REPORT ON DEEP-SEA RESEARCHES

Carried on during the months of July, August, and September, 1870, in H.M. Surveying Ship "Porcupine." *

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(*Continued from p.* 334.)

DIRECTING our course again towards the Algerine coast, we kept nearly parallel to it during the greater part of the next day, occasionally sweeping the bottom with the "tangles," which gave us abundance of Polyzoa, Echinoderms, &c., of well-known types, without any specimens of novel or peculiar interest. We reached Algiers on the afternoon of the 26th; and as it was necessary to take in coal, we remained in harbour until the 29th, when we resumed our easterly course, still keeping near the coast. The weather now began to be oppressively hot; the surface-temperature of the sea rising to 76° or 78°, and that of the air being often several degrees higher. Wishing to see what would be the point at which the effect of this extreme superheating would cease to manifest itself, we took a set of serial soundings at Station 53, with the following result, which we incline to consider typical of the condition of the proper surface-water of the Mediterranean in the summer season :—

	° Fahr.
Surface	77
5 Fathoms	76
10 ,, ...	71
20 ,, ...	61.5
30 ,, ...	60
40 ,, ...	57.3
50 ,, ...	56·7
100 ,, ...	55·5

Thus the amount of heat lost in the first 20 fathoms is no less than 15°·5; and as much as 9°·5 of this loss shows itself between 10 and 20 fathoms.

Again proceeding into deep water, we perseveringly explored the bottom with the dredge; and from a bottom of 1,508 fathoms we brought up some hundredweights of the same barren mud as had previously given so much trouble to so little profit. The sieve and the washing-tub again returned for answer "barren all." Disappointing as this negative result was to us as zoologists, there are aspects under which it may be viewed that may give it no small value to geologists. On these, however, we can more fittingly enlarge hereafter. Once more, shifting our ground a few miles, we put down our dredge in 1,456 fathoms, and brought it up loaded with a similar profitless freight.

We now determined to keep closer to the shore, and worked for several days along the African coast, for the most part using the "tangles," the ground being too rocky for the dredge. Here we came upon a small fleet of coral fishers, and were not a little interested in finding that they employed "tangles" similar to our own as their most effective method of collecting. We swept the shore with these very assiduously, usually between 50 and 100 fathoms; and although we obtained Polyzoa, Echinoderms, and corals in considerable abundance, there were not many of special interest. We may note, however, that several of the Polyzoa which occurred in the region in which the red coral is found had, when fresh, a red colour nearly as brilliant as that by which it is characterised; but this colour, in the Polyzoa, was quite evanescent.

The extreme heat of the weather having produced an exhausting effect upon our crew, especially on the engineers and stokers, Capt. Calver considered it desirable to give them rest; and we accordingly made for the Bay of Tunis, which we reached at mid-day on Saturday, Sept. 3rd. The town itself is situated at the head of a shallow lagoon, or salt-lake, that communicates with the sea by a narrow channel, and at this entrance there is a small sea-port named the Goletta, having a basin for vessels of moderate size. The lake, although about six miles long, has only from six to seven feet of water at its deepest part; and when the water is unusually low, a small steamer, which plies between the Goletta and Tunis, is not always able to run, as happened at the time of our visit. Owing to the great evaporation, and the absence of any stream of fresh water, the water of this lake is usually very salt; but when heavy rains fall the level is considerably raised, and the saltness is diminished. Thus the condition of this lake in regard to that of the sea outside is sometimes that of the Mediterranean in regard to that of the Atlantic, and sometimes that of the Baltic towards the German Ocean; and we would suggest whether it might not be possible, through our Consulate (which has an office at the Goletta), to have a regular series of observations made upon the relative densities of the water of the lake and that of the sea, and upon the direction of the upper and under current in the channel of communication between them, that might furnish valuable data for the complete elucidation of the subject of currents occasioned by excess of evaporation. We availed ourselves of this short rest to visit the town of Tunis, which, for the most part, retains its genuine Moorish character; and the ruins of Carthage, a few miles off, the most remarkable part of which consists of a series of immense reservoirs for water, supplied by an aqueduct that brought it from a range of mountains at no great distance, from which also the modern town of Tunis is supplied.

This part of our work having brought us to the neighbourhood of the Island of Pantellaria, we landed on it with the view of visiting, if possible, a cavern which had the reputation of being "of icy coldness." As we found, however, that a whole day's delay would be involved, we gave up the idea; and we afterwards obtained elsewhere the information we desired. The continuance of the very hot weather having brought a large part of our crew to a state of such exhaustion as to render a continuation of our operations undesirable, Captain Calver considered it expedient to proceed to Malta without further delay; and we anchored in the Harbour of Valetta on the morning of Saturday, September 10. Here we found it necessary to remain for ten days, the illness of our chief engineer, which we at first hoped might be only temporary, proving sufficiently serious to require that a substitute should be found for him. Our time was passed very pleasantly in visits to the various objects of interest in which the island abounds, and in the enjoyment of the kind hospitality of His Excellency the Governor, Vice-Admiral Key, and other officers. The time was too short for any careful examination of the geology of the island; but one point which struck me as of special interest in relation to the deposit at present forming on the Mediterranean bottom will be specially noticed hereafter.

Quitting Valetta Harbour at midday on September 20, we steered in a N.E. direction towards a point about sixty miles distant, at which a depth of 1,700 fathoms was marked on the chart. This we reached early the next morning (60); and a sounding being taken, 1,743 fathoms of line ran out. As this was the greatest depth we had anywhere met with in the Mediterranean, and as the basin in which the sounding was taken is cut off by the shallows between Sicily and Tunis from all but superficial communication with the western basin, we watched the heaving-in of the sounding apparatus and its accompaniments with no little interest. The thermometers recorded a temperature of 56°, which was one degree *higher* than that which we had met with in our two deepest soundings (1,456 and 1,508 fathoms) in the western basin. The sample of the bottom brought up in the tube of the sounding apparatus indicated the prevalence of a yellowish clayey deposit so similar to that which had elsewhere proved so disappointing, that we could not feel justified in pressing Capt. Calver for the sacrifice of nearly a whole day, which would have been required for a single cast of the dredge at this depth. The specimen of bottom-water brought up by our water-bottle surprised us by its very small excess of density above the surface-water; the specific gravity of the former being only 1·0283, whilst that of the latter was 1·0281; and the proportion of chlorine per 1,000 being 21·08 in the former, whilst that of the latter was 20·77. The surface-water being here *more* dense than the average, the bottom-water was *less* dense; a result which a good deal surprised us at the time, but which subsequent comparison with the densities of specimens taken from the greatest depths we had sounded in the western basin showed to be by no means exceptional. And when we came to reason out the mode in which surface-evaporation may be presumed to operate in augmenting the density of the water beneath, we found it to be quite in accordance with *a priori* probability, that the *deepest* water should show the *least* excess of density above the water at its surface.

Having thus satisfied ourselves, so far as we could do by a single set of observations, that the physical conditions which we had found to prevail in the western basin of the Mediterranean present themselves also in the eastern, we steered for the coast of Sicily; and in a few hours came in sight of Syracuse, with the lofty mass of Etna as a magnificent background in the remote distance. The clouds which lay upon its summit during the earlier part of the day gradually

* Extracted from the Proceedings of the Royal Society.

dispersed as we approached it, so that we could distinctly trace the outline of its cone, save where this was obscured by a constantly shifting semi-transparent cloud. Whether this was a light smoke given off from the cone, or a film of vapour condensed by the contact of a current of warm moist air with the colder surface of the mountain-summit, we were unable to distinguish, though we watched it with great interest during the whole afternoon. We steamed quietly along the Sicilian coast during the night, so that sunrise the next morning found us in the narrowest part of the Strait of Messina, between Messina and Reggio; and we shall not easily forget the beauty of the spectacle we then beheld on either shore. Passing through the once-dreaded Charybdis, the dangers of which are rather poetical than real, and leaving on our right the picturesque castle-crowned rock of Scylla, we passed out of the "Faro," which narrows at its northernmost extremity to about three and half miles, into the open sea to the north of Sicily, studded by the Lipari Isles; and steered direct for Stromboli, stopping at 10 A.M. to take a sounding (station 61). This gave us a depth of 392 fathoms, and a bottom temperature of 55°·7, which afforded no indication of unusual elevation. Here again we found the density of the bottom-water scarcely in excess of that of the surface-water; and it was even lower than the surface-water in another sounding taken somewhat further on, (station 62), and at a depth of 730 fathoms, which gave a bottom temperature of 55°·3.

	Sp. Gr.	Chlorine.
Surface	1·0281	21·32
Bottom, 392 fathoms . . .	1·0282	21.36
Bottom, 730 fathoms . . .	1·0280	21·22

This result, again, surprised us much at the time; but we are now inclined to attribute it to the decrease of surface-evaporation, consequent upon the marked decrease in the heating-power of the sun, which showed itself in the change of the relative temperatures of the sea and air. For whilst for some days before we put into Malta, the surface-temperature of the sea had ranged between 76° and 78°, and the temperature of the air had been usually about 1° *higher*, we now found that while the surface-temperature of the sea ranged between 73°·6 and 76°·6, the temperature of the air was between 2° and 4° *lower*. This difference continued to show itself nearly all the way to Gibraltar; the daily averages of the surface-temperature of the sea ranging between 73°·1 and 75°·6, whilst those of the temperature of the air ranged between 68°·5 and 72°·0. We now approached the rugged cone of Stromboli, from the summit of which there was constantly issuing—as has been the case since the time when the neighbouring island of Hiera was fabled to be the workshop of Vulcan—a cloud of smoke, indicative of active changes in the molten depths beneath. Of this activity, however, we had found no special indication in the temperature-soundings taken nearest to the island. Whether the *general prevalence* in the neighbourhood of Sicily of a bottom-temperature averaging about a degree above that of the western part of the Mediterranean, is due to subterranean heat, is a question which can only be determined by a larger number of observations than we had the opportunity of making. As we neared Stromboli, we were much struck with the height to which the energetic industry of its inhabitants had carried the vine-cultivation all round the cone, save on two slopes looking N.W. and S.E., over one or other of which there is a continual discharge of volcanic dust and ashes. Although no flames were visible during daylight, we could distinctly perceive occasional flashes as night came on. Our course was now laid straight for Cape de Gat, which we passed on the 27th of September, arriving at Gibraltar on the evening of the 28th. The only scientific observations which we had the opportunity of making during this part of our voyage were confirmatory of those which we had made at the commencement of our Mediterranean cruise as to the lower temperature and inferior density of the surface-water, both which we attribute to the inflow from the Atlantic.

Having taken in at Gibraltar as much coal as we could carry, we left the harbour at 9 A.M. on the 30th September, and proceeded at once towards the scene of our previous observations. We thought it worth while, however, to take a sounding in our way towards this, near the 100-fathom line (station 63), for the sake of ascertaining the temperature and specific gravity of the bottom-water. The depth was found to be 181 fathoms, showing that the slope from the shallow to the deep portion of the channel is here very rapid. The bottom-temperature was 54°·7, that of the surface being 68°; and the specific gravity of the bottom-water was 1·0280, that of the surface being 1·0271. This bottom-water thus agreed closely in both particulars with that of the *deep* mid-channel, as ascertained in our first set of observations, and confirmed by our second.

We then steamed out to a point (station 64) nearly identical with that from which our previous investigations had been carried on; and commenced our work with a temperature-sounding. The surface-temperature (65°·6) proved to be here *less* by 2°·4 than it had been found to be at station 63; and this although it was taken an hour later in the forenoon, when an increase might have been expected. It thus corresponded closely with what had been previously found to be the average temperature of the Strait in mid-channel, both during the first approach at Gibraltar from westwards, and during our own experiments at the commencement of the Mediterranean Cruise; and the continuation of the like observations during the remainder of the day and ensuing night gave the same remarkable result, the *rationale* of which will be considered hereafter. The depth was somewhat less than at the neighbouring station 39, being 460 fathoms instead of 517; but the bottom temperature was a little lower, being 54°·7 instead of 55°·5. The respective specific gravities of the surface and bottom waters, and of that of the intermediate stratum of 250 fathoms, were found to coincide almost exactly with those previously determined, as the following comparative statement shows:—

	Sp. Gr. Station 39	Sp. Gr. Station 64
Surface	1027·1	1027.1
250 fathoms	1029·3	1029·2
Bottom	1028·1	1028·3

Now the density of the *bottom*-water here corresponds so exactly with that which prevails over the *deeper* bottom of the western basin of the Mediterranean, whilst it so considerably exceeds that of the *bottom* as well as of the *surface* water of the Atlantic, that we cannot fail to recognise it as belonging to the Mediterranean basin; so that, if it has any motion at all, we should expect that motion to be from east to west. Still more certainly may this be affirmed of the *intermediate* stratum, the density of which corresponds with that of the bottom waters of the *shallower* part of the Mediterranean basin; the greatest depth (586 fathoms) at which such water was obtained, being at station 40, the nearest point to the Strait from which a specimen of bottom water was obtained. And it may be further predicated that a stratum of water of a density of 1029·3 could not overlie water of the density of 1028·1, unless it *moved over* the stratum below, that is, unless (1) the two strata were moving in opposite directions, or (2) were moving at different rates in the same direction, or (3) the upper stratum were in motion in either direction, and the lower stratum were stationary. It will presently appear that the second of these conditions is the one which obtains in the present case.

We now proceeded to repeat our experiments with the "current-drag," with the view of obtaining, if possible, unequivocal evidence of the existence of that westerly under-current, which so many considerations combined to render probable. The direction of the wind during this set of experiments was from the east, or opposite to that of the surface-current; and its force (3 to 4) was sufficient, by its *meeting* the current, to produce a considerable swell, which necessitated the employment of a larger boat, and rendered it unsafe to allow her to drift without men. The sectional area of the boat was therefore greater than on the former occasion, giving the in-current a stronger hold upon her; but, on the other hand, the surface she presented to the wind was also greater; and as this acted in the opposite direction, the latter increase might be considered to neutralise the former, or even rather to exceed it, so as to render the boat more capable of being carried westwards by the "current drag," if this should be acted on by an outward under-current. The rate of surface-current was tested as before, and proved to be 1·823 mile per hour, its direction being N.E. by E. ½ E. This was a retardation of more than a mile per hour as compared with the former observation; and that it was not attributable to the mere surface-action of the easterly wind, was clear from the result of the next observation, which showed that the retardation extended to a depth far below the influence of surface-action.—The "current-drag" having been lowered to 100 fathoms' depth, the drift of the boat was reduced to 0·857 mile per hour, or *less than half* its surface-drift; its direction was nearly the same as that of the surface-current, viz., E. by N. ½ N. The "current-drag" was then lowered to

a depth of 250 fathoms; and in a short time the boat was seen to be carried along by it in a direction (W.N.W.) *almost exactly opposite* to that of the middle *in*-current of the Strait. The rate of outward movement of the boat was 0·400 mile per hour; but from the considerations formerly stated, it is clear that the actual rate of the under-current must have exceeded that of the boat on the surface. The "current-drag" was then lowered down to a depth of 400 fathoms; and again the boat was carried along in nearly the same direction as in the previous experiments, namely N.W. ½ N.; but more slowly, its rate of movement being 0·300 mile per hour.

Thus, then, our previous deductions were now justified by a *conclusive proof* that there was at this time a return-current in the mid-channel of this *narrowest* part of the Strait, from the Mediterranean towards the Atlantic, flowing beneath the constant surface-stream from the Atlantic into the Mediterranean; and it will be shown hereafter, by a comparison of all the results of our observations, that a strong presumption may be fairly raised for the *constant* existence of such a return-current, though its force and amount are liable to variation.

As the determination of the boundaries of this return-current, and of the amount and conditions of its variation, could

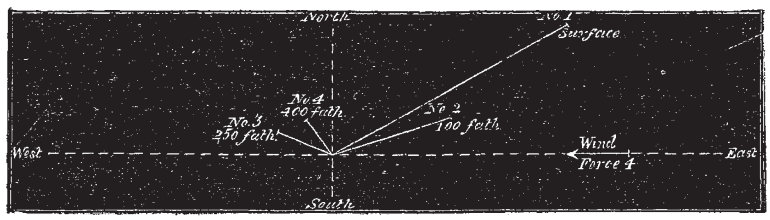

FIG. 1.—Rate (per hour) and Direction of Movement of Surface-Float, and of Current-Drag at different Depths; with Force and Direction of Wind.

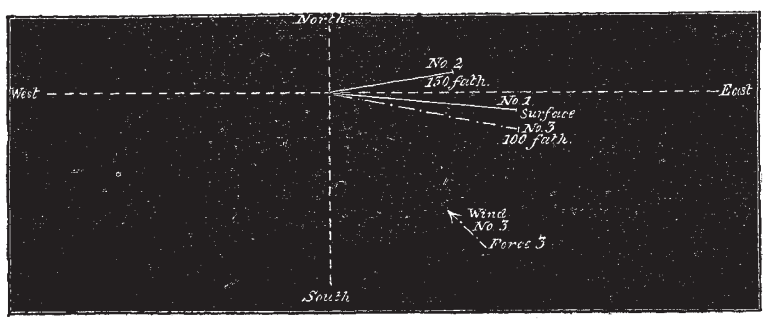

FIG. 2.—Rate (per hour) and Direction of Movement of Surface-Float, and of Current-Drag at different Depths; with Force and Direction of Wind in No. 3. (No Wind in Nos. 1, 2.)

only be effected by multiplied simultaneous observations a different points, with ample license as to time, neither of whicht fell within the scope of the present expedition, we were obliged to content ourselves, as regards this locality, with what we had found ourselves able to accomplish; and at the conclusion of this day's work we proceeded westwards under easy steam, so as to be able to resume our experiments the next morning in the *shallowest* part of the Strait.

The average surface-temperature of the mid-stream during our outward passage through the Strait proved to be 66°; thus corresponding exactly with what we had found it to be on our inward passage seven weeks previously. This depression, as compared with the surface-temperature of the Strait itself nearer the shore, both north and south, and with the temperature of the Mediterranean to the eastward and that of the Atlantic to the westward, is extremely remarkable. We shall hereafter inquire how it is to be explained.

The breadth of the Channel between Capes Spartel and Trafalgar is about twenty-three nautical or twenty-six and a half statute miles. Its northern half is much shallower than the southern, the 100-fathom line off the Spanish coast running at about twelve miles' distance from Cape Trafalgar; whilst along the African coast it keeps much nearer the hore, being at only two miles' distance from Cape Spartel. Between these two lines, the greatest depth marked in the chart is 194 fathoms; and this occurs off Cape Spartel, at less than a mile from the 100-fathom line. Between this and the opposite border of the deeper channel, the depths vary from 130 to 180 fathoms; the abruptness of the differences at neighbouring points indicating a rocky bottom, of which we soon had unpleasant experience.

SCIENTIFIC SERIALS

IN the *Journal of Botany* for March we find a continuation of the useful catalogue of new species of Phanerogamous plants published in Great Britain during the year 1870, and of Mr. Hiern's paper on the forms and distribution over the world of the *Batrachian* section of *Ranunculus*. Dr. Dickie contributes a paper on the distribution of Algæ, and Mr. A. G. More the commencement of a Supplement to Bromfield's "Flora Vectensis." Short notes, reviews, and reports of Societies fill up the number.

THE *American Naturalist* for February contains several interesting papers. Among them is one on the ant-lion (*Myrmeleo immaculatus*), a Neuropterous insect, by Mr. J. H. Emerton, with drawings of its matamorphoses; one on the resources and climate of California, by Rev. A. P. Peabody; notes on some birds in the Museum of Vassar College, by Prof. Jas. Orton; a short account of the spores of Lichens, by Mr. H. Willey; the Sperm Whales, giant and pigmy, by Dr. Theodore Gill, illustrated with numerous drawings, including the skull of *Callignathus simus* and *Physeter macrocephalus*. The Natural History Miscellany comprises also several shorter papers of much interest, including one on the morphology and ancestry of the King Crab, by the editor, Dr. A. S. Packard, jun.

THE March number of the *Geological Magazine* (No. 81) commences with a long article by Mr. James Croll "On the Determination of the Mean Thickness of the Sedimentary Rocks of the Globe." The author disusses the different methods which have been adopted in order to obtain an approximate estimate of the time occupied in the fo oation of the sedimentary rocks, and remarks that in all these researches it must be borne