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The Catalan process for the direct production of malleable iron and its spread to Europe and the Americas

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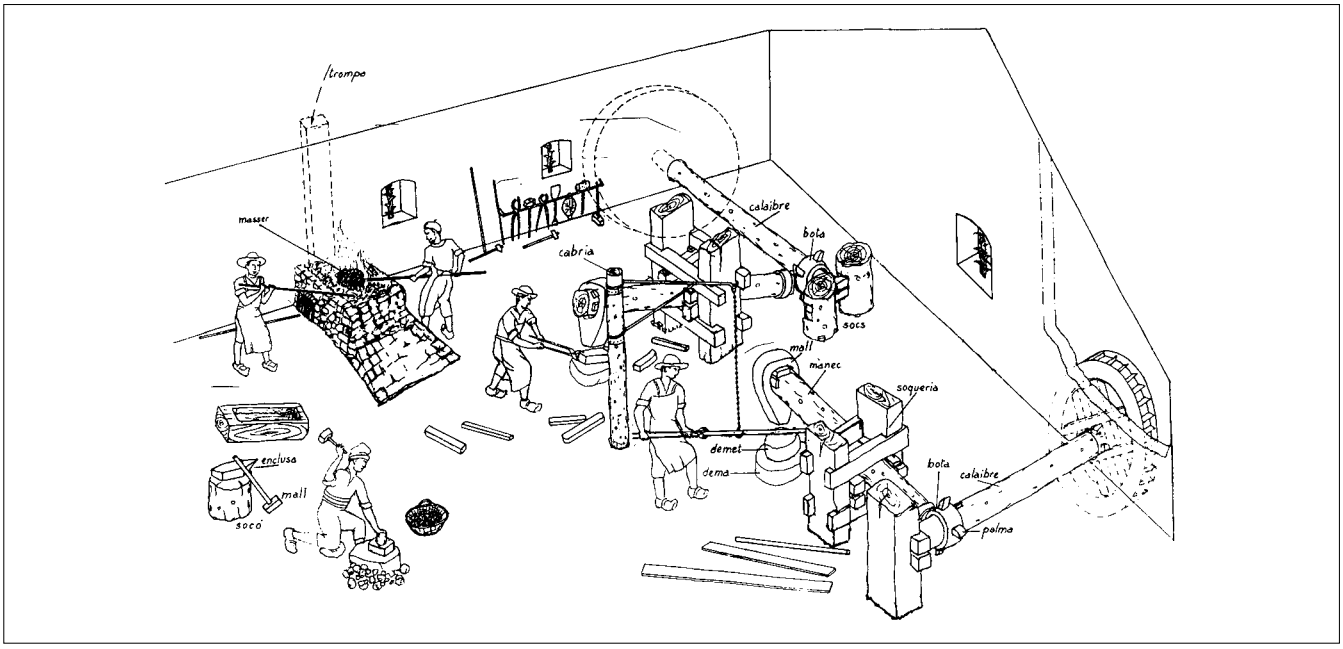
From the beginning of the Iron Age, in the second millennium before the Christian era, iron was obtained from ores using the bloomery process, which comprised the following stages:

a) Introduction of the crushed mineral and charcoal into a cavity or low furnace.
b) Combustion of the charcoal, aided by a strong air current to reach sufficiently high temperatures (around 1200ºC) and production of a high-reduction gas (CO).
c) Progressive reduction of the mineral using the reducing gas, which produced a solid yet spongy lump of iron and liquid slag that had to be separated from the metal.
d) Compacting and purifying of the bloom through hammering and the subsequent shaping of it by smithy work.

The skills and innovative spirit of the people who carried out these operations resulted in changes to them over the course of centuries. Innovations in the system affected the shape, dimensions and construction materials used to build the furnaces, the way of filling them with ore and charcoal, the procedure used for adding air, the way and point in time of separating the slag, etc. These changes progressively improved the productivity of the system and the quality of the end product.

Iron-making technology spread from the Middle East to Central and Western Europe, and at some point in time difficult to determine, it made its way to the eastern Pyrenees, where iron ore was abundant. The route of its arrival may have been by land (through ancient Gaul) or by sea, by sailors from the eastern Mediterranean (Phoenicians or Greeks) who not only brought their goods to the Iberian Peninsula, but also brought their technology with them.



Reproduction ideal of a "farga". Of the book "Fargues" by J. Mateu.

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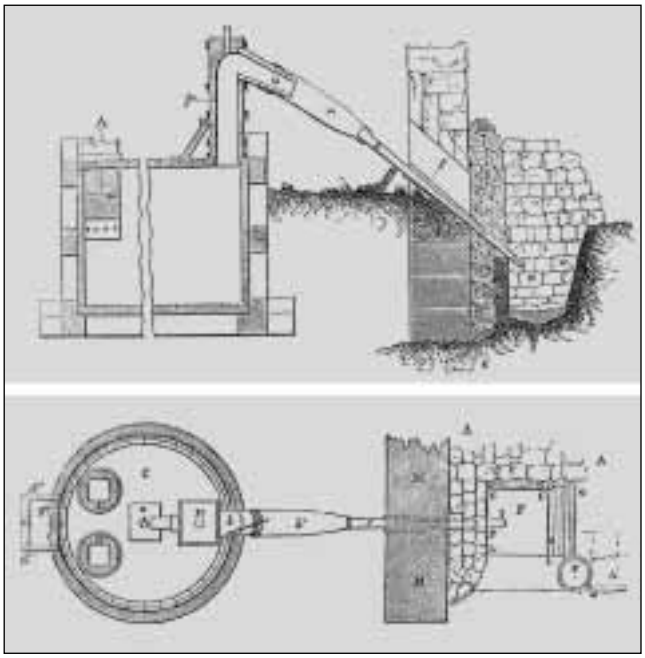


"Wind box" and furnace of a "farga" of the Pyrenees. By Richard, 19th century.

Significant remains exist of iron ore extraction and production in Catalonia dating back to Iberian and Roman times. Large accumulations of slag, the by-product of iron ore reduction, can be found in the Canigó mountains and other parts of the Pyrenees. These slag deposits include ones that date back to the beginning of the Christian era. Some authors consider the eastern Pyrenees to have been a major iron-producing centre since Roman times.

A wealth of documents refer to the iron-making establishments in Catalonia during the Middle Ages, which suggests the iron industry was already an important part of the local economy. The remains of some of these production sites have been identified. The term *farga*, used to describe the sites where iron was obtained and processed, appears in documents dating back to medieval times. The terms *fàbrega* and *fabregada* are also found. But there is no reference to the way work was carried out in the *fargues* of the period.

It was also during the Middle Ages (12th century) that hydraulic power was first used to drive hammers in the *fargues*. This highly important technological improvement led to the disappearance of the *fargues* in mine entrances, very often located in hard-to-reach mountainous regions, forcing them to move near watercourses. During this period the expression *molina ferri* began to appear in documents, in reference to the use of water-powered wheels. Catalonia appears to have been a pioneer in the use of this new technology.

Through ups and downs, iron has continued ever since to be manufactured in Catalonia, especially in the Pyrenees region. Iron-making flourished in the 16th century, with a large number of reducing plants and workshops where iron products were processed. The Jesuit priest Pere Gil offers testimony to this in a manuscript dating from 1600, where he ponders the mining and iron industries of Catalonia. He refers especially to the Pyrenees region and the Roussillon, and highlights the importance of iron exports to Valencia, Castille, the islands of the western Mediterranean and the coastal regions of France and Italy. Other documents speak of frequent exports of Catalan iron from the regions of Conflent and Vallespir, sent by sea to Genoa, Marseilles and other locations (N. Sales, 1984).

Although references to the technology used continued to be scarce, it is known that around 1600 the furnaces changed shape from being circular or oval to square. The hydraulic *trompe*, introduced in the 17th century (a few decades after its invention in Italy), was used to obtain pressurised air for combustion. The *trompe* consisted of one or more tubes through which water was channelled by gravity. The water absorbed the air through holes in the tube, due to the Venturi effect. The air was separated from the water in a receptacle, called the «wind box», and was sent by adjustable pressure to the furnace nozzle. The *trompe* became one of the characteristic elements of what became known as the «Catalan method».

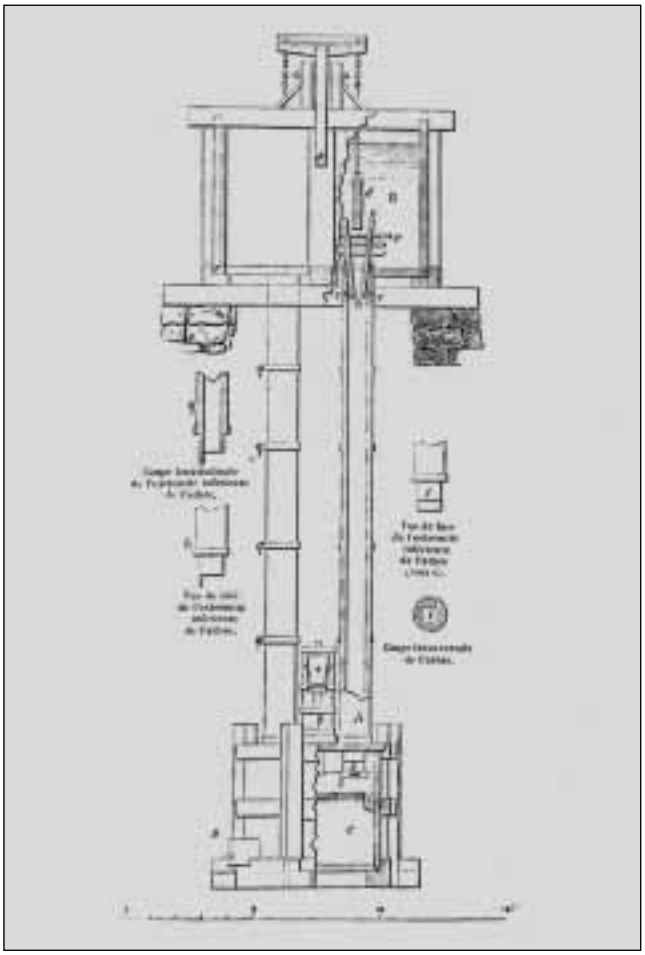
Fargues and iron makers were very active in the 17th and 18th centuries, although the industry declined during the 19th century. Meanwhile, from the 14th century (or possibly even earlier), the indirect system for reducing iron ore was developed in different regions of Europe. This system, based on the use of blast furnaces, reached higher temperatures and produced iron in liquid state. However, this iron had a very high carbon content and, after solidifying, rendered a product (pig iron) that was too brittle and could not be wrought. It had to be subjected to a second treatment known as refining (in liquid state and in an oxidising atmosphere) in order to reduce the carbon and obtain malleable iron. The end product of this indirect method was obtained in two stages.

As refining methods were perfected, the indirect system began to replace the direct one. The low-furnace method was no longer able to compete against the blast furnace with the advent in the mid-19th century of the Siemens-Martin furnace and the Bessemer converter. By the end of the 19th century all the *fargues* had been shut down.

Nevertheless, it was precisely in the years leading up to its disappearance, in the mid-19th century, that the work of the *fargues*, having archieved its maximum degree of perfection, was thoroughly studied and described by French mining engineers who supervised the mines and metalwork operations in the northern Pyrenees. The fullest descriptions, by T. Richard and J. François, were based on observations made in Roussillon, and above all in the Ariège region. The title of François' work (1843) is quite explicit: «Research into the deposits and direct treatment of iron ores in the Pyrenees, and particularly in the Ariège».

According to these descriptions, the furnace used in the *fargues* was a low bloomery with a square bottom and inverted tapered-pyramid shape. It was relatively small (measuring some 60cm on its side). It was made of stone and the inner walls were lined with iron slabs. One of the walls had a workable opening through which the liquid slag could be removed.

For injecting air, the furnace had a single nozzle located



A “trompe de l’Ariège” (Pyrenees). By Richard, 19th century.

at a specific height and inclination. A *trompe* was used to obtain airflow at the proper pressure.

The furnace was charged in a particular way as well, with the crushed ore being introduced into the part opposite the nozzle and the charcoal added from the nozzle side. The pressure (and hence the airflow) was varied at different times during the process, and the slag was removed periodically. Powdered mineral, charcoal and water were added periodically as well on the nozzle side.

The solid iron bloom obtained from the lower part of the furnace weighed some 150kg and could be composed according to choice of very soft, malleable iron («common iron») or steel («good iron»). The bloom was transported to the hammers (driven by hydraulically powered wheels) and hammered to compact it and remove any residual slag.

The construction materials, work methods and yields obtained were described in painstaking detail by the French authors mentioned above.

Appearance and dissemination of the expression Catalan forge

The descriptions by the French specialists were adopted universally by technical literature under the names «Catalan forge», «Catalan method» and «Catalan hearth».

The expression «Catalan forge» could already be found in French texts dating from the 18th century. One of the first to use the term «Catalan» was Tronson de Coudray in 1775 (J. Canteloube, 1993). However, it would come as no surprise if it were discovered to have been used previously in colloquial language.

There is evidence that the *fargues* in Ariège studied in the 19th century were called «Biscayne forges» before being renamed «Catalan forges», and that the workers in the County of Foix were originally from Biscay (Basque Country). It appears this migration of Biscayne workers came to an end in the late 16th or early 17th century. It has been said that they were replaced by Catalan workers, and it would not be farfetched to suppose they brought with them some technological innovation in the reduction process, thus giving rise to the name change.

Indeed, the work method at the *fargues* in Catalonia were very similar to those used in most of Western Europe, including the regions of Ariège, Aude, Haute Garônne, Corsica, Liguria, Aragon, the Basque Country, Navarre, Cantabria, Asturias, and El Bierzo. One author goes so far as to claim the Catalan method was the original, and that other methods were offshoots: the Biscay method, the Navarre method, the Italian method (M.H. Landrin, 1859).

The specific terminology used in the process is also quite similar, despite the language differences of the various regions. For instance, the names used for the walls and other elements of the furnace (such as *porgues*, *piec del foc*, *contravent*, *cava*, *lleiterol*, or *restanca*) are practically the same in Catalonia, Castile and France (R. Uriarte, 1993).

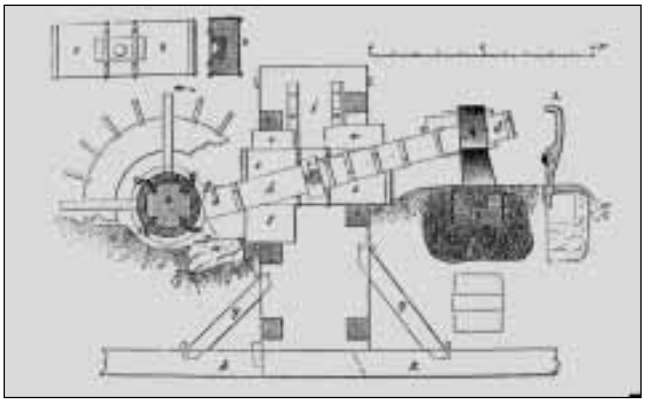
The Catalan term *farga*, however, was not used in Spain or France. Yet, in certain regions like Aveyron (Languedoc, France), place-names that derive from the term *fàbrega* abound: La Fabrègue, Fabreguèttes, Les Fabres, Le Fabrégal (G. Gavignaud, 1977).

It appears, therefore, that the method used in the regions mentioned had a common origin, or at least important technology exchanges were made through skilled workers travelling from one iron-making region to another.

References to the Catalan method are also frequent in texts which deal with iron production in the countries we have mentioned. We will now take a look at some examples.

In Cantabria, an 1866 text tells of the existence of 6 «forjas a la catalana» (Catalan-style forges). Another text, dating from 1872, states that *a ferrería* (iron maker) in Ramales had «a hammer used in the old Catalan system and a *martinete*, with air being supplied by two *trompes*».

In the El Bierzo, region of north-western Spain, the system used by iron makers during the modern era would be the Basque version of the Catalan forge, i.e. using bellows operated by hydraulically-driven wheels instead of the characteristic *trompe* used by the Catalan method, which was not introduced in the region until the 19th century (J.A. Balboa de Paz, 1992). A 19th-century *ferrería* is preserved in good condition in the town of Compludo. Equipped with a *trompe*, it is identical to a Catalan *farga*.



Hammer of a “farga”. By Richard, 19th century

J. Percy (1865) speaks of the Catalan forges in Liguria, Italy, some of which applied a system for recovering lost heat. The same author, discussing the Catalan process, comments: «This procedure received its name from Catalonia, a province of northern Spain, where it was probably introduced for the first time in Western Europe».

Veronique Izard (1994), who studied the iron-making industry of the western Pyrenees in detail, accepts the Catalan origin of the *fargues* in Ariège when she states: «The inhabitants of Ariège copied the procedure from the Catalans and found it to be more advantageous to increase the size of the furnaces».

Germans also studied the *fargues* of the northern Pyrenees. In the *Mining and Metallurgy Archive* published by Dr. E.J.B. Karsten in 1825 (volume 9), the *fargues* were called «Katalonischen Frischhütten». Volume 8 of this publication contained the results of tests conducted with the *trompes* of the furnaces in Vicdessos (Ariège). Other events also point to the fact that the Germans studied and applied the *trompe*.

After all we have said, we will now try to explain why the expressions «Catalan forge» and «Catalan method» were accepted and became famous. We can summarise it in the following points:

a) The eastern Pyrenees had abundant stores of iron ore whose characteristics made it well suited to reduction using the direct system. Hence the implementation since long ago of an iron-making industry in the region, which thrived throughout the Roman Empire and the Middle, Modern and Contemporary Ages, continuing up until very recently. This tradition, in an area that comprised a large part of the Catalan territory, facilitated the accumulation of know-how favourable to the progress of the work methods used to reduce iron ore.
b) Catalonia was one of the pioneers in applying some of the technological advances that made the system progress, e.g. the application of water power to drive the hammers and the use of the *trompe*.
c) In the Modern Age, a cottage industry arose around the *fargues*. The iron was transformed and the products (nails, weapons, etc.), of remarkable quality, achieved wide renown.
d) The movement of skilled labour between the different countries of Western Europe probably led to the transfer of some of the characteristics of the method used in Catalonia to other iron-producing regions whose inhabitants would have considered them to be important innovations and recalled their Catalan origin.
e) It was a source of prestige that in the latter part of its history, the Catalan method was able to compete successfully against the progressive use of the indirect method (blast furnaces) and continued to be used through to the end of the 19th century.
f) The Catalan method was one of the few processes that was explained in detail in written documents (A. Espelund, 1989). This led it to be included in scientific literature, becoming a paradigm of the direct system of obtaining iron and a necessary point of reference in metallurgical treatises. There are reproductions of *fargues* or parts of them in museums situated not only in towns and cities within the Catalan sphere (Colliure, Villefranche de Conflent, Ripoll), but also in major capitals such as London and Paris.

Head of a hammer of a “farga” in Andorra.

Slag of "farga" of Vall Ferrera (Pyrenees).

Possible implementation of the Catalan forge in the Americas

Many American historians speak of the *Catalan forge* or *Catalan hearth* when they refer to the first iron-making establishments of the New World, where iron was unknown to the natives when the European colonisers (Spaniards, Portuguese, British and French) arrived.

It is clear that the first plants to be built in both North and South America used the direct method. However, further research is necessary to determine whether or not these were true *fargues*.

According to Brazilian historians, the first iron furnaces in the Americas were built by Alfonso Sardinha in the State of São Paulo, Brazil, in 1597. Sardinha took advantage of the iron-making know-how acquired by his father in the Iberian Peninsula. The furnaces were set up near the magnetite deposits of Araçoiaba (an Indian term that means «the place where the sun hides»), where the Royal Iron Factory of Ipanema was subsequently founded. The historian Jesuino Felicissimo (1969) does not hesitate to assert that the furnaces were «catalao» or «rustico» and his description of them is based on 19th-century studies and drawings by François in the Pyrenees. Obviously, such a description is not valid when applied to forges built in the 16th century. Remains of these forges have survived, but it is impossible to know what they looked like or how they worked. One cannot, however, discard the possibility that they resembled the *fargues* of the period used in the Pyrenees.

There is also evidence of the use in Brazil of Italian and African forges, the latter built with technology provided by black slaves.

In the early 19th century, the German Baron of Eschwege built German versions of the Catalan furnaces in Cogonhas (Minas Gerais, Brazil) (Monteiro Salazar, 1996). They were

Remains of the bloomery built by Alfonso Sardinha, the 1597 in Araçoiaba (Brasil).

equipped with *trompes* like the Catalan versions, but the shape of the furnaces was different (F. Toussaint, 1988). Also during the 19th century, the Frenchman Monlevade set up an iron-making plant following the Catalan system, although using the «Ariège variant».

In Venezuela there were *fargues* in the Orinoco, the remains of which are still standing (O. Dam, 1993). Apparently, the Catalan Capuchin monks used a Catalan forge in Santa Rosa de Upate around the year 1743. The Capuchin archives of Barcelona speak of «15 forges and *fargues*» in Venezuela in 1842 (F.R. Morral, 1993).

We will now turn to the possible *fargues* found in North America.

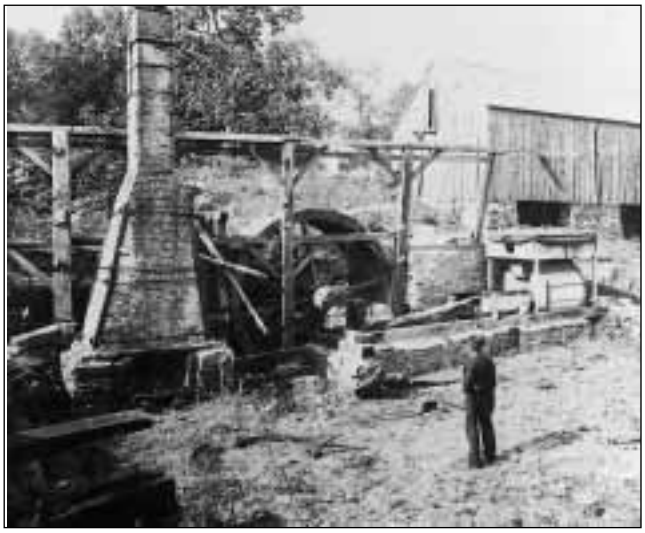
Authors have spoken of the existence of Catalan forges in Mexico during the colonial period, but in the 19th century the iron-making facilities were called *ferrerías* (M. Bargalló, 1955), which evoke a contribution by workers from the north of Spain, where the term *ferrería* was used.

There were direct iron ore reduction plants in many states of the United States, primarily in Mississippi, Tennessee, North Carolina, South Carolina, New York, and New Jersey. In addition, most of the colonies had their own forges to meet their local needs (Gordon, 1992). Historians have made frequent references to the Catalan method when speaking of such plants.

The Scandinavian author Akerman wrote in 1868: «The Catalan procedure is in use in the states of New York and New Jersey.»

According to J.M. Swank (1892), there were German-type «Catalan forges» in operation in New Jersey from 1710, many of which had *trompes*.

In Adirondacks, New York, there were 32 bloomery forges operating in the mid-19th century. These forges had a heat-recovery system that increased their output. This improvement appears to have been introduced around 1850. The heat-exchange unit was placed on top of a square-based low furnace like those of the *fargues*. One of these forges in the Adirondacks, located in the town of Split Rock, was built



Windham forge in New Jersey. The brick stack encased the iron pipe of the heat exchanger that preheated the air blast. Photograph taken in 1892 and published in "Archeomaterials" in 1992.

in 1825 and is considered to be representative of the most primitive form of the iron-making process used in the region (Ross F. Allen et al, 1991). This facility did not have the heat-exchange system, and it used the *trompe* that was characteristic of the Catalan forge instead of a mechanical pump. In other words, this forge is what appears to best resemble a *farga*.

However, specialists in early American iron making assure that these forges operated according to the «American procedure». T. Sterry Hunt (1869) has suggested this American procedure was the heir to the German bloomery system, and was developed thanks to the metallurgical experience of 18th-century German immigrants rather than the first British colonisers. Hunt refers to the German bloomery described by Karsten in 1816 and states that the way the furnace is charged is different from the method used in the Catalan forge.

It is true that if the British colonists had introduced the low bloomery to North America, they would have built it with a round plan, like those developed in Britain, which «were still being commissioned as late as 1636 in the more remote parts of The British Isles» (R.F. Tylecote, 1992). This author, Tylecote, when speaking of the Catalan forge, after noting that it has a square plan, states: «This type of plant only went out of use in the early years of the 19th century in Europe, and perhaps rather later in the northern parts of New York State.» This would seem to confirm the existence of some kind of relationship between the Adirondacks furnaces and the Catalan forge.

In Mission San Juan de Capistrano, California, excavations have uncovered the existence of two furnaces dating back to circa 1790 which, according to Magalousis and MacLeod (1993), were probably used to produce iron. Between the two furnaces there are water channels that appear to have had the purpose of driving the *trompes*. The furnaces, however, have a circular plan and are very wide. They do not resemble the furnaces of the *fargues*. That said, the use of the *trompe* and the fact that Gaspar de Portolà's expedition, which included a Catalan volunteer corps, arrived in California in 1765 (several years before the estimated construction of the furnaces), makes the existence of some type of Catalan influence in their construction seem plausible.

According to André Bérubé, in 1734, for a very brief period, a «bloomery» or «Catalan hearth» operated at the Forges de Saint-Maurice in Quebec, Canada. Bérubé claims the hearth resembled the forges used in Vermont and New York in the mid-19th century. The author illustrates these forges with a drawing that evokes a *farga* furnace.

Professors Gordon and Kilick (1992) believe American authors adopted the term «Catalan forge» in the mid-19th century to describe any type of bloomery, causing a great deal of confusion. Indeed, various interpretations exist with regard to the origin and evolution of iron ore reduction methods in America.

The following conclusions can be drawn in relation to the implementation of the Catalan forge in the Americas:

- Few remains exist throughout the Americas of the older iron ore direct-reduction furnaces. Relatively descriptions of the technology used are also scant and incomplete. It is true that in many cases the presence of the *trompe*, characteristic of the Catalan forge, is noted.
- The heyday of colonisation of the Americas coincided with the flourishing of the *fargues* in Europe.
- It is true that any direct-reduction method is often described as the «Catalan method». Nevertheless, in addition to Catalan origin, texts written by American historians speak also of Biscayne, Italian and African origin, Catalan-German version and Catalan-Ariège version. In other words, there was always an awareness that several different technologies were in use, and that the Catalan method was an important point of reference amongst them.
- There was a consistency in some places (Venezuela, California) between the presence of possible *fargues* and Catalan colonisers, amongst whom there may have been iron-reduction experts.
- There are references to the establishment of German or Catalan-German version bloomeries. In fact, German influence was not present during the early stages of colonisation. However, the Germans had studied the Catalan method and the Pyrenees *trompe*, and it is possible that when they reached the Americas, they took with them other elements of *farga* technology in addition to the *trompes*. In the United States, German technology seems to have represented an intermediate step between the Catalan method and the American method.
- It is evident that there are vast gaps in the history of iron and steel making in the Americas, especially during the colonial period. More in-depth study (documentary, archaeological, metallurgical, etc.) should provide a better understanding of the iron-reduction facilities in the

Americas and should allow the determination of whether they can be considered as derived, more or less directly, from an industry developed over many centuries in the eastern Pyrenees, primarily in the lands of Catalonia, which has come to be known as the Catalan method.

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