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Volcano and Earthquake Show Nature's Awesome Power

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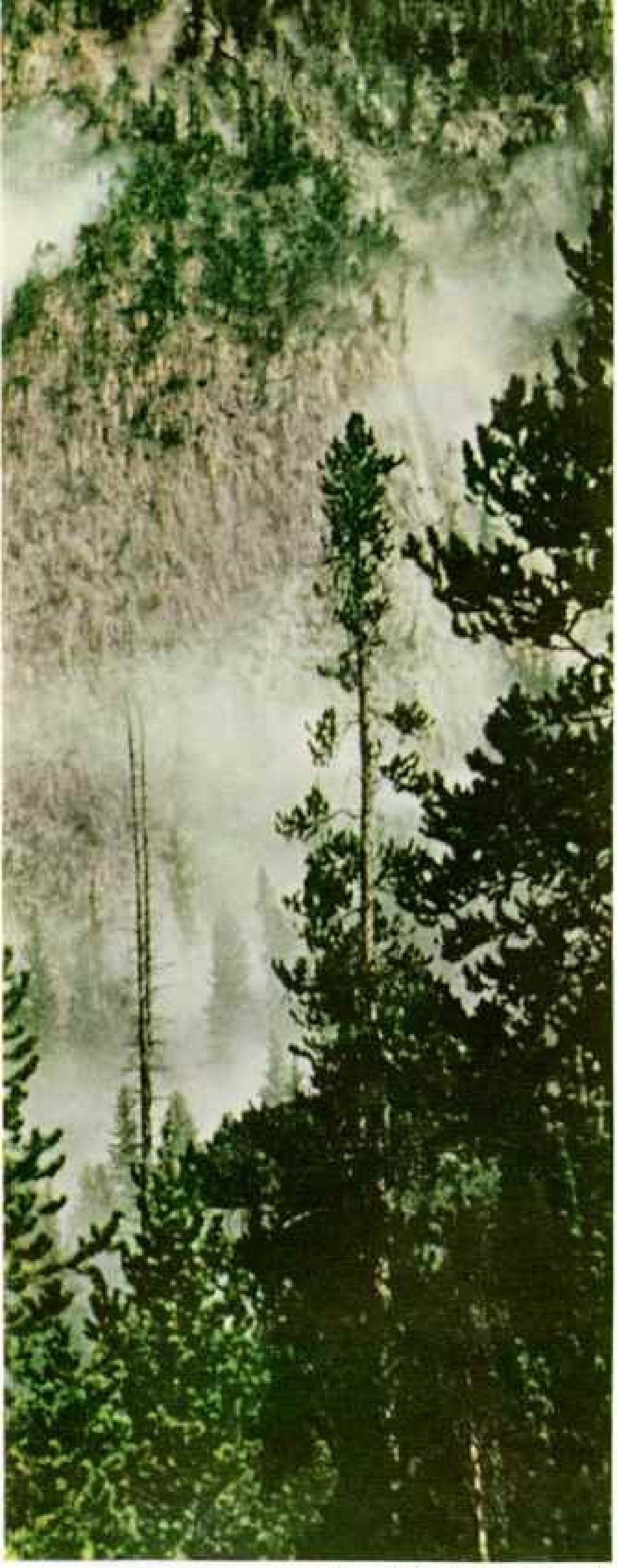


YELLOWSTONE NATIONAL PARK RANGER ELY DAVIS

jolted Mount Jackson in near-by Yellowstone Park, nine hours after the first quake, an alert ranger made this extraordinary color photograph.

Montana's historic 1959 earthquake wrenched the Rockies, created a lake, and touched off new geysers in Yellowstone Park

The Night the Mountains Moved

By SAMUEL W. MATTHEWS
National Geographic Senior Staff

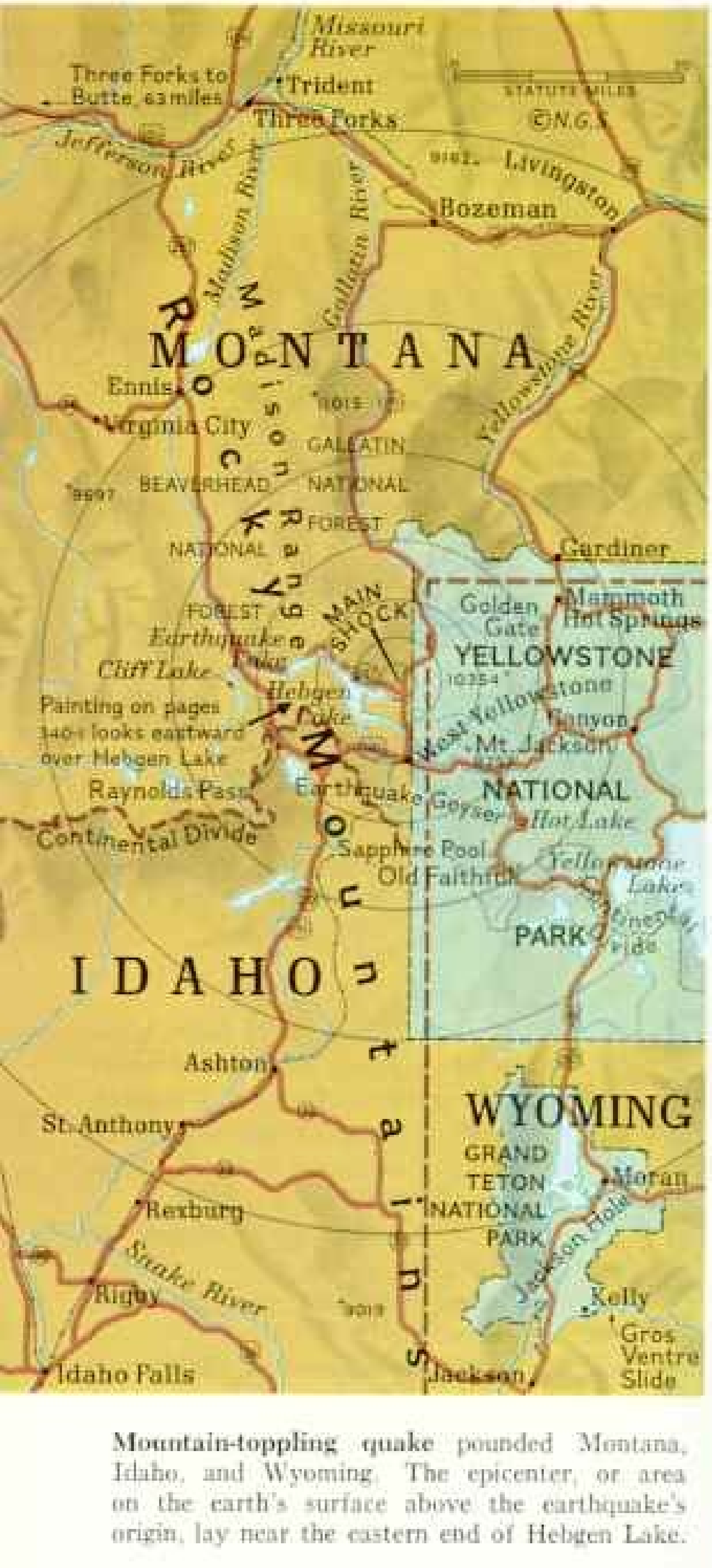
Kodachromes by National Geographic Photographer J. BAYLOR ROBERTS

LATE that clear and gentle night a full moon rode above the tumbled mountainland where Montana, Wyoming, and Idaho meet. Along the mile-high Madison River the air hung cool and still. Monday, August 17, 1959, was nearly over.

Suddenly, 22 minutes and 45 seconds before midnight, an earthquake of historic force wrenched thousands of square miles of the northern Rockies. The earth's crust, warped by unimaginable strain, broke and shifted along several faults, or fractures. A lake in southwestern Montana tilted. Water leaped a dam in racing waves.

Downstream in the Madison's narrow canyon, a mountain face 1,300 feet high and half a mile wide split off and came roaring down on sleeping campers. Eighty million tons of rock and earth smashed into the river and splashed 430 feet high against the facing slope (pages 332-3). Water and terrible blasts of air shot out from under the thundering slide.

In Yellowstone National Park, 20 miles east, the peaks trembled, rockfalls cascaded across roads, and steaming geysers, mud volcanoes, and boiling-hot pools erupted simultaneously in unseen splendor.



Today, months later, earth scientists, naturalists, and engineers are still studying the earthquake region. They have surveyed, plumbed, measured, and mapped. From their work gradually has come a detailed picture of a convulsion of nature that dramatically reshaped an American wonderland.

To report on the earthquake's effects, what caused them, and what they will mean to residents and visitors for years to come, NA-

Mountain-toppling quake pounded Montana, Idaho, and Wyoming. The epicenter, or area on the earth's surface above the earthquake's origin, lay near the eastern end of Hebgen Lake.

Trees teeter along a cliff, or scarp, that suddenly split Cabin Creek Campground in Gallatin National Forest. Exposed soil and gravel trace the Hebgen Fault, a rift in the earth's crust that parallels Hebgen Lake's north shore for eight miles (painting, page 340). A visitor from Salt Lake City, Utah, photographs a fissure that snakes through a shattered fireplace.

TIONAL GEOGRAPHIC photographer Joe Roberts and I spent many days exploring the area.

We first saw the Madison Slide on a September day when rain laced with snow slashed through the canyon. Earthquake Lake, the water dammed by the slide, stood 180 feet deep in the gorge, twice the depth of man-made Hebgen Lake six miles upstream.

Water ripped and foamed down the slide's face, into the riverbed below. Bulldozers, half drowned, labored in the rapids. Joe and I found ourselves atop a wall of shattered rock, hundreds of feet above what once had been a popular camping spot within the Gallatin National Forest in Montana.

Rock Creek Campground had stood beside one of North America's most famous trout-fishing rivers, on the one hand, and a major park-to-park highway, Montana 287, on the other. Now road and river ended abruptly at

this massive barrier, and somewhere beneath rock and water lay the campground (painting, page 340).

That night of August 17, the Bennett family of Coeur d'Alene, Idaho, had been among those camped in the canyon mouth. Eastbound for Yellowstone after a day in the gold-rush atmosphere of Virginia City, Montana, they had decided to sleep under the stars. They pulled their station wagon off the highway into a pleasant turnout beside the river, and settled for the night.

Some 250 other vacationists slept in the canyon that August night. When the earthquake struck, tents, trailers, and cabins lurched and jounced as if shaken by angry bears. Actually, many campers at first thought bears were attacking them.

The Bennetts, oddly, were not greatly alarmed. The four children, in bedrolls on the ground, slept on. In the station wagon their mother and

Where a Mountain Fell: Nature Erects a Dam and Creates a Lake

Jarred loose by the earthquake, 80 million tons of rock slid off a spur of the Madison Range, leaving the naked scar on the left side of the ridge. The avalanche dammed the Madison River and buried Montana State Highway 287 beneath some 400 feet of rubble (center). Water backing up behind the slide formed Earthquake Lake. Bulldozers carved roads and shaped a spillway over the crest of the slide.

The slide threw up a barrier with a base five to eight times thicker than that needed for a man-made rockfill dam of similar height. Its volume, 43.4 million cubic yards, equals a third of the fill required by the Nation's largest earthen structure, the Fort Peck Dam across the Missouri River.

The new lake now stretches five miles upstream and reaches a depth of 130 feet at the toe of the dam.

father awoke, but merely wondered "what the loud noise had been."

Some time later, Mrs. Bennett remembers, they heard another great roar. Hastily they went to check on the children. Mrs. Bennett felt a blast of wind and saw her husband grab a small tree for support. She saw him "lift off his feet, hang for a second like a flag, and let go."

She never saw him alive again. One of her children flew by, and a car rolled over and over past her. Then she lost consciousness.

"The first thing I knew I was in water, rolling and banging into things," 16-year-old Philip Bennett told me (opposite).

When he stopped, he knew his left leg was badly broken. He felt no pain, but he was entirely naked and very cold. The earth trembled, and huge shadows rolled in the sky —dust clouds, he realized later. He crawled crablike into a clump of trees and dug into the mud to keep warm. All night he stayed awake, sure that more water would come rushing down on him, "preparing for it."

At dawn searchers heard Phil and Mrs. Bennett calling for help, and found them in the dry riverbed on the edge of the slide. Later they found the battered, lifeless bodies of Mr. Bennett and his other three children.

Wind Tears Clothes From Campers

Seven families between the Bennetts and Rock Creek Campground were buried alive by the rock, earth, and trees of the landslide. Other people in the campground proper were picked up by water that backwashed 100 feet up the mountainside, and by the hurricane-velocity gusts shot out as the slide displaced air in its path. Several had their clothes literally torn from their bodies.

Nine, in all, could be counted dead. Nineteen more are still missing to this day, pre-

Survivors await rescue on a slope facing the slide-scarred ridge. Fearing a flood if Hebgen Dam gave way, pajama-clad campers leaped out of bed and fled to high ground.

PAUL K. LEHMAN AND EVERETT C. HARE

ALBERT MOLDVAY (ABOVE) AND NATIONAL GEOGRAPHIC PHOTOGRAPHER J. BAYLOR ROBERTS © N.G.S.

Victims Bed Down on Bales of Hay

Rescued by helicopter, the injured lie beside West Yellowstone airfield awaiting evacuation by ambulance plane to Bozeman, Montana.

Some of the 250 campers trapped by the earthquake in Madison Canyon abandoned their cars and scrambled across the slide. An emergency road let others drive to safety. The quake's toll: nine dead, nineteen missing.

Plucky survivor, 16-year-old Philip Bennett of Coeur d'Alene, Idaho, suffered a mangled leg but remained conscious until rescued. His father, brother, and two sisters perished in the slide. Nurse Mona Reid autographs his cast as he leaves the hospital in Ennis, Montana, after 47 days.

JOHN P. STACY, U. S. GEOLOGICAL SURVEY (ABOVE) AND WILLIAM B. HALL

Shattered by the Quake, State Highway 287 Disappears Into Hebgen Lake

Its bed warped, the lake today drowns part of the north shore under nine feet of water and exposes its southeast rim. Four big landslips cut the road.

Cadillac plunges off a zigzag crack across U. S. 191. Alarmed by the quake, the driver and his family were fleeing for West Yellowstone when the car turned turtle. The occupants crawled out of the hole where the windshield had been.

sumed lost beneath hundreds of feet of rock.

"That south wall of the canyon must have been on trigger edge for years," Dr. Jarvis B. Hadley of the U. S. Geological Survey told me—"a mountain slide simply waiting for an earthquake to happen."

Dr. Hadley was one of more than 25 geologists, geophysicists, ground-water experts, and other scientists assigned by the Survey to study the earthquake area. He had felt the quake himself; on the night of the slide he was in the town of Ennis, 45 miles downstream.

"Rock layers in the mountain face tilted steeply toward the river," the geologist explained. "They were weathered and cracked, relatively soft schists and gneiss mixed with slippery mica, with clay in the old clefts and cracks. These greased the skids when the face came down.

"At the base of the ridge ran a buttress of marblelike dolomite. This ledge broke cleanly, probably in the first quake. It had been holding up the mountain."

The layers above snapped, shifted slightly, much as sheets of glass stacked together might move, then hesitated.

Just how long the mountainside hung, a few minutes or as long as three quarters of an hour, neither geologists nor campers themselves can be sure. But as the earth continued to tremble and rock under repeated aftershocks, the slope suddenly began moving.

"When it moved, most of it came down as one mass, 200 to 400 feet thick, and it came fast," Dr. Hadley said. "The main slide was over in less than a minute."

Slide Builds an 80-million-ton Dam

By studying aerial photographs and contour maps of the slide, Army Engineers and geologists calculated the volume of rock and earth that fell: 43.4 million cubic yards, weighing about 80 million tons.

Hoover Dam on the Colorado, highest in the Western Hemisphere, contains only 4.4 million cubic yards of concrete, or one-tenth as much material. Grand Coulee on the Columbia holds only a quarter the slide's volume. Calculated another way, enough material slid into the Madison Canyon to cover Manhattan Island two feet deep.

"For a dam, it fell in the logical spot in the canyon, with the right types of rock pretty much in the right places," Lt. Col. Walter W. Hogrefe of the U. S. Army Corps of Engineers told me.

The slide blocked the Madison River with nearly a mile of rock, 200 to 400 feet deep along its crest. Within a week, Army flood-control technicians, hydrologists, and hard-helmeted construction men were at work cutting and rock-paving an emergency spillway.

"Did you ever hear of the Gros Ventre Slide?" Colonel Hogrefe asked me. "In 1925, about 100 miles from here east of Jackson Hole, a mountain much like this one came down and blocked the Gros Ventre River.

"Nothing was done to stabilize it, and two years later the crest washed out suddenly. Six people were drowned, and the town of Kelly, Wyoming, was swept away in the flood."

Damage that would be caused by a similar flood in the Madison Valley might exceed $15,000,000, Colonel Hogrefe estimated.

The Engineers, authorized by law to assist State and local officials in flood fighting and rescue operations, had little time. Winter was coming fast in the high Rockies. And an added menace loomed upstream.

Cracked Dam Holds Back a Flood

Hebgen Dam had been gravely damaged by the earthquake. Its concrete core had cracked, and the earth fill on both sides had slumped. Behind it Hebgen Lake, brimful, held enough water to cover a third of a million acres a foot deep (page 354).

Should Hebgen go out, the wave rushing down the Madison would sweep over the slide and on down the valley. It would flood Ennis and many a ranch and resort, and perhaps not be checked until beyond the point where the river meets the Gallatin and the Jefferson to form the mighty Missouri (page 356).

To repair its 44-year-old dam, the Montana Power Company wanted to draw down Hebgen Lake as soon as possible. But the slide across the river below first had to be stabilized.

For two months the Engineers worked $3,000,000 worth of roaring rock-moving machines around the clock. They cut a notch more than 50 feet deep to lessen the grade of the rapids and permit an added flow of water without risk of sudden washout.

By November 1 the job was done. But severe blizzards a few days later prevented repairing Hebgen Dam before spring.

Joe Roberts and I climbed the back face of the shattered mountain above the Madison. On the torn and fissured ridge, wind whispered eerily through dry grass. We peered down the dizzying slide face, sheer and bare. Below, Earthquake Lake stretched away through the canyon, blue and placid against its forest-dark walls, five miles long.

Serpentine fence along State 287 illustrates the enormous force that squeezed and sheared the earth. Geologists study such details to assess the quake's effects.

The night of the earthquake, as the Madison Range gave its first massive shudder, strange and sudden things happened along the shores of Hebgen Lake, rimmed by summer homes, fishing resorts, and dude ranches, and on the north shore by Highway 287.

At four different places the road broke away and slid into the heaving water (page 336). The lake bottom itself tilted and folded, draining water in from both ends, then sloshing it northwestward toward the dam in a rushing wave, like a full dishpan rocked back and forth.

Near the Yellowstone Park boundary, east and slightly north of the lake, the ground suddenly broke and dropped. An earth cliff, or scarp, appeared where level ground had been a moment before.

The cliff, in places twice as high as a man's head, cleaved the Y-shaped junction of State 287 and U. S. 191, zigzagged uphill through groves of pine and quaking aspen, and curved north and west along the face of steep canyon ridges above the lake (page 352). The great wound ran nearly 20 miles.

Another jagged scarp, closer to the lake shore, followed the slope above Highway 287 northwest past Hebgen Dam. It sheared straight through Cabin Creek Campground in the upper end of Madison Canyon (page 330).

Geologist Finds a "Pot of Gold"

One man was glad to be caught in the quake: geologist Irving J. Witkind of the Geological Survey. He was fast asleep in his field trailer on a hillside above the northeast arm of Hebgen Lake when the earth heaved.

"I thought my trailer was loose and rolling downhill," he recalls. "I came charging out to stop it, though how I expected to do it I'll never know.

"Then I saw trees swaying, without any wind, and knew it was an earthquake. I thought of the ranch houses below me, and started down in my jeep. I almost drove straight over a 14-foot scarp that wasn't there the day before.

"For a geologist to be sitting on top of a fault when it slips is like falling over a pot of gold," Dr. Witkind said with a grin. "In two summers of mapping that region around Hebgen Lake, I had traced what ap-

(*Continued on page 347*)

Broken center stripe and rifts in the pavement reflect the earthquake's violence. Motorists bypassed this stretch of U. S. 191 by driving on the shoulder.

Red Canyon Fault Scarp

West Fork Fault Scarp

Hebgen Fault Scarp

Boat Mountain

Parts of lower lake
8 to 10 feet deeper

Hebgen Dam

Cabin Creek
Campground

EARTHQUAKE LAKE

Madison Range

Madison Slide buried Rock Creek Campground
and dammed Madison River, forming 'Quake Lake

Montana Highway 287

Madison River

MISSOURI FLATS

Ennis, Montana, 42 miles downstream,
evacuated at 3 a.m. in fear
Hebgen Dam had failed

N.G.S.

HOW THE EARTHQUAKE SCARRED THE ROCKIES AND FORMED A LAKE

Fault scarps exaggerated for clarity

Main shock began at a point 8 to 10 miles beneath earth's surface

Fault cracked U.S. Highway 191

Montana Highway 287 cut in four places

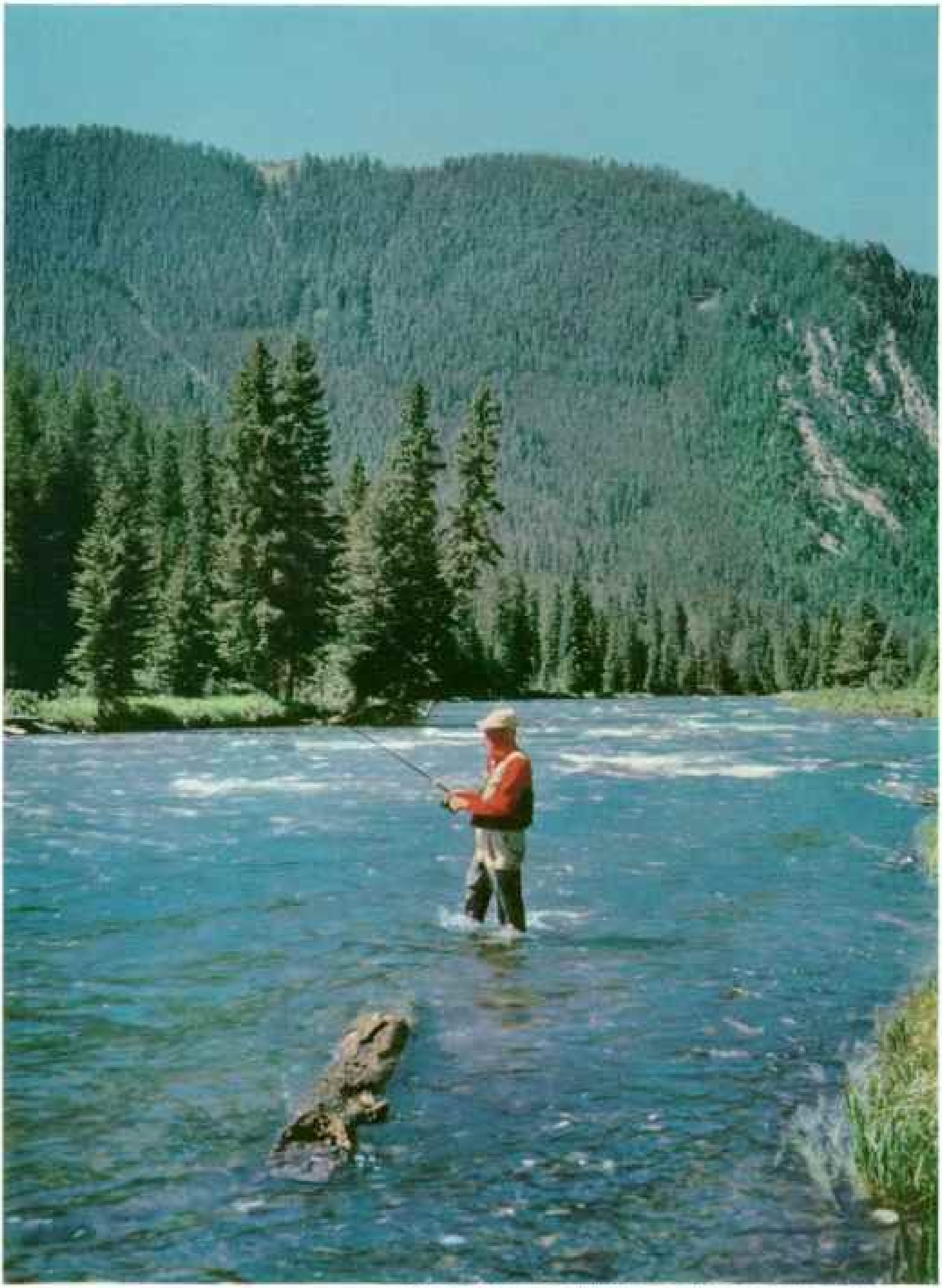
Upper lake 8 to 10 feet shallower

HEBGEN LAKE

10,609 feet

NORTH

R. W. Nicholson
National Geographic Staff



ERNST PETERSEN, COURTESY MONTANA POWER COMPANY © NATIONAL GEOGRAPHIC SOCIETY

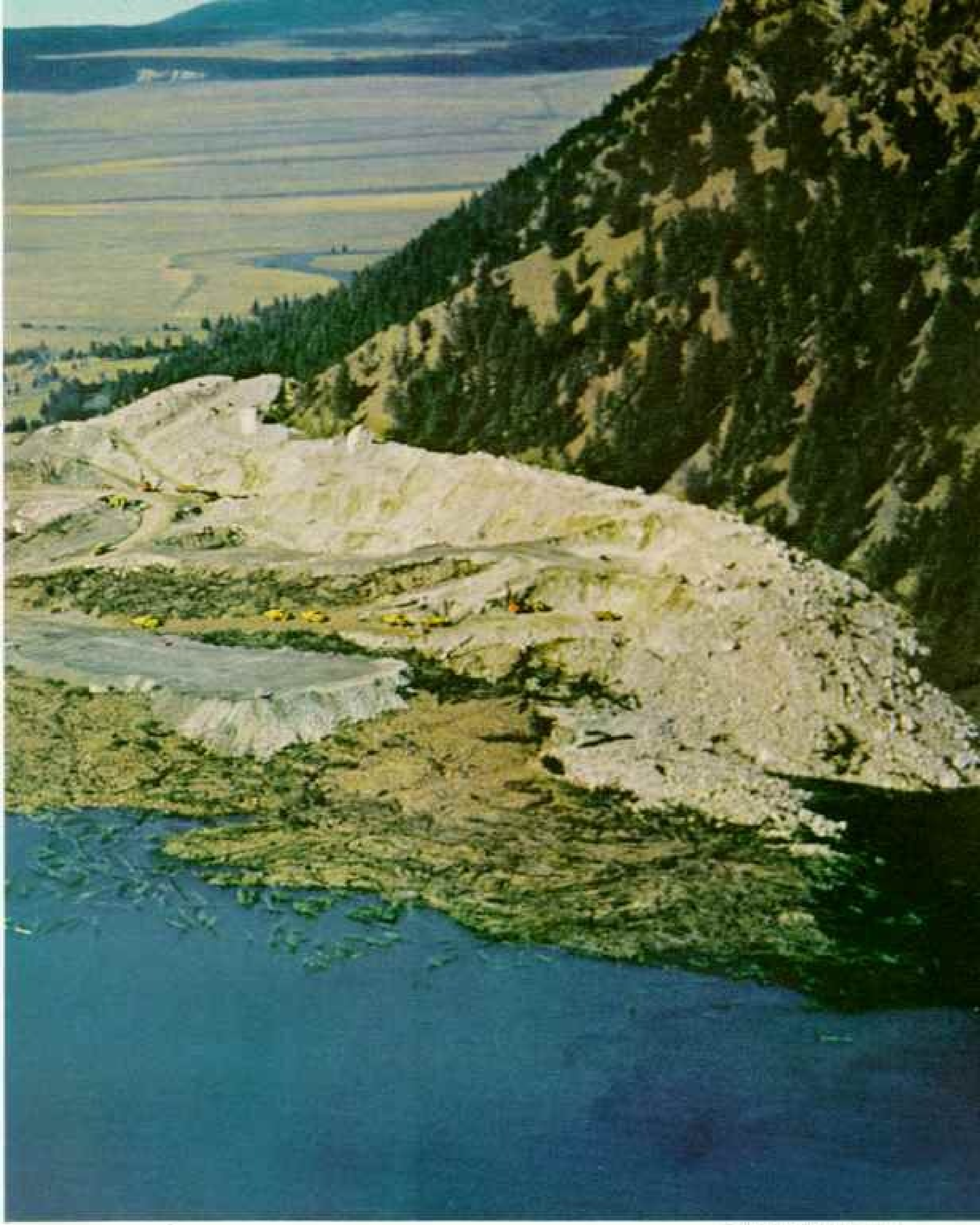
Before the Slide: A Fisherman Wades the Madison Where a Dam Now Lies

Blanketed by trees, the canyon wall rose to an elevation of 7,600 feet. This entire section thundered down, damming the river and burying part of Rock Creek Campground, on the near side. Herbert Hoover often has fished the Madison, a famous trout stream.

After the Slide: A bulldozer crosses the spillway carved across the barrier's crest, 200 feet above the old riverbed where the fisherman (above) casts for trout. Earthmovers often foundered in the rapids. One truck tumbled down the spillway, but the driver escaped serious injury. Pulverized rock scars the denuded slope.

Men and Machines Toil Around the Clock to Shape a Spillway Over the Slide

Soft rock resting against a wedge of dolomite covered the face of the mountain that fell. When the earthquake snapped the dolomite buttress, a mass of rock up to 400 feet thick plunged down the slope at left and splashed upward against the opposite canyon wall. Water surging from the Madison River flung campers from their beds and



flipped house trailers end over end. Dammed by the slide, the river rose three to six inches an hour. Fearing the overflow would wash out the barrier and send a flash flood coursing downstream, Army Engineers hastily notched the crest to lower the lake, slow the flow of water over the natural dam, and reduce erosion.

Crushed dolomite glistens along the right fringe of the slide. Earthmovers, glinting in the morning sun, crawl over the schist and gneiss that make up the dark bulk of the slide.

Missouri Flats, named for homesteaders from the Midwest, sprawls beyond the canyon mouth. Gallatin National Forest ends below the slide.

peared to be an old fault line. Now I got down on my hands and knees and almost kissed the scarp. It was *mine!*"

Dr. Witkind was indeed on top of the earthquake. Seismic data telegraphed to Washington, D. C., from all across the West fixed the focus of the first great shock eight to ten miles deep in the earth's crust. The epicenter, or surface location directly above the focus, lay just northeast of the geologist's campsite.

For weeks he traced and mapped the jagged breaks through the mountains, on horseback and afoot (page 353). Meanwhile other Survey specialists studied the tilted lake, the broken highways and twisted fences, and the shifted ground.

Quakes Reshape a Land of Wonders

Inside Yellowstone Park, not far to the east, the earthquake struck with a rumble "like a heavy train crossing a trestle," as a Union Pacific man described it. "The ground got right up and shook—like a horse galloping," another visitor said.

Buildings jerked, swayed, and creaked. The huge log-built Old Faithful Inn echoed with a "Whoom! Whoom!" as if it were a drum.

Rockfalls cascaded through high ravines. Huge boulders bounded and smashed down onto roads, leaving swaths of felled trees in their wake (below).

"We had 18,000 people inside Yellowstone that night," Superintendent Lemuel A. Garrison told me later. "The Lord had His arms around us. Not one person was killed or badly hurt. Think what could have happened if the quake had come during daylight—at Old Faithful Inn, for example, where the chimney fell into the dining room."

Among those in the park was Andrew H. Brown of the National Geographic staff, who was gathering material and photographs for a forthcoming article on Yellowstone.

Brought full awake by the "rolling roar" that rocked and bounced his cabin at Canyon, Andy Brown experienced also the aftershocks that jarred the park for days. While roads were still closed and campers trapped between slides were being guided out, he interviewed park officials and saw the many immediate changes in Yellowstone.

Falling Rock Menaces a Road Repair Crew at Yellowstone's Golden Gate

An avalanche spawned by the first quake buried the road, which runs through a notch in northwestern Yellowstone. As men labored to clear the debris early next morning, an aftershock unleashed a second slide. One rock struck the earthmover as the driver backed to safety. The other men fled on foot amid a rain of boulders. Dick Ferguson, a park employee, had his camera ready when the aftershock struck.

Giant boulder blocks the highway a few miles from the park's west entrance. Some rocks bounced all the way to the river. Ranger Bob Perkins surveys shattered trees.

DICK FERGUSON (ABOVE) AND ANDREW H. BROWN, NATIONAL GEOGRAPHIC STAFF © N.G.S.

Park Naturalist George D. Marler, who has lived for years with Yellowstone's steaming, spouting thermal features, told him:

"Nature turned a climactic page in her book. It could have taken hundreds of years to bring about what happened here in a few hours."

Shocks Set Off New Geysers

The earthquake unleashed a sudden tremendous surge of thermal energy in the park. Geyser basins exploded into violent activity. Quiet pools and dormant vents erupted with a whishing and a whistling—a weird chorus of sound and fury.

"I only wish I could have seen what happened when the first shock hit," George Marler said wistfully. "Most of the geysers and pools must have erupted simultaneously. The swash marks show how violently they threw water."

Old Faithful seemed just as faithful after the earthquake; its average 61-minute cycle of eruptions slowed only slightly to 65 minutes. But elsewhere Yellowstone both gained and lost a host of geysers and other hot-water features.

Castle, Daisy, and Great Fountain, among many others, speeded

MELVILLE BELL GROSVENOR

Picnic spot on the Madison now lies far under water. Photographed a year before the slide, the scene captures the tumbling river and lofty bluffs that attracted campers to Madison Canyon.

The picnickers, Mr. and Mrs. Sumner Gerard (left) and Mrs. Melville Bell Grosvenor, sit on a bank where fish now feed in Earthquake Lake (above).

NATIONAL GEOGRAPHIC PHOTOGRAPHER J. BAYLOR ROBERTS © N.G.S.

Cabins float and trees drown as 'Quake Lake creeps up the walls of Madison Canyon

up their performances. Clepsydra, which had erupted only about every four days, went into a continuous "wild phase," pouring out enough steam to drive most of the heat and power plants in the park.

Cascade Geyser, which had not erupted for 40 years, blew its top. Economic Geyser, still for 25 years, began playing 50 feet high every half hour. The Giantess fountained as high as 200 feet for more than four days of uninterrupted glory.

Grand Geyser, one of the highest performers in the park, quit cold. But, as if in repayment, an entirely new "Earthquake Geyser" began playing 75 and 100 feet high at the end of a steam-spouting rift in the Lower Geyser Basin.

Most dramatically, Sapphire Pool in Biscuit Basin changed from a serene, limpid dispenser of silvery gas bubbles to a seething, soaring giant among geysers (page 358).

Not until three weeks after the first earth-

quake did Sapphire blow up. Then it played, regularly and furiously, for eight days. A sharp after-tremor shut it off. Sixteen days later another jolted it to life again.

Since then, constantly on trigger edge, Sapphire has spewed skyward every half hour to two hours. "Yellowstone has seen nothing like it since Excelsior erupted in the 1880's," George Marler said.

All across Yellowstone's superheated wonderland, naturalists spent the fall and early winter measuring depths, taking temperatures, charting the changes the earthquake produced. Their hooded, steam-shrouded figures startled late-season park visitors. Men with long poles fishing in boiling-hot pools? They must be out of their minds!

"The unique underground plumbing system of Yellowstone offers science a chance to learn more of what happens below the surface during an earthquake," Superintendent Garrison told me. "The National Park Service has already begun such a study."

"The Yellowstone region of western Montana will continue to feel earth tremors for months, if not for years, as the earth shakes down to a new equilibrium," forecast Prof. Stephen W. Nile of the Montana School of Mines. A physicist, and Collaborator in Seismology for the U.S. Coast and Geodetic Survey, he ranks as chief earthquake recorder and consultant for his State.

Scientist Shaken by His Subject

The night of August 17, Dr. Nile was vacationing at a dude ranch 30 miles north of West Yellowstone, Montana. Without access to his big seismographs bolted to solid concrete at Butte, the excited professor did what he could to time and record intensities of the

Broken Crockery Litters a Kitchen Floor in West Yellowstone

Temblors ruptured gas lines, toppled chimneys, emptied bookcases, tossed television sets to the floor, and sent groceries flying from shelves. Mrs. Elt Davis (below) retrieved only four cups and three dinner plates from a service for 12.

ELT DAVIS

NATIONAL GEOGRAPHIC PHOTOGRAPHER J. BAYLOR ROBERTS © N. G. S.

Children play in the rubble-strewn yard of the West Yellowstone school. Blocks jarred from walls and chimney clutter the playground a month after the quake.

tremors. He used a teaspoon on a string as a pendulum, and a glass of water to detect vertical jolts.

Joe Roberts and I later visited Dr. Nile's office at Butte, jammed with books, instruments, and sheafs of seismograms—the "fingerprints of the jittery earth," as he called them. He showed us tracings of aftershocks that still were being recorded, dozens a day, at the Butte seismograph station.

"Montana's earthquakes," Professor Nile told us, "are direct proof that the Rocky Mountains around us are still growing."

The Madison Range began rising from an ancient sea bed about 50 million years ago, geologists say. The tremendous underground forces that folded and uplifted these mountains still press on them, relentlessly bending and distorting their rock layers.

Finally, when the warped layers can bend no more, they snap along a fault, releasing the terrible energy of an earthquake.

"Try pushing your hand down and away from you as hard as you can on the desk," Professor Nile said. "It will jump suddenly rather than slide smoothly. A fault works the same way; it breaks and rebounds with sudden lurches. In fact, modern earthquake theory speaks of 'elastic rebound.'"

Shock waves from a shifting fault travel outward in all directions through the earth. Seismographs register two main types, P and S waves—primary and secondary, or "push" and "shake."

"The P wave is just like sound in air," Dr. Nile said. "The rock moves to and fro in the direction the wave is moving. That's the fastest wave, and it arrives first—right

there." He pointed to a sharp jump on a seismogram.

"The other shakes the rock particles from side to side as it passes, like waves in a clothesline when you waggle it. The S wave came along . . . here!" And he pointed to a second and smaller peak.

"The time interval between them tells us how far away the earthquake took place," the seismologist continued. "With three or more records from different points, we can plot the epicenter.

"It took the Hebgen Lake shock 28 seconds to reach Butte. An earthquake in Japan arrives here in 10 to 12 minutes."

From seismograph records the magnitude of a shock can also be calculated, Dr. Nile told us, using logarithmic scales devised by Drs. Charles F. Richter and Beno Gutenberg of the California Institute of Technology.

Few U. S. Earthquakes More Violent

Caltech's measurements gave the Montana earthquake a magnitude of 7.1, ranking it as one of the six strongest recorded shocks ever to jolt the United States, outside of Alaska.

The famous San Francisco earthquake of 1906, which killed 450 and set fires that consumed the city, had a magnitude of 8.3; Kern County, California, suffered a shock of 7.7 in

NATIONAL GEOGRAPHIC PHOTOGRAPHER J. BAYLOR ROBERTS © N. G. S.

Red Canyon Fault Draws a Jagged Line Across the Face of a Wooded Ridge

Just as winding stores energy in a watch spring, a strain within the earth's crust slowly builds up energy in the rock. When the strain grows too great, the rock breaks and takes a new position. Such a movement releases explosive energy, triggering an earthquake.

The scarp above Red Canyon Fault cleaves the hills north of Hebgen Lake.

Scarp furrows the earth above Hebgen Fault. Dr. Irving J. Witkind of the United States Geological Survey examines the cleft, which took shape when the lower face fell away. His assistant, William Quinlivan, takes notes.

1952; and earthquakes in sparsely populated regions of Nevada in 1915, 1932, and 1954 registered 7.6, 7.3, and 7.1 respectively.

Probably the greatest earthquakes ever to hit the United States wrenched the Mississippi Valley in 1811 and 1812, long before modern seismographs. Jarring an enormous area, the shocks wrecked the town of New Madrid, Missouri, and created Reelfoot Lake by dropping the northwest corner of Tennessee.

For sheer horror, none surpasses the Japanese earthquake of 1923, which

caused the death of a quarter of a million people and leveled Tokyo and Yokohama. But the worst earthquake year on record was 1906, when cataclysmic shocks hit not only San Francisco, but Colombia and Ecuador, Chile and New Guinea, Formosa and the Aleutian Islands, Japan and Sinkiang in western China.

Newly revised lists give greatest magnitude, 8.9, to the Colombia-Ecuador quake of January 31, 1906, and to a shock off the Japanese coast in 1933. The great Assam-Tibet earthquake of 1950 and at least five others follow with magnitude 8.7.*

Restless Earth Keeps Trembling

Fortunately, such severe shocks are rare, but our planet's crust is never still. More than a million earthquakes occur each year, seismologists estimate. About 700 detectable tremors strike the United States annually.

"Montanans seem to forget it," Dr. Nile said, "but this State gets a perceptible jolt about every two years, and a real wallop once every decade. Since seismograph records have been kept, truly severe earthquakes have hit Montana in 1925, 1935, 1947, and now 1959."

Most earthquakes fall in a few belts of greatest activity. One rings the Pacific Ocean. Another runs from Burma to the Mediterranean and on into the Atlantic. In the United States the most active regions lie in Alaska and along the 600-mile San Andreas Fault in California.

The San Andreas Fault shifted 21 feet horizontally in 1906. In last year's Montana shocks the movement was chiefly vertical. Precise measurements by geologists and Coast and Geodetic Survey teams found changes in elevation of as much as 19 feet along the northern shore of Hebgen Lake.

Other, more far-reaching effects may have occurred as well. The entire Yellowstone region may have changed its level above the sea. Whether this is so, only future surveys covering hundreds of miles can tell.

Within two weeks of the August earthquake,

* See "Caught in the Assam-Tibet Earthquake," by F. Kingdon-Ward, NATIONAL GEOGRAPHIC, March, 1952.

MONTANA POWER COMPANY

Damaged but Still Standing, Hebgen Dam Corks a Flood

An earthen structure with a concrete core, the dam regulates the flow to downstream reservoirs. Built half a century ago by the Montana Power Company, it stands 87½ feet high and 718 feet long.

The quake cracked the core and shattered the spillway. During repairs water flows through a diversion tunnel.

If Hebgen Dam had given way, a wall of water would have washed over the slide six miles downstream and flooded the Madison Valley.

"It was this high." Caretaker George Hungerford describes a wave that swept over the dam. Fresh concrete will be pumped into the crack caused by the quake.

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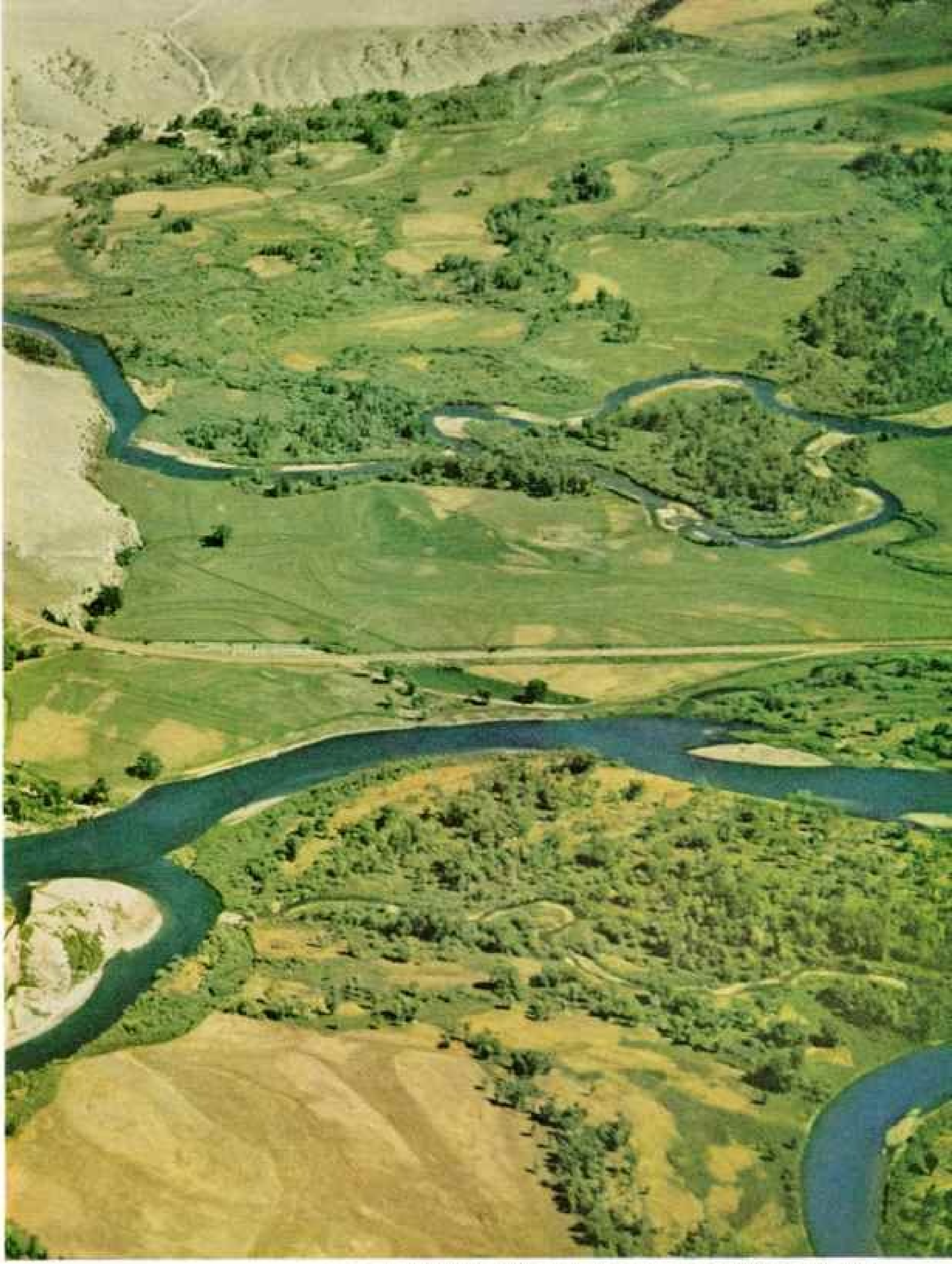
Three Forks of the Missouri Converge in a Maze of Islets and Twisting Rivers

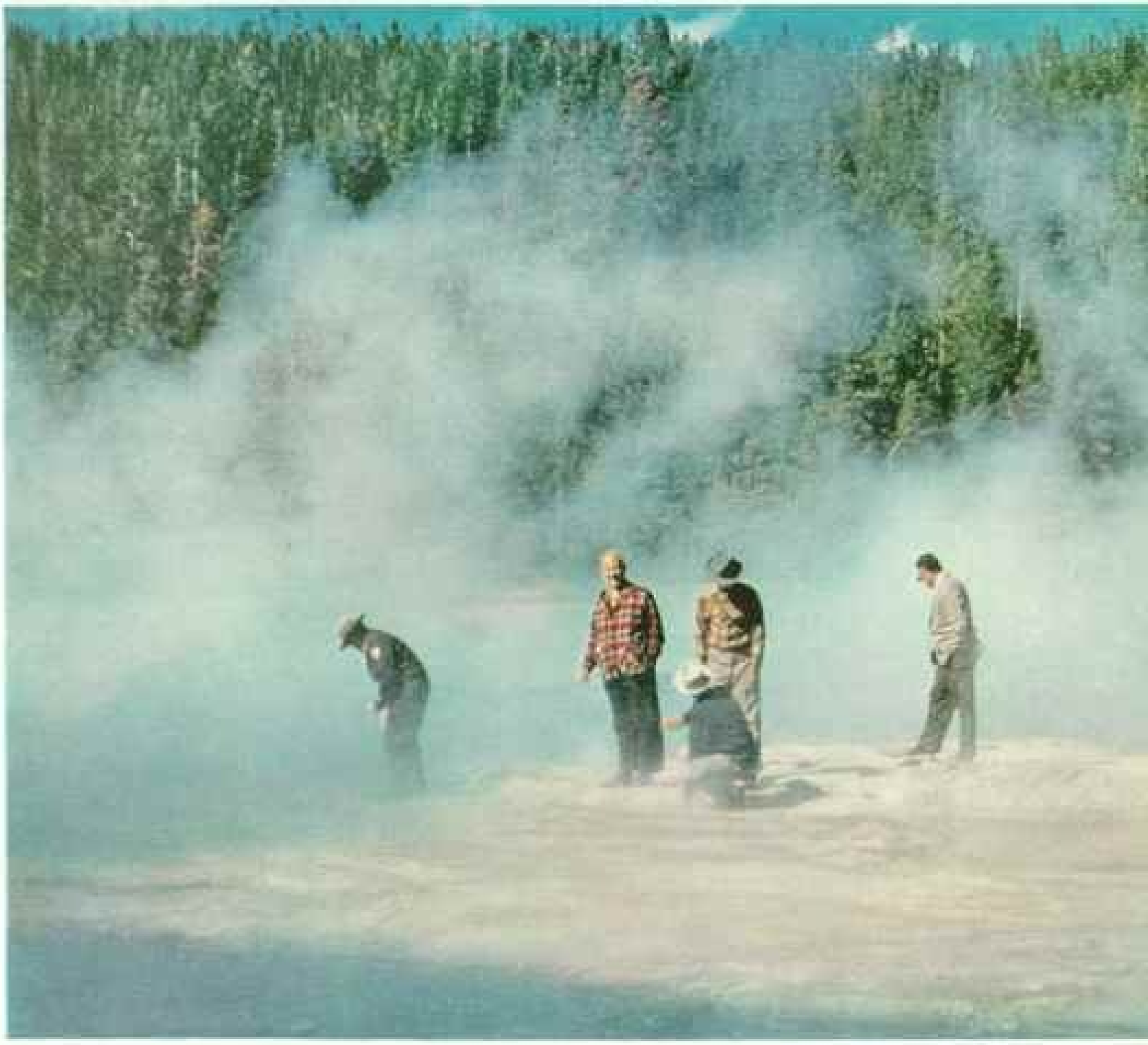
Lewis and Clark, who camped here in 1805, discovered the parent streams and named them for President Jefferson and two members of his cabinet. The Jefferson (lower left) unites with the Madison (center) and flows between a highway and tracks of the Chicago, Milwaukee, St. Paul



AIRBRUSHED BY MELVILLE BELL GROSVENOR AND SUMNER MATSON. PILOT © NATIONAL GEOGRAPHIC SOCIETY

and Pacific. The Gallatin—for Albert Gallatin, Secretary of the Treasury—snakes in at the top, below the Northern Pacific's right of way. Missouri River, highway, and railroads then pass Trident, Montana (upper left), where a plume of dust usually hangs over a cement plant. Dams along the "Big Muddy's" tributaries curb floods that once plagued the confluence.

Here, 60 miles north of the Madison Slide, abandoned river channels indent farm and forest lands. The town of Three Forks lies between the Madison and Jefferson, just out of the picture.



NATIONAL GEOGRAPHIC PHOTOGRAPHER J. BAYLOR ROBERTS (OPPOSITE) AND ELI DAVIS © N.G.S.

Steam from Hot Lake in Yellowstone billows above Steady Geyser's mouth. Conrad L. Wirth (second from left), National Park Service Director, inspects cracks in the rim.

Sapphire Pool, a Mouse That Became a Lion, Scalds the Yellowstone Sky

Earth tremors warped the subterranean plumbing that feeds the park's thermal springs. Old geysers changed schedule, new ones exploded, and bubbling springs burst into violent activity. Last September placid Sapphire Pool suddenly became a geyser, blasting 30 to 50 tons of water a hundred feet or more into the air in frequent eruptions.

the U. S. Forest Service had designated the stricken region along the Madison as a special "geologic area." A task force of highway engineers, geologists, and watershed specialists drew plans for its protection.

"We hope to enable people to see just what nature has done," Regional Forester Charles L. Tebbe told me in his headquarters at Missoula.

Montana's able, plain-spoken Governor J. Hugo Aronson expressed the same hope. "The Madison River has always attracted visitors," he told me. "They will keep coming, and they will want to see the effects of Montana's worst earthquake."

To restore highway travel, State and Forest Service engineers are already planning two new roads. One, an entirely new primary highway linking Montana and Idaho, will cross the Continental Divide over Raynolds Pass, a wide, gentle saddle just south of the Madison Canyon. The other, far more difficult to build, will again thread the canyon, running across the giant landslide and along Earthquake Lake.

Access trails and overlooks will enable vacationists to see the devastation produced in a few awesome moments last August—mute testimony to the terrible power of mountains that moved in the dark of night.