THE ROLE OF METALLURGY IN THE HOLY QUR'ĀN: HISTORICAL CONTEXTS AND CONTEMPORARY SCIENTIFIC PERSPECTIVES

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Abstract

The Holy Qur'ān, revealed approximately 1400 years ago, encompasses teachings that extend beyond spiritual guidance to include insights into natural phenomena. This study investigates the Holy Qur'ān's perspectives on metallurgy, specifically focusing on iron extraction and steel production as described in Surah Al-Kahf. Through a descriptive-analytical qualitative approach and thematic analysis of verses 96 and 97, which detail the construction of a barrier using iron and molten copper, this research explores the metallurgical processes implied in the text. Surah Al-Kahf was chosen for its explicit references to iron and its applications, particularly in the narrative of Dhul-Qarnayn, offering a unique lens for examining ancient metallurgical knowledge. By comparing these Quranic descriptions with modern scientific understanding of iron smelting, alloying, and purification, the study reveals a remarkable alignment between the two. The findings suggest that the Holy Qur'ān references advanced metallurgical techniques,

such as the use of fluxes and alloying agents, which parallel contemporary practices in iron and steel production. This research not only highlights the Holy Qur'ān's scientific dimensions but also contributes to the broader discourse on the intersection of religious texts and scientific knowledge, demonstrating the potential for interdisciplinary dialogue between theology and materials science.

Keywords: *Holy Qur'ān, Surah Al-Kahf, metallurgy, Iron, metalling*

Introduction

The Holy Qur'ān revealed over 1400 years ago, contains numerous references to scientific phenomena that have intrigued researchers for centuries.[1] While primarily a source of spiritual guidance, it also alludes to natural phenomena and scientific concepts that have been subjects of extensive study and interpretation[2]. Among the various scientific fields hinted at in the Holy Qur'ān, metallurgy—specifically the mention of iron—holds a distinctive position.[3] Iron is referenced six times the Holy Qur'ān, underscoring its historical and scientific significance.[4] Surah Al-Hadid (57:25) states that iron was "sent down" from the heavens, aligning with modern scientific understanding that iron formed in stellar cores and reached Earth via meteorites.[5]

This study centers on Surah Al-Kahf, verses 96 and 97, which narrate the story of Dhul-Qarnayn, who constructed a barrier using iron and copper to protect a community from Gog and Magog.[6] These verses describe a process of filling the gap between two mountains with iron blocks, heating them until they glow red, and then pouring molten copper over them.[7] This depiction presents a fascinating metallurgical process that warrants examination from a contemporary scientific perspective.[8] The objective of this research is to analyze these verses and explore potential evidence of iron extraction, alloying, or other metallurgical techniques in light of modern scientific knowledge.[9] By dissecting the described process, we aim to understand its implications for metalworking methods and determine whether it reflects advanced knowledge for its time.[10]

The Holy Qur'ān's scientific references have been widely explored in existing literature, covering fields such as astronomy, biology, and physics.[11] However, in-depth analyses of its metallurgical allusions, particularly in the context of Surah Al-Kahf, remain scarce.[12] Moqaddasi *et al.* have proposed that the barrier comprises a metal matrix composite of iron and copper, exhibiting properties fully comprehensible only through modern metallurgical insights.[13] Despite such contributions, a gap persists in understanding the specific techniques and processes mentioned in these verses from

a contemporary scientific standpoint. This research seeks to bridge that gap by examining the verses through the lens of modern metallurgy, focusing on the use of iron and copper in the described method.

The metallurgical process outlined in Surah Al-Kahf is intriguing for its detailed sequence: stacking iron blocks, heating them to a red-hot state, and pouring molten copper atop them. In modern metallurgy, such a technique could suggest the creation of a bimetallic structure or composite, where iron provides strength and copper enhances corrosion resistance.[14] Historically, ironworking was known in the 7th century, particularly in regions like the Arabian Peninsula, but the specific combination of iron and molten copper described here is unusual for that era.[15] This raises questions about whether the process hints at advanced metallurgical knowledge predating its widespread recognition. To address this, our study interprets the Quranic description and compares it with current metallurgical practices.

Iron's significance in the Holy Qur'ān extends beyond Surah Al-Kahf. Surah Al-Hadid (57:25) not only mentions iron's celestial origin but also highlights its utility and strength, qualities critical to human civilization.[16] Modern science confirms that iron, formed through stellar nucleo-synthesis, was delivered to Earth via meteoritic impacts, a concept that resonates with the Quranic term انزلنا"*anzalna*" (sent down).[17] This intersection of divine text and scientific fact invites further exploration of other metallurgical references, such as the barrier in Surah Al-Kahf.[18] The process described—heating iron to a glowing state and coating it with copper—may imply a rudimentary form of cladding or alloying, techniques refined in later metallurgical advancements.[19] Such an interpretation could position the Quranic narrative as a precursor to sophisticated metalworking practices.[20]

The scarcity of detailed metallurgical analysis in Quranic scholarship motivates this study. While general works, such as Bucaille's exploration of science in the Holy Qur'ān, touch on natural phenomena, they rarely delve into metallurgy.[21] Moqaddasi *et al.* stand out by suggesting the barrier as a composite structure, yet their analysis lacks a comprehensive comparison with modern techniques.[22] This research builds on their foundation, offering a detailed examination of the process and its scientific plausibility.

The study aims to provide a detailed interpretation of the metallurgical process described in Surah Al-Kahf, verses 96 and 97, and analyze its relevance in light of contemporary metallurgical knowledge. By examining the Quranic description of stacking iron blocks, heating them until red-hot, and pouring molten copper atop

them, this research explores the potential scientific basis behind these methods. In modern metallurgy, such a technique suggests the creation of a bimetallic composite, where iron offers structural strength and copper enhances corrosion resistance. The specific combination of these materials in the Quranic narrative raises intriguing questions about whether this reflects an advanced understanding of metal properties, predating its widespread recognition in history. By bridging the gap between scriptural analysis and material science, this study not only contributes to Quranic exegesis but also fosters a broader interdisciplinary dialogue on the intersection of religious texts and scientific advancements.

Background, History, and Review of Literature

Numerous books, papers, and scientific interpretations have been written on this topic throughout the millennium. The Holy Qur'ān mentions several scientific breakthroughs that have only been made possible by advancements in technology, which is one of the features of the science of miracles found in the Holy Qur'ān.[23] The science of the twentieth century has been the only means of discovering many of the scientific facts that are mentioned in the Quranic verses in a very succinct, profound, and amazing way.[24] These scientific facts, which are based on the most recent scientific discoveries, could not have been known 1400 years ago when the Holy Qur'ān was revealed.[25] The Holy Qur'ān is a guidebook that points people in the direction of Allah Almighty, using a variety of methods of reasoning, wise counsel, polite debate, and scientific evidence that supports its teachings.[26] Below, we have presented research related to verses 96 and 97 of Surah Al-Kahf, which is the subject of our research, along with scientific research in various fields that examines various themes of the Holy Qur'ān and their relationship with modern scientific understanding.

1. Surah Al-Kahf

Surah Al Kahf has 110 Ayahs and is the 18th Surah in the Holy Qur'ān. It was revealed somewhere between the 8th and 10th year of Prophethood before the Hijrah/Migration to Madinah, at a time when the persecution of Muslims and Islam was at a peak. The Arabic word "*Kahf*" (كهف) means "The Cave," and this Surah emphasizes that Allah protects those who remain righteous and follow the correct path. Four narratives summarized in Surah Al-Kahf offer valuable wisdom and guidance for contemporary readers. Each story, including the accounts of the Companions of the Cave, the Man with Two Gardens, Prophet Musa's encounter with Khidr, and the parables of Dhul-Qarnayn, imparts profound lessons on faith, perseverance, and the intricate dynamics of power and justice. Surah Al-Kahf serves as a timeless reservoir of moral and spiritual insights,

encouraging believers to reflect on the deeper meanings embedded within these narratives. The narratives of Surah Al-Kahf in the Holy Qur'ān have significantly influenced the religious and socio-political landscape of north-west Nigeria.[27]

2. Dhu al-Qarnayn, the builder of the iron dam against Gog and Magog

The Holy Qur'ān refers to Dhu al-Qarnayn, often known as "the two-horned one," particularly in Surah Al-Kahf (Chapters 18:83–98) was a believer has ruled over the entire world.[28] Dhu al-Qarnayn is often regarded as a powerful and virtuous monarch known for his extensive travels and interactions with various ethnic groups and cultures. Scholars have debated the identity of Dhu al-Qarnayn; some propose that he may represent a historical figure, such as Cyrus the Great or Alexander the Great, while others interpret him as a mythical character symbolizing ideals of leadership and justice.[29] According to the Holy Qur'ān, Dhu al-Qarnayn undertook three significant campaigns: first to the west, then to the east, and finally to a region with a mountain pass. During his expeditions, he encountered and addressed the needs of various populations. His most significant achievement was constructing a wall to protect a community from the invasions of the notorious tribes, Gog and Magog, known for their destructiveness.[30]

The Holy Qur'ān mentions Gog and Magog, often referred to as *Yaʾjūj wa-Maʾjūj* (یاجوج و ماجوج) in Arabic, as two tribes that posed a serious threat to humanity.[31] In the documents of Quranic commentators, Gog and Magog are mentioned with the Mongols, who are sometimes called Turks or Tatars, or two peoples in the Old Testament with the names "Gog and Magog". Gog and Magog are portrayed as destructive, chaotic forces that wreak destruction.[32] Apocalyptic elements in the Bible and the Holy Qur'ān, among other religious writings, are linked to their emergence.[33] The Hebrew word "Gog" translates to "mountain." While many people believe that "Gog" refers to a title assigned to a leader, some interpretations suggest it denotes a nation. According to the first-century historian Josephus, "Magog" is a Hebrew term used during Ezekiel's time to refer to the Scythians, a group with a vast territory that extended as far as China. In Ezekiel 38:15, it is stated that "Magog" is located "in the far north."[34] According to the ancient world maps, Gog and Magog appear in the far northeastern part of Asia, west of the Caspian Sea surrounded by mountains and blocked at its south end by a wall, until the eighteenth century.[35]

In Islamic mythology, Gog and Magog stand for the greatest difficulties and tribulations that humanity will encounter; they

frequently symbolize despotism and moral decline.[36] Gog and Magog stand for chaos and devastation, while Dhu al-Qarnayn represents the principles of justice and leadership.[37]

3. *Dam made of iron and molten copper*

Using iron and molten copper, Dhu al-Qarnayn constructed an impressive barrier that is said to be impenetrable, demonstrating sophisticated technical abilities that some academics connect to prehistoric metallurgical understanding.[38] The Holy Qur'ān says that Dhu al-Qarnayn built a wall to keep Gog and Magog in control so they couldn't destroy the earth.[39] This wall is considered to be a stopgap solution because Islamic eschatology indicates that they would ultimately break free during the end times, causing a great deal of upheaval. The story of the Dhu al-Qarnayn, which resonates strongly with the Islamic worldview, highlights themes of protection, moral duty, and the ultimate victory of good over evil.[40]

Dhu al-Qarnayn constructed a massive dam using iron blocks, effectively filling the valley. Depending on the interpretation, the wall may have reached a height of approximately 1,800 meters. However, it is more plausible that he built the dam to a significant height between the towering valley walls, rather than the 1,800 meters suggested by some translations.[41] Iron has been the main construction material of the Dhu al-Qarnayn dam.[42] He requested pieces of iron, which he heated and then coated with molten copper to create a solid barrier. This method leveled the space between two mountain rocks, resulting in a remarkable and impregnable structure. This indicates that the dam is situated in an area abundant in iron mines.[43] It was said that this barrier was so strong that Gog and Magog could not climb or break through it.[44] This feature demonstrates the efficacy of the construction methods of Dhu al-Qarnayn, which included fusing copper and iron to strengthen the dam.[45] Protection from chaos and corruption, symbolized by Gog and Magog, is symbolized by the dam. Dhu al-Qarnayn's unwillingness to take payment in kind for constructing the dam highlights his altruism and dedication to the populace's well-being, providing an example of a leader who prioritizes service above self-interest.[46] The close connection of Dhu al-Qarnayn with Allah Almighty is demonstrated by his acknowledgment that divine backing was vital to the success of his activities.[47] He recognizes that the dam's building is a favour from his Lord and that it will ultimately be taken down when the time comes, symbolizing the transient nature of earthly walls that avert catastrophe. The strategically significant location of the dam is between two mountains. The location was presumably picked to optimize its efficacy against the dangers posed by Gog and Magog, who were wreaking havoc on the country with their rampant corruption.[48] Strong construction, impenetrability, symbolic defense

against disorder, dependence on divine assistance, and tactical geographic placement are the defining features of the Dhu al-Qarnayn Iron Dam and show how Dhu al-Qarnayn acted as a leader and defender during difficult times.[49]

4. Iron extraction and processing from ancient to modern times

Over millennia, iron extraction and processing have changed dramatically in response to advances in knowledge and technology.[50] Before 3000 BC, iron was first used in meteorites, which produced naturally occurring iron-nickel alloys.[51] Meteoric iron was used as early as 3500 BC, as evidenced by artifacts such as beads from Egypt. Bowl furnaces and stone-built shaft furnaces were used to recover iron from ores in areas like Anatolia and Persia circa 2000 BC.[52] The early methods of smelting iron resulted in a spongy mass known as a bloom because the furnaces could not achieve the temperatures required to completely melt iron.[26] Between 1200 and 500 BC, a period known as the Iron Age occurred when iron largely replaced bronze in tools and weaponry. During this time, iron production methods experienced tremendous breakthroughs, most notably the creation of wrought iron, which was made by heating and hammering blooms to remove impurities. Southern India started exporting wootz steel, a premium steel with a carbon concentration in between that of wrought iron and pig iron, around the fourth century BC. The fact that this steel was so highly valued and traded demonstrated the progress made in the area of metallurgy.[53]

The manufacturing of iron was further advanced in the medieval and early modern eras by several important innovations.[54] For example, the introduction of water-powered hammers in the 1100s increased the efficiency of forging iron bars, and the development of blast furnaces in 1709 allowed for the production of cast iron at higher temperatures.[55] Ultimately, the Industrial Revolution was sparked by Abraham Darby's successful substitution of coke for charcoal in the smelting of iron, which substantially reduced costs and increased production efficiency.[56] The manufacture of iron and steel underwent radical modifications during the Industrial Revolution and the contemporary age.[57] The Bessemer converter, created in 1856 by Henry Bessemer, revolutionized the production of steel and replaced wrought iron by forcing air through molten pig iron to eliminate impurities and produce mild steel. William Siemens created the regenerative open-hearth furnace in 1861, which made it possible to produce steel in a more regulated manner. Subsequent development of the fundamental oxygen process increased both quality and efficiency.[58] By the 1950s, new techniques such as direct reduction and smelting reduction had been developed, allowing for the manufacture of iron at lower temperatures and with alternative reducing agents, such as coal and natural gas, eliminating

the need for blast furnaces. From the utilization of meteoric iron to the development of advanced contemporary steelmaking techniques, the history of iron extraction is characterized by continuous innovation. Each phase was built upon previous discoveries, leading to the modern, highly productive, and diverse iron and steel industry.[59]

About 1400 years ago, the Holy Qur'ān in Surah Al-Kahf briefly mentions a modern technique for iron extraction and suggests a contemporary method to prevent mechanical and chemical corrosion of the wall constructed by Dhu al-Qarnayn, mentioned in verses 96 and 97 of Surah Al-Kahf. With inspiration from this verse, Althahban *et al*.[60] applied ancient techniques within a modern context and demonstrated that only composites created by preheating the steel rods to temperatures below the recrystallization temperature of steel (723°C) achieved optimal bonding between the copper matrix and the steel rod. The results of the microhardness test indicated that heating the steel rod to 600°C yielded the highest overall hardness value. By utilizing the step-by-step production method referenced in the Holy Qur'ān, the researchers enhanced the mechanical and tribological properties of the iron alloys.

Methodology

This study is descriptive-analytical qualitative research on thematical findings of verses 96 and 97 of Surah Al-Kahf in the Holy Qur'ān according to modern findings about the extraction of iron, alloying, and steelmaking of iron. Thematic analysis of words in this verse was performed according to several authoritative sources, including the Dehkhoda Dictionary[61], the Amid Dictionary[62], Al-Mufradat fi Gharib Al-Qur'ān by Ragheb Isfahani[63], Quranic verses from the translation by Mufti Taqi Usmani[64] and Qamus al-Qur'ān written by Seyyed Ali Akbar Qurashi.[65]

This study employs a qualitative thematic analysis to explore the metallurgical insights in Surah Al-Kahf (verses 96-97) and their connection to modern scientific principles. To ensure a comprehensive approach, we conducted an in-depth review of classical linguistic sources, including authoritative dictionaries and Quranic exegeses, to analyze key terms within their historical and semantic contexts. Additionally, scientific literature on metallurgy was examined to align the Quranic descriptions with modern processes such as smelting, heating, and alloying. A comparative analysis was performed to map these ancient descriptions to contemporary steelmaking techniques, while ensuring that anachronistic interpretations were avoided. To enhance scientific credibility, quantitative data related to iron properties and alloy formation was incorporated.

Results and Discussion

1. Extraction of iron, alloying, and steelmaking of iron in Light of Quranic verses

Verses 96 and 97 of Surah Al-Kahf in the Holy Qur'ān state the story of Dhul Al-Qarnayn and the construction of a vast barrier made of iron and copper alloy (brass) against Gog and Magog. This depiction highlights the utilization of iron in ancient construction practices, shedding light on the remarkable advancements in metallurgy during that era, as if it were inscribed. Below we have explained these two verses.

آتُونِي زُبَرَ الْحَدِيدِ ۖ حَتَّىٰ إِذَا سَاوَىٰ بَيْنَ الصَّدَفَيْنِ قَالَ انفُخُوا ۖ حَتَّىٰ إِذَا جَعَلَهُ نَارًا قَالَ آتُونِي أُفْرِغْ عَلَيْهِ قِطْرًا ﴿٩٦﴾ فَمَا اسْطَاعُوا أَن يَظْهَرُوهُ وَمَا اسْتَطَاعُوا لَهُ نَقْبًا ﴿٩٧﴾

Translation[66]*:*

Bring me big pieces of iron.. (They proceeded accordingly) until when he leveled up (the gap) between the two cliffs, he said, .Blow.. (They complied) until when he made it (like) fire, he said, .Bring me molten copper, and I will pour it upon this (96) So they (Ya'juj and Ma'juj) were not able to climb it, nor were they able to make a hole in it. (97)

The term "زُبَرَ " refers to pieces, and "الْحَدِيدِ" means iron. It can be implied that "زُبَرَ الْحَدِيدِ " denotes the crushed pieces of iron ore (such as hematite and magnetite), which are the initial material required for iron purification. Here, even the prominence of crushing iron ore at the beginning of the iron purification process is emphasized by the term "زُبَرَ " Iron ore is found in nature as the minerals magnetite ($Fe2O_4$), hematite (Fe_2O_3), goethite (FeO (OH)), limonite (FeO (OH).$_n$(H_2O)), and siderite ($FeCO_3$).[67] Among these minerals, hematite, and magnetite are more important due to the higher percentage of iron. Utilizing crushed iron ore to increase the surface area enhances the efficiency of chemical reactions, thereby improving the refining processes of iron.[68] Also, smaller ore fragments reduce smelting time and improve energy efficiency and production capacity.[69] Using smaller pieces of iron ore improves the separation of particles to remove impurities through magnetic separation and flotation.[70] In addition, due to the reduced volume, it facilitates easier transportation, ultimately improving overall efficiency and reducing production costs.[71]

Middle and straight path "سَاوَىٰ", might refer to a precise location in the middle of two mountains, which could be a flat and smooth area, perhaps situated between two mountain peaks.

Similarly, "الصَّدَفَيْنِ", the edge and foothills of a mountain, refers to the surroundings of the mountains and the area adjacent to them. Therefore, these two words together can convey the spatial concept of being between two mountains. Today, the routine method for extraction of Iron is iron smelting in a huge industrial fireplace called a blast furnace (Figure 1).

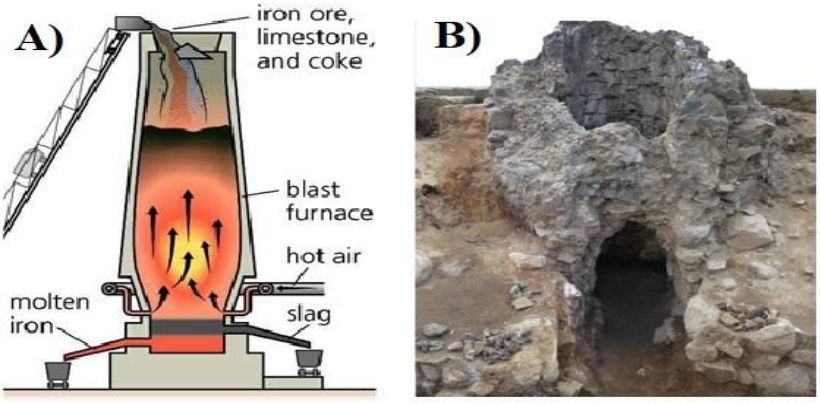

Figure 1. A) A diagram of the blast furnace in the iron-making industry. B) Ancient furnaces made of stone and clay.[72]

We can imagine that the furnace itself is a kind of space between two mountains, where these two mountains may represent the two sidewalls or lateral sections of the furnace. This furnace is likely constructed at a very tall height, which this height could be understood as a sort of flat surface between two mountains. In ancient times, iron smelting furnaces were usually constructed using stones and soil.[73] Therefore, we can assume that iron ore pieces and other raw materials are placed between the two mountains (or two sidewalls) of the furnace, which could be described as being between two mountains "سَاوٰى بَيْنَ الصَّدَفَيْنِ". Therefore, the concept of the iron smelting furnace as a location between two mountains, filled with raw materials such as iron ore pieces, and constructed using stones and soil, could be logical considering the meanings of the words used in the verse.

According to the root of the word "الصَّدَفَيْنِ" which is derived from the word "صدف", we can refer to the hard shell of all mollusk animals, including bivalves and gastropods that have an external cover[74]. These animals have one or two hard calcareous shells made of calcium carbonate and chitin that cover their soft bodies. According to the primary components of the shells of all mollusks, the term "الصَّدَفَيْنِ" may refer to the use of lime or calcium carbonate in steel production processes. Lime is one of the raw materials used in the steel production process.[75] Lime serves as a source of calcium to purify molten iron and eliminate pollutants.

Consequently, the term "الصَّدَفَيْنِ" may refer to the role of minerals, such as lime, in the steel production process. This implies that the mountains, which resemble iron smelting furnaces, contain limestone and calcium carbonate. Calcium carbonate, with the chemical formula $CaCO_3$, is a non-organic compound commonly found as limestone and plays a pivotal role in steelmaking processes. It serves as a cleansing and temperature-regulating agent in steel furnaces. Firstly, as a cleansing agent, calcium carbonate decomposes at high temperatures in blast furnaces or electric furnaces, turning it into calcium oxide. This calcium oxide reacts with silicates and other impurities in the iron melt, forming slag that separates impurities like silicon, phosphorus, and sulfur from the raw iron, thereby enhancing steel quality. Secondly, calcium carbonate, by regulating furnace temperature and slag chemistry, optimizes the steelmaking process and improves the final steel quality.[76]

If we consider "ساوٰی" to mean equalizing two mountain slopes, it implies filling the area between two mountains with iron ore so that it becomes abundant with iron ore from the base of the mountains to near their peaks. This suggests the filling of the iron smelting furnace with iron ore, as this action is crucial for optimal performance in the iron smelting process.

When refining iron, filling the furnace with iron ore up to the edge of the furnace is essential for optimal operation. This practice ensures efficient heat transfer throughout the entire charge and promotes the uniform reduction of iron ore to metallic iron. Additionally, maintaining a full furnace helps stabilize the thermal conditions inside the furnace, preventing temperature fluctuations that could disrupt the reduction process.[77]

The term "انفُخُوا" is in the verse, meaning to blow warm air or oxygen, which indicates the process of oxygenation with hot air of 1200 degrees Celsius in a blast furnace as a key stage in the iron refining process to transform iron ore from solid to liquid state.[78] Oxygen plays a vital role in the iron refining, particularly in methods such as oxygen steelmaking or electric arc furnace steelmaking. Oxygen combines with the fuel (usually coal or wood) and accelerates the combustion reaction, thereby increasing the temperature of the furnace. Oxygen also interacts with impurities present in the molten iron, facilitating the production of high-purity steel. The Bessemer process, one of the earliest steel production techniques, involves blowing oxygen through molten iron. Through these reactions, oxygen helps remove unwanted elements like carbon, silicon, phosphorus, and sulfur, transforming them into gases such as carbon dioxide and silicon and phosphorus oxides, which are either eliminated from the melt or separated as slag.[79] Historically, iron

refining took place in furnaces with manual bellows, which supplied air to the furnace. These bellows, operated by hand or foot, provided additional oxygen to the combustion environment.[80] This increased oxygen supply enhances the combustion process, generating sufficient heat for iron melting. Consequently, iron separates from its ore, forming molten metal that can be cast into various shapes once cooled.[81] This process is not only vital for the production of pure iron but has also enabled significant advancements in engineering and technology throughout history.[82] The ability to produce iron and steel with the required mechanical properties has been fundamental to the development of civilizations and progress in construction, tools, and even military industries.[83]

According to the meaning of " نَارًا" (it means fiery), the phrase "جَعَلَهُ نَارًا: he had made it (red) as fire" can refer to the smelting process using fire until the red melted Iron ore appears. This process as a critical technique in extractive metallurgy is employed for extracting various metals, including silver, iron, copper, and other base metals from ores. Metals are melted in a container known as a crucible, which is selected based on the melting temperature of each metal. With the application of high heat and the addition of chemical-reducing agents, the ore is decomposed, and other elements are separated as gas or slag, leaving the base metal behind. Thus, the use of the word " نَارًا: fiery " might refer to the smelting temperature of iron which is (1200 degrees Celsius), at which the iron ore transitions from solid to liquid state. This stage is crucial for separating iron from its impurities. To make a fire, a fuel such as wood is needed to generate high heat for the melting of Iron ore. Today, coke is used for iron refining and steelmaking processes and acts as a carbon source to react with oxygen in iron oxides and produce pure molten iron. Without coke, the iron refining and steelmaking process would not be efficient and of adequate quality. In ancient times, the process of steel production was typically carried out using carbon-based furnaces or bloomeries. In bloomeries, iron ore and charcoal as a carbon source were placed in a furnace to provide the necessary carbon for reacting with iron oxides. The resulting steel was typically utilized in the form of ingots as final products. Although this process was simple and rudimentary, over time, with technological advancements, more complex and superior methods for steel production were developed.[84]

The term "أُفْرِغْ" in Arabic grammar is an imperative verb meaning "pour," while "عَلَيْهِ" means "on it," and "قِطْرًا" refers to molten copper or molten metal. "أُفْرِغْ عَلَيْهِ قِطْرًا" (Pour molten copper onto it) may imply adding other metals to produce alloys with desired properties. As mentioned, "قِطْرًا" refers to molten copper or zinc. However, molten zinc is mostly used in metal coating processes to

prevent corrosion of iron and steel. Galvanization is one of the most recognized examples of using molten zinc, where steel or iron components are immersed to create a protective layer. This protective layer prevents oxygen and moisture from reaching the metal surface corrosion. Coating steel with zinc and copper are two common methods in various industries, each with its characteristics and applications. Zinc coating, due to its high resistance to corrosion and rust, is suitable for parts exposed to specific environmental conditions such as marine environments or chemical industries. In addition to environmental resistance, this coating also has good electrical conductivity properties and is used for electrical components. On the other hand, copper coating steel, considering the anti-corrosion and electrical conductivity properties of copper, is used to prevent corrosion and increase electrical conductivity in metal components. Additionally, as a decorative coating, copper coating on steel is used inside buildings to enhance the beauty and strength of components. The choice between these two types of coatings depends on the specific requirements and conditions of use.[85]

When iron rusts and oxidizes, its surface deteriorates, leading to a reduction in its volume. This process, known as rusting or corrosion, can eventually result in the formation of holes and the degradation of the metal. To prevent surface corrosion, metal coating or making alloys with some metals is useful. Here, molten iron or molten copper was used for coating iron.

Ductility refers to the property of a material that allows it to undergo stretching or changing its shape, without fracturing, and to retain the altered shape once the external forces are removed. Consequently, it represents the ability of materials, such as copper, to be permanently deformed without breaking.[86] By the ductility properties of copper, the iron-copper alloy has more toughness than iron and copper alone. Since copper is more resistant to the 'thermal heat affected zone' than iron, the dam is also thermally impermeable.[87] Copper, as a semi-stable metal, does not react with water. However, it does undergo a slow reaction with atmospheric oxygen, forming a protective layer of brown-black copper oxide. This layer shields the underlying metal from further corrosion, in contrast to the rust that develops on iron in moist air.[88] Using copper in the structure of Dhu al-Qarnayn's Dam makes it thermodynamically and kinetically durable in a corrosive environment. In verse 97 of Surah Al-Kahf, the term "نَقْباً" (hole) can be interpreted, based on the explanations above, as referring to iron rusting and corrosion. Therefore, verse 97 can be related to the discussion of producing stainless alloys and creating strong steel, which formed a solid barrier that no one could penetrate or destroy.

In essence, these two verses vividly portray the intricate process of iron refinement through strong imagery and explicit commands, indicating not only technical knowledge but also the need for great skill and precision. This reflects a profound understanding of the technological processes used for metal production and processing at that time. The purification and utilization of iron in ancient times signify a high level of knowledge and expertise in metallurgical technologies. This verse not only touches upon the historical and mythological aspects of the story of Dhu al-Qarnayn but also echoes the technical knowledge regarding the extraction, refinement, and application of metals in engineering structures, which remains significant to this day. This fundamental principle was mentioned in the Holy Qur'ān over 1400 years ago.

Conclusion

This study has explored the Quranic perspectives on iron extraction, alloying, and steelmaking through a detailed thematic analysis of verses 96 and 97 of Surah Al-Kahf. The research demonstrates that these verses, describing Dhu al-Qarnayn's construction of an iron barrier, contain terminology that strikingly parallels modern metallurgical processes. Specifically, the phrase "زُبَرَ الْحَدِيدِ" (crushed iron ore) aligns with the initial step of crushing ore to enhance smelting efficiency, while " سَاوٰى بَيْنَ الصَّدَفَيْنِ" (filling between two mountains) suggests a furnace-like structure. The command "انْفُخُوا" (blow air) corresponds to oxygenation in blast furnaces, "جَعَلَهُ نَارًا" (made it fiery) reflects the high-temperature smelting process, and "أُفْرِغْ عَلَيْهِ قِطْرًا" (pour molten metal) indicates alloying or coating to improve durability, such as with copper to prevent corrosion. These linguistic interpretations, grounded in authoritative sources like the *Dehkhoda* and *Amid* dictionaries, reveal a sophisticated understanding of metallurgy embedded within the Holy Qur'ān, revealed over 1400 years ago.

The significance of these findings lies in their demonstration of the Holy Qur'ān's advanced scientific foresight, bridging ancient textual descriptions with contemporary materials science. By elucidating the metallurgical knowledge within these verses, this study not only enhances our appreciation of the Holy Qur'ān's scientific dimensions but also underscores its timeless relevance as a source of inspiration for technological inquiry. However, the interpretations rely heavily on linguistic and thematic analysis, which may vary among scholars due to differing exegetical approaches. Additionally, the historical metallurgical capabilities at the time of revelation remain underexplored,

presenting a potential limitation that warrants further investigation.

Looking forward, future research could extend this analysis to other scientific phenomena in the Holy Qur'ān, such as the properties of different metals or natural processes, or investigate the metallurgical practices prevalent in the Arabian Peninsula and surrounding regions during the 7th century to contextualize these findings historically. Such studies could further solidify the correlation between Quranic descriptions and scientific principles. Ultimately, this work contributes to both religious and scientific discourse by fostering interdisciplinary dialogue between theology and materials science. It offers a unique perspective on the natural world, affirming the Holy Qur'ān's capacity to harmonize ancient wisdom with modern knowledge and encouraging a deeper exploration of its multifaceted teachings.

Declarations

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3. Conflict of interest

The authors declare no conflict of interest.

Notes and References

[1] Ali Moghaddasi, "Why the Dhul-Qarnayn's Dam is Impenetrable? A Chemical and Physical Study," *Journal of Interdisciplinary Quranic Studies* 1 (2022): 71-82; Motahareh Soltani et al., "Olive Improves Eyesight: A Study of the Quranic Evidence and Literature," *International Journal of Early Childhood* 14 (2022): 4158-4163.

[2] Maurice Bucaille and Alastair D. Pannell, *The Bible, the Qur'an, and Science: The Holy Scriptures Examined in the Light of Modern Knowledge* (2003); Motahareh Soltani et al., "The Holy Qur'an's Five Plants resemble Five Sensory Receptors in the Microscopic Appearance: An analysis," *Hamdard Islamicus*, Pakistan, 46:1 (2023).

[3] Moore Kl, *The Developing Human: Clinically Oriented Embryology* (1988): 279-280.

[4] Melanie Guénon, "ʿAbd al-Majīd al-Zindānī's iʿjāz ʿilmī Approach: Embryonic Development in Q. 23: 12–14 as a Scientific Miracle," *Journal of Quranic Studies* 21 (2019): 32-56.

[5] Edward Lipiński, *The Aramaeans: Their Ancient History, Culture, Religion* (Peeters Publishers, 2000).
[6] Al-Tabari, *The History of Al-Tabarī* (State University of New York Press, 1985).
[7] Muḥammad ibn Aḥmad Qurṭubī, *Tafsīr Al-Qurṭubī: The General Judgments of the Qur'an and Classification of What It Contains of the Sunnah and Āyahs of Discrimination* (Diwan Press, 2018).
[8] Ismail Ibn Kathir, *Tafsîr Ibn Kathîr* (Dar-us-Salam, 2000).
[9] S Mousa et al., "Mechanical and Bond Behavior of an Advanced Quranic Metal-Matrix Composite Material (QMMC)," *International Manufacturing Science and Engineering Conference*, 2019, American Society of Mechanical Engineers.
[10] *Ibid.*
[11] Mohammad M. Haque and Ahmad Faris Ismail, "Engineering Materials and Manufacturing Processes from Quranic Perspective," *Advanced Materials Research* 83 (2010): 834-841.
[12] S Mousa, et al. *Mechanical and Bond Behavior… op.cit*
[13] Ali Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit.*, 71-82.
[14] *Ibid.*
[15] *Ibid.*
[16] Attahir Shehu Mainiyo, "Impact of Quranic Narratives in Surah al-Kahf on the Life of Muslims in North-West, Nigeria," *Al-Risalah: Jurnal Studi Agama dan Pemikiran Islam* 14 (2023): 299-315.
[17] Lipiński, The Aramaeans, *op.cit.*
[18] *Ibid.*
[19] *Ibid.*
[20] Putri Zulaikha, "Kajian Kitab Tafsir Marah Labid Syeikh Nawawi Al-Bantani," *AT-TAKLIM: Jurnal Pendidikan Multidisiplin* 2 (2025): 215-140.
[21] Bucaille and Pannell, *The Bible, the Qur'an,….op.cit*.
[22] Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit.*
[23] Ziauddin Sardar, Explorations in Islamic science (Mansell, 1989).
[24] *Ibid.*
[25] Abolqasem Bagheri, Fariborz Hosseinjanzadeh, and Mohammad Shaygan Mehr, "The Consideration of Physics and Chemistry Sciences in the Holy Quran," *Journal of Applied Environmental and Biological Sciences* 4 (2015): 260-265.
[26] Ebrahim Azarpour, Maral Moraditochaee, and Hamid Reza Bozorgi, "Transliteration Quranic Plants in Verses of the Holy Quran," *Advances in Environmental Biology* (2015): 121-131.
[27] Mainiyo, "Impact of Quranic Narratives …. *Op.cit.*
[28] Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit*
[29] Scott D. Westrem, "Against Gog and Magog," in *Text and Territory: Geographical Imagination in the European Middle Ages* (1998): 54-75; Abdella Yimam Ali, "Dhul Qarnain, Abyssinia (Ethiopia) and The People of Ād."; Moghaddasi, "Dhul-Qarnayn's Dam," 71–82.
[30] Westrem, "Against Gog and Magog…*op.cit.*; Ali, "Dhul Qarnain…,*op.cit.*
[31] Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit*
[32] *Ibid.*
[33] *Ibid.*
[34] Adam Silverstein, "Enclosed Beyond Alexander's Barrier: On the Comparative Study of ʿ Abbāsid Culture," *Journal of the American Oriental Society* 134 (2014): 287-306.
[35] Andrew Gow, "Gog and Magog on Mappaemundi and Early Printed World Maps: Orientalizing Ethnography in the Apocalyptic Tradition," *Journal of Early Modern History* 2 (1998): 61-88.
[36] Nicholas M. Railton, "Gog and Magog: The History of a Symbol," *Evangelical Quarterly: An International Review of Bible and Theology* 75 (2003): 23-43.
[37] *Ibid.*
[38] Ali, "Dhul Qarnain and Abyssinia." …*op.cit*
[39] Railton, "Gog and Magog… *op.cit*

[40] Silverstein, “Alexander's Barrier,” 287–306; Railton, “Gog and Magog: History of a Symbol,” 23–43.
[41] Aymen Labidi, "The Holy Quran Revelation: Copper and Its Astonishing Benefits for Humankind from a Chemical Perspective," (2021); Moghaddasi, “Dhul-Qarnayn's Dam,” 71–82.
[42] *Ibid.*
[43] Labidi, “Copper in the Quran.”; Moghaddasi, “Dhul-Qarnayn's Dam,” 71–82.
[44] *Ibid.*
[45] Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit.*
[46] *Ibid.*
[47] Moghaddasi, "Why the Dhul-Qarnayn's dam… *op.cit.*; Labidi, " Copper in the Quran …*op.cit.*
[48] Labidi, “Copper in the Quran.”..
[49] *Ibid.*
[50] Ian McNeil, *An Encyclopedia of the History of Technology* (Routledge, 2002).
[51] Amelia Carolina Sparavigna, "Meteoric Iron in Ancient Egyptian and Chinese Cultures, from Pyramids to Circumpolar Stars," *Available at SSRN* 4113311 (2024).
[52] Jana Siegelová and Hidetoshi Tsumoto, "Metals and Metallurgy in Hittite Anatolia," *Insights into Hittite History and Archaeology* (2011): 275-300; Andrea Squitieri, "Stone Vessels in the Near East during the Iron Age and the Persian Period: (c. 1200-330 BCE)," (2017).
[53] Jana Siegelová and Hidetoshi Tsumoto, "Metals and Metallurgy in Hittite Anatolia," *Insights into Hittite History and Archaeology* (2011): 275-300; Andrea Squitieri, "Stone Vessels in the Near East during the Iron Age and the Persian Period: (c. 1200-330 BCE)," (2017).
[54] Jeroen De Beer and Jeroen de Beer, "Future Technologies for Energy-Efficient Iron and Steel Making," in *Potential for Industrial Energy-Efficiency Improvement in the Long Term* (2000): 93-166.
[55] PJ Mackey, *Oxygen in Non-Ferrous Metallurgical Processes Past, Present and Future* (Elsevier, 1987).
[56] Lee T Wyatt III, *The Industrial Revolution* (Bloomsbury Publishing USA, 2008).
[57] BS Russell, "British Steel Industry, The," *J. World Trade L.* 2 (1968): 243.
[58] Basil Turner, "Siemens' Open Hearth Steel Furnace," *Journal and Abstract of Proceedings of the Sydney University Engineering Society* 5 (2000).
[59] Thomas Battle et al., *The Direct Reduction of Iron* (Elsevier, 2024).
[60] Sultan Althahban et al., "The Effect of Reinforcement Preheating Temperatures on Tribological Behavior of Advanced Quranic Metal-Matrix Composites (QMMC)," *Materials* 15 (2022): 659.
[61] Mohammadali M Shoja et al., "Herbal Diuretics in Medieval Persian and Arabic Medicine," *The Journal of Alternative and Complementary Medicine* 21 (2015): 309-320.
[62] Hassan Amid, *Amid Dictionary* (Tehran: Sika Publications, 2010).
[63] Ragheb Isfahani and Hussein Ibn Muhammad, *al-Mufradat fi Gharib al-Quran* (Safwan Adnan Davoodi, Beirut, Dar Al-Alam Al-Shamiya, 1992).
[64] Mufti Muhammad Taqi Usmani, *The Noble Quran: Meaning with Explanatory Notes* (Turath Publishing, 2020).
[65] Sayyid Ali Akbar Qurashi, *Qamus al Qur'an*, vol. 5 (Islamic Library, 2001).
[66] Mufti Muhammad Taqi Usmani, The Noble Quran…*op.cit.*, 18:96-97.
[67] Ahindra Ghosh and Amit Chatterjee, *Iron Making and Steelmaking: Theory and Practice* (PHI Learning Pvt. Ltd., 2008).
[68] David C. Yang, *Reagents in Iron Ore Processing* (Routledge, 2018).
[69] Ghosh and Chatterjee, *Iron Making and Steelmaking*.
[70] *Ibid.*
[71] *Ibid.*
[72] Haifeng Liu et al., "Cast Iron-Smelting Furnace Materials in Imperial China: Macro-Observation and Microscopic Study," *Journal of Archaeological Science* 86 (2017): 50-59.
[73] *Ibid.*

[74] Antonio G. Checa, "Physical and Biological Determinants of the Fabrication of Molluscan Shell Microstructures," *Frontiers in Marine Science* 5 (2018): 353.
[75] *Ibid.*
[76] Ghosh and Chatterjee, *Iron Making and Steelmaking*.
[77] *Ibid.*
[78] Sicong Tian et al., "Inherent Potential of Steelmaking to Contribute to Decarbonisation Targets via Industrial Carbon Capture and Storage," *Nature Communications* 9 (2018): 4422.
[79] Ghosh and Chatterjee, *Iron Making and Steelmaking*.
[80] Algirdas Vaclovas Valiulis, *A History of Materials and Technologies Development* (VGTU Leidykla „Technika", 2014).
[81] *Ibid.*
[82] *Ibid.*
[83] *Ibid.*
[84] *Ibid.*
[85] *Ibid.*
[86] Moghaddasi, "Dhul-Qarnayn's Dam," 71–82.
[87] *Ibid.*
[88] Ji Eun Lee, Hyun Dong Lee, and Gi Eun Kim, "The Effect of Corrosion Inhibitor on Corrosion Control of Copper Pipe and Green Water Problem," *Environmental Engineering Research* 17 (2012): 17-25.