1 From Riquet to Watt

Pierre-Paul Riquet (1604–1680)

The idea of a canal between the Atlantic and the Mediterranean, cutting out the long and dangerous haul around the coasts of the Iberian Peninsula, had been conceived by Leonardo da Vinci. Although much discussed, it remained no more than an idea until the middle of the seventeenth century, when the Grand Canal de Languedoc came into being. Voltaire, writing of the building achievements of the reign of Louis XIV, described it as 'le monument le plus glorieux' and Skempton describes it in the *History of Technology* (Singer *et al.*, 1954–84) as, 'the greatest feat of civil engineering in Europe between Roman times and the nineteenth century.' Nowadays the canal, known as the Canal du Midi, is mainly used by pleasure boats but there is still some commercial traffic.

The man who was responsible for the construction of the canal was born at the town of Béziers, not far from Montpellier, on 29 June 1604 to Guillaume Riquet, a wealthy lawyer, and his wife. The Riquet family are said to be of Italian origin, but centuries earlier they had settled in the Languedoc region of France. Riquet was educated at the Jesuit college in Béziers, where he excelled in science and mathematics, but he received no formal training in engineering. At 19, he married Catherine de Milhau, the daughter of a wealthy bourgeois family of Béziers, whose dowry was such that he was able to purchase the old chateau and estate of Bonrepos, near the little village of Verfeil 12 miles to the east of Toulouse, on the slopes of the valley of the river Girou. He thereby became Baron de Bonrepos, but I will continue to call him Riquet.

Seven years later, in 1630, Riquet was appointed as a collector of the salt tax in Languedoc, and it was not long before he became farmer general of the tax for the entire province. This tax was first introduced in France in 1206 and had become one of the chief sources of state revenue. The franchise was a lucrative but onerous one, which entailed a great deal of travelling throughout Languedoc and in this way Riquet gained an intimate knowledge of the country through which the canal would pass. In 1632, he appointed as his deputy an ex-school friend of his, named Paul Mas, a doctor of law who

was the cleverest lawyer in Béziers, and later became his brother-in-law. In the same year, Riquet's father died and his son inherited the principal part of his estate. He made the family house in the Place St Félix in Béziers the centre for his business in south-eastern Languedoc. This was extremely profitable and, assisted by the efficient Paul Mas, he made so much money that he was able to undertake the even more lucrative business of a military contractor, supplying the King's armies in Cerdagne and Rousillon, with the result that by the time he was 50 Riquet had amassed a fortune of several million livres. He acquired a town house in the Place St Pantaléon in Toulouse; and as the years went by he spent an increasing amount of time there.

The King, Louis XIV, and his great finance minister Jean-Baptiste Colbert (1619–83), had decided that the time had come to build the Grand Canal de Languedoc. They placed Riquet in charge of the project, ably assisted by a young engineer named Francois Andreossy (1633–88) and an official named Pierre Campas, well known to Riquet. Andreossy was a citizen of Narbonne but was born and educated in Paris, where he studied science and engineering. Having completed his education in the capital he returned to Narbonne, but in 1660 he went to Italy, where he had family connections,

so that he could study the canals of Lombardy. Andreossy became Riquet's right-hand man throughout the period of the construction of the canal, supplying the professional expertise that Riquet lacked. It is debatable whether he or Riquet should be given the major share of the credit for the success of the great enterprise. However, it was Riquet, already 60 by the time construction began, whose drive and enthusiasm were essential. Riquet enlisted the support of the powerful Archbishop of Toulouse and together they travelled to Paris in 1662 to see Colbert. They explained to him the route of the canal and how they proposed to overcome the difficulties it presented. To canalize the natural channel of a river by means of locks and cuts was one thing; to construct a purely artificial waterway through high and difficult country and to ensure that it had an adequate water supply was quite another. Colbert was and remained enthusiastic and the king, on his advice, approved it, and appointed a royal commission to supervise the undertaking.

There were many unexpected difficulties, and at one stage the commissioners deemed it impossible to bore a tunnel through a sandy hill. By using a picked labour corps, Riquet managed to drill the tunnel before the commissioners heard about it, and when it was completed he lit the interior with triumphal torches and invited his critics to join him in a walk through it. After that he generally had his own way but the canal was not opened until 1681, after some 15 years of concentrated labour. More than 8,000 men were employed on the project. It is carried for considerable distances on built-up embankments, and 100 locks raise it 620 feet above sea level. The broad deep waterway is borne over rivers and through hills by many aqueducts, cuttings and tunnels. Although the Languedoc waterway followed the bed of the river Garonne for some of its length, on the canal section, between Agde and Toulouse, it was completely independent of the river, being fed by water brought from distant streams.

Riquet staked his private fortune on the vast undertaking and accumulated a huge debt. He never lived to see the canal complete and open to traffic. He was growing old and suffered from bouts of ill health as a result of endless work and worry. On 1 October 1680 he died at the age of 76. The canal was officially opened on 15 May the next year. Riquet died so encumbered by debts amounting to more than two million livres that his heirs were obliged to sell most of his shares in the concern. The canal did not begin to pay its way until 1724, some 43 years after it had been built.

An edict had been issued whereby the builders of the canal and their successors were to be granted the ownership of the canal in perpetuity with exemption from taxes on the property and various other valuable rights. This legal document was the subject of much argument when the king died in 1715. It was argued that huge sums of money had been expended on its construction by the king and the provincial parliament. In 1768, by which time the canal had become reasonably profitable, the States of Languedoc offered to purchase the canal for 8,500,900 livres but, although the purchase was approved by the king, the provincial government changed its mind and the canal remained in the hands of the shareholders until the outbreak of the French revolution. After the restoration, ownership was restored to the Riquet family until 1897, when it was taken over by the state, which abolished the tolls.

Sébastien le Prestre de Vauban (1633–1707)

The future exponent of siege warfare was born in the village of Saint Léger-de-Foucherest, south-east of Avallon in the Nivernais. The precise date of his birth is uncertain but it is known that he was baptised on 15 May 1633. His father, an impecunious country gentleman, sent him to the Carmelite college of Semur-en-Auxois to be educated. After spending seven years there he joined the rebellion of the Fronde as a cadet under Condé in 1651, but within two years had been taken prisoner. He then transferred his service to the King's side: he rapidly rose to be ingénieur ordinaire du roi, in which capacity he distinguished himself in the seven years of war against Spain that ended in 1659. The next year he married Jeanne d'Osnay, who came of a similar family to his own. He spent the next seven years partly in his birthplace of Saint Léger-de-Foucherest, but mainly travelling France in discharge of his military duties. He received the support and friendship of the Marquis de Louvois, Louis XIV's powerful minister of war, for whom he drew up in 1669 his *Memoir pour servir a l'instruction dans la conduite des sièges* (Vauban, 1740). In 1672, the king declared war on Holland, and, two years later, on Spain again. When his army was about to launch an attack, Louis XIV used to bring his court to watch the spectacle while enjoying a picnic.

In 1678, Vauban was appointed Commissary General of Fortifications, in which capacity he ringed France with fortresses, some of which are still intact while others can still be traced clearly from the air. Excellent photographs of the surviving fortifications will be found in Bornecque (1984). For defence, Vauban designed vast polygonal works of stone and earth, the

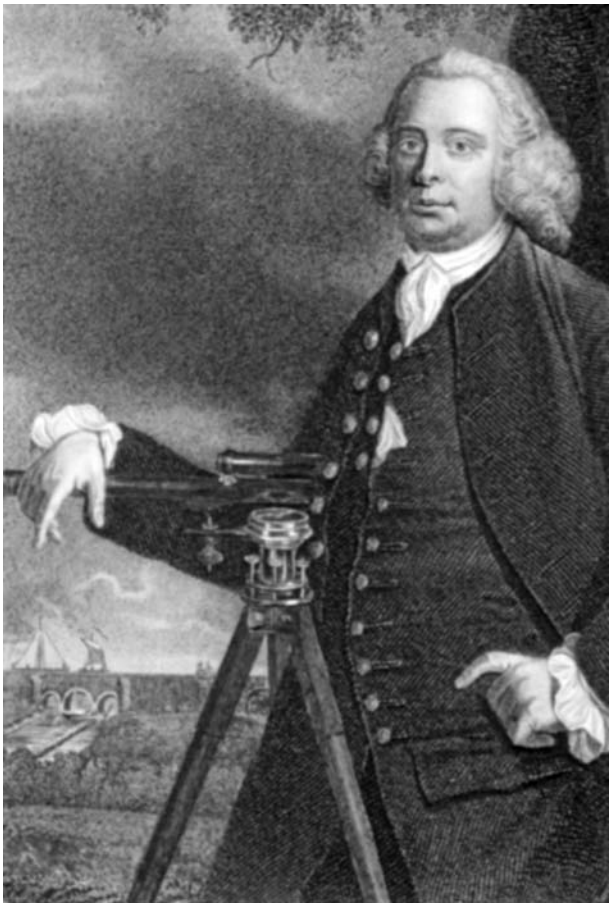
walls being defensible by flanking fire from musketry as well as artillery on the ramparts; further protection was provided by carefully sited two-storeyed gun chambers, whose thick walls and roof prevented the cannon from being put out of action. Vauban conducted a whole series of successful siege operations against fortresses guarding the Flemish frontier, culminating with the capture of the stronghold of Old Breisach in just a fortnight in 1703, the year in which he was created a Marshal of France. For attacking fortresses he elaborated the use of trenches dug as parallels to bring the besieging forces within striking distance, first at Maastricht in 1673, and invented the ricochet battery, which was first employed at Philipsburg in 1688. In the seventeenth century, war consisted above all in a series of sieges. It was said, not without truth, that once a town was besieged by Vauban, the town was taken. It was also said that a town fortified by Vauban was a town impenetrable, but his contribution to defensive tactics was less remarkable. The king created him Marquis d'Humières for his services.

Vauban was a military engineer, not an architect; the massive simplicity of his mighty walls was magnificent but the elaborate entrance gateways he built were amateurish and heavy-handed. Although fortifications were his speciality, Vauban was called upon to design the three major aqueducts required for Riquet's Languedoc canal and for the misconceived Maintenon canal, which was intended to convey the waters of the Eure to the chateau of Versailles, although this was never completed. Peace was declared in 1684, but four years later war broke out again and this time the French army suffered a series of major defeats. Although the country was virtually bankrupt, the king was squandering huge sums on Versailles and other projects. Vauban's attempts to influence the French government were unsuccessful. The autocratic and selfish king had surrounded himself with self-serving courtiers who would not listen to Vauban. For example, he made a splendid plea for the recall of the protestant Huguenots, who left France after the revocation of the Edict of Nantes in 1685. Most notable, however, were the statistical studies, which grew out of the surveys he made of so many regions for military purposes, posthumously published under the ironical title *Les Oisivetés* (leisure affairs). These provided the background to his famous protest against the system of privilege that was ruining France, *Projet d'une dixme royale* – a plea for a single progressive tax to be imposed on all classes. However, too many people benefited from the existing system of taxation, which made the rich richer and the poor poorer, and Louis XIV gave orders for the book to be suppressed. After the great marshal died of pneumonia in Paris on 30 March 1707, his funeral was attended by just a few friends and relatives. The ungrateful monarch he served so devotedly for over 50 years was not represented.

In 1699, Vauban had been elected an honorary member of the Académie Royale des Sciences and in 1705 was made a Chevalier de l'Ordre de Saint Esprit. His wife died the same year; she had seen little of her hard-working husband for most of her married life, and it seems likely that he was unfaithful to her. She had two daughters by him and one son who died in infancy.

James Brindley (1716–1772)

In the eighteenth century, England had a fine network of roads but most of them were in an appalling state. Transport by sea or river was used wherever possible. On the continent, canals had been constructed in various locations, and the technology was well developed. Transport by canal barge was slow but sure. When sails could not be used barges were hauled by men



or by horses. Horses could haul a much heavier load on a waterway than they could on even a well-maintained road. England was slow to realize the advantages of canals. Such canals as existed followed the course of rivers and other natural waterways. The Duke of Bridgewater showed that they could be constructed almost anywhere. Like Riquet, he became heavily indebted as a result.

Francis Egerton, the third Duke of Bridgewater, inherited property in various parts of the country. The most important of his estates was Ashridge, west of London, but in the north there was Worsley, near Manchester. A consumptive weakling in his youth, he was not expected to achieve much. His guardians packed him off on the customary extravaganza known as the grand tour of European countries, especially France and Italy. He was

fortunate in his 'bearleader', who moderated his behaviour and made sure that, as well as having a good time, he gained an understanding of the arts and the industries of the places they visited. On his tour he saw the Grand Canal of Languedoc, and other feats of engineering. In Rome, he started to build up a collection of paintings that was later to become of the finest in the country, when he took advantage of the sale of the collections of the French aristocracy after the Revolution. On his return to England, he dissipated much of his fortune at the gaming tables of London, but when he tired of that he retreated to Worsley, where his estate included some coalmines. These produced no more than a small income, and he was determined to increase it.

The duke's agent, John Gilbert, devised a plan for a canal on which the coal could be transported from the duke's mines to Manchester, where it would be sold. This would be a great improvement over transport by packhorse. The duke was enthusiastic about the project, and set about raising the necessary funds. However, an engineer was needed to design and build the canal, and this is where the subject of this profile comes in.

James Brindley was born in a remote hamlet near Buxton, Derby, the son of a once-prosperous yeoman, who had lost most of his money through gambling. At the age of 17, after some years working as a ploughboy, he was apprenticed to a wheelwright and millwright near Macclesfield. He was, to a large extent, self-taught, since the master and journeymen of the shop were an incompetent and drunken lot. In 1742, he was able to start up on his own in Leek, repairing and setting up machinery of many kinds, including the flint mills required by Josiah Wedgwood for his pottery. In 1758, he patented an unsuccessful attempt to improve the inefficient Newcomen steam engine, used to pump water out of coalmines, and was employed in a survey for an abortive project for a Mersey–Trent canal route.

Brindley's famous association with the Duke of Bridgewater began in the following year, when the duke was reconsidering his Worsley canal scheme with a view to avoiding a costly descent by locks down to the river Irwell and then up again the other side. Brindley proposed an aqueduct to carry the canal over the river. Such aqueducts were a novelty in Britain although not on the continent, as the duke would know. The scheme was completed in 1761; it was a great success and the owners of the land through which it passed, who had tried very hard to stop its construction, were dumbfounded.

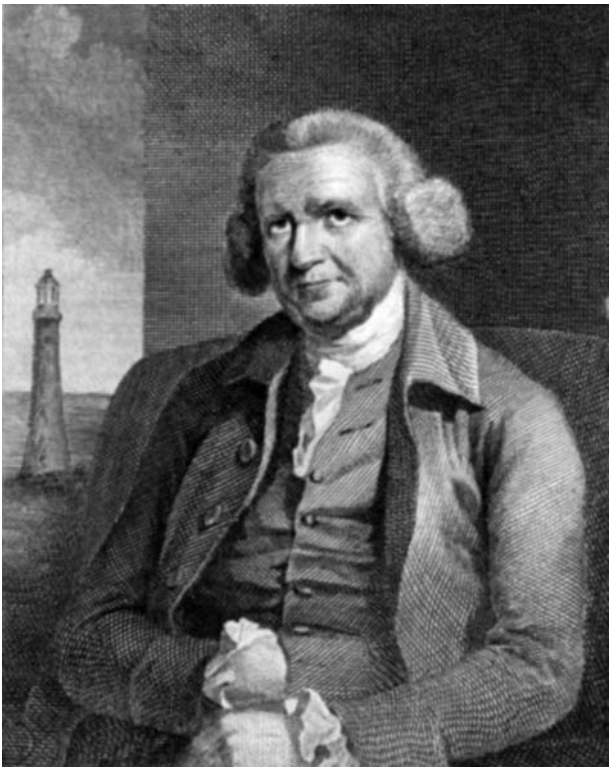
Brindley was subsequently employed to make the extension of the Worsley canal to Runcorn in 1762–7. The duke's triumph initiated what became canal mania. The members of the Bridgewater–Gilbert–Brindley triumvirate were involved in many projects, both large and small. The duke was one of the main promoters, with Wedgwood, of Brindley's biggest achievement, the Grand Trunk Canal linking the Mersey and the Trent across Cheshire and Staffordshire. Although this canal was not completed until six years after Brindley's death, he found time to lay out six others, making a total of 365 miles of canal.

Experience taught Brindley many things, but the ability of the semiliterate workman to solve the problems of such major works as the Burton aqueduct and the Hardcastle tunnel was surely the result of exceptional intelligence. Though he held strong opinions and prejudices, he was full of original ideas. He spoke with a strong Derbyshire accent, impressing the parliamentary committee considering the plan for the duke's canal. He was already 50 when he married a 19-year-old girl named Anne Henshall, daughter of his clerk of works on the Grand Trunk Canal. The marriage took place in 1765; they lived in a pleasant old-fashioned manor house at Turnhurst, Staffordshire. He died there on 27 September 1772. He left two daughters; his widow, still young, married again.

John Smeaton (1724–1792)

The engineer and instrument-maker John Smeaton was born at Austhorpe Lodge near Leeds on 8 June 1724. The eldest son of the attorney William Smeaton by his wife Mary, he had a younger brother, who died in childhood, and a sister, Hannah, eight years his junior. John entered his father's office to learn law after leaving Leeds Grammar School at the age of 16. At home, he spent his leisure time in a well-equipped workshop, wrapped up in mechanics. He was encouraged by the famous instrument-maker Henry Hindley of York to make some tools and clocks. Perhaps in the hope of reviving his son's interests in the law, Smeaton's father sent him to continue his legal studies in London in 1742, but to no avail, for with his father's consent and the encouragement of scientists in London he decided to become an instrument-maker like Hindley.

In 1748, Smeaton opened a shop of his own in London, selling Hindley's work as well as his own. Contact with instrument-making in the north, where the emphasis was on precision, led Smeaton to attach importance to accurate measurement throughout his life. The vacuum pump he produced in 1749 was capable of achieving rarefactions several times better



than any other model. His previous time in London had already brought him into contact with members of the Royal Society, who recognized him as a young man of exceptional intelligence, and, on the strength of papers read before them in the period 1750–4, he was elected to the fellowship in 1753. Six years later he gave a series of lectures to the Royal Society on his research into the natural powers of wind and water, for which he received the prestigious Copley medal. There was uncertainty as to whether overshot or undershot water mills were more efficient: he settled it decisively in favour of the former. For windmills and sailing ships, he found that the Dutch had already found the most efficient designs.

Smeaton had travelled through the Low Countries in 1755 to view harbour and drainage works in what is now Belgium and Holland; his detailed account of what he saw was published by the Newcomen society in 1938. When he returned, he successfully undertook several minor engineering projects and prepared plans for a projected bridge over the Thames