acknowledging the sovereignty of its Queen,—is unique in the history of nations, and strikingly illustrates the adaptability of British institutions to the novel requirements of a free people. The peculiar circumstances resulting from the union of a colony formed under the fostering restraints of French ecclesiastical and civil rule with one of purely English origin, and settled in part by loyalist emigrants from the United States, begot difficulties which were more and more felt as the mother country removed from Canada one after another of the restrictions on self-government. It will form an interesting chapter in the history of Britain in relation to her colonies, to note the freedom with which, when those of British North America had, as it were, attained their majority, they were left to frame a scheme of confederation suited to their circumstances; and when, after free deliberation, it had been matured to the satisfaction of those most directly interested in the results, the Imperial Government received it at their hands, and the British Parliament gave it the force of law. At the very period when this novel experiment in the history of colonization had been carried out to completion, and was open to the test of experience, the vice-regal duties were entrusted to the earl of Dufferin as governor-general of Canada. In the exercise of his duties he has visited many portions of the Dominion; and towards the close of an extensive tour in the summer of 1874, he thus gave expression to the results of his observations:—"Everywhere I have learnt that the people are satisfied,—satisfied with their own individual prospects, and with the prospects of their country; satisfied with their Government, and the institutions under which they prosper; satisfied to be the subjects of the Queen; satisfied to be members of the British Empire. Indeed, I cannot help thinking that, quite apart from the advantage to myself, my early journeys through the provinces will have been of public benefit, as exemplifying with what spontaneous, unconcerted unanimity of language, the entire Dominion has declared its faith in itself, in its destiny, in its connection with the mother country, and in the well-ordered freedom of a constitutional monarchy. It is this very combination of sentiments, which appears to me so wholesome and satisfactory. Words cannot express what pride I feel as an Englishman in the loyalty of Canada to England. Nevertheless I should be the first to deplore this feeling, if it rendered Canada disloyal to herself,—if it either dwarfed or smothered Canadian patriotism, or generated a sickly spirit of dependence. Such, however, is far from being the case. The legislation of the Parliament of Canada, the attitude of its statesmen, the language of its press, sufficiently show how firmly and intelligently its people are prepared to accept and apply the almost unlimited legislative faculties with which it has been endowed; while the daily growing disposition to extinguish sectional jealousies, and to ignore an obsolete provincialism, proves how strongly the young heart of the confederated commonwealth has begun to throb with the consciousness of its national existence. At this moment not a shilling of British money finds its way to Canada; the interference of the Home Government with the domestic affairs of the Dominion has ceased; while the imperial relations between the two countries are regulated by a spirit of such mutual deference, forbearance, and moderation, as reflects the greatest credit upon the statesmen of both. Yet so far from this gift of autonomy having brought about any divergence of aim or aspiration on either side, every reader of our annals must be aware that the sentiments of Canada towards Great Britain are infinitely more friendly now than in those early days when the political intercourse of the two countries was disturbed and complicated by an excessive and untoward tutelage; that never was Canada more united than at present in sympathy of purpose, and unity of interest with the mother country, more at one with her in social habits and tone of thought, more proud of her claim to share in the heritage of England's past, more ready to accept whatever obligations may be imposed upon her by her partnership in the future fortunes of the empire." (D. W.)

CANAL

NAVIGABLE canals may perhaps be most conveniently treated under two classes, *Barge* or *Boat* Canals, now in many cases almost superseded by railways and *Ship* Canals, which, judging from the stupendous works of this class recently executed and now in contemplation, seem as yet far from having exhausted the important aids they are destined to afford to navigation.

After giving a historical notice of early canals, the following article contains a brief notice of Barge Canals; a digest of general engineering principles applicable to the construction of all canals; an account of Ship Canals recently constructed; and a notice of Ship Canals which have been proposed and are ere long likely to be carried into execution for facilitating ocean navigation.

From the writings of Herodotus, Aristotle, Pliny, and other ancient historians, we learn that canals existed in Egypt before the Christian era; and there is reason to believe that at the same early period artificial inland navigation also existed in China. Almost nothing, however, save their existence has been recorded with reference to these very early works; but soon after the commencement of the Christian era canals were introduced and gradually extended throughout Europe, particularly in Greece, Italy, Spain, Russia, Sweden, Holland, and France.

In speaking, however, of the earliest of these works, it is not to be supposed that they resembled the modern canals now constructed in our own and other countries. Early as inland navigation was introduced, it was not until the invention of canal-locks, by which boats could be transferred from one level to another, that inland navigation became generally applicable and useful, and it has been truly remarked "that to us, living in an age of steam-engines and daguerreotypes, it might appear strange that an invention so simple in itself as the canal-lock, and founded on properties of fluids little recondite, should have escaped the acuteness of Egypt, Greece, and Rome."[1] Not only, however, had the invention escaped the notice of the ancients, but what is more striking, the several gradations made towards the attainment of that simple but valuable improvement appear to have been so gradual that, like many discoveries of importance, great doubts exist as to the *person* and even the *nation* that was the first to introduce canal-locks. One class of writers attributes the discovery to the Dutch, and Messrs Telford and Nimmo, who wrote the article "Inland Navigation" in Brewster's *Edinburgh Encyclopædia*, adopt the conclusion that locks were used in Holland nearly a century before their application in Italy; while, on the other hand, the invention has been strongly and not unreasonably claimed for engineers of the Italian school, and in particular for Leonardo da Vinci, the celebrated engineer and painter.[2] Without, however, entering into a discussion of this question, which it is now perhaps impossible to solve, we may safely state that during

[1] *Quarterly Review*, No. cxlvi. p 281

[2] Frisi *On Canals*, p. 154.

the 14th century the introduction of locks, whether of Dutch or Italian origin, gave a new character to inland navigation, and laid the basis of its rapid and successful extension. And here it may be proper to remark, that the early canals of China and Egypt, although destitute of locks, do not appear to have been on that account formed on a uniformly level line, unadapted to varying heights. It is very doubtful, indeed, if the use of locks has even yet been introduced into China, intersected as it is by many canals of great antiquity and extent, the imperial canal being about 1000 miles in length. "This canal appears to have been completed in 1289, and is said to extend for a distance of forty days' navigation, and is provided with many sluices, and when vessels arrive at these sluices they are hoisted by means of machinery, whatever be their size, and let down on the other side into the water."[1] Nevertheless the invention of locks was, as has been stated, a most important step in the history of canals; and that mode of surmounting elevations may be said to be almost universally adopted throughout Europe and America. Inclined planes and perpendicular lifts have, it is true, been employed in those countries, as will be noticed hereafter; but the instances of their application are undoubtedly rare.

But without tracing the gradual introduction of canals from country to country, we remark at once that we find the French at the end of the 17th century, in the reign of Louis XIV., forming the Languedoc Canal, designed by Riquet, between the Bay of Biscay and the Mediterranean, a gigantic work, which was finished in 1681. It is 148 miles in length, and the summit level is 600 feet above the sea, while the works on its line embrace upwards of one hundred locks and fifty aqueducts, an undertaking which is a lasting monument of the skill and enterprize of its projectors; and with this work as a model it seems strange that Britain should not, till nearly a century after its execution, have been engaged in vigorously following so laudable an example. This seems the more extraordinary, as the Romans in early times had executed works in England, which, whatever might have been their original use, whether for the purposes of navigation or drainage, were ultimately, and that even at an early period, converted into navigable canals. Of these works we particularly specify the Caer Dyke and Foss Dyke cuts in Lincolnshire, which are by general consent admitted to have been of Roman origin. The former extends from Peterborough to the River Witham near the city of Lincoln, a distance of about 40 miles; and the latter extends from Lincoln to the River Trent, near Torksey, a distance of 11 miles.

Of the Caer Dyke the name only now remains; but the Foss Dyke, though of Roman origin, still exists, and as it is the oldest British canal, the reader may be interested to learn the following facts as to its history. Camden in his *Britannia* states that the Foss Dyke was a cut originally made by the Romans, probably for water supply or drainage, and that it was deepened and rendered in some measure navigable in the year 1121 by Henry I. In 1762 it was reported on by Smeaton and Grundy, who found the depth at that time to be about 2 feet 8 inches.[2] They, however, discouraged the idea of deepening by excavation. They say they found "the bottom to be either a rotten peat earth, or else a running sand," and that though the deepening of the navigation is in "nature possible," yet it "cannot be effected without removing one of the banks in order to widen the same," which would not only turn out expensive, but would "occasion much loss of time and profit to the proprietor while the work is executing." Nothing followed on this report; but in 1782 Smeaton was again called in, and deepened the navigation to 3 feet 6 inches, not, however, by widening the canal or dredging, but by raising the water-level 10 inches.[3] From that period nothing more was done to enlarge the water-way, or adapt it to increased traffic. Meantime the adjoining Witham navigation having been improved, the defects of old Foss became more apparent, and in 1838 Mr Vignoles was consulted, and made an elaborate report on alternative schemes for increasing the depth to 4 and 6 feet; nothing, however, was done till 1840, when Messrs Stevenson were employed to design works for assimilating the Foss Dyke as far as practicable, both as regards width and depth, to the navigable channel of the Witham. The depth was found to be 3 feet 10 inches, and its breadth in many places was insufficient to admit of two boats passing each other, and for their convenience occasional passing places had been provided. It was resolved to increase the dimensions of the canal, and to repair the whole work. Accordingly it was widened to the *minimum* breadth of 45 feet, and deepened to the extent of 6 feet throughout. The entrance lock communicating with the River Trent at Torksey was renewed, and a pumping engine was erected for supplying water from the Trent during dry seasons, and thus that ancient canal, which is quoted by Telford and Nimmo as "the oldest artificial canal in Britain," was restored to a state of perfect efficiency, at a cost of £40,000, and now forms an important connecting link between the Trent and Witham navigations.

Notwithstanding the existence of this early work, however, and of some others in the country, particularly the Sankey Brook navigation, opened in 1760, it cannot be doubted that the formation of the Bridgewater Canal in Lancashire, the Act for which was obtained in 1759, was the commencement of British Barge Canal Navigation, of which we propose first to treat, and that Francis, duke of Bridgewater, and Brindley the engineer, who were its projectors, were the first to give a practical impulse to a class of works which, under the guidance mainly of Smeaton, Watt, Jessop, Nimmo, Rennie, and Telford, has been very generally adopted throughout the country, and has undoubtedly been of vast importance in promoting its commercial prosperity.[4]

According to Mr Smiles, the barge-canals laid out by Brindley, although not all executed by him, were:[5]—

	Miles.
The Duke's Canal, Longford Bridge to Runcorn	24
Worsley to Manchester	10
Grand Trunk, from Wilden Ferry to Preston Brook	88
Wolverhampton	46
Coventry	36
Birmingham	24
Droitwich	5
Oxford	82
Chesterfield	46
	361

It is believed that the length of the inland boat navigations constructed in Britain exceeds 4700 miles, and the system has been extensively carried out both in Europe and America. Many of them were made at great cost through hills and over valleys. The Harecastle tunnel on the Grand Trunk Canal, made by Brindley, and afterwards doubled by Telford, is nearly a mile and a half in length, and the Pont-y-Cyssylte aqueduct, on the Ellesmere Canal, over the Dee, constructed by Telford at a cost of £47,000, has nineteen openings 45 feet span, and is elevated 126

[1] *Travels of Marco Polo*, by Col. Yule, C.B.

[2] Smeaton's *Reports*, vol. i. p. 55, London, 1812.

[3] Smeaton's *Reports*, vol. i. p. 74, London, 1812.

[4] *History of Inland Navigation, particularly those of the Duke of Bridgewater*, London, 1768; Hughes's *Memoir of Brindley*; Weale's *Quarterly Papers*, London, 1843.

[5] Smiles's *Lives of the Engineers*.

feet above the river, the canal being carried across in a cast-iron trough.[1]

It must be obvious, that to construct a navigable channel through a country varying in level, and affording, perhaps, no great facilities for obtaining a supply of water, infers high engineering skill. Vast reservoirs must in some cases be formed for storing the water necessary to supply, during dry seasons, the loss by lockage, leakage, and evaporation. Feeders must be made to lead this water to the canal, hills must be pierced by tunnels, valleys must be crossed on lofty embankments, or spanned by spacious aqueducts, and, above all, the whole must be conceived and laid out with scrupulous regard to the all-important object of securing the works against injury from an overflow of water during floods, and a consequent inundation of the surrounding country. Moreover, the necessity of laying out the canal in level stretches, and surmounting elevations by means of locks or inclined planes, occurring at intervals, often occasions much difficulty and greatly restricts the resources of the engineer. Taking, then, all these circumstances into consideration, and bearing in mind that canals were the pioneers of railways, we think it may safely be affirmed that the canal engineers of former days had more serious *physical* difficulties to contend with than are experienced in carrying out the railways of modern times, if we except such works as the Britannia Bridge, the high-level bridge of Newcastle, the Boxhill tunnel, and some other kindred works. But, indeed, their *mechanical* difficulties were also greater, for the introduction of steam, and its wide-spread application to all engineering operations, afford facilities to the engineers of the present day which Smeaton at the Eddystone, Stevenson at the Bell Rock, and Rennie and Telford in their early navigation works, did not enjoy. The distinguished merits of the engineers who practised in the former and at the commencement of the present century, cannot indeed be over-estimated, and had it been within the scope of this article it would have been profitable and instructive to have described in detail some of the grand aqueducts and other works on the lines of our canals. For this reference is made to the articles AQUEDUCT, BRIDGE, TUNNEL, and RESERVOIR, all of which are more or less applicable to the formation of canals. We shall only therefore offer to the student the following summary of engineering principles generally applicable to all cases.

A canal cannot be properly worked without a supply of water calculated to last over the driest season of the year, and in that respect, except as to the quality of the water, demands all the care requisite in investigating the sources of water for supplying towns. If there be no *natural* lake in the district, available for supply and storage, the engineer must select situations suitable for artificial reservoirs, and the conditions to be attended to in selecting their positions are the same as those for water-works. They must command a sufficient area of drainage to supply the loss by leakage, evaporation, and lockage, due to the length of canal, number and size of the locks, and probable amount of traffic. The capability of the district to afford this supply will depend on the area of the basin drained and the annual amount of rainfall. The offlets from the reservoirs must be at such an elevation as to convey water to the summit-level of the canal. The embankments for retaining the water must be erected on sites affording a favourable foundation, and, if possible, in situations where an embankment of small height and length may dam up a large amount of water. It is further necessary to consider whether the subsoil of the valley forming the reservoirs is throughout of so retentive a nature as to prevent leakage, and it is essential to provide, by means of waste weirs, for the discharge of floods. The Caledonian Canal, to be afterwards noticed, is in this respect very favourably situated, the whole supply being obtained from natural lochs. In other cases, such as the Union, Forth and Clyde, Crinan, Birmingham, and other canals, it was necessary to construct large reservoirs in which the water is stored in winter and led in feeders to points convenient for supplying the canal in summer. Where the canal communicates with the sea or a tidal river, and where the natural supply is small, as at the Foss Dyke already referred to, the water is raised by pumping engines. It will readily be seen, therefore, how important it is to reduce to a *minimum* the loss of water due to leakage from deficient workmanship, as well as to lockage of the traffic through the canal, and (while on this subject) it may be stated that the *up* consumes a greater amount of water than the *down* traffic, for an *ascending* boat on entering a lock displaces a volume of water equal to its submerged capacity; the water so displaced flows into the lower reach of the canal and the lower gates are closed, the boat is then raised, and on passing into the higher reach of the canal its displacement lost on entering is supplied by water withdrawn from the higher reach. A *descending* boat, on the other hand, on entering a lock likewise displaces a volume of water equal to its submerged capacity, but the water in this case flows back into the higher reach of the canal, where it is retained when the gates are closed. Mr Fulton gives the consumption of 25-ton boats through locks of 8 feet lift as about 163 tons of water in ascending, and 103 in descending.[2] Several proposals have been made for reducing the loss of water by side ponds to receive part of the water, but all such plans delay the traffic and have not come into general use.

The barge-canals constructed in this country are between 4 and 5 feet in depth. When the soil in which they were made was retentive, they were formed as shown in the cross-section, fig. 1. But when the soil was porous, clay

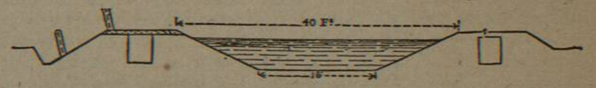

FIG. 1.—Section in retentive soil.

puddle was introduced, as shown in fig. 2. Professor Rankine says the depth of water and sectional area of water-way should be such as not to cause any material

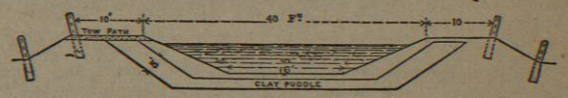

FIG. 2.—Section in porous soil.

increase of the resistance to the motion of the boats beyond what it would encounter in open water, and gives the following rules as fulfilling these conditions :—

Least breadth at bottom = 2 × greatest breadth of boat.
Least depth of water = $1\frac{1}{2}$ foot + greatest draught of boat.
Least area of water-way = 6 × greatest midship section of boat.

In laying out a line of canal the engineer is more restricted than in forming the route of a road or railway, where gradients can be introduced to suit the undulating surface of the country. A canal, on the contrary, must follow rigidly the bases of hills and windings of valleys, to preserve a uniform level, accommodation being made for the road traffic by erecting suitable "fixed" and "movable" bridges. It is important, as already stated, to lay out the work in long level reaches, and to overcome

[1] *Life of Telford*, London, 1838.

[2] Fulton's *Canal Navigation*.