The Royal Observatory, Greenwich.

THE Royal Observatory was founded in the reign of King Charles II. to assist in the solution of the important and difficult question of determining longitude at sea. The use of the method afterwards known as "lunars" had been suggested. As the moon moves round the sky in a month, its position among the stars changes rapidly: if, then, an almanac can be prepared giving the position of the moon among the stars according to the time of some fixed place, say Greenwich, the navigator can by observation of the moon determine the Greenwich time. It is an easy matter to determine his local or ship time, and the difference gives the longitude. In the seventeenth century the movement of the moon was not known with nearly sufficient accuracy for this method to be available, and even the positions of the fixed stars were very imperfectly charted. The Royal Observatory was founded to remedy these defects, and Flamsteed, the first Astronomer Royal, was charged to make observations for "rectifying the tables of the motions of the heavens and the places of the fixed stars so as to find out the so much desired longitude at sea, for perfecting the art of navigation."

At the suggestion of Sir Christopher Wren the site for the Observatory was chosen on a hill in Greenwich Park. A grant of 500*l.* was made by the King, bricks were obtained from a disused fort at Tilbury, and the Observatory was built according to the design of Wren by Sir Jonas Moore, Master-General of the Ordnance. The foundation was laid on August 10, 1675, and the building completed in the following year.

The Rev. John Flamsteed was appointed Astronomer Royal at a salary of 100*l* a year, but he was not provided with any instruments. He brought with him an iron sextant of 6 ft. radius, and Jonas Moore lent him a smaller one and two clocks. The use of clocks as part of an observatory equipment dates from about this time. Flamsteed made repeated appeals, but in vain, for money to erect an instrument in the meridian, which, he was convinced, would give greater accuracy and was essential for referring the position of the stars to the equinox. In 1683 he erected a mural circle at his personal expense, dividing it with his own hands. This instrument was not very satisfactory, but in 1688, as he was in better circumstances, he had a larger one constructed for him by Abraham Sharp, at a cost of 120*l.* Sharp was his friend and assistant, and the two worked together for several years, determining the position of the equinox, the obliquity of the ecliptic, and the positions of sun, moon and stars. The "Historia Coelestis," which contains an account of his methods and results, was published partly by himself and completed after his death by Abraham Sharp in 1725. It may be noted that Flamsteed was one of the first astronomers to use telescopic sights in his observations, as he was one of the first to make use of clocks. His observations were a great advance on those of earlier astronomers, though they are now only of historical interest. His catalogue of the positions of more than 3000 stars was corrected early in the nineteenth century by Francis Baily, who remarks that Flamsteed's British Catalogue is one of the proudest productions of the Royal Observatory.

On the death of Flamsteed in 1719, he was succeeded by Halley, the friend of Newton, who secured the publication of the "Principia." He rendered many services to science, but is best known for his prediction of the return of the comet to which his name was afterwards given. When Halley came to the Observatory, it was without instruments, as Flamsteed's executors had claimed those which he had used. In 1721, Halley installed a small transit instrument. Although the design is open to criticism, the instrument is of interest as the earliest specimen of a very important type. In 1725 he had a large iron mural quadrant constructed by Graham. With his instrument he made many observations, particularly of the moon.

Bradley succeeded Halley in 1742. From his observations at Wanstead he had discovered the aberration of light in 1729. He continued his observations for many years and announced the discovery of nutation of the earth's axis in 1748. With the help of his nephew, who was appointed his assistant, he commenced observations with Halley's instruments. He applied for funds for new instruments, and on the recommendation of the Board of Visitors, seconded by the Council of the Royal Society, was granted 1000*l.* by King George II. With this money he obtained an 8 ft. brass quadrant, and a transit instrument of 4½ ft. focal length and an object glass of 2·7 inches. These were both made by Bird. He also obtained a clock by Shelton, which is still in use at the new magnetic station at Abinger.

With these instruments, Bradley laid the foundations of modern astronomy of position. His skill in the design and use of his instruments rendered his observations far more precise than those of any of his predecessors. The observations were collected and reduced after his death by his friend Hornsby. They were later re-reduced by Bessel in his "Fundamenta Astronomiae," and again late in the nineteenth century by Auwers. Our present knowledge of the direction of the sun's motion in space, and the existence of two star streams, is largely dependent on proper motions derived by comparing later observed positions of stars with those found by Bradley.

Bradley's successor, Bliss, lived only two years after his appointment and was succeeded by Maskelyne in 1764. Maskelyne had been sent at Bradley's suggestion to observe the transit of Venus at St. Helena in 1761. He made practical application during his voyage of methods of determining longitude at sea by lunar observations, and soon after his return published the "British Mariner's Guide," the forerunner of the "Nautical Almanac," which commenced in 1767. These works gave precise directions and presented astronomical data in the simplest and most suitable forms for their application to navigation. During the forty-four years of his tenure of office, he was very assiduous in the observation of sun, moon, planets and a small number of the brighter stars, being specially attracted by the problem of determining the position at sea, to which the Observatory owed its origin. His famous expedition to Schiehallion to determine the mean density of the earth was made in 1774. Towards the end of his life he found that the quadrants of Graham 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]

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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.