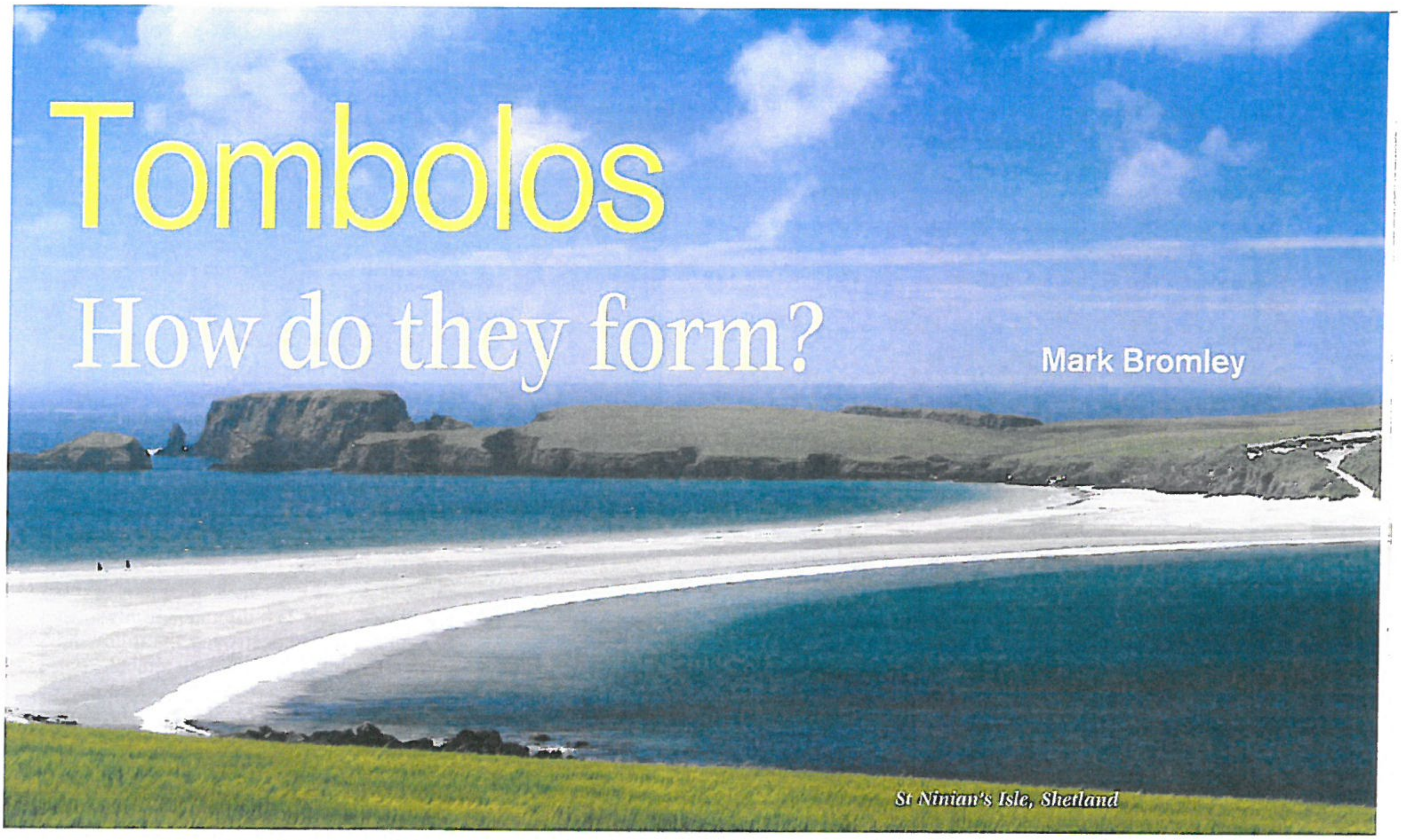
Tombolos

How do they form?

Mark Bromley



St Ninian's Isle, Shetland

Coasts are a major AS topic for all the main exam boards. This article looks at tombolos, depositional coastal landforms made up of beaches that connect islands to the mainland. It uses case studies from Peru to show the difference between true tombolos and similar-looking features of different origin, and to identify the reasons why tombolos develop in some places, but not in others.

A **tombolo** is a beach deposit which links an island to the mainland. Tombolos are formed by the effect of islands on wave approach to the coast. Islands act as obstructions, and cause waves to refract as they wrap around them. The waves then approach the coast at an angle from both sides of the island. Due to the action of **longshore drift** (Inset 1 and Figure 1) they move sediment around both sides of the island and it accumulates between the lee of the island and the mainland.

It is often difficult to identify true tombolos in areas that have experienced a lot of coastal development. The original processes become hidden under buildings which consolidate mobile sediments. In Britain, the largest active sand tombolo is on St Ninian's Isle in the Shetlands. Here the lack of development allows easy observation of the physical processes that built the feature. A tombolo may also join two islands together, as has happened at Isla Margarita, Venezuela.

Controls on development of tombolos

Two coastal geomorphologists from Japan, Sunamara and Mizuno, have predicted that the development of tombolos is controlled by the ratio between distance from the shoreline and the width of the island. They established a mathematical relationship that

Inset

Longshore drift

Longshore drift is a process by which sediment is moved along the coast. It is caused by waves arriving at an angle relative to the coast. This means that when a wave breaks on the beach, the **swash** moves sediment up the beach at an angle. When the water moves back down the beach (**backswash**) it is pulled by gravity straight down the beach slope.

The result, as shown in Figure 1, is that sediment is moved by the swash from A to B and then the backswash moves it from B to C. The overall movement of a particle of sediment from one wave is therefore from A to C. If this movement is repeated over a long period of time vast quantities of sediment can be moved along the coast in a certain direction, confirming the direction of longshore drift.

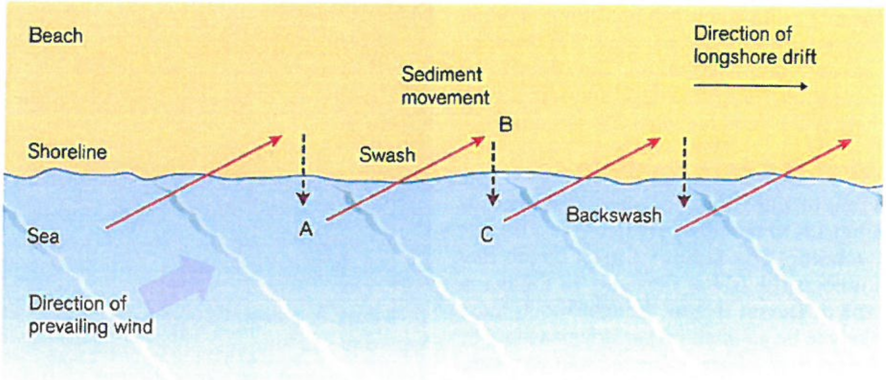


Figure 1 *Longshore drift*

Table 1 Ratios of distance from mainland to width of islands for the three locations in Peru

Location	Tombolo	Distance from mainland (*L*, metres)	Width of island (*J*, metres)	Ratio *L/J*	Comment
Puerto Viejo island 1	No	45	230	0.19	Expanded salient in summer
Puerto Viejo island 2	No	215	150	1.43	Temporary tombolo in summer only
Lagunillas	Yes	260.4	74.4	3.5	In theory there should be no tombolo
Mendieta	Yes	60.4	161.7	0.3	Fits the theory

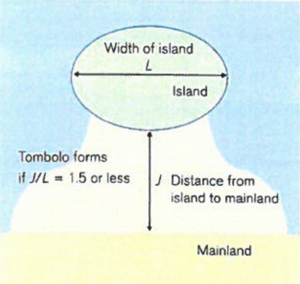


***Figure 2** If the ratio of the island's offshore distance (J) to its width (L) is equal to or less than 1.5 a tombolo is predicted to form*

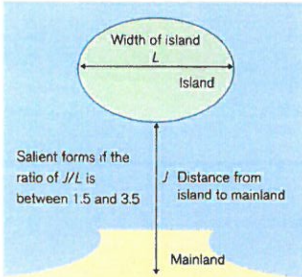


***Figure 3** If the ratio of the island's offshore distance (J) to its width (L) is between 1.5 and 3.5 a salient is predicted to form*

tombolos would only develop if the distance from the shore (*J*) was less than 1.5 times the island's width (*L*). This allows waves to refract around the island, becoming less powerful as they do so. It creates constructive waves, which meet in the lee of the island, depositing sediment. This sediment builds out from the island to create a tombolo.

If the ratio is greater than 1.5 a tombolo will not form. Instead, a sediment deposit in the lee of the island, known as a **salient**, will result. Figure 2 shows the conditions necessary for tombolo formation, and Figure 3 shows those required for the formation of a salient.

An island therefore has to be a critical distance from a beach if it is going to affect the plan-form of the beach. If the distance between the mainland and the island (*J*) is more than 1.5 times the island's width (*L*) there will be no change in the coastline.

What is a true tombolo?

Some of the beach features described as tombolos in the past may not in fact be true tombolos. The famous Chesil Beach that connects the Isle of Portland to the mainland of Dorset is now thought much more likely to be an offshore bar driven ashore by storms than a feature created solely by longshore drift in the lee of Portland. Chesil's extreme length in relation to the width of the island suggests that this is the case. Certainly it cannot be the result of wave refraction.

Wave refraction seems to be the most important process forming true tombolos. The angle at which the waves arrive at the gap between the island and the mainland is critical. If the waves are acutely to one side of the island compared to the other then they will drive through the gap, even if it is relatively small. Wave refraction complicates the theory of Sunamara and Mizuno, as we shall see in relation to examples from the Peruvian coast.

Peru: a case study

By looking at three locations on the coast of Peru it is possible to see how these processes operate and how seasonal changes in wave type have a big impact on tombolo formation. The three locations are shown in Figure 4. Puerto Viejo does not possess a permanent tombolo despite the fact that it has two large islands close to the shore. The distance from the shore to the island is much less than 1.5 times the width of the island (see Table 1) but tombolos only form in summer, to be destroyed the following winter. Lagunillas does have a tombolo, but the ratio of width to distance from shore is outside the theoretical limit. Mendieta fulfils the criteria for tombolo formation and has a permanent tombolo made of sand.

Puerto Viejo

The first question is, why does Puerto Viejo not possess a permanent tombolo? The answer appears to lie in the fact that, during the winter, the prevailing southwest swell (of considerable size as it is produced in the 'roaring forties') hits the coast exactly at the entrance between the island and the mainland (Photograph 1). A large volume of water is therefore squeezed through the gap, the entrance to which faces southwest. The waves do not lose enough power to deposit sediment but instead enter with sufficient force to prevent deposition occurring. Figure 5 shows the angle of the waves relative to the island. Tombolos do form in the summer, as described below, but are not permanent features.

Lagunillas

In theory the island at Lagunillas is too far away from the shore to allow the formation of a tombolo. Looking at the feature more closely, however, it appears to be a rocky platform with beach deposits on top (Photograph 2). Large areas of rock are visible on one side of the feature, including small cliffs 2 metres high. Clearly this is not a tombolo, but merely looks like one. Signs of erosional activity rather than deposition are present at the ends of the tombolo, as shown in Photograph 3.

The uplift of the coast of Peru due to tectonic activity (see Geography Review Vol. 12, No. 4) could be responsible for this

1 Winter in Puerto Viejo: waves scour through the gap between the island and the headland

2 An apparent tombolo at Lagunillas is in fact a feature created by coastal uplift

3 Undercutting at Lagunillas adds to the evidence that this is not a tombolo

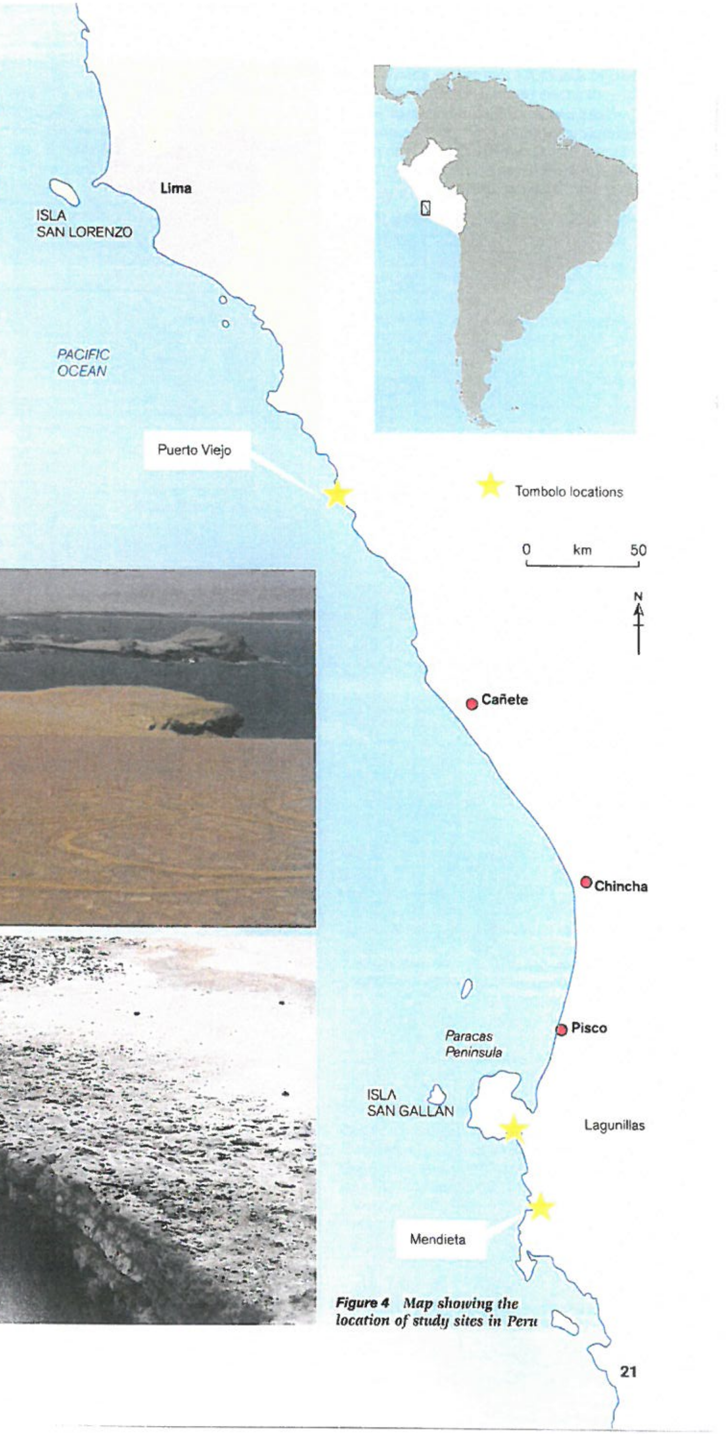


***Figure 4** Map showing the location of study sites in Peru*

feature as it raises the marine abrasion platform that then becomes covered with beach deposits and wind-blown material. So this example at Lagunillas illustrates a phenomenon known as **equifinality**, which means that similar-looking landforms may result from more than one process.

Mendieta

The only example of a true tombolo at the sites surveyed is at Mendieta (Photograph 4). First, it fulfils the requirement that the distance of the island from the shore is less than 1.5 times the width of the island. Second, the tombolo is made of the same material as the rest of the beach (sand). Third, although the waves do not arrive straight on to the island, they are not at too acute an angle. This helps them to refract around the island on both sides.

Given the short distance between the island and the mainland, the waves are very weak in the lee of the island. This encourages deposition and so a tombolo is built. Figure 6 shows how the action of a small cove created by an arch in the island leads to highly refracted waves passing through the small opening.

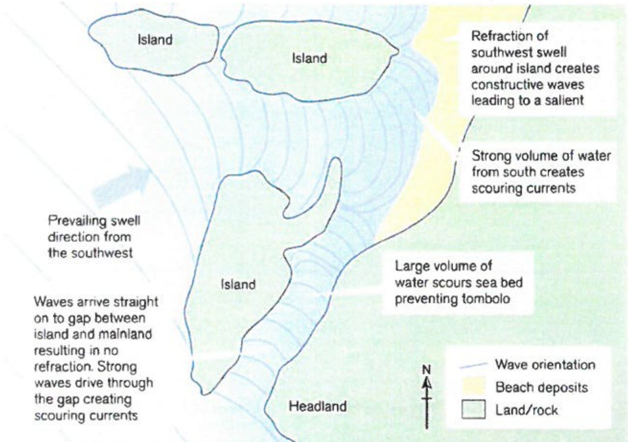


Figure 5 *The situation at Puerto Viejo for most of the year*

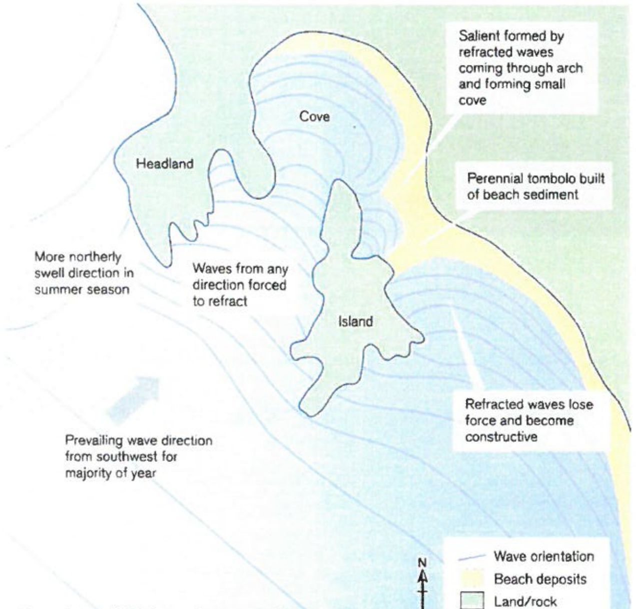


Figure 6 *Tombolo formation at Mendieta*

The importance of swell direction

The three examples from Peru indicate that it is not just distance and width that are important in tombolo formation but also wave direction relative to the island. This is reinforced by the fact that at locations where tombolos do not develop all year round, a change in swell direction and wave size in the summer tends to aid the development of temporary tombolos. These last for a few months before the swell starts coming from the storms in the South Pacific.

Puerto Viejo develops these temporary tombolos in the summer (see Figure 7) because a reduction in wave size means waves can begin to deposit sediment. At the same time the change in swell to a more northerly direction aids refraction on both sides. Huge expanses of sand can be deposited (see Photograph 5) and then wiped away as the equinoctial storms, in autumn, start to send waves with enormous force through the gap between the island and the mainland. Tombolos are therefore not a simple feature governed by distance from the shore. Instead they result from a variety of factors. On the coast of Peru the situation is complicated by fast rates of uplift and by the periodic variations in wave power that accompany El Niño and La Nina events. In addition, the existence of similar-looking landforms which are created by other processes, such as erosion or tectonic uplift, mean that any landform has to be looked at carefully to ascertain how it formed.

Backswash The movement of water back down the beach when the swash has lost energy. Backswash moves back down the beach according to the maximum beach slope.

Equifinality A situation in which similar-looking landforms have been created by different processes.

Longshore drift The transport of sediment along the coast by wave action.

Salient A protrusion in the plan form of a mainland beach created by deposition in the lee of an island.

Swash The movement of water up the beach created by the wave breaking on to the coast. Swash moves in the same direction as waves hit the shore.

Tombolo A beach feature which connects an island to the mainland.

4 Refraction occurring on both sides of a tombolo at Mendieta

5 The seasonal tombolo at Puerto Viejo

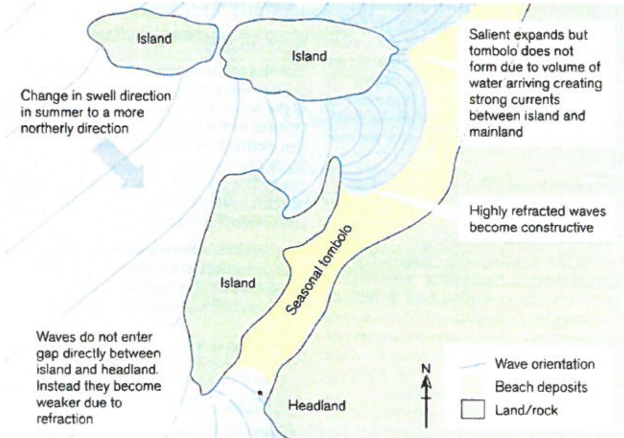


Figure 7 *The situation at Puerto Viejo in the summer*

Key points

- A tombolo is a beach deposit which links an island to the mainland.
- Tombolos form where waves refract around islands and deposit sediment between the island and the beach.
- The formation of tombolos is controlled by the distance between the island and the beach.
- Features that appear to be tombolos may have been formed by different processes.
- Tombolos do not always form as permanent features in places where the conditions appear to be right.

Questions for discussion

(1) Why would alignment of the gap between the island and the mainland be less important in coasts without a strong swell environment?

(2) What effect will rises in sea level have on tombolo formation on stable (non-emergent) coastlines?

Useful reading and links

Bird, E. C. F. (1984) *Coasts: An Introduction to Coastal Geomorphology*, Blackwell.

Bromley, M. (1999) 'Tectonic uplift and coastal features in Peru', Geography Review Vol. 12, No. 4, pp. 36–39.

Woodroffe, C. D. (2002) *Coasts: Form, Process and Evolution*, Cambridge University Press.

You can use Google Earth to view Chesil Beach (50.35.6N/2.29.6W) and tombolos at Llandudno (53.22.12.N /3.50.24W).

St Ninians Isle, Shetland Islands (tombolo): www.fettes.com/Shetland/tombolo.htm

Mark Bromley *studied geography at Jesus College, Oxford and did his Masters at Manchester University. He has taught geography for nearly 20 years in Britain and Peru. He is a keen surfer, which keeps him in contact with the coast*

Deposition, Tombolo, Coast, Longshore drift, Wave refraction