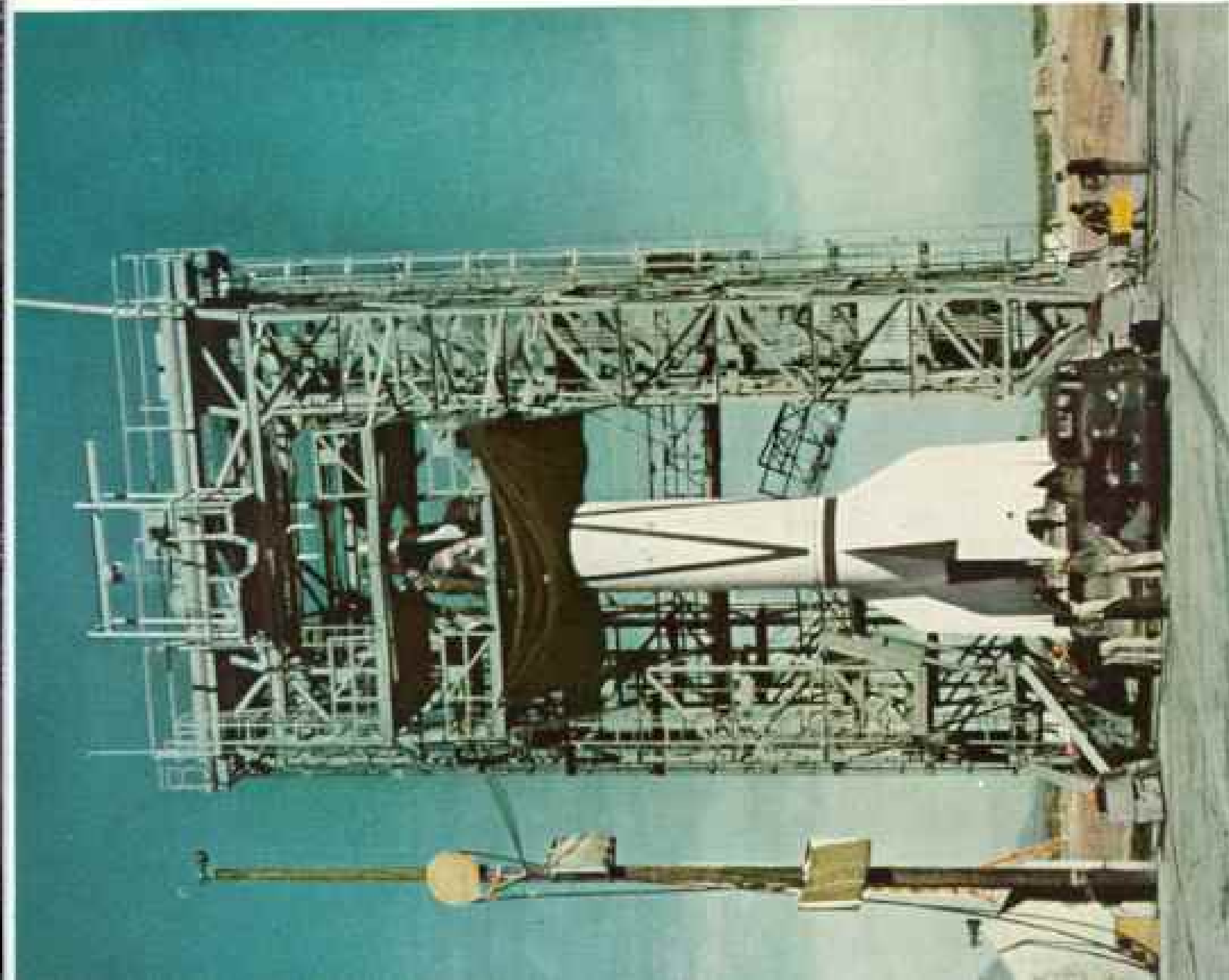
Another use for the pictures of the earth taken from the V-2's is in determining the rocket's orientation in space—that is, "which end is up," at any given instant. We need to know this in order to tell from what direc-

* See "How We Fight with Photographs," by F. Barrows Colton, NATIONAL GEOGRAPHIC MAGAZINE, September, 1944.



A V-2 Rocket, Built to Spread Death, Prepares to Explore Upper Air for Science

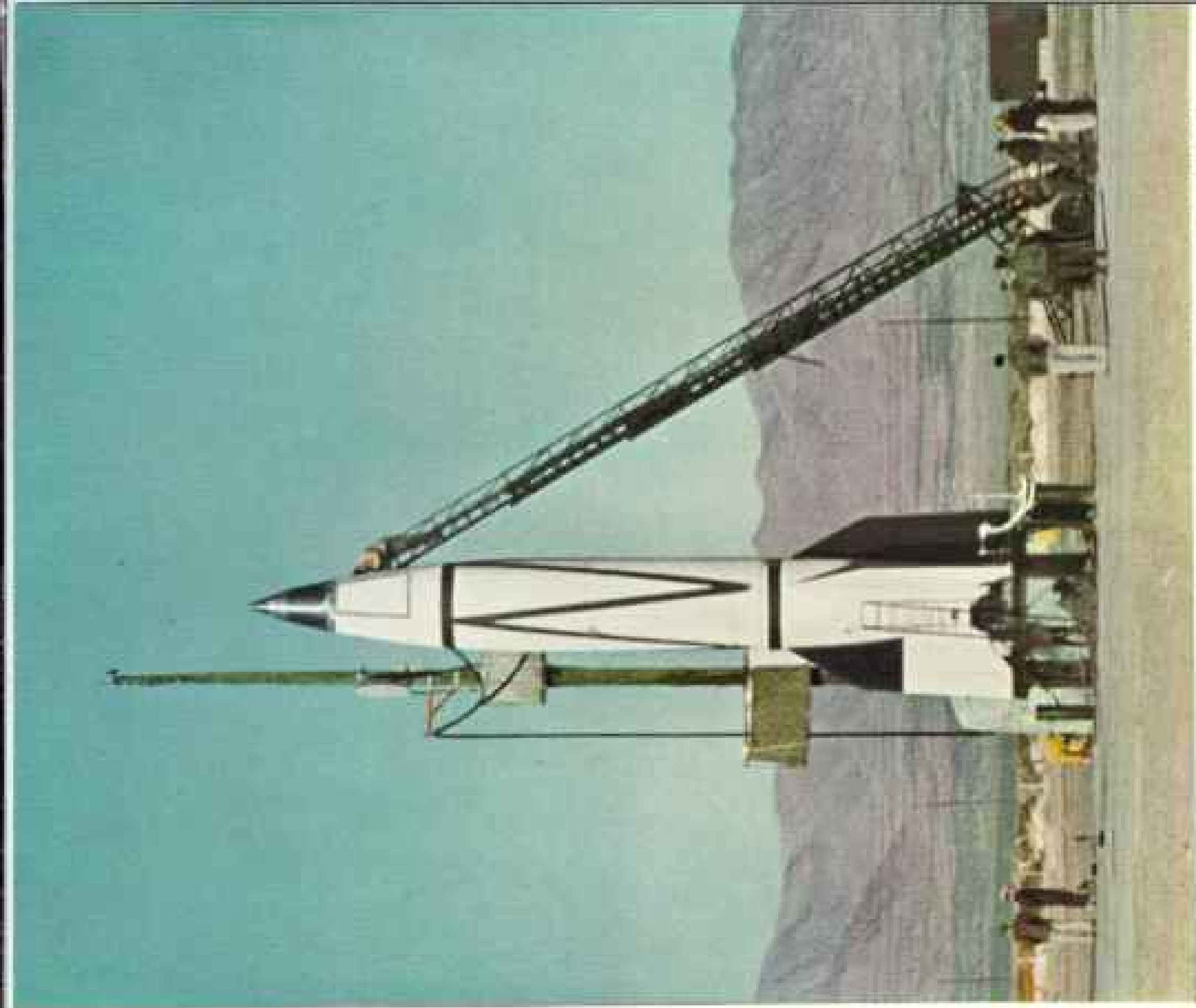
This captured German missile will rise 80 miles or more with American research implements. A transport wagon delivers and erects the 14-ton burden at the launching platform at White Sands Proving Ground, New Mexico.



© National Geographic Society

Scientific Instruments Are Placed in Rocket's War Head

Originally the nose compartment carried one ton of high explosive. The huge servicing crane is rolled away before launching (opposite picture).



Kodachrome by Orin T. Helmer

Last-minute Checkups Are Made from an Extension Ladder

Electric cables leading from the pole (left) are used to open fuel valves and fire the rocket by remote control.

Time to Take Cover! Red Smoke from the Blockhouse Warns that the Rocket Will Be Fired in 15 Minutes

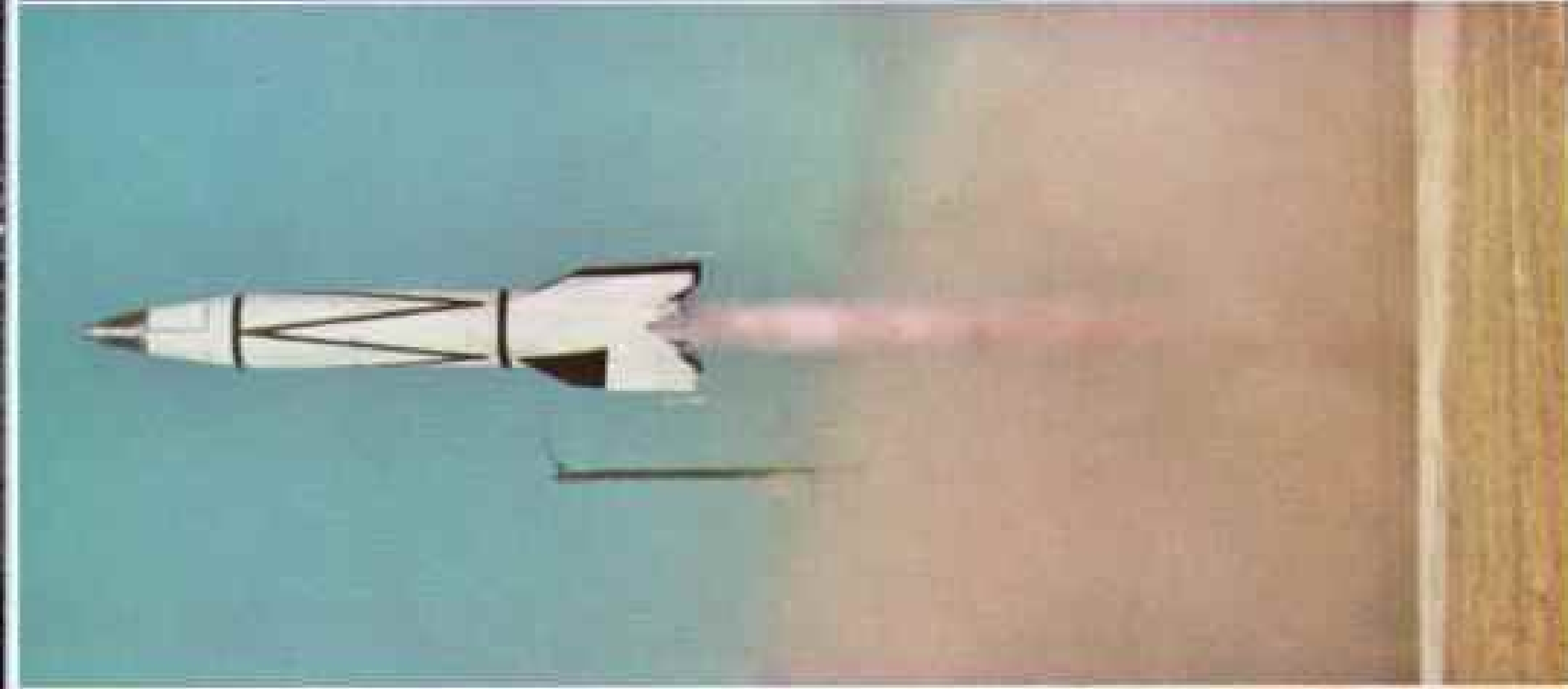
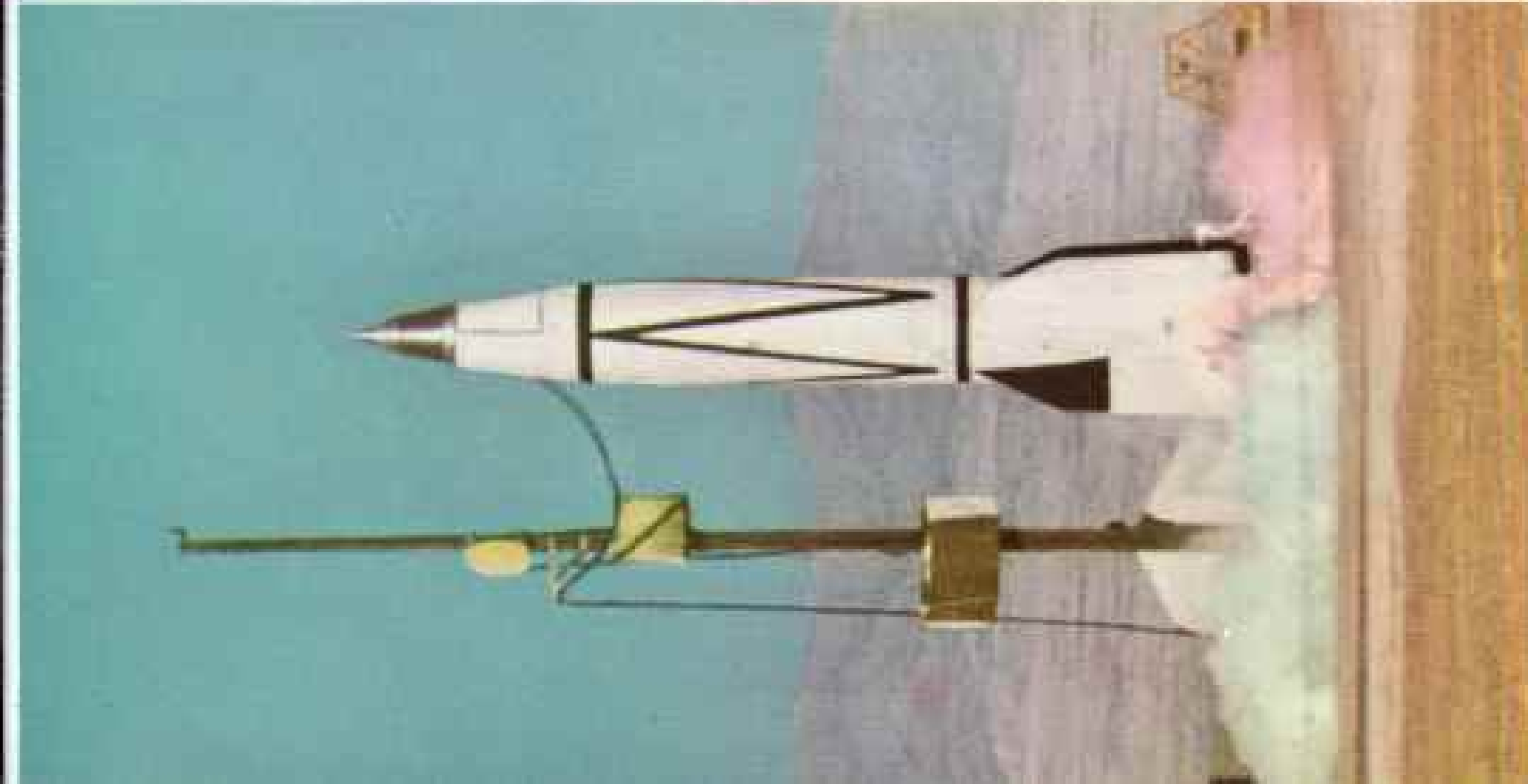
Before take-off all personnel must clear the area or go into the concrete shelter used by the launching crew. Its roof, 14 feet thick, and walls, 12 feet, are proof against explosion or even a direct hit. Launchers watch the rocket through a 6-inch glass window set in the recess. The smaller concrete wall just to left of the rocket is a shelter for fire fighters who will go into action with high-pressure hose lines already laid if the launching fails and the missile bursts into flame.

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Illustration by Clyde W. Hottel





With a Deafening Rumble, Spouting Smoke and Flame, the Rocket Rises Slowly at First, Then Picks Up Terrific Speed

Pictures show the missile at the moment of firing; one second later; three seconds later at 100 feet; and the vapor trail left behind as it reaches 20 miles. Winds twist the vapor trail. The V-2 consumes its 10 tons of liquid oxygen-alcohol fuel in only 60 seconds, then travels by momentum.

The Author Stows His Fluorescent-red Camera Aboard. A Theodolite Atop San Andres Tracks the Rocket's Course

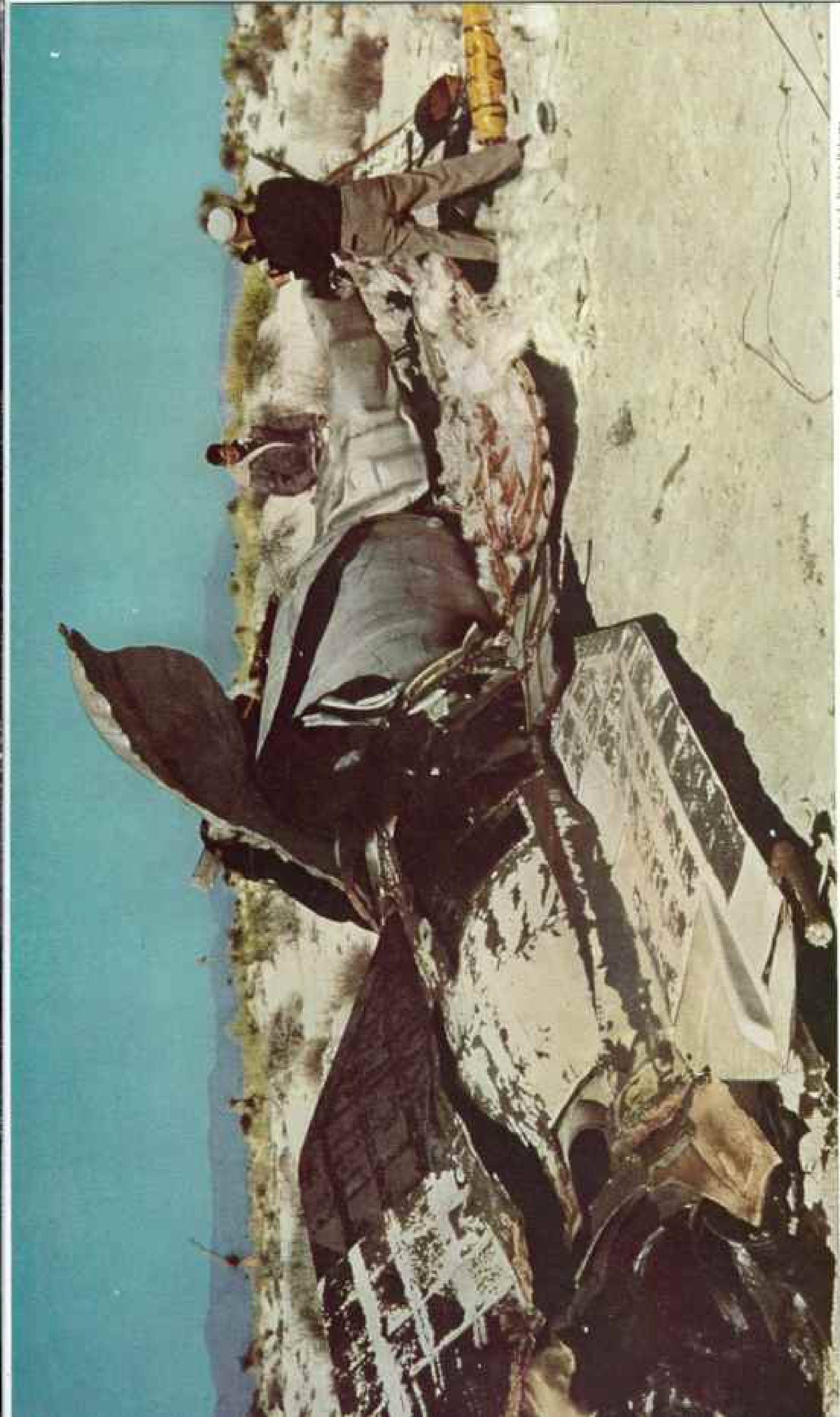
Pictures of the earth are taken automatically as the missile rises and falls. The rocket's flight is plotted, photographed, and radar-tracked from desert and mountaintop stations; they locate its falling point within one square mile. White Sands National Monument is at left beyond Lake Lucero.

© National Geographic Society

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Kodachrome by J. Taylor Roberts





V-2 Crashes in the Desert 33 Miles from the Firing Point. Scientists Recover Instruments and Records

Scientific apparatus in the mid-section, blown apart from the heavy war head, usually survives the fall. Bottles at extreme right collected air samples at various altitudes. Some rockets carry seeds to determine whether powerful cosmic rays in the upper atmosphere affect plants' hereditary characteristics.

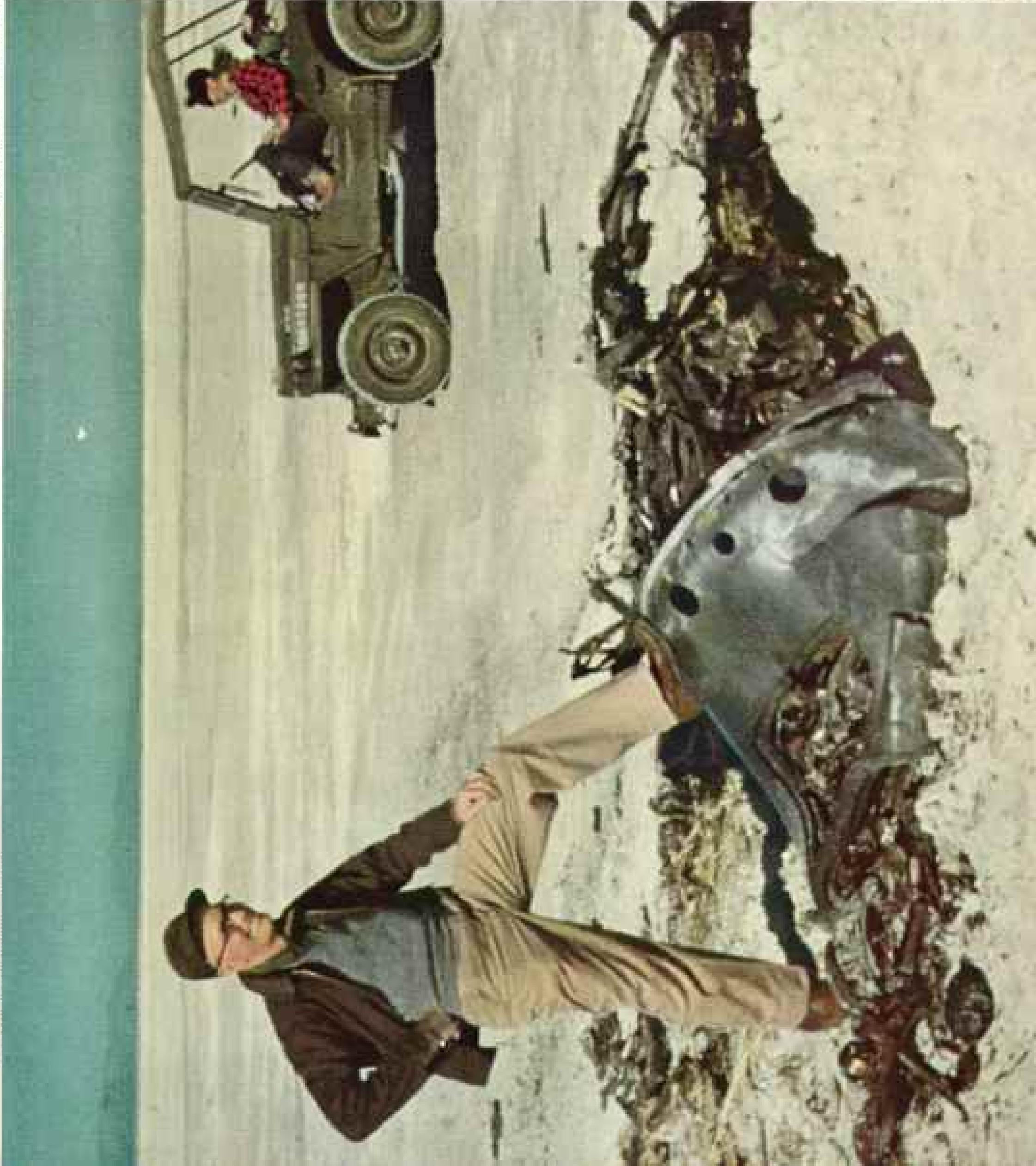
Only Junk Remains After War Head Hits at 700 Feet a Second. Steel Container Preserves Author's Film, but Not Camera

Staff photographer J. Baylor Roberts stands on wreckage of the war head, blown free when the rocket was falling 40 miles above earth. Its instruments were smashed, but the data they gathered were collected through messages automatically radioed to the ground. Only steel film magazine and lens (right) survived (page 317).

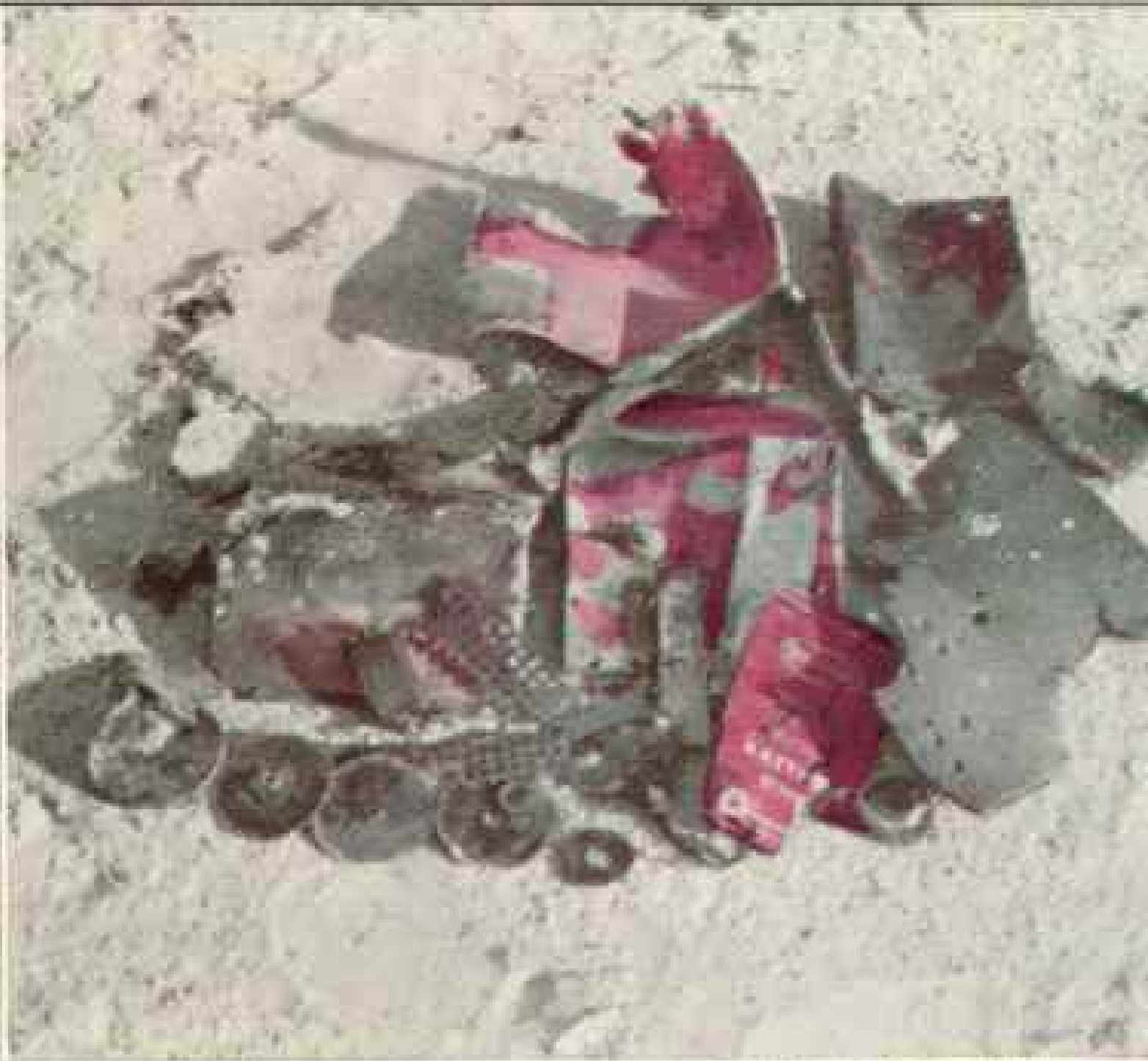
© Matheson's Geographic Society

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Reproduction by Charles T. Dutton



Reproduction by J. Baylor Roberts



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Katastrones by Otto T. Hollier

▲ This Camera Was Tough. It Survived Two Crashes, but the Third Finished It ▲

Installed in the V-2's main body, the instrument lived through one flight and was sent on a second. Blown free high above the ground, it needed only minor repairs after the landing (left). The third crash smashed it (right). Film in the steel magazine survived all three flights.

Below: Another camera lies smashed in mid-section wreckage. Like other rocket cameras, it was painted red to facilitate recovery if it fell far from the rocket. Cottonlike glass wool insulated fuel tanks.



tion come the heaviest bombardments of cosmic rays from outer space that strike the rocket during its flight. This is one clue to their origin, perhaps in the sun or the more distant stars.

These rays are electrically charged particles constantly raining down upon the earth with tremendous energy. They are more powerful even than the rays generated in the atomic bomb and flash through the human body from 10 to 20 times a second, though without any known effect.

Geiger counters in the rockets register the numbers of rays coming in from various directions at each second of the flight. For example, they may show more rays entering through the nose than through the sides at one second past eight; but unless we know which way the nose was pointing at that moment, we cannot tell from what direction this heavy bombardment was coming.

After climbing to about 25 miles, the V-2 begins to wobble, spin, and tumble, so that its nose keeps pointing in different directions. But by measuring angles in the pictures taken on the flight, each of which is timed, it is possible to tell how the rocket was oriented at any given instant. If the picture taken at one second past eight shows that the rocket was moving tail downward, we know the nose was pointing upward. If more cosmic rays were coming into the nose than from other directions at that moment, then we know this heavy bombardment was arriving from directly overhead.

Rockets at White Sands are launched almost vertically upward, to insure that they will reach the greatest possible altitude. An automatic pilot is set before firing to keep them on course, but they cannot be controlled after they get into the air. Fuel can be cut off by radio, however, if it appears the rocket is veering so that it may fall in inhabited country.

V-2 Record Height Is 116 Miles

Highest altitude reached so far by a V-2 is 116 miles. One Wac Corporal rocket, developed in this country, attained a height of 250 miles with the aid of a V-2. It was carried up to about 20 miles on the V-2, then fired from there, and the extra push of the larger rocket added to the Wac Corporal's own power carried it to this record altitude.

No cameras were sent up on this flight, since all available weight was devoted to fuel and instruments and there would have been small chance of recovering anything after a fall from so great a height.

Some of our high-altitude photographs of

the earth were made from the Aerobee rocket.* Less complicated and cheaper to build than the V-2, it has reached heights of 78 miles and will be used to carry on upper-air research after the supply of V-2's has been exhausted.

Both the V-2 and Aerobee have gained information about the high upper atmosphere that was impossible to obtain in any other way. The flights have measured the original cosmic-ray particles that come in from outer space before they plunge down into the earth's atmosphere. Except for a few balloon flights, it was possible previously to study only the less-powerful secondary rays created when the original rays strike and disrupt atoms of air.

Ultraviolet rays from the sun have been measured which never penetrate to the earth's surface, since they are absorbed by a layer of ozone that blankets the globe between 20 and 30 miles up.

Vacuum at 80 Miles Up

At about 80 miles high, the rockets reveal, the atmospheric pressure is as little as one ten-millionth of that at the earth's surface, which means that the air at that height is so rarefied that it is actually a high vacuum.

Striking changes in heat and cold were measured as the rockets climbed. Over White Sands the temperature drops steadily to about -63° F. from the surface up to 10 miles, and fluctuates slightly for another 10 miles. From 20 to 30 miles the temperature is about 65° F.; it falls once more to -150° F. at about 50 miles, and at 75 miles climbs again to 212° F., the sea-level boiling point of water.

All this information is sent back to the ground by automatic telemetering systems. Temperature, for example, is measured by a thermocouple, made of two different metals welded together. The two metals react to temperature changes and, in so doing, generate a small electric current the strength of which is proportional to the temperature. This varying current is converted into a radio signal which varies in strength in the same way, recording on the ground the changes in heat and cold aloft.

Corn seeds and fruit flies have been sent up more than 85 miles on some rockets in an effort to discover whether the powerful bombardment of cosmic rays at such altitudes would cause mutations or hereditary changes in future generations of the plants and

* The Aerobee was developed for the Navy by the Douglas Aircraft Company and the Aerojet Engineering Corporation, under the technical supervision of the Applied Physics Laboratory.



Thunderheads Are Mere Cotton Wisps When Seen from 35 Miles Up. Earth's Curvature Is Visible on Horizon 400 Miles Away

Large thundercloud at right center has typical anvil shape. Others show at upper left and far right, among scattered cumulus. "Lakes" in foreground are lava beds north of White Sands Proving Ground, New Mexico (page 525). Dark line in right foreground is Southern Pacific railroad track. White line beside it is Highway 24.

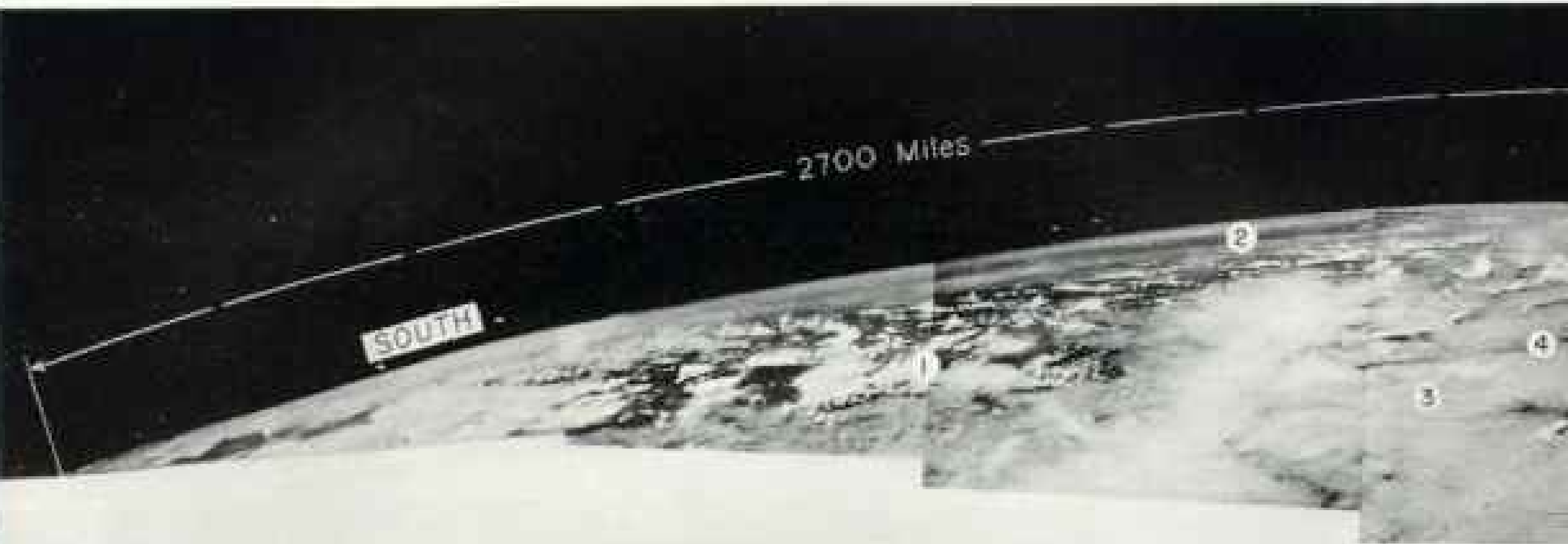
**Looking 60 Miles
Straight Down:**

**Rio Grande Is Etched
Sharply Against Desert**

Elephant Butte Reservoir in southwestern New Mexico is in the upper right-hand corner. Elephant Butte itself appears as a white dot in the water at the extreme left. Caballo Reservoir is the other large body of water, with the town of Hot Springs on the river between the two. Along the river bend are irrigated lands and the towns of Arroyo, Derry, Garfield, Salem, Hatch, Rodey, Rincon, and Angostura. Black Range is at upper left, San Andres Mountains at lower right. Small clouds at left cast sharp black shadows. Area shown in this picture is 4,500 square miles.

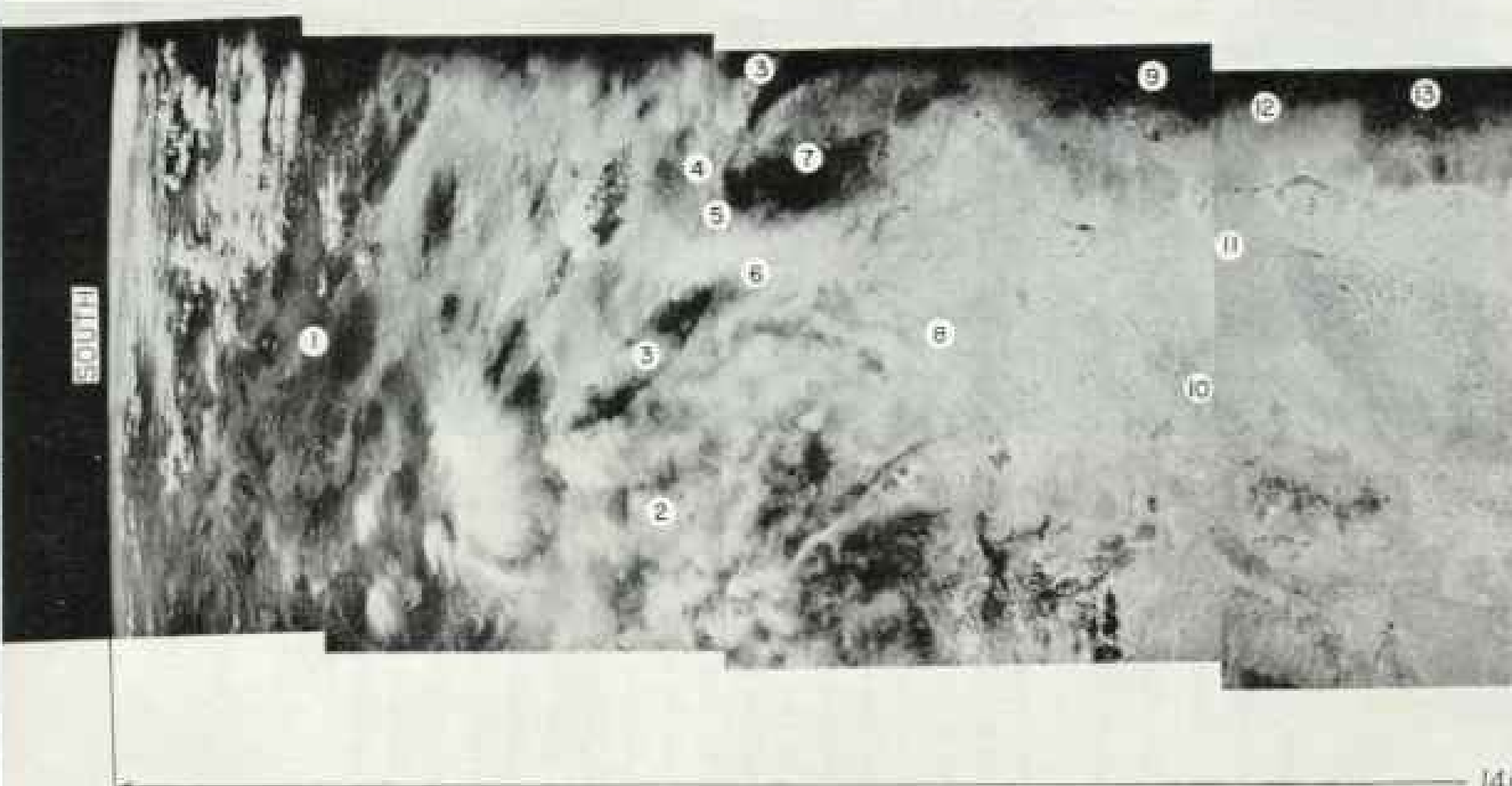
C. H. Serris, Official-Photop
Dartmouth University (A.P.L.)





▲ Million-square-mile Sweep Touches 10 States, Mexico, Pacific

A composite of eight photographs made from a V-2 rocket, the picture embraces the semicircular area shown in the diagram at the left. Though the photographs appear rectangular, the segments of territory that they actually cover are shaped like pieces of pie, as indicated by the sections shown in the diagram. Because the camera was pointing at an oblique angle, causing distortion, the foreground of each photograph is on a much larger scale than the background. Pictures were taken from 60 miles up. Distance from center foreground to horizon is 720 miles. Curvature on the horizon is not that of a great circle like the Equator, but corresponds to the curving boundary of the area shown in the diagram. Cloud clusters are storms. A large overcast is at left of center. Numbers indicate: 1, Mexico; 2, Gulf of California; 3, Lordsburg, New Mexico; 4, Peñoncillo Mountains; 5, Gila River; 6, San Carlos Lake, Arizona; 7, Mogollon Mountains; 8, Black Range; 9, San Mateo Mountains; 10, Magdalena Mountains; 11, Mount Taylor, New Mexico; 12, Albuquerque, New Mexico; 13, Manzano Mountains; 14, Valle Grande Mountains; 15, Rio Grande; 16, Sangre de Cristo Mountains.





† Vast Panorama Runs from Central Wyoming Deep into Mexico

The seven photographs in this composite were made from an Aerobee rocket at 70 miles' altitude. Middle picture is looking straight down, but others were taken with camera pointing at more and more oblique angles. Each photograph outward from center therefore embraces a larger amount of territory, as shown in diagram. Five small sections in the neck of the "hourglass" represent areas covered by the five central pictures in this strip. Large wedges show what is included in photographs at either end. Numbers indicate: 1. Mexico; 2. Texas; 3. Rio Grande (indicated in three places); 4. Ciudad Juárez, Mexico; 5. El Paso; 6. Biggs Air Force Base; 7. Franklin Mountains; 8. Southern Pacific railroad, with highway alongside; 9. Organ Mountains; 10. Tularosa Basin; 11. V-2 and Aerobee launching sites; 12. White Sands Proving Ground, New Mexico; 13. San Andres Mountains; 14. White Sands National Monument; 15. Holloman Air Force Base; 16. Alamogordo, New Mexico; 17. Tularosa, New Mexico; 18. Sacramento Mountains; 19. Lava beds (page 527); 20. Atomic bomb test site; 21. Albuquerque, New Mexico; 22. Wyoming.





White Sands Proving Ground

One Rocket's Impact Dug a Crater 30 Feet Deep

Falling in one piece, the missile struck the desert at a speed of more than 3,000 feet per second, and the remains of it were never recovered. Most V-2's are blown apart in the air at about 40 miles' altitude so that the war head and main body fall separately with much less force (page 328).

insects, but the results have not yet been determined.

Puffs and trails of smoke have been released from rockets to learn the direction of the wind at various heights.

Samples of air at various altitudes have been captured in steel bottles strong enough to survive the rocket's fall. The samples disprove a long-held belief that helium and hydrogen, being lighter than oxygen and nitrogen, would rise higher in the earth's atmosphere and concentrate at the upper levels. The bottles' contents showed that the proportions of these four gases in the air is no different up to 45 miles aloft than at sea level.

Lonely Desert Scene of Rocket Tests

White Sands Proving Ground lies in south-central New Mexico in the Tularosa Basin, between the San Andres and Sacramento Mountain ranges, about 50 miles north of El Paso, Texas. Its name is derived from the White Sands National Monument, which is located within the proving-ground area.*

The site, chosen after a survey of the entire United States, is flat, timberless, and sparsely populated, making it ideal for the firing of long-range rockets. Cloudless skies prevail about 85 percent of the time, so that rockets can be followed throughout their flights by telescopes and cameras.

Army Ordnance is in charge of the proving ground, although units of all the armed services are stationed there, as well as civilian scientists representing many industrial concerns and universities.

Assembly and launching of the V-2's at White Sands is a complicated, exacting process, performed by the General Electric Company under the techni-

* See "White Sands of Alamogordo," by Carl P. Russell, NATIONAL GEOGRAPHIC MAGAZINE, August, 1935.



National Geographic Photographer J. Bertram Roberts

Truck Pulls Jeep Out of Sand on the Way to Recover Instruments from a Fallen V-2

When a rocket falls in the White Sands area, search planes locate it and guide radio-equipped vehicles across the desert to the spot, a trip that may take many hours. Scientific apparatus not damaged in the crash is salvaged and remains of the missile are removed (pages 518-520). The impact area where the rockets fall covers 5,000 square miles in New Mexico. It is divided into one-mile squares by red pyramids, 20 feet high, marked with letters and numbers to help locate the point of fall from the air.

cal supervision of Army Ordnance. Many of the electronic parts have deteriorated since 1945, and new ones have had to be made.

All the rocket parts and the scientific apparatus to be sent aloft are carefully tested to make sure everything will work properly and that one piece of equipment will not interfere with the operation of another.

Tension High on Firing Day

Tension runs high on the day of a V-2 launching, for it is the climax of many months of work by scores of people, all of which would be wasted if anything went wrong. Scientists often work around the clock the previous day, and long before dawn they start the final checkout of the delicate instruments installed in the rocket's war head and main body (page 513).

Three hours before firing time about 10 tons of alcohol and liquid oxygen are pumped into the V-2's fuel tanks. An armed guard is on hand to enforce the strict rule against smoking while this dangerous work is under way.

At X minus 45 minutes all roads into the

proving-ground area are blocked off. At X minus 15 minutes a red smoke signal warns personnel to take cover in the blockhouse (page 515).

About this time, too, the electronic circuits of the instruments in the rocket are turned on by remote control, since they need from one to 20 minutes of warming up before they will function properly. Some instruments use so much current that they are warmed up by power from outside, then switched to batteries in the rocket only a few seconds before firing.

At X minus 30 seconds the telemetering radio signals are switched on, to make sure the instruments in the rocket will properly transmit back to earth the data they collect on the flight (page 521).

Generates 500,000 Horsepower

At the word "Fire!" a switch is thrown that opens the valves in the fuel tanks, allowing a little oxygen and alcohol to flow down into the combustion chamber, where a spark ignites the mixture. If it burns properly, the final switch is thrown, starting the fuel pumps

and disconnecting the cables that control operation of the rocket before take-off.

Then the V-2 is on its own. As the pumps spray fuel with full force into the flaming combustion chamber, hot gases pour out of the tail with a thrust of 25 tons, sending the rocket zooming aloft with an estimated 500,000 horsepower (page 516).

The backward kick of the rocket engine gives a maximum acceleration of 180 feet per second per second, which means that in each second of its flight it travels 180 feet per second faster than in the previous second.

This is only five or six times the force of gravity, less than the "G" force exerted on many a jet-plane pilot pulling out of a dive. A passenger, therefore, might ride a V-2 on its upward flight without harm from acceleration. But he would need an oxygen supply, a pressurized compartment or suit, protection from heat generated by the rocket's speed and from both the heat and ultraviolet rays from the sun at high altitudes, and he would have to get out somehow before the rocket crashed.

In barely 65 seconds, when the rocket has reached a height of about 20 miles, its fuel is consumed, and it climbs the rest of the way to the top of its flight by momentum.

Automatic Pilot Steers Rocket

So slow is the rocket's take-off that its steering vanes on the tips of the tail fins do not operate effectively at first, and it is kept stable by special carbon vanes projecting into the stream of the exhaust. When the fuel is consumed, the other vanes take over, holding the V-2 on its pre-set course as long as the air is thick enough to give them something to push against.

Both sets of vanes are controlled by the automatic pilot. In the rarefied upper air the vanes no longer provide control and the rocket wobbles and spins as it flies.

Radar sets follow the rocket's flight to help locate the point where it crashes in the desert. Motion pictures also are made of the rocket in the air with the time, elevation, and azimuth, or directional, bearing recorded on each frame of the film, from which can be determined the V-2's speed, altitude, and position in space at any instant of its flight (page 517).

About 40 miles above the earth, on the rocket's downward course, the war head, containing most of the scientific apparatus, is automatically blown off. The main body then tumbles end over end, which slows down its fall considerably, so that instruments installed in it have a much better chance of surviving the impact with the ground.

If the war head were left in place, the rocket would plunge down nose first and strike at a speed of more than 3,000 feet per second (page 526).

Exposure 1/500 of a Second

Our cameras are usually installed in the main body of the rocket, pointing out through the side (page 517). Though they are almost always broken up in the final crash, the film is unharmed, and it is much cheaper to build a new camera for each flight than to make one strong enough to survive an indefinite number of impacts at speeds of about 500 feet per second (page 520).

Several types of cameras were used on the V-2 flights. An exposure time of 1/500 of a second at *f*:5.6 was fast enough to compensate for the rocket's motion. Eastman Aero-graphic infrared film with an 89A filter proved to be the best film-filter combination.

Pictures in color also were taken, but were not too successful from altitudes above 30,000 feet, since color film penetrates haze little better than the human eye. Generally speaking, color film is most effective for photographic reconnaissance below 20,000 feet, and infrared for higher altitudes.

Though not a true guided missile itself, since its course cannot be controlled after take-off, the V-2 rocket was a forerunner of these new types of weapons that promise to revolutionize modern war. Some of the new knowledge of the upper air gained by the V-2 flights is proving useful in the design and development of guided missiles.

Types of Guided Missiles

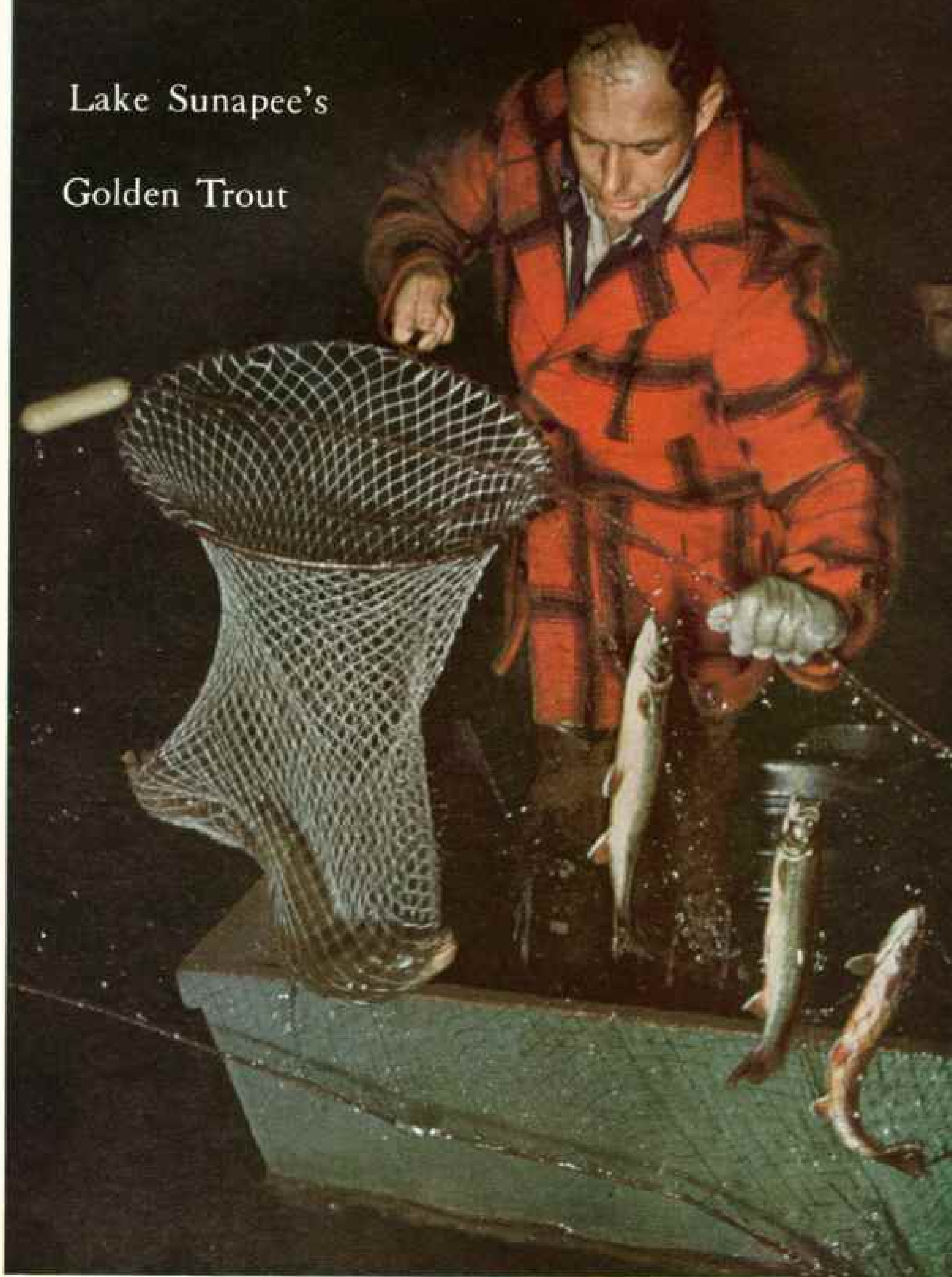
A true guided missile is a projectile that can be steered to a target by remote control, or that seeks out the target after it is fired, changing its course radically if necessary.

Such missiles may be used eventually by planes against hostile planes, enemy missiles, or ground targets. They also may be fired from the ground against fast jet-powered enemy aircraft or missiles, or at long range against ground targets in enemy territory.* Rockets, which are not guided missiles, have seen action as weapons in Korea as well as in World War II.

People working with rockets often are asked when one will be sent to the moon. The answer is that it probably could be done today, if we felt like spending the millions of dollars that such an exploit would cost.

* See, in the NATIONAL GEOGRAPHIC MAGAZINE: "Flying in the 'Blowtorch' Era," by Frederick G. Vosburgh, September, 1950; and "Air Power for Peace," by General H. H. Arnold, February, 1946.

Lake Sunapee's Golden Trout



New England's Rare and Beautiful Golden Trout Live Only in Three Icy Lakes

To increase Nature's yield, this hatchery man removes adult fish from gill and dip nets in Sunapee Lake, New Hampshire. Later he will strip them of roe and milt (p. 533) and hatch the young in troughs. He works by night, the only time the fish leave the depths to spawn. Distinct from the West's golden variety, Sunapee trout (*Salvelinus aureolus*) are found only in New Hampshire, Maine, and possibly Vermont.



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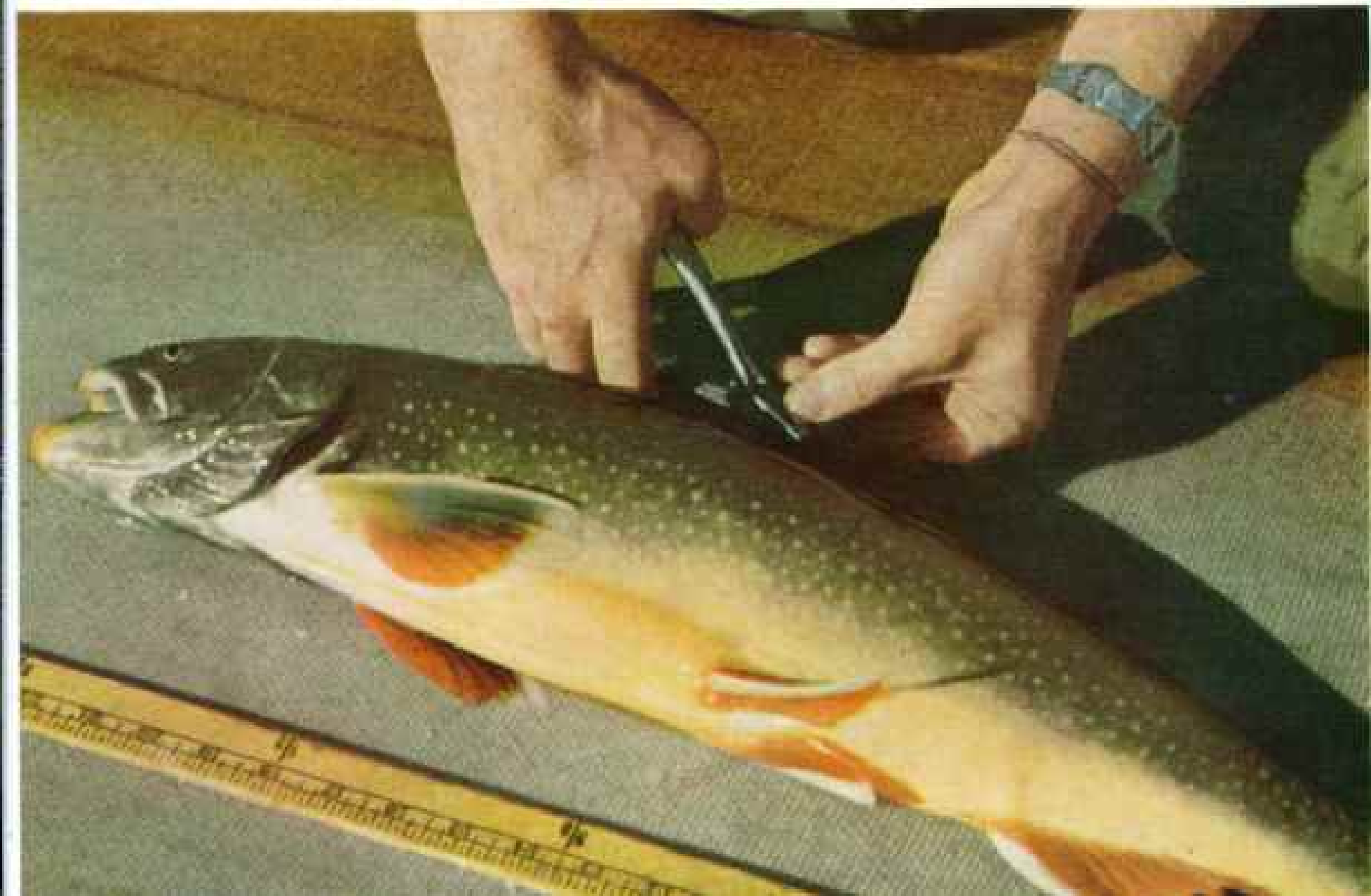
Illustrations by Robert F. Stein

▲ At Midnight, Golden's Witching Hour, Fish Biologists Take Stock

Their gill net's catch emptied into a tub, one man separates males and females. He transfers them to floating live boxes (not shown), in which they will be towed ashore. His associate takes notes on sex and water temperature. This specimen is a spawning male.

▼ Some Trout, Like Autos, Wear Numbers; This 23-incher Is Tagged on a Fin

The sportsman who catches the 6-pound beauty should turn in the tag, together with the fish's length and weight, to the New Hampshire Fish and Game Department. Comparison of old and new data increases knowledge of the handsome, scrappy golden's life.





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Illustration by Robert F. Stone

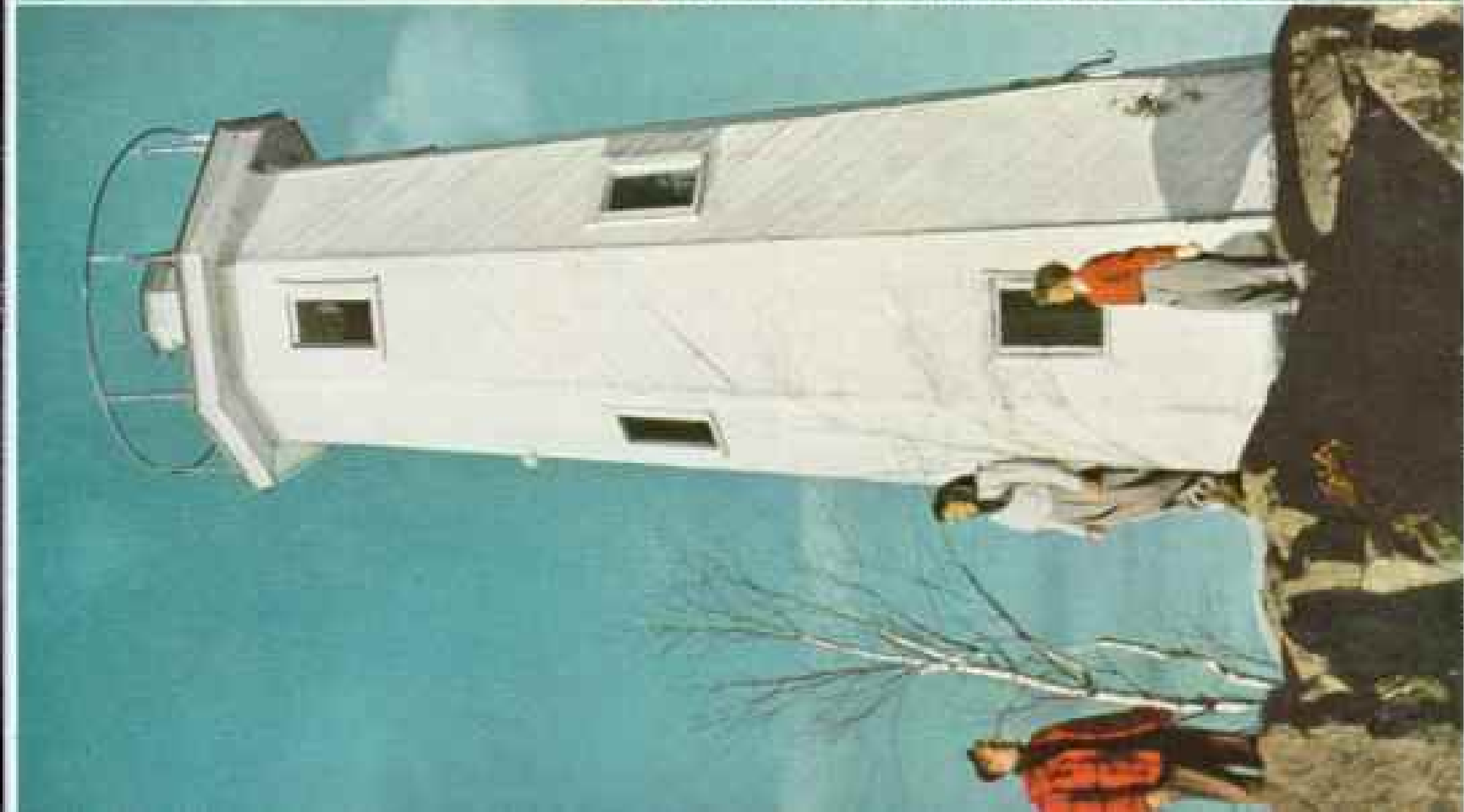
♣ **This Trout Sleeps Through Class in College; He's Anesthetized**

Colby Junior College biology students, counting fin rays and scale rows, learn to identify golden trout. So students may see male's coloration (below). John Dodge of New Hampshire's Fish and Game Department displays a live trout. Death extinguishes its brilliance.

♣ **Golden Males Wear Flaming Dress: in Fall, Their Nuptial Season**

Aurculus (golden halo) is named for his autumn colors. Other times he matches the females' sober silver-gray. Sunapee people who seldom see the golden phase, which occurs in closed season, call the fish "white trout." Tail is forked, unlike that of brook trout.

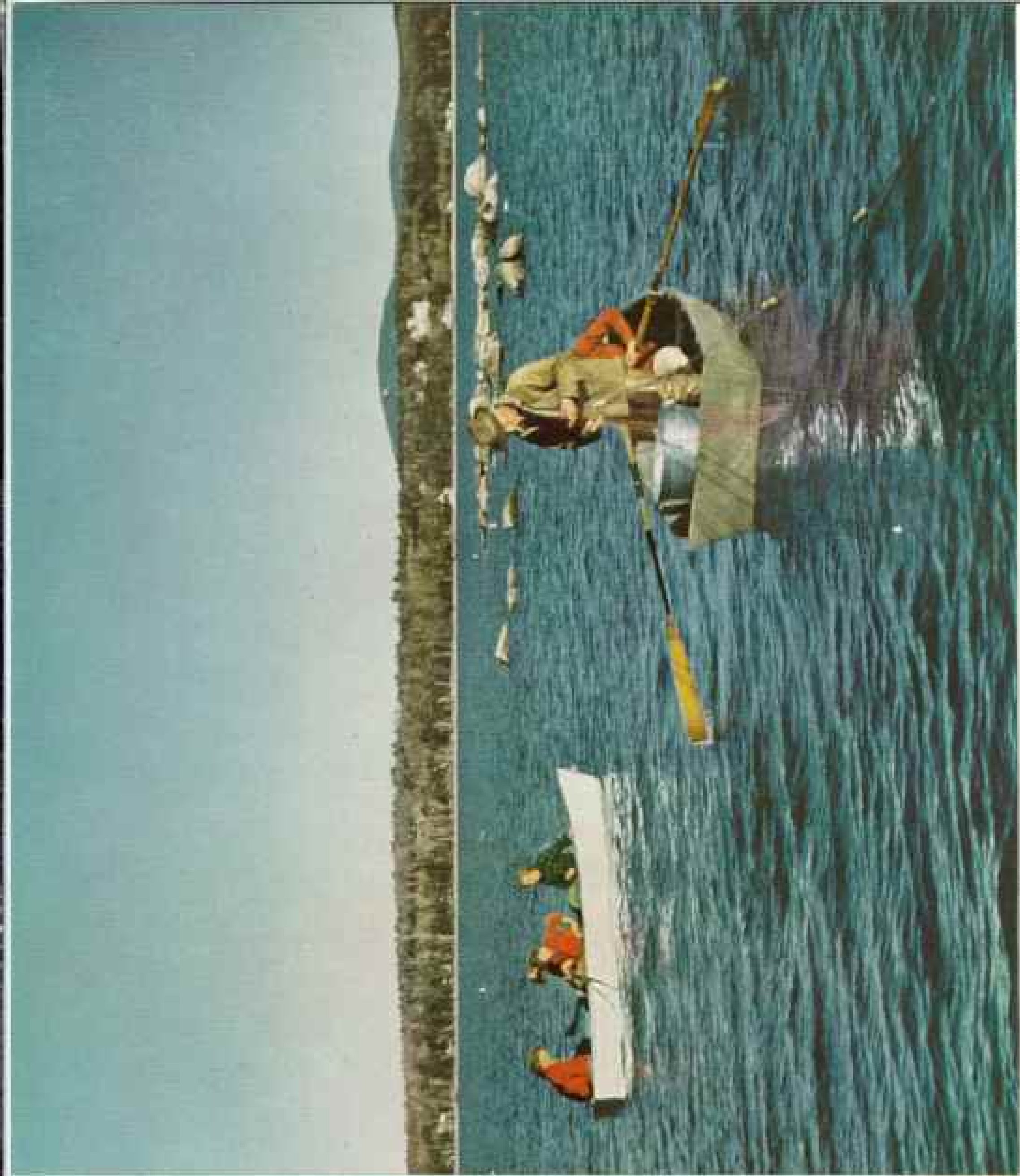




© National Geographic Society

Loom Island Light Stands Guard over Sunapee's Rocky Shallows, Where Goldenfish Rise to Spawn by Night

Of 20 reefs in Sunapee Lake, the trout apparently like only those around the lighthouse. At October's end they swim up from the lake's deepest hole (over 100 feet) and lay their eggs among the rocks. Fish culturists set gill nets to trap them for artificial brooding. Each year they release 15,000 hatchery-reared goldenfish.



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Illustration by Robert E. Wilson

Culturists, Aiding Nature, Strip Eggs from "Ripe" Fish

Each autumn, hatchery workers strip some 50,000 eggs. Gently stroked, the female on the left extrudes her thousand eggs. They emerge so swiftly that the golden globules blur into a solid stream.

Fertilizing milt (from a male (right) must be mixed immediately with the eggs, for the ova remain viable only a few minutes after exposure; the sperm lives less than a minute. Only the gaudiest males are chosen, for bright coloration denotes potency.

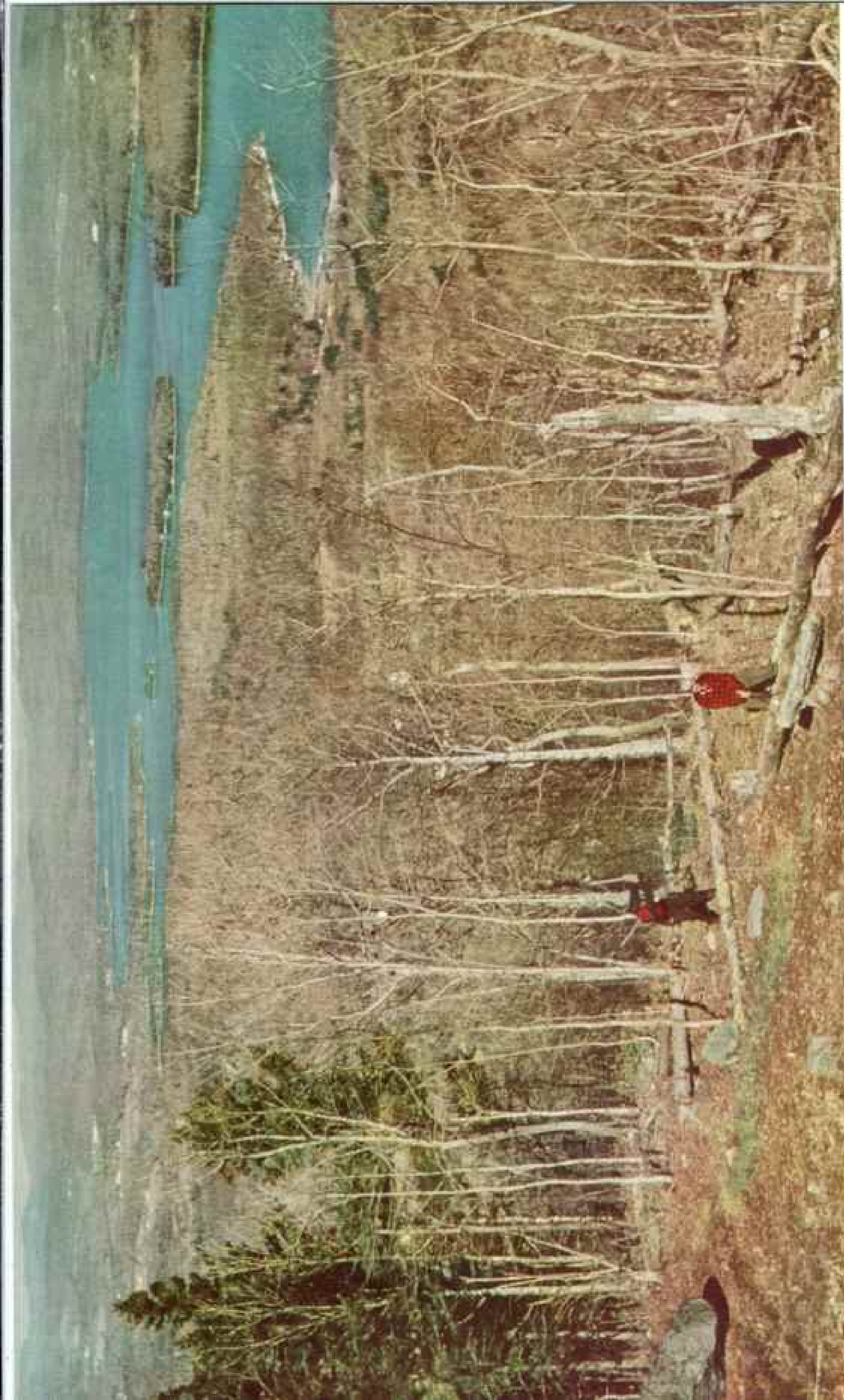
Handlers keep the fish out of water for no longer than 60 seconds. They work with wet hands so as not to remove the coat of mucus, the fish's protection against parasitic fungus.

Once fertilized, the eggs go to hatchery troughs filled with running water. Fry hatch in the spring, four months later.

Soon after spring breaks up the lake ice, fishermen start trolling for goldens from the surface down to a depth of 30 feet. Later, as the water warms and trout seek cool temperatures at lower levels, anglers sink their lures to 60 feet and more. Many are taken by still fishing in water up to 100 feet deep.

Living in the depths, goldens seldom rise to a fly. Smaller fish bite on a piece of smelt; big ones prefer live bait.





Mountains, Forests, Homes, and Resorts Surround New Hampshire's Deep and Chilly Sunapee

This lake in 1882 gave the world its first knowledge of eastern golden trout. In 1949 it yielded a record catch, a golden weighing 9½ pounds.

Hatchery-reared Golden in an Aerated Tank Car Go Home to Ancestral Waters . . . White Eggs Are Infertile "Blanks"

Golden grow slowly at first. These two-year-olds, released at the lake's edge, are only 6 to 8 inches long. Henceforth, feeding on smelt near the lake bottom, they will fatten rapidly. Right: Some 30 percent of fertile eggs survive to maturity. In the wild state only a small percentage become adult fish.

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Illustrations by Robert R. Heaman





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Ketchikan, Alaska by Robert F. Dixon

★ A Living Lesson in Biology Comes from Sunapee's Textbook

Held by a Colby College student, this big male will be liberated once he has been stripped of milt. As dusk falls, he may return to spawning grounds. The golden is one of the chars, a trout family found in northern waters. Some run to sea; this species is landlocked.

✧ Sunapee Is Tested All Year Round for Any Change Harmful to Fish

One man, using a fine-mesh net, takes samples of plankton, the minute organisms which nourish the golden's prey. His companion measures the water's chemical composition. Perch, pickerel, black bass, landlocked salmon, brook and lake trout share Sunapee's waters.



Men Against the Hurricane

BY ANDREW H. BROWN

IT WAS what the flying hurricane hunters call a "hairy hop."

U. S. Navy plane "Five Uncle 34" staggered through a savage whirl of wind, cloud, and rain. The speeding aircraft bucked the biggest, toughest, and most ruthless of storms, the black-browed hurricane.

A scant 500 feet beneath that dark-blue Privateer of Patrol Squadron 23, 100-mile-an-hour winds of a hurricane ripped the Gulf of Mexico to shreds of foam. Torrential rain rasped against the plane's windshield.

The wings waved wildly. Rivets strained as severe turbulence racked the thin-skinned craft. Pilot and copilot both wrestled with the controls, struggling to hold the plane level. Surely the "eye" of the spinning storm couldn't be far away now! (The eye is the nearly calm vortex of the hurricane toward which its great winds converge; pages 543, 548.)

Punching the Hurricane's "Eye"

Suddenly and gratefully the Privateer rushed into nearly still air. The black and stormy weather dropped behind, cut off sharp as a wall. The eye, at last! Clouds were high, thin, and whitish. The orange sun was a baleful, sickly orb.

Here the flying was smooth and good. Everybody relaxed. There was even time for a quick cup of coffee while the aerologist fulfilled the main purpose of the flight—reporting by radio the location and intensity of the hurricane.

The quiet eye was only about 20 miles in diameter, so respite was brief before the swift-moving plane angled cautiously out of the calm core. Then it barreled back through the wicked weather to safety and home base.

Few peacetime assignments of our Navy and Air Force air crews match the hazard—and the usefulness—of flying into the wildest and most destructive of all storms, the howling hurricane that ravages the Spanish Main. Reports sent back from these airborne weather stations are crucial in preparing warnings to gird against the great storm's blows.

Hurricane Is Bully and Blowhard

A hurricane is a bruising bully that will knock down anything it can. It kills and crushes indiscriminately. The name "hurricane" apparently derives from the Carib Indians' *huracan* ("big wind") or *Hunraken*, god of stormy weather to Guatemala Indians.

People are prone to think an atom bomb explosion the most tremendous display of

power known to man. Yet, as one weatherman put it, "The atom bomb to a hurricane would be just like a flea to an elephant."

The late Dr. W. J. Humphreys, veteran of the United States Weather Bureau, studied the physical force built up by tropical cyclones. His conclusion: "A full-fledged hurricane generates more energy than 1,000 atom bombs exploding simultaneously."

A hurricane can lift two billion tons of water a day (in the form of water vapor) and dump the whole enormous load as rain within 24 hours. Two such storms, each lasting ten days, could fill the entire basin of 115-mile-long Lake Mead, the huge reservoir behind Hoover Dam.

Nature on the rampage is nowhere more impressive—and frightening—than on hurricane-lashed seas. Capt. Irving Johnson, NATIONAL GEOGRAPHIC contributor, weathered and briefly described a hurricane experienced in a racing sloop in mid-Atlantic.

"We were shaken around like beads in a rattle," he related. "Calking spewed out of the deck planking as great seas wrenched the hull. The storm drove the vessel, running under bare poles, at an unbelievable speed of 10½ knots (12 mph) by the log!"

On land, one hurricane last year doubled steel highway signs as you might bend a strip of soft lead (page 542). It beheaded parking meters as easily as a small boy lops daisies with a stick. A steel radio tower, 196 feet tall, toppled before its weight of wind.

More Dreaded than Spanish Fleet

At the outbreak of the Spanish-American War President William McKinley called in James Wilson, his Secretary of Agriculture. (The U. S. Weather Bureau, today part of the Department of Commerce, at that time operated under the Department of Agriculture.)

The President said: "Wilson, I am more afraid of a West Indian hurricane than I am of the entire Spanish Navy." The present West Indian weather service, later greatly expanded, was soon started as a war measure.

Grandmother of all modern hurricanes was the New England storm of September 21, 1938, that swept up out of the south to maul Yankeeland.

This gusty tramp from the Tropics "picked" 4,000,000 bushels of apples in 24 hours. It ripped through New England forests like a colossal electric shaver, clipping off and damaging a quarter of a billion trees, including



National Geographic Photographer Justin Locke

Dean of Hurricane Forecasters, Grady Norton Has Lived with Big Winds for 19 Years

He stands high above the Miami water front outside the penthouse office of the Weather Bureau, of which he has charge. Norton is senior member and chief arbitrator of the Joint Hurricane Warning Center, set up in 1943. The U. S. Navy and Air Force are also major partners. Private Teletype links the three agencies scattered around the Miami area (pages 543 and 545).

a million cherished shade trees. The storm crushed 26,000 automobiles and whitened windows of Vermont houses with ocean salt carried 120 miles from the sea.*

The mighty blow brought hordes of salps (strange deep-ocean denizens) into coastal harbors, hurtled tropical birds into unfamiliar "down East" surroundings, and knocked down so many wires that telegrams were sent from Boston to New York City by way of London!

Never has a recorded hurricane caused greater property loss. The storm claimed about 600 lives and cost New England more than a quarter of a billion dollars.

From earliest days right up until the 1920's and 30's, hurricanes kept a grisly tryst with death. Storm casualties frequently ran into four figures.

The "old" storms took such a fearful toll

* See "Geography of a Hurricane," by F. Barrows Colton, NATIONAL GEOGRAPHIC MAGAZINE, April, 1939.

of lives not because they were more violent, but because of lack of warnings. More primitive methods of those days for coping with unsanitary conditions and disease added to the death lists.

The September, 1928, Florida hurricane killed 1,836 people. In contrast, as a result of the August, 1949, storm, just two persons died. Yet this big blow closely followed the course of the blustery assassin of 1928.

Hurricane Watch Is International

What has brought about this striking reduction in hurricane fatalities? What are men doing to cope with these storms, apart from saving lives?

Last hurricane season I went hunting the answers. My first call was at the U. S. Weather Bureau headquarters in Washington, D. C., where hurricane specialist Ivan R. Tannehill told me:



Up Go the Dread Red Flags That Warn of an Approaching Hurricane

Before the days of radio forecasts, two flags with black centers were the chief means of alerting coastwise shipping. Now the U. S. Weather Bureau, many days in advance, sends out radio messages on the storm's position and course and predicts its arrival 24 hours ahead. During the peak, bulletins are flashed every hour.

Breaking Out of the Storm, a Flying Hurricane Hunter Lets Down to Home Base

In from a search flight over the Atlantic, an Air Force RB-29 drops wheels and flaps for an approach to Kindley Air Force Base, Bermuda. Big planes of the Air Weather Service take turns with Navy aircraft from Florida and the West Indies flying into hurricanes to plot their location, intensity, and probable path.

Reports from ships, islands, or aircraft first spot the storms. The Navy dispatches its flights to be at the storm vortex in midmorning; the Air Force gets its planes to the hurricane in midafternoon. This "one-two" vigil keeps the storm under constant watch.

In-flight radio messages describing the storms go to the Joint Hurricane Warning Center in Miami, Florida. If the hurricane is approaching land, warnings are issued promptly.

In the storm area the "storm snoopers" fly at 1,500 feet altitude, or lower, to keep the sea in sight to drift-meter readings may be taken on the ocean surface. Turbulence of the air near the center of a tropical cyclone racks aircraft and often makes veteran flyers sick.

Sometimes RB-29's fly 2,000 miles on one storm-seeking hop.

NATIONAL MILITARY
RECONSTRUCTION, OFFICIAL





Hurricane Winds and Fire Guttled Colossal Navy Blimp Hangars at Richmond, Florida, in September, 1945. Specks (Left Foreground) Are Men



The Miami Herald

Even Steel Highway Signs Bow Before the Hurricane's Might

The best of warnings can't prevent some damage; the late-August hurricane of 1949 knocked from Florida citrus trees 17,000,000 boxes of unripe fruit (page 560). Highest wind ever recorded in a hurricane was 186 miles per hour in the great New England storm of September, 1938. This hurricane caused greater property loss than any other tempest in history (pages 537, 558).

"To make sure the big storms don't surprise us, we have to find and follow them. To find them we need all the weather information we can get from the vast area where they grow and range. Most of that 'hurricane belt' is empty ocean."

Going on a blind search for hurricanes in those watery wastes even with radar-equipped aircraft would be pretty much a needle-in-a-haystack proposition. But once a big cyclone or area of suspicious weather is discovered, then the flying weather stations take over a major role.

"It's like calling out the fire engines," said Mr. Tannehill. "Somebody has to pull the alarm."

To keep track of West Indian hurricanes, weather reports are greedily gleaned from hundreds of vantage points dotting the republics in the West Indies and Central America, from British, French, and Nether-

lands colonies around the Caribbean Sea, and from Mexico and southern United States.

"Biggest, and blankest, areas are the open oceans. Reports from ships there have inestimable value," Mr. Tannehill said. "Merchant vessels of all countries join in a voluntary ship-to-shore exchange of weather data. Ships find it a good bargain—trading regular weather observations for forecasts and storm warnings."

Ships sometimes send hurricane reports while crews are fighting to keep afloat. Similarly, heroic observers on isolated cays and islands stick to their posts and keep transmitting reports by radio even after a storm has spread devastation all around them.

Surface ships try to flee or to avoid severe weather, especially hurricanes, by promptly changing course.

Next I flew to south Florida, deep in the seasonal hurricane area, to visit the Joint



John Randolph from Press Association

"And There I Was, Five Miles Up, Looking a Hurricane Right in the Eye!"

This historic view of the calm core of a hurricane was shot near Key West from an Air Force plane flying far above the storm. The dark area is the cylinder-shaped vortex that extends from land or sea to the hurricane's top, here only about 20,000 feet (page 548).

Hurricane Warning Center at Miami. This cooperative activity was set up in 1943. The U. S. Weather Bureau, Air Force, and Navy are its controlling members. Its function is to coordinate hurricane warnings and make them more accurate, complete, and effective.

I ran up a \$20 taxicab bill the first day visiting the three widely separated agencies in Miami and vicinity; yet the chiefs of the Joint Center chat together on a private three-way Teletype circuit nearly as easily as if they occupied the same building.

Three Services Track Hurricanes

The hurricane-warning trio I interviewed comprised Grady Norton, in charge of the Miami office of the Weather Bureau; Comdr. Edwin T. Harding, USN, officer in charge, Navy Hurricane Weather Central; and Capt. Hugh W. Ellsaesser, U. S. Air Force hurricane officer. In May, 1950, Capt. Paul R. Drouilhet took command of the Navy Central.

Much of the Joint Center's most vital information comes from aerial weather-reconnaissance flights into the growing and moving storms.

Tracking hurricanes with airborne weather stations, an outgrowth of experimental flights of World War II, has now fully "come of age." Today Air Force aircraft based in Bermuda, and Navy planes in Florida and the West Indies, keep an alert watch from June to November. They're ready to roar out to meet the hurricane at the drop of a barometer anywhere between northwest Africa, Panama, and Newfoundland.

Dovetailing land, ship, and aircraft reports, the Weather Bureau, Air Force, and Navy meteorologists of the Joint Center agree in advance on the substance of their hurricane warnings, which are released simultaneously.

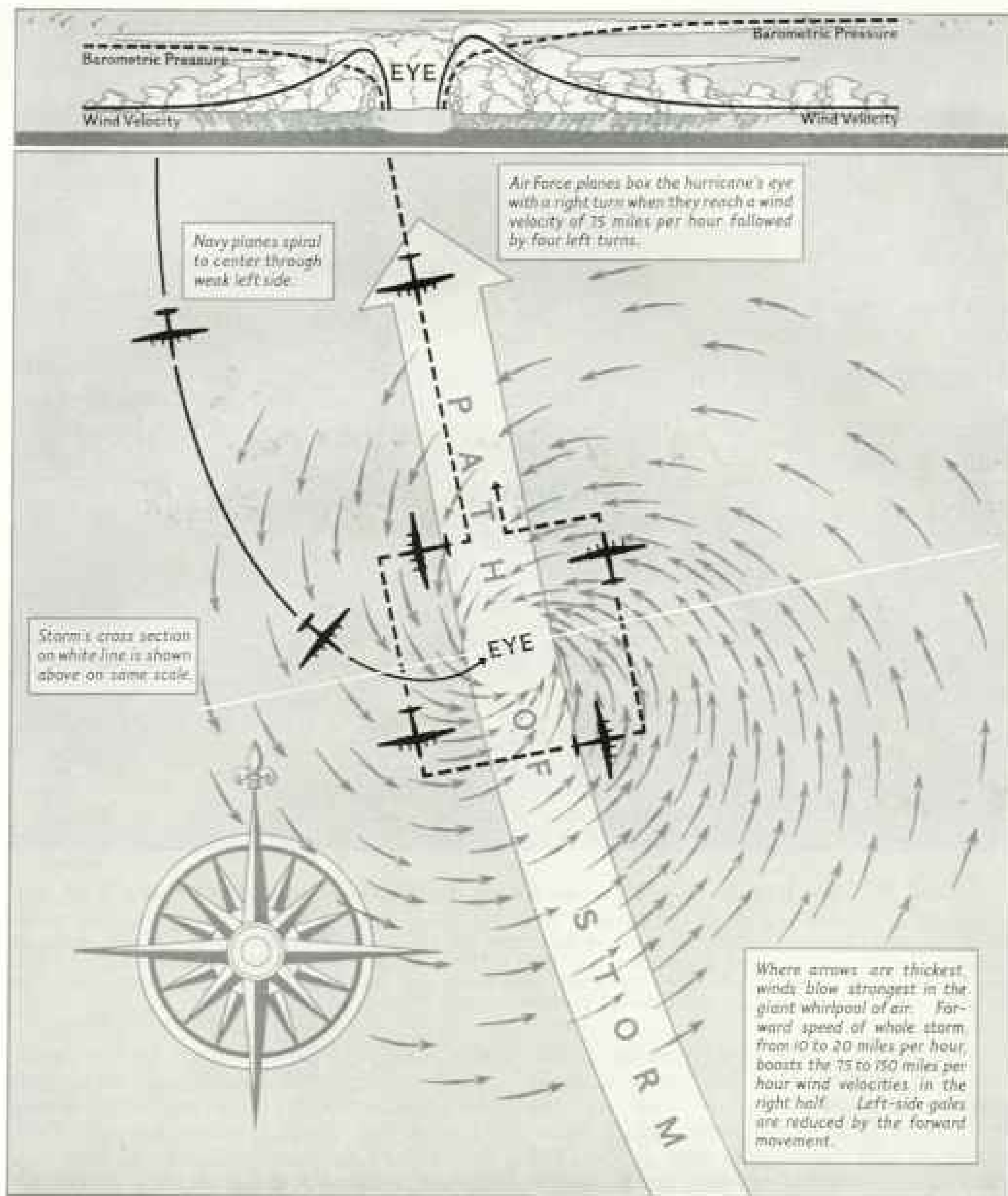
Bulletins are independently issued. The Weather Bureau's job is to warn the public and merchant shipping; the Navy alerts its



The Miami Herald.

A Race Track Doubles as a Shelter When a Big 'Cane Strikes

Under the betting windows at Hialeah race track families from flimsy homes or areas subject to flooding settle down to outlast a hurricane. The Red Cross maintains stocked shelters in sturdy schools, churches, and business buildings in all cities subject to hurricanes (page 539).



Drawn by Irvia H. Altman

Spiraling Hurricane Winds Blow Hardest Near the "Eye," Where Pressure Is Lowest

Main diagram shows how air currents circle about the calm center, moving faster to the right of the direction of the storm's forward movement. This applies only to hurricanes north of the Equator, whose winds spiral counterclockwise. South of the Line, winds move clockwise, and so are strongest to left of the storm's forward course (page 548). Cross section at top illustrates how wind velocities reach maximum near center, then decrease outward. Barometric pressure is lowest in the eye, rising toward the storm's rim.

ships at sea and naval installations; and the Air Force issues advisories to its bases and to Army establishments.

The Weather Bureau's spare and sandy Grady Norton is the dean of American hurricane forecasters. He takes tropical tempests

in stride from the penthouse of the Miami Technical High School building (page 538).

As middleman between storm gods and hurricane-wary public, forecaster Norton is one of the single best-known citizens in south Florida. His radio voice has become a tradi-



Lone Watcher Recoils from Stunning Crash of Monster Wave Against Sea Wall

Much of the roadway leading to Baker's Haulover (left), north of Miami Beach, collapsed under terrific pounding by hurricane-driven swells of September 20, 1948. Repeated damage to this stretch forced building of a new bridge and approaches safe from clawing waves. Slow, heavy swells tumbling on a beach often signal a distant hurricane's approach. The storm may travel only 10 to 20 miles an hour, but its great winds can send waves rolling ahead at 30 mph (page 555).

tion on the air lanes during hurricane season.

Norton dryly says his forecasting successes pale beside those of Father Noah; yet the Ark's population was a mere "token force" compared with the army of men, women, and children who owe life and limb to the tireless labors of Norton and his military associates.

Hurricane, "Public Enemy No. 1"

"When a hurricane's on the loose," Norton told me, "this office becomes what you might call an orderly madhouse. All local newspapers post reporters here, as do the major press association services. The Red Cross stations a man at my elbow, ready to alert disaster preparedness facilities.

"As the hurricane moves in, we try to figure out where and how hard it will strike. We give people time to batten down their property and take cover.

"Commander Harding, Captain Ellsaesser,

and I keep in close touch," he continued, "on the Teletype line linking my office with Navy and Air Force hurricane headquarters. At least half an hour before advisory time, we reach an agreement on location, intensity, speed of movement, and probable future course of the storm."

Norton explained that most hurricanes never come near continental United States. To be on guard for the occasional storm that does strike the mainland, much of the elaborate warning system has been set up.

When a hurricane levels sights at the coast, the Weather Bureau starts issuing warnings to the target area two or three days before it hits. Before last August's storm had spent its force, the Bureau had issued 33 advisory and warning bulletins (page 559).

Within 15 or 20 minutes after a warning goes on the wires it's heard by Teletype and international radio halfway around the earth.



Nearly Rolling Her Flight Deck Under, Carrier *Langley* Wallows Through a Typhoon

Gun and director stations, dipping toward the giant waves, normally are 40 feet above the water. A typhoon, Pacific "big brother" of the hurricane, strikes with fearful power: a 1944 storm capsized three destroyers and damaged 28 ships, many seriously. Eight hundred officers and men were lost. An Atlantic storm the same year sank the destroyer *USS Warrington*. Light carrier *USS Langley* was part of Task Force 38 operating in the South China Sea.

Norton has direct wires to 21 Florida radio stations and to a powerful short-wave station that rebroadcasts to small towns.

"I sometimes broadcast every two hours steadily for two-and-a-half days," he said. "At the storm's climax we often put bulletins on the air two or three times an hour. By the time you wrestle with one of these big blows for a couple of days without letup, you're about ready for a padded cell."

Where the Storms Are Born

Principal beneficiaries of the Joint Center's warnings are Florida, the southeastern States and Gulf coast, the Bahama Islands, and the West Indies. Many interests in those regions are keenly sensitive to the vagaries of the big storms. They include Cuba's sugar growers, Florida orchardists and truck farmers, chemical and oil industries in the Gulf States, cotton growers in Georgia and the Carolinas,

and coastal and offshore fisheries throughout the area.

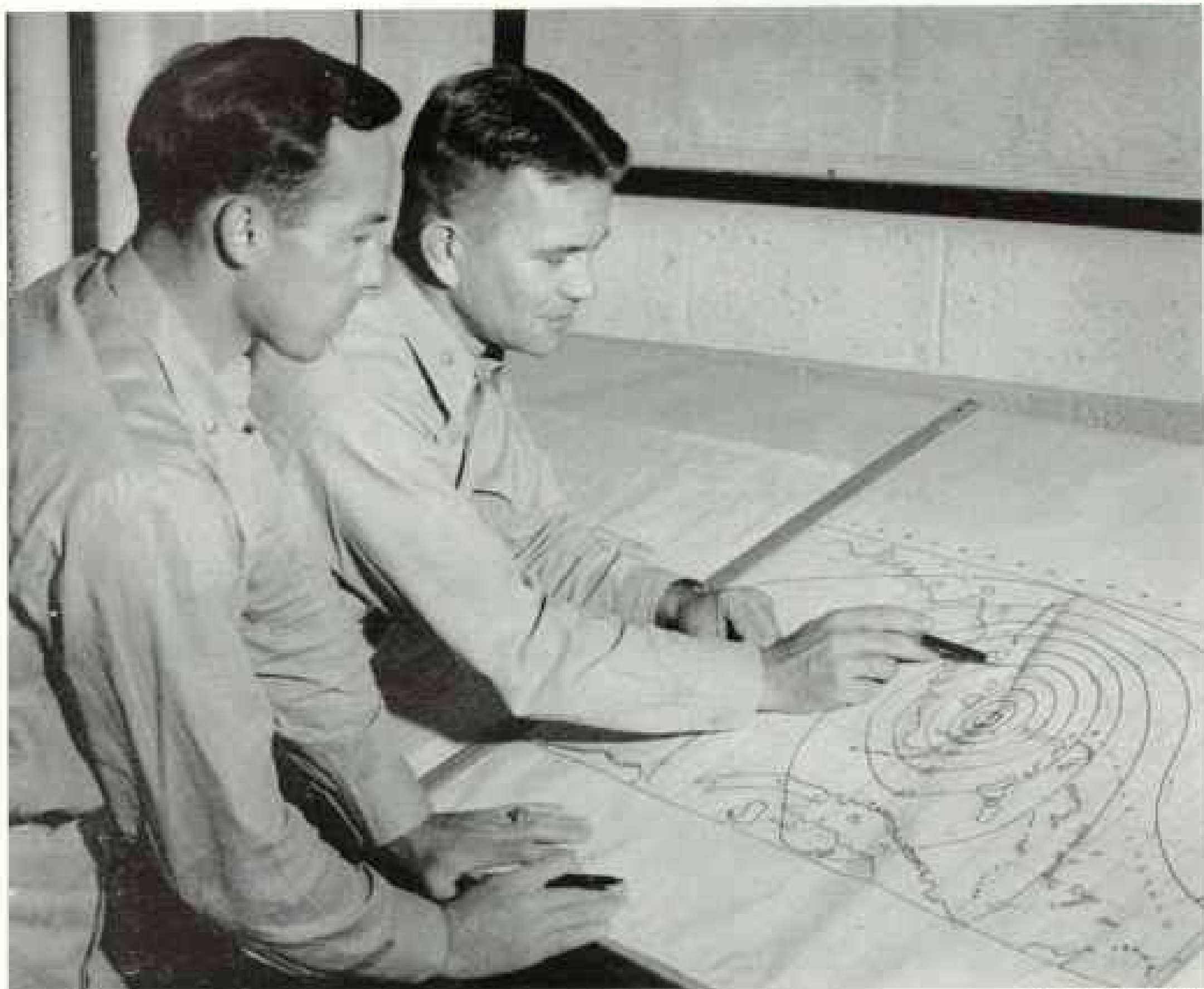
Mr. Norton leaned over a weather map that showed current pressures, winds, temperatures, fronts, and precipitation over the Caribbean Sea and the western North Atlantic.

"The West Indian hurricane may blow up as far east as here," he explained, pointing to the Cape Verde Islands, off North Africa, "or as far west as here," placing his palm over the Bay of Campeche, southwestern bulge of the Gulf of Mexico.

"It may wind up its giant storm-spring anywhere in the tropical Atlantic Ocean between latitude 0° and 30° N."

In the sultry doldrums, Norton explained, between the trade winds blowing from north-east and southeast, air movement is light or in fitful zephyrs. There humidity is high, heat intense, evaporation enormous.

No one yet understands just how this com-



U. S. Navy, Official

"The Way I See It, She's Headed Right Up the Florida Peninsula!"

Comdr. Edwin T. Harding points out to a fellow Navy aerologist his forecast of the future path of a hurricane centered near Palm Beach, Florida. Until recently, Commander Harding was officer-in-charge of the Navy Hurricane Weather Central at Miami. The map is an enlarged extract from the weather chart drawn four times a day. Concentric lines are isobars that pass through places of equal barometric pressure.

bination of conditions starts the storm to marshaling its fearsome mechanism of boiling cloud, raging wind, and teeming rain.

How the Hurricane Takes Shape

Birth of a hurricane begins with moist air, heated by the sun, rising from the surface of the tropical sea. This air doesn't rise in a layer, but funnels up into an area of natural updraft, as hot air in a room is drawn up a chimney flue.

As the air rises it cools, and the water vapor in it condenses into rain. In this process the moisture gives up the heat that originally vaporized it from the ocean below. Thousands of tons of rain are formed in a hurricane, so that fabulous amounts of heat are fed back into the air. This heat, adding to the force of the storm's updraft, is one main source of a hurricane's power.

As the air goes spiraling upward, more hot,

moist air rushes inward from all sides to replace it and keep the updraft moving.

Motion of the earth rotating eastward deflects these in-pouring currents to one side. This starts the air spiraling counterclockwise, and the rising column of air begins to spin this way too, when north of the Equator. South of the Equator the spin is in the other direction.

Whirling faster and faster, the storm officially becomes a hurricane when its winds reach 75 miles per hour. Drawing ever tighter about the center, the great winds form a roaring ring around a central area of calm air, the "eye," 15 to 30 miles across (p. 545).

In the eye the atmospheric pressure is very low, but near the rim of the cyclone, which may be 100 to 150 miles outward from the center, the pressure is relatively high. The greater the difference in pressure between the center and rim of the storm, the harder the winds blow (page 543).



U. S. Navy, Official

Even Pet Dog and Rocking Chair Find Space on a Navy Storm-rescue Craft

When torrential rains of a hurricane made a lake of the Everglades, the Navy sent this amphibious Weasel to evacuate marooned settlers. Florida has spent millions to drain its flat, low-lying southern reaches, averaging less than 50 feet above the sea. In such level land rainwater dumped by hurricanes runs off slowly, may pile up to second-story depth (page 554).

Shape of a hurricane is like a phonograph record, a thin, flat disk of whirling winds 200 to 300 miles across, but only 7 to 12 miles in vertical thickness. It may cover an area as large as Missouri. The winds blow around the circle up to 150 miles per hour or more. But the storm as a whole moves at a modest 10 to 20 miles per hour, just as a top, spinning at high speed, travels slowly across the floor.

It may take anywhere from a day to a week for a full-fledged hurricane to develop. Born at sea, the cyclone most frequently also dies at sea, maybe 10 days later and 3,000 miles from its birthplace.

A Hop with a Navy Storm-chaser

Rounding second base on my tour of the Joint Hurricane Warning Center, I visited the Navy at Master Field, a few miles north of Miami.

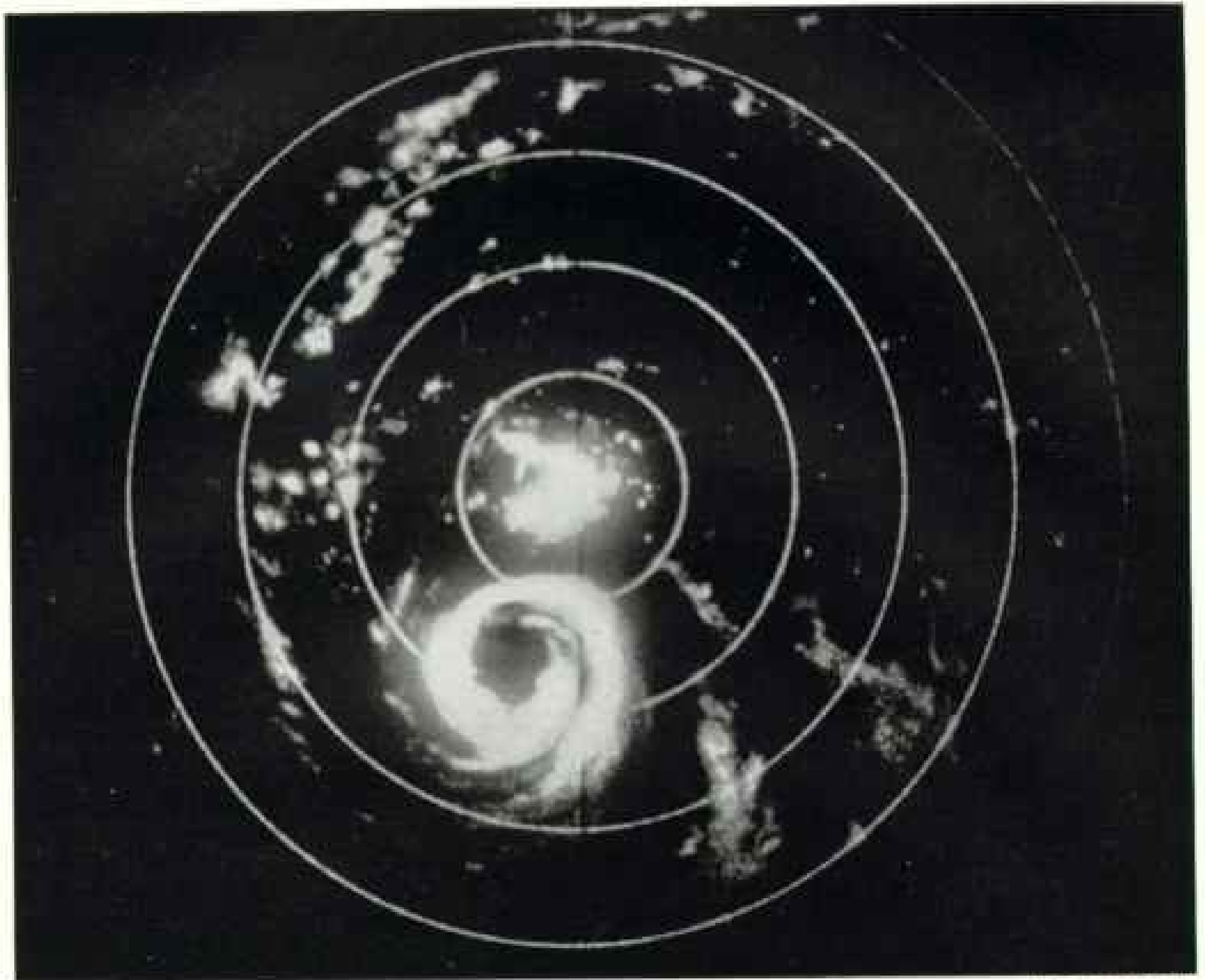
Comdr. Edwin T. Harding showed me the

workings of the Navy Hurricane Weather Central, which he commands. Harding also had operational control over the reconnaissance squadron based there.

"Our 'recon' aircraft try never to let a hurricane get out of sight for more than a few hours," he said. "We have an aircraft taking off in an hour to look at a suspicious area over the Bahamas. Why don't you go along?"

So in one of the Navy's hurricane-hunting Privateers we soon were throbbing eastward above the blue Gulf Stream.

Equipment crammed the high-tailed PB4Y-2. There were the aerologist's radar altimeter and the radar scanning set used to search out the actual eye of the storm. Navigator and weather officer took turns huddling over the drift meter, which aids navigation and gives wind speed by "reading" the ocean waves.



U. S. Navy, Official

In the Radar Scope, the Eye of an Intense Hurricane Shows Up Like a Spiral Nebula

Electric pulses bouncing back from heavy rainfall around the center of the storm form this pinwheel of light in a radar photo made at the Boca Chica Naval Air Station, near Key West, Florida. Twenty-mile rings around the bull's-eye that marks location of the radar set indicate the hurricane's heart is about 30 miles away. Other bright spots are showers, dense clouds, or land areas. Land-based radar took this picture, but both Navy and Air Force use similar equipment in aircraft spying on hurricanes (page 557).

The aerologist also consulted his aneroid barometer, which gives atmospheric pressure, and his psychrometer, which records relative humidity. Up front were automatic pilot and automatic direction finder, the latter called "the bird dog" because it "sniffs out" the way home.

Talk increased on the plane interphones as we drew near the suspected storm area.

"Radarman to pilot! There is heavy rain 10 miles ahead on this course."

"Pilot to radarman. Very well. Give me a course through a light spot."

"Radarman to pilot. Aye, aye, sir! Turn eight degrees to port."

"Pilot to radarman. Eight degrees to port."

On our Bahamas flight we found rain squalls, heavy cloud, and mild turbulence, but not a sign of a big blow; so we gulped welcome hot coffee and sped back to Florida,

Commander Harding showed me a typical message alerting a storm-seeking Privateer for a flight into a hurricane.

TAKE OFF AT 1000 Z [Greenwich time] FOR 10N 71W X STORM ESTIMATED NEAR 100 KNOT INTENSITY IN EASTERN SEMICIRCLE X IF FEASIBLE OBTAIN CENTER FIX PRIOR CIRCUMNAVIGATION X LATER INTO WILL BE SENT PRIOR 0100H Z X ACKNOWLEDGE

The flight to the storm area, often four hours long, is made normally at 1,000-1,500 feet. Approaching the eye, the plane slowly drops down to 500-foot altitude.

Navy Penetrates 80 Percent of "Eyes"

Navy and Air Force flyers use individual techniques for hunting down big cyclones. Navy patrols fly into the actual eyes of about four-fifths of the storms they investigate.

"Blind flying" conditions generally prevail



Wide World

When the Weatherman "Warns In" a Hurricane, Miami's Quickly Batten Down

Men are fitting numbered panels over plate-glass windows of Eastern Air Lines' office on Miami's handsome but exposed Biscayne Boulevard. Stores and offices close well before a storm's arrival, so people have time to go home and prepare for the blast. Miami's chances of hurricane-force winds (75 mph or over) in any given year are about one in seven.

near the hurricane core. Weather planes must sneak in under the "soup" to keep in sight of ocean waves and streaks of foam and spume lined up with the wind.

Air Force aircraft more often locate the center by skirting around it, especially at times when it would be needlessly dangerous to buck through lashing winds near the eye.

The flyers head toward the center's suspected location until they find winds of hurricane force, 75 miles an hour. Then they fly a roughly rectangular course, bringing the plane successively to three other points around the storm where 75-mile winds are found. At the center of the "box" formed by this flight course, the hurricane core must lie (diagram, page 545).

When fuel reserves and daylight allow, the weather crews fly into the eye as a double check.

The right half of the storm as you look

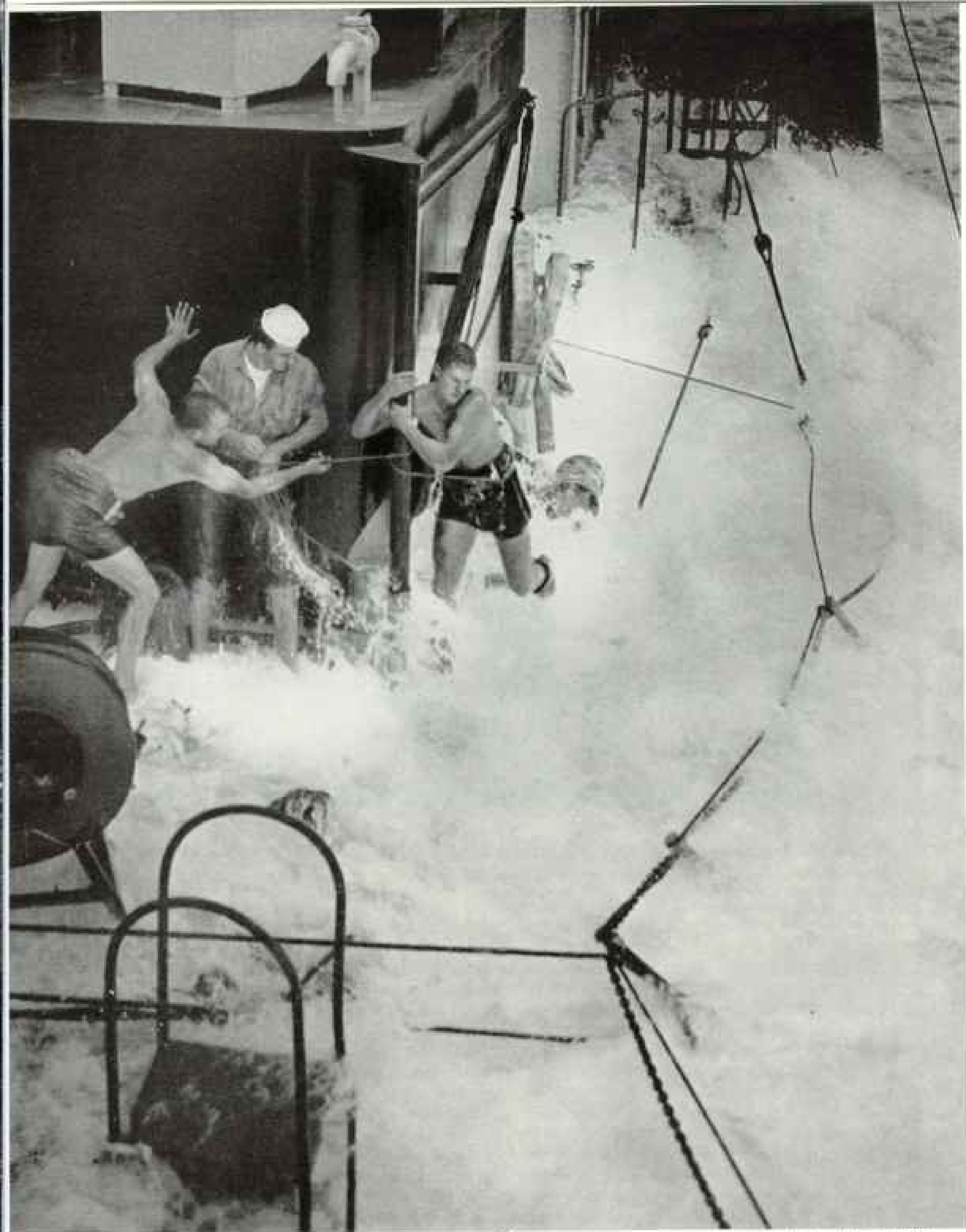
forward along its path of movement is the more violent. This is because in that area the forward speed of the whole cyclone—perhaps 20 miles per hour—is *added* to the velocity of the hurricane's own winds, blowing counterclockwise (in the Northern Hemisphere). The two movements added together produce the storm's maximum winds.

This effect of extra push is especially true of the right front quadrant, which also is the wettest and usually the most turbulent part of the storm.

Contrariwise, the left half of a hurricane is less unruly. On that side the hurricane's winds, blowing in general toward the rear, are slowed down by the storm's forward motion.

This somewhat quieter left half provides the "back door" through which the "recon" plane fights its way into the tempest.

Keeping the wind on his port quarter, the pilot spirals in to within 15 or 20 miles of



Men Fight for Footing as an Avalanche of Spume Engulfs a Tanker's Decks

Two of the crew hold the safety line of a third as he waits for the welter of foam to retreat. Hungry waves tore loose steel stanchions and carried away life boats and rafts when this tanker, manned by the U. S. Coast Guard, fought for life through a hurricane north of Cuba. Usually hurricanes are most violent over the sea; they "dry up" and lose force over land. "The bottom really dropped out of the barometer" when the steamship *Arctuna* recorded a pressure of 26.16 inches in a typhoon east of the Philippines. Even in severe storms, normal sea-level pressure (nearly 30 inches) drops only an inch or an inch and a half. A 1943 typhoon (Pacific version of the hurricane) ripped the bow clean off the heavy cruiser *Pittsburgh*.

the storm's eye. By then weather is so turbulent that the pilot's choice as a rule is to head directly for the calm core. He has eight other men with him who have no desire to stay longer than necessary in the band of violence ringing the eye!

Perhaps 20 or 30 miles away, the radar operator picks up the eye on his screen (pages 550 and 557). It's a glowing image of the crescent-shaped rain bands around the center. He gives the pilot the correct heading and "talks" him inward to the eye, keeping his own eyes glued to his scope.

The aircraft tosses and bumps in the wildly buffeting air. The navigator quits work and hangs grimly to his seat. The aerologist long since has given up trying to read the drift meter, for the plane's pitching, thumping, and yawing render it useless.

"Fred Clampitt . . . Is Turning Green"

At this frightening climax on one flight, Milt Sosin, veteran hurricane reporter of the *Miami Daily News*, jotted down an observation of a fellow passenger: "Fred Clampitt, WIOD news editor, is turning green. No, it's not fear. He's sweating so much that the colored shark repellent in a pocket of his life jacket is starting to run."

After more hard jolts the plane suddenly bursts into the blessed quiet of the hurricane eye. Weather officer and navigator get busy again with their chores.

"In one storm," a Navy pilot told me, "the eye was unusually large and exceptionally quiet. We sighted a freighter right in the calm center. We buzzed her for a closer look. The crew were sunbathing right there bang in the middle of a hurricane!"

As the Navy Privateer fights back out through the wall of thudding wind, an Air Force RB-29 prepares for take-off from Bermuda to do its stint at keeping the big storm under surveillance.

Upshot of such a flight is a warning message like this:

WARNING NUMBER TWO X NAVY RECONNAISSANCE CENTERS STORM AT NINETEEN DEGREES THIRTY MINUTES NORTH EIGHTY-TWO DEGREES WEST MOVING NW AT 11 KNOTS ATTENDED BY WINDS OF 110 KNOTS WITHIN 25 MILES OF CENTER AND 65 KNOTS WITHIN 70 MILES OF CENTER X INDICATIONS ARE THAT STORM WILL CONTINUE NW MOVEMENT AT SAME SPEED FOR NEXT 12 HOURS WITH A SLOW CURVE TO A MORE NORTHERLY DIRECTION AFTER THAT

Ashore and at sea there's plenty of time, thanks to reports from the flying weather stations, for everyone to brace for the blow.

According to Warning Center plan, the Navy recon planes schedule their flights to

be in the storm at about 9 in the morning. The Air Force takes off in time to reach the hurricane heart at 3 in the afternoon.

Air Force Flies Storms in RB-29's

To see the Air Force part in the "hurricane shuttle," I flew to Kindley Air Force Base, Bermuda (pages 540, 557).

Hefty RB-29's of the Air Weather Service, in their sooty war paint, seemed out of place in idyllic Bermuda. Beyond the runways, turquoise waters of Castle Harbour lapped coral shores. Pastel homes and hotels jeweled cedar-green hills. The air in October was soft and warm as May.

Lt. Col. Clyde A. Ray, commanding the 375d Reconnaissance Squadron at the time of my visit, said his crews may fly 2,000 miles on one storm-seeking jaunt. Sometimes they make eight hops into a single hurricane.

The RB-29's have to find the eye moving across vast stretches of empty sea, then back-track to a small spot of mid-ocean land only 15 miles long and 5 miles wide!

"Don't you 'home' on the Kindley Field range station?" I asked Capt. Robert K. Dusenberry, chief navigator.

"Only in an emergency," he replied. "We must maintain combat proficiency. There's no radio beam over a bomb target."

"So our boys find their way by dead reckoning and celestial navigation. That leaves little margin for error out here where one acre of ocean looks like a million or two others."

Another navigator, brawny Lt. Paul Ferris, said it was no good to get too cocky, for, as he sagely put it, "even the best toreador sometimes gets gored."

The aircraft fly at 1,500-foot altitude or lower on these missions to keep contact with the sea. Extremely precise drift-meter readings are necessary for accurate determination of position.

A single flight may flash as many as 20 to 30 radio reports to the Joint Hurricane Warning Center at Miami.

Spotting Cyclones Not Easy

Capt. Hugh W. Ellsaesser, Air Force hurricane officer in Miami, plots and studies tropical cyclones and informs the Bermuda squadron when the Joint Center wishes Air Force flights scheduled into hurricanes or areas of suspicion.

"Spotting a big storm on the weather map isn't always easy," he pointed out. "Any marked change in the normal trade-wind flow, a 24-hour drop in the barometer, or a report of torrential rainfall—any of these can mean trouble."



U. S. AIR FORCE OFFICIAL

Storm Snoopers Stalk a West Indian Hurricane

From his forward station in the "greenhouse" of an RB-29, the weather officer hands back a coded message to the pilot, who will pass it on to the radio operator. At the Joint Center in Miami, this report will be charted with others to track the "big cane." As the plane hits the violent core, observers stop work, hang on to their seats. Once in the eye, flight is serene for a few minutes.

"If a hurricane builds up in an isolated region, a report of changing or rising winds from a ship may alert us. The message might show an ENE wind at 45 miles an hour where the weather map has previously been flat and featureless."

Charts of Atlantic hurricane paths from year to year show that most of them follow curving routes from southeast to west or northwest, toward the West Indies and southern North America. Reaching the regions of prevailing westerly winds, they recurve north or northeast, sometimes hitting the eastern United States on the turn.

Storms originating in the western Carib-

bean or the Gulf of Mexico may follow a nearly northerly path.

Some storms wander aimlessly, occasionally even doubling back to cross their own tracks like half-tied knots.

One cyclone won the name "Yankee Hurricane," because after its birth east of Bermuda it moved *toward* the Equator, hitting Florida from the northeast.

Hurricanes Die Out over Land

As the hurricane passes inland, over big islands or continental mainland, friction causes it to lose its power and violence. A storm also dissipates rapidly when it moves over cooler waters, where it no longer can draw strength from the transfer of warm seas' heat into motive energy (page 548).

Characteristic of a hurricane is prodigious rainfall. Occasionally the teeming downpour in 24 hours of a tropical cyclone has exceeded the total average *annual* rainfall for familiar great cities like Chicago, San Francisco, Paris, Rome, or London.

Baguio in the Philippines in July, 1911, was soaked by 46 inches of rain in 24 hours. In four days skies have emptied more than eight feet of rain on Jamaica. The Miami Weather Bureau once recorded 1.32 inches of rain in 10 minutes!

Slow Waves on the Beach? Beware!

In flat, low-lying land, like southern Florida, water dumped by hurricanes often piles up faster than it can soak into the ground or drain away to sea. Floods send animals and reptiles, as well as humans, hustling for higher ground. Livestock often must swim through turgid floodwaters toothed with unrooted trees, roofs, fence rails, and telephone poles.

A hurricane sends swells crashing ashore, sometimes at a great distance from the storm center, with a frequency of only four or five waves to the minute compared with the usual Atlantic "beat" of seven or eight. So if slow, heavy swells are tumbling on the beach when local winds are light, beware! (Page 546.)

When Gulf of Mexico waters surged into the streets of Galveston, Texas, in 1900, wiping out 6,000 people and reducing the city to matchwood, many residents blamed a "tidal wave." But a tidal wave, strictly speaking, is caused by a submarine earthquake. At Galveston a hurricane was the culprit.

The floods that often smite low-lying sea-coast areas coincident with passage of a hurricane are caused by water piled up by the storm's winds. Such inundations have accounted for at least three-quarters — some say 90 percent—of all hurricane deaths throughout history.

Water rose four feet in four seconds in that Galveston disaster. A weather observer there reported, "The water at the time was about 8 inches deep in my residence, and the sudden rise of 4 feet brought it above my waist before I could change my position."

Today Galveston is protected by a mighty man-built sea wall $7\frac{1}{2}$ miles long.

A storm flood is naturally deeper and more damaging when the astronomical (moon) tide is high at the time the hurricane hits. Contrariwise, low tide coinciding with the cyclone wave may greatly lessen its power to destroy.

Hurricane suffering is multiplied in tropical towns because people in those languid latitudes



The Miami Herald

Let the Wind Scream! Emergency Supplies See Them Through

If the milkman fails to make his rounds, this household will have canned milk. Tinned meats and other precooked foods are handy in case gas line breaks prevent cooking. If power lines fail, there are candles and kerosene lamps to fall back on. If the mother's foresight is complete, she will fill her bathtub and big pots and jars with water. Thus do folks in the "hurricane belt" prepare for "the wildest and most destructive of all storms" (page 559).

so often live in flimsy homes jammed together along the waterfront. That's why typhoons leave such a trail of woe along western Pacific shores and why Bay of Bengal cyclones are such havoc-raisers.

The Pacific typhoon and the cyclone of India are the "same breed of cat" as the Atlantic hurricane. But the typhoon uses its claws more frequently and over a longer season. The tally of typhoons averages more than 22 a year, compared with seven hurricanes a year in the Atlantic.

Typhoon-tracking by the military services was a high-priority mission during the recent



Typhoon Seas Roll the U. S. Light Cruiser *Santa Fe* Almost on Her Beam Ends

Six-inch guns of her forward turret, turned to the port side, point upward nearly to a 45-degree angle as she swings far over to starboard in a storm in the South China Sea. Screaming winds lash the sea surface to foam. Life net floats are lashed to the tops of the gun turrets to keep them from going overboard or flying about, though normally they are left unsecured, ready to float free if the vessel sinks.

Pacific war. In June, 1945, a typhoon, with brutal strength, ripped the bow clean off the heavy cruiser *Pittsburgh*.

Guam is headquarters for Pacific typhoon analysis. Both Air Force and Navy aircraft fly out from there on storm-study sweeps.

Okinawa was the victim of a terrible typhoon on July 23, 1949. "Gloria," as it was called, raked the island with 175-mph winds. Despite ample warning by the Air Weather Service, the storm inflicted multimillion-dollar damage.

"Quonset-type structures were crushed like matchboxes and carried away like straws," said an official report. "Their corrugated roofs rippled like flags."

A cook at Kadena Air Force Base hurried into a large walk-in refrigerator when things got too hot. "It was the safest place I could think of at the time," he said. "The building blew away, but the reefer stayed."

"To obtain upper-air data vital to hurri-

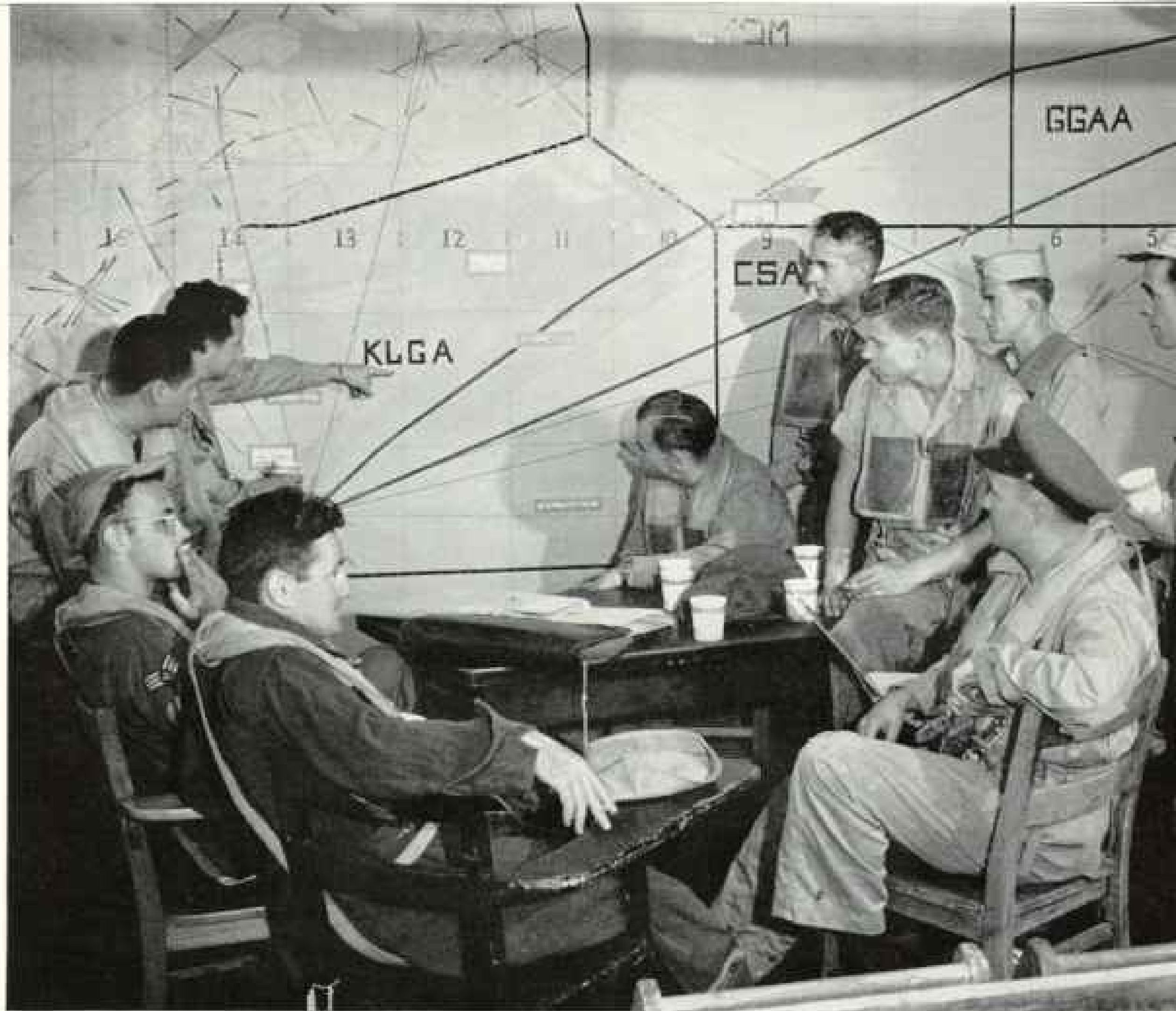
cane study," Captain Ellsaesser told me, "observing stations use pilot balloons, rawin, and radiosonde. Pilot balloons are watched through a theodolite to reveal speed and direction of the upper winds. Rawin does the same job to greater altitudes and even through clouds by tracking the balloons by radar.

"Radiosondes are small balloon-borne transmitters that send back radio signals to a ground receiver, giving temperature, barometric pressure, and relative humidity at higher levels in the atmosphere.

"Now we're experimenting with dropsondes," Ellsaesser continued. "These are small transmitters released by parachute from high-flying aircraft. They relay to the plane the same readings as the radiosonde."*

But radar, I learned, is the darling of the hurricane hunters.

* See "Weather Fights and Works for Man," by F. Barrows Colton, NATIONAL GEOGRAPHIC MAGAZINE, December, 1943.



After a "Hairy Hop," Tired Storm-seekers Relax over Cups of Coffee

This crew of a recon plane hasn't yet shed life jackets at Kindley Air Force Base, Bermuda. One man points to the spot where they chased a hurricane. Prominent are call letters of radio stations that keep contact with transatlantic airliners. Two diagonal black stripes mark flight tracks between Bermuda (lower left) and England. Cross marks (upper left) are beam paths of radio range stations on the mainland.

Both Navy and Air Force now use new radar to spy out and pinpoint hurricane centers while the spotting plane stays well outside the roughest weather. This equipment is especially useful for tracking hurricanes at night, when less sensitive sets would be largely inadequate and when flying near the storm center would be dangerous to aircraft.

Night flights of radar-equipped Navy B-17's from Patuxent River Naval Air Station, Maryland, and of Air Force radar planes from Bermuda, all requested from Miami, supplement the daytime hurricane hops.

What is the image the radar scanner sees, or photographs, on his scope? To the uninitiated the "picture" looks like rather shapeless patches, luminous and greenish in appearance. But the radarman says: "See these glowing crescents? They show where rain is heaviest; their curving shape reveals the hurricane eye" (page 550).

You learn that radar pulses bounce back

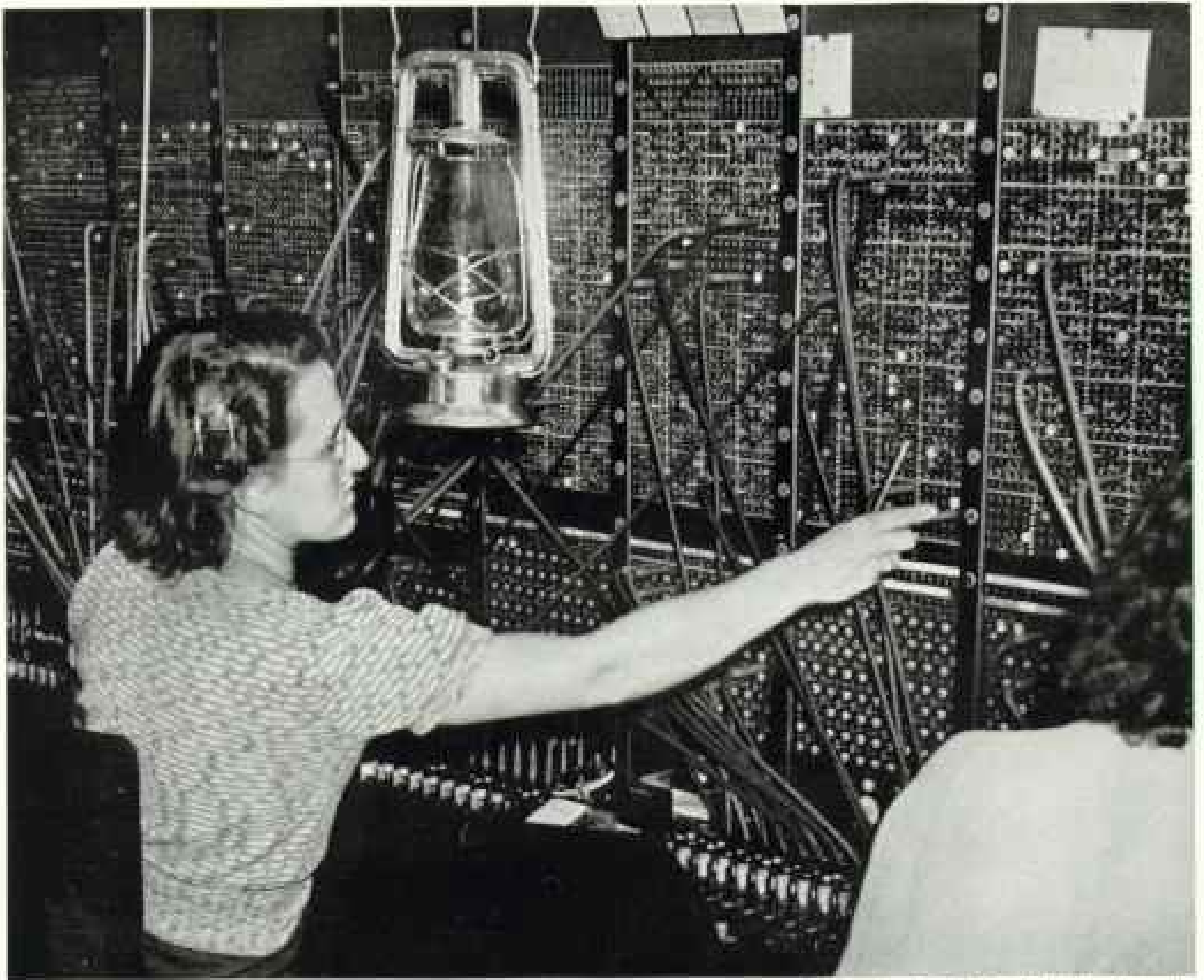
from water droplets in the air. Echo pulses shape up on the radar screen into patterns that trained observers can instantly identify.

"The center of a tropical cyclone shows up so well on radar," Captain Ellsaesser explained, "because the big and copious raindrops in the clouds around the eye toss back the strongest echoes."

Radar Watches Storm Move In

Line-of-sight range is necessary for radar reach, just as it is for television reception. So a high-level flight aiming by radar at a high-level target (the hurricane two miles above sea or land) obviously allows the longest straight-line sight (actually hundreds of miles) without interference from the earth's curvature.

The most precise "fix" on a storm is possible when radar shows the hurricane eye and identifiable islands or other landmarks in the same view.



The Southern New England Telephone Company

When the Big Blow Struck New England in 1938, Life Returned to the Kerosene Age

A telephone operator at Middletown, Connecticut, plugs in to complete an emergency call after smashing winds, floods, and waves crippled utilities. The bright glare of the photographer's flash bulb momentarily dims the lantern's gleam. The Bell System rushed extra repairmen from as far away as 1,500 miles when hurricane-felled trees knocked out half a million New England phones.

The Navy uses ship and shore radar, too, to "tie down" storms. Key West, dangling unprotected at chain's end of the Florida Keys, has suffered many a "one-two punch" from hurricanes. At close-by Boca Chica airfield, the Navy in September, 1948, on surface radar tracked a violent hurricane approaching from Cuba. That "watched pot" boiled for sure; it lashed Boca Chica with estimated 150-mph winds, the worst blow there since 1919!

The \$200,000,000 Louisiana-Gulf of Mexico oil industry now has radar protection of its own. Many of the drilling rigs stand far out in open waters of the Gulf. The Humble Oil & Refining Company bought and mans a radar set installed at Grand Isle, Louisiana, that supplements Joint Warning Center bulletins.

This double-barreled warning system assures roustabouts, "roughnecks," and drillers plenty

of time to "button up" their oil rigs before a storm strikes.

In addition, the oil company radar is extra protection for the multimillion-dollar Gulf States shrimp industry, concentrated especially in Louisiana and Texas waters. When the scope shows a storm coming close, crews can cap wells before they jump into boats heading for the mainland.

If a well were not capped, and the drill hole should "come in" while the rig was vacated for a hurricane alert, free-flowing oil might pollute the shrimping grounds and kill off millions of delectable crustaceans.

The Navy in Miami also is pursuing research on micro-seismic detection of hurricanes. Seismologists have long been able to detect earthquakes, except purely local shocks, almost around the earth. A tremendous storm like a tropical cyclone causes deep vibrations in the very skin of the earth. These waves



C. B. Nerry, Official

Careful Hands Cradle Precious Cargo in a Hurricane Rescue

Tense expressions reflect the drama of an evacuation from the fringes of the Everglades. Wire mesh in background houses the air propeller that drives this shallow-draft airboat, ideal for flood work. Adequate hurricane warnings have reduced loss of life in tropical cyclones to a fraction of the old-time toll.

activate delicate seismographic instruments that can be so placed as to give information that will position a hurricane center.

Greeting an Unwelcome Visitor

Hoist hurricane warnings at midnight from Vero Beach southward to include Greater Miami area. All usual hurricane emergency measures should be taken the remainder of the night and Friday forenoon.

Sufficient information has now been received to indicate that the hurricane center will approach the southeast Florida coast . . . in 18 to 24 hours. The hurricane is increasing in force and may become very severe by the time it reaches Florida. Our next advisory will be at 2:00 a.m.

Norton—Weather Bureau

With this warning, issued at midnight, August 25, 1949, the Miami Weather Bureau alerted southeast Florida to yet another tropical cyclone.

Up went hurricane warnings along the water front. At night, it was two red lanterns

with a white one hung between. By day, square red flags with square black centers, one above another, gave the alarm (page 539).

The Red Cross mobilized its shock troops and opened stocked shelters in schools, churches, and business buildings (page 544).

Newspapers and radio announcers cautioned the populace: "Get off the streets. Take cover. Put up storm shutters or board up windows. If you live in a flimsy house, go at once to the nearest shelter. Don't touch fallen wires. Get out of low-lying waterfront areas.

"Replenish stocks of canned and precooked foods. Gas lines may break. Lay in candles, lanterns, kerosene, and get new flashlight batteries. Power lines may fail. Disinfect your bathtub. Fill it and all big pots with water. Mains may burst in the storm" (page 555).

Up and down the coast everyone dropped "business as usual" to face the common peril. Palm fronds rattled in the rising gale. Automobiles crawled, alert for debris. Crashing

seas clawed at the shores, reaching for beach cabanas, hotels, unoccupied winter homes.

There was a limit to what could be done to save docks, boats, warehouses, barns, and gardens. Most susceptible of all to damage, and least defensible, were field crops and orchard fruits.

Out on fabulous Miami Beach, steel-and-concrete ocean-front hotels were almost invulnerable to hurricanes. And thousands of storm shutters shielded acres of window glass from the cyclone's huff and puff (page 551).

But losses of decorative plantings, lawns, and beaches, and damage to swimming pools and walkways couldn't be entirely prevented, if the storm center passed that way. Learning from bitter experience, Greater Miami has put into effect strictly enforced building codes in late years to ensure that every possible safeguard is used in home construction.

At 4 p.m. on August 26, 1949, the hurricane plunged across the Florida coast. The eye passed Delray Beach between 6 and 6:30.

The big wind scalped houses, snapped palm trees, festooned streets with twisted wires, sand-blasted paint from automobiles. Men and women stayed out of sight.

For all the careful preparation, the damage toll mounted up and down Florida: two killed, 133 injured, 265 dwellings destroyed, 24,338 homes damaged, \$45,000,000 damage in that one State, including 17,000,000 boxes of unripe citrus fruit knocked from the trees.

Hurricane Is News Everywhere

A hurricane is always a "natural" as news. It combines human adventure, scientific interest, suspense, and often the drama of heroism.

"When a hurricane smacks the Southeast, it hits front pages all across the Nation," Grady Norton pointed out. "And you can bet California papers don't spare the headlines!"

Fortunately, there's a lighter side even to a hurricane.

The day after passage of a recent storm, the *Miami Herald* headed its weather report, "Blew Skies."

Last year's first hurricane worthy of a name headed toward Florida while President Truman was in Miami to address the Veterans of Foreign Wars. Traditionally, and for convenience, hurricanes get alphabetical tags—"A for Able" for the season's first, "B for Baker" for number two; and so on.

In salute to the Chief Executive, newsmen dubbed this storm "Harry." When the season's second hurricane (and one carrying much more authority!) slapped the Southland, both custom and courtesy could be served. They called it "B for Bess"!

In 1947 the battleship *Missouri* was bringing back President Truman from South America. Navy aerologists didn't know the ship's whereabouts until after issuing a warning on a storm near the Lesser Antilles.

Out of the blue, the *Missouri* sent a message to keep them well posted on the cyclone. Commander Harding already had been up most of the night, so he called Grady Norton at the Weather Bureau to needle him.

HARDING—"Grady, you'd better get out of that sack and start bending isobars. Your boss is down on the *Missouri* in civilian clothes. We're not allowed to issue forecasts to civilians, so it's up to you to be sharp on today's advisories unless you want to wind up on the farm back home."

NORTON—"Well, by golly! How do you think you'll like that weather station in the Aleutians if the *Missouri* runs into the storm?"

The Public Visits—by Phone

One day I was in the Miami Weather Bureau office looking over storm records. Across the room, one of the meteorologists was almost continuously busy answering the telephone.

"It's not bad now when there's no hurricane around," Mr. L. G. Pardue observed. "But when a storm's moving in—whew! On one day during the early October hurricane we answered 3,000 calls.

"Mr. Doakes wants to know if he has time to walk his dog before the storm hits. Mrs. Jones asks when Miami stores will open for hurricane sales of damaged goods. One man's question was, 'How soon can I send my wife out to work?'"

I could understand that it must be a relief to the busy Weather Bureau staff when phone wires blow down and cut off the needless, anxious, and often hysterical queries. Legitimate calls, of course, always are welcomed.

Reassurance, when it's warranted, is what the people want. Lawrence Thompson, a *Miami Herald* writer, did it this way:

There is no new hurricane on the way to Miami. The old hurricane, that passed through here Tuesday, has not turned around and is not coming back toward Miami.

Relax. Go to the show. . . . But don't call the Weather Bureau or the newspaper just because your neighbor heard somebody else's neighbor say somebody else had heard another hurricane was about to come this way.

The Weather Bureau has never in recent years reneged on its matter-of-fact assurance that "No tropical disturbance of serious proportions will ever reach our coasts without being reported well in advance." To this record of success, aircraft reconnaissance by Air Force and Navy, and radar's "magic eye," make vital contributions.

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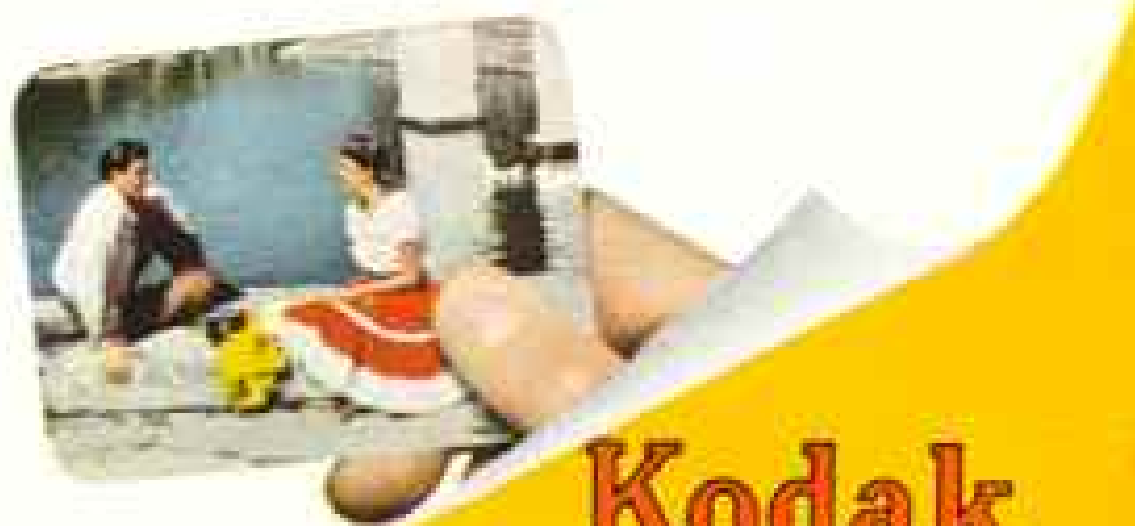
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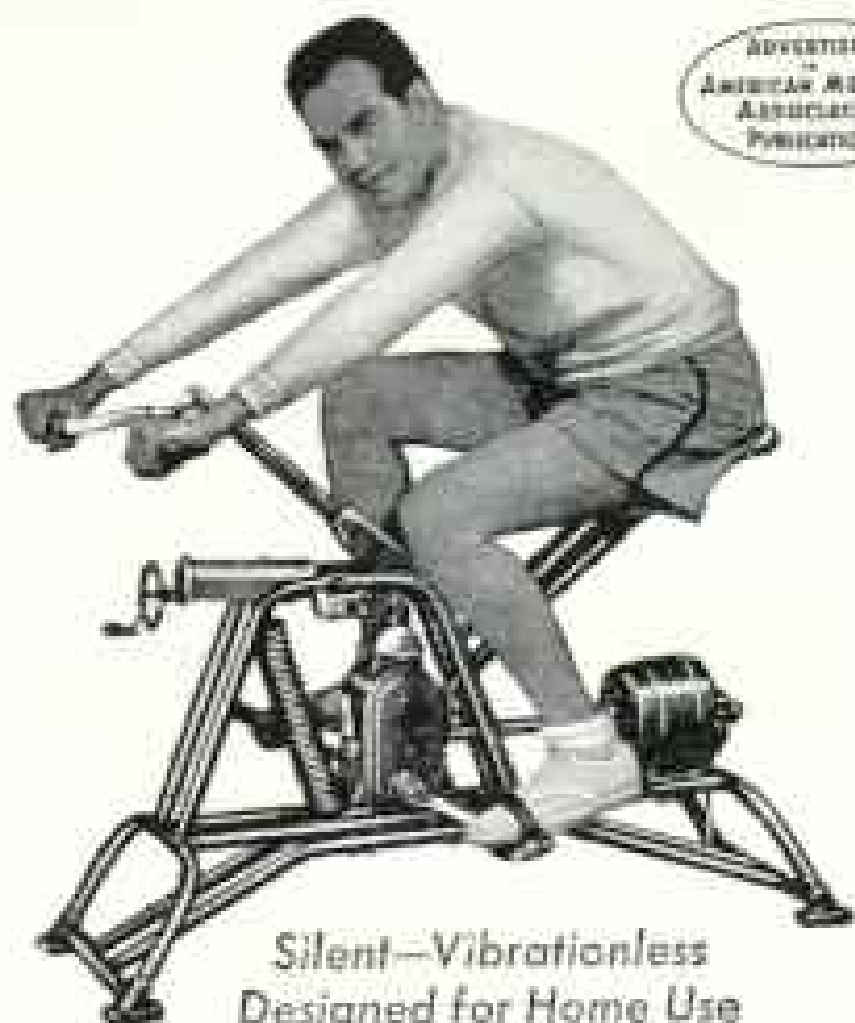
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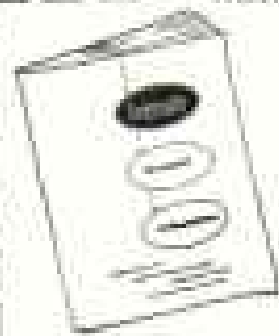
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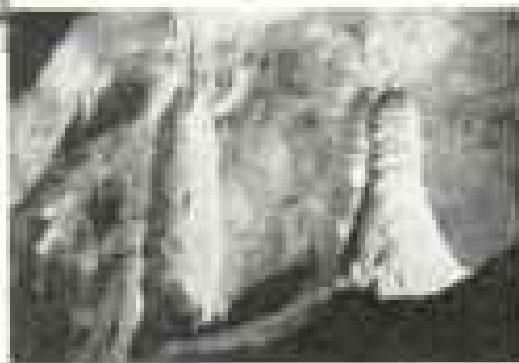
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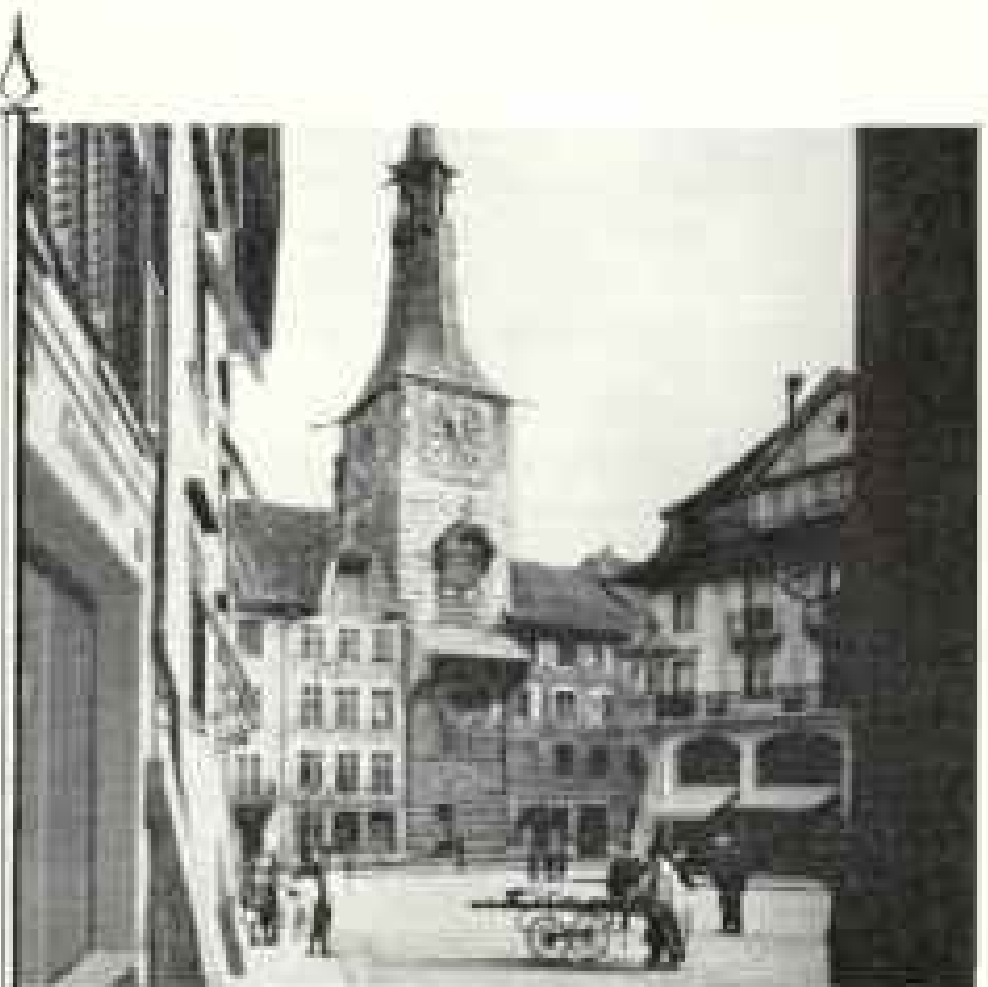


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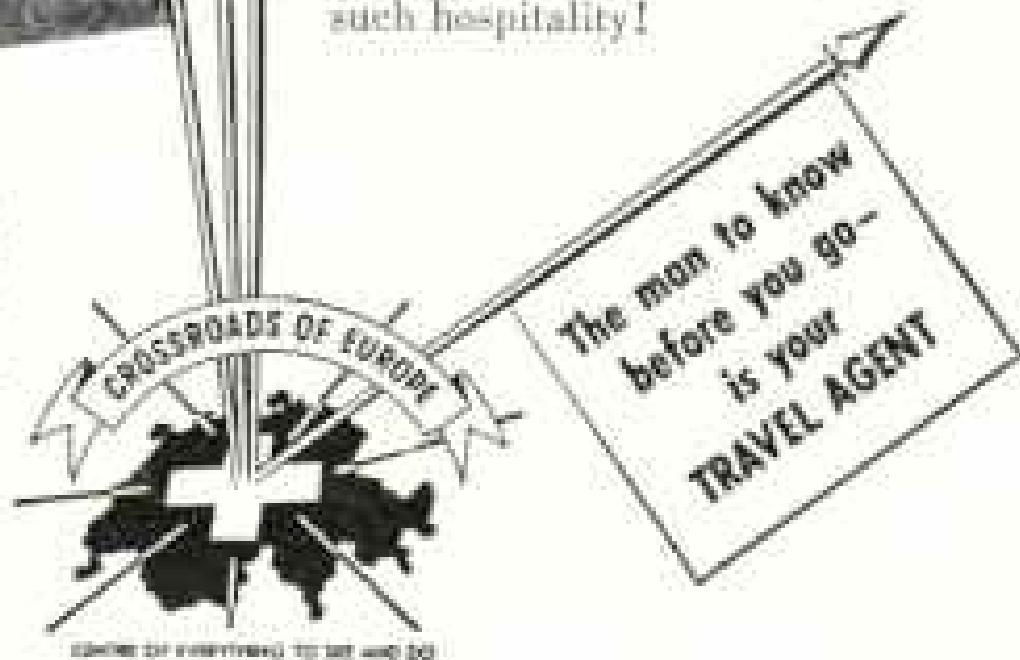


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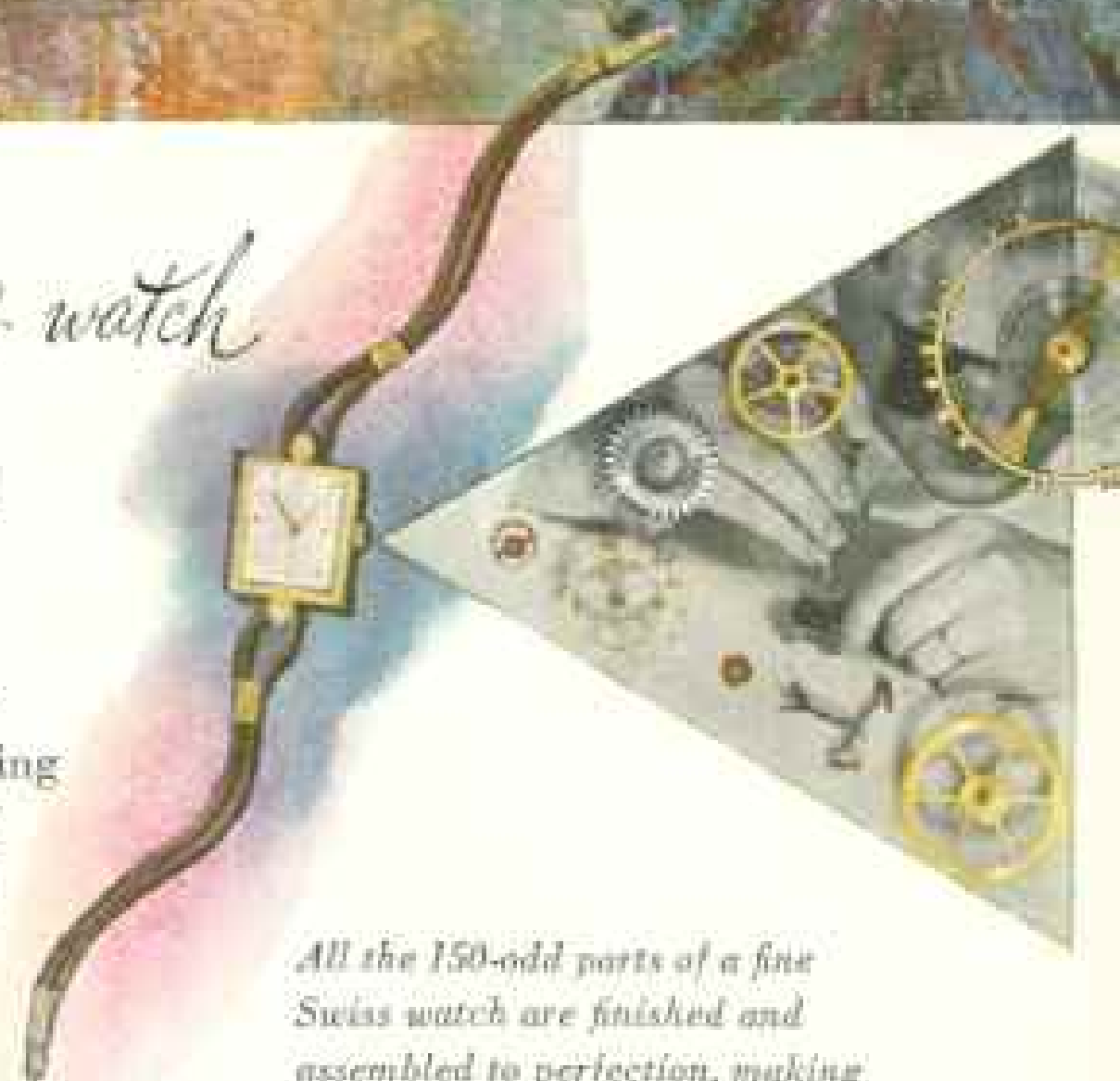
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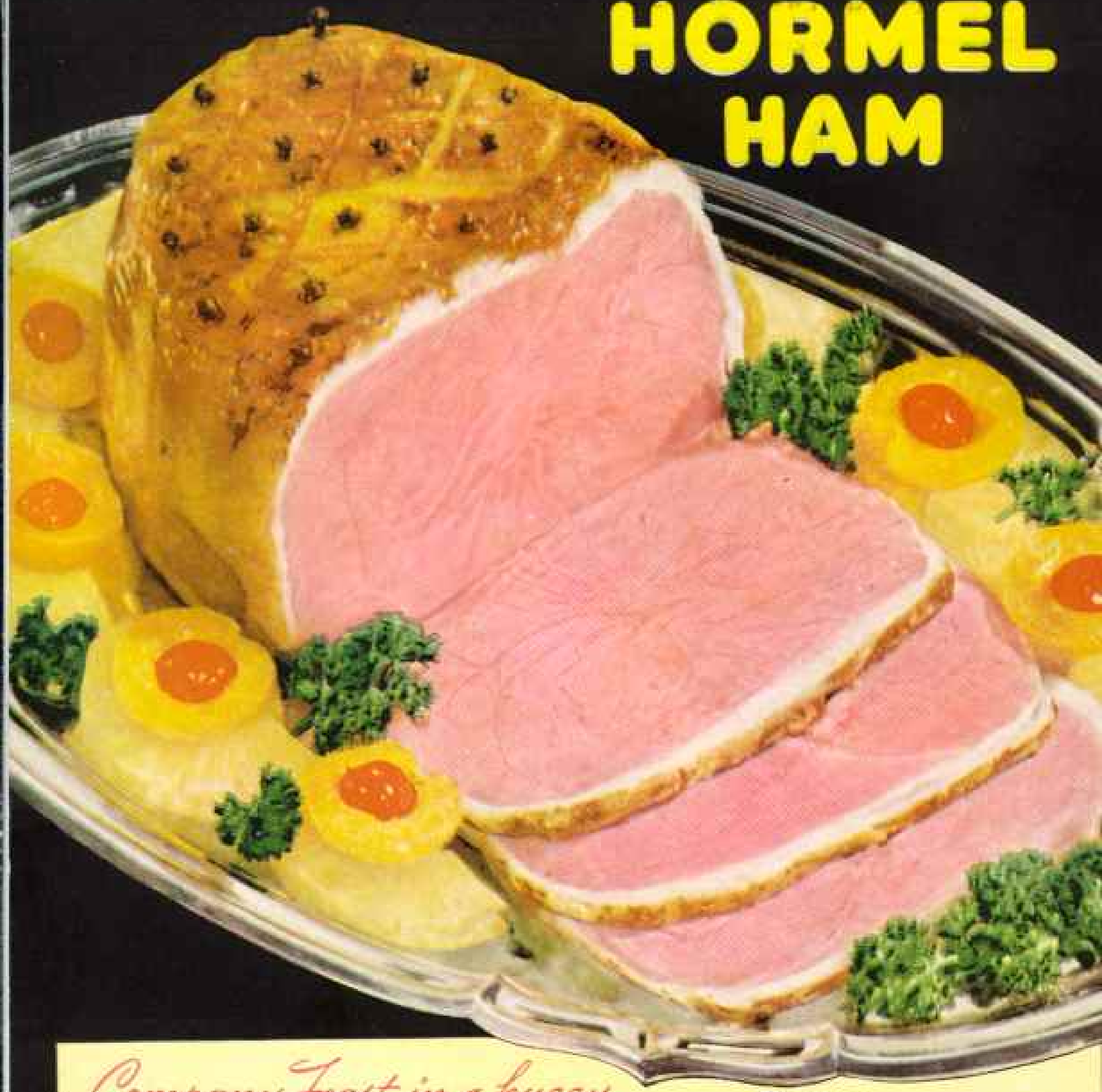


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