

METALLURGY IN THE BIBLE: IRONWORKING AND THE DISPOSAL OF THE GOLDEN CALF

SUSAN V. MESCHEL

INTRODUCTION

In this article we will examine two questions in the Bible in light of the science of metallurgy: when the Israelites acquired the ability to work iron, and how the Golden Calf was destroyed.

IRONWORKING DESCRIBED IN THE BIBLE

The ability to forge iron and to make tools and weapons was a sign of technical development in ancient society. Metalworking in the earlier books of the Bible deals with manufacturing objects from silver, gold, and copper, which have relatively low melting points and are therefore much simpler to fashion than iron artifacts. Silver, gold and copper have melting points of 1064° C, 962° C and 1085° C, respectively.¹ As opposed to these relatively low melting metals, iron melts at 1538° C, thus requiring a considerably higher temperature to be fashioned into implements. The temperature needed to melt copper or bronze (bronze is 90% copper and 10% tin) could be reached in the ancient furnaces through the use of bellows, which provided the necessary forced draft of air to facilitate combustion.² The production of iron implements was possible only with the development of carburized iron (0.8% carbon) and the progress in quenching and tempering technology.³ Current chemical analyses are able to show if the iron in excavated artifacts was carburized and thus prove the level of technology. It is of some interest to see whether our ancestors possessed the technical know-how to produce their own plowshares, axes, spears, and other iron objects without the help of neighboring craftsmen.

The blacksmith was called *nappah* (user of bellows) or *pehami* (user of charcoal). These terms indicate that there was some activity involving smelting and the use of ovens, and that blacksmiths had some idea of the need for

Susan Meschel attended the Technical University in Budapest, Hungary. In 1957 she immigrated to the USA, where she continued to study chemistry at the University of Chicago (M.S., PhD). She taught both at the University of Chicago and at Roosevelt University and was involved in research in high temperature thermodynamics. She is currently Adjunct Professor at the Illinois Institute of Technology in the Materials Science Department.

blowing air to increase the temperature of their ovens. The Bible recognizes the significance of metalworking, noting that Tubal-cain was a craftsman of copper and iron (Gen. 4:22), one of only three early professions singled out in Genesis 4 (herdsman, musician, metalworker). The Bible also appreciates the value and importance of having ore deposits. Canaan is described as a *land whose rocks are iron and from whose hills you can mine copper* (Deut. 8:9). The Book of Job (28:1-6, 9-10) even describes the difficulties of the mining process.

Many of the citations of metalworking in the earlier books of the Bible refer to silversmiths or coppersmiths, for example:

His mother took two hundred shekels of silver and gave it to a smith. He made of it a sculptured image and a molten image (Judg. 17:4).

He was the son of a widow of the tribe of Naphtali and his father had been a Tyrian, a coppersmith. He was endowed with skill, ability, and talent for executing all work in bronze . . . now the pails, the scrapers, and the sprinkling bowls, all those vessels in the House of the Lord that Hiram made for King Solomon were of burnished bronze. The king had them cast in earthen molds, in the plain of the Jordan between Succoth and Zarethan (I Kgs. 7:14, 45-46).

The last two citations refer to a named person, Hiram of Tyre, who was invited to create copper or bronze objects for the Temple of King Solomon. They also prove that the Israelites were familiar with the sand casting method used for bronze. Working with iron was much more difficult, however, since its melting point was too high for the technique established for bronze objects. The prophet Samuel relates:

No smith was to be found in all the land of Israel, for the Philistines were afraid that the Hebrews would make swords or spears. So all the Israelites had to go down to the Philistines to have their plowshares, their mattocks, axes, and colters sharpened. The charge for sharpening was a pim for plowshares, mattocks, three-pronged forks and axes, and for setting the goads. Thus on the day of the battle, no sword or spear was to be found in the pos-

session of any of the troops with Saul and Jonathan; only Saul and Jonathan had them (I Sam. 13:19-22).

This indicates that the Israelites had to pay the Philistines to do their iron work for them at the time. It is not clear whether the Israelites lacked the technical expertise to forge iron or whether they had the knowledge but were prohibited by the Philistines to make use of it. However, if the Israelites took their farm implements to the Philistines for repair, they must have had such iron tools to begin with. Even so, there is no way of knowing if these tools were originally made by the Israelites or purchased from the surrounding nations.

King Uzziah of Judah (c. 785-734 BCE) provided his army with shields, spears, helmets, and mail (II Chron. 26:14), but the Bible does not say who produced these items. However, during the reign of Hezekiah (727-698 BCE), a major tunnel was cut through the rock to the Pool of Siloam (II Kgs. 20:20).⁴ The apocryphal Book of Ben Sira (175-200 BCE) refers to the tools used for this project: *Hezekiah fortified his city and brought water into the midst of it. He tunneled the sheer rock with iron and built pools for water* (Ben Sira 48:17).⁵ The construction of Hezekiah's tunnel indicates that the Israelites had by then acquired an expert knowledge of ironworking.

Isaiah the prophet confirms the activity of Hebrew ironsmiths in remarkably poetic detail: *The woodworker encourages the smith; he who flattens with the hammer encourages him who pounds the anvil. He says of the riveting, 'It is good!' and he fixes it with nails, that it may not topple* (Isa. 41:7). *The craftsman in iron, with his tools, works it over charcoal and fashions it by hammering, working with the strength of his arm* (Isa. 44:12). *It is I who created the smith to fan the charcoal fire and produce the tools for his work* (Isa. 54:16). This last citation clearly refers to the technique for producing carburized iron, forging and perhaps making wrought iron objects, with heat treating the metallic surface by means of a carbon source. If we accept the traditional date of Isaiah as the pre-Exilic era, we will have evidence of solid progress in ironworking by the seventh-eighth centuries BCE. However, many scholars attribute these passages to Deutero-Isaiah, dating from the sixth century BCE.

The prophet Ezekiel also gives a vivid description of the technology, with a moralistic tone: *The House of Israel has become dross [slag] to Me; they are*

all copper, tin, iron, and lead...As silver, copper, iron, lead, and tin are gathered into a crucible to blow the fire upon them, to melt them, so will I gather you in My fierce anger and cast you into the fire and melt you (Ezek. 22:18-22). This is, of course, a general description of pyro-technology, not specifically one of forging iron. Nevertheless, it is an impressive technical description.

The Bible famously compares Egypt to an iron crucible: *The Lord took and brought you out of Egypt, that iron blast furnace, to be His very own people* (Deut. 4:20); *I freed them from the land of Egypt, the iron crucible* (Jer. 11:4). Deuteronomy speaks of blowing air to increase the temperature of the blast furnace, which indicates some ability to produce iron implements, but this may refer to the technical capability of the Egyptians rather than that of the Israelites.

In the Book of Kings we read that Nebuchadnezzar deported thousands of skilled workers: *He exiled all of Jerusalem, all the commanders and all the warriors – ten thousand exiles – as well as all the smiths and artisans* (II Kgs. 24:14). The Hebrew term *harash* ("smith") is the same word used in I Samuel 13:19, where we are told: *No smith was to be found in all the land of Israel, for the Philistines were afraid that the Hebrews would make swords or spears*. Thus, by the time of the First Temple's destruction in 586 BCE, Jews had become familiar with the work of a blacksmith.

From this overview it remains unclear as to when the Israelites became skilled in ironworking. The early books of the Bible indicate that the Philistines were more skilled in the technique, but the Israelites may have acquired it by the time of Hezekiah and certainly by 586 BCE.⁶

THE DISPOSAL OF THE GOLDEN CALF

An extensive literature discusses the Golden Calf, which we read about in the Book of Exodus. The issues arising usually deal with the moral concerns and social development of the Israelites. My focus is on a scientific problem: How did the Israelites dispose of the statue?

The Book of Exodus describes the making of this idol: *And all the people took off the golden rings that were in their ears and brought them to Aaron. This he took from them and cast in a mold, and made it into a molten calf* (Ex. 32:3-4). The plain meaning of this text is that the Golden Calf was made

of cast gold. However, pure gold is too soft for the production of durable artifacts, copper-gold alloys being normally used in making jewelry. The percentage of gold in the alloy is reflected in the karat rating assigned. One gold alloy used in the biblical period was electrum, consisting of 50 percent gold and 50 percent silver.⁷ The jewelry that the Israelites gave to Aaron was probably gold alloy, and so too the Golden Calf.

How was the Golden Calf destroyed by Moses? Exodus and Deuteronomy describe the same process: *He took the calf that they had made and burned it; he ground it to powder and strewed it upon the water and so made the Israelites drink it* (Ex. 32:20). *As for that sinful thing you had made, the calf, I took it and put it to the fire; I broke it to bits and ground it thoroughly until it was fine as dust, and I threw its dust into the brook that comes down from the mountain* (Deut. 9:21).

The reference to burning the gold, as opposed to the more normative process of melting it, is puzzling. Furthermore, how was the burned metal ground into dust? These texts have been subject to different interpretations, most of which are not consistent with our modern scientific understanding.

Ibn Ezra (on Exodus 32:20) explains that the Golden Calf was melted down and a chemical was added to blacken and char the gold. This is what the Bible calls "burning" the gold. However, Ibn Ezra does not say which chemical was used. The whole purpose was to make the gold unusable and it was then reduced to a powder. This idea is also found in the commentary of Hizkuni. William Bird Herapath, a nineteenth-century scientist, also suggested that chemical methods were used, but with the effect of dissolving the gold, and he believed⁸ that aqua regia (a mixture of nitric and hydrochloric acid) was employed.⁸ There is no evidence, however, that the Israelites knew of such a reagent. The production of these acids synthetically is a twentieth-century development. According to another nineteenth-century hypothesis, the Golden Calf was fused with a mixture of potassium nitrate (niter) and sulfur, yielding a soluble compound.⁹ This is a more plausible idea, since KNO₃ (niter) and sulfur were known in the biblical period, and they could certainly fuse metals in furnaces.

Ibn Ezra further explains that once the gold had been chemically blackened, it was beaten into thin sheets and shredded, to make it seem pulverized. Thus, the Golden Calf was not really ground to dust but cut into shreds, or the

shreds were then reduced to powder.¹⁰ Radak explains that iron tools were used for this purpose.¹¹

Alternatively, the calf was not made of solid gold but of wood overlaid with beaten gold. When the wood burned, the gold would have melted into granules and these were scattered over the water. Abrabanel and Isaac Arama interpret Exodus 32:20 to mean that wooden objects used with the idol were burned, while the Golden Calf itself was ground to dust.

There is a further complication: gold powder would sink in the brook before the Israelites could drink it. Nahmanides, commenting on the same verse, writes that either the gold was ground so fine that it did float, or that only a little was thrown into the water at a time and the Israelites quickly drank it, or that the whole outcome was miraculous.

David Frankel, in his study of this question, hypothesizes that an ancient editorial or copyist's error occurred and suggests reversing the two parts of the previously cited verses (Ex 32:19-20),¹² as follows: *He became enraged and hurled the tablets from his hands and shattered them at the foot of the mountain; then he ground it to powder and strewed it upon the water and so made the Israelites drink it*, followed by *He took the calf that they had made and burned it*. In this reading of the text, it is not the gold that is pulverized and scattered over the water but the tablets. Assuming that the tablets were of limestone or marble, the process is technically quite reasonable. Limestone can be broken and powdered without the use of any sophisticated equipment. Such powder would mix with the water and could float on it, since its density is not high, whereas the gold powder would sink to the bottom.

Frankel also points out that in ancient Ugaritic and Sumerian cultures the total annihilation of a god was achieved by burning it in fire, grinding and strewing the ashes in a field or in water, or by allowing birds eat the remains. However, the requirement to drink the ashes was not part of these rites. Frankel compares Moses forcing the Israelites to drink water with the powdered tablets suspended in it to the rite of the *sotah*, the wife suspected of adultery (Num. 5:11-31). There, the suspect woman was tested by having to drink water mixed with curses from a text washed off a holy scroll: *The priest shall put these curses down in writing and rub it off into the water of bitterness. He is to make the woman drink the water of bitterness that induces the curse so that the curse inducing water may enter into her to bring on bitter-*

ness (Num. 5:23-24). In this case, the tablets themselves served as the scroll that was mixed with water in order to determine who had sinned. Since this approach is based on reordering the biblical verses, it is not surprising that traditional commentators never suggested anything of the kind.

As a scientist, Frankel proposes a segment switch that appeals to me. The physical and chemical process of crumbling limestone or marble and dissolving it in water is simple to perform by ancient technology. The melting of the gold is also consistent with the level of ancient technology available to the Israelites. Thus, Moses compelled the Israelites to drink the water with the powdered tablet suspended in it as a test with God's words. This alternate approach frees the contemporary reader from having to assume that advanced chemical and technological processes (or miracles) would be needed to explain how Moses disposed of the Golden Calf.

NOTES

1. T. D. Massalski, H. Okamoto, P. R. Subramanian and L. Kacprzak, *Binary Alloy Phase Diagrams* (Materials Park, OH: ASM International, 1990) pp. 8, 360, 1702.
2. R. J. Forbes, *Metallurgy in Antiquity. A Notebook for Archaeologists and Technologists* (Leiden: E. J. Brill, 1950).
3. J. R. Partington, *Origins and Development of Applied Chemistry* (London: Longmans, Green and Co., 1935) pp. 486-493; James D. Muhly, "How Iron Technology Changed the Ancient World and Gave the Philistines a Military Edge," *Biblical Archaeology Review*, November-December (1982) pp. 230-242.
4. Forbes, op. cit. See also, "Sound Proof: How Hezekiah's Tunnelers Met," *Biblical Archaeological Review*, September-October (2008) pp. 50-57.
5. In Ben Sira 38:28 we also have a detailed description of an ironsmith's shop: *So too is the smith sitting by the anvil, intent upon his handiwork in iron. The breath of fire melts his flesh, and he wastes away in the heat of the furnace. He inclines his ear to the sound of the hammer, and his eyes are on the pattern of the object. He sets his heart on finishing his handiwork, and is careful to complete its decoration.*
6. Forbes, op. cit.; Muhly, op. cit.
7. Partington, op. cit., pp. 486-493.
8. W. B. Herapath, *Philosophical Magazine*, 3 (1852) p. 528.
9. T. Thomson, *A History of Chemistry* (London: Colburn and Bentley Publishing Co., 1830) p. 256; H. E. Roscoe and C. Schorlemmer, *A Treatise in Chemistry* (New York: D. Appleton and Co., 1877) p. 519.
10. D. J. de Solla Price, *Science Since Babylon* (New Haven: Yale University Press, 1961) p. 27; M. Levey, *Chemistry and Chemical Technology in Ancient Mesopotamia* (Amsterdam: Elsevier Publ. Co., 1959) pp. 178-196.
11. This idea is also found in *Yalkut Midreshei Teiman*. See Yosef Assia, ed., *Hummash Otzar Ha-Rishonim*, vol. 2 (Jerusalem: Makhon Torat Ha-Rishonim, 2003) p. 730.

12. D. Frankel, "The Destruction of the Golden Calf: A New Solution," *Vetus Testamentum*, 44 (1994) pp. 330-339.

ACKNOWLEDGEMENTS

I wish to thank Rabbi Elliot B. Gertel for his interest and encouragement. This paper is dedicated to my teacher, Rabbi Sandor Scheiber, who inspired me as a teenager to read the Bible with a critical eye; and to Rabbi Ira Eisenstein, who was instrumental in helping me as a new immigrant in the USA to find a way to continue my studies in science. I also wish to thank Judy Meschel for constructive criticism and editorial comments.



INSTRUCTIONS FOR AUTHORS

Detailed *Instructions for Authors* and journal style can be found on our Internet website:

<http://www.jewishbible.org>

