you reach grey limestone exposures at the head of the beach. This limestone is a much paler grey than that seen in Balscadden Bay, and it is not possible to see layering. Further to the west the limestone appears to be stained brown in places. This is where the original calcite ($CaCO_3$) has been replaced by a new mineral, dolomite ($CaMg(CO_3)_2$). Further on it is possible to see boulder clay resting on the limestone. The top of the limestone, where the boulder clay has been washed away, locally appears to be scored by parallel grooves. These were gouged out by blocks of rock embedded in the base of the ice sheet as it moved slowly across the land surface. The grooves are called glacial striae, and they indicate the direction in which the ice sheet was moving.

EXCURSION 4: SUTTON

Ian Sanders

How to get there: DART to Sutton Station, and 25 minute walk to Sutton Dinghy Club on Strand Road. Bus No. 31B from Lower Abbey Street to Strand Road, followed by a walk of 10 minutes. Parking is possible for a few cars on the road.
Geological horizon: Cambrian, Lower Carboniferous, & Quaternary.
What to see: Carboniferous limestone; a raised beach.
Duration: about 1 hour.
Notes: Half or lower tide makes it easier to get around the rocks at Bottle Quay (Stop 2).

On the Sutton side of the peninsula, as at Howth, it is possible to examine Quaternary, Carboniferous and Cambrian rocks. The itinerary is complimentary to that at Howth, with somewhat different aspects of the rocks displayed.

Stop 1. Sutton Dinghy Club. Take the concrete steps down to the beach to the right of the club house. In the vertical rock face beside the steps note that the rock is yellowish brown in colour and does not show layering. One or two large (up to 1 metre) patches are conspicuously grey in colour. The grey rock is limestone. It fizzes when a drop of acid is placed on it. The surrounding brownish rock is dolomite. Dolomite is calcium magnesium carbonate ($CaMg(CO_3)_2$) and it also contains a trace of iron which gives it the brownish colour. Dolomite does not fizz with acid unless it is first powdered. Dolomite is formed when magnesium bearing water soaks through limestone, and half the calcium atoms are removed and replaced by Mg atoms. At this place virtually all the original limestone has been altered to dolomite. Only a few residual patches of the limestone survive. Earlier this cenfury dolomite was extracted from a quarry about 150 m inland from here. It was shipped from a small harbour called Bottle Quay (Stop 2). The original limestone was formed from shell fragments which accumulated on the sea bed during the Carboniferous Period, about 340 million years ago.

Continue about 25 m north past a boat house to low, rounded outcrops of dolomite. Look closely at the rock surface where it emerges from beneath a covering of pebbly mud and sand at the head of the foreshore. You should find that it has been deeply scored by a series of parallel grooves. These grooves were carved into the rock surface during

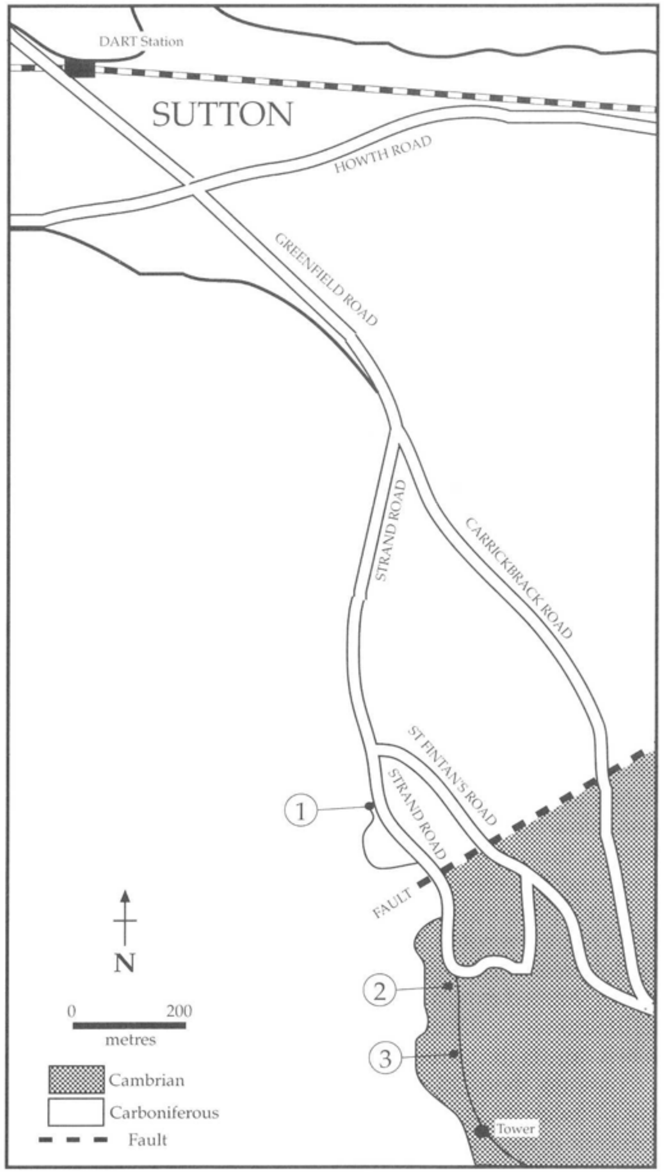

Figure 7. The geology of the Sutton area.

the last ice age. A great sheet of ice, perhaps 1 km thick, covered this area (and most of the rest of Ireland) and this sheet was continually creeping southwards under its own weight. Loose boulders and cobbles of hard rock were embedded in the base of the ice sheet, and were heaved powerfully across the underlying bedrock, gouging lines and grooves in it as they moved along. The grooves are known as glacial striae. Their orientation suggests that here the ice once moved in either a NW or a SE direction. When the ice melted (about 14,000 years ago) the loose rocky material trapped within it remained left behind as an unsorted mixture of pebbles, sand and mud known as boulder clay. The pebbly material covering the striated bedrock is an example of boulder clay. Much better examples, however, may be seen at the second stop.

Stop 2. Bottle Quay. Retrace your steps back to the road and walk or drive to a sharp bend where the road turns inland. Go through a gap in the wall to the beach. Alternatively, if the tide is less than three-quarters in you can walk along the beach to Bottle Quay, but take care you don't slip on wet rocks. You will pass a solitary outcrop of pale grey limestone before passing a large concrete retaining wall. This wall is built across the site of the fault which separates Carboniferous rocks from Cambrian rocks. All rocks to the south are Cambrian in age.

At Bottle Quay the solid bedrock is cream in colour with dark brown staining, and it is extremely hard. The rock is quartzite. As explained in the preceding (Howth) itinerary, quartzite began as a thick deposit of sand on the Cambrian sea floor somewhat more than 500 million years ago. The quartzite is not layered here, but it is cut by a series of steep cracks, known as joints. The joints were probably formed when enormous stresses in the earth's crust caused the hard and brittle quartzite to fracture in a regular fashion.

The quartzite has a remarkably flat, nearly horizontal surface, about 2 m above mean sea level. A thick deposit of boulder clay is resting on this surface. It is possible that the flat surface was eroded by breaking waves at a time (before the last ice sheet advance) when sea level was higher than it is today. The wave-eroded surface would have been smoothed by ice-sheet erosion before the ice melted and dropped its charge of boulder clay. The boulder clay itself is unusual here. Pebbly boulder clay in the upper part of the cliff rests on a lower pebble-poor boulder clay. The two different types may have been formed during separate ice melting events.

Just beyond a small cove you may notice that the rock appears to consist of broken and recemented pieces of quartzite. This is a fault breccia not unlike the one occurring in Balscadden Bay, but here it is associated with a much smaller fault entirely within the Cambrian rocks.

Stop 3. Make your way carefully along the shore to the slight promontory about 200 m south of Bottle Quay (half way between it and the Martello tower). The bedrock below the boulder clay is no longer quartzite. It is layered green rock alternating between smooth, silky and easily split layers (mudrock), and more blocky layers (sandstone). These layers are known as beds or strata of rock, and are sloping towards the sea. They were originally deposited as horizontal layers of mud and sand which gathered on the floor of the Cambrian sea. A great thickness of mud and sand (and clean quartz sand) built up, and the lower layers became severely compressed by the weight of the upper layers. The layers became converted into solid rock - mudrock, sandstone and quartzite respectively. They also became tilted and, eventually, uncovered by upward movement of the earth's crust and removal of the upper layers by erosion. During these earth movements the sandstone beds tended to crack. The cracks pulled apart and the spaces later became filled with white quartz to form quartz veins. A layer of sandstone riddled by intersecting quartz veins may be seen near the head of the beach just beyond the promontory.

Look carefully at the boulder clay overlying the green bedrock at the promontory and just beyond it. Dark grey boulder clay at the bottom is separated from brown boulder clay above by a sloping layer of coarse pebbles and blocks. This intervening layer is associated with shells of limpets and small whelks and it is believed to be the remains of an ancient pebble beach. Again this evidence points to a time in the past when sea level was higher than it is today. Since the beach deposit is sandwiched between older and younger boulder clays, the high sea level stand seems to have occurred during the ice age after one ice-melting event, but before the last melting of ice, some 14,000 years ago.

EXCURSION 5: BLACKROCK

Patrick Wyse Jackson

How to get there: DART to Blackrock Station; Bus Nos. 6, 6a, 7, 7a, 8, 17, 45; Car parking close to railway station.
Geological horizon: Silurian - Devonian.
What to see: Explosion breccia in the Leinster granite. Use of granite and Carboniferous limestone for walls.
Duration: 1 hour.
Warning: Be careful of slippery rock surfaces.

This short trip will examine an unusual feature (a breccia) developed in the Leinster granite. In addition the walls in Blackrock Park are of interest.

Stop 1. The DART Station is a typical sturdy railway building, built in the 19th century. Have a look at the granite pillars that are by the entrance. They are probably quarried from Dalkey. They are unusual, as pillars of their size are more commonly of limestone. Walk to Blackrock Park by way of a path bounded by a high wall on your left and by the railway tracks on your right. Stop and have a close look at the wall. Are the blocks of stone irregular in shape or have they been 'squared' by the stone masons? The wall is built of the same type of stone that you have just seen at the Dart Station. This granite contains three major minerals - quartz (glassy), feldspar (white-cream), and mica (silver or black crystals). Draw a small piece of this stone taking care to show the arrangement of the different minerals. Are the crystals all the same size? Are they randomly distributed, or are there clumps of similar mineral types? In a note book describe in a few lines the rock - colour, size and arrangement of crystals.

Stop 2. Go into the Park, walk past the Bandstand on your right, and head to the walls on your left. These walls divide the park from the gardens of a number of large houses. One of these houses was frequently visited by John Wesley, the founder of Methodism, in the 1770s. Look closely at the walls. Are they built of the same stone used in the walls seen a few minutes ago? No! They are built of a grey stone called limestone. This limestone was deposited in a shallow sea during the Carboniferous period some 340 million years ago. You might be able to find some fossils in the rock. In addition you will probably be able to see some layering (called bedding, by geologists) in the rock - when sedimentary rocks are deposited they are