CHAPTER IV

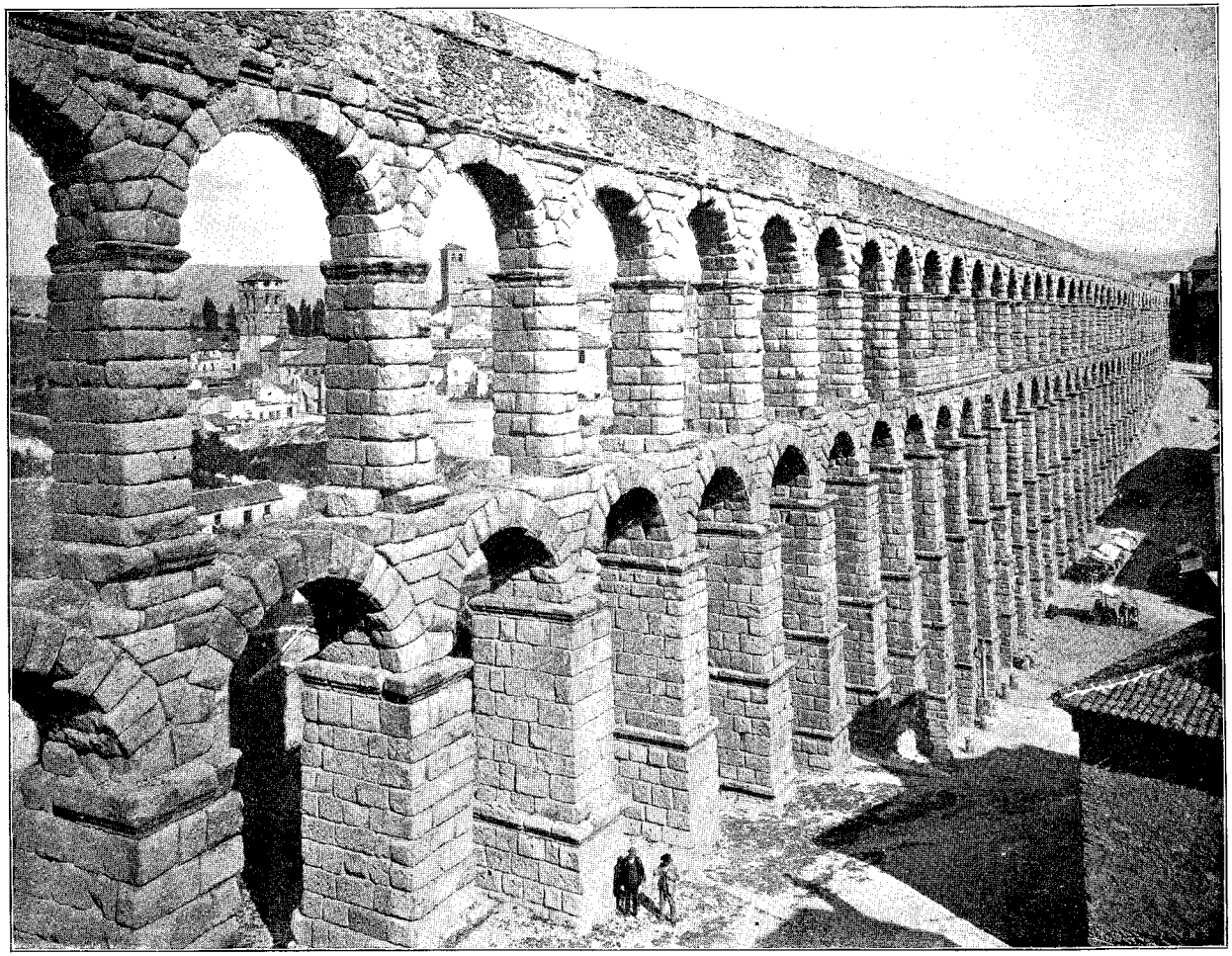
AQUEDUCT BUILDING AND THE WATERS OF THE AQUEDUCTS

Barbaris qui Romulidas jungis auditorio.
DRACONTIUS, *Carmina minora*
(ed. Duhn), i. 13.

By whom both the barbarians and Romulus' descendants are taught.

CHAPTERS 17–22, both inclusive, of "De Aquis," evidently form a division of the writer's work, such as he may have written at a single sitting, after having given us in Chapters 5-15 the brief history of each of the nine aqueducts in existence A. D. 97, as detailed in the previous chapter of the present book. Much of the matter touched on in "De Aquis," 17–22, has already been commented on, and all of it will be clear from the two maps prepared for this volume, the one showing the route of the aqueducts within the city, the other showing the lines of the aqueducts from their sources to the city. In studying these maps, we enjoy the same privileges which Frontinus says he enjoyed from the plans of the aqueducts which he had made for his own use. Lack of modern facilities of reproduction of maps no doubt prevented him from attaching copies of the same to his "II. Books" as he first wrote them. But had he and his immediate successors given us such copies, the monks of Montecassino would not have failed to reproduce them. Those people were great draughtsmen, and they made original drawings in the way of "illuminations" to some of their other manuscripts, that are marvels of delicate work.

But we can make such plans as described for ourselves, and as Frontinus says, 17: "In this way we reap the advantage of having, as it were, the works referred to directly before us, and of being able to study them, as though we stood by their side."



AQUEDUCT OF SEGOVIA IN SPAIN.

Built under Trajan, about A. D. 109.

Only eight feet wide, twenty-seven hundred feet long, ninety-five feet high. Still in use.

It must be remembered that we are speaking of the works of a very practical people. They were engineers by nature, rather than architects or men of science only; they taught the useful from choice, rather than that which was merely beautiful in design or tendency. They felt comparatively little predilection for "pursuing science for science's sake," as the phrase goes, while they pursued to the utmost of their abilities, and most ably for their day, that "art of directing the great sources of power in nature, for the use and convenience of man," which constitutes the profession of the civil engineer. The difference between their point of view and that of the Greeks was recognized long ago. Strabo, v. 3, 8, says: "The cities founded by the Greeks are reputed to have prospered by reason of the attention given by their builders to placing them in beautiful and favorable situations, in the vicinity of some harbor or in a fruitful region of country. But the Romans did mainly that which the Greeks neglected; I allude to paved streets, to aqueducts, and to those sewers, by means of which all the refuse of the city is swept into the Tiber."

Everybody knows how common a thing it is to find the remains of an aqueduct of Roman times in any country they once had possession of. Mommsen[1] names eleven Roman cities thus provided. Marchetti[2] describes nineteen such aqueducts besides those of Rome; Leger enumerates seventy-five; and there may actually be in existence the ruins of two hundred or more. Pliny the Younger was proconsul only a year or two, nevertheless he found time to cause not less than two aqueducts to be built during his tenure of office. He speaks of two, and may have built more.[3] The Roman aqueduct of the ancient Bologna is a remarkable work described by Gozzadini;[4] and there are many others described in the works of Rondelet, Leger, Merckel, and elsewhere.

Let us now get a clear idea why a people like this built these long and high aqueducts from choice. Let us stamp out, if we can, the shallow notion that those men did not know that water would rise

[1] *Z. f. gesch. Rechtsw.*, xv. 306.
[2] *Sulle Acque di Roma*, 1887.
[3] *Epist.*, x. 46 and 93.
[4] *Acqued. de Bologna;* also by Lanciani, *Frontino*, p. 549.

as high in a pipe as the source from whence it came. This belief can be disproved so easily that it becomes a marvel that so false an idea should continue to demand notice. Here, for example, is Vitruvius,[1] a Roman builder, the predecessor of Frontinus by about one hundred years, who wrote ten books on architecture, between 16 and 13 B. C. He tells us how to build what are now called inverted siphons.[2] He

PONT DU GARD, NEAR NISMES, SOUTHERN FRANCE.[3]

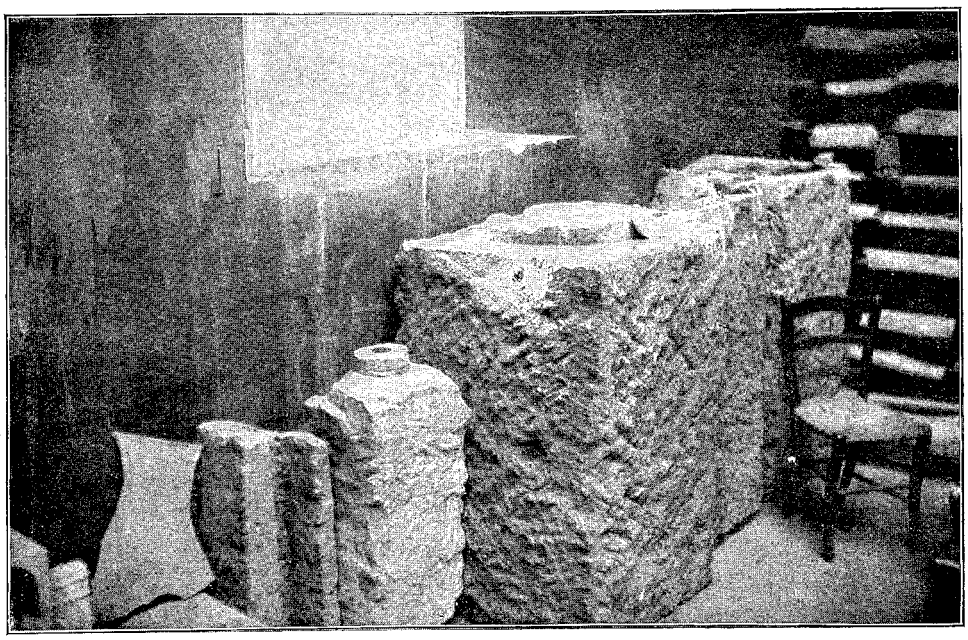
says it may be done with lead pipe, or with drain pipe. If of lead and ten feet long, make them weigh twelve pounds per inch in circumference; that is, make them uniformly a little over five-sixteenths of an inch thick. As he makes them one and one fourth inches to twenty-four inches in diameter, he leads people into making twenty-four inch pipe, that will stand only about forty-one feet head, while

[1] Vitruv., viii. 6, 5-6.

Lanciani, *Frontino*, p. 554, on siphons; or Rondelet, or Leger, or Merckel.

[3] Roman aqueduct built about A. D. 150; possibly A. D. 18 by Agrippa. The road-bridge is a mediaeval addition. One hundred and sixty feet high, top story ten feet wide, and nine hundred feet long.

the one and one-fourth inch pipe should stand nineteen times that head. These pipes, as we shall see, were all soldered, not seamless drawn, but the strength of the joint was equal to or was greater than that of the metal. However, they could be, and we know that they frequently were surrounded by masonry, whose weight could be depended on to increase the strength of the siphon. That this was done, both in the



ROMAN WATER PIPE MADE OF BORED-OUT BLOCKS OF STONE.[1]

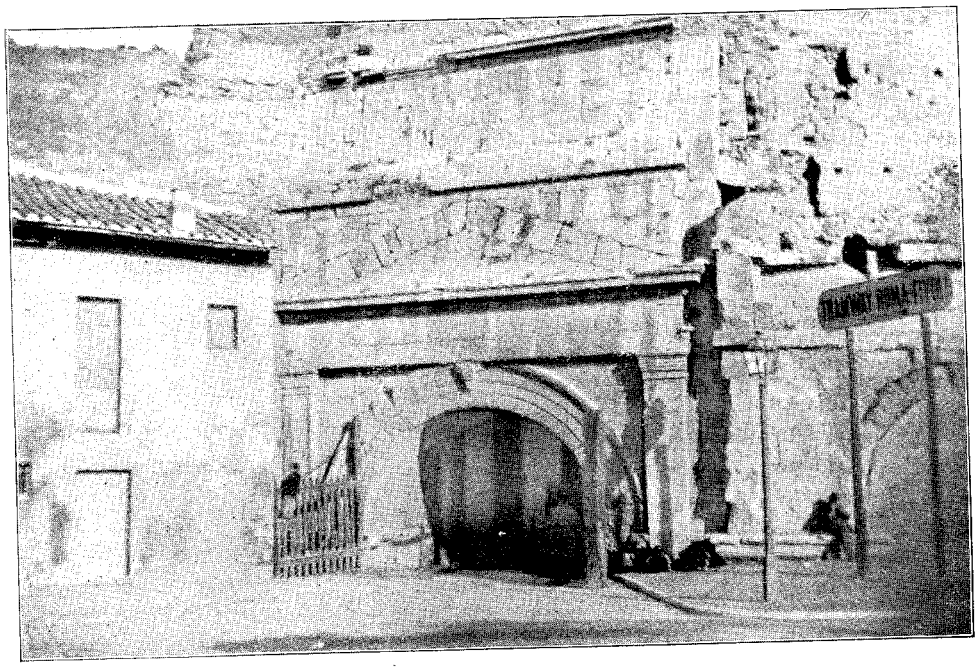
case of the lead and of the drain-pipe siphons, we know from the remains of both kinds which have been found: as for example, the lead pipe siphons at Lyons, France, the ancient Lugdunum; being nine parallel lines of pipe, twelve inches to eighteen inches in diameter, and one inch thickness of metal,[2] under two hundred feet head; and a drain-pipe siphon, reinforced with masonry, at Alatri, in Italy, built by L. Betilienus Varus, 125 B. C., and built to withstand some three hundred and forty feet head.[3] Vitruvius tells us how, in laying such pipe,

[1] Now in the Magazzino Archeologico at Rome. From a photograph taken by the author.

[2] Leger, Alfred, *Les Travaux Publics aux Temps Romains*, 1875. Also Rondelet, 94.

[3] Lanciani, *Ancient Rome*, and his *Frontino*, 537. *Central-Blatt d. Bauverw.* July 2, 9, 1881. This L. Betilienus Varus was a leader of men, and seems to have been a contractor, as may be gleaned from the inscription a grateful city set up to his memory. It may be translated as follows: "L. Betilienus L. F. Varus caused these things to be made, which with the

the mortar at the joints should be made of lime and oil, what is now called "pointing up" mortar, and used to finish the joints on the outside of buildings; that at the angles should be placed a bored-out block of stone; that such siphons must be filled very slowly; and that it is a good plan to put ashes inside, to begin with, so as to stop fine leaks; a little trick of the trade called "puddling with ashes,"



PORTA TIBURTINA.[1]

which, in the case of canal gates and the like, is the common New England practice, about nineteen hundred years after Vitruvius.

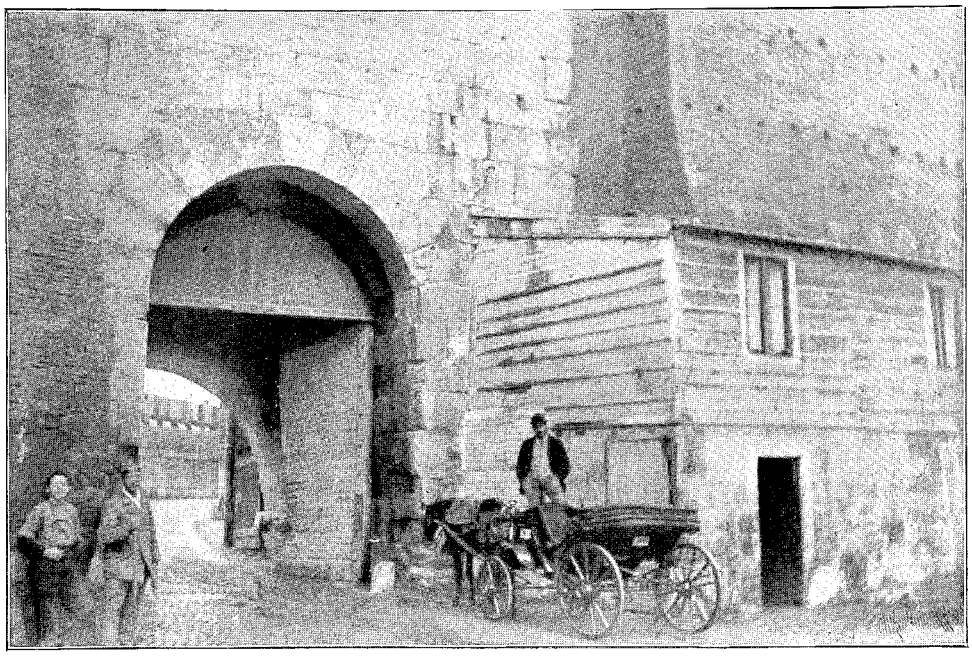
Vitruvius learned much that he knew from the Greeks, and in speaking of inverted siphons, he states what the Greeks called them.

approval of the Senate are written below: Every lane in town; the gate leading to the citadel; the play-ground, sundial, market-place, seats, and plastering of the town hall, tank for bathing, tank at the gate, water in the town raised on arches to a height of 340 ft. He made his pipes strong. On account of these things the Senate twice ordered him to be made censor, and voted that a pension was due his son. The people gave this monument to the man who had twice been censor." C. I. L., i. 1, 166; Lanciani, *Frontino*, 556.

[1] Observe the moulding of the pediment cut away to gain room for still another inscription. The former abutments of the arch have been buried up in the course of time, and the moulding at the springing of the arch is now used as a bench.

Remains of Greek drain-pipe siphon aqueducts have been found in Asia Minor,[1] and are shown in modern books of travel.

In the "Natural History" of Pliny the Elder, written about A. D. 79, (31, 57), it is said in plain language, speaking of water: that "it climbs to the height of its own origin:" "subit altitudinem exortus sui." So also says "De Aquis," 18. "The several aqueducts reach the city



CITY GATE.[2]

at different elevations. Whence it comes, that some deliver water on higher grounds, while others cannot elevate themselves to the higher summits; for the hills have gradually grown higher, on account of the accumulation of rubbish produced by the frequent fires.[3] There are

[1] Belgrand, *Les aqueducs Romains*, 1875. Louvre, Greek inscription, No. 133, aqueduct at Mylasa, 323–317 B. C. Middleton, ii. 348.

[2] Porta Tiburtina, or rather the gate built in line of Porta Tiburtina through the city wall, four hundred years later. From a photograph taken by the author.

[3] In Lanciani, *The Ruins*, etc., 102, are given some data permitting one to form a precise judgment as to the amount of débris which the life and death of the artificial elements that went to make up the City of Rome would produce in the course of time. Thus the threshold of Porta Tiburtina, built 4 B. C. by Augustus, is ten feet below the threshold of Porta S. Lorenzo, built in 402; making nearly one-fourth inch per annum. At the foot of the Palatine Hill, at the House of the Vestals, this layer of rubbish was seventy-two feet thick, the maximum

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