

# Literary Evidence for Crucible Steel in Medieval Spain

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*ABSTRACT: This work evaluates Andalusī Arabic (Hispano-Arabic) and Romance (early Castilian) literary evidence for the previously unknown use, working and production of crucible steel in medieval Spain between the 10th and the 13th centuries AD. No evidence has to date been presented indicating that the inhabitants of medieval Spain were producing or working, or even that they were familiar with, steels of crucible origin. In presenting the first evidence for this, the present paper significantly contributes to furthering our knowledge concerning early Islamic ferrous technology,*

## Introduction

The aim of this paper is to assess the evidence for crucible steel in medieval Spain, through the analysis of textual sources. Indications of iron and steel occasionally occur in the Andalusī Arabic and Romance literature, but to date no study has been aimed at investigating the metallurgical significance or general informative value of this evidence. The examination of particular terms and their contexts has now provided relevant information concerning the use, working and production of crucible steel, and at times additional details concerning working and/or production sites can also be derived. Frequently, however, the literary sources only confirm that there was familiarity with crucible steel in medieval Spain.

In the past, it appears to have been a general notion that knowledge and use of crucible steel existed in the early Islamic world as a whole. In fact there are still many Islamic regions that have not been submitted to in-depth study, so it cannot be taken for granted that all peoples under Muslim rule were familiar with—or were using—crucible steel.

At the outset, it is important to mention a number of speculative statements in relation to crucible steel in medieval Spain, which, up to the present, have been the only—and furthermore unsubstantiated—published material. A number of authors (*eg* Forbes 1957, 57; Calvo 1964, 53; Lombard 1971, 178; Glick 1979) have claimed that crucible steel was imported to, and used, worked and produced in Islamic Spain, without presenting any early literary or physical evidence in support. It was therefore necessary to examine primary, contemporary literary sources more closely for evidence for crucible steel.

The term ‘Indian’ in early literature will be discussed first; then written indications for crucible steel in Andalusī Arabic and Romance literary sources will be examined. The textual evidence is grouped together according to the nature of the information it provides.

## The Term ‘Indian’ in Early Literature

The Arabic term *al-hind* (Indian) and the interpretation of its significance are central to the present work. Earlier research has suggested that *al-hind*, and variants such as *muhammad*, *hindiyya*, and *hinduwānī*, referred to steel

(Yule and Cordier 1975, (I) 93). Bronson (1986) suggested that in certain contexts the term probably indicated steel of crucible origin, and Lang *et al* (1998, 11) stated that it was used by Islamic authors as synonymous with crucible steel. However, the significance of this term needs to be examined further, and therefore additional evidence in support of the view that it referred to crucible steel is presented here. A number of references provided by early Eastern authors add weight to this argument, and the analysis of the term's occurrence in the literary sources of medieval Spain also strengthens this idea.

Of significance is the passage by the 3rd-century AD Alexandrian alchemist Zosimos (trans Berthelot 1888, (III) 332). This is the earliest known piece of written evidence confirming that *Indian steel* was made in crucibles. Another formula for the making of *Indian steel* in crucibles is found in an undated Arabic manuscript fragment from Gotha (Rāghib and Fluzin 1997, 68). Al-Birūnī, who wrote in the 11th century, described the making of crucible steel in the following manner:

'As for the compound of *narmāhan* (*ie* bloomery iron, see Allan and Gilmour 2000, 555) and its water [cast iron], the latter being the first to become liquid in the purification process, it is *fūlādh*. The area of Ḥarāt is especially noted for *fūlādh*, and it is called *baīdat* ['eggs'] on account of its shape. These 'eggs' [ingots] are long and round-bottomed according to the shape of the crucibles [in which they are made] and from them *Indian swords* etc are fashioned' (trans Allan 1979, 75).

Al-Birūnī applies the word *fūlādh* when describing the steel produced. Furthermore, we note that the term *Indian* is mentioned in the context of crucible-steel making. The reference by al-Birūnī to the making of *Indian swords* indicates that *Indian* in this case does not imply the geographical origin of the swords, but rather that *fūlādh* was used in their manufacture. In another discussion concerning an *Indian sword*, al-Birūnī states that the use of the term *Indian* for the blade did not refer to its geographical origin, but instead that it described an 'essential characteristic of the weapon' (trans Sa'īd 1989, 214). It would seem probable that al-Birūnī was hinting at the material properties. If we bear in mind al-Birūnī's statement that *Indian swords* were made of *fūlādh*, and that *Indian steel* was made in crucibles with charges of varying composition, this most likely signifies that steel produced by a crucible process is suggested by the term *Indian*.

No earlier research has been aimed at determining the

metallurgical significance of the term *Indian* in Andalusī Arabic. In an attempt to translate an occurrence of the term *al-hind* in Andalusī literature, Vallvé Bermejo (1980, 213) stated that the 'Indian method' of steel-making consisted of 'repeatedly tempering and cooling the iron, until it acquired the hardness and hardening of steel'. Working from the conclusion that the term *Indian* referred to steel made by crucible processes, we shall examine relevant references to *Indian steel* in the Andalusī literature.

The term *fūlādh*, which occurs less frequently than *al-hind* in the Andalusī Arabic literature, has been identified by earlier research as referring to steel of crucible origin (Allan and Gilmour 2000, 555). Earlier authors (Dozy and Engelmann 1869; Casares 1915) have suggested that the Arabic term *al-hind* found its way into the medieval Castilian vocabulary as *alfinde*, *alhinde*, *alhynde* and *alinde*. Upon reflecting on the significance of this Arabism and its application in medieval Castilian literature, the common conclusion of these authors was that the term was intended exclusively to indicate 'steel' or 'steel from India', but without further explanation.

The first question to arise should be why this Arabic term should ever be used, if the plain significance was that of 'steel'. It is worth noting that the conventional medieval Castilian word for steel, *ie azero/açero*, was not used to describe *al-hind/Indian steel*. One would perhaps have expected the term *azero/açero* together with a reference to the geographical origin of the material, that is, India. Earlier research has concluded that Arabic terms were frequently incorporated into Castilian to describe crops, technology and materials introduced to the Peninsula from the Eastern Islamic world (Glick 1979). It is thus concluded here, that the Arabic term described a steel type for which there was no corresponding term in Castilian, *ie* crucible steel. The conclusion that *Indian* in the context of early Islamic ferrous metallurgy referred to crucible steel, drawn earlier in this section, further underlines this suggestion.

## References to Crucible Steel in the Andalusī, Arabic and Romance Literature

### *Evidence of familiarity with—and availability of—crucible steel*

The 10th-century Andalusī author Idrīs al-Yamānī writes that certain shields made of hardened leather were capable of withstanding, and even cracking, the purest *fūlādh* (trans Pérès 1990, 357). The fact that the writer

comments on the breaking of *fūlādhī* blades further indicates that these were known to be more fragile than other blades. This piece of text, however, only implies that knowledge of crucible steel and its properties existed in al-Andalus at this stage, and offers no further information.

At the end of the 11th century, Ibn al-Labbāna, a poet at the °Abbādid court of Mu°tamid at Seville, wrote a short poem on arms and armour. In this, a sword is referred to as being *Indian*, that is, *muhannad* (trans Pérès 1990, 355). The author appears to have had a thorough knowledge of weaponry and warfare, grouping offensive and defensive weapons together. This wording indicates that blades of Indian steel were known and used in al-Andalus at this stage.

The Almoravid warrior-poet Abū Bakr al-Şayrafī (al-Şayrafī, trans Pérès 1990, 358), who wrote at the beginning of the 12th century, provides us with some information concerning his view of the quality of Indian swords. After the Almoravids had lost a battle against the Christians, the writer gave advice on changes in tactics and weaponry that he thought appropriate. Among other things, he suggested that thin-bladed *hinduwānī* swords should be used, as these were able to pierce the heavy armour worn by the Christian soldiers more easily, and because they were sharper than other swords.

The agronomist Ibn al-°Awwām, who was active in Seville during the latter part of the 12th century (and possibly through to the beginning of the 13th century), confirms the familiarity with crucible steel in al-Andalus at this time. In his *Book of Agriculture* (*Kitāb al-Filāḥa*), he discusses remedies for curing wounded and sick animals. He mentions a number of surgical instruments and their manufacture in this manual, and recommends that one specific instrument should be made of *Indian steel* (*ḥadīd hindī*), as it had to be very sharp (Ibn al-°Awwām 1988, (II) 582). The instrument was intended for surgery close to the eye of the animal, a task calling for high precision, which again appears to indicate that Andalusī authors attributed high edge qualities to *Indian steel*. This reference to *Indian steel* indicates that the alloy was well-known, and then most probably available, in the area of Seville at this stage.

Writing in Naşrid Granada in the 14th century, the writer Ibn Hudhayl describes the differences between ‘Frankish’ blades and those made of *Indian steel*:

Si le deux marges du sabre sont en acier tandis que la lame elle-même est en fer, le sabre est dit *mudakkar*

(acéré) ce qui est le propre des sabres francs. Les Arabes affirment que leur fabrication est œuvre de génies: ils résistent mieux aux coups que l’on porte avec eux, même pendent la froidure, au lieu que le sabre *hindy* se brise fréquemment lorsqu’il fait froid et se montre meilleur quand il fait chaud (trans Mercier 1924, 231).

From this quotation we can deduce that Ibn Hudhayl had a certain degree of knowledge concerning the construction and qualities of different types of blades. He juxtaposes ‘Frankish’ and *Indian* (*hindī*) blades, comparing their different characteristics. This passage clearly describes two generic blade types, *ie* European-style iron-steel composites and those made of *al-hind*. Whether or not the latter blades were imports from India is not possible to derive from the wording.

The 14th-century Andalusī writer Ibn al-Khaṭīb confirms that mirrors manufactured from crucible steel were known in al-Andalus in his day. The author compared the appearance of the Granada sky one day with a mirror, saying: ‘When we arrived in Granada, the sky was polished like a double-edged sword, as clear as an *Indian* [*steel*] mirror (*mirāt al-hind*)’ (trans Dozy and Engelmann 1869, 142-3).

Romance literary sources furthermore confirm the familiarity with, and apparent availability of, crucible steel in Christian regions of Spain. *The Books of Astronomical Knowledge* (*Libros del Saber de Astronomia*) from c 1277, attributed to King Alfonso X, the Learned (ruling between 1252-1284), describe the making of astronomical instruments of different kinds, as well as their applications. The second book, which deals with the manufacture of astrolabes, was written by the learned Isaac b. Sīd of Toledo (who was also known as Rabiçag). When describing the making of spherical astrolabes, the author gives instructions of how, and with what tools, lines should be cut into the surface of the finished brass globe. The lines needed to be neatly cut into the metal surface of the sphere by means of a two-legged compass especially made for the purpose. Describing one of the legs of the compass, he says:

‘. . . This movable shank should be of steel (*açero*), or of *Indian steel* (*alfinde*), so that you can cut into the brass with it’ (Alfonso X 1863, 118; present author’s translation).

Further on in the treatise, the same author discusses the manufacture of another tool, which was also used to cut lines into astronomical instruments of brass:

‘. . . Take a rod of *Indian steel* (*alfinde*) or of steely/steeled iron (*fierro calçado con açero*), and make a very sharp point’ (Alfonso X 1863, 129; present author’s translation).

In the *Lapidary* (written *c* 1278), a work also commissioned for the Castilian King Alfonso X, additional explanatory remarks on *alhinde* are given during the discussion on the different qualities of metallic iron:

‘. . . There is iron to which, upon melting, medicaments are added by which it makes itself so strong [hard] that it cuts the other kinds of iron, and this the Moors call *alhinde*, and in some lands it is named *andanico*. . .’ (Alfonso X 1980, 27; present author’s translation).

As we see here it is attested in the *Lapidary* that *alhinde* is steel resulting from a secondary process, by the reference to certain substances that needed to be added to the iron during a liquefying operation. The same procedure can be found in texts by early Islamic authorities such as al-Kindī and al-Birūnī, describing crucible steel making (Allan 1979). It is significant that reference is made to the great hardness of this steel in the *Lapidary*, by stating that it cuts all other kinds of iron. Confirmation of the hardness of the material is given by Andalusī, Near- and Middle Eastern, and Castilian writings, as shown in the present paper. The Castilian treatise furthermore indicates that *andanico* is synonymous with *alfinde*, which means that the steel was known also by this term in medieval Spain. During his travels in Central Asia at the end of the 13th century, contemporary with the writing of the *Lapidary*, Marco Polo remarks on the *andanicum* produced in Kirmān (Iran) and Chingintalas, a region to the north of Tibet. Yule and Cordier argue that *andanicum* is a Latinisation of the Persian *hundwāni*, that is, Indian steel (Yule and Cordier 1975, (I) 93). This hypothesis seems perfectly applicable also for *andanico* in medieval Spain, as the Andalusī authors occasionally also used the variant *hinduwānī*. However, as we at present only know of the reference to *andanico* in the *Lapidary*, no further conclusions can be drawn about this term.

### *Recorded use of crucible steel*

The earliest known specific indication of *Indian steel* in al-Andalus (*ie*, Islamic Spain) shows its employment for war purposes at the end of the 10th century, as recorded by the 14th century Granadine historian Ibn al-Khaṭīb. He notes that during the attack on Barcelona in 985, the soldiers of al-Manṣūr, effective ruler of the

Córdoba Caliphate at the end of the 10th century, were equipped with armour pieces of *Indian steel* to protect themselves from the sword blows of their ‘Frankish’ [Catalan] adversaries (trans Millás Vallicrosa 1922, 160 and Vallvé Bermejo 1980, 213). Ibn al-Khaṭīb thus confirms that vambraces (armour pieces for the arms) were made of *al-hind*.

One may assume that the *Indian steel* vambraces worn by al-Manṣūr’s soldiers were produced in the workshops at Córdoba. During the reign of al-Manṣūr in the 10th century, there were two important workshops for the production of arms and armour at Córdoba and at Madinat al-Zahrā’, which was situated just outside the capital. These two industrial centres had to produce 13,000 shields and 12,000 bows altogether annually, the manufacture being split equally between the two. The monthly production of arrowheads reached 20,000 (Ibn al-Khaṭīb, trans Vallvé Bermejo 1980, 214). This extensive arms and armour production furthermore clearly reflects the war capacity of the Córdoba Caliphate.

The use of *Indian steel* in warfare is further confirmed in the 11th century, again applied by Muslims in an attack on Christian troops. In 1086, the Christian southward expansion caused the ‘Abbādid Amīr of the *Taifa* (Petty Kingdom) of Seville, Muṭamid, to ask the north Africa-based Yūsuf b. Tāshfīn and his Almoravid troops for help against the Christian King, Alfonso IV. Yūsuf first intervened with his main power, a bodyguard consisting of 4000 mounted black warriors, at the battle of al-Zallāqa, near Badajoz. Yūsuf’s bodyguard made use of Indian steel swords (*suyūf al-hind*) in this battle, together with shields and javelins (Ibn Khallikān, trans Hoffmann 1995, 243-8).

It seems likely that the weaponry was brought from Almoravid north Africa, as the troops were reported to have gone directly from there, through Algeciras in the south Peninsula, to the battle. The swords were thus brought over the Straits of Gibraltar, and it appears most likely that they also were manufactured in North Africa.

### *Documented working of crucible steel*

Ibn ʿAbdūn, a market inspector or *muḥtasib* working in early 12th-century Seville, provides us with a hitherto unknown term most probably used to describe cast [crucible] steel, while discussing qualities of material that according to law had to be used by the Sevillian steel-tool makers. In his *ḥisba*, that is, reference manual for market inspectors, he states:

‘The knifemakers are to be instructed: . . . that in the manufacture of scissors, knives, scythes and other similar tools, they may use only steely/steeled iron (*mudhakkār*), or otherwise, *‘amal al-ṭarā’ih* (Ibn ‘Abdūn 1955, 59:10-14; present author’s translation).

Ibn ‘Abdūn specifies that either steely/steeled iron or another type of ferrous material, that is, *‘amal al-ṭarā’ih*, had to be used by the Sevillian steel-tool manufacturers. The only earlier suggestion as to the translation of the expression *‘amal al-ṭarā’ih*, is ‘pieces of cast iron’ (Corriente 1997, 327). However, even though it is possible that cast-iron technology existed in Spain in the 12th century, there is at present no evidence to prove the production or use of the material in this area. Furthermore, despite the use of malleable cast iron tools and weapons in Ancient China from c 400 BC (Wagner 1993, 338; Rostoker 1987, 145-8), we have no knowledge of whether or not this technology was used in Islamic Spain, or indeed anywhere outside China.

We shall instead suggest another interpretation of the term. *‘Amal* is the noun derived from the Arabic verb ‘to work’ and ‘to make’. The word *ṭarā’ih*, stems from the verb ‘to throw’ and ‘to cast’. Directly translated, thus, *‘amal al-ṭarā’ih* would mean ‘cast work’, hereby probably indicating a smelting/melting process by which the metal had been brought to a liquid state. The existence of the related term *ṭarḥa*, meaning ‘mould’ (Goitein 1967-93, (I) 367), would also support this hypothesis. As the description concerns an iron-carbon alloy suitable for the manufacture of edged tools, and excluding the very small possibility that the term refers to malleable cast iron, it is suggested here that in the context of Andalusī ferrous metallurgy, *‘amal al-ṭarā’ih* refers to cast steel, *ie* steel most likely produced by a crucible process.

We can in consequence also note that Ibn ‘Abdūn does not use the terms *al-hind* or *fūlādh* to describe cast steel, but only refers to the manufacturing process. This appears to be an indication as to the degree of knowledge of the Andalusī market inspectors concerning materials and manufacturing techniques.

### *Written evidence for the production of crucible steel*

So far we have only dealt with literary evidence for the knowledge, use and availability of crucible steel in medieval Spain. However, we also have the opportunity to examine previously unidentified early written indications for its indigenous production in al-Andalus.

It is not until the mid- to late 12th century that we have written evidence of crucible-steel production in the area under discussion. A passage relating to Seville in the geographical treatise (*Kitāb al-Ja‘rāfiyya*) by the Andalusī author al-Zuhrī, reads as follows:

‘This city produces *Indian steel* (*al-hind*), and the mineral used to make the *Indian steel* is taken from a mine close to the city’ (al-Zuhrī 1968, 218; present author’s translation).

This piece of evidence is important in the discussion of indigenous production of crucible steel in al-Andalus, as it is the first indication for its existence there. Al-Zuhrī describes neither any primary smelting operation(s) nor a secondary (crucible) steelmaking process, which may indicate that he did not have the interest or knowledge to describe how production was undertaken. However, his remark that the ore used in the production of *Indian steel* came from a mine close to the city implies that the alloy was produced—and not just worked here. He uses the specific term (*al-hind*) for this alloy, while in other parts of the treatise he generally applies the generic term for iron and its alloys, *ḥadīd*, when referring to iron and steel produced in the Peninsula.

The Andalusī writer Ibn Sa‘īd referred to Sevillian crucible steel during the first half of the 13th century with the term *fūlādh*, describing it as being of excellent quality (Ibn Sa‘īd, copied by al-Maqqarī 1949, (I) 202; present author’s translation). Ibn Sa‘īd did not mention the use of Sevillian *fūlādh* in the manufacture of objects, and therefore it seems plausible to assume that he alluded primarily to the production of the raw material. The fact that al-Zuhrī mentioned the production of crucible steel in Seville about 50 years earlier would add weight to this argument. When describing another steelworking site, Murcia, Ibn Sa‘īd used the generic term for iron and its alloys (*ie*, *ḥadīd*), when clearly referring to edged steel weapons and edged steel tools. This may indicate that Sevillian *fūlādh* was of higher quality, or that the alloy was only produced at this locality. When the Christian King Ferdinand III of Castile took the city in 1248, the event marked the peak of Castilian expansion, and at present we cannot be certain whether or not the manufacture and/or working of crucible steel continued after the Christian conquest.

We have hitherto not been aware of any early Castilian written evidence for the production of crucible steel in Islamic Spain. The passage we shall now examine is thus the first known Romance reference to indigenous production of crucible steel in al-Andalus, and it is

therefore of great significance to the discussion in this paper. A part of the work *The Miracles of Saint Domingo of Silos*, a Castilian text written at the end the 13th century by the friar Pero Marín (d c 1293), treats the misfortune of a certain Domingo Bono in the year 1285. This Christian was captured by a band of slave-traders and sold in Ronda (between Málaga and Gibraltar), and brought to Ceuta (now Spanish territory on the North African coast bordering Morocco), where he had to work as a slave for a Muslim master. The passage is clear and detailed. Pero Marín records Domingo Bono's fate after having arrived at Ceuta as follows:

'He [Domingo Bono] was put in strong irons [by the 'Moors'], and at daytime he made *Indian steel* (*alhynde*), which is of such importance for warring, being a very strong [hard] kind of steel from which they forge swords and javelins. At night-time he was kept in quarters deep underground' (Marín 1988, 136-7; present author's translation).

The passage indicates that actual production of *Indian steel* took place in southern al-Andalus. It can also be noted that the steel produced at this locality was destined for the manufacture of weapons, but regrettably the text gives no indication as to whether this was also carried out in Ceuta. The wording '*Indian steel* . . . being a very strong kind of steel from which they forge swords and javelins', is evidently an allusion to the fact that the 'Moors' made and worked this material. We can observe that this information is confirmed by the *Lapidary* of Alfonso X, referred to above, indicating that Christians did not produce the material, at least not at this time. It is, however, important to stress that the Christians were aware of the qualities of this 'very strong steel'; even though its production may have been exclusively in the hands of Muslim steelmakers.

## Conclusion

The discussion in the present paper has yielded new and relevant literary evidence for crucible steel in the early Islamic world. Based on the examination of Andalusī Arabic and Romance literary evidence undertaken here, it is for the first time possible to conclude that crucible steel was used, worked and produced in medieval Spain.

Crucible steel was used in Islamic Spain from at least the late 10th century, but there are no known textual indications as to its working and production prior to the 12th century. The Andalusī Arabic and Romance written sources evaluated here pinpoint two localities for crucible-steel production in southern al-Andalus during the 12th- and 13th centuries, that is, Seville and Ceuta.

Crucible steel may, however, have been worked and produced elsewhere in al-Andalus at other times in the Islamic period.

This paper has identified additional Arabic, Andalusī Arabic and Romance written sources supporting the suggestion put forward by earlier research that the term 'Indian' denoted crucible steel. Furthermore, it is suggested that the previously unknown meaning of the Andalusī Arabic term, '*amal al-ṭarā'ih*', is cast [crucible] steel.

One may expect to find examples of crucible steel in Spain, but to the knowledge of the present author no such evidence has yet been presented or discovered, nor has any survey been aimed at identifying or retrieving remains of crucible steel production in this area.

## Acknowledgement

The research for this paper has been financially supported by the Ministry of Education and Culture, Madrid, Spain.

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