and Bird needed to be replaced. Pond, from observations made at Westbury in 1801–1806, had shown the advantage of using a complete circle instead of a quadrant. Maskelyne gave instructions to Troughton for the construction of an instrument of this form, but did not live to see the completion of this beautifully designed and excellently divided circle.

On the death of Maskelyne in 1811, Pond was appointed Astronomer Royal. The mural circle made by Troughton, and the transit instrument made by the same great artist in the year 1816, were the greatest improvements in astronomical instruments since the time of Bradley. A second circle by Jones was added in 1825. Pond introduced the method of observing stars by reflection in mercury with one instrument while they were being observed directly with the other. On the following night the rôle of the two instruments was changed. Pond's observations were of a very high order of accuracy, so much so that Chandler traced in them the small changes caused by variation of latitude. His Catalogue of 1112 stars was a most valuable contribution to the accurate determination of stellar positions. Pond was also able with these instruments to show that several alleged discoveries of parallax of stars of the order of about 1″ were incorrect. Another benefit which the Observatory derived from Pond was an increase in the number of assistants from one to six, resulting in a considerably increased output of observations.

Airy succeeded Pond in 1835 and retired from his post in 1881 at the age of eighty. His contributions to optics, tides, metrology and many practical questions are outside the scope of this article. He introduced into the Observatory very orderly and business-like methods of reduction of observations and their regular and prompt publication. Of the new instruments which he installed, the transit circle erected in 1851 has been the most valuable. Its use led to a great increase in the number of observations. He introduced the use of registration on the chronograph, a method invented in the United States. He also introduced the system of telegraphic transmission of time daily from the Observatory to the General Post Office for distribution over Great Britain. The great equatorial, erected in 1860, with a 12·5-inch object glass by Merz, was for a time the largest refractor in England. Airy's reduction on a uniform system of the lunar and planetary observations made by his predecessors since the time of Bradley was a great contribution towards the formation of accurate tables of the movements of sun, moon and planets. He extended the scope of the Observatory by the introduction of magnetic and meteorological observations.

Christie succeeded Airy in 1881 and retired in 1910. During his tenure of office, photographic observations became a part of the regular work of the Observatory. The daily photography of the sun, and measurement of the position and size of the spots, was actually begun in Airy's time but was developed considerably by Christie. A share was taken by Greenwich in the photographic chart and catalogue of the heavens, and for this purpose the astrographic telescope was obtained. Additions to the equipment were made in the 28-inch visual equatorial, used mainly for observations of double stars; in the altazimuth, essentially a transit instrument which can be placed in any azimuth; and in the Thompson equatorial, consisting of a 26-inch photographic refractor and a 30-inch reflector, the gift of the eminent surgeon Sir Henry Thompson. The large increase in the buildings and instruments made in Christie's time were very necessary for the Observatory to maintain its high position. A great extension took place in the output of the Observatory in meridian astronomy. The part assigned to Greenwich in the astrographic chart and catalogue was carefully carried out. A thorough determination was made of the solar parallax by observations of Eros. Valuable series of double star observations were made with the 28-inch telescope, and the two telescopes of the Thompson equatorial were employed on a variety of problems.

In conclusion, it may be truly said that the original intention of the founders of the Observatory has been carried out consistently for 250 years. The pursuit of the practical problem of the determination of longitude has involved long series of observations which have contributed very largely to our knowledge of the movements of sun, moon and planets. At the present time a larger share is given to questions of purely astronomical interest, but the practical applications of science are still interwoven with them in observations of position of sun and stars, the distribution of time, the care of the Navy chronometers and the compilation of magnetic charts. F. W. D.

Problems of the Rhone Delta.[1]

By R. D. OLDHAM, F.R.S.

IV.

WHEN, in 1711, the Rhone broke away from its former course to the sea, it more and more adopted the new channel until, in 1724, the older one was definitely closed to navigation; the river, following the course it still maintains, had established its channel to the sea-face, and in 1725 the town of Arles complained of the difficulties of the new mouth, where extensive sand-banks had formed. The river, in fact, having reached the open sea, was subject to conditions which are described in reports of the nineteenth century; the deposit of silt, where the current is checked on reaching the sea, combined with the effect of the waves in sorting and casting back the coarser grained material, together with the absence of any tidal scour, led to the formation of low sand-banks, known as *they*, barely emerging from the water when the sea-level was low, and submerged when it was raised by a river flood or an onshore wind. The main channel of the river was blocked by a well-defined bar, on which the water might reach a depth of a couple of feet, but was mostly under a foot, and through this bar a narrow and constantly changing pass admitted, in favourable circumstances, vessels of up to 6 feet, but usually not more than 4½ to 5 feet, in draft. Only in fine weather was this

[1] Continued from p. 54.

narrow channel practicable, and for 120 days in the year the passage was too dangerous to allow of any vessel entering or leaving the river; even when the channel was otherwise clear, vessels might find that it had shoaled too much to admit them, and have to tranship their cargo into lighters of shallow draft.

Various attempts were made to overcome these difficulties. The first was the construction of a canal from Arles to Port de Bouc, but the dimensions of the canal were too small to render it serviceable. The next scheme was to restrict the river to a single narrow outlet, in the hope that the scour of the current would

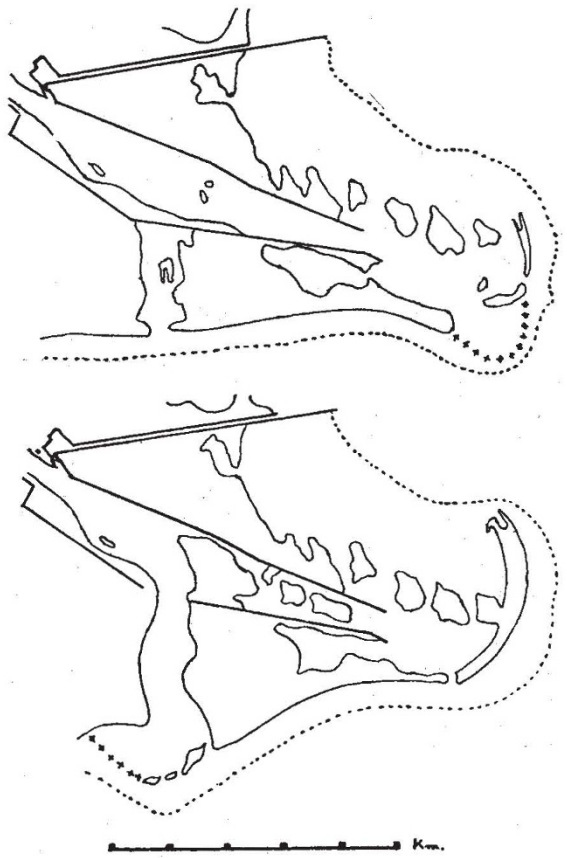

FIG. 5.—Mouth of the Rhone in 1893 and 1913. Dotted line marks the contour of 5 m. depth of water.

maintain a deep channel, and in 1852–55 embankments were carried along both banks to the mouth, the last of the lateral outlets being closed in 1856. At first, success seemed to have been attained, the channel deepened to 12 feet, but in a couple of years a new bar had formed, further out, and the channel shallowed to its old depth of 4 to 6 feet. This plan having proved a failure, it was decided to cut a ship canal from the Gulf of Fos and form a port on the river near the Tour St. Louis, and by 1871 the port and canal, with its locks, were completed. This proved a modified success, the Port of St. Louis established itself as one of the principal of the minor ports on the Mediterranean coast of France, and would doubtless have attained greater prosperity but for malaria, with which this part of the delta is infested.

Meanwhile the mouth of the Rhone had been advancing south-eastwards at a rate of about 60 metres a year, and threatened to block the fairway to the Port of St. Louis, so it was decided to reopen the Grau de Roustan, which had been the principal lateral outlet of the river on the western side. In 1893 the embankment with its stone revetment was removed, and a narrow cut opened to the river through the land which had been formed since the embankment was made. This cut, as was expected, was widened by the river, which rapidly adopted this channel as its main outlet to the sea, the previous main channel becoming more and more blocked with sand-banks. At the end of twenty years a complete change had come over the mouth of the Rhone. The channel of 1893 had been almost completely filled up, only a narrow and shallow channel remaining; the low *theys*, the bar at the mouth, had been washed away by the sea, and a continuous barrier of dry sand, crowned with sand dunes, formed at about 700 metres behind the previous position of the mouth. The old Grau de Roustan had become the sole outlet of the river, which had built up new land to 1200 m. in advance of the old shore-line, and the mouth was blocked by a row of *theys* and a bar, like that which had formerly blocked the mouth of the river, and such as will always be formed where a silt-bearing river enters an almost tideless sea.

It is of some interest to compare this description of the conditions at the mouth of the Rhone, in the nineteenth century, and the measures undertaken to overcome the difficulties, with the accounts which we have of the campaigns of Caius Marius in 103–102 B.C., in the course of which he encountered the same difficulties and adopted similar measures to overcome them. Plutarch, in his life of Marius, says that the mouth of the Rhone being barred and almost filled up with sand and mud, the passage became narrow, difficult, and dangerous for the ships which brought provisions; so Marius, bringing his army, drew a great trench and, by turning a great part of the river, brought it to a convenient point on the shore where the water was deep, and this still retains the name it took from him. To this account Strabo adds that, after the defeat of the barbarians, Marius gave the canal to the people of Marseilles, who derived great revenue from tolls on ships passing along it, notwithstanding the entrance continued difficult to navigate, on account of the deposits and the flatness of the country, so that in foul weather the land could not be discerned, even when one was quite close.

The account which these writers give of the entrance to the Rhone shows that conditions were the same as in the nineteenth century, and suggests that what Marius did was analogous to the solution arrived at some 2000 years later, when the St. Louis canal was dug; and Strabo's account of the difficulties which arose, in later times, is matched by the formation of sand-banks, and a bar, across the Grau de Roustan, when that became the main channel of the Rhone. The digging of a canal a mile and a half long, or very likely less, would not have been too great a work for an army to undertake in the time at his disposal; once dug, access would be made easier for a while, but in course of time, as the river abandoned its old course and adopted the new one, all the difficulties and dangers of the entrance to the river would reappear. That no trace of this canal

remains is not to be wondered at; the river continued to bring down silt and extend the delta for eight centuries after it had been dug, and then came the subsidence which caused any trace of the work of Marius, necessarily lying near sea-level, to be buried under twelve to fifteen feet of silt or water.

During the last two centuries, in which the river has been building up the projection from the old sea-front of the delta, which has reached a length of about 9 kilometres, and has added nearly 40 square kilometres to the area of the delta, changes of a different character had been taking place farther west. The river, during the period in which it had flowed in the channel of the Vieux Rhône, had built up a prominence of some four or five kilometres, but as soon as the course of the river had changed, and the transport of fresh material had ceased, this prominence was attacked by the waves of the sea, and rapidly removed. Opposite the Faraman lighthouse, the recession of the sea-front amounted to about 4·5 kilometres between 1710 and 1870, after which equilibrium seems to have been nearly established and recession became slow. The material removed from this part of the coast was mainly swept to the westwards, where part of it went to form the projection of the Pointe de Beauduc, but part was drifted round the point, to form the continuous barrier and sandy beach which borders the Golfe de Beauduc. Maps of the seventeenth and early eighteenth centuries show no trace of this, the Pointe de Beauduc is not indicated, and the Golfe is bordered by an archipelago of islands, separated by channels, open to the sea and penetrating inland to the Étang de Vaccarès. The date at which these conditions were altered, by the formation of a continuous beach and barrier along the coast, cannot be determined with precision, but in the Cassini map, constructed in the 'seventies of last century, the barrier is shown, and the sea-face is almost as mature in form and outline as on the most recent maps, so we may put the transition, from the immature to the mature form of the existing sea-coast, as having taken place round about the close of the eighteenth and the commencement of the nineteenth centuries.

This completes the cycle of changes which this region of the Rhone delta has undergone, since definite information commenced with the advent of the Romans. At the outset, the extent and outline was not materially different from that of the present time, but the land stood about fifteen feet higher above sea-level than nowadays, the extensive salt lakes and marshes were all dry land, and the Camargue was a fertile, populous, and prosperous region. Along the sea-coast there were probably lagoons, separated from the sea by a continuous barrier, sand dunes and sandy beach, which swept round the coast in smooth and even curves, characteristic of a mature coast-line. At the mouth of the river, which lay farther west than the present mouth, a projection had been formed by the alluvium brought down by the river, exactly analogous to that which has been built up along the present channel. These conditions continued during the rise and fall of the Roman dominion in Gaul until, in the eighth and ninth centuries, a subsidence of the land took place, by which not only were the low level deposits along the coast and at the mouth of the river plunged beneath the sea, but a larger part of the higher ground behind them was also brought below sea-level. The matured coast-line disappeared and was replaced by the immature condition of an archipelago of islands, and the river, instead of debouching in the open sea, ended far inland in a land-locked inlet of shallow water. Then, for some eight centuries or so, the river was occupied in filling up the submerged areas of the delta, and in pushing forward its mouth until, about the middle of the seventeenth century, it again reached the sea-front, and about a century and a half later the continuous barrier and beach, with the curved outline of maturity, was again established. Along the sea-coast the delta had resumed the general type, and approximately the outline, of earlier times, but, in the interior, large areas of what was then dry land are still occupied by salt water lakes and marshes, which have been protected, by accidents of surface configuration, from the deposits of the river, and still remain much as they were left at the close of the period of subsidence.

Evolution and Intellectual Freedom.

SINCE going to press last week, we have been favoured with several further messages on the subject of the campaign in the United States against the teaching of the principle of biological evolution. We are glad to be able to publish these expressions of opinion upon the attempt thus being made to restrain intellectual freedom and progressive thought. As to the trial now being held at Dayton to test the validity of the anti-evolution law of the State of Tennessee, there can be no question that leaders in all departments of intellectual activity in Great Britain regard it with amazement. It is not for us to suggest that a teacher was justified in breaking the law of a State of which he was the paid servant, but what does astonish us is that the citizens of the State should tolerate a law which makes references to evolution and the descent of man illegal. So far as actual teaching of these subjects in schools is concerned, most men of science would not insist upon attention being devoted to them; but when the ban extends to colleges and universities, the matter becomes of prime importance.

There can be no research for truth in Nature if natural truth, including that of the creation of the universe, the earth, and man, has to be regarded as revealed, once for all, in the Biblical record. It would be impossible for any teacher of science to be true to his intelligence and yet give instruction under such conditions. There is, fortunately, no probability of limitations of the kind advocated by Mr. W. J. Bryan and the Fundamentalists being placed upon biological teaching in Great Britain; and for the sake of human progress, we trust that the reactionary movement which they represent will fail of its object. The attack has come from the advocates of traditional doctrine and not from workers in scientific fields, who ask only to be free to extend natural knowledge by research and instruction, without being bound by the words of any master. No one supposes that the problem of organic evolution has been solved, but of the fact of evolution there is not the slightest doubt, and only by further inquiry can we understand fully its course and significance. Whatever Mr. Bryan and his followers may