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COASTAL LANDSLIDES OF NORTHERN OREGON

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Introduction

The increased development of the Oregon coast for domestic housing, recreation, and industry makes it economically important to understand processes of coastal erosion and deposition. Of all the erosional processes, landsliding is undoubtedly the most important. It is active along 70 of the 150 miles of northern Oregon coast, from the Columbia River to Florence.

In the past, investigations of coastal landslides have followed mainly a reactionary approach. Only after property has been damaged or rendered valueless by landslides have detailed studies been made to determine the causes of the movements and the feasibility of preventive measures. In Oregon, studies of coastal landslides have been few. Diller (1896) and Smith (1933) described landslides as they occurred in accessible wave-cut cliffs and areas of local subsidence. Broad erosional processes effecting changes in the Oregon coast were studied by Dicken (1961), who included references to coastal landslides as they altered shoreline topography and composition of beaches. General estimates of the length of coast already affected by landslides were made by Byrne (1963, 1964). Terrace subsidence in the Newport area was studied by Allen and Lowry (1944) after a 1,000-foot section of the coast dropped 20 feet, opening fissures and shifting houses. A spectacular 125-acre slide in Ecola Park, near Tillamook Head, was described in detail by Schlicker, Corcoran, and Bowen (1961).

Most general literature on landslides is contained in various engineering publications that deal directly with road building, railroad engineering, or some phase of construction. This literature is voluminous, and extensive bibliographies are given by Eckel (1958), Ladd (1935), and Sharpe (1938). An excellent summary of landslides

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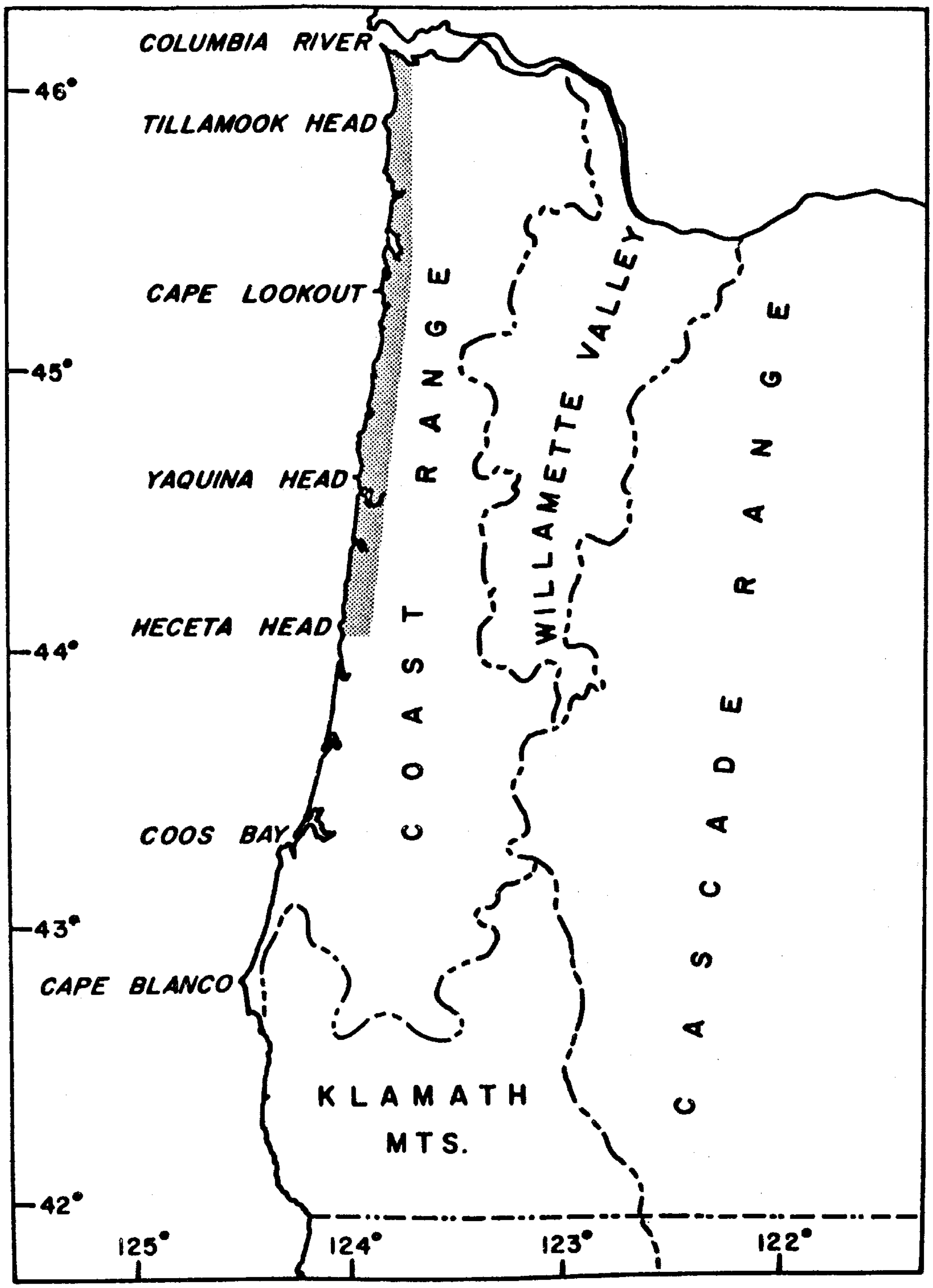


Figure 1. Index map showing geomorphic provinces of western Oregon. Shaded portion indicates area studied.

in general was presented by Schlicker in The ORE BIN of May 1956.

The field study represented by this report was undertaken to provide data on the location and causes of active landslides, and to determine, if possible, the frequency of landslides and rate of coastal retreat.

Coastal Physiography and General Geology

The northern Oregon coast, from the Columbia River to a point six miles north of the Siuslaw River (Figure 1), includes a wide variety of shoreline features. Short, narrow beaches lie at the base of low cliffs which form the seaward edge of uplifted marine terraces. Numerous headlands, estuaries, and bays interrupt the continuity of the terraces and beaches. Where the coastline is low, near the bays, active sand dunes are present. Stabilized dunes are evident in some of the low areas and on some of the terraces.

Tertiary marine sediments dominate the rocks exposed to erosion. These rocks range in age from Eocene to Miocene, and consist of micaceous and tuffaceous sandstones, siltstones, mudstones, and shales, with some glauconite beds.

Sediments of Pleistocene(?) age are exposed in marine terraces along the coast. These deposits consist of cross-bedded sand and silt with layers of gravel and very coarse sand, fossil wood, peat, and, in some places, thin beds of sandy clay. The Pleistocene sediments occur as terrace caps that unconformably overlie Tertiary rocks. Although often unreported on geological maps, these deposits figure prominently in local landslides and must be included when the total material available for mass movement is considered.

Igneous rocks of Eocene and Miocene age form all but one of the headlands (Cape Kiwanda) and constitute the most resistant features of the northern coast. These rocks are dense to very finely crystalline basalt flows, pillow lavas, flow breccias, agglomerates, and tuffs. Dikes of gabbro, diabase, and diorite intrude both igneous and sedimentary rocks, forming resistant "spines" and locally disrupting and contorting the sediments. A summary of the lithologies exposed along the coast is presented in Table 1.

TABLE 1. Coastal lithology significant to landslides along the northern Oregon Coast (figures in statute miles).

Material	Total length	Terrace Cap
Sedimentary rock	33.38 mi.	20.42 mi.
Igneous rock	36.76	16.90
Beach, dune sands	79.60	- - -

Distribution of Tertiary sedimentary and igneous rocks and Quaternary sediments is shown in some detail on geologic maps that cover the following coastal areas: Astoria to Cape Lookout (Warren and others, 1945); Cape Kiwanda to Cape Foulweather (Snavely and Vokes, 1949); Newport to Waldport (Vokes and others, 1949);

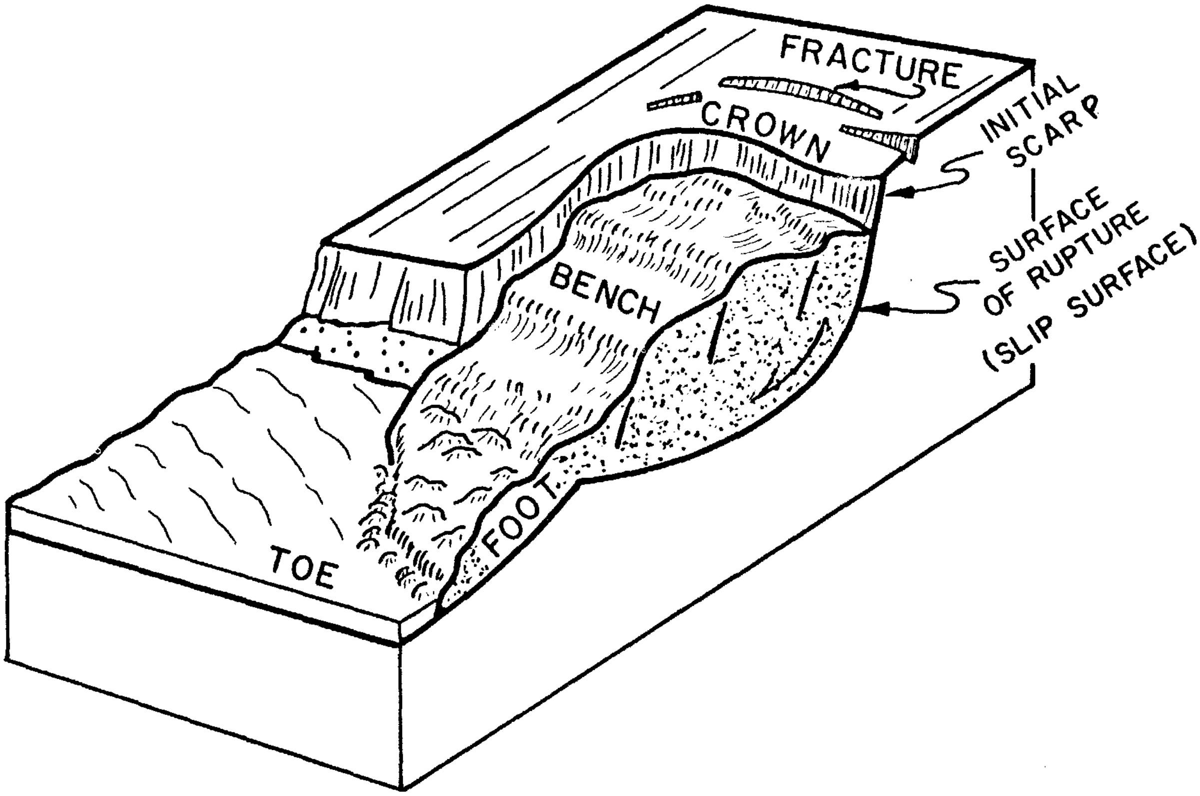


Figure 2. Landslide nomenclature.

and Heceta Head to Florence (Baldwin, 1956). A geologic map of western Oregon (Wells and Peck, 1961) combines in a generalized way the information of the four maps cited above.

Landslide Characteristics

The term "landslide" has been used to represent a variety of types of masswasting. Although specific cases of landslides may involve an earthflow or a block fall rather than the strict slide of a mass along a plane, the word is used to describe what is apparent: that a portion of land has slid or moved from one position to another. A landslide, then, is a relatively rapid displacement of a mass of rock, residual soil, or sediments adjoining a slope, in which the center of gravity of the moving mass advances in a downward and outward direction (Terzaghi, 1950).

Landslide morphology

Each landslide has its own characteristics. The mechanisms, materials, and boundary restrictions may be quite different from slide to slide. However, slide nomenclature has been more or less standardized and is summarized in Figure 2.

For coastal landslides the toe usually is in direct contact with the ocean. When a slide reaches the ocean, waves immediately begin to act on the toe, removing the finer material and leaving larger boulders and cobbles to outline roughly the original toe. Where slide toes are composed of smaller fragments, wave activity may carry away most of the toe material. This produces a wave-cut cliff in what was formerly the bottom or foot of the slide. The cliff is often backed by a gently sloping bench; the surface upon which the slide moved is located beneath this bench.

Landslide mechanism

The force of gravity acts to produce landslides. Prior to the actual movement, earth material beneath a slope is subjected to shearing stress. If the shearing stresses in the material are less than the average shearing resistance, the slope is stable. When the stress is equal to or exceeds the resistance, a landslide occurs. It is the failure of material under gravity-induced shear stress that allows slope material to slide.

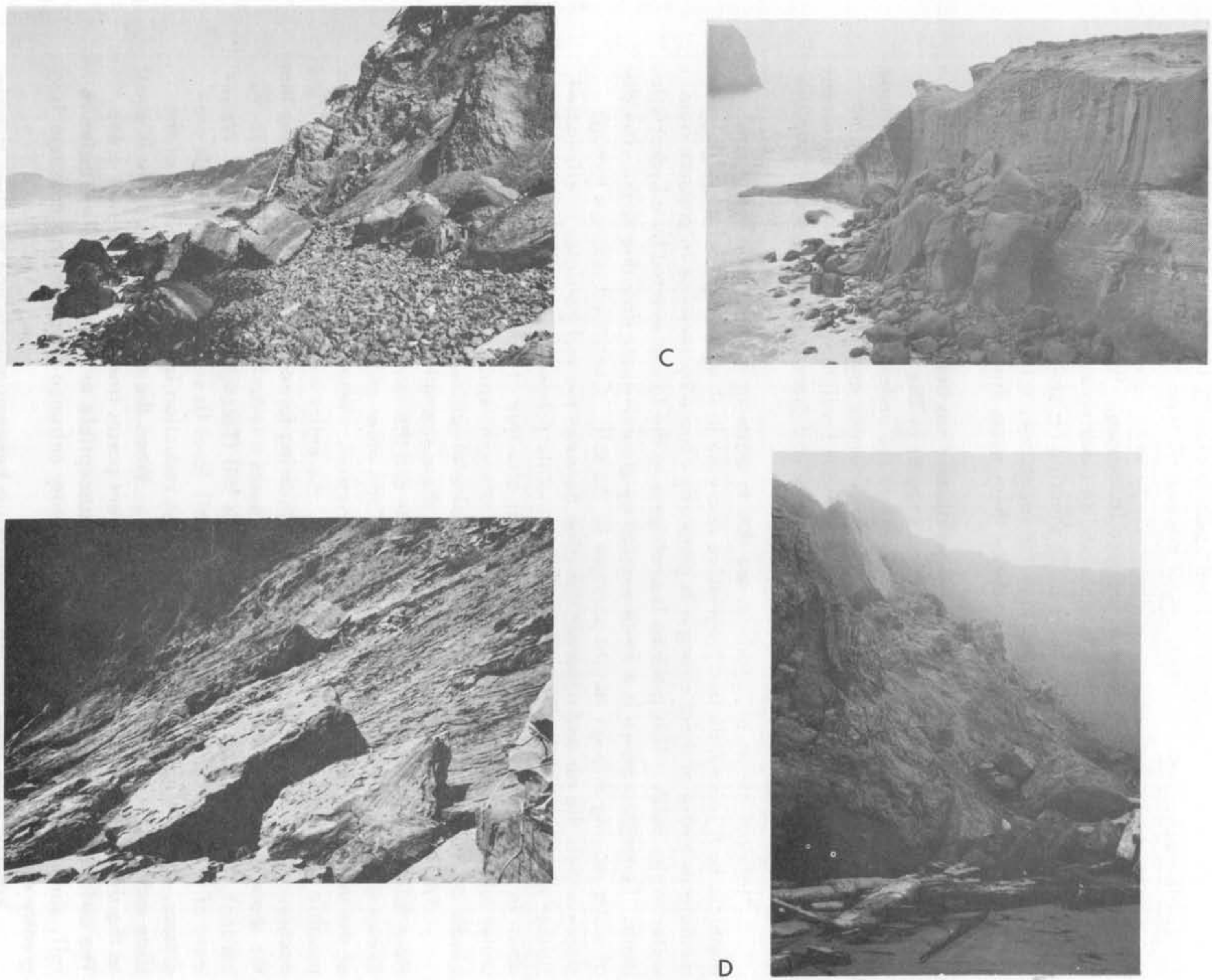
The actual mechanism of slide development has been described by numerous workers. The following is from Schlicker's report in The ORE BIN for May 1956.

"External causes of landslides are due to the undercutting of the toe of a slope (oversteepening), addition of weight from embankment material or waste deposited along the upper edge of the slope, and from added weight of increased moisture content. Earthquakes or vibrations can be a cause and there is no doubt that vibrations from any source may 'trigger' a slide.

"Internal causes of landslides are due to water in the ground. The groundwater produces both immediate and progressive decrease in shear strength of the soil. Immediate decrease of shear strength is generally caused by increase in pressure from water in the voids. This pressure is analagous to the forces exerted by a hydrostatic head. Seepage pressure is a force exerted by ground-water flow due to the viscosity of water moving through minute passages in the soil. Continued seepage through slopes expels the air and apparent cohesion between the soil particles is eliminated, further weakening the soil. Although this mainly concerns conditions of rapid draw-down in reservoirs and stream channels, it is also true of saturated soils below the water table. Progressive decrease in shear strength results from removal of the soil binder and chemical decomposition of the mineral grains by ground-water action.

"As the shearing forces approach the shear strength of a soil mass, certain sections fail by rearrangement of the soil grains and the formation of hairline cracks. Excess water in the disturbed soil is forced into other sections of the soil and failure of the soil mass continues as if by chain reaction. When the shear strength along a possible slide plane is reduced sufficiently, the entire mass becomes mobile and slide occurs. At the moment a slide begins the shearing forces are but slightly greater than the shear strength of the soil, but sliding causes a reduction in strength of 20 to 90 percent, depending on the sensitivity of the soil (Terzaghi, 1950, p. 112). Movement of the slide rapidly increases as the soil loses its strength. As the slide progresses, the driving force is reduced through reduction in slope and mixing of the slide material with more stable foreign soil. When the resisting force again is equal to the shearing force of the soil the movement passes from sliding into slow creep. The surface of an old slide is particularly susceptible to the effects of excessive rainfall, since numerous deep fissures provide easy entrance for water and drainage is greatly disrupted."

When a slide stops moving, equilibrium between gravity and the slide material's shearing resistance is established. Removal of the toe may upset the equilibrium by unloading the base, thus permitting repeated movement of the slide.



A

B

C

D

Figure 3. Landslide types: A, rock and debris slump; B, block and rubble slide; C, rock fall; D, debris shift.

Landslide classification

Numerous attempts have been made to classify landslides. Most classifications have been based on size and rate of movement, type of movement, type of material, and organization of material in the moving mass.

The simplified classification used in this paper is a modification of the classification used by Eckel (1958). Four categories based on the nature of the slip surface constitute the classification. These basic types are summarized in Table 2 and are depicted in Figure 3.

TABLE 2. Basic landslide types.

Landslide type*	Nature of slip surface
Slump	Concave
Slide	Planar
Fall	Indeterminate - movement essentially vertical
Shift	Indeterminate - movement indeterminate

*The type of material moved can be used as a modifier, for example, movement of rock and terrace material along a concave slip surface would be termed "rock-terrace slump." If materials are considerably mixed, the word "debris" is applied to the landslide type.

Distribution of landslides

The distribution of coastal landslides according to this classification is shown in Plate 1, pages 228 and 229. The pattern plotted in the offshore position represents the landslide type; the lithologic symbol indicates the general lithology at the coastline modified from the geologic map of western Oregon (Wells and Peck, 1961). No attempt has been made to show the distribution of terrace deposits. However, mention is made in the text where terrace sediments are significant to landsliding.

The following discussion, divided into three sections for sake of convenience, describes landslides of the northern Oregon coast, from north to south.

Tillamook Head to Cape Meares

Landslides have cut deeply into the sea cliffs of Tillamook Head and have moved more than 180 acres of property on the entire headland. On the north side of Tillamook Head, mudstones of the Astoria Formation form cliffs nearly 200 feet high. In two places where old slides have occurred, vegetation is too thick for details of slide configuration to be observed. These landslides were viewed near their crown from a trail over the headland. The slides are long and narrow and are being eroded by small streams. At West Point, the contact between basalt and Astoria sediments is exposed in the cliff face. From this point southward to Indian Beach, rock and debris falls are the main mass movements. Highly weathered basalt continually falls to narrow rocky beaches or directly into the ocean.

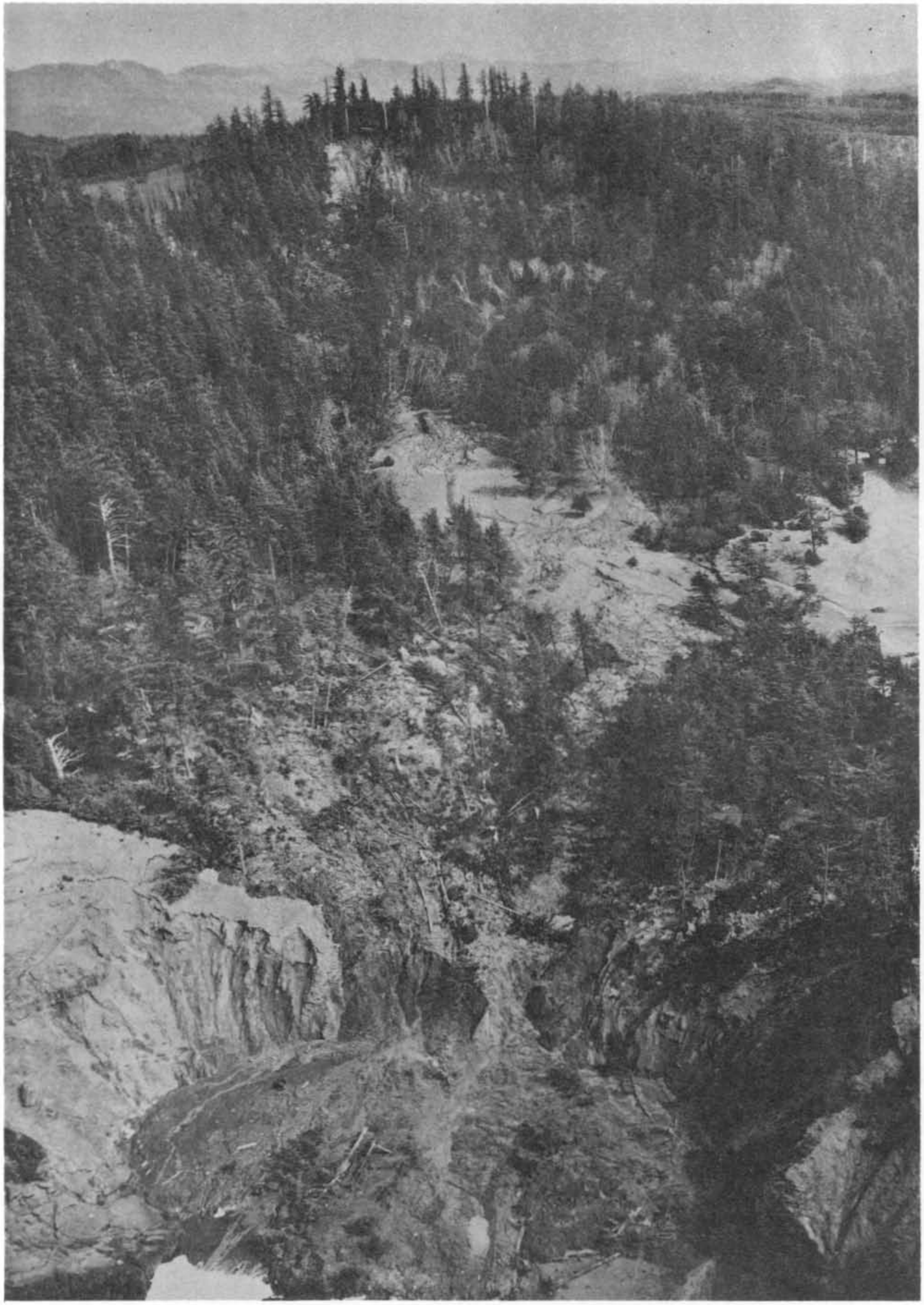


Figure 4. Ecola State Park landslide of February, 1961.

Three active landslides are included within the 1.6 miles of Ecola Park coastline on the south side of Tillamook Head. Sedimentary rocks in the park are thin-bedded sandstones, silty shales, and clayey siltstones of the Astoria Formation. Basalt flows and agglomerates are associated with the sediments; numerous dikes and sills have intruded the strata. According to Schlicker and others (1961), igneous intrusion took place before complete sediment consolidation, squeezing the sands and silts into complex folds with small axial faults. The most recent large landslide in the park occurred in February, 1961 and involved 125 acres of land, extending half a mile inland from the shore (Figure 4). The slide moved three feet per day at the outset, slowing down and stopping two weeks later. This 300-yard-wide slide was channelled between two basalt masses at the shoreline. Its toe has since been greatly eroded by waves. This slide which began as a debris slump, exhibited a vertical displacement of 40 feet at the crown and a maximum horizontal displacement of 100 feet at the middle.

Other landslides have occurred within the park. One slide is visible at Bald Point between Indian Beach and Ecola Point; an older landslide has its crown about half a mile inland from Bald Point. Sedimentary rocks in the landslide appear to be riding over basalt flows at the base of the toe. Erosion by wave action has removed material from the toe and has left only basalt boulders and cobbles to outline its extent. The basalt base may protect Bald Point from complete erosion by waves.

Between Ecola and Chapman Point steep scarps are associated with rock and debris fall. An old landslide near the north end of Chapman Point is partly concealed by vegetation, although the general slide outline is still visible.

Minor terrace debris slumps with some rock falls occur on small, local headlands from Chapman Point eight miles southward to Cove Beach, on the north side of Cape Falcon. Along Chapman and Cannon Beaches minor terrace sand slumps are prevalent, and near the village of Tolovana Park erosion and subsequent movement of unconsolidated terrace sands have shifted the foundations of some cottages. Between Cannon Beach and Tolovana Park, opposite Haystack Rock, the seaward-dipping Astoria Formation crops out on the cliff and provides natural slip planes for the overlying loose sands. Most slumps along this part of the coast occur along cliffs less than 20 feet high. South of Silver Point, mudstones of the Astoria Formation are intruded by basalt and are overlain by about 15 feet of terrace sand. Basalt dikes exposed as small, resistant promontories separate minor slumps of sedimentary rocks. The largest landslide in this area forms a bench 120 feet wide and 60 feet long, with a 20-foot-high initial scarp. On the south side of Humbug Point, intrusions have disrupted and contorted the sediments. Minor terrace debris shifts with 10-foot-high wave-cut cliffs in the toes are continuous in this area. Arch Cape, 250 feet high, is eroding by rock fall with some soil creep on the top.

Along Cape Falcon, an igneous headland, rock falls are common. Near the western point of the cape, basalt is overlain by sedimentary rock dipping westward. This, in turn, is overlain by a thin terrace sand cap.

In Smuggler Cove (Short Sand Beach), nearly 1,700 feet of dark-gray shale interbedded with fine-grained sandstone of Blakely age (Oligocene-Miocene) are exposed. Thin beds of siltstone, graded shale, and tuffaceous sandstone occur in this sedimentary section. At the north end of the beach, blocks of fine-grained sandstone, averaging 7 by 4 by 2 feet, move as dip-block slides over beds dipping 29° to the south. Debris slumps appear to be more prevalent along the southern

Figure 5. Rock-terrace slump which has destroyed 20 acres of land on Cascade Head.

Figure 6. Slumping of Eocene shale south of the Salmon River. Where basalt cap has been breached, landsliding has been most rapid.

section of the beach, however. Part of the cliff behind the southern portion of the beach is protected by a 6-foot-high berm of cobbles and driftwood. This berm decreases undercutting of the cliff by acting as a partial wave barrier. Such a barrier is lacking on the northern third of the beach. A cross section of the hillside on the north shows vegetation and soil creep on the upper hillside, debris slump or shift in the middle, and block slide on the lowest reaches of the hill. The southern portion of this headland area, namely Neahkahnie Mountain, is eroded by block falling. Near Neahkahnie Beach, there is a vegetated remnant of an old debris shift consisting of Astoria rocks or terrace deposits.

Although landslide erosion is not very active along the coast from Neahkahnie Beach to Cape Meares, significant changes have taken place along Bayocean Peninsula at Tillamook Bay. Wave erosion of this sand spit is now well known and will not be discussed in this report. Wave erosion is rapid at the village of Cape Meares near the south end of the Bayocean Peninsula, but resistant igneous dikes help to decrease the rate of wave erosion and of landsliding close to the cape.

Cape Meares to Yaquina Head

Cape Meares headland exhibits rock and debris fall all along the wave-cut cliffs. Massive basalt is capped by unconsolidated sand at an elevation of about 350 feet; small areas of soil creep disrupt vegetation and contribute to the debris fall from the cliffs. A 300-foot-wide benched slump on the north end of Short Beach, south of the lighthouse, has moved down to the beach. Boulders now outline the landslide toe, since finer slide debris has been removed by waves.

Stacks and wave-cut platforms in the basalt give some protection from wave attack on Cape Meares. This type of protection varies along the cape, but is present to some degree as far south as Oceanside. South of Oceanside, terrace and dune sands are involved in small local slumps. This type of minor movement extends southward to Cape Lookout.

Cape Lookout is a narrow igneous headland jutting 1.75 miles into the sea. Rock and debris falls are common along its sheer cliffs. On the north, at the landward end of the cape, 20-foot-high dune and terrace shifts partially cover basalt. The remainder of the cape has rock falls, with minor soil creep on the slopes above the cliffs. Generally, there is no visible talus from these falls, because rocks fall directly into 40 to 60 feet of water.

A 1,000-foot-wide benched slump is exposed on the south landward end of the headland. South of the cape for one mile, small shifts of terrace material partially conceal sedimentary rock outcrops. Near Camp Meriwether, terrace sands with tree and stump debris compose the sea cliff.

From Camp Meriwether to Sand Lake, there are 40- to 60-foot cliffs of terrace and dune sands. This area, notable for the high dunes extending one mile inland, is retreating by minor dune and terrace slumps. From the end of the dune area southward to Sears Lake, there are no landslides.

Near Sears Lake, one mile south of Tierra del Mar, the coast road cuts through a small slump in deeply weathered siltstone. The slump, having moved down the west face of a small hill, extends to the sea west of the road cut. Judging from the appearance of a 15-foot-deep fracture, part of the hillside broke away at this initial scarp and moved downslope; smaller step-scarps are common above the main scarp.

Sedimentary rocks in the vicinity of this slump dip seaward 5°.

Cape Kiwanda, four miles north of the entrance to Nestucca Bay, is the only major headland composed of sedimentary rock on the northern Oregon coast. Sandstone of the Astoria Formation, which erodes as block fall, constitutes the promontory. Comparison of photographs taken about 1915 with recent pictures suggests that little erosion has taken place on the seaward edge of the cape. Block falls have removed sandstone from the sides of the cape, however, and continue to produce visible erosion of the headland.

Several thin dikes have combined with the joint pattern of the rocks to control the erosion which has resulted in the southwest orientation of the headland. Haystack Rock, 0.5 mile to the southwest, probably offers some protection against waves from the southwest.

From Cape Kiwanda southward along North Kiwanda Beach and Kiwanda Beach, minor sand shifts are evident. For most of the distance low coastline relief and wide beach conditions extend to 0.6 mile south of Neskowin at the north end of Cascade Head.

Cascade Head is a volcanic mass composed of basalt flows, pyroclastic rocks, and sediments of the Nestucca Formation of late Eocene age. The headland has been greatly modified by erosion. Extensive landsliding has taken place in six small embayments that have been eroded into the headland after wave activity removed resistant basalt. Siltstones are now exposed in cliffs behind the beaches. On portions of the headland that are composed entirely of basalt, rock fall is the principal type of mass movement.

Twenty acres of pasture have slumped to the sea in the largest landslide on Cascade Head (Figure 5). This slide is 0.1 mile north of the Salmon River and contributes soil and boulder debris to a narrow crescent beach at the base of the seacliff. The whole feature is about 2,500 feet wide, but consists of two slides partly separated by a dike that diverts the smaller of two movements. Residents of the area report that the main slide occurred in 1934. Trees and low brush now cover the gently-sloping slump bench. The crown scarp, at an approximate elevation of 600 feet, is 8 feet high. A series of sub-parallel fractures, 2 to 6 feet deep, are present up-slope from the crown. The toe of the slide has been eroded by waves, producing a cliff 30 to 60 feet high in the slide debris.

Between the mouth of the Salmon River and the village of Roads End, landsliding takes place along a series of crescent-shaped bays (Figure 6). The bays have been eroded in siltstones and shales of the upper Eocene Nestucca Formation. The points of the crescents consist of more resistant basalt. The bays have developed as a result of slumping of the shales following erosion of the north-trending basalt cap which protected the shales. Lack of vegetation on the slumps indicates that they are active. Rock falls are common in the basalt areas.

From the village of Roads End to Lincoln Beach, terrace and beach sands are involved in small, local shifts. Near Oceanlake (now part of Lincoln City), cliffs of terrace sand on sedimentary rock rise to 50 feet in height. Serious property loss is occurring where residents do not attempt to protect or strengthen the cliff. Debris slumps are continually taking place in Lincoln City, from the former towns of Oceanlake through Delake and Nelscott. Seaward-dipping sandstone crops out near Gleneden and Fogarty Creek Beaches and provides natural planes along which overlying terrace sands are moving as minor slumps.

Figure 7. Riprap at Boiler Bay helps to slow down landsliding and to protect U.S. Highway 101.

Figure 8. Terrace slump near Beverly Beach.

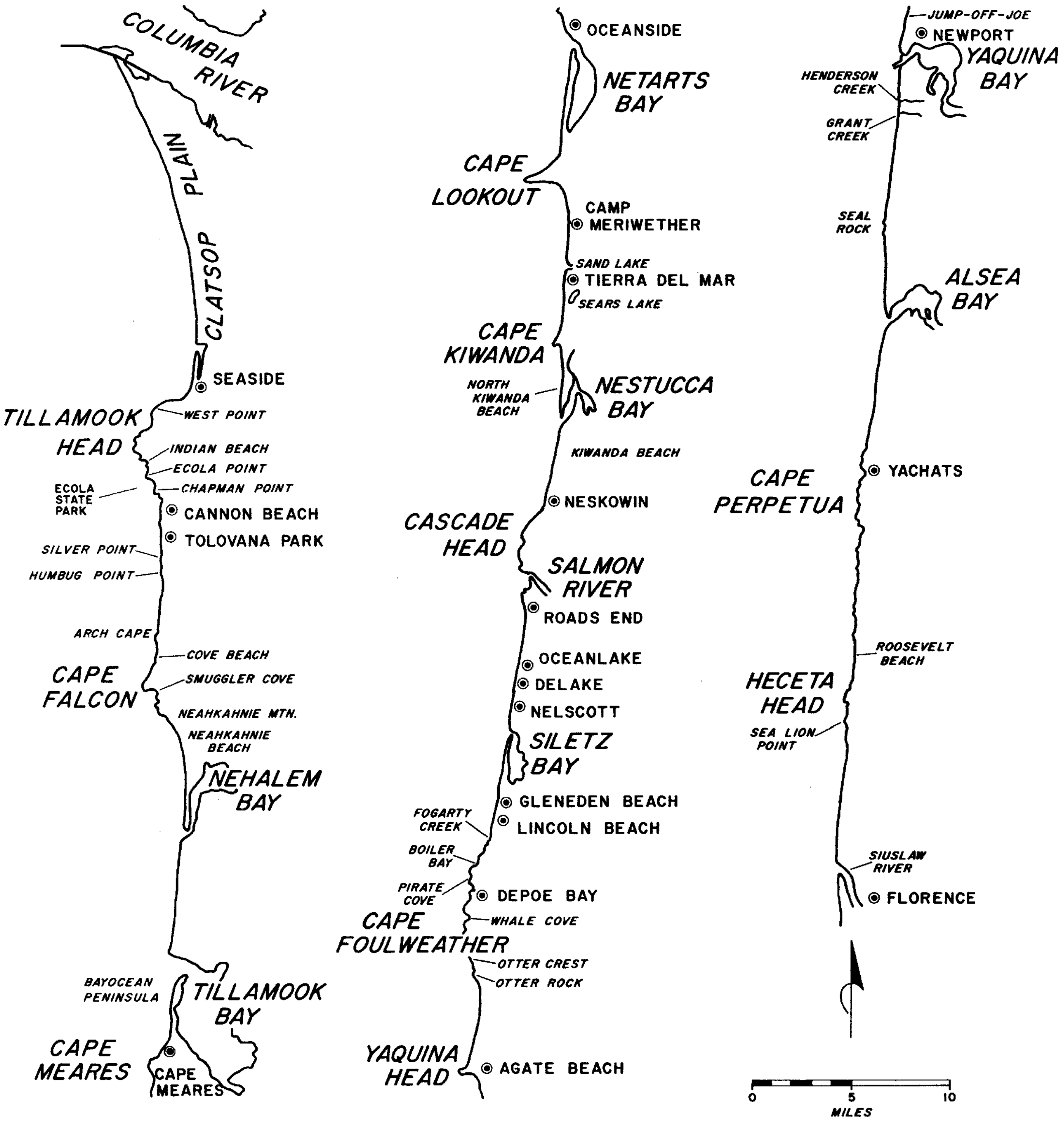


PLATE 1. LANDSLIDE DISTRIBUTION ALONG NORTHERN OREGON COAST.

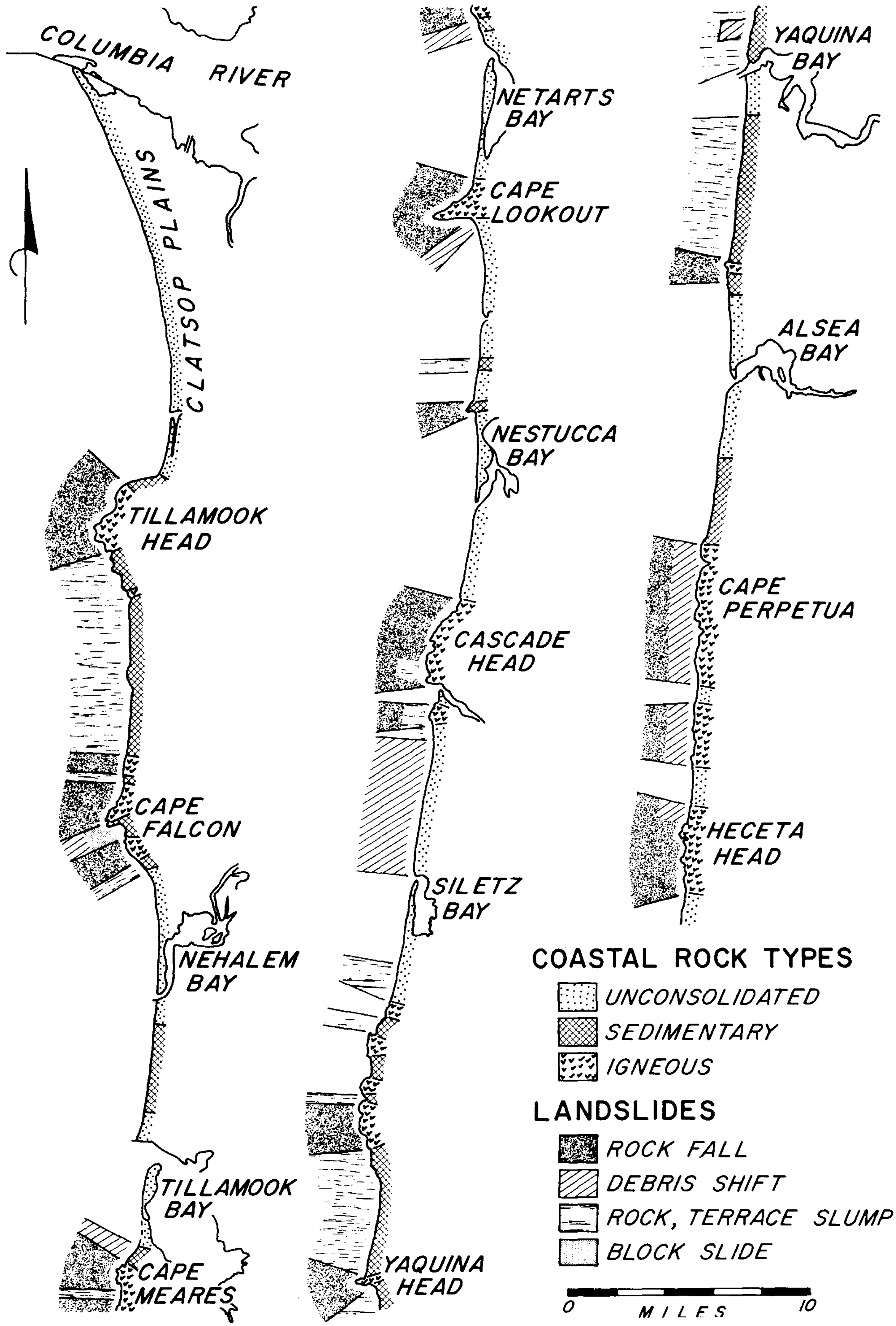

COLUMBIA RIVER
CLATSOP PLAINS
TILLAMOOK HEAD
CAPE FALCON
NEHALEM BAY
TILLAMOOK BAY
CAPE MEARES
NETARTS BAY
CAPE LOOKOUT
NESTUCCA BAY
CASCADE HEAD
SILETZ BAY
YAQUINA HEAD
YAQUINA BAY
ALSEA BAY
CAPE PERPETUA
HECETA HEAD
COASTAL ROCK TYPES
UNCONSOLIDATED
SEDIMENTARY
IGNEOUS
LANDSLIDES
ROCK FALL
DEBRIS SHIFT
ROCK, TERRACE SLUMP
BLOCK SLIDE
0
MILES
10

Figure 9. Slumping of Astoria Formation and overlying terrace deposits adjacent to north side of Yaquina Head.

Figure 10. Terrace slump in an area of seaward-dipping Miocene sandstones and shales at Newport.

Fishing Rock, a small headland 0.3 mile south of Lincoln Beach, marks the start of Miocene pillow lavas, flow breccias, and tuffs which interfinger with sandstones of the Astoria Formation. For the next 6 miles southward, the Miocene basalts and sandstones are covered by terrace sands. Sedimentary rock is exposed in four coves but is partially protected from direct wave attack by barrier stacks and basalt benches. This is the situation in Boiler Bay, Pirate Cove, part of Depoe Bay, and Whale Cove. In these coves, sedimentary rocks dip 12° to 16° to the southwest. Between the coves, basalt-flow breccias resist erosion and the overlying terrace sands remain in place. At the east end of Boiler Bay, strata under the highway have been weakened by waves. Large basalt blocks have been dumped at the base of this sea cliff to retard landsliding (Figure 7). At Cape Foulweather, south of Whale Cove, basalt forms resistant cliffs with small indentations which have been cut back into overlying terrace sands. The mass movement on Cape Foulweather is primarily block and debris fall.

Yaquina Formation sandstone overlain by terrace sands is exposed in wave-cut cliffs 0.3 mile south of Otter Crest to the beach south of Otter Rock. This material is eroded by block and debris slump. Strata dip 17° to the northwest in this area, but many blocks have slumped and rotated on the surface of rupture, causing tilting of the beds and anomalous bedding attitudes near the beach. Local slumping loosens the rock, and later debris slides roll blocks onto the beach. Slide areas 60 feet wide have resulted where block slumping has been most intense.

From Otter Rock to Yaquina Head, shales, sandstones, and mudstones of the Astoria Formation, which are overlain by unconsolidated terrace sands, are continually slumping down 10- to 80-foot cliffs (Figure 8). Vegetation on cliff edges is disrupted as undercutting of the cliff and terrestrial erosion progresses. Consolidated rock dips 14° to the southwest throughout this area.

Yaquina Head to Heceta Head

On the north end of the village of Agate Beach, severe cliff slumps and subsidence have resulted in extensive property damage. Immediately north of Yaquina Head is a 1,000-foot-long benched debris slump. The bench is well vegetated. Evidence for continued cutting back of the cliff can be seen on the crown edge from a trail over the south side of the bench. Partially coherent blocks of terrace sands have calved off the edge of the slump. Rocks underlying the terrace deposits dip southwest with an average inclination of 14°. Adjacent to Yaquina Head, about one acre of land at the foot of Fossil Street in Agate Beach has been destroyed by cliff-block slumping (Figure 9). A ragged 15-foot-deep crack has opened at the crown where a large block of Astoria Formation and terrace sands have pulled away from the land. This fissure has been widened by erosion. Seaward, blocks become progressively broken and skewed from original attitudes and finally accumulate as debris shift on the beach. Reorientation of the blocks increases seaward as the removal of cliff debris by waves makes the leading edge of the slide less stable and hence prone to further downward movement. Mass movement just north of Yaquina Head is much more severe than erosion in areas of similar lithology and rock attitude within two miles of the headland. Interpretation of U.S. Coast and Geodetic Survey Chart 6056 (1962) shows that underwater contours effecting changes in approaching wave-front directions would greatly concentrate wave energy within 0.3 mile of the headland. Convergence of wave energy is an additional erosional factor near headlands. Basalt rock fall is common to the remainder of Yaquina Head. Some protection is given the headland by offshore basalt remnants.

From Yaquina Head to Yaquina Bay, wave-cut cliffs rise to about 80 feet with debris slumps, rock-terrace slumps, and rock falls dominating mass movement. At Jump-off-Joe, on the north end of Newport, a number of large rock-terrace slumps have abruptly terminated several roads and have moved houses and associated property down and toward the sea. Subsidence of loosely consolidated Pleistocene terrace sands and underlying Tertiary sediments has affected an area 1,000 feet long and 200 feet wide on the north side of the point called Jump-off-Joe and an equivalent area on the south side (Figure 10). Sandy shales and argillaceous sandstones of the Astoria Formation and mudstones of the Nye Formation underlie terrace deposits and dip seaward about 21°. Land movement has been attributed to ground-water lubrication and slippage along bedding planes of the Astoria and Nye (Allen and Lowry, 1944). More than 16 acres of property have been involved in the Newport subsidences.

From Yaquina Bay to Alsea Bay there are three areas where lithology distinctly controls the type of mass wasting. Minor dune-sand slumps occur in the unconsolidated sands two miles south of Yaquina Bay and four miles north of Alsea Bay. Relief is low and the slumps do not materially affect houses or other cultural features. Terrace subsidence and debris shift occur on seaward-dipping mudstone of the Nye Formation about two miles south of Yaquina Bay in the vicinity of Henderson and Grant Creeks. The present slump near Grant Creek is 300 yards long, 200 yards wide, and has an initial crown scarp varying from 6 to 20 feet high (Figure 11). Vegetation is thick on the subsided bench, but hummocky topography is visible, as is the disrupted jackstraw arrangement of trees. A few houses on the crown have not as yet been affected by the movement. From this point to Seal Rock there are continuous minor terrace-debris shifts over seaward-dipping Nye and Yaquina rocks. The rocks dip to the northwest with an average inclination of 14°. Within a mile north and south of Seal Rocks, sea stacks form a solid line about 300 feet from the cliff. The cliff of terrace sand is partially protected from erosion by this line of basalt stacks, but where the stacks are farther apart more intense wave activity acts on the coastline. Spaces in the stacks north of Seal Rock have allowed waves to cut the cliff back 100 feet farther than on the protected cliff to the south. Intermittent protection is continuous to Squaw Creek, one mile south of Seal Rock.

For 6.3 miles south of Alsea Bay there is a little erosion. The terrace is low, averaging about 20 feet high, and some minor slumps occur in unconsolidated sand.

About a mile north of Yachats, the longest basalt outcrop on the northern Oregon coast begins. For 9.8 miles to the southward, late Eocene basaltic rocks form a resistant edge along the coast in the Cape Perpetua area. Unconsolidated terrace sands overlying the basalt are protected from significant marine erosion. The basalt bench receives full impact of the waves, and this greatly reduces erosion of the overlying sand. The basalt is well jointed (Byrne, 1963) and has been eroded along these fractures. Joint-controlled surge channels permit waves to erode the base of the terrace sands, producing local areas of debris slumping. The basalt coastal strip becomes well dissected and terminates 0.4 mile south of Roosevelt Beach. From there to Heceta Head low terrace slumps are common (Figure 12). In the Heceta Head - Sea Lion Point headland area, the basalt mass again crops out. It has sheer cliffs where minor soil or debris creep contributes to headland rock falls.

Figure 11. Large slump south of Newport.

Figure 12. Terrace slumps in the Roosevelt Beach area south of Cape Perpetua.

Summary of Landslide Types and Lithology

Landslides on the Oregon coast occur as the four basic types: slump, slide, fall, and shift. Each type is usually associated with a definite coastal lithology or combination of lithologies. Igneous headlands and the headland material overlying igneous rocks are most susceptible to falls, either rock or debris. The resistant igneous rock is massive, providing few if any bedding planes upon which slopes can develop. Undercutting is slow and, when rocks break off, they fall in tabular masses leaving vertical cliffs. Joints and faults control the erosion of the igneous headlands. These fractures are zones of weakness that are eroded by waves. Evidence for weakening by joints is seen in each headland but is most prominent on the western side of Tillamook Head and along Cape Perpetua.

Sedimentary rocks are involved in each type of landslide. Deep weathering of the sediments weakens the rock and makes the cliffs susceptible to undercutting by the waves. Unloading of the cliff base disrupts equilibrium of the relatively coherent rock mass and slumping occurs. Block slides or "glides" are unusual in the sedimentary sequence, because beds are usually too thin for a separate block to detach and slide. Where sandstone has resisted deep weathering, some slides of tabular bodies on bedding planes have occurred, as on Cape Falcon.

Unconsolidated sands, silts, and gravels of uplifted marine terrace and dune deposits usually have no specific plane of movement and move as debris shifts. Mineral and rock grains, acting as individual particles, provide no firm plane for movement of one mass over another. Slip-face sand movement, resulting in a cone or small fan, is common on dune and terrace faces. However, more often the over-steepened terrace cliffs move as debris shifts.

Landslide Frequency and Rate of Coastal Retreat

Frequency of landsliding on the coast appears to be correlated with high winter waves and increased precipitation. Byrne (1963) graphed the occurrence of major landslides by months of the year as reported in The Newport Journal News (1925-1949) and the Tillamook Headlight Herald (1916-1936). His graph is shown in Figure 13. It is obvious that most landslides occur from late fall to early spring and that the highest frequency of slides is during December and January, the period of major storms. Most of the newspaper articles indicated that sliding occurred during or immediately after extended periods of torrential rains.

Property losses have been extensive in sparsely populated regions of the northern coast. Ecola Park and Cascade Head have undergone considerable alteration. Landsliding has destroyed or disrupted more than 200 acres of land in four separate slides. The 1961 Ecola Park slide moved about 125 acres of recreation land during a two-week period. The slide north of the Salmon River on Cascade Head occurred in 1934, and carried 20 acres of pasture downward to the sea; the noise of the rock movement was heard at that time by a nearby resident. Two other landslides on Cascade Head have each destroyed more than 14 acres of grazing land.

Severe damage to buildings, roads, and utilities has occurred in the village of Cape Meares and in the city of Newport. Reliable maps showing sea-cliff recession have been obtained from Township deed plats in Tillamook and Lincoln Counties (Figure 14, A and B).

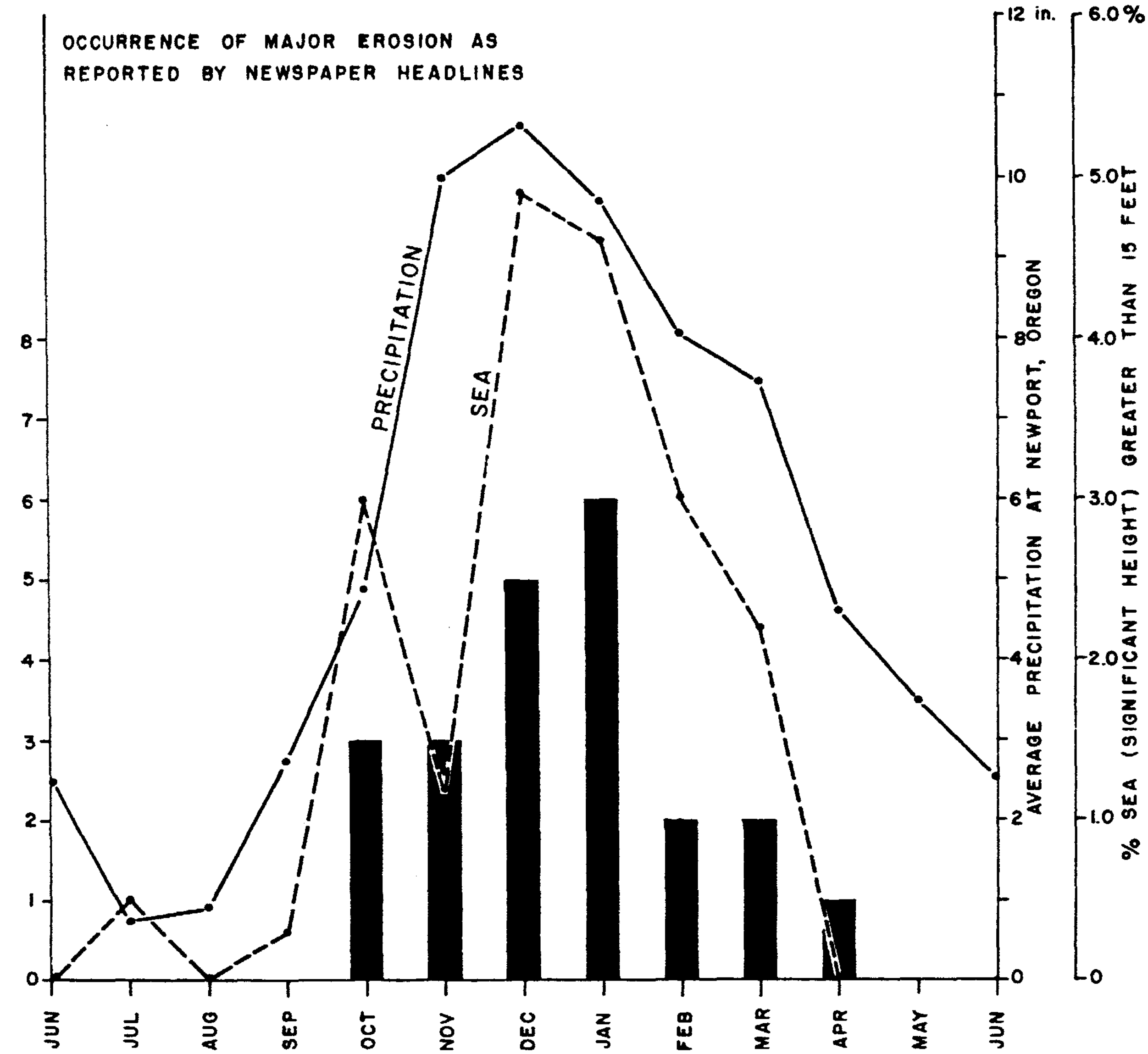


Figure 13. Monthly occurrence of landslides, high seas, and precipitation (after Byrne, 1963).

Coastline erosion in the vicinity of Cape Meares has been affected by jetty construction on the north side of the entrance to Tillamook Bay. This jetty apparently upset equilibrium of sand transport by waves along the coast, causing a starvation of sand in the area south of the jetty. This resulted in the subsequent cut-back of the entire sand and gravel spit including the Cape Meares village area. Dicken (1961) estimated erosion of the southern portion of Bayocean Beach to be about 500 feet from 1939 to 1961. Closer to Cape Meares headland, the coastline is composed of more resistant marine clays and sandstone overlain by terrace sands and angular landslide debris. Here, the coastline was cut back 320 feet between 1939 and 1961. During the winter of 1960-1961, a street at right angles to the coastline in Cape Meares retreated 75 feet, with most of the loss occurring from September to April. Figure 14A shows the retreat of the bluff line from 1953 to 1964 as determined from aerial photographs and field inspection. Minimum coastal retreat in this area has

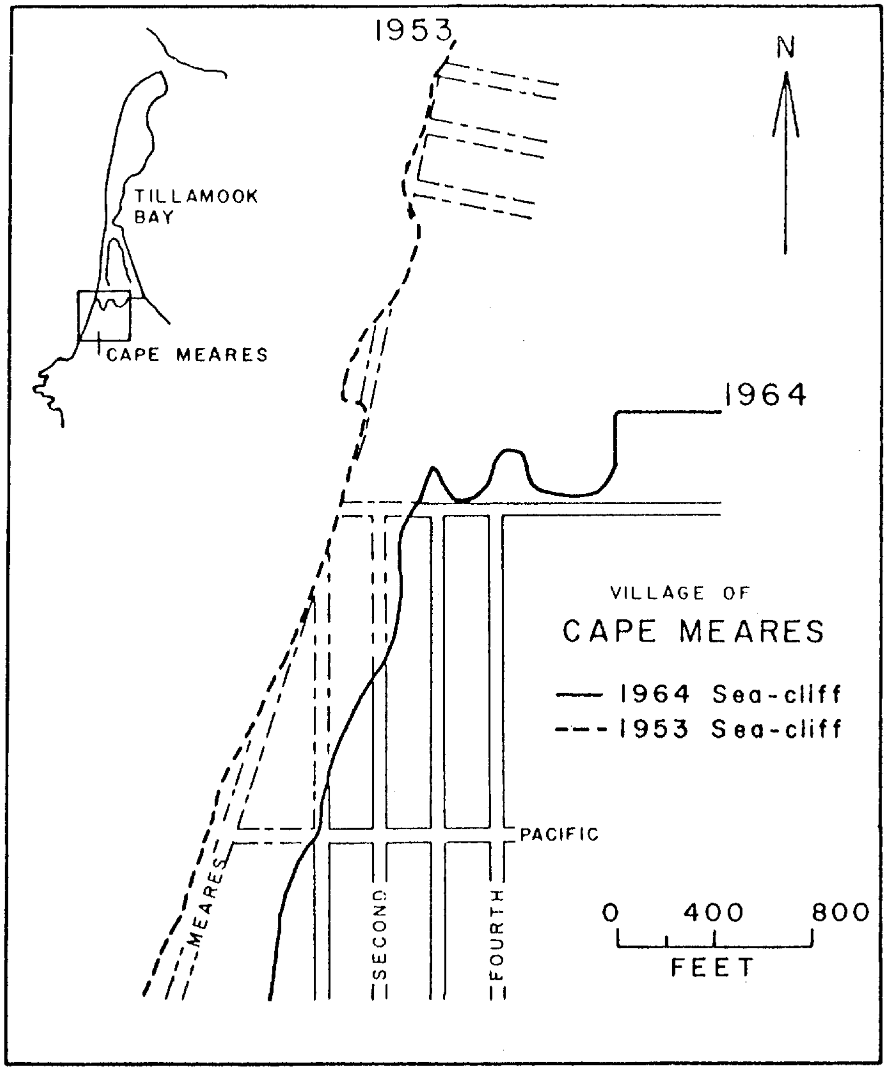


Figure 14A. Coastal retreat at Cape Meares, 1953 to 1964. ↑

Figure 14B. Coastal retreat at Newport, 1902 and 1912 to 1964. →

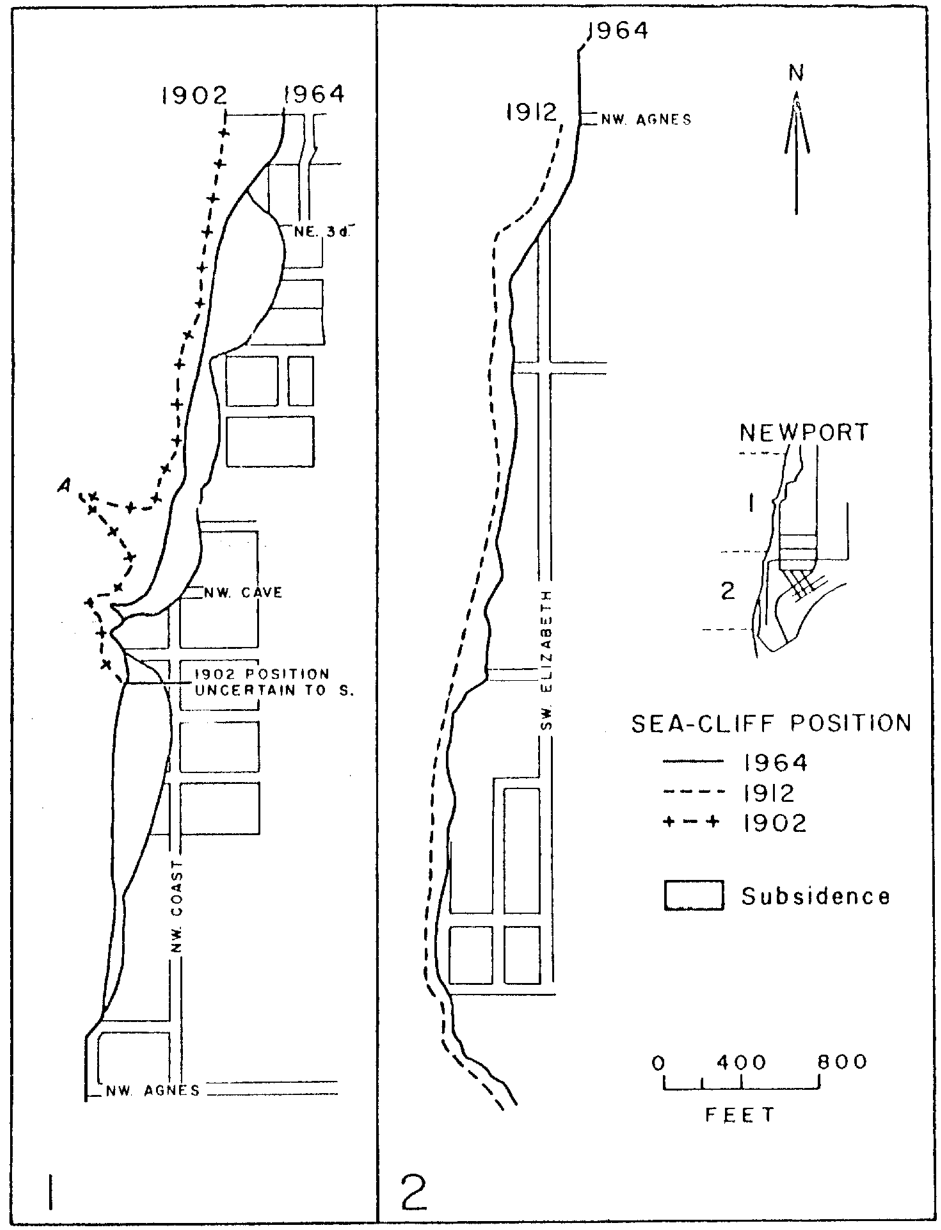


Figure 15. Low-cost preventive measures: riprap and "keep off" signs at Oceanlake (Lincoln City).

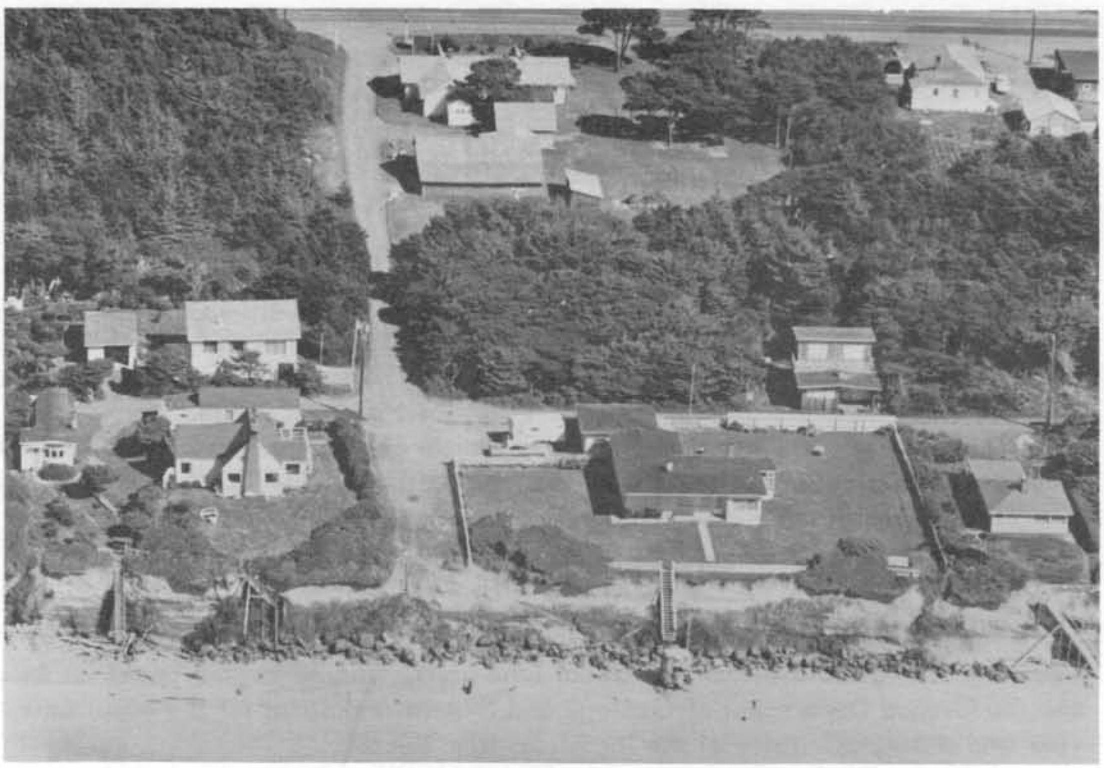


Figure 16. Riprap at base of sea cliff north of Seal Rock.

been 300 feet since 1953. Thus, in this area the average yearly coastal retreat is about 30 feet.

In Newport, coastal retreat has been equally serious (Figure 14B). Historical plat survey maps of 1902 and 1912 were used to indicate former positions of the sea cliff. Retreat of the coastline within the northern half of the city from 1902 to 1964 ranges from 35 to 490 feet. The range is smaller in the southern part, 40 to 220 feet for the period from 1912 to 1964. Thus, here the coast has experienced an average retreat of about half a foot to 8 feet annually.

Landslide Prevention

Total prevention of coastal landslides is an expensive undertaking. Such procedures as rock bolting, construction of complicated drainage systems, retaining walls and sea walls, and buttressing are well beyond the means of the average property owner. However, where limited steps have been taken to retard small but economically damaging slides, the results appear to be well worth the effort.

In Oceanlake and near Seal Rock attempts are now being made to control the undercutting of the terrace material. Basalt boulders piled at the base of the cliffs serve to weight the cliff base and prevent outward movement (Figures 15 and 16). Such riprap also lessens the wave impact on the cliff base by providing a leading edge of resistant material to absorb much of the wave energy.

On U.S. Highway 101 at Boiler Bay, north of Depoe Bay, a successful attempt has been made to prevent waves from undercutting the highway on the east edge of the bay (Figure 7). The entire exposure of Astoria Formation and overlying terrace sand has been covered by riprap. This inexpensive measure has retarded cliff recession and probably has saved a section of the highway.

Grass and low brush planted on slopes hold sand in place and help to prevent rain and runoff from eroding property. On the inhabited slopes of Tillamook Head, property owners who allow brush and grass to flourish have had little trouble with slippage or destruction of stairs or structures on the hillside. Even in very soft terrace sands of Lincoln City, the few attempts at planting to stabilize slopes have helped local erosional problems. Extensive planting of grass on unconsolidated sands along the beach at Salishan is helping to hold steep slopes.

Other preventive measures include terracing and reduction of cliff angle by lowering and leveling the cliff top and dumping extra material in front of the cliff. Wooden rain covers have been built on some cliffs. Warning signs and fences have partially succeeded in protecting cliff faces from public destruction.

Where property owners have remained indifferent to implementation of nominal preventive measures, beach stairways, cottage yards, and even dwellings have tumbled over cliffs. Simple safeguards, however, have more than paid for themselves.

Acknowledgments

Appreciation is expressed to the County Assessors of Tillamook and Lincoln Counties, who made available historical land plats. Thanks go to Richard G. Bowen and the Oregon Department of Geology and Mineral Industries for the opportunity to view and photograph many of the landslides from the air.

This report is based on a master's thesis by William B. North carried out under Office of Naval Research contract NONR 1926 (02).

References

Allen, John Eliot and Lowry, Wallace D., 1944, An investigation of the sea-cliff subsidence of March 30, 1943 at Newport, Oregon (abs.): Oregon Academy of Science Proc. 1: 31 (1943-1947).

Baldwin, E. M., 1956, Geologic map of the lower Siuslaw River area, Oregon: U.S. Geol. Survey Map OM 186.

Byrne, John V., 1963, Coastal erosion, northern Oregon. In Essays in Marine Geology in Honor of K. O. Emery. Los Angeles, Univ. Southern California Press, p. 11-33.

____________, 1964, An erosional classification for the northern Oregon coast: Assn. American Geographers Annals 54, p. 329-335.

Dicken, Samuel N., 1961, Some recent physical changes of the Oregon coast: Eugene, Oregon, Univ. of Oregon Dept. of Geography, 151 p.

Diller, Joseph Silas, 1896, A geological reconnaissance in northwest Oregon: U.S. Geol. Survey Ann. Rept. 17, pt. 1, p. 441-520.

Eckel, Edwin B. (ed.), 1958, Landslides and engineering practice: Washington, D.C., Highway Research Board (Nat. Acad. Sci. National Research Council Pub. 544, Highway Research Board Spec. Rept. 29, 233 p.)

Ladd, George Edgar, 1935, Landslides, subsidence, and rock falls: American Rwy. Eng. Assn. Bull. 37(377), p. 1-72.

North, William B., 1964, Coastal landslides in northern Oregon: Oregon State Univ., Dept. of Oceanography master's thesis, 85 p.

Schlicker, H. G., 1956, Landslides: The ORE BIN, vol. 18, no. 5, p. 39-43.

Schlicker, H. G., Corcoran, R. E., and Bowen, R. G., 1961, Geology of the Ecola State Park landslide area, Oregon: The ORE BIN, vol. 23, no. 9, p. 85-90.

Sharpe, C. F. Stewart, 1938, Landslides and related phenomena: New York City, Columbia Univ. Press, 137 p.

Smith, Warren D., 1933, Geology of the Oregon coast line: Pan-American Geologist, vol. 59, p. 33-44.

Snavely, P. D., Jr., and Vokes, H. E., 1949, Geology of the coastal area from Cape Kiwanda to Cape Foulweather, Oregon: U.S. Geol. Survey Map OM 97.

Terzaghi, Karl, 1950, Mechanisms of landslides: In Application of Geology to Eng. Practice, Berkey Vol. Geol. Soc. America, p. 83-123.

U.S. Coast and Geod. Survey, 1962, Approaches to Yaquina Bay, rev. ed. 1 sheet (Bathymetric chart 6056).

Vokes, H. E., Norbisrath, Hans, and Snavely, P.D., Jr., 1949, Geology of the Newport-Waldport area, Lincoln and Lane Counties, Oregon: U.S. Geol. Survey Map OM 88.

Warren, W. C., Norbisrath, Hans, and Grivetti, R. M., Geology of northwestern Oregon west of Willamette River and north of Lat. 45° 15': U.S. Geol. Survey Map OM 42.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U.S. Geol. Survey and Oregon Dept. Geology and Mineral Ind.

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NEW RECORD SET IN WORLD MINERAL PRODUCTION

The U.S. Bureau of Mines has announced that world mineral production reached a new high in 1964. On the basis of a detailed study of 65 mineral products, the bureau estimated that production of 43 of them reached new peaks in 1964.

The bureau's appraisal showed that aluminum production in the world was 10.7 percent above its former record of 1963. Production of bauxite increased 9.7 percent. Copper also reached a new world peak in 1964; mining output was 4 percent larger than 1963. Production of zinc and tin rose 9 and 2 percent respectively over 1963, but lead declined 2 percent. World production of steel ingots and castings in 1964 was 13 percent higher than in 1963.

Of the precious metals, gold rose to a new high, more than 4 percent above 1963. Silver production declined about 1 percent in 1964, compared with the previous year.

Against a background of growing world energy requirements, coal remains the chief source of power. However, its proportional share of total energy requirements continued the declining trend which has generally prevailed since the turn of the century. The production of coal increased 3.8 percent over 1963 and petroleum rose 8 percent.

Most of the 23 nonmetallic minerals included in the Bureau of Mines tabulation rose to new production highs in 1964. They were: asbestos, hydraulic cement, diatomite, feldspar, fluorspar, gypsum, magnesite, mica, phosphate rock, potash, pyrites, salt, strontium, sulfur, talc, and vermiculite. (American Mining Congress News Bulletin No. 65-22, Oct. 27, 1965)

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MINING ACTION PENDS IN CONGRESS

H. R. 11711 - Mineral Exploration: Ullman (Ore.). Committee on Ways and Means (a clean bill, substituted by the committee for H. R. 4665). Would allow current deduction of exploration expenditures incurred before development stage, subject to recapture as ordinary income or depletion deduction at producing stage. Committee amendment limits application of bill to deposits within the United States or outer continental shelf, and excludes coal. The committee report is expected in January.

H. R. 10194 - Recordation of Mining Claims: Aspinall (Colo.) (by request of the Interior Department) (Leg. Bull. 65-8, p. 1). Identical to S. 2248 by Senator Jackson (Wash.) (Leg. Bull. 65-7, p. 1). In House Interior Committee; no hearings yet scheduled.

Would require owners of all unpatented mining claims to file a statement with the Secretary of the Interior regarding the location and ownership of their claims. Statements pertaining to claims located prior to enactment would have to be filed with BLM within two years after enactment, and statements relating to locations made after enactment would have to be filed within 90 days following location of the claim. Failure to comply with these requirements within the times specified would terminate the rights of the holder to the mining claim.

Would also require mining claimants to file with the Secretary, within 90 days after the expiration of every annual assessment year, a statement of the assessment work performed during that year. Failure to file such a statement for two consecutive years would result in termination of the mining claimant's rights to the claims involved. (American Mining Congress Legislative Bull. No. 65-10, Nov. 5, 1965)

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AMERICAN MINING CONGRESS PASSES RESOLUTIONS

The American Mining Congress passed a number of resolutions on policy statements at its annual meeting, held this year at Las Vegas, Nevada, October 11 to 14. Statements from resolutions on public lands and on gold are given in digest below.

Public lands

Our growing population, expanding economy and modern armament require a constant increase in the supply of minerals and metals. This is the responsibility of the American mining industry. For the mining industry to meet these demands under a free-enterprise system, the public lands of the United States must be freely open to location so that the prospector and engineer can make new discoveries and open new mines.

The law of discovery, as intended by Congress in enacting the mining laws and as interpreted by the contemporaneous decisions of the courts, encouraged the search for and development of new ore deposits. The law of discovery recently has been so far distorted by the office of the Solicitor of the Department of Interior as to discourage rather than encourage this search. And as a result of such an interpretation of the mining laws, the titles of unpatented mining claims have become uncertain. The original concept of discovery, it was continued, should be restored.

The Department of Agriculture and its Forest Service and the Department of Interior and its Bureau of Land Management, and all other governmental agencies dealing with the public lands, were urged to administer their regulations fairly and uniformly, and to formulate and carry out their regulations in a manner which will encourage and not discourage the development of our mineral resources.

Gold

It was urged that immediate steps be taken to stimulate domestic gold production. While the United States' complex monetary problems will not be solved by any probable increase in gold production, nevertheless, since any increment in the gold reserve is in the national interest, the organization recommended enactment of legislation by the Congress of the United States to provide tax incentives or financia assistance payments, or both, to present and potential domestic gold producers to stabilize and insure greater life of existing properties, to reopen closed mines, and to stimulate aggressive search for new gold ore reserves.

It was recalled that a federal financial incentive program activated exploration which led eventually to the creation of a vigorous domestic uranium mining industry, and it was urged that by the same token federal financial assistance payments would lead to revitalization of the gold mining industry in the mining camps of the West.

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ANOTHER 7,600 ACRES TO BE WITHDRAWN

The Corps of Engineers, United States Department of the Army, has filed an application for the withdrawal of nearly 4,000 acres of land from all forms of appropriation under the public land laws, including the mining and mineral leasing laws. The land involved lies along Elk Creek, a tributary to the Rogue River in Jackson County. The applicant desires to use the land for flood control, irrigation, hydroelectric generation, and other authorized purposes in connection with the Elk Creek Reservoir Project.

A second withdrawal totalling 3,309 acres has been requested by the Corps in Jackson County. The withdrawal is related to the Lost Creek Reservoir Project on the Rogue River.

Still another withdrawal involves 320 acres in Morrow County for use in connection with the John Day Wildlife Management Area.

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WORLD-WIDE SURVEY OF THERMAL SPRINGS PUBLISHED

"Thermal Springs of the United States and Other Countries of the World -- a Summary," by Gerald A. Waring, revised by R. R. Blankenship and Ray Bentall, has been published by the U.S. Geological Survey as Professional Paper 492.

The first part of the 383-page book describes briefly the origin and characteristics of thermal springs in general; presents maps showing their distribution, including a map of Oregon; and tabulates the springs throughout the world by country and geographic area. Information given includes location, temperature, rate of flow, chemical quality, and associated rocks. For Oregon, 126 thermal springs are reviewed. The second part of the paper is devoted to bibliographic references, also arranged geographically.

Professional Paper 492 is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C., 20402. The price is $2.75 (paper cover).

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ENGINEERING GEOLOGISTS FORM LOCAL CHAPTER

A local chapter of the Association of Engineering Geologists was founded on June 29, 1965, at a meeting held in Portland, Oregon. The AEG is a national organization made up primarily of geologists whose work is related to engineering. There are several classes of membership, depending upon the interest and experience of the member.

Anyone wishing to inquire about the local chapter should contact Douglas A. Williamson, Chairman of the Oregon Section of the AEG, 697 W. 12th Street, Eugene, Oregon, or Paul W. Howell, Membership Chairman, 9130 S. W. Borders Street, Portland, Oregon.

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