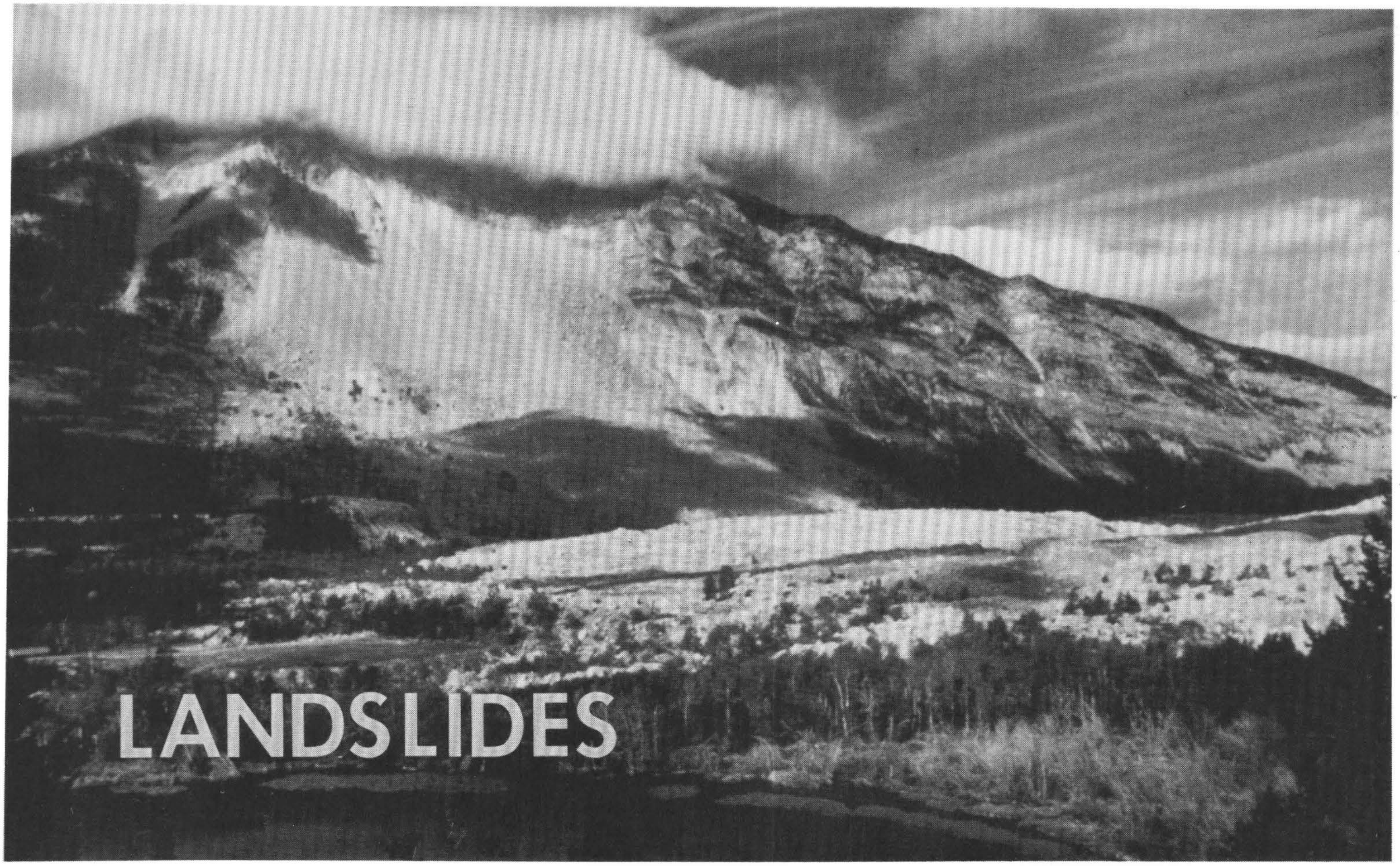

LANDSLIDES

The slopes above streams and rivers are subjected to a variety of processes that cause them to recede and retreat from the river or stream channel. These processes, collectively called **mass wasting**, can be classified according to rapidity of movement and according to the type of materials that are transported. Gravity is the force behind all such downslope movement. Factors that enable the force of gravity to overcome the resistance of inertia and friction to move more material downslope include: saturation by water which acts as a lubricant, steepening of slopes by streams, waves, or road construction, alternate freezing and thawing, and earthquake vibrations. Mass wasting of surface material is widespread process that can be found in high mountains, desert hillsides, deep ocean shelves, steep ocean shores and even on thė moon and other rocky planets. The major methods of mass movement include:

Rockfall: Large or small amounts of rock material break away from the face of a cliff as a result of weathering, and in the most rapid type of mass movement, free fall or bounce along an irregular slope to the base of the cliff forming talus.

Rockslide: Rock material slides along a plane of structural weakness such as a bedding plane. Although they are most common on steep slopes, they can even occur on slopes of 15 degrees. Millions of tons of rock may plunge down slope at speeds greater than 160 km (100 mi) per hour in what is often the most catastropic form of mass wasting.

Debris slide: Dry to moderately-wet, loose rock fragments and soil move rapidly over the surface of underlying bedrock. The interface of moving material and underlying bedrock is dry in a debris slide.

Debris avalanche: Loose earth on a steep slope becomes wet and slides to the bottom of the slope.

Snow avalanche: Unstable snow breaks loose and plunges down slope carrying rock and debris, carving avalanche chutes.

Debris flow: Rock fragments, mud, and water flow downslope as a thick viscous fluid. Debris flows may begin as slumps and continue as flows. Movement may be as slow as that of freshly poured concrete or as rapid as that of a river.

Mudflow: Silt and clay particles with water content as high as thirty percent follow stream valleys until the terrain flattens. Then they spread out as fans. Mudflows are sometimes over 100 m (330 ft) thick; they can float large boulders and move houses from their foundations. The speed of movement depends on the slope and the water content of the flow.

Landslide: Unconsolidated rock material and even the bedrock itself may be involved in what is usually a rapid movement of material beginning with the slumping of stream banks or sea cliffs, or the sliding of mountain sides. Landslides move as a unit or series of units along a definite plane (in contrast to debris flows which move as viscous fluids). The material moves downward and outward along a curved plane. Eventually the material breaks into fragments that slide over uneven ground at the base until friction overcomes the force of motion.

Slumping: A resistant rock overlies a weaker rock layer. The weaker rock is eroded undermining the resistant rock and producing an unstable condition. Slump blocks can be as much as 5 km (3 mi) long and 150 m (495 ft) thick. They may move in a matter of seconds or gradually slip over a period of several weeks.

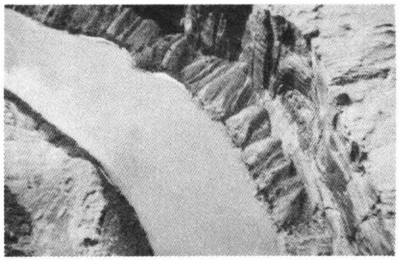
Solifluction: The upper zone of saturated soil flows slowly down even the most gentle slopes in arctic and subarctic regions where an impermeable permafrost area exists. Water can not percolate into this permafrost area so the thawed surface remains saturated and flows as a viscous fluid.

Rock Glacier: Angular rock debris resembling glaciers move as a body down slope at rates ranging from 3 cm (1.2 in) a day to 1 m (3.3 ft) a year. A considerable amount of ice exists in the pore spaces between the rock fragments and is responsible for much of the movement. The increased weight of rock fragments falling onto the flow cause the ice to flow. Steep cliffs and a cold climate that keeps ice permanently frozen are conditions that most often result in rock glaciers. A steep flow front, lobes, and concentric ridges on the flow are evidence of rock glaciers.

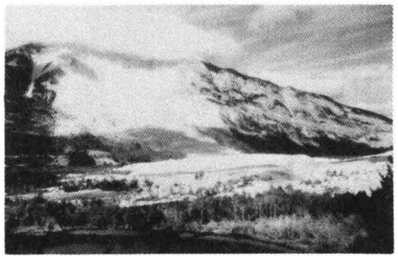
Creep: The mantle on a slope moves downward almost imperceptibly under the constant pull of gravity. In areas subject to cold winters the water in the layers of soil or clay freezes and increases in volume. This lifts the rocks upward at right angles to the slope. However, when melting occurs the rocks fall vertically and so are moved downhill. Wetting and drying has the same effect since moisture causes expansion of clay materials. Burrowing organisms displace particles permitting the force of gravity to move them. Growing plant roots and the tramping of animals also force soil material downslope.

ROCKFALLS AND SLIDES

(1) Talus cones formed from rockfalls in Glen Canyon above Kane Creek, Arizona. (Navajo Sandstone)



(2) Results of the rock slide of 1903 at Frank, Alberta, Canada. In less than two minutes 40 million cubic yards of rock from Turtle Mountain slid along a plane of structural weakness to cover the town of Frank.



(3) In 1970, an earthquake-induced rock and snow avalanche on Mt. Huascaran, Peru, buried the towns of Yungay and Ranrahirca, killing more than people. The avalanche started with a sliding mass of glacial ice and rock about 909 km (3,000 ft) wide and 1.6 km (1 mi) long that swept downslope about 14.4 km (9 mi) to Yungay at an average speed of over 160 km (100 mi) an hour. Ice picked up morainal material and by the time the mass reached Yungay, it is estimated to have consisted of about 2,200,000 m^3 (80,000,000 ft^3) of water, mud, and rocks.

③

(4) Results of the 1963 rockfall avalanche of volcanic debris on Little Tahoma, Mt. Rainer, Washington. There were no witnesses to the event.

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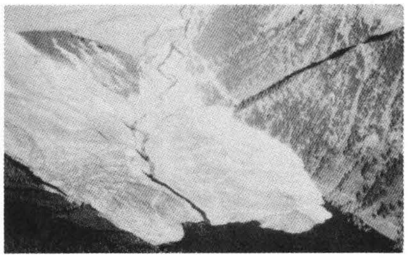
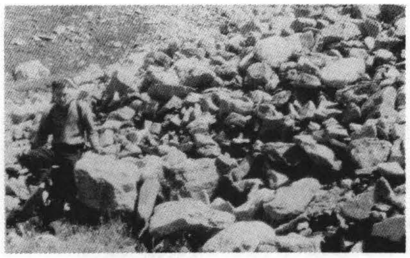
(5) Earthquake-induced slide and alluvial fan on downstream side of Madison River, Montana. Light colored rock is dolomite marble, the more resistant rock that supported weathered, mica-rich, overlying layers. An earthquake in 1959 fractured this dolomite and caused a great avalanche of rock, dirt, and trees to cascade from the steep south wall of the Madison River Canyon, about 394 m (1,300 ft) above the canyon floor. The avalanche formed a barrier 60.6 to 121.2 m (200 to 400 ft) high that completely blocked the gorge and the flow of the Madison River and created a lake. Twenty-eight people were believed to have been engulfed in the 88,000 kg (80 million ton) slide.



(6) Talus cones formed by rock falls and rock slides in the Canadian Rockies. Note the mudflow in the lower center of the photograph.

MUDFLOWS AND EARTHFLOWS



(7) MAYFLOWER MOUNTAIN MUDFLOW IN THE TEN MILE RANGE NEAR CLIMAX, COLORADO, IN 1961. THE FLOW WAS GENERATED ON A STEEP TALUS SLOPE. NOTE THE LARGE BOULDERS TRANSPORTED BY THE FLOW. FINER MATERIAL HAS BEEN ERODED FROM THE TOP OF THE FLOW. THE PHOTOGRAPH WAS TAKEN ONE MONTH AFTER THE EVENT.

(8) MUDFLOW SCAR IN NEVER-SUMMER RANGE, ROCKY MOUNTAIN NATIONAL PARK, COLORADO ONE MONTH AFTER THE EVENT IN JUNE 1978. THE FLOW CONSISTED OF COLLUVIUM DEPOSITS ON BED ROCK AND WAS PERCIPITATED BY AN IRRIGATION DITCH THAT LEAKED WATER AND SATURATED SOILS.

(9) THE SLUMGULLIAN MUDFLOW IN THE SAN JUAN MOUNTAINS DAMMED LAKE FORK, AND FORMED LAKE SAN CRISTOBAL (LOWER LEFT) AT LAKE CITY, COLORADO. THIS FLOW WAS DISCOVERED BY THE EARLIEST SETTLERS TO THE AREA AND IS STILL ACTIVE.

(10) RESULTS OF MUDFLOW OF EARLY 1970'S IN A SADDLE OF THE OWLSHEAD MOUNTAINS, SOUTH DEATH VALLEY, CALIFORNIA. THE PHOTOGRAPH IS ORIENTED NORTH EAST.

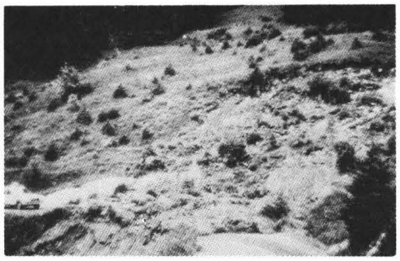
(11) EARTHFLOW IN RAPID BAY VALLEY, FLEURIEU PENIN, SOUTHERN AUSTRALIA. THE LATERIAL LINES ON THE HILLSIDE SHOW CREEP.

(12) EARTHFLOW ON MISSION PASS IN THE CALIFORNIA COASTAL RANGES. THE LATERIAL LINES ON THE HILLSIDE SHOW CREEP.

SLUMPS AND SUBSIDENCE

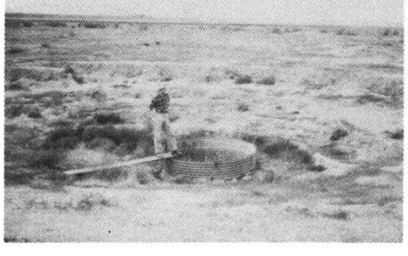
(13) SLUMP ON THE PACIFIC PALISADES IN SOUTHERN CALIFORNIA NORTHWEST OF SANTA MONICA. TWO SLUMPS ARE VISIBLE IN THE PHOTOGRAPH--ONE AT THE CENTER JUST BELOW THE ROAD AND THE OTHER JUST BEHIND THE FIRST.

(14) RECENTLY REACTIVATED SLUMP/EARTHFLOW BELOW CHALET DU FER LEYSIN, SWITZERLAND. THE FLOW CONSISTS OF COLLUVIUM ON SLOPING BEDROCK. AREA OF OLDER FLOW IS MARKED BY GRASSY AREA AND YOUNG TREES. MOST RECENT FLOW COVERS ROAD IN FOREGROUND. RED SOIL SHOWS EXTENSIVE WEATHERING.

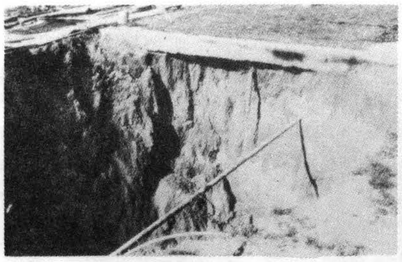


(15) THE HEAD OF A SLUMP IN THE BLACK HILLS OF NORTH DAKOTA.

(16) SUBSIDENCE DUE TO THE PUMPING OF WATER FROM WATER TABLE IN THE SAN JOAQUIN VALLEY, CALIFORNIA.



(17) SINKING CAUSED BY THE COLLAPSE OF A COAL MINE NEAR LAFAYETTE, COLORADO.

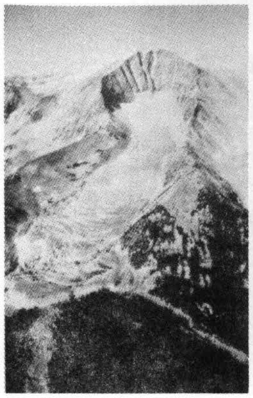


ROCK GLACIERS

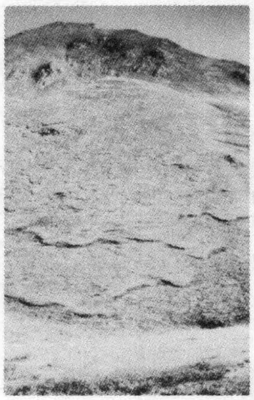
(18) ROCK GLACIERS IN TERTIARY ROCK ON MT. SOPRIS, COLORADO.

SOLIFLUCTION

(19) SOLIFLUCTION FLOWS (LOBES) NEAR SUSLOSITNA CREEK, ALASKA.



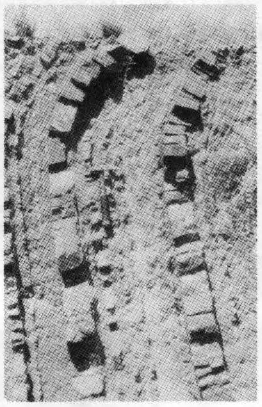
(18)



(19)

CREEP

(20) CREEP IN HAYMOND FORMATION (SANDSTONE AND SHALE) NEAR MARATHON, TEXAS. THE APPARENT BENDING OF SANDSTONE BEDS IS ACTUALLY PRODUCED WHEN BEDS FRACTURE INTO SMALL VERTICAL SECTIONS. THESE SECTIONS ARE THEN MOVED DOWN SLOPE AT DIFFERING RATES DEPENDING ON DEPTH FROM THE SURFACE. THE BLOCKS CLOSEST TO THE SURFACE ARE DISPLACED DOWNSLOPE TO THE GREATEST EXTENT.



PHOTOGRAPH CREDIT: WE SINCERELY THANK B. BRADLEY AND THE UNIVERSITY OF COLORADO'S GEOLOGY DEPARTMENT FOR THE PHOTOGRAPHS PROVIDED IN THIS SET.

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