

Ground-swell propagated across a broad and deep ocean produces by far the most imposing breakers. So long as the water remains deep and no wind blows, the only trace of the passing ground-swell on the open sea is the huge broad heaving of the surface. But where the water shallows, the superficial part of the swell, travelling faster than the lower, which encounters the friction of the bottom, begins to curl and crest as a huge billow or wall of water, that finally bursts against the shore. Such billows, even when no wind is blowing, often cover the cliffs of the north of Scotland with sheets of water and foam up to heights of 100 or even nearly 200 feet. During northwesterly gales, the windows of the Dunnet Head lighthouse, at a height of upward of 300 feet above high-water mark, are said to be sometimes broken by stones swept up the cliffs by the sheets of sea-water which then deluge the building.

A single roller of the ground-swell 20 feet high falls, according to Mr. Scott Russell, with a pressure of about a ton on every square foot. Mr. Thomas Stevenson conducted some years ago a series of experiments on the force of the breakers on the Atlantic and North Sea coasts of Britain. The average force in summer was found in the Atlantic to be 611 lb. per square foot, while in the winter it was 2086 lb., or more than three times as great. On several occasions, both in the Atlantic and North Sea, the winter breakers were found to exert a pressure of three tons per square foot, and at Dunbar as much as three tons and a half.<sup>255</sup> Besides the waves produced by ordinary wind action, others of an extraordinary size and destructive power are occasionally caused by local atmospheric disturbances. Such are proba-

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<sup>255</sup> T. Stevenson, *Trans. Roy. Soc. Edin.* xvi. p. 25; treatise on "Harbors," p. 42.