Editor's Message
Happy 200th birthday Mr Darcy and our thanks for your law! A tribute editorial celebrating the life and times of the father of our science, Henry Darcy (1803–1858)

Craig T. Simmons, Associate Editor

On October 29th and 30th 1855, Henry Darcy carried out column experiments with Mr Charles Ritter in a hospital in Dijon, France, to determine "the laws of water flow through sand". In a translation from his original report, his experiments showed that "for sand of comparable nature, one can assume that the discharge volume is directly proportional to the head and inversely proportional to the thickness of the layer traversed". In those experiments, Darcy had discovered the secret of one of nature's laws. Today, Darcy's Law is commonplace in almost every aspect of hydrogeology, soil science, petroleum engineering and other fields involving flow in porous media.

This year marks the bicentenary of the birth of Henry Darcy, the founding father of the science of fluid flow in porous media. Henry Philibert Gaspard Darcy was born on June 10, 1803 in Dijon, France, and died there on January 3, 1858. This editorial is a tribute to the life of Darcy and an opportunity to reflect upon the many contributions he made to hydraulics, most notably Darcy's Law. As is usual with an editorial, space is limited and this discussion can only be brief. Thankfully, there are now a number of excellent papers published relating to Darcy's life, his family and education, the discovery of his law and the process of that discovery, translations of the original French text and even discussion on the correct spelling of his name [see for example, Freeze and Back (1983), Freeze (1994), Philip (1995), Brown (2002)]. For those Darcyphiles [to coin a term used by Freeze (1994)!] amongst us, these papers make for some very interesting reading. This editorial draws extensively upon them. Therefore, I acknowledge the amazing efforts of all previous authors whose countless hours digging up books in dusty archival collections, whose pilgrimages to Dijon to visit tourist offices, libraries and cemeteries and efforts in translating original French works into English now afford us a wealth of previously unknown information about Darcy. It is their time, perseverance, passion and curiosity that make this tribute editorial possible.

Let's celebrate Darcy's 200th birthday by reflecting upon the achievements of Henry Darcy and to search back, even for a moment, to our scientific roots. Why search for our scientific roots? Freeze (1994) in his paper titled "Henry Darcy and the fountains of Dijon" puts it very nicely when reflecting upon the introduction to Chapter 2 of the text book he and John Cherry wrote (Freeze and Cherry 1979). The chapter begins with the following introduction that Freeze (1994) then comments upon in the statement "The birth of groundwater hydrology as a quantitative science can be traced to the year 1856. It was in that year that a French hydraulic engineer named Henry Darcy published his report on the water supply of the city of Dijon, France. In the report Darcy described a laboratory experiment that he had carried out to analyze the flow of water through sands. The results of his experiment can be generalized into the empirical law that now bears his name..... And that's it..... The rest of the chapter describes cross-sections, and inflow and outflow tubes, and manometers. There is not another thing about Henry Darcy. Not even why his name is Henry rather than Henri; or whether he was tall or short, or rich or poor".

There has been growing curiosity in Darcy's life in recent years and this has led to answers to some of these questions. In his biographical essay describing his pilgrimage to Dijon, J.R. Philip (1995) has provided two reproductions of Darcy: one of the young Darcy at age 18 and the other of the mature Darcy. The latter mature portrait is shown in Fig. 1. And just to give a little Darcy trivia for a moment, we also know that he was 1.69 m tall, had light brown hair, blue eyes and a cleft chin! (Brown 2002). And what of Darcy's name? As Philip (1995) points out, everything he uncovered in his visit to Dijon, Darcy's native town, clearly used the English spelling Henry and not Henri. Indeed, it is this anglicized form that also appears on the title pages of the famous "Fontaines Publiques" report (see Fig. 2) and his great-nephew Paul Darcy uses it in the title of his Darcy biography and throughout that text (Freeze 1994).

Two hundred years have passed since Darcy's birth and almost 150 years since Darcy published his most

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Fig. 1 Henry Darcy in the later years of life. Portrait by F. Perrodin from the collection of the Bibliothéque Municipale de Dijon. From Philip (1995) and Brown (2002)

famous text on the construction of the municipal water supply of Dijon, "Les Fontaines Publiques de la Ville de Dijon" (Darcy 1856). This report was prepared by Darcy when working as Inspector-General of the French Imperial Corps of Bridges, Highways and Mines in Dijon. The report was 680 pages long and contained 28 plates of figures. As Brown (2002) points out, while much of the material addresses the Dijon water supply, Darcy also discussed several other topics including groundwater, sand filters and pipe manufacture. But Darcy left his greatest gift buried in the depths of the report. Part 2 of Appendix D, on pages 590–594 in a subsection titled "Determination of the Laws of the flow of water through sand" contained the results of his famous column experiments. Freeze (1994) described their appearance as "hardly front and center". One interesting point, however, is whether Darcy truly realised the significance of his findings. In a more recent paper titled "Henry Darcy and the making of a law" Brown (2002) provides a very thorough account of Darcy's life and pays particular attention to the process of his discovery, noting that many earlier publications suffer from a lack of historical perspective. He suggests that Darcy understood the significance of his law since he "devoted almost a full page in the introduction to describing its results. In comparison, some sections of greater length were only given one or two sentences".

Some other notable published works are a review of Darcy's experiment by Hubbert (1969) that provides an excellent theoretical discussion of the law, and a partial translation of Darcy (1856) by R.A. Freeze in a collection of classic papers in hydrogeology for the Benchmark-Papers-in-Geology series (Freeze and Back 1983). A very interesting account of the life and times of Darcy was presented by Freeze (1994) drawing upon a 63-page biography of Henry Darcy written by a great-nephew published in 1957 (Darcy 1957) that Freeze discovered in a small bookstore in Dijon in 1988. Philip (1995) in his paper titled "Desperately seeking Darcy in Dijon" provides a very interesting account of some less well known aspects of Darcy's character, life and work based upon a short visit to Dijon and archival material from the Dijon Bibliothéque Municipale. Philip (1995) was devastated to discover that the people of Dijon didn't seem to know who Darcy was nor seem to care. Yet it was less than 150 years earlier that the town of Dijon mourned the death of Darcy. As described by Philip (1995), "Darcy, with great vision and skill, designed and built a pure water supply system for Dijon, in place of previous squalor and filth. Dijon became a model for the rest of Europe. Darcy selflessly waived fees due to him from the town, corresponding to about $1.5 million today. Medals were struck recognizing his skill and selflessness; and a monument celebrates his great work". The translated inscription on Darcy's tomb expresses the strong sentiment felt in Darcy's time and it is only fitting to quote that directly here (Philip 1995):

"He conceived the project, made all the studies, pursued to the end the execution of the works to which Dijon owes the creation and the abundance of its public waters. Doubly benefactor of his native town through his talent and his selflessness".

But how did such great things come to be? It is useful to briefly trace some of the key steps in Darcy's life. In 1821, Darcy entered L'Ecole Polytechnique, Paris, beginning his study in science and engineering. In 1823, at the age of 20, he was admitted to L'Ecole des Ponts et Chaussées (School of Bridges and Roads), Paris. This was the academic arm of the Le Corps des Ponts et Chaussées, "an elite fraternity of engineers that had influential status in mid-nineteenth century France" (Freeze 1994). This progression was usual for the better students at the time and would shape the course of the rest of Darcy's life (Brown 2002). A list of the schools graduates and teaching staff reads like a cast of science and engineering stars and includes Antoine Chézy (1718–1798), Louis Marie Henri Navier (1785–1836), Gaspard Gustave de Coriolis (1792–1843), Arsene Jules Emile Juvenal Dupuit (1804–1866) and Henri Emile Bazin (1829–1917), to name just a few. Coriolis was also teaching at the Polytechnique during Darcy's residence (Brown 2002).

Darcy joined the Corps as an engineer upon graduating in 1826 and spent most of his working life with them stationed in Dijon. The Corps was an active and vibrant part of French life in the mid-19th century. According to Freeze (1994), Darcy and other prominent scientists and

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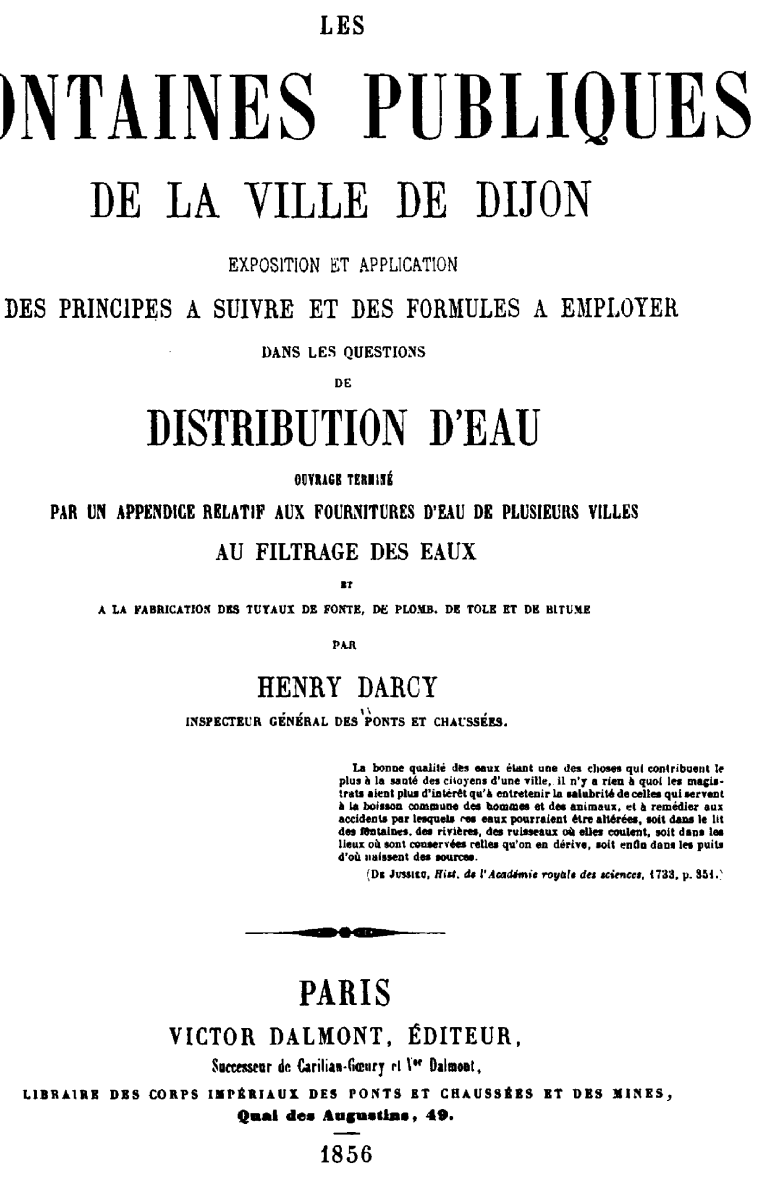

LES

FONTAINES PUBLIQUES

DE LA VILLE DE DIJON

EXPOSITION ET APPLICATION

DES PRINCIPES A SUIVRE ET DES FORMULES A EMPLOYER

DANS LES QUESTIONS

DE

DISTRIBUTION D'EAU

OUVRAGE TERMINÉ

PAR UN APPENDICE RELATIF AUX FOURNITURES D'EAU DE PLUSIEURS VILLES

AU FILTRAGE DES EAUX

ET

A LA FABRICATION DES TUYAUX DE FONTE, DE PLOMB, DE TOLE ET DE BITUME

PAR

HENRY DARCY

INSPECTEUR GÉNÉRAL DES PONTS ET CHAUSSÉES.

La bonne qualité des eaux étant une des choses qui contribuent le plus à la santé des citoyens d'une ville, il n'y a rien à quoi les magistrats aient plus d'intérêt qu'à entretenir la salubrité de celles qui servent à la boisson commune des hommes et des animaux, et à remédier aux accidents par lesquels ces eaux pourraient être altérées, soit dans le lit des fontaines, des rivières, des ruisseaux où elles coulent, soit dans les lieux où sont conservées celles qu'on en dérive, soit enfin dans les puits d'où naissent des sources.

(DE JUSSIEU, *Hist. de l'Académie royale des sciences*, 1733, p. 351.)

PARIS

VICTOR DALMONT, ÉDITEUR,

Successeur de Carilian-Gœury et Vve Dalmont,

LIBRAIRE DES CORPS IMPÉRIAUX DES PONTS ET CHAUSSÉES ET DES MINES,

Quai des Augustins, 49.

1856

Fig. 2 Cover of the original Darcy "Fontaines Publiques" report. From Hubbert (1969)

engineers attained public recognition and status in their tenure working there. Darcy rose to prominence in the period 1834–1848 as he carried out a number of significant projects, including not only the development of the town water supply for Dijon, but also in the construction of a number of road projects, navigation works and bridges. In 1840, he was appointed to the position of Chief Engineer for the Department of Cote d'Or at the young age of 37. To place his famous column experiments in context, it should be noted that they were only carried out a year before their publication in 1856. Most of the work on Dijon's water supply was undertaken much earlier in Darcy's career, in the period 1835–1840.

But it was not all fun and joy for Darcy. He suffered political persecution and in the later years of his life, his health deteriorated. In 1848, he was suspended from duties shortly after the French constitutional monarchy was replaced by a provisional republican government, since he was considered "dangerous for the new state of things" (Darcy 1957). Apparently, he had too much influence in Dijon for the new Commissioner's liking (Brown 2002). Nonetheless, Darcy seemed to go on undeterred. He was appointed to Bourges to work on a canal project and prepared plans for a new project to provide drainage and irrigation throughout the Sologne region. After the formation of the Second Republic and the election of Louis Napoleon, he was transferred to Paris where he was appointed Chief Director for Water and Pavements (Brown 2002). By 1850, he was promoted to the rank of Inspector General, 2nd Class, which provided Darcy with major research opportunities. Building upon his interest in pipe flow that had grown whilst working on the Dijon water system, he carried out an experimental program to examine pipe friction coefficients. He made the first accurate measurements of turbulent pipe velocity distributions and provided the very first evidence of the existence of the

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fluid boundary layer. His contribution is acknowledged in the joint naming of the Darcy–Weisbach pipe friction formula. As Brown (2002) points out, besides the discovery of his law, he was the first to show that significant flow resistance occurs within aquifers and the first to recognise the law's similarity to Poiseuille flow describing flow in small diameter pipes at low velocity. Whilst, according to Brown (2002), it appears that Darcy had discovered "the kernel of the truth" by 1854, it was not until the work of Reynolds in 1883 that the differences between laminar and turbulent flow were truly quantified. Darcy completed his pipe flow report in 1854 and in the period between the submission of this report and its publication, he completed his most famous text "Les Fontaines Publiques de la Ville de Dijon" (Darcy 1856). In this period, Darcy's health was clearly deteriorating. He had a "nervous disorder" that was apparently noticed as earlier as 1842 (Freeze 1994). He also exhibited symptoms of meningitis and he lost consciousness at a conference in Paris in 1853 (Darcy 1957). In 1855, just a few years after his assignment to Paris, he was granted release from all duties except research. In his final years, Darcy gave full attention to his experimentation. He returned to Dijon to work on two sets of experiments, those with Bazin on the Burgogne Canal and those with Ritter in the hospital laboratory. The first column experiments were carried out in October 1855 and just two years later, on January 3 1858, at the age of 55, Darcy died. He had apparently fallen ill with pneumonia, no doubt brought on by the lingering effects of many years of poor health (Freeze 1994). In 1857, just before he died, he was unanimously elected to hold the prestigious Chair of the French Academy of Sciences, a position held previously by Cauchy.

As a research community, we remember Darcy for his many contributions to hydraulics and most notably for his law. He was clearly a great scientist and engineer who did much more than just the column experiments for which he is most well known. After reading the above accounts, what becomes immediately apparent is that we should also remember Darcy as a great man and outstanding citizen. He received many honours in his life, but what makes his achievements more admirable are the personal, professional and political problems he both endured and overcame in order to carry out his scientific research. Most enjoyable to read is the Epilogue to his paper written by Freeze (1994) that really captures the essence of Darcy's life. It is so well written that I can hardly do better than quote directly from it here:

"I can see his path through life in its various roles: as a successful young student; as a fraternal brother in the Corps des Ponts et Chaussées; as a young engineer of such renown that he is asked to design the water supply for the city of Dijon; as the administrator of a large regional engineering office; as a respected leader of the community; as a victim of political pressure in a time of tumult; and as a research scientist who made lasting contributions to mankind".

Today, without any thought at all of the origins of its discovery and the difficulties encountered on the way to its discovery, we are fortunate that we can quickly write down Darcy's Law, plug in some measured values for hydraulic conductivity and hydraulic gradients, and estimate groundwater flow rates! It is unlikely Darcy could ever have known just how important his law would become to so many problems not yet encountered, in fields of study not yet conceived in his time (Brown 2002). In our own field, hydrogeology has evolved since Darcy's time from one dominated by hydraulics to include a plethora of unsolved (perhaps intractable) problems. Dealing with heterogeneity in subsurface environments and predicting solute transport in those systems is just one such example. In addition, there has been much discussion on the future of hydrogeology (see Editors message in Hydrogeol J 11:415–417, 2003). In this year, Darcy's 200th birthday, let us honour Darcy and his life and times by not only reflecting upon the past, but, most importantly, looking towards the future. Share some Darcy history with students and colleagues. Celebrate the life and times of the man who gave us his law and who set the stage for the field of science we now call hydrogeology.

This editorial touches upon only some of the key aspects of Darcy's life, and only does so in the barest detail. The papers referred to throughout are an excellent source of information for those interested in delving deeper into the story of Darcy: his law, the scientist and the man. But, before closing, there are a couple more thoughts worth pondering over, even for a moment. What do you think Darcy would say if he were alive now and could spend some time with us as a community reflecting upon hydrogeology's past and present, but, also, more importantly, gazing into hydrogeology's future? The answer to this question will never be known, but one thing is very likely. A man and scientist of Darcy's calibre would have had something to say about our future and would have expected us to be thinking about it. He would undoubtedly have been at the forefront of the community leading today's research. In writing the final words here, I also cannot help but wonder what the tribute editorial celebrating Darcy's 300th birthday in the year 2103 will have to say about our science. It is an interesting thought isn't it?

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