THE SCIENCE OF EXPLOSIVES AS APPLIED TO WARLIKE PURPOSES

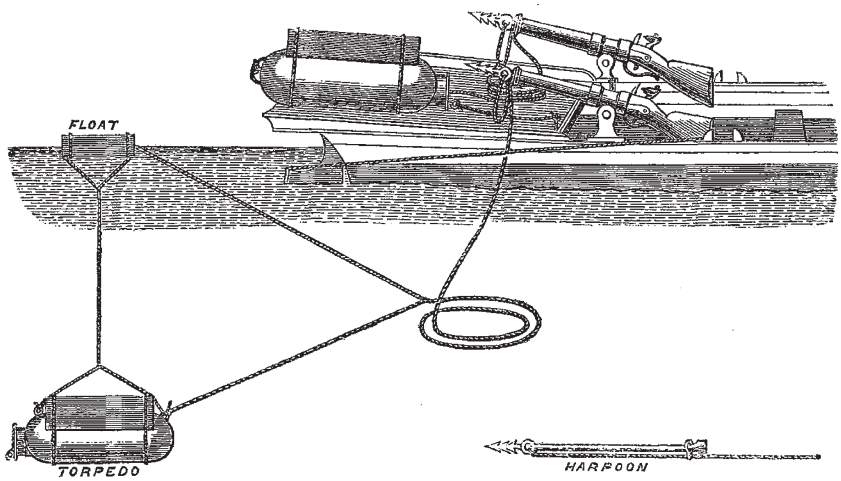
I.—EARLY STUDY AND APPLICATION OF EXPLOSIVES

THE protracted and disastrous war between the Northern and Southern States of America was fruitful in the development of expedients to serve as auxiliaries to the hitherto well-recognised materials of defence and attack. No subject connected with the details of that war has, however, received more general attention on the part of European Powers, great and small, than the extensive and successful applications of a somewhat ancient class of war-engine, the value of which up to that time had received no practical demonstration, but which is now on every hand regarded as destined to play a most important part in future wars.

The idea of employing floating or submerged charges of gunpowder as agents for the destruction of ships and other marine structures, has been occasionally put into practice from a somewhat early date, although with but few instances of success. The earliest form of marine-mine was the so-called *Explosion Ship*, which the Dutch appear to have been the first to employ. When Antwerp was besieged by Alessandro de Farnese, Duke of Parma, in 1585, a boom or boat-bridge was constructed across the Scheldt by the besiegers, and this, an Italian engineer, Jambelli, undertook to destroy for the Dutch. Four large flat-bottomed vessels were each of them loaded with several thousand pounds of powder, over which were placed fireworks and large masses of stone; two of the boats were provided with slow matches, the burning of which had been timed, and the others fitted with clock-work contrivances by whose agency the powder was to be exploded at a pre-determined period. The vessels, thus equipped, together with a number of fire-ships, were allowed to drift towards the boom, and, on its centre being reached, one of them immediately exploded with such violence as to destroy several of the ships composing the structure, and likewise to kill 800 men and wound many more, among whom was the Prince Farnese himself.

Vessels of this kind were repeatedly used by the English in the seventeenth century; thus an attempt was made in 1693 to destroy St. Malo by the explosion of a vessel of 300 tons laden with a large quantity of gunpowder, besides various other combustibles; and similar attacks were likewise directed with little or no success two years later against St. Malo, Dieppe, and Dunkirk. For some time after these operations explosion-vessels seem to have fallen into disuse, there being no instance of their employment on record until 1809, when Lord Cochrane destroyed a boom in the Basque Roads by exploding in contact with it a vessel laden with very closely packed gunpowder. Some unsuccessful attempts at the destruction of English ships by means of explosion-vessels were also made by the Americans during the War of Independence; but this very wasteful and uncertain mode of applying gunpowder in marine operations appears to have been since then altogether abandoned, until the late American War, when Admiral Porter, of the United States Navy, added one more to the list of unsuccessful operations of this kind, by endeavouring to destroy or disable Fort Fisher by the above means.

The earliest form of submerged self-acting mine was the so-called *floating petard* used by the English during the operations in Rochelle, in 1628. These implements of warfare consisted of small cases of sheet-iron filled with powder and fitted with a spring which was released as soon as the drifting machine came into collision with a ship, or other obstruction, and thus determined the explosion of the powder by means of a match-lock. They appear to have been too small to inflict any serious injury upon ordinary vessels, and many of them were captured by the French. Similar contrivances were constructed by an American, Mr. Bushnell, in 1777, who endeavoured to apply them to the destruction of the English fleet anchored near Philadelphia in that year; but the machines were started at too great a distance from the ships, and drifted away in wrong directions, the damage inflicted by them being limited to the destruction of a ship's boat and her crew, who were engaged in capturing one of the dangerous shoal. In 1800 another American, Robert Fulton, submitted to the French Government several projects for the destruction of ships by means of submarine mines, or as they were called at the time, infernal machines. This gentleman appears to have spent three or four years in perfecting his system of warfare, but received such scant assistance and encouragement from his own Government, that in 1805 he determined to offer his invention to the English, who about that time had been creating a considerable panic in the French fleet off Boulogne, by sending among the vessels a number of fire-ships and small drifting mines of a self-acting nature, termed *catamorons*.



THE FIRST SO-CALLED "TORPEDO" PROPOSED BY FULTON IN 1800

The first of Fulton's torpedoes, of which trial was made by the English naval authorities, consisted of a metal vessel holding about 100lb. of gunpowder, and fitted with a clockwork instrument which could be regulated to

release a flint-lock at a determined period after it was set in motion. The machine was partly encased in cork, so that when charged with powder it was a little heavier than sea-water, and it was attached by a line to a box float, whereby it could be kept suspended at any particular depth. These torpedoes were carried in harpoon-boats, and connected by long lines with harpoons fired from small guns at the ship to be attacked. If the harpoon was successfully planted in the ship's side, the torpedo was drawn into the water by the line, and this, as it ran out, released a pin from the torpedo, setting the clock-work in motion. The submerged torpedo was then supposed to drift into close proximity with the ship by the time the flint-lock caused ignition. Several French ships were attacked by means of these explosive machines—which, by the way, Fulton was the first to term *torpedoes*—but although they were in some instances successfully exploded, the enemy's vessels sustained no material injury, from the fact that the charges were immersed in too great a depth of water. Fulton's drifting torpedoes were employed in a more simple form in an experiment made in October 1805, in the presence of the principal officers of the fleet commanded by Lord Keith, on which occasion a 200-ton brig, the *Dorothea*, anchored for the experiment off Walmer Castle, was destroyed at one operation. The torpedo employed contained 180lb. of powder, and was suspended at a depth of fifteen feet; it was simply allowed to drift with the tide against the hulk, the clockwork which regulated the explosion being timed to run eighteen minutes before the machine was cast adrift.

The torpedoes made use of by the Russians in the Baltic in 1855, were mechanical self-acting machines, containing charges of from 8lb. to 10lb. of powder; they were constructed with some care and ingenuity, and if they had been but of larger size, their existence would have greatly jeopardised the safety of our ships. The machines were conical in form, and were so arranged as to explode on being struck by a passing vessel, the blow causing the fracture of a glass tube containing sulphuric acid, which, falling upon a tuft of cotton wool saturated with chlorate of potash, sulphur, and sugar, at once ignited the charge.

But it was not, as previously stated, until the subject of torpedoes was seriously taken in hand by the Americans during the recent war, that torpedo-warfare assumed a grave and wide-spread importance. In the hands of the Confederates especially, the applications of submarine mines to warlike purposes were very carefully studied, and with such marked success, that, according even to the official despatches of the Federals themselves, twenty-five ships are admitted to have been destroyed. In the first instance *mechanical* torpedoes only were used, such, viz., as exploded by means of percussion arrangements fitted on the outside, or by a drifting line attached to a trigger, but these were afterwards succeeded to some extent by machines ignited at will from the shore by electricity. The latter were, in the opinion of Admiral Porter, of inferior value, from the fact of their ignition not being effected at the proper time; and the gallant officer reports, that on one occasion he safely ran the gauntlet through a channel bristling with these machines, by simply sending forward as pioneer a sham *Monitor* built of logs, and furnished with an imitation turret, which passed without damage over several torpedoes exploded at her, and was afterwards followed by the fleet unharmed.

Consequent upon the successful employment of torpedoes by the Confederates, the Federals turned their attention more closely to the matter, building a torpedo-boat especially for this kind of warfare, and reconstructing six *Monitors* for the same purpose.

The perfection to which submarine mines have been brought up to the present time, and the various methods adopted for applying electricity to their ignition, will form the subject of the second part of this paper.

THE DEEP-SEA SOUNDINGS AND GEOLOGY

SOME little time ago an eminent geologist, Professor Gümbel of Munich, applied to Sir Roderick Murchison for specimens of the Deep-sea Soundings which have lately been the subject of so much discussion. Sir Roderick mentioned Dr. Gümbel's wish to me, and I immediately sent him a small quantity of North Atlantic mud from 2,350 fathoms, which had been preserved in spirit. The following translation of a letter, dated April 18th, 1870, with which Dr. Gümbel has favoured me, and which embodies the result of his researches hitherto, will, I am sure, be read with the greatest interest by geologists and biologists. I may mention that I long since found coccoliths in the nummulitic limestone of Egypt. T. H. HUXLEY

Many thanks for sending me the specimen of mud obtained by the deep-sea dredge. I have already subjected it to searching investigation, and have obtained results, which have the most important bearing upon my other work. Although my inquiries are, at present, only commenced, it will possibly interest you to receive some information respecting them. I call the new kind of investigations which I have begun to carry out, "Deep-sea investigations on the dry land;" *i.e.*, examinations of the different calcareous rocks, with reference to the share which the smallest organic forms, similar to those at present existing in the deep sea, have had in their formation. When limestone is soft and earthy, traces of the smallest marine animals can be detected by triturating it in water. In chalk, for instance, from Palestine, I have convinced myself, in the most unequivocal manner, of the formation of the calcareous mass, for the greater part from your so-called coccoliths, besides *Foraminifera*, &c., which have long been known. Similar soft calcareous rocks are unfortunately rare in older formations. With these another process must be adopted. I started from the fact that in many of these calcareous rocks, the original calcareous portion of the organic beings is replaced by silica, and that hence in such rocks, by the separation of chert or flint, at least a part of the calcareous portion of the coccoliths and coccospheres might be replaced by silica. It was to be expected that the exterior form might suffer by this replacement, as, in fact, the chalk coccoliths have become materially different in their form from those of the existing deep-sea ooze.

I found, in fact, by treating such a siliceous limestone with very dilute acetic or hydrochloric acid, in the fine mud which is left, an organic residuum corresponding to the coccoliths of the present day. Even in the Trenton limestone, and in a yellow limestone of the Potsdam series, corresponding minute bodies were to be recognised, although sparingly, presenting themselves amongst an incredible multitude of other minute particles of organic origin. The microscope discloses, like the telescope, in the vault of heaven, a new world of the smallest organic beings, respecting which, however, I must say nothing at present, but confine myself to the coccoliths. These casts of coccoliths are found very sparingly. I explain this from the circumstance that the silica is chiefly the result of the decomposition of large masses of organic material, especially of the larger testacea. I obtained, however, important results by subjecting the deep-sea ooze, for which I am indebted to your kindness, to the action of the acids. These with violent development of carbonic acid, dissolve the minute bodies of the coccoliths, of the coccospheres, and perhaps also those of *Bathybius* (although of this I am not quite sure), and there remain only certain peculiarly formed but very much changed portions of the coccoliths as roundish discoidal flakes, the organic portion of the original coccoliths. In single isolated coccoliths this change of form is difficult to follow, but this can easily be done in those which appear to be firmly bound up (enveloped?) with a mass of the granular flakes (*Bathybius*?); and after the operation of the acid, can be again easily recognised in their exact position. Accompanying these coccoliths transformed by the action of acids, are countless little bodies extremely similar to those which can be obtained, in most cases, by dissolving siliceous limestone in acids.

This is the first commencement of researches which I propose following up, with, I hope, important results; since thin sections are of no good in studying these minute forms. I cannot close these notes of the researches with which I am at