1977/8. Cliff stability investigation of a property at Lindisfarne.

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At the request of the Municipality of Clarence, an engineering geological investigation was undertaken of the cliffed section of the River Derwent foreshore that forms the western boundary of A.L. Pearce's property, 'Salamis' in Talune Street, Lindisfarne.

It is proposed to subdivide the area [EN282555] and build a series of blocks of flats each consisting of three units. Three of these blocks are to be built close to the cliff face with each block consisting of three single storey units stepped at different levels and cut into the slope behind the cliff.

INVESTIGATIONS

The officers of the Municipality of Clarence were concerned about three geological problems associated with this subdivision proposal.

(1) The excavations for the units and their various service drains would allow surface water to infiltrate at lower levels in the soft bedrock, creating stability problems, increasing the erosion rate and accelerating the cliff retreat. The Muniicpal officers acknowledge that the existing rate of cliff retreat was slow.

(2) The increase in amount of surface water infiltration associated with the activities of the occupants of the units would, in time, create instability in the soft rock of which the cliffs are composed.

(3) At what distance was it considered safe to build from the cliff edge, allowing for a life expectancy of 100 years for the units?

In an attempt to answer these problems the following investigations were undertaken:

(1) A geological examination of the rocks exposed on the cliffs at Beltana and Lindisfarne Points between Talune Street and the ferry wharf.

(2) An examination of old maps and of aerial photographs taken in 1948 and 1976 in an attempt to estimate the rate of cliff retreat by marine erosion.

(3) A seismic survey to establish if the soft basaltic rock continues behind the cliff to the eastern boundary of the subdivision, and to establish if this rock has the same degree of alteration and weathering as the basalt exposed on the cliff (plate 1).

(4) A series of short seismic spreads on the small steps close to the cliff edge.

(5) Two 3 m deep hand auger holes, one of which was drilled near the cliff edge, the other close to the tennis court on the eastern boundary of the subdivision.

GEOLOGY

Beltana Point is composed of Tertiary basalt overlain by river gravel and grey sandy soil. Along Pearce's cliff section the gravel occurs only at the northern boundary where it is less than 25 mm thick. Elsewhere along this section, only small quartzite and siltstone pebbles derived from this gravel are present in the sandy soil which is about one metre thick.

The basalt is highly vesicular and closely layered and contains abuntant iron nodules. These nodules fill many of the vesicles and may be up to 5 cm in diameter. The iron oxide has also crystallised into the vesicles, forming small geodes lined by kidney ore structures.

The weathered basalt is soft, has an earthy texture and appears to have been altered on extrusion. Only in the centre of some concentrically weathered zones does the rock become at all hard, forming small nodules, although no completely fresh unaltered or unweathered basalt was found on the cliff face. The basalt is soft but because it is massive, having only a few widely but regularly spaced vertical joints (plate 2) it is erosion resistant and forms near vertical cliffs.

Joints occur at 1-1.5 m intervals and are often open, the joint walls separated by up to 50 mm (plate 3). The joints appear to be mostly cooling contraction joints but some veins containing weathered clay minerals are present. The horizontal banding of the basalt is the result of vesicle layering and vesicle density (vesicles frequently form 50-60% of the rock surface). Where these vesicles become particularly dense and closely spaced, the rock weathers differentially and rapidly to form a grey-white clay. Such layers or areas in the basalt are less resistant to erosion, as seen at the northern point on the northern boundary of the subdivision.

CLIFF TOPOGRAPHY

A series of small steps or terracettes forms a distinct change in slope towards the cliff edge. This zone ranges from 5-10 m in width. These steps are thought to be associated with the open vertical joints exposed along the cliff face (plates 2, 3).

One wide U-shaped cliff embayment occurs immediately north of the brick sea wall. The cliff line is eroded back 3-8 m for a distance of about 15 m. This embayment is apparently the result of the collapse of a cave; The softer grey-white highly vesicular weathered basalt, which is fractured by a series of open vertical joints has been more strongly eroded. Another similar but smaller embayment occurs approximately midway along Pearce's cliff line. This narrower notch shows the same association of the grey-white weathering, highly vesicular basalt and open vertical joints.

These embayments are evidence of active marine erosion of the cliff line in the area. The cliff retreat rate is so slow that no retreat rate could be measured for the 28-year period covered by the aerial photograph records.

Active marine erosion has occurred from north of Pearce's boundary to Talune Street, where wave action driven by north-westerly winds across the River Derwent has broken and breached a well constructed sea wall and has eroded the cliffs. Wave action from north-westerly winds is far more erosionally active and destructive than from the south-east, the wave direction to which Pearce's cliff section is exposed.

SEISMIC SURVEY

Two seismic refraction spreads 50 m in length with a geophone interval of 3 m were fired parallel with and close to the cliff edge. Three velocity layers were recorded (V_0 = 500-600 m/s, V_1 = 900-1200 m/s and V_2 = 1500-1800 m/s). A cross spread, 65 m in length and with a geophone interval of 5 m, was fired from the cliff line to the eastern boundary of the subdivision near the tennis court. Similar seismic velocities were recorded (V_0 = 600 m/s, V_1 = 1200 m/s and V_2 = 1500-1900 m/s). No higher velocities were recorded even when the shot point was extended as close to the eastern boundary as possible. The seismic results suggest that the basalt under the remainder of the subdivision is similar to that exposed along the cliff line.

Hand auger holes drilled to a depth of more than 3 m penetrated one metre of soil then a thin clay layer and bottomed in what appeared, from the small fragments recovered, to be weathered vesicular basalt.

Short seismic spreads, 6 to 23 m in length were fired across the small steps that occur behind the cliff face. Geophone intervals of 30, 60 or 150 cm were used. Three or more geophones in the 30 and 60 cm spreads were placed on the steps while only one geophone was situated on each step on the 150 cm spread.

The velocity curves on the 30 and 60 cm spreads were markedly stepped, reduction in seismic velocity occurring between steps (V_0 = 300-335m/s, stepping to V_1 = 460-490 m/s and with V_2 = 610-670 m/s). With the 150 cm spacing spread no stepping was apparent (V_0 = 180 m/s at west end, 300 m/s at east end of the spread, V_1 = 730-790 m/s and V_2 = 1370-1520 m/s). The low V_0 velocity (180 m/s) was recorded only at the west end of the spread and is associated with the terracettes and change of slope near the cliff edge. The stepping of the seismic velocities in the 30 and 60 cm spreads is thought to be due to a series of open vertical joints on the cliff face which probably continue for a distance of some 7-10 m (*i.e.* to the change of slope in the terrace profile).

CONCLUSIONS

Although the altered basalt forming the cliff is soft, it is a surprisingly stable and competent rock. The loads imposed by the units should not create any structural problems.

Marine erosion with some minor cliff retreat has occurred at Pearce's, but its rate is so slow along this particular section of Beltana Point that it is insignificant and appears to present no great hazard. It is not exposed to the waves generated by north-westerly winds which cause active erosion further north.

The open joints exposed on the cliff face are related and associated with the change in slope of the terrace profile where it falls by a series of small steps to the cliff edge. If these joints are as open as appears along the cliff face then increased surface drainage down these joints could form potential slip failure or movement. This unstable zone is narrow (about 7-10 m in width) and it is in this zone that existing failures have occurred. Increased surface water infiltration associated with the development of the area could possibly accelerate this slow natural process.

RECOMMENDATIONS

The present small sea protection wall existing along the southern section of the block should be completed to the northern boundary.

The units should not be built on the zone some 7-10 m wide that occurs immediately behind the cliff, because of its potential instability.

The sewerage, storm water and other service drains should not be dug along this zone, but should be sited behind the units.

Light structures such as concrete patios, carports, driveways etc. from which the surface water run off could be directed away from the vertical joints could, if essential, be built on this zone.

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Plate 1. *Typical cliff section in basalt.*

Plate 2. *Cliff section showing widely spaced vertical joints.*

Plate 3. *Open joint in basalt.*