# The Coastline of Djursland

## A study in East-Danish shoreline development

By Axel Schou

Abstract

*The peninsula of Djursland on the east coast of Jutland in the centre of Denmark proper has been analysed in relation to shoreline development. All stages of simplification are represented ranging from initial moraine coasts to totally simplified equilibrium forms.*

*The geomorphological analysis should be compared with the results of investigations concerning wave force, see Sofus Christiansen: Wave-Power and the Djursland Coast. Geografisk Tidsskrift, vol. 59, 1960. Concerning placenames, see map. p. 30 in this paper.*

### Geomorphology and coastal dynamics

Coast types as well as shoreline development are results of an interplay between two distinctly different complexes of phenomena, the geological structures of the land area and the marine activities of the surrounding seas. Concerning geological structure Denmark is an area of glacial accumulation formed by deposition in the varying marginal zones of the Pleistocene ice cap. The terrestrial nuclei which form the skeleton of the Danish landscape pattern consist of the enormous quantities of boulders, gravel, sand and clay, all forming a pattern of moraine landscapes and glaciofluvial plains.

During the Riss-Saale glaciation the area of Denmark proper was completely covered by an ice cap. In the last glacial period, the Würm-Weichsel glaciation, the extreme limits of the ice cap never extended far enough to cover the southwestern part of the peninsula of Jutland. That it did not do so is to a very large measure the explanation of the great difference between West Denmark and East Denmark today, as to both relief features and coast types. The main stationary line of the last ice sheet through Jutland (fig. 1 ) is a geomorphological borderline of distinct significance. Southwest of this line old moraine landscapes of the Riss-Saale glaciation lie

between the vast outwash plains of the last glacial period and the whole region is characterized by its flat topography. East and north of the line young moraine landscapes are predominant: large-featured hills with steep slopes and great differences in level in the marginal zones alternate with smooth moraine flats and small local outwash plains.

The peninsula of Djursland is situated in the centre of the Denmark-proper area that lies east of the main stationary line (fig. 1); as regards geological substratum and surface layers it is a typical Danish region in which nearly all Danish relief forms are represented.

Concerning dimensions as well as types of marine activity there are pronounced differences between the North Sea and the inner Danish seas (the Kattegat, the Danish Straits and the Baltic). For example, in the North Sea the maximum height of waves is 5 m., whereas the highest waves observed in the Baltic are only 3 m. The tidal range at the North Sea coast near the Danish-German border is 2 m., in Esbjerg the difference between the tide levels is only 1.5 m., and farther north at the west coast of Jutland this value diminishes. At the Scaw spit near the entrance to the inner Danish seas the tidal range is insignificant. This means that in the Kattegat and the Baltic only a very small tidal wave is generated. The tiny tidal amplitudes which can be calculated here are normally covered entirely by non-periodical level changes mainly caused by wind pressure. Finally, it should be noted that west winds are predominant, as illustrated by the direction resultant of wind work (DRW) calculated for the island of Anholt in the Kattegat (fig. 1).

The different marine environments have created highly differing coast types in West Denmark and East Denmark. This means that the west coast of Jutland is exposed to strong wind and wave activity, the fetch in the NW-direction being more than 1500 km. as a maximum and 500 km. as a minimum, the depths increasing to 10 m. very near the coast. As glacial deposits offer only slight resistance to wave attack, mature stages in the simplification of the shoreline are reached at all exposed localities. The west coast of Jutland with its north-south direction approaches a straight line because of marine activity caused by westerly winds. The direction of the coastline was not determined by the initial relief, but is due to the forces of the sea. The sea has cut cliffs through all earlier hills and built bars before the former intermediate bays. An almost uninterrupted zone of dune landscapes has developed along the west

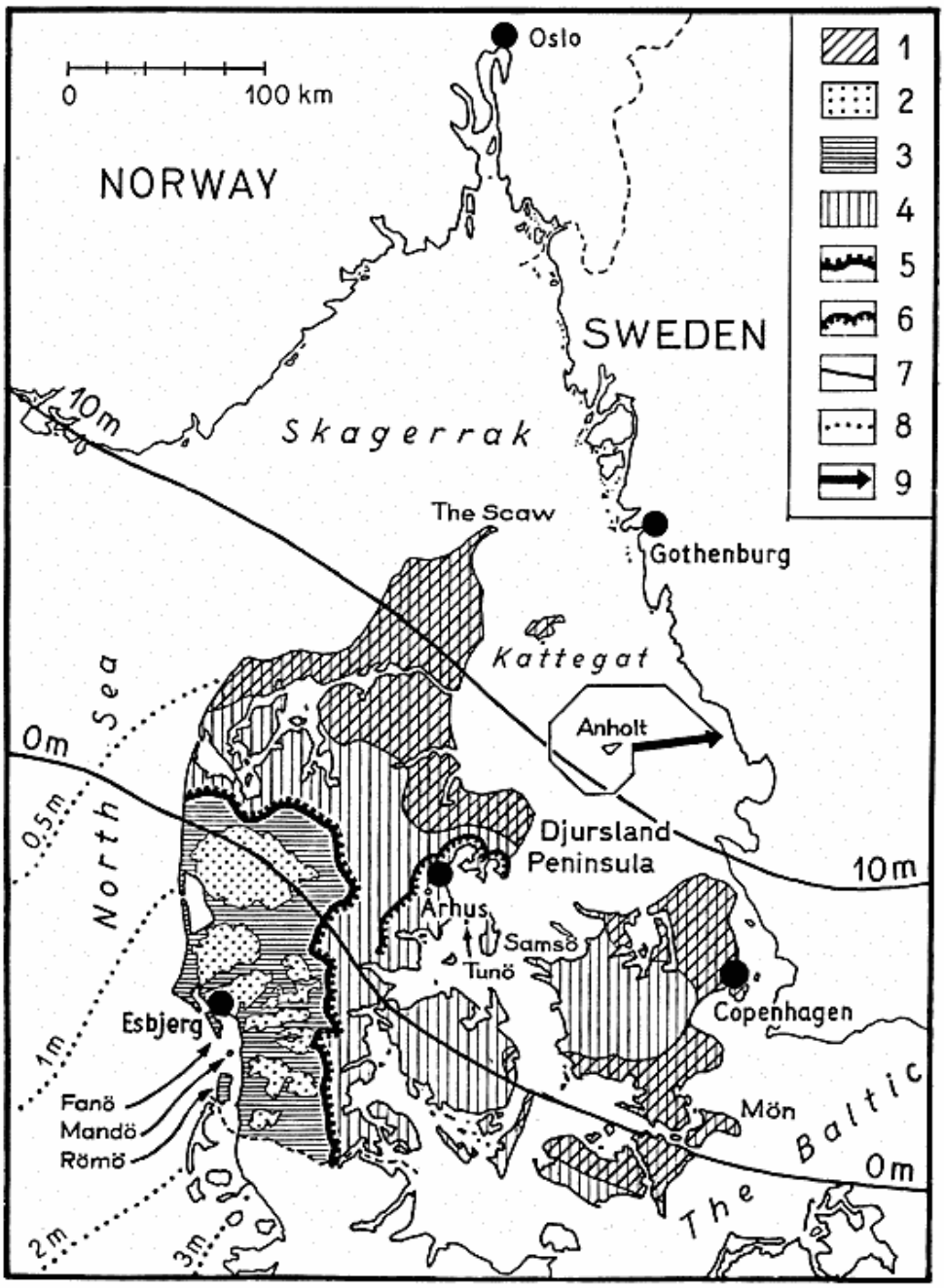


Fig. 1. *The physical-geographical environment of the Djursland peninsula.*

1. Area where limestone rocks form the substratum under the Quaternary deposits.
2. Old moraine landscapes, Riss/Saale glaciation.
3. Outwash plains of the Würm/Weichsel glaciation.
4. Predominant young moraine landscapes, Würm/Weichsel glaciation.
5. Main stationary line of the last glaciation.
6. Terminal moraine in the Djursland peninsula.
7. Lines of equal elevation since the Stone Age (Litorina-Tapes epoch).
8. Lines of equal tidal amplitude.
9. Direction resultant of wind work.

coast, continuing southward on the west coasts of the islands of Fanö, Mandö and Römö. Owing to the tides there are salt marsh coasts along the southwestern part of the shoreline of Jutland.

The East-Danish coast type is much more varied than the West-Danish type described above. East Denmark being of an archipelago nature, the fetches reach all dimensions, and the water depth is highly variable, which means that the complex of morphogenetic agencies is to be found in a rich variety of combinations. The resulting form-complexes are also influenced by the post-glacial isostatic and eustatic level changes which are still active. North Denmark is still in a state of emergence but with little velocity, about 1 mm. a year. The southern part of the country has sunk since the Stone Age and is still sinking at a similar rate. It must be added that human activities of many kinds: harbour building, reclamation and coast protection are factors of great importance in this densely inhabited land.

### The Djursland peninsula

The existence of this peninsula on the east coast of Jutland is partly the result of uplift of the limestone substratum between fault lines. Djursland is a horst formation of the bedrock where resistant Cretaceous limestone withstood erosion by the ice sheets of the glacial periods. The shoreline of the northeast corner is bordered by limestone cliffs. The subterranean dislocations which are so characteristic of Central Europe were also contributory to the shoreline configuration of Denmark (see fig. 5).

Nevertheless, Denmark's shoreline is mainly governed by the surface relief of the moraine deposits of the Würm glaciation. Where these accumulations of moraine material are of considerable thickness they form projections on the coastline. This is the case on the south coast of the Djursland peninsula (fig. 2), where the hilly landscapes are explained as marginal moraines formed along the front of a glacier, which during the final Baltic stage of the Würm-Weichsel glaciation following the Baltic depression moved from south to north and had its extreme limit here. The bays, Kalvö Vig and Æbeltoft Vig, are submerged central depressions formed by erosion under the ice lobes of this glacier snout.

The peninsula of Djursland is a significant example of various types of Danish moraine coasts as well as various stages in shoreline development. The north coast is exposed to an open sea area with a maximum fetch of about 300 km., while the south coast faces the

islands of Samsö and Tunö, north of the Funen archipelago, where the maximum fetch is not more than 25 km. Governed by these circumstances marine erosion and beach drifting have been very effective along the north coast which is totally simplified, while the southern shoreline still retains all typical features of the initial moraine coast.

For coastal research concerning bay closing, tombolo building, spit growth, and the formation of cuspate forelands a region of this kind offers the best chances.

With regard to coastal features and stages of shoreline simplification nine different types may be distinguished in the Djursland peninsula (fig. 2).

I. Initial moraine coast — Kalvö Vig, South Djursland.
II. Young simplification stage of a moraine coast —Æbeltoft Vig, South Djursland.
III. The equilibrium moraine cliff shoreline of the west coast of Helgenæs, a beach drift source-locality.
IV. The beach drift drain-locality of Begtrup Vig.
V. Mature, simplified festoon-shaped East Djursland shoreline.
VI. Totally simplified part of the East Djursland shoreline.
VII. Earlier (»fossil«) shorelines of the Litorina strait of Kolindsund.
VIII. Tectonically determined limestone cliff coast, Northeast Djursland.
IX. Old simplified complex shoreline of North Djursland.

I. *Kalvö Vig, a »Bodden« coast in initial stage.*

The bay of Kalvö, being a submerged central depression, has the dimensions of the ice-lobe which generated the initial cavity in the surface relief by glacial erosion. Concerning the shoreline configuration many details may be explained as results of the landscape-creating activities of the glaciers during the Baltic stage, the last phase of the Würm-Weichsel glaciation. The bay west of the Hestehave woods, southwest of the town of Rönde, is the deepest, »drowned« part of a subglacially eroded valley formed by meltwater flowing upwards as a result of hydrostatic high-pressure, with a northern direction in an ice tunnel during the last glaciation. Now this valley contains a small consequent river course running in a southerly direction to the bay. Other indentations of the shoreline, for example

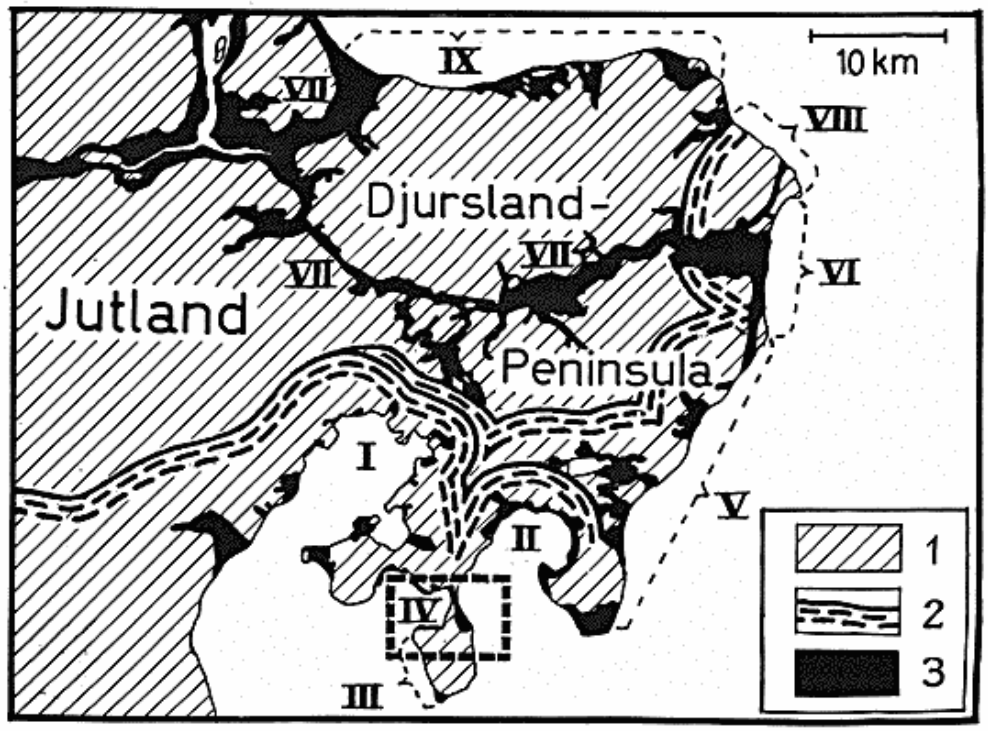


Fig. 2. *Geomorphological map of the Djursland peninsula.*

1. Young moraine landscape, Würm/ Weichsel glaciation.
2. Marginal moraines.
3. Coastal plains formed by marine accumulation combined with upheaval of land (3—5 m.) and reclamation. The frame indicates the area shown in fig. 3 C.

I. The bay of Kalvö Vig.
II. The bay of Æbeltoft Vig.
III. The totally simplified cliff shoreline of Helgenæs.
IV. The bay of Begtrup Vig.
V. The mature simplified festoon-shaped east coast.
VI. The totally simplified east coast.
VII. The earlier "fossil" shorelines of the strait of Kolindsund.
VIII. The limestone cliffs.
IX. The old simplified north coast.

Knebel Vig, may be explained as relief cavities originated by resisting dead ice in the late-glacial period, when the surrounding area was flooded by meltwater which caused sedimentation around the ice lumps. The sheltered position of the bay in the angle between the east coast of Jutland and the south coast of Djursland combined with the narrow inlet explains the fact that wave activity is only small and the resulting shoreline simplification insignificant. The post-Litorina 2.5 m. land upheaval is responsible for the dead cliff shoreline and the bordering narrow coastal plains, for example on the north coast of Egens Vig. However, even if the wave activity is weak it has caused small-dimensioned but typical beach drift phenomena in exposed localities. The island of Kalvö thus was welded to the mainland by a tombolo which was later stabilized by isostatic uplift as well as by human activity, construction of road and fortifi-

cations necessitated by the existence of the medieval castle of Kalvö, of which the tower ruin still remains on the former island. Similar tomboloes have developed at Sködshoved, near the south entrance to the bay as well as at Dejred Öhoved at the entrance of Knebel Vig. As a whole the Kalvö Vig shoreline may be characterized as an initial moraine coast only slightly modified by wave activity and level changes.

II. *Æbeltoft Vig, a »Bodden« coast modified by shoreline simplification.*

Compared with Kalvö Vig, this bay is more open and exposed to effective wave attack from the southeast, the fetch in this direction being 60 km. As a consequence the shoreline simplification caused by beach drifting has progressed to a certain degree. The lake Bogens Sö at the west coast is a lagoon lying between the elevated cliff shoreline of the Litorina sea and the delimiting beach ridge plain. In contradiction to Kalvö Vig the shoreline at the head of Æbeltoft Vig is not in conformity with the initial relief contours indicated by the elevated Litorina shoreline. The smoothly rounded curve may be explained as an approximation to the idealequilibrium formation of a bay exposed to beach drift dynamics. Promontories like Bogens Hoved on the west coast and Ahl Hage on the east coast are of quite different origin, the former being caused by the resistance of moraine accumulation, the latter being a cuspate foreland (fig. 7). The diminishing grain size north along the Ahl Hage beach, in conjunction with the occurrence of recurved spits on the north coast of this foreland, demonstrates that in accordance with the general laws of bay closure beach drift into the bay is responsible for the formation of this cuspate foreland, which acts as a breakwater providing the necessary shelter effect for the harbour of Æbeltoft. The Ahl Hage foreland is based on an extensive submarine sand accumulation, Sandhagen, clearly shown on airphotos (fig. 7). The existence of this extensive accumulation on the eastern shoreline is governed by the strong beach drift along this shoreline with its western exposure.

*III. The west coast of Helgenæs, a totally simplified cliff shoreline.*

The southernmost prominence of Djursland, Helgenæs peninsula, does not profit from the sheltered conditions which characterize the Kalvö Vig region described above. The west coast of Helgenæs in particular is exposed to effective wave attack generated by the

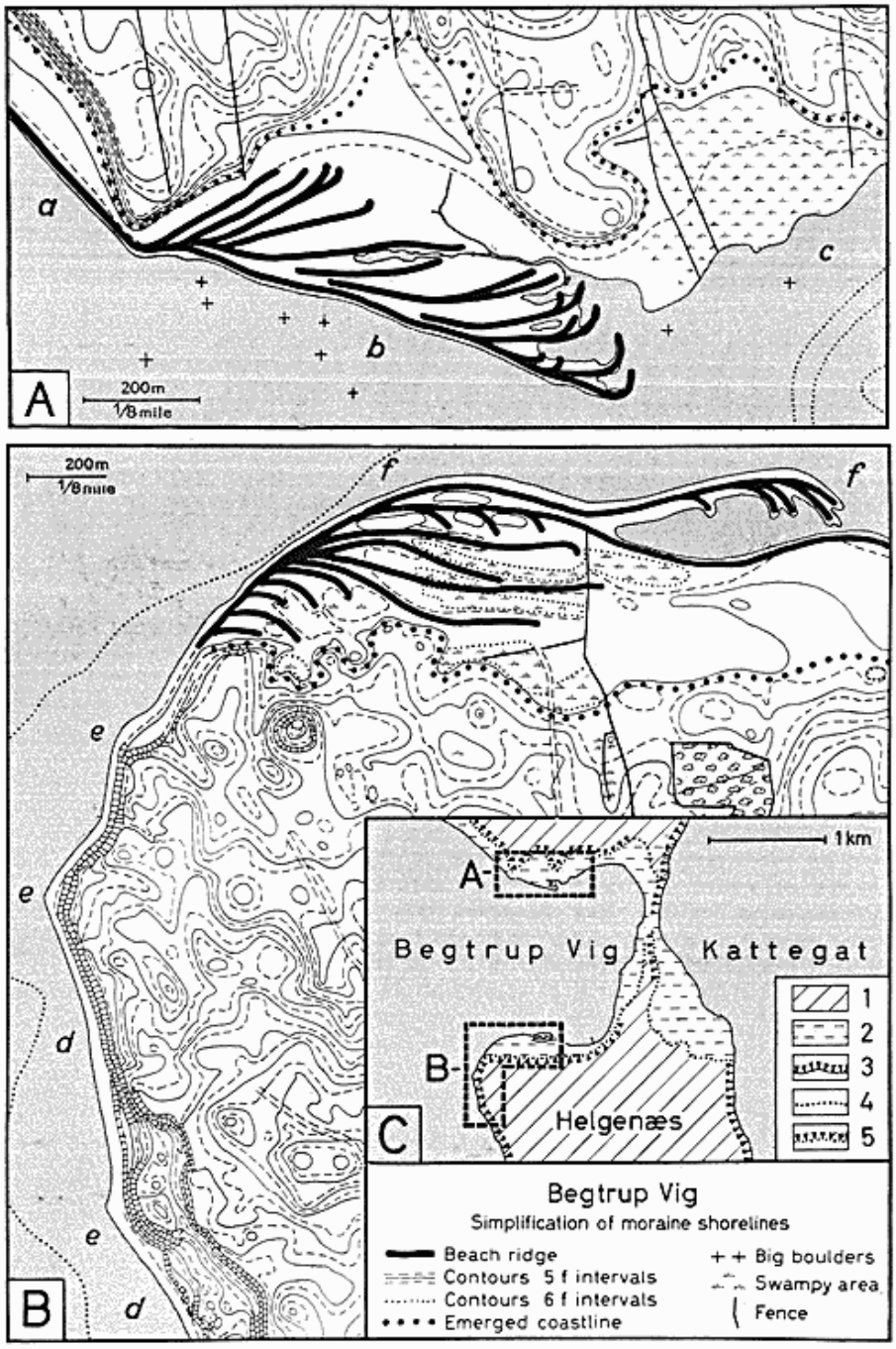


**Fig. 3.** *Begtrup Vig. Stages in shoreline simplification.*

A. Bay closing stages. Strands Gunger. a. Bay totally closed by coastal plain development combined with upheaval of land (3 m.). b. Mature closing stage. Spit complex under growth before the elevated Stone Age cliff shoreline. Surveying 1954, (cfr. airphoto 1945, fig. 4). c. Former bay, filled up by vegetational growth, sedimentation of fine-grained material and upheaval of land but without beachridge development until now.

B. Stavsöre. d. Northern part of the simplified Helgenæs west coast. e. Precipice of the shoreline caused by slides of Tertiary plastic clay. f. Old spit complex structures in the coastal plain. g. Recurved spits in the growing stage.

C. Begtrup Vig, localization map (cfr. framed area in map fig. 2).

1. Young moraine landscape. 2. Coastal plain. 3. Cliffs. 4. Shoreline of the stone age sea. 5. Dead cliffs.

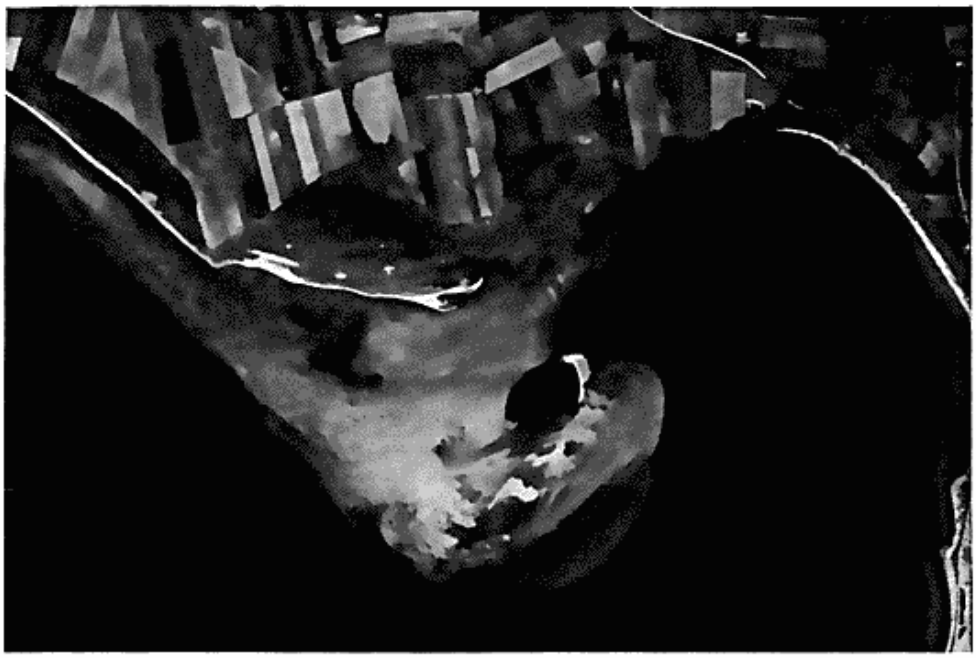

Fig. 4. *North coast of Begtrup Vig.* A recurved spit complex has developed before a former bay of the Litorina Sea. The west part of the shoreline is totally simplificated. Airphoto 1945. Concerning explanation of topographical features and stages of shoreline simplification cfr. fig. 3 A.

On the offshore outside the spit complex the white shade indicates sand masses brought into the bay by beach drifting caused by westerly winds. The bottom in this shallow-water area shows a surface with tunnels and ridges formed by moderate swell. The eastend of this sandplatform has a steep slope the shape of which is due to current action caused by wind pressure in the narrow opening of the bay between this sedimentation platform and the corresponding one at the south coast. On these platforms future bayclosing spit complexes may develop with orientation in continuation of the NW-SE running shoreline shown in the left part of the photo. The seashore limiting line of the fieldpattern area indicates the shoreline of the Litorina Sea.



dominant westerly winds over a sea area with water depths of more than 20 m. and a fetch of about 20 km. As a result of the marine activity the moraine cliff shoreline from the south cape Sletterhage to Stavsöre at the entrance to the bay of Begtrup is totally simplified, demonstrating the equilibrium form of the locality carved by erosion, the orientation of the shoreline NNW-SSE being very nearly at a right angle to the resultant of wave-work (fig. 1, p. 30). This cliff shoreline is retreating without altering its orientation. Small prominences of the shoreline are caused by earth slides which occur as a result of the retreating of the cliffs after wave attack, in particular in places where lenses of Tertiary plastic clay in the moraine are exposed in the cliff face (fig. 8). The sliding clay masses often exhibit stepped fractures. As a result of these cliff-forming processes large masses

of boulder clay are delivered to the littoral zone and exposed to beach drifting. The coastal stretch is overnourished; in Per Bruun's terminology it is called a source-locality of beach drift material.

*IV. Begtrup Vig, bay closing in different stages.*

This bay was a sound in the Litorina age, Helgenæs being at that time an island, which later was welded to the Djursland peninsula by a tombolo (fig. 3, C) which afterwards became stabilized partly by the post-Litorina uplift and partly by the building of fortifications on the strategically important tombolo. Exposed to the westerly winds the beach drift into the bay is very considerable. At the southern entrance the bay acts as a drain-locality for the beach drift along the west coast of Helgenæs. Here sand masses have built up a platform on which beach ridges and recurved spit systems are formed at Stavsöre (fig 3, B) as the youngest part of a beach ridge plain constructed in front of the elevated Litorina cliff shoreline. Lagoons in various stages of filling up by sand accumulation and vegetational growth may be seen (fig. 3, B, e, f).

The analoguous process is to be seen at the northern entrance to the bay (fig. 3, A). Here the cliffs of Mols Hoved act as a source of beach drift material. South of the village of Strands typical stages in bay closure can be demonstrated in the airphoto (fig. 4). At locality a the former bay of the Litorina age is now closed by a bar and the shoreline is simplified totally. Farther to the east at b, a bay is in the mature stage of closing. A spit complex is in a phase of rapid growth (fig.9). This system of beach ridges is a result of accumulation processes in the 20th century. It is possible to indicate the future locality of bay closure. The airphoto shows distinctly that enormous masses of sand have been moved into the bay mouth where they now form the foundation for further spit formation. It is to be foreseen that these submarine accumulation platforms at the north and south shore of Begtrup Vig will combine and form a base on which spit systems from north and south and bar islands in the central part may finally be welded together, forming a bar across the entrance of the bay.

*V. The mature simplified, festoon-shaped coast of East Djursland.*

The east coast from Hasenöre to Havknude exhibits the festoon-shape that is typical of mature stages in shoreline simplification. The prominences Brokhöj (34 m.), Jærnhatten (49 m.), Glatved-Limbjerg (40 m.) and Havknude (14 m.) are moraine hills, at Glat-

ved with a content of limestone boulders. The resistance of these moraine nuclei is a result of the dimensions of the Quaternary accumulations. The festoon parts of the coastline consist of shingle ridges built up between the moraine nuclei as bar-islands (fig. 5) and tomboloes separating lagoons from the sea by the closure of bays and straits between the former moraine islands. Some of these barred parts of the former sea area still exist as lakes, for example Nörresö, east of Rugaard, and lake Draaby, farther to the south. In other cases the lagoons are overgrown, now forming swampy areas like Gungerne east of Boeslum, separated from the sea by a beach ridge plain with a covering of dune sand. The recent beach ridges along this shoreline have a maximum level of 2.5 m. above Danish Ordnance Datum. Old elevated beach ridges rise to a level of 7.5 m. Earlier coastal features often are truncated by the recent shoreline development, for example at Katholm, where Havknude represents a former island in the Litorina sea. It was separated from the mainland by a strait which today is still identiable as a low-lying area east of Katholm woods.

*VI. The totally simplified part of the Djursland east coast.*

The northern part of the east coast of Djursland, from Havknude to Fornæs, is totally simplified. A beach ridge plain, Hessel Hede, grew out from the south at the entrance of the Litorina strait of Kolindsund, which is now followed by the course of the river Grenå, the mouth of which has been deflected in a northernly direction by the growth of the spit system. As a consequence of the strong wind activity the Hessel Hede area has been covered by blown sand, this deposit disguising the structures of the original beach ridge plain. The conifer plantation established as a shelter against dangerous wind erosion also hides the surface relief. Like many other Danish harbours the original Grenå harbour was localized to the mouth and the lower course of the river. The need for deeper harbour basins caused by the increasing size of ships has been met by the construction of the modern harbour of Grenå at the sea coast, sheltered by a large pier from the heavy beach drift from the south.

The old stage of simplification which is indicated by the ruler-straight course of the shoreline stretch described here may be explained by the fact that calculations of wave force show a maximum value in this locality of the east coast. The adjustment of the shoreline orientation to the terminant direction at a right angle to the resultant vector of wave force is nearly complete (see fig. 1, p. 30).

Fig. 5. *Accumulation locality of the Djursland coastline* (cfr. fig. 2, section V). Festoon-shaped beach ridge plain built up between the moraine nuclei Glatved and Havknude, the latter to be seen in the distance. The shingle ridges are built up by stone material from the boulder clay and the glaciofluvial deposits. Axel Schou phot. 1955.

*VII. The earlier (»fossil«) shorelines of Kolindsund.*

The Litorina strait of Kolindsund mentioned above once used to run eastwards through a depression, originally a subglacial valley which in the Litorina age separated the northern part of Djursland as an island from the mainland. A part of this strait remained as a lake which was reclaimed in the 19th century. Its former basin is now a cultivated plain, characterized by the pattern of draining ditches and the surrounding reclamation canal, running along the dead cliffs of the »fossil« Litorina sea shoreline. In other places the former strait now remains as swampy areas, the most extensive one being the bay of Pindstrup Mose, from which the peat is used as fuel in the plywood and veneer manufacturing plant which has been built here. Concerning extension of the former strait, see fig. 2.

*VIII. The limestone cliffs.*

At Fornæs, near the lighthouse it is possible at low water to observe a wave-cut platform abraded in solid limestone with a thin veneer of beach deposits, this fact indicating the existence of the underground horst on which the localization and existence of the Djursland peninsula depend. Farther to the north the Danian limestone rises to a higher level and forms a shoreline of steep cliffs running NW-SE. The vertical clean-cut cliff walls of Sangstrup Klint

Fig. 6. *Erosion locality of the Djursland coastline* (cfr. fig. 2, section VIII). The limestone cliff of Sangstrup at low water summer conditions. The abrasion plane exposed in the foreground. At the top of the cliff the glacially eroded surface of the Danian limestone can be seen covered by a thin layer of moraine. Axel Schou phot. 1955.

and Karleby Klint form the abrupt limit of the landmass of Djursland here at the northeast corner of the peninsula. In the lower parts of the cliffs wave-cut caves are proofs of the force of marine attack. The abrasion plane cut in the limestone is overstrewn with boulders that are being washed out from the fallen parts of moraine masses which cover the glacially smoothened surface of the limestone beds. In the breaker zone these boulders are eroding pot holes in the wave-cut platform, an illustration of the dynamics of abrasion. Surface forms caused by the chemical solvent action of sea water may have some effect too; shallow depressions along the fissure lines of the chalk might be explained in that way (fig. 6).

In Djursland limestone cliffs are only to be seen at this locality, but they are typical elements of the coastal landscapes of Denmark, particularly in the eastern part of the country where the limestone cliff dimensions are greater than here. This is caused partly by the high position of the Senonian and Danian sediments, partly by the dislocation of the limestone beds by ice pressure in the glacial age.

North of the limestone cliff of Karleby Klint a depression forms the limit of this coastal type. The adjacent northern shoreline is characterized by the moraine cliff of Gerrild Klint, and here the typical north coast type of shoreline starts with a smooth 90-degree curve, which may be explained as the ideal equilibrium form of coastlines with a finite length, to use the terminology of Per Bruun.

*IX. The old simplified North Djursland shoreline.*

In contradiction to the south coast of Djursland the shoreline of the north coast is quite independent of the initial moraine relief. The main east-west orientation is to some extent tectonically determined, as the underground limestone horst forms the eastern prominence. It is the most simplified stretch of the Djursland coastline, developed partly by the closure of all original bays and sounds, partly by erosion in the moraine deposits. The equilibrium form of the recent shoreline is an approximation to the terminant direction at right angles to the wave force vector (see fig. 1, p. 30), the great fetch of 300 km. with northern orientation being the dominant factor in the calculation of this value indicating the strength and orientation of wave action. The smooth curved connection of the northern shoreline of Djursland with the east coast of Jutland may be explained as an adaptation to the equilibrium shoreline of bay heads, according to Per Bruun's hypothesis.

A geomorphological analysis shows that this simplified shoreline consists of elements of different origins. The western part, Hevring Hede, is a recurved spit complex built out from east to west, closing the northern entrance to the former strait that separated the northern part of Djursland from Jutland during the Litorina transgression. To a certain degree blown sand has disguised the initial structures of this marine foreland, but in many places the fan-shaped pattern of the beach ridge plain is still indicated by the configuration of the contours in the ordinance sheet, scale 1:20.000. The heavy wind activity of this coastal stretch causes severe wind erosion in the farm lands, in particular in localities with light sandy soils, first and foremost in spring when precipitation often is very small.

The eastern part of the north coast at Knudshoved consists of several moraine nuclei connected by tomboloes, in this way separating former sea areas and lagoons, which later became barred foreland partly by the accummulation of blown sand and partly by vegetational growth.

Like other beach drift shorelines the north coast of Djursland is unfavourable to navigation. The need for a fishing harbour has been met by the construction of the Bönnerupstrand harbour of the island-harbour type. This particular harbour construction with sand-tight moles surrounding a basin which is connected with the shoreline by a bridge which presents only a minimum of hindrance to the beach drift. This particular Danish harbour type has been adopted with slight modification in many similar localities. Quarrying for

Fig. 7. *Ahl Hage, a cuspate foreland at the entrance to the bay of Æbeltoft Vig* (cfr. fig. 2, II). The foreland has developed on a wide platform of sand, Sandhagen, built up by beach drifting into the bay. The whole foreland complex acts as a breakwater for the harbour of Æbeltoft constructed in the bay behind it. The grain size of the beach material is diminishing from south to north. The dark shade in the interior of the foreland indicates the conifer plantation established to protect the agricultural area against blown sand.


gravel and stone which is an industry of importance, has caused a need for loading facilities, which has been met by constructing extensive piers on the broad off-shore, dimensioned as to length in order to reach areas with depths sufficient for the necessary navigation.

There is a significant discrepancy between the recent shoreline and the old mature shorelines of the Litorina age. Elevated Litorina cliff shorelines bordered by coastal plains occur for example south of Bönnerup and southeast of Stavnshoved, with an orientation quite

Fig. 8. *The Helgenæs west coast, a source-locality for beach drift.* Lenses of Eocene plastic clay in the moraine cause earthslides when exposed in the cliff, and overlying boulder clay masses are brought into the littoral zone. The coarse-grained materials, shingle and pebbles are transported by beach drifting along the coast, while the fine-grained sand and clay particles are taken away by current action (cfr. fig. 3 B).

Axel Schou photo.

different from the shoreline of today. The recent shoreline is thus a complex of accumulation localities and recent cliffs representing an old stage of simplification, the orientation partly governed by the earlier coastline, partly by the recent dynamics.

Even if the Djursland shoreline is of rather limited extent, about 100 km. long, it is possible there to find typical examples of all Danish coast types except the real tidal salt marsh, which to merely a small degree may said to be represented by some flat shores of the beach meadow type in sheltered bays where wave activity proceeds far from the shoreline. Concerning dimensions the Djursland coastal complex cannot rival certain localities in other parts of Denmark. The limestone cliffs in the island Mön rise to 100 m. above sea level, the Römö beach in southwest Jutland is ten times as extensive as any Djursland beach and, compared with the West Jutland dune landscapes, the sand agglomerations on the north coast of Djursland are only insignificant. Anyhow, Djursland is a typical part of Denmark as regards physical geographical features, and in particular with regard to shoreline development.

Fig. 9. *Strands Gunger at the north coast of the bay of Begtrup Vig, a drain-locality for beach drift* (cfr. fig. 3 A). A recurved spit complex has developed before the former cliff shoreline of the Litorina sea. The recurved spits as well as the windblown tree on the cliff edge in the foreground indicate the west-east orientation of the direction resultant of wind work.
Axel Schou photo.

## LITERATURE

*Bruun, Per* (1946–47): Forms of Equilibrium of Coasts with a Littoral Drift. Geogr. Tidsskr. 48. København.

*Bruun, Per* (1951): Littoral drift along sea shores. Ingeniøren 10. København.

*Bruun, Per* (1954): Coastal stability, København.

*Christiansen, Sofus* (1958): Bølgekraft og kystretning. With a Summary: Wave-power and shoreline orientation. Geogr. Tidsskr. 57. København.

*Guilcher, A.* (1954): Morphologie littorale et sous-marine.

*Guilcher, A.* and others (1957): Les cordons littoraux de la Rade de Brest. Extrait du Bull. d'Information du Comité Central d'Oceanogr. et d'Etude des Côtes IX: 1.

*Jessen, Axel* (1920): Stenalderhavets Udbredelse i det nordlige Jylland. The extension of the Stone Age Sea (Tapes-Litorina Sea) in Northern Jutland. D. G. U., II Rk. Nr. 35.

*Johnson, D. W.* (1919): Shore Processes and Shoreline Development.

*Kannenberg, Ernst-Günther* (1951): Die Steilufer der Schleswig-Holsteinischen Ostseeküste. Kiel.

*King, Cuchlaine A. M.* (1959): Beaches and Coasts. London.

*Köster, R.* (1958): Die Küsten der Flensburger Förde. Schr. des Naturwis. Vereins f. Schleswig-Holstein. Kiel.

Fig. 9. *Strands Gunger at the north coast of the bay of Begtrup Vig, a drain-locality for beach drift* (cfr. fig. 3 A). A recurved spit complex has developed before the former cliff shoreline of the Litorina sea. The recurved spits as well as the windblown tree on the cliff edge in the foreground indicate the west-east orientation of the direction resultant of wind work.
Axel Schou photo.

## LITERATURE

*Bruun, Per* (1946–47): Forms of Equilibrium of Coasts with a Littoral Drift. Geogr. Tidsskr. 48. København.

*Bruun, Per* (1951): Littoral drift along sea shores. Ingeniøren 10. København.

*Bruun, Per* (1954): Coastal stability, København.

*Christiansen, Sofus* (1958): Bølgekraft og kystretning. With a Summary: Wave-power and shoreline orientation. Geogr. Tidsskr. 57. København.

*Guilcher, A.* (1954): Morphologie littorale et sous-marine.

*Guilcher, A.* and others (1957): Les cordons littoraux de la Rade de Brest. Extrait du Bull. d'Information du Comité Central d'Oceanogr. et d'Etude des Côtes IX: 1.

*Jessen, Axel* (1920): Stenalderhavets Udbredelse i det nordlige Jylland. The extension of the Stone Age Sea (Tapes-Litorina Sea) in Northern Jutland. D. G. U., II Rk. Nr. 35.

*Johnson, D. W.* (1919): Shore Processes and Shoreline Development.

*Kannenberg, Ernst-Günther* (1951): Die Steilufer der Schleswig-Holsteinischen Ostseeküste. Kiel.

*King, Cuchlaine A. M.* (1959): Beaches and Coasts. London.

*Köster, R.* (1958): Die Küsten der Flensburger Förde. Schr. des Naturwis. Vereins f. Schleswig-Holstein. Kiel.

*Munch-Petersen, I.* (1918): Bølgebevægelse og Materialebevægelse langs Kyster. (Wave movement and beach drifting). Fysisk Tidsskr. 16. København.

*Munch-Petersen, I.* (1933): Materialwanderungen längs Meeresküsten ohne Ebbe und Flut. Hydrologische Konferenz der Baltischen Staaten. Leningrad.

*Price, W. Armstrong* (1953): The Classification of Shorelines and Coasts. Contribution No. 15. Dept. of Oceanogr., The A.&M. College of Texas.

*Schou, Axel* (1945): Det marine Forland (The Marine Foreland). Folia Geogr. Danica IV. København.

*Schou, Axel* (1949): Atlas of Denmark I. The Landscapes. København.

*Schou, Axel* (1949): Danish Coastal Cliffs in Glacial Deposits. Geogr. Annaler. Stockholm.

*Schou, Axel* (1952): Direction Determing Influence of the Wind on Shoreline Simplification and Coastal Dunes. Proc. XVII Int. Congress.

*Schou, Axel* (1956): Die Naturlandschaften Dänemarks. Geogr. Rundschau 11.

*Steers, J. A.* (1945): The Coastline of England and Wales. Cambridge.