When the water depth shoals to less than ¼ the crest-to-crest distance between successive deepwater waves, the waves begin "to feel the bottom" and to adjust their speed in accordance with changes in the local bathymetry. This influence of depth on the propagation of waves increases with continued shoaling until, for shallow-water depths of less than 1⁄20 the wavelength, it becomes the dominating factor.

As a deepwater wave travels into shallow water, it undergoes two important alterations in its speed of propagation. First, the wave propagates at exactly the same speed as the group as a whole, compared to deep water where its speed is twice the speed of the group. Second, the wave speed becomes directly proportional to the square root of the water depth, whereas in deep water its speed is totally independent of depth. More specifically, in deep water, the wave speed $C_d = \sqrt{gL/2\pi}$, where L is the wavelength and g is the acceleration of gravity, whereas in shallow water $C_s = \sqrt{gD}$, where D is the total depth of water beneath the wave. The first alteration means that in shallow water it is possible to stick with an individual wave as it advances over the bottom, much as surfers do. In this case, the waves behave more like a collection of solitary waves, each independent of the other, than a closely tied group within a wave train. The second alteration leads to an important phenomenon called refraction, the bending or curving of the direction of travel of a wave as it encounters changes in the factors that affect its speed. (As an analogy, mirages and the shimmering of hot pavement are produced by the refraction of light "waves" as they pass through layers of air of different temperature. The bending occurs because the speed of light increases as the air becomes warmer. Refraction causes the apparent bending of an oar sticking out of the water, as shown in Fig 8.1). Intermediate-water waves are also refracted by the bottom but to a lesser degree than shallow-water waves.

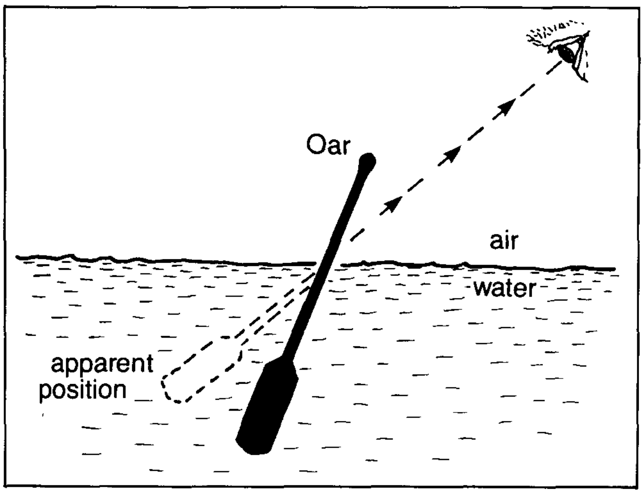

FIG. 8.1. Apparent bending of oar due to refraction of light as it passes from water to air. Speed of light increases as density of medium decreases, so light ray emerging from water is curved toward sea surface. Projection of ray paths back from observer's eye, makes oar appear bent and slightly smaller.

Refraction

The bending of wave patterns in shallow water stems from the direct dependence of wave speed on depth. If one part of a wave's crest (or trough) is in deeper water than an adjoining part of the same crest (or trough) the former will move more rapidly and the wave front will curve round. The bending always occurs in such a way that the wave becomes more aligned with the contours of the bottom (Fig. 8.2). This is the reason waves on a beach are always closely parallel to the shoreline just before they break, despite the fact that they may initially approach the beach at large angles. The old saying that "points of land draw the waves" derives from the fact that refraction tends to concentrate waves at headlands but to diffuse them in bays. Refraction also causes waves to concentrate over submarine ridges and to spread out over submarine canyons, and accounts for the existence of criss-cross wave patterns in the lee of an island where one would normally expect to be shielded from any wave action (Fig. 8.3, 8.4). Finally, longer waves such as swell are bent more than shorter waves simply because they feel the bottom sooner and have more time to be influenced by the changing bottom contours.

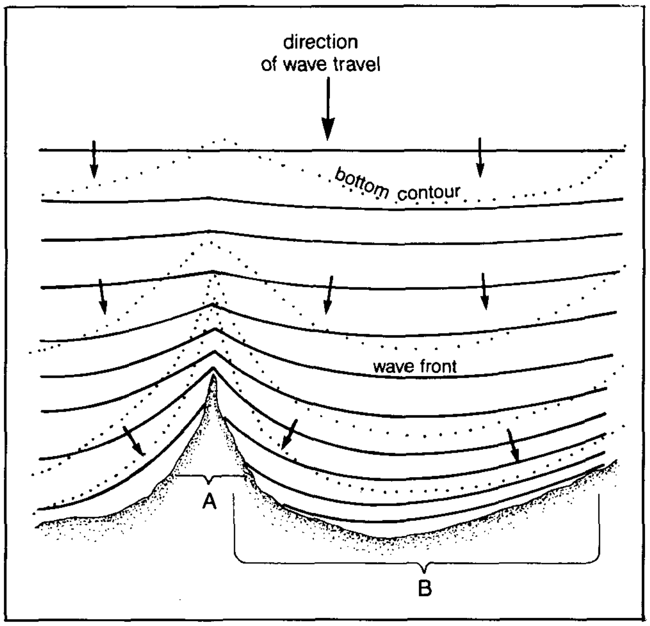

FIG. 8.2. Refraction of ocean waves approaching a coast. Bathymetric contours (dotted lines) shoal shoreward. Wave crests (solid lines) propagate in direction of arrows or "rays." Waves converge toward submarine ridge and associated point of land, A, and diverge outward within embayment, B.

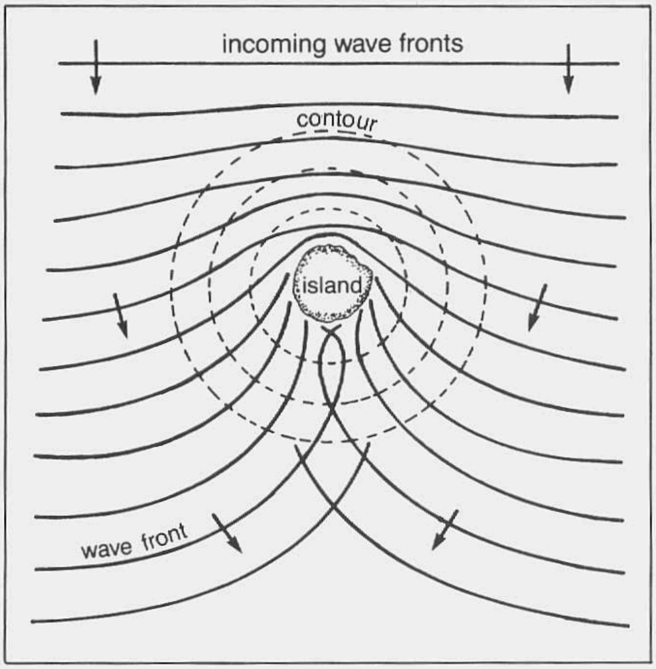

FIG. 8.3. Refraction of swell around nearly circular island forms criss-cross interference pattern in lee geometric shadow zone. Broken lines represent bottom contours with depths increasing gradually outward.

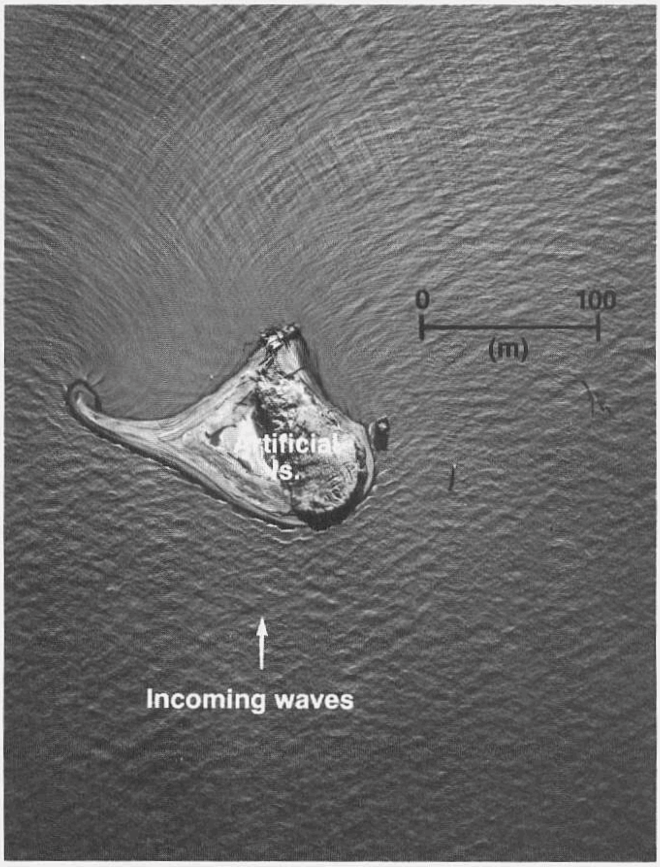

FIG. 8.4. Refraction of wind waves around artificial island (Netserk F-40) in Beaufort Sea immediately seaward of Mackenzie River delta (July 1978). Typical water depths 10 m in area. Refracted waves break parallel to shoreline and form criss-cross pattern in lee of island. Refracted waves curve sharply around to lee shore. (Courtesy F. Stephenson)

Refraction is somewhat responsible for the sloppy conditions around offshore shoals such as Swiftsure Bank. For example, swells with wavelengths exceeding 120 m and from the southwest would swing around as they passed over the Bank (minimum depth about 30 m). This in turn would lead to a concentration of wave energy on the northern side. In a sense, then, Swiftsure Bank acts like a giant imperfect "lens," which tends to focus the energy of the swell toward the Vancouver Island shoreline between Pachena and Carmanah points.

The tendency of swell heights to decrease within Juan de Fuca Strait is in part a refraction effect. Because the Strait is a submarine valley, it gradually deepens toward midchannel, and thereby causes the swell waves to bow outward as they advance. As a result, the energy of a particular swell is spread out and wave height diminishes. Eventually, of course, the waves become nearly aligned with the bottom contours and break at the shore where they give up their energy. Continuation of this process generally leads to ever-improving wave conditions inward along the axis of the Strait.

Diffraction

When waves impinge on a protruding barrier such as a jetty, breakwater, or sharply pointed promontory, a portion of the wave energy makes its way into the shadow zone behind the barrier by the process known as diffraction. As a consequence, there can be appreciable wave action in the lee of a natural or man-made breakwater that would seemingly have afforded a well-protected anchorage. The diffracted waves in such circumstances have not turned the corner in the sense of being refracted but have originated from the tip of the barrier, which acts like a source of waves as it scatters the original incoming waves in all directions (Fig. 8.5a). (Diffraction of light waves at the edge of an obstacle is the reason shadows are inherently fuzzy.)

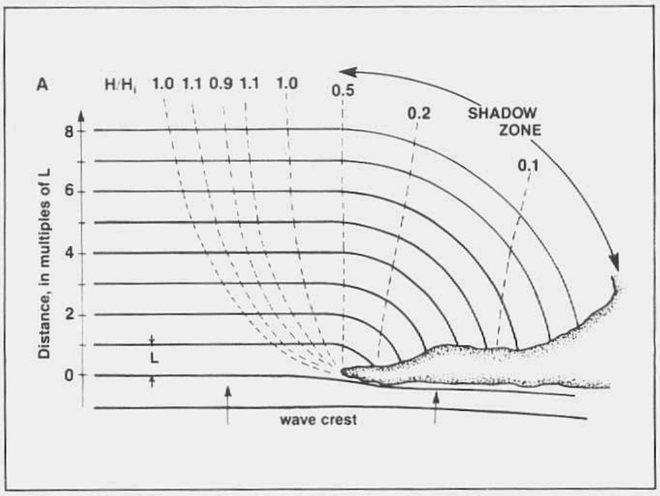

FIG. 8.5. (A) Diffraction of series of incoming waves by headland or jetty, waves penetrate into geometrical shadow zone behind barrier. Broken lines give ratio of local wave height (H) to incident height (H_i). Inward distances measured in multiples of incoming wavelength, L.

Although wave heights generally diminish rapidly in the lee of a barrier, there are certain areas close to the "line of sight" of the incoming waves where the amplitude of the waves is actually increased. The gap in an across-harbor breakwater or between two sand spits can also generate a complicated diffraction pattern (Fig. 8.5b). An example of diffraction occurs within the harbor of Oak Bay Marina near Victoria, which opens into the waters of Juan de Fuca Strait via a narrow gap in an artificial barrier (see Fig. 2.37a). Wave diffraction patterns can also be seen behind the Steveston, Iona, and North Arm jetties at the mouth of the Fraser River and in the lee of the Ogden Point breakwater at the entrance to Victoria Harbour.

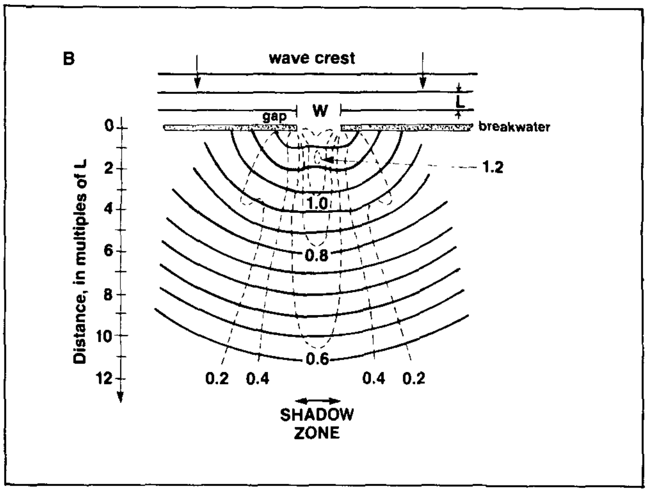

FIG. 8.5. (B) Diffraction of waves at breakwater gap width, W, equal to twice the wavelength, L. Broken line as in (A) (From U.S. Army Coastal Engineering Research Center 1977)

Reflection

In addition to refractive and diffractive effects, waves impinging on a coast may undergo total or partial reflection back to sea. The proportion of incoming wave energy reflected from a coast depends on the beach slope and the wavelength of the waves. The longer the waves for a specific beach slope the greater the reflection, because longer waves experience a greater change in depth over each wavelength than shorter waves; in a relative sense the beach appears steeper to long waves than to short waves.

For swell and wind waves that propagate over beach slopes flatter than about 10%, almost all the wave energy is lost to breakers and little returns seaward as reflected waves. Gently sloping beaches behave as almost perfect absorbers of waves. The energy given up by the breaking waves goes into the formation of currents, turbulence, noise, and the movement of beach sediments. As the beach face steepens, an ever-increasing amount of wave energy is reflected away from the shore. In the extreme case of a perfectly straight vertical wall or cliff that extends several wave heights beneath the water surface, the waves are totally reflected and initially reverse direction with only a slight decrease in height. This is common along the rugged coasts of British Columbia and Washington, and can further be seen where wind waves bounce off the hull of a large ship.

When reflection takes place, the reflected waves propagate away from the point of contact with an equal but opposite angle to that of the incident waves, like light from a mirror (Fig. 8.6). Therefore, waves that approach head-on to a smooth vertical cliff will be reflected along the same path as the incoming waves, leading to the formation of standing waves and a choppy sea within a short distance from the cliff. Confused, choppy sea conditions tend to exist close to steep shores when the waves strike at an angle. In this case, the inherent irregularities of the shoreline scatter the arriving waves in all directions, rather than along a single direction.

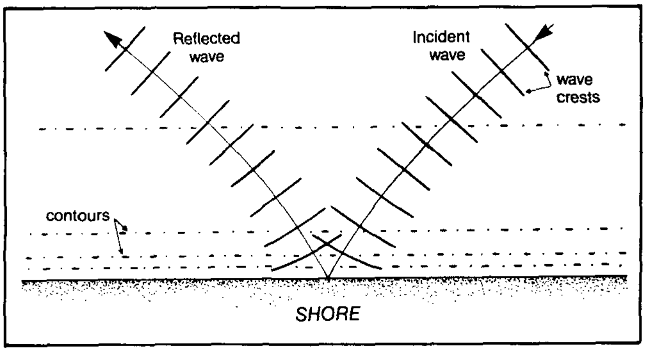

FIG. 8.6. Reflection of waves at comparatively steep coastline. Waves are refracted slightly before reflected, then refracted again as they propagate seaward.

Under certain conditions of beach slope and wavelength, refraction can combine with reflection to "trap" some of the incoming wave energy along a beach, shown schematically in Fig. 8.7. The reflected wave attempts to return to sea but is curved back toward the shore by the bottom topography and the process is repeated. In most situations, the trapping is usually far from perfect as irregularities in the bathymetry and wave patterns allow a fraction of the wave energy to leak seaward after each reflection. This, combined with other effects such as friction, causes the height of the trapped wave to diminish as it travels parallel to the beach and the wave eventually

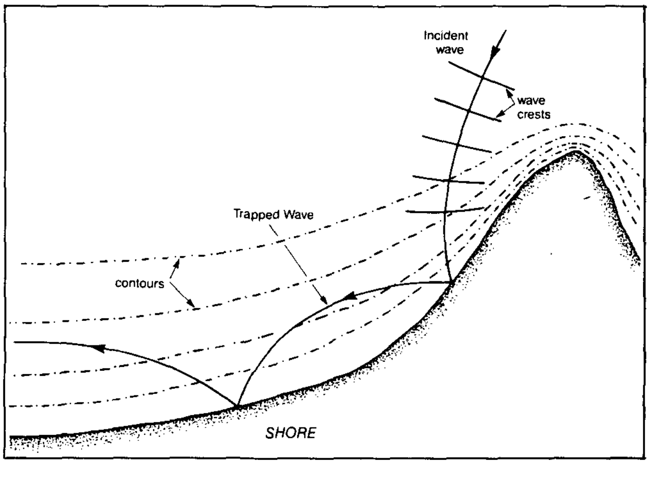

FIG. 8.7. Incoming waves trapped through combined reflection and refraction at coastline. For certain wavelengths and bottom slope, series of incident waves cannot return seaward after reflection and is confined to nearshore region. Friction and some wave energy leakage seaward gradually reduce wave height alongshore.

disappears. There is now observational evidence to show that ocean swell is commonly trapped over broad coastal beaches and that the energy of tides and tsunamis is often captured by continental shelf regions. Mid-ocean islands, seamounts, and banks also act as energy traps for tidal motions, and thereby cause complex tide and current patterns around their periphery.

Steepening

In addition to altering the speed, the transition from deep to shallow water changes the height and length of the waves. Only the period remains the same. Contrary to popular misconception, the height of a wave does not begin to increase immediately after it advances into a shoaling region. In fact, there is an initial lowering of the wave, although at most the decrease is usually less than 10% of the deepwater height (Fig. 8.8). Studies have shown that this reduction in wave heights takes place in water depths between ½ and 1⁄17 as large as the wavelength. A wave 170 m long would begin to decrease in amplitude when the water depth fell to 85 m and would not regain its original height until the depth shoaled to 10 m. Once the ratio of depth-to-wavelength becomes smaller than 1⁄17, there is a rapid increase in the height until break-point is reached.

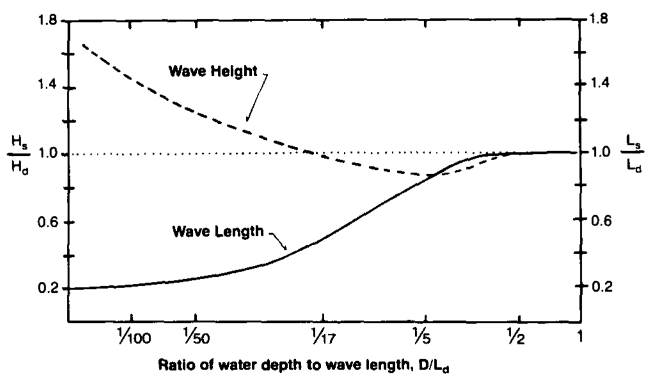

FIG. 8.8. Change in wave height (broken line) and wavelength (solid line) accompany decrease in water depth. Ratio H_s/H_d is height of wave in shoaling region divided by height in deep water; ratio L_s/L_d is wavelength in shoaling region divided by wavelength in deep water. (From King 1966)

Unlike the height, the length of a shallow-water wave continually decreases as the depth decreases (Fig. 8.8), and the decrease proceeds at a rate proportional to the lowering of the wave speed. The effect of this reduction in crest-to-crest separation is to increase the steepness of the waves as they enter shoaling water. This increase in steepness is at first small, because the tendency of the shortening wavelength to steepen the waves is partly counterbalanced by their initially lower amplitudes. When the ratio of the depth to the wavelength reaches 1⁄17 the steepening proceeds rapidly as both effects contribute to enhanced wave slopes.

Associated with the change in steepness is a change in wave form; the crests become narrower and more peaked, while the troughs become broader and flatter. This alteration is most noticeable for long low swells, which deform from smooth undulating crests in deep water to sharp conspicuous crests in very shallow water.

To what degree the offshore height of a wave will increase as the shore is approached depends on a number of factors, such as the shape of the wave, the slope of the beach, and the smoothness of the bottom. As a crude estimate, the height of an incoming wave will have increased by a factor of approximately 1.5 by the time it is ready to break. More exact values are given in Table 8.1, which shows growth of the incoming wave heights will be greater for greater beach slopes or for longer wavelengths.

TABLE 8.1. Ratios of breaker heights to the deepwater swell heights for four different beach slopes and for two values of the ratio of incoming wave height to wavelength. Example: value of 1.60 indicates that, for beach slopes of 5% (or 1 in 20) and for swell waves with lengths 100 times their heights, breakers are a factor of 1.6 higher than wave height in deep water. Values are applicable for low swell but not for steep sea waves whose growth would be less. (From Iversen 1952)

Slope (%)	Breaker height ÷ deep-water height	
	$\frac{\text{height}}{\text{length}} = 0.01$	$\frac{\text{height}}{\text{length}} = 0.02$
2	1.31	1.12
3.3	1.43	1.23
5	1.60	1.31
10	1.76	1.40

Long waves, therefore, amplify more than short ones and steeply sloping beaches enhance the wave heights more than gradually sloping beaches.

An increase in steepness occurs anywhere a wave begins to feel the bottom and is responsible for the amplification of long swell over shallow continental shelf regions.

Breaking

A shallow-water wave will break for two basic reasons: (1) the wave becomes so steep it can no longer support its own weight and the crest collapses. As mentioned in Chapter 6, this generally occurs when the wave height reaches 1⁄7 of the wavelength; or (2) the speed of the water that circles around with the crest of the wave exceeds the speed of the wave, so the water in the crest overtakes the wave form, and causes it to fall over and break. A rule of thumb used by oceanographic engineers is that a wave will break when its height exceeds ¾ of the local water depth. Thus, a 3-m swell would break in 4 m of water (water depth is always measured at a point half way between the trough and crest). As previously mentioned, the height of the wave when it breaks will be about 1.5 times larger than its height in deep water.

For the sake of definition, breakers can be placed into four categories: spilling, plunging, collapsing, and surging, although in reality these often grade into one another. Spilling breakers move forward with a foaming turbulent crest (Fig. 8.9). The wave does not lose identity

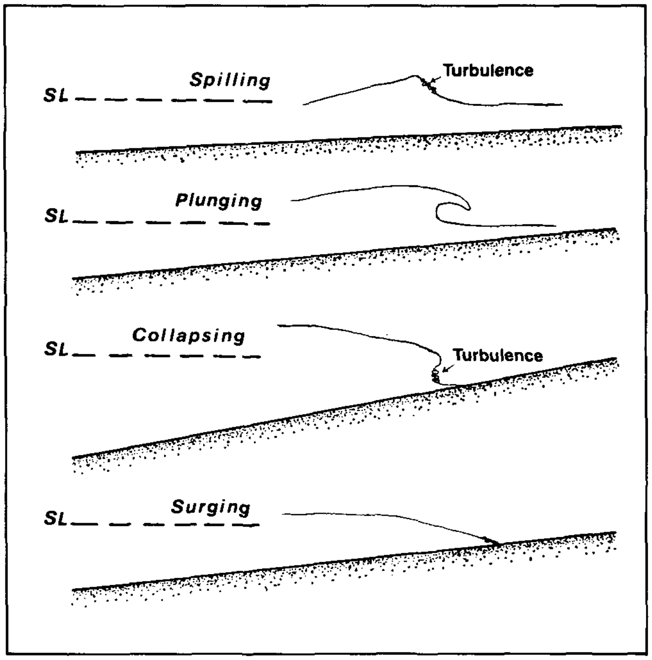

FIG. 8.9. Cross-sections of the four types of breakers (SL, approximate mean sea level). (From Galvin 1972)

but gradually diminishes in height until it becomes a swash on the shore. Breakers of this type are formed when steep, deepwater waves advance over a gently sloping, often sandy, beach. They are responsible for the rows of breakers that generally characterize many wider shoals and beaches along the exposed outer coast. Plunging breakers collapse with a splash as the crest curls over and falls into water receding from the previous wave. This type of breaker occurs when relatively low, deepwater waves move up a steep beach; shingle beaches commonly have plunging breakers. A collapsing breaker is somewhat similar to a plunging breaker. The difference is that the initial point on the vertical wave front from which the curling tongue of water originates is well below the point of maximum height of the wave. Moreover, the wave essentially collapses right onto an exposed beach face rather than into a depth of water associated with the previous wave as with plunging breakers. Lastly, the waves may not really break at all, but instead retain relatively smooth profiles that slide up and down the beach with only a minor display of foam and turbulence. These are surging waves.

Observations indicate that, for a specific beach and constant wave period, the type of breaker changes as the incoming height of the wave increases. As the wave height increases, the breakers change from surging to collapsing to plunging to spilling. The same sequence is found if the wave height and wave period are kept the same but the slope of the beach is continually decreased; it also occurs if the height and beach slope are kept fixed but the wave period is decreased.

The zone between the breaker line, delineated by the first series of breakers, and the shore is called the surf zone. The zone between the last breaker and dry land is called the swash zone (see Fig. 2.16).

Longshore Currents

One important aspect of breaking waves is their ability to generate currents that flow parallel to the shoreline within the surf zone. These longshore (or littoral) currents occur because each wave thrusts the water forward when it breaks. They form (1) when crests of the breaking waves approach the shoreline at an angle, or, (2) when there is a gradation of the breaker heights from one part of the surf zone to another.

In the first case, the current is produced directly through the accumulated effect of many breakers over a period of time. For this current to flow parallel to the shoreline the waves must break at an angle to the shoreline, so each breaker has the tendency to push the water along the beach. The onshore component of each breaker's thrust, on the other hand, does not create an onshore current because the effect is counterbalanced by an offshore pressure gradient. In this particular process, shorter waves produce stronger currents than longer waves of the same height because they suffer less refraction and are more likely to approach the beach at an angle. Currents in excess of 50 cm/s can be generated in this way during prolonged periods of high waves.

In the second case, the higher breakers pile up more water in the surf zone than lower breakers, regardless of how they approach the beach. As a consequence, a current is set up parallel to the shore to transport water away from the region of the larger breakers. This process together with the previous one, is a regular cause of longshore currents along the North American west coast. Currents of this nature are also generated over broad expansive shoals in the Strait of Georgia, such as Roberts Bank and Sturgeon Bank off the mouth of the Fraser River. The transport of sediments and pollutants and the erosion of shorelines are important engineering aspects of these currents. Ediz Hook and Dungeness Spit on the southern shore of Juan de Fuca Strait are extensive sediment deposits created in part by the longshore currents set up by predominantly eastward propagating waves that break in the Strait.

Rip Currents

Actually, the along-the-shore extent of a longshore current is always limited and the water that has accumulated in the surf zone through the action of the breakers must eventually return to sea. It often does this by forming a series of strong narrow currents called rip currents that flow directly seaward through the surf zone. The longshore current is said to "feed" the rip current. (A typical surf zone current regime is in Fig. 8.10). Rip currents can attain speeds of 1.0–1.5 m/s (2–3 kn) within the surf zone, but spread out and decelerate once outside the zone. The location of these currents is often marked by deep channels through the sand bars, which give the water a darker appearance. Because of the enhanced depths, moreover, waves rarely break in rip channels, although the effect of the opposing rip current may cause very short waves to form a chop similar to a wind chop. Along the

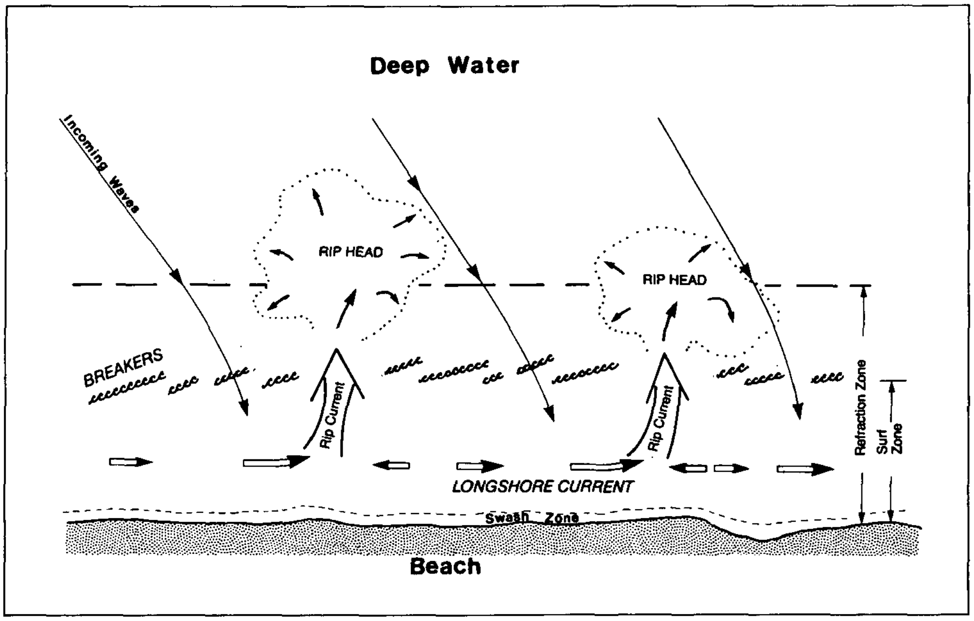

FIG. 8.10. Schematization of nearshore circulation regime generated by breaking waves that advance shoreward at an angle to beach. Refraction begins when waves reach refraction zone at ½ depth of incoming wavelength. Rip current diverges and weakens at rip head. Similar pattern occurs if waves approach beach head-on, but breakers on left higher than on right.

beaches of southern California, there is always a noticeable longshore current produced by the large ocean swell that breaks at the exposed Pacific coast. Rip currents can be seen as intense flows that lead seaward via deep, narrow, breakerless channels. While body surfing off Long Beach (Vancouver Island) and Kalaloch Beach (Olympic Peninsula), the author has been aware of fairly strong longshore currents, and distinct rip currents in the lee of offshore rocks and shoals.

It should be pointed out that why rip currents form is still not fully understood, although the location and intensity of these currents apparently depend on the submarine topography, the configuration of the coast, and the height and period of the waves. Anyone venturing into the surf zone should be prepared if they unexpectedly find themselves swept seaward. According to all authorities, the best plan is not to struggle against the current but to swim across it. Because rip currents are always narrow, a swimmer will soon find himself in a region of reduced flow, where the shoreward propagating waves will tend to carry him shoreward. From a precautionary point of view it is worth noting that rip current and longshore current velocities strengthen on a falling tide, greatest increases take place immediately prior to low tide when water draining from the beach is directed toward the deeper rip channels where it adds to the seaward flow. This effect is particularly relevant to beaches along the coasts of Washington and British Columbia, where the tidal range is large. But not everyone treats rip currents as sinister manifestations of the circulation pattern in the surf zone. Experienced surfers, boaters, and scuba divers, for example, will sometimes use these seaward currents to get a free ride through the breaker zone into deeper water. Rip currents may also be essential to the removal of pollutants dumped into the nearshore region.

The study of rip currents began in the early 1940s on the beaches of California, where it was discovered they were an integral part of nearshore circulation cells similar to Fig. 8.10. Often there were a series of cells and associated rips strung out along the length of the beach. The alongshore spacing between the rip currents was aproximately 4 times the distance from the shoreline to midpoint of the breaker zone. Early evidence further showed that the velocity and seaward extent of the rip currents was related to the height of the incoming waves and that rips were located away from the largest breakers. Where the waves were breaking at an oblique angle to extensive beaches, the location of the rip currents slowly migrated along the beach in the direction of the longshore current. It is now thought that rip currents are linked to an alongshore variation in wave set-up, the lumping up of sea level above the still water depth due to breaking waves. Longshore currents flow away from regions of greater set-up (higher breakers) and feed into seaward flowing rip currents at alongshore locations of lesser set-up (lower breakers). Thus, the problem of accounting for the locations and strengths of rip currents is reduced to an understanding of the longshore variation in wave set-up.

The most obvious mechanism capable of producing such variations is wave refraction, whereby the offshore bottom contours cause wave energy to concentrate into one area to produce high waves, and to diverge at an adjacent area to produce low waves. Submarine canyons and ridges are capable of generating rip currents in this way (Fig. 8.11). Refraction may also be responsible for the rip current pattern along Long Beach on the west coast of Vancouver Island (Fig. 8.12). The inward curvature of the bottom contours causes incoming waves to diverge away from three main areas that mark the locations of major rip currents: the center of the beach off Green Point, the large

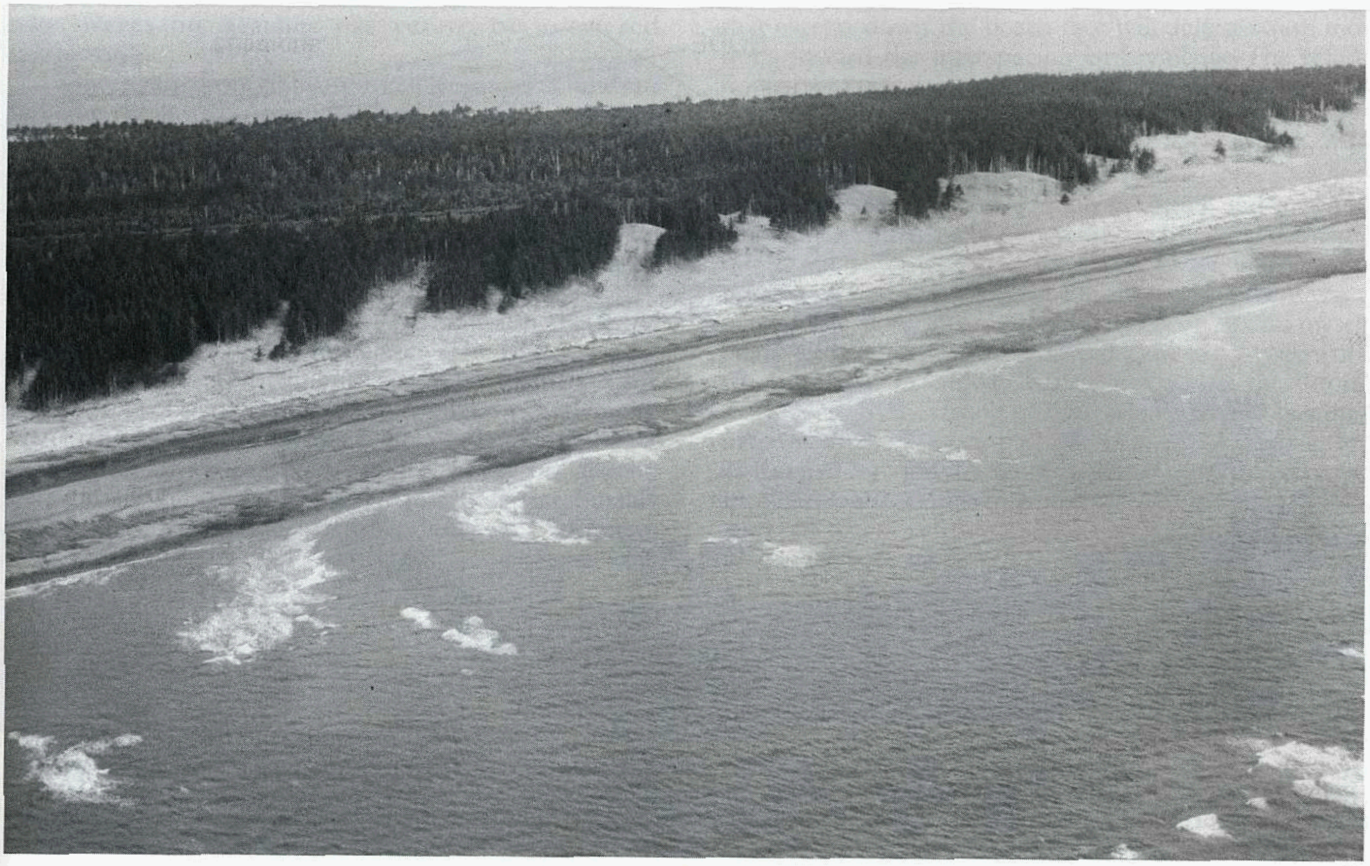

FIG. 8.11. Modified rip cells (horizontal circulation cells) near Rose Spit, Queen Charlotte Islands, July 1979. Rhythmically spaced cells caused by waves breaking over bars that project from shoreline; circulation pattern is shoreward flow along transverse bars and seaward rip current mid-way between bars. Large dunes in background over 10 m high and driven into forest by strong southeasterly gales. (Courtesy J. Harper)

rock offshore of the Airport road, and the area in front of the former Wickannish Inn. Midway between these areas, and at the prominences at either end of the beach, the waves converge to produce comparatively large breakers that drive the longshore currents feeding into the rip currents.

In many instances, the offshore beach profiles are uniform so refraction is the same along the entire beach and there is no differentiation in wave set-up, yet rip currents still persist. This fact has recently led to a theory based on the combined effect of incoming waves with another type of surface wave called an edge wave. Unlike the shoreward propagating sea or swell waves, edge waves depend on the beach or "edge" for their existence, and lean against it for support much like an ordinary wave traveling along a wall or the side of a pool. Thus, the crests

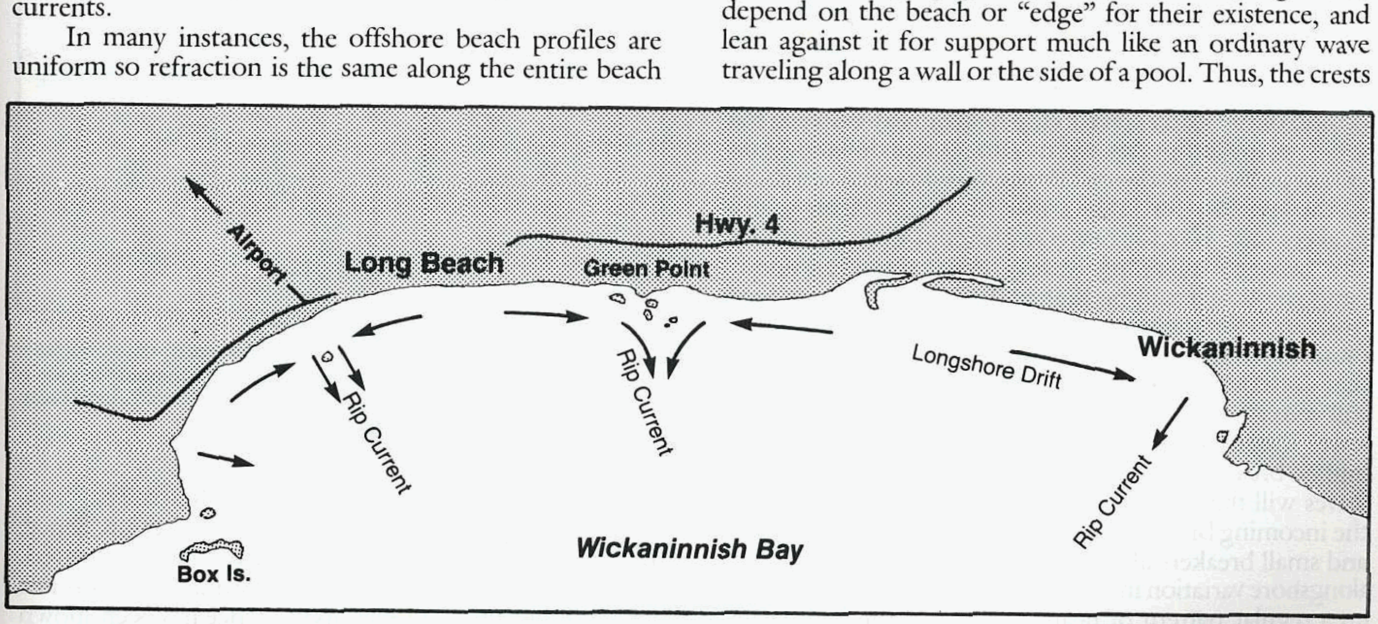

FIG. 8.12. Prevailing pattern of longshore currents and rip currents during summer in Wickaninnish Bay (Long Beach) on west coast Vancouver Island. (Parks Canada 1974)

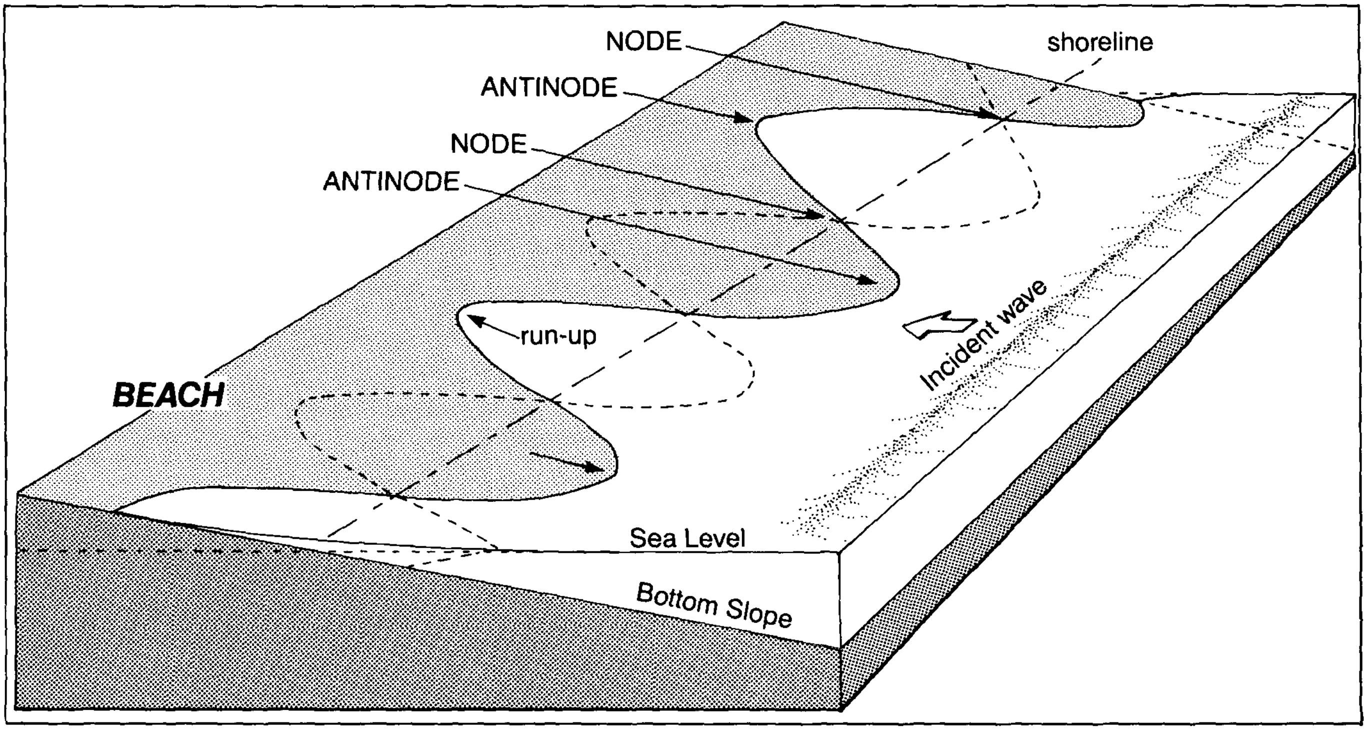

FIG. 8.13. Schematic diagram of simple standing edge wave pattern at gradually sloping shoreline. Solid line and broken line mark water's edge along beach at two different times (½ cycle apart) of an edge-wave cycle. Motions at antinodes are cyclic reversals of run-up and backwash; no edge-wave induced motions at nodes. Combined effect of breaking incident surface gravity waves and edge wave are responsible for nearshore circulation patterns as in Fig. 8.14.

and troughs of edge waves are at right angles to the shoreline rather than parallel to it. In addition, they attain maximum heights or depressions close to shore, accompanied by a rapid decrease in height seaward where they become negligible just outside the breaker zone (Fig. 8.13). Edge wave motions oscillate between run-up and backwash along the length of the sloping beach face. To produce the observed patterns of rip and longshore currents, standing edge waves of the same period as the incoming waves must be present along the beach. At the position of the nodes there will be no up and down motion of the water elevation, while midway between the nodes, at the antinodes, maximum up and down motion will occur. Because the up–down motion at the antinodes has the same rhythm as the arrival time between successive breakers (e.g. 10 s for one complete up–down cycle and 10 s between incoming waves), every second antinode along the beach will be higher than the still water level when an incoming wave breaks. The two effects combined cause higher than normal breakers at fixed locations. Adjacent antinodes, on the other hand, are always below the still water level at the instant of breaking, and result in lower than normal breakers midway between regions of higher breakers. Only at the nodal points of the edge waves will there be no additional effect on the height of the incoming breakers. This persistent generation of large and small breakers along the beach produces a consistent alongshore variation in breaker height, which in turn, sets up a regular pattern of nearshore circulation cells, with rips at the positions of the low breakers at every second antinode of the edge wave (Fig. 8.14).

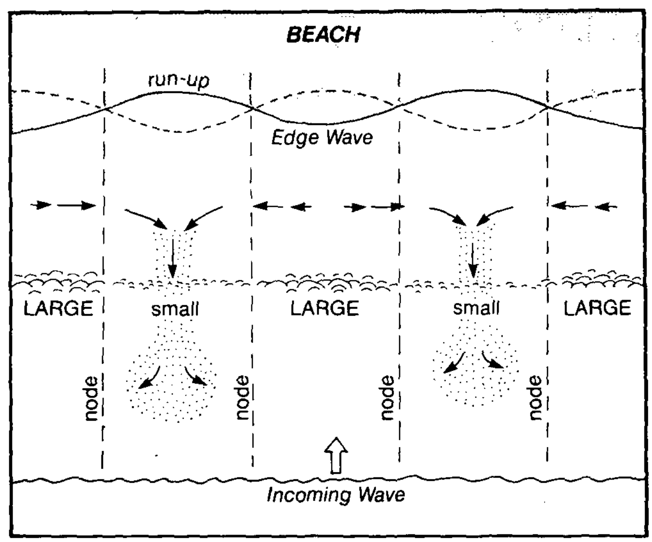

FIG. 8.14. Plan view of Fig. 8.13 shows position of rip currents relative to edge-wave nodes. Small breakers occur where combined heights of incoming surface waves are partially reduced by edge wave; large breakers where two types of waves reinforce one another.

Various researchers have advanced alternate explanations for along-the-beach variations in wave set-up, hence, rip formation, and to date the problem is far from solved. Indeed, the edge wave concept for natural beaches is not universally accepted, though its existence has been shown to be responsible for rip formation in laboratory model basins. The basic question about the origin of the standing edge waves on beaches has yet to be answered satisfactorily.

Once a nearshore circulation cell is created, it tends to stabilize the bottom configuration through scouring. This can then act to stabilize the rip current positions, and make them less susceptible to changes in the edge wave or incoming wave patterns. With the establishment of a series of submarine bars and rip channels there need no longer be an alongshore variation in breaker height to maintain the longshore-rip current circulation.

A large-scale cuspate shoreline may also mark the presence of well-defined rip currents. The rips flow seaward from the embayments between the rhythmic topography of sediment-formed prominences and underwater ridges, although certain evidence suggests that once the cuspate structure is fully established the rip currents that initially produced it weaken and disappear. Smaller scale beach cusps of ridges or mounds of coarse sediments that extend down the beach face will deflect swash motions toward the interspacing embayments. The return flow concentrates into something resembling a "rip current" though, unlike a true rip current, velocities are not steady with time and do not depend on a gradation in offshore breaker height.

Man-made structures, such as jetties and groynes, sometimes initiate riplike currents by deflecting the natural littoral drift away from the shore. Once, when swimming on a deserted beach in Fiji over which there was a perceptible alongshore current, I suddenly found myself being swept seaward as I drifted close to a rock-work structure that extended about 10 m across the littoral zone. Though the strong offshore flow presumably terminated a short distance past the end of the groyne, my instinctive reaction was to swim across the current and to speculate on its extent from the safety of the shore!