(*Paper No. 2524.*)

"Securing the North Cliff, Scarborough."

By ROBERT AYTOUN, Assoc. M. Inst. C.E.

THE northern extremity of Scarborough stands upon land from 100 to 175 feet above sea-level, which after falling abruptly to the sea-beach, forms the North Cliff and Undercliff, and skirting the North Bay for about $\frac{3}{4}$ mile. The cliff was subject to extensive slips, and the undercliff to erosion by the sea.

The construction of the sea-wall described by Mr. W. Eliot, M. Inst. C.E.,[1] has secured the undercliff at that part from the sea; and during its progress, the Corporation employed men in draining, laying out, and securing the cliff and undercliff, at first under the superintendence of Mr. Leonard Thompson; and from January 1889 under the Author, as regarded works for preserving the cliff.

The rocks of the north cliff and undercliff belong to the middle and lower oolites. The main bulk of the undercliff from A to C (Plate 8, Fig. 1) consists of shale, mingled at intervals with irregularly bedded masses of sandstone. Above this lies a quantity of débris, from 10 to 30 feet thick, which has fallen or slipped from the adjacent cliff. The cliff, rising behind at varying elevations, is composed of boulder clay from B to D (Plate 8, Fig. 1), underlaid by the same estuarine rock as the undercliff (Plate 8, Figs. 8 and 9). From B to A it consists of sandstone, below which is a bed of shale covering a band of hard limestone—cornbrash—in all about 10 feet thick; and below the cornbrash is the upper estuarine series, of great depth, and forming the foundation of the whole cliff and undercliff (Plate 8, Figs. 6 and 7). The distinction between cliff and undercliff is less marked in the boulder clay, from B to D, than in the sandstone section, where the difference culminates at A in a precipice 120 feet high.

The north cliff and undercliff were exposed to the following destructive agencies:—

1. The erosion of the shale foundation of the undercliff by the sea.

2. The infiltration of water from rain or springs amongst the

[1] Minutes of Proceedings Inst. C.E., *ante*, p. 289.

loose débris on the undercliff, leading to disintegration of the mass and slips on the shale base.

3. The dipping of the surface of the underlying shale of the undercliff seawards, greatly facilitating slips.

4. The disintegrating action of atmospheric influences, especially frost, upon the exposed shales of the estuarine and cornbrash strata.

The measures adopted to arrest the work of destruction were as follows:—

1. The erosive action of the sea was prevented by the sea-wall skirting the base of the undercliff.

2. The loose saturated mass, forming the upper portion of the undercliff, was drained by a series of timbered trenches, 3 feet wide, cut through the clay or sandstone débris to a minimum depth of about 2 feet into the solid shale substratum. At the bottom of each trench, 4-inch stoneware pipes were laid; and the trench was filled with rubble to a height of 2 or 3 feet above the impervious shale. When, however, the material was very wet or specially liable to disturbance, the rubble was carried up to the top of the trench. These trenches were carried at right angles to the "trend" of the cliff, about 30 feet apart. The 4-inch pipes were led from the trenches down the face of the undercliff to a 12-inch main under the Albert Drive, or were joined, where practicable, into a 6- or 9-inch path drain, running diagonally down the face of the undercliff.

In the boulder-clay portion of the cliff, from C to B (Plate 8, Fig. 1), a longitudinal cutting was made in short lengths in the loose undercliff at the base of the cliff down to below the water-bearing beds, to prevent the percolation of water from the gravel beds in the cliff into the upper portion of the undercliff. Pipes were led up from the transverse drains already mentioned, and inserted in the solid cliff along the bottom of the cutting. Above the pipes, a rubble wall or screen, 18 inches wide at the base and 9 inches at the top, was packed against the side of the cliff; and the loose material of the undercliff was then banked against it, forming a buttress to the cliff and a protection against atmospheric destruction. The screen of rubble protected the made bank effectually from infiltration from the cliff, and also from the action of surface water from above.

3. At several places in the undercliff, however, the inclination of the surface of the shale, underlying the disintegrated mass of undercliff, together with a lubricating film formed on the surface of the shale, which was not affected by drainage, promoted a slow

but continuous motion seawards of the superincumbent mass, which it would have been most hazardous to attempt to arrest by retaining walls founded on the precarious shale base. Timbered pits, averaging 22 feet in length transversely and 12 feet wide, were accordingly sunk down to the shale, which was then cut into benches in the solid, dipping landwards about 1 in 6. Drain pipes were laid along the low edge of each bench, and connected with the deep transverse drains mentioned above. The benches were next covered with 1 to 2 feet of dry rubble, and the pit re-filled with excavated material. The retaining bank thus created by a succession of pits distributed the pressure on the foundation far more than would have been possible with a wall; making it least at the front edge of the undercliff, where there was most danger of a fracture of the shale foundation. In two places a greater depth of stone was placed upon some of the benches, and packed by hand in the front of the bank. This was rendered necessary at Z Z (Plate 8, Figs. 1 and 9), on account of the small base of the undercliff, and at Y Y (Plate 8, Figs. 1 and 8), by the special persistency of the sliding movement. On the site of the old "Rock Gardens" (Plate 8, Fig. 7), the benching was much facilitated by the removal of a great part of the material above the area to be benched for filling behind the sea-wall. The areas of shale benched in this way amounted to about 3,500 square yards.

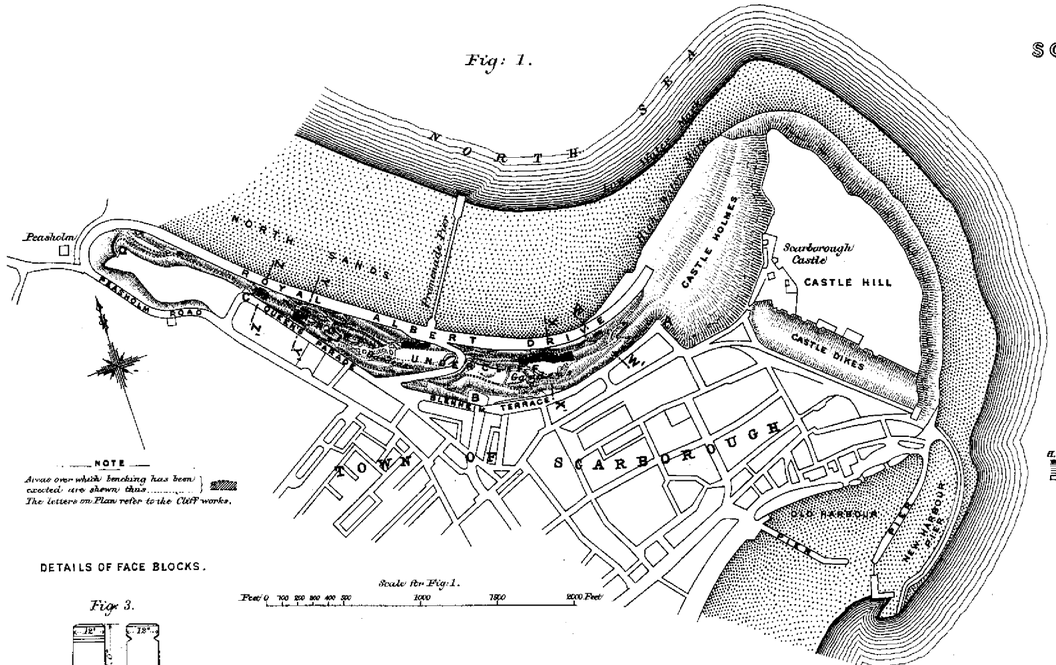
4. The disintegration of the exposed shale by atmospheric influences was prevented by covering it, where practicable, with sods, secured in position by small wooden pegs. At the base of the sandstone cliff, however, the face of the cornbrash and lower shales fell so precipitously towards the undercliff that the exposed shale had to be covered with a screen of stones, against which the débris of the undercliff was banked up, and sodded or sown (Plate 8, Figs. 6 and 7).

The works were completed in June 1890; and the area of undercliff thereby rendered available for public use, on the north side of Scarborough, is over 19 acres. The cost of the works, exclusive of excavation for filling behind the sea-wall, and of property rights purchased by the Corporation, was rather over £12,000.

The Paper is accompanied by three tracings, from which the sections of cliff in Plate 8 have been reduced.

SCARBOROUGH IMPROVEMENT WORKS.

Fig: 1.

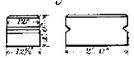


DETAILS OF FACE BLOCKS.

Fig: 3.

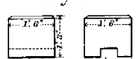
HEADERS.

Fig: 4.



STRETCHERS.

Fig: 5.

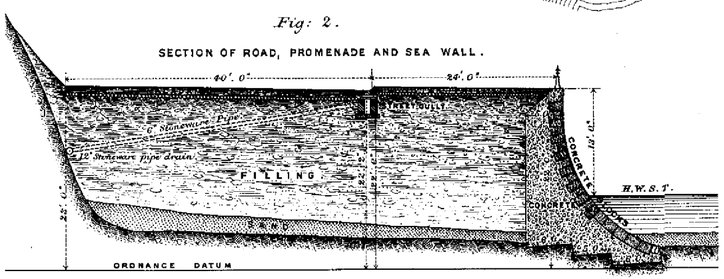


LOWER BLOCKS.

Scale for Fig: 1.

Fig: 2.

SECTION OF ROAD, PROMENADE AND SEA WALL.



NORTH SEA WALL AND DRIVE.

Scale 10 Feet = 1 Inch, Fig: 2.

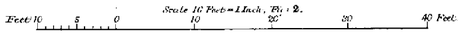


Fig: 6.

SECTION ON W. W'.

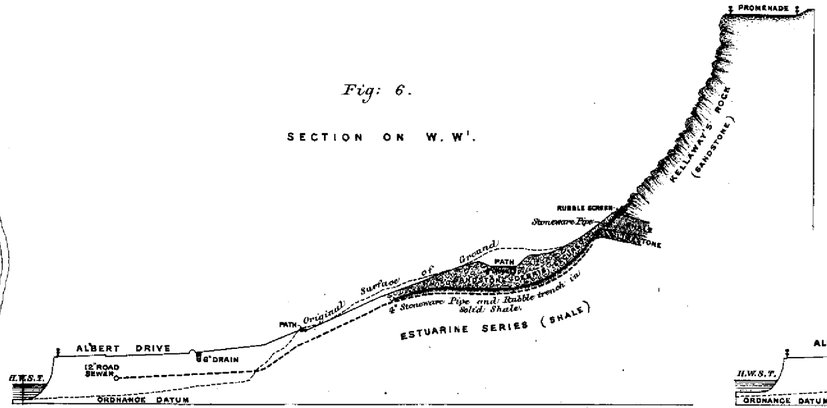


Fig: 8.

SECTION ON Y. Y'.

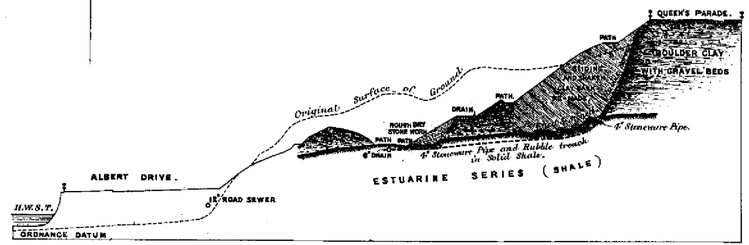


Fig: 7.

SECTION ON X. X'.

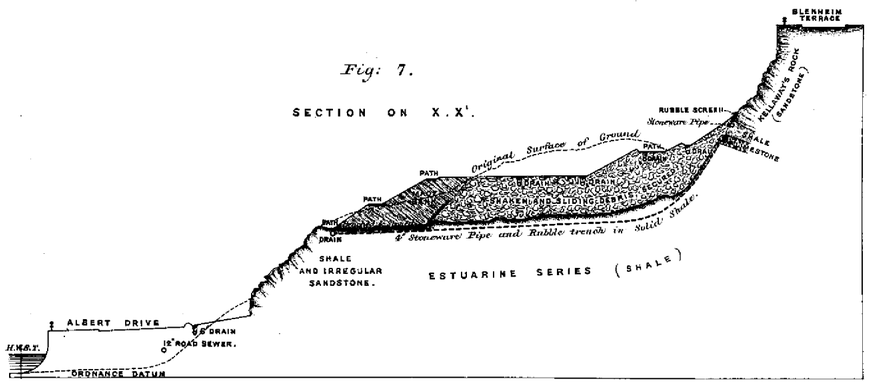
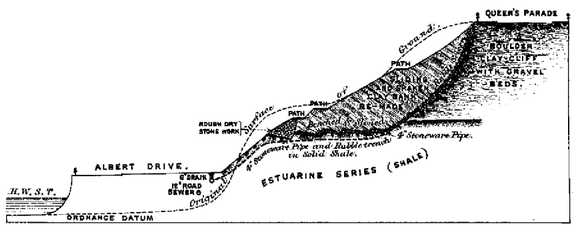


Fig: 9.

SECTION ON Z. Z'.



NORTH CLIFF WORKS.

Scale 50 Feet = 1 Inch. Figs: C. 7. & 8.

R. AYTOUN, DELT

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