The John Murray Expedition to the Arabian Sea

By LIEUT-COL. R. B. SEYMOUR SEWELL, C.I.E.

THE John Murray Expedition has now completed its first three months' work, during which time the H.E.M.S. *Mabahiss* has made four cruises, each of approximately three weeks' duration, namely, (1) down the Red Sea and round the head of the Gulf of Aden between Perim and Aden; (2) around the Gulf of Aden and out into the Indian Ocean to the south-east of Socotra; (3) along the southern and south-eastern coast of Arabia; and (4) up the Gulf of Oman. We have thus completed our programme of work across the northern part of the Arabian Sea and have carried out observations at 90 stations, of which 18 were in the Red Sea and the Straits of Bab el Mandeb, 20 in the Gulf of Aden or to the south-east of Socotra, 27 along the coast of Arabia, and 25 in the Gulf of Oman and its approaches. Of these stations, 15 have been 'complete' ones, including both physico-chemical and biological observations; at 41, physico-chemical observations only have been made; trawls or dredges have been carried out at 37; and at 8, observations have been made with the Priestman grab.

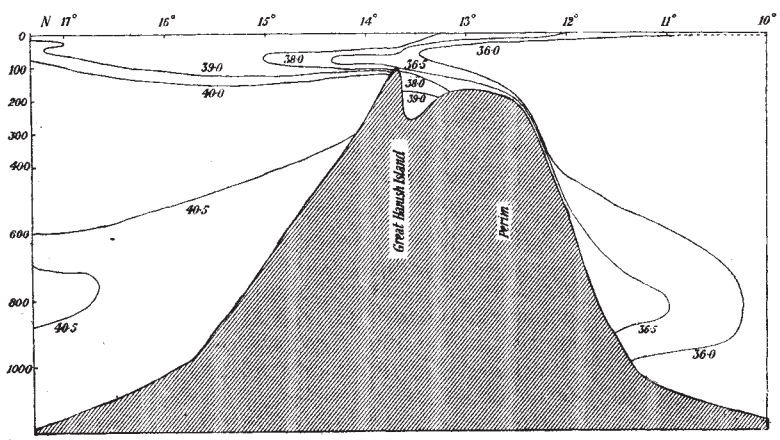

FIG. 1. Salinity of the water in the Straits of Bab el Mandeb. (*Depths in metres.*)

TOPOGRAPHY AND BOTTOM DEPOSITS

Thanks to the installation of the echo-sounding machine, we have been able to carry on an almost continuous survey of the bottom during our four cruises. In the Red Sea we were able to confirm the presence of a deep area having a depth of 2,204 metres (1,205 fathoms) in lat. 25° 24′ 12″ N., long. 36° 12′ 12″ E. The bottom in the deeper levels consists largely of a rock, or coarse gravel, containing a high percentage of calcium carbonate, that appears to be forming *in situ*.

We have three times traversed the Gulf of Aden along its whole length and have been able to detect the presence of no less than ten definite ridges that run obliquely across the northern and central parts of the Gulf in a north-east to south-west direction, the more westerly ridges showing a tendency to curve westwards. We have not yet been able to define the most southerly limits of these ridges, but we hope to do so during our return journey in April next.

Along the Arabian coast, throughout the area that we have investigated and extending from Ras Nus, the western headland of Khorya Morya Bay, to Ras al Hadd at the eastern extremity, the coast line is for the most part composed of high vertical, or in some places even overhanging, cliffs, some of which rise to a height of 600–800 ft. and are composed of a stratified sandstone alternating with horizontal bands of a harder material or limestone. A similar formation is also to be found on the Khorya Morya islands, though some of the steep hills are composed of granite. To seaward there is a broad, gently-sloping shelf; but at or near the 50 fathoms level the sea-floor drops with great rapidity and is very irregular, running out in a complicated series of submarine promontories, between which are deep gullies. Much of this bottom consists of rock that played havoc with our nets. On one occasion we brought up in the dredge from a depth of 1,416 metres (774 fathoms) a half to three quarters of a ton of angular granite blocks of various sizes, without any trace of associated sand or mud, constituting a definite scree slope, and there can be little doubt that the whole coast-line is part of a large geological fault.

Where not composed of rock, the bottom consists of a brown or green mud, and towards the eastern end in the neighbourhood of Ras al Hadd this green mud smells very strongly of sulphuretted hydrogen. Six observations showed that this is present between the depths of 95 metres and 1,253 metres, though most strongly marked at 421–457 metres, the occluded water from a bottom-sample at 421 metres containing as much as 29·39 milligrams of sulphuretted hydrogen per litre. This occurrence of sulphuretted hydrogen in the bottom deposit affords a parallel to the condition found in the Black Sea and in some of the enclosed fjords, but its presence along an open sea-coast was scarcely to be expected and its cause must at present remain unsolved. A very similar mud bottom, composed of green mud, or in the deepest depths of a grey clay, but not impregnated with sulphuretted hydrogen, is found throughout the whole of the Gulf of Oman and along the coast of Makran and Baluchistan below a depth of about 250 metres.

Between Ras al Hadd and the Indian coast in the neighbourhood of Karachi the echo-sounder has clearly revealed the presence of a submarine ridge that runs westward towards the entrance to the Gulf of Oman more or less parallel to the hill ranges of Baluchistan and Makran. To the south of this ridge and separated from it by a level plain with a fairly constant depth of 1,850 fathoms (3,383 metres) lies a second ridge that runs towards the south-west, and immediately to the south-east of this is a deep gully, bounded in its turn by the edge of a plateau that slopes gradually downwards towards the south-east. The bottom of this gully lies 2,000 fathoms below the sea surface and its general character reminds one strongly of a river bed. Have we here the now submerged bed of the Indus, where it flowed out into the Arabian Sea at a point more to the north of its present mouth or, possibly, the mouth of the great Indo-brahm river, the existence of which was postulated by Pascoe and Pilgrim ?

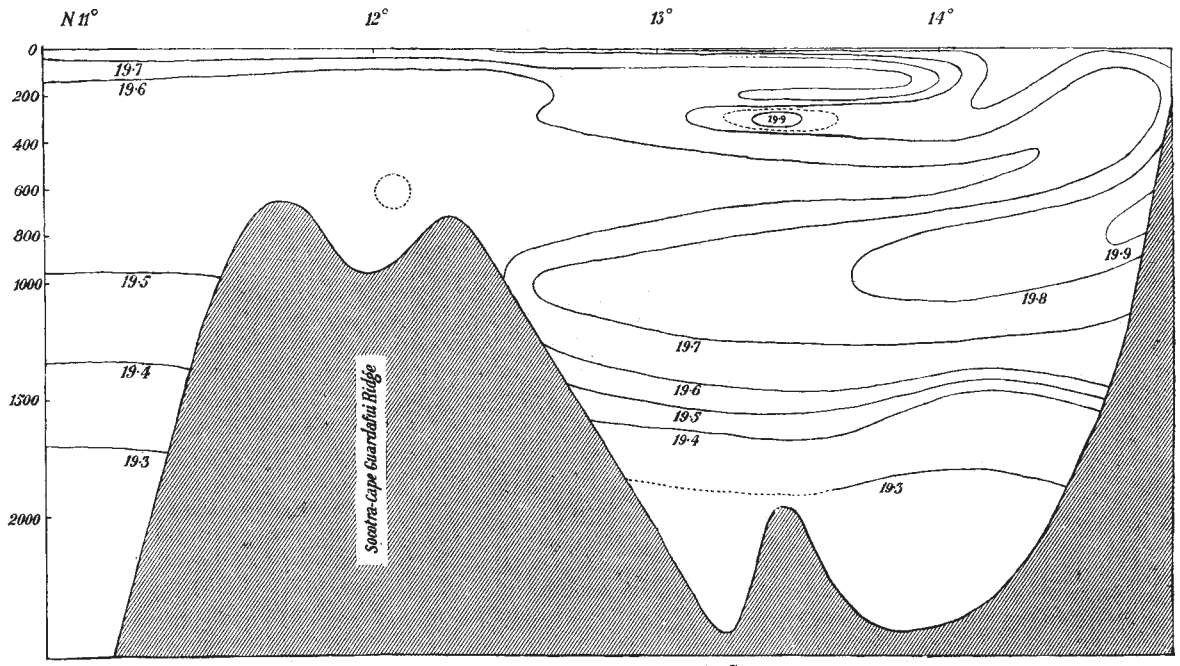

FIG. 2. Halogen content of the water of the Socotra current.

PHYSICO-CHEMICAL RESULTS

The physico-chemical examination of the sea-water of the Red Sea at all depths between the surface and the bottom indicates that there is in all probability a vertical circulation going on between a depth of 200–300 metres and the bottom, for at a depth of about 400–500 metres the temperature and both the halogen- and oxygen-content of the water are at a minimum and exhibit a clear increase in passing either upwards towards the surface or downwards to the bottom. We hope to carry out further observations on this point during our return journey.

On our way through the Straits of Bab el Mandeb a series of observations was made on the character of the sea-water and the fauna of the shallow channel that connects the Red Sea with the Gulf of Aden. There were indications of at least three different strata of water in the Straits, of which the uppermost was flowing out of the Red Sea, while the second and by far the largest of these water masses was flowing into the basin between the depths of 70 metres and 160 metres. The lowest stratum, namely, that of the bottom water of the Red Sea, was extremely small or even non-existent and scarcely passes over the sill near Great Hanish Island (Fig. 1). This condition of the water movements affords a marked contrast to the results obtained by the *Magnaghi* (1924) and the *Ormonde* (1927) in the months of April and May (*vide* Schott[1]). At this latter season of the year it is the outflowing bottom current and not the inflowing current that is the chief characteristic.

A number of serial observations on the sea-water in the Gulf of Aden have shown that there is in the Gulf a very complicated system of deep currents, and this is especially the case at the eastern end, where the "Socotra" current, to which Matthews has directed attention[2], sweeps northwards, partly through the gap between Cape Guardafui and Socotra and partly to the east of the island. A series of five stations running from south to north were made across this part of the Gulf and the results obtained indicate a deep and complicated vertical rotation of the water masses (Fig. 2).

At three places along the Arabian coast, lines of stations were run in order to detect, if possible, any upwelling of cold antarctic bottom-water; but so far as our observations go, there was no

sign of any such phenomenon. On two occasions, off Ras Sukra and Ras Madraka, at the two ends respectively of Sukra Bay, there was a definite fall in the temperature of the surface water by as much as 2·5° ; this apparently was not due to the upwelling of deep water ; but was probably caused by water upwelling from only moderate depths under the influence of the tidal currents.

In the Gulf of Oman (Fig. 3), our observations indicate that whereas there is an outflowing current that extends from the surface down to some 30–70 metres and a second similar current extending from 125 metres down to 350 metres on the northern and 500 metres on the southern side of the Gulf; between these two layers there is a stratum of inflowing water that can be traced up the Gulf as far north as Station 71 (lat. 25° 35′ 00″ N., long. 56° 42′ 18″ E.). The bottom water, the upper limit of which lies at a depth of some 350 metres on the northern side and at about 500 metres on the southern side in the vicinity of Muscat, appears to be an offshoot of deep Indian Ocean water that is moving northwards into the Gulf through the gap between Arabia and the Karachi plateau, to which I have already directed attention.

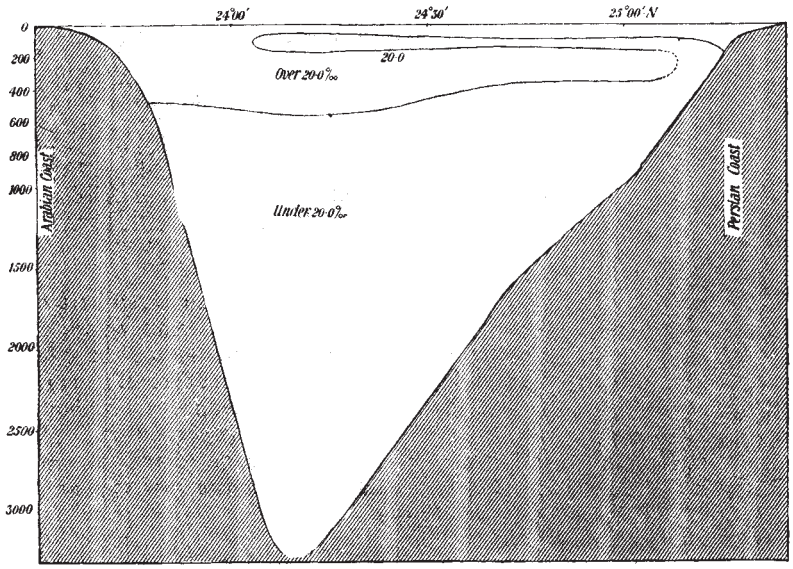

FIG. 3. Halogen content of the water across the Gulf of Oman in the region of Muscat.

BIOLOGICAL OBSERVATIONS

On the biological side, two areas have proved to be extremely interesting—not because of the richness of their fauna, but, on the contrary, because of its paucity or even complete absence. The first is the deep part of the Red Sea. During our cruise down this region in September, we carried out several trawls and dredges in depths ranging from 55 metres to 1,167 metres, and in four hauls in depths below 260 metres we were unable to detect any sign of living organisms on the bottom, which, as already mentioned, consists of a calcareous rock that appears to be in process of formation *in situ*. In view of the enclosed character of the basin, the depth of the entrance channel at Great Hanish Island just to the north of the Straits of Bab el Mandeb being only some 160 metres, the water of the Red Sea below this depth, as is well known, has a very high salinity (40 per mille and above) and a high temperature (22°–23° C.), though the oxygen content of the bottom water is higher than we expected to find and ranges from 1·32 to 1·65 c.c. per litre at depths between 800 metres and 1,500 metres in the northern part, sinking to less than 1·0 on the bottom in the southern area ; but such conditions are of themselves scarcely sufficient to account for the complete absence of life.

The discovery of the second area, in which all life is either completely absent or is extraordinarily scanty, came as a complete surprise. I have already referred to the region of the Arabian coast near Ras al Hadd, where we discovered a bottom deposit of soft green mud that smelt strongly of sulphuretted hydrogen ; such an area we would expect to find largely, if not entirely, devoid of animal life, but this azoic area appears to extend far beyond the limits of the region where sulphuretted hydrogen is to be found and can be traced throughout the whole extent of the Gulf of Oman. In this latter area the bottom consists of either a soft green mud or a grey clay, and between the depths of approximately 300 metres and 1,750 metres there is an almost complete absence of animal life, and even at so great a depth as 3,351 metres an hour's trawl only resulted in the capture of two starfish.

In the accompanying tables I have given the various stations and their depths in the Gulf of Oman and off the Arabian coast, and it seems clear that this azoic area not only lies at a deeper general level in the Gulf of Oman than on the Arabian coast but also that there is a difference of level on the two sides of the Gulf of Oman. The upper limit of the azoic area on the Arabian coast near Ras al Hadd lies somewhere between 83 metres and 102 metres and the lower limit between 1,253 metres and 1,536 metres. The depth of the lower limit, however, probably increases as we pass towards the north-east, where we found prolific life at a depth of 952 metres, the trawl bringing up a number of fish and crustacea and thousands of Ophiuroids ; in 1906 the R.I.M.S. *Investigator*, when trawling in the near vicinity, also secured a good catch, though the net was badly torn (*vide* Lloyd, 1907, p. 2[3]). There can thus be little doubt that this area is a fertile one ; but a little to the east at a depth of 1,253 metres we were within the zone of sulphuretted hydrogen and the catch after

an hour's haul consisted of a single crab, *Paralomis* sp.

In the Gulf of Oman, the upper limit of the dead area appears to lie at a slightly different level on the two sides. On the southern side in the vicinity of Muscat the great bulk of the fauna disappears between 210 and 269 metres, though a few live animals were obtained at a depth of 610 metres; off the coast of Persian Makran no life

ARABIAN COAST

Station No.	Depth in metres.	Character of bottom	Results.
53	13	Rock : *Lithothamnioneæ*.	A good and varied catch.
80	16–22	Sand and Shells.	A good catch.
45	40	*Lithothamnioneæ*, etc.	A good and very interesting catch.
43	83	? No sample obtained.	A small but interesting catch.
79	102	Green Mud (H_2S).	Very little animal life.
48	201	Rock.	A very small catch. Net torn.
77	350	Green Mud (H_2S).	A single crab ; *Paralia alcocki*.
56	457	Green Mud (H_2S).	No living organisms ; dead shells of *Rostellaria delicatula* and *Encephaloides armstrongi*.
57	428–750	Green Mud (H_2S).	Very little life ; one dead shell of *Rostellaria delicatula* and a few moribund *Encephaloides armstrongi*.
55	802	Stratified green mud.	No sign of living organisms.
54	952	Green mud and soft rock.	A good catch; thousands of Ophiuroids.
58	1253	Green mud (H_2S).	A single crab : *Paralomis* sp.
50	1536–1737	Brown mud.	Catch very small.
59	1977	Soft Green mud.	Catch very small.

was detected at a depth of 448 metres and it is somewhat significant that these levels correspond very fairly closely with the upper level of the deep inflowing mass of water that is running up the Gulf under the out-flowing Persian Gulf water. That this water is not *per se* responsible for the absence of life is clearly shown by the results of several horizontal hauls at depths down to as much as 1,500–2,000 metres, for at all depths numerous red deep-sea prawns and small fish, such as *Bregmaceros* sp. and Scopelids, were obtained. It would appear, therefore, that the sterility of the area must be attributed either to some harmful character of the bottom deposit or else to some seasonal change in the general conditions of the deep water.

The surface waters and the inshore areas in both regions, in marked contradistinction, appear to be particularly fertile. Along the Arabian

GULF OF OMAN

Station No.	Depth in metres.	Character of bottom.	Results.
72	75	Grey clay and shells.	A good and varied catch.
71	106	Grey-green mud and sand.	A moderate catch.
70	109	Soft green mud.	Moderately good catch ; 213 living examples of *Rostellaria delicatula* and several *Pirula* sp.
75	201	Soft green mud.	A good catch.
67	269	Soft green mud.	No living organisms ; dead shells of *Rostellaria delicatula* and a few Serpulid tubes.
64	448	Grey clay.	No signs of living organisms.
66	610	Brownish-green mud.	Several dead shells of *Rostellaria delicatula* and 3 living examples ; a few Serpulids.
65	912	Green mud.	No living organisms.
68	1491–1518	Soft green mud.	No living organisms.
81	3350	Grey mud.	Two starfish.

coast we have carried out several successful trawls, special attention being paid to areas where the charts indicate the presence of coral; in every case we have found that true reef-forming corals are absent, though we have dredged a number of specimens of *Lophohelia*, *Caryophyllia* and *Flabellum*, some still living though many of them dead. The chief ingredient of the reef appears to be *Lithothamnioneæ*.

[1] Schott, G., "Uber die Wasserbewegungen im Bab el Mandeb". *Ann. der Hydrographie und maritime Meteorologie*, January 1929.
[2] Matthews, D. J., "The Percy Sladen Trust Expedition to the Indian Ocean in 1905 : No. VII. Physical Oceanography". *Trans. Linn. Soc. London*, **19**, Part 1, 1926.
[3] Lloyd, R. E., "Contributions to the Fauna of the Arabian Sea, with descriptions of new Fishes and Crustacea". *Rec. Ind. Mus.*, **1**, Part 1, Calcutta, 1907.

Recent Discoveries at Choukoutien*

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UPPER PALÆOLITHIC CULTURE IN "UPPER CAVE" SEDIMENTS

A DETAILED account of the results of the Choukoutien excavations up to May 1933 has already been presented in our memoir "Fossil Man in China" (Mem. Geol. Surv. China. Series A, No. 11). In that report it was noted that above the *Sinanthropus* deposits there occurred towards the top of the hill a pocket of grey sediments of apparently modern facies, the site being described as the "Upper Cave". During the past season, Mr. W. C. Pei has systematically investigated the deposits of the latter site, ably assisted by Mr. M. N. Pien. Their efforts have been rewarded by the discovery of much additional material of unexpected archæological significance.

(1) *Sedimentary and lithological characters of Upper Cave deposits.* The "Upper Cave" was a true cave but became completely filled with a mixture of grey cave loam and angular flat limestone fragments, the latter being derived from the collapsed portion of its roof. The roof is preserved over a quite large recess of the cave

* Report of excavations during the field season 1933, presented at the annual meeting of the Geological Society of China on November 11.