0 PREFACE

This document is part of the "**HÂRN-GUILD-TEAM**"-project (**HGT**), initiated and coordinated by the **EUROPEAN HÂRNMASTER GUILD** (**EHG**). The goal of the **HGT** is to elaborate all the guilds and societies forming the Hârnic Mangai.

"**METALLURGY**" is a gaming resource for the fantasy world of Kethira, as published by Columbia Games in its HârnWorld/-Encyclopaedia Hârnica series. This article should be accompanied by three other documents:

1. "**MINES IN LYTHIA**",
2. "**MINING**", and
3. "**MINERS' GUILD**".

While (1) lists details on all mines of Lythia and (2) gives an overview on mining techniques, (3) presents detailed information on the powerful Lythian Miners' Guild, who monopolizes the winning of minerals, but also performs the smelting of metals.

In this text, references are marked in **BOLD CAPITALS**. Important phrases are typed in *ITALIC CAPITALS* where they are explained. Citations from any sources are printed in *italic* and enclosed by quotation marks, followed by a reference to the source.

1 INTRODUCTION

This document focuses on Lythian metallurgy. It is based upon Terran history as was in the late medieval period. The main source for this text is:

> [Agricola 1557] Georgius Agricola: *De Re Metallica Libri XII*; Basel 1556 (latin), Basel 1557 (german by P. Bech).

The information found in Agricola's compendium is translated to the Lythian situation at 720 TR, as described by the official HârnWorld publications.

This article is organized into sections on

2. History of Metallurgy & Metalcraft
3. Metals & Minerals
4. Concentration
5. Smelting
6. Alloying and Refinement
7. Smelteries
8. Occupational diseases
9. Side Effects of Metallurgy
10. References

While western Lythia is superior to eastern Lythia in metalcraft, the east is more sophisticated in alchemy (**LYTHIA 3**).

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REFERENCES

Please visit the websites at
www.johalla.de/EHG
www.columbiagames.com
www.kelestia.org

2 HISTORY OF METALLURGY & METALCRAFT

This section gives an overview on the development of human metallurgy and metalcraft. The elder races, Sindarin and Khûzdul, had already reached their present state of knowledge and craftsmenship, when they entered Kethira during manikind's dawn.

2.1 STONE AGE

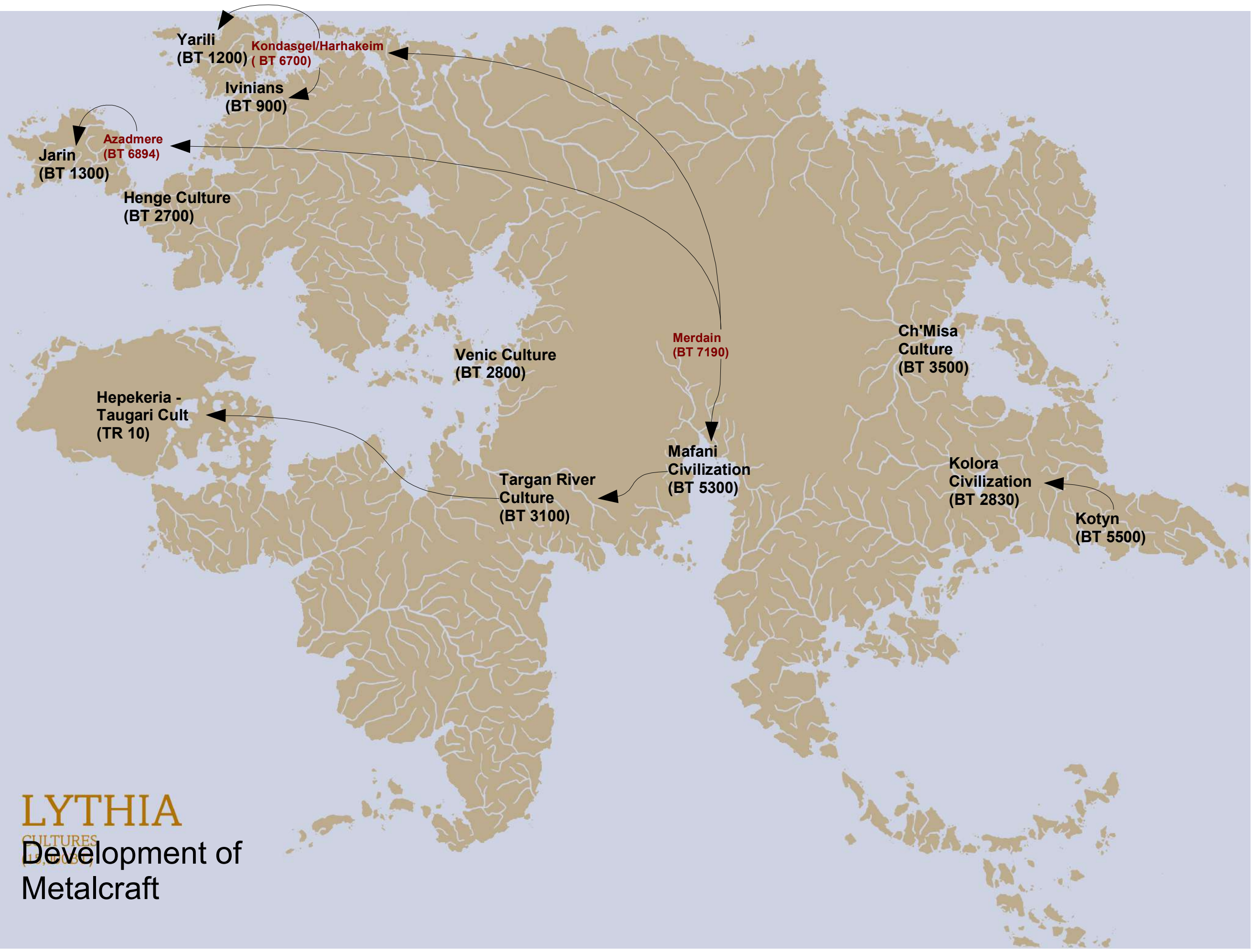
In early days, the prehistoric humans used natural resoources like flintstone to create tools and weapons. Native metals and alloys, like gold, silver, platinum or copper are used for ornaments, but are to soft to make useful tools of it. The latest periode of the stone age (called chalcolithicum) is characterized by the upcoming use of copper for ornamentation. Copper was easily smelted from its ores, but as pure copper is a soft metal, it cannot be used to make weapons or amour. Lead and copper have also been used for clamps in megalithic masonry in the Ziggurat Culture in Molkuria, around 6,500 BT.

2.2 BRONZE AGE

The manufacture of bronze has developed at 5,500 BT in Molkura, and reached the Mafani Culture around 5,300 BT. The Ch'misan culture reached Bronze Age around 3,500 BT. It is assumed, that contacts to the Khûzdul of Merdain propelled the adoption of bronze making by the ancient Mafani cultures. In 3,800 BT, most lythian tribes either have reached Bronze Age, or had contact to neighboured tribes who practized metalcraft.

Bronze can be properly cast into any form and is hard enough to make blades and armour of it.

The manufacture of brass may have been developed in parallel to that of bronze.



Though meteoric iron was used sporadically to make weapons, tools and ornaments, iron metallurgy was still unknown, and the use of this metal was strongly limited.

2.3 IRON AGE

The first signs of use of human iron come from Molkura, where around 3,800 BT, small items, such as the tips of spears and ornaments, were being fashioned from iron recovered from meteorites. Some resources suggest that by 2,900 BT iron was being created in Molkura as a by-product of copper refining, as sponge iron, and was not reproducible by the metallurgists.

Otherwise, the manufacture of iron seems to be linked to the presence of khûzan metallurgist, who taught parts of their craft to neighboured human tribes either for goodwill, or – more likely – in exchange for food. Anyway, the knowledge of iron smelting aroused in proximity to the ancient khûzan settlements and spread over most of the continent. It were khûzan smelters from Harhakeim and Kondasgel, who taught the craft of metalworking and ironworking to the Yarili after 1,200 BT, and even to the invading Ivinians prior to 200 BT, when they banned Ivinians from their territory and finally sealed their cities in 438 TR. The dwarfs of Merdain may have passed on the knowledge of steel production with the wind furnace to humans of the Mafani civilization around BT 2,000:

By 2,400 BT, increasing numbers of smelted iron objects appear in the Mafan region. Most of them seem to be khûzan artifacts or human made ones based on khûzan iron. However, their use appears to be ceremonial, and iron was an expensive metal, more expensive than gold. In ancient mafani epics, weaponry is mosty bronze, but iron ingots are used for trade. By 2,400 BT to 2,000 BT, iron was used increasingly in Mafan, with an increasing amount of man made iron, but did not supplant the dominant use of bronze. In the period from 2,000 to 1,800 BT, there was a rapid transition in the Mafani region from bronze to iron tools and weapons. The critical factor in this transition does not appear to be the sudden onset of a superior ironworking technology learned from the Khûzdul of Merdain, but instead the disruption of the tin supply. Concurrent with the transition from bronze to iron was the discovery of carburization, which was the process of adding carbon to the irons of the time. Iron was recovered as sponge iron, a mix of iron and slag with some carbon and/or carbide, which was then repeatedly hammered and folded over to free the mass of slag and oxidise out carbon content, so creating the product wrought iron. Wrought iron was very low in carbon content and was not easily hardened by quenching. The people of Mafan found that a much harder product could be created by the long term heating of a wrought iron object in a bed of charcoal, which was then quenched in water or oil. The resulting product, which had a surface of steel, was harder and less brittle than the bronze it began to replace.

From Mafan, the art spreaded to the Targan River Culture, and – in TR 10 – finally reached the desert of Hepekeria:

“The secrets of the manufacture of Hepekerian steel are jealously guarded by the Taugari Cult, a spiritual/artisan class that has existed since 10 TR. The cause of its foundation is unclear, and heavily masked by legend, but it seems likely that refugees from the Targan Genocide brought the steel-making art to Hepeker. It is known that the Targan Empire (the predecessor of Dalkesh) contained weaponcrafting clans of considerable skill. Some believe that the techniques were passed from the fabled khuzdul city of Merdain [BT 7,190 – ???], to the ancient Mafani [BT 5,300 – BT 1,550], and from there to the Targan River cultures [BT 3,100 – TR 7]. Why the skill seems to have been lost everywhere else in the world is a mystery. The Taugari cultists dwell in small permanent settlements in the heart of the desert. They acquire iron by mining several ore-rich rock outcroppings and occasionally in trade with the coastal cities. Taugari swords are seldom available in trade; the Numec tend to regard their weapons as semi-sacred objects.” (**THE NUMEC OF HEPEKERIA** ***BY BILL GANT***)

“Taugari Cult - The secretive brotherhood of the Inadan class. Basically a specialized group of swordsmiths and iron forgers, their practices are shrouded in mystery and mysticism. More than half of the cult members are (loosely) aligned with the Jmorvi chantry at Silgora, known to them, but not

appearing on any registers of the Shek P'var. Some speculate that the Taugari Cult is nothing more than a Shek P'var plot to control the Numec tribes, though this appears unlikely. The cult was founded in 10 T.R. by a Targan refugee, who passed on the metallurgic secrets of his people, including the use of the wind forge." (**HEPEKERIA/TAUGARI CULT *BY R. AIRIQ WILLIAMS***)

In Diramoa the first irons used were also meteoric iron, with archeological evidence for items made of wrought iron appearing in central Diramoa, near Ibchi, in the 11th century BT. These items were made of wrought iron, created by the same processes used by the Mafani, and were thought to be imported by non-Ch'Misan people. In the later years of the Mu-Qin Dynasty (-213 BT), a new iron manufacturing capability began because of a highly developed kiln technology. Producing blast furnaces capable of temperatures exceeding 1300 K, the Diramoans developed the manufacture of cast, or pig iron.

If iron ores are heated with carbon to 1420–1470 K, a molten liquid is formed, an alloy of about 96.5% iron and 3.5% carbon. This product is strong, can be cast into intricate shapes, but is too brittle to be worked, unless the product is decarburized to remove most of the carbon. The vast majority of Diramoan iron manufacture, from the Mu-Quin dynasty onward, was of cast iron. Iron, however, remained a pedestrian product, used by farmers but not the nobility until the Ju-Tan dynasty (93- TR).

Cast iron development lagged in central and western Lythia, as the smelters could only achieve temperatures of about 1000 K. Iron is still being made by the working of sponge iron into wrought iron. In western Lythia, the cast iron process is unknown.

Iron smelting uses charcoal as both the heat source and the reducing agent. Only the Khûzdul, also use coke, as a fossil fuel, for smelting iron.

3 METALS & MINERALS

On Kethira, nine different *METALS* are known to the scolars: Mythral (platinum), gold, silver, copper, mercury (quicksilver), iron, lead, tin, and antimony.

Other metals are unknowingly used, as they are contained in natural alloys, ores or other used minerals – their true, elemental or metallic nature has yet not been discovered. Among this are zinc, palladium, nickel, manganese, and cobalt.

Additionally, other mineralic resources are produced by the Miners' Guild: arsenic, sulphur, borax/tincal, soda ash, vitriol, sal ammoniac, saltpetre.

This section gives an overview on the metals and minerals processed by lythian miners and smelters.

3.1 TRUESILVER

Truesilver (platinum, mythral) is a heavy, malleable, ductile, precious, gray-white metal, resistant to corrosion. The only known reagens that dissolves platinum in the mixture known as aqua regia.

On Kethira, platinum is known as truesilver or mythral. It is mined and process solely by the Khûzdul, who appreciate it above gold and primarly use it in jewelry and artifacts. A few scholars may use mythral for alchemistic laboratory equipment or arcane purposes.

Platinum is often in a native state or in *PLATINIRIDIUM*, a natural alloy. The platinum ores *SPERRYLITE* (platinum arsenide, $PtAs_2$) and *COOPERITE* (platinum sulfide, PtS) are not worked on Lythia. While native platinum is found in alluvial deposits, its ores occur in some nickel and copper ores. On Kethira, the only known (and worked) truesilver deposit is located in the mines of Azadmere.

3.2 GOLD

Gold is a metallic element that exhibits a yellow color en masse but can be black, ruby, or purple when finely divided. It is the most malleable and ductile metal known and can be beaten into thinnest sheets (*GOLD LEAF*). A soft metal, gold is often alloyed with other metals to give it more strength. Gold is not affected by air and most reagents, but aqua regia dissolves it.

Native gold contains usually 8-10% silver, but often much more. Natural alloys with a high silver content (more than 20%) are called *ELECTRUM*. Gold will also alloy with many other metals; alloys with copper yield a redder metal, alloys with iron are green, alloys with platinum metals produce white, natural bismuth with silver alloys produce black.

Applications of gold include jewelry, coinage, embroidery (gold thread in gold brocade or damask), restorative dentistry, and it is used for gilding and gold-plating (e.g. illumination of manuscripts with gold leaf).

Gold is usually found as the native metal or alloy. Occasionally large accumulations of native gold (*NUGGETS*) occur, but usually gold occurs as minute grains. These grains occur between mineral grain boundries or as inclusions within minerals. Common gold associations are quartz – often as veins and sulfide minerals. The most common sulfide associations are pyrite, chalcopyrite, galena, sphalerite, arsenopyrite, stibnite and pyrrhotite. Hydrothermal ore deposits of gold occur in metamorphic rocks and igneous rocks; alluvial deposits and placer deposits originate from these sources.

The primary source of gold is usually igneous rocks or surface concentrations. A deposit usually needs some form of secondary enrichment to form an economically viable ore deposit: either chemical or physical processes like erosion or solution or more generally metamorphism, which concentrates the gold in sulfide minerals or quartz. Common deposit types are reef or vein. Primary deposits can be weathered and eroded, with most of the gold being transported into stream beds where it congregates with other heavy minerals to form placer deposits. In all these deposits the gold is in its native form. Another important ore type is in sedimentary black shale and limestone deposits containing finely disseminated gold and other platinum group metals.

Gold ore grades may be as little as 0.5 g/1000 kg on average in large easily mined alluvial deposits (applying hydraulicking or hushing in mining), typical ore grades in open-pit mines are 1-5 g/1000 kg, ore grades in underground or hard rock mines are usually at least 3 g/1000 kg on average. The latter deposits are processed by crushing and grinding of the ore and consecutive extraction of the gold by means of gravity separation, amalgamation, roasting or adsorption on a fleece. Ore grades of 30 g/1000 kg are usually needed before gold will be visible to the naked eye, therefore even in gold mines you will often not see any gold.

Gold is found in Azerya, Homora and Imdalia.

3.3 SILVER

Silver is a soft, very ductile and malleable precious metal with a brilliant white metallic luster that can take a high degree of polish. Pure silver has the whitest color, and the highest optical reflectivity of any metal. It is stable in pure air and water, but does tarnish when it is exposed to hydrogen sulfide, or air with sulphur in it.

Commercial grade *FINE SILVER* is at least 99.9% pure silver. Silver is the main coinage metal in western Lythia. Coins are minted from sheets, made of an alloy containing 90% of silver, and 10% of other metals – usually copper – to harden the mint metal. Silver is widely used for juwelry, and tableware, which are traditionally made from

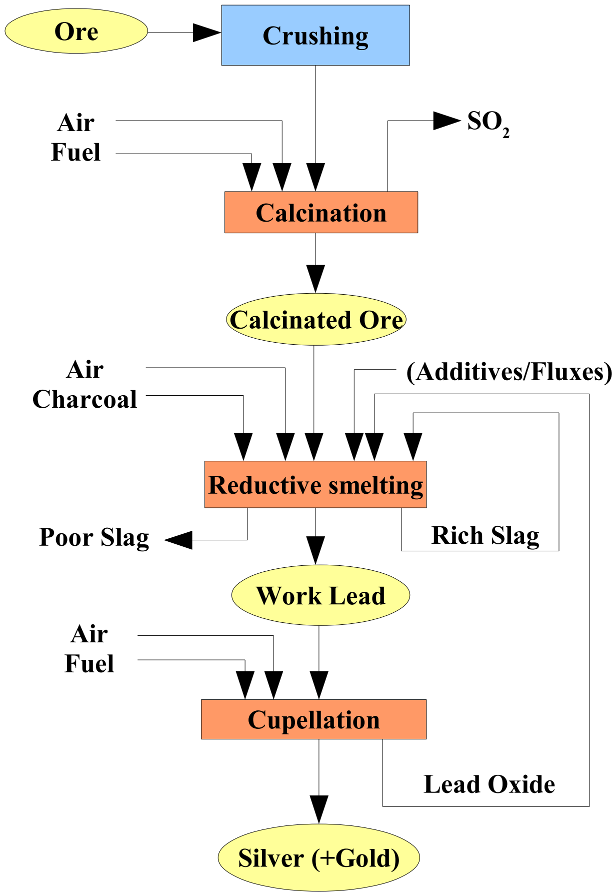


Figure 1: Processing scheme for argentiferous lead ores (e.g. galena with < 2% Ag).

the silver alloy known as *STERLING SILVER*, (an alloy of at least 92.5% silver and up to 7.5% other metals, usually copper). Other applications are platings for highly-reflective mirrors, solders and brazing alloys. In legend, silver is traditionally seen as harmful to supernatural creatures like werewolves and vampires. Silver has germicidal effects. Various kinds of silver compounds are sold as remedies for a variety of diseases.

Silver is found in native form, or in form of ores, combined with sulphur (*SILVER-GLANCE*/glaserz/vitreous silver/argentite, Ag_2S), arsenic, antimony, or chlorine (*HORN SILVER*, AgCl). The principal sources of silver are sulfidic copper, copper-nickel, gold, lead and lead-zinc ores. Although some silver-bearing ores contain silver as their largest metal value, virtually none has silver as its main constituent. A typical ore might contain 0.085% silver, 0.5% lead, 0.5% copper, and 0.3% antimony.

On Lythia, major silver deposits are worked in Mafan, Molkuria, Tzengai, and Umelria.

3.4 COPPER

Copper is a reddish-coloured metal.

Copper may well be the oldest metal in use. It is used for coinage, statuary, building construction (roof tilings), copper plumbings, in cookware (frying pans), for alloying (e.g. bronze, brass, speculum metal, Sterling silver, red gold). Copper is also used as a component in ceramic glazes, and to color glass. The metal, when powdered, is a fire hazard. Copper compounds are toxic: 30g of copper sulfate is potentially lethal in humans. Copper in drinking water at concentrations higher than 1 mg/l can stain clothes and items washed in water.

Besides being part of various ores, copper can be found in its native form in some locations. Minerals such as the carbonates azurite and malachite are sources of copper, as are sulfides such as chalcopyrite, bornite, covellite, chalcocite and oxides like cuprite. As usual, the chief minerals are sulfides, which are oxidized in the withering zone of the deposits and form various brightly colorful green and blue oxides and carbonates, which are generally preferred for copper smelting.

Rich copper ore deposits are located in Azerya, Diramoa, Kaneum, and Trierzon.

3.4.1 CHALCOPYRITE

Chalcopyrite is one of the most important of copper ores. It has chemical composition $CuFeS_2$. It has a brassy to golden yellow color and hardness of 3.5–4. Due to its color it is often confused with pyrite.

3.4.2 PEACOCK ORE

Peacock ore (bornite, Cu_5FeS_4) is a sulfide mineral with a brown to copper-red color on fresh surfaces that tarnishes to an iridescent purple surface. The name derives from its purple to bronze iridescence. Bornite is an important copper ore mineral and occurs widely in porphyry copper deposits along with more common chalcopyrite. It also is found in pegmatites. It is important for its copper content of about 63% by mass.

3.4.3 COVELLITE

Covellite (also know as covelline, CuS) is coloured in an enchanting indigo blue. It is associated with chalcosite in zones of secondary enrichment of copper sulfide deposits. Commonly found with and as coatings on chalcocite, chalcopyrite, bornite, enargite, pyrite, and other sulfides. It often occurs as pseudomorphic replacements after other minerals, and very rarely occurrs as a volcanic sublimate.

3.4.4 COPPER GLANCE

Copper glance (chalcocite, Cu_2S) is an important sulfidic copper mineral ore. It is opaque, being colored dark-gray to black with a metallic luster. It has a hardness of 2½–3.

It is sometimes found as a primary vein mineral in hydrothermal veins. However, most chalcocite occurs in the supergene enriched environment below the oxidation zone of copper deposits as a result of the leaching of copper from the oxidized minerals. It is also often found in sedimentary rocks. Chalcocite has been mined for centuries and is one of the most profitable copper ores. The reasons for this is its high copper content (67% atomic ratio and nearly 80% by weight) and the ease at which copper can be separated from sulphur.

Since chalcocite is a secondary mineral that forms from the alteration of other minerals, it has been known to form pseudomorphs of many different minerals. A *PSEUDOMORPH* is a mineral that has replaced another mineral atom by atom, but it leaves the original mineral's crystal shape intact. Chalcocite has been known to form pseudomorphs of the minerals bornite, covellite, chalcopyrite, pyrite, enargite, millerite, galena and sphalerite.

3.4.5 CUPRITE

Cuprite (Cu_2O) is an important ore of copper. Its dark crystals with red internal reflections are in the isometric system, appearing as cubic, octahedral, or dodecahedral forms, or in combinations, with a deep red color. In spite of its nice color it is rarely used for jewelry because of its low hardness of 3.5–4 .

3.4.6 MALACHITE

Malachite is a carbonate mineral ($Cu_2CO_3(OH)_2$) with a hardness between 3.5 and 4. It most often forms botryoidal, fibrous, or stalagtitic masses.

Malachite is used as a mineral pigment in green paints. The pigment is moderately lightfast, very sensitive to acids and varying in colour.

Malachite often results from weathering of copper ores and is often found together with azurite ($Cu_3(CO_3)_2(OH)_2$). Except for the green colour, the properties of malachite are very similar to those of azurite. Typically malachite is associated with copper deposits associated with limestones, the source of the carbonate.

3.4.7 AZURITE

Azurite ($Cu_3(CO_3)_2(OH)_2$) is a carbonate mineral It is often found in association with the green mineral malachite as a result of the weathering and oxidation of copper sulfide minerals.

The name azurite comes from the Karuia word for blue. Azurite is used in jewelry and also collected as a beautiful mineral specimen.

Azurite has been used as a blue mineral pigment for centuries. When mixed with oil it turns slightly green. When mixed with egg yolk it turns green-grey. It is also known by the names Blue Bice and Blue Verditer.

3.5 MERCURY

Mercury, also called quicksilver, is a heavy, silvery, and liquid metal. Mercury easily forms alloys with almost all common metals, including gold, and silver, but not iron. Any of these alloys is called an *AMALGAM*.

Mercury is used in the amalgamation process of refining gold and silver ores. Other applications are mirror-making, and gold/silver-plating of objects and jewelry. The metal is used in some cultures for folk medicine and ceremonial purposes which may involve ingestion, injection, or the sprinkling of elemental mercury around the home. Mercury vapours are highly toxic.

Mercury is mostly obtained by reduction from the mineral cinnabar. Native, liquid quicksilver can be found in some cinnabar deposits.

Lythian deposits are found on the border between Emelrene and Palithane, and in Molkuria.

3.5.1 CINNABAR

Cinnabar, or mercury sulfide (HgS), is the chief ore mineral of mercury. It is commonly encountered with pyrite, and stibnite in veins near recent volcanic rocks and in hot-springs deposits.

The metal is extracted by heating cinnabar in a current of air and condensing the vapor.

3.6 IRON

Iron is the most abundant metal, extracted from iron ore, and is hardly ever found in the elemental state. In order to obtain elemental iron, the impurities must be removed by chemical reduction. Iron is used in the production of steel, which is an alloy with different metals and some non-metals, particularly carbon.

Iron is the most used of all the metals. *STEEL* is the best known alloy of iron, and some of the forms that iron takes include:

- *PIG IRON* has 4% – 5% carbon and contains varying amounts of contaminants such as sulphur, silicon and phosphorus. Its only significance is that of an intermediate step on the way from iron ore to cast iron and steel.
- *CAST IRON* contains 2% – 3.5% carbon and small amounts of manganese. Contaminants present in pig iron that negatively affect the material properties, such

as sulphur and phosphorus, have been reduced to an acceptable level. It has a melting point in the range of 1420–1470 K, which is lower than either of its two main components, and makes it the first product to be melted when carbon and iron are heated together. It is extremely strong, hard and brittle. Working cast iron, even white hot cast iron, tends to break the object.

- *CARBON STEEL* contains between 0.5% and 1.5% carbon, with small amounts of manganese, sulphur, phosphorus, and silicon.
- *WROUGHT IRON* contains less than 0.5% carbon. It is a tough, malleable product, not as fusible as pig iron. It has a very small amount of carbon, a few tenths of a percent. If honed to an edge, it loses it quickly.
- *ALLOY STEELS* contain varying amounts of carbon as well as other metals, such as chromium, vanadium, molybdenum, nickel, tungsten, etc.

Most iron is found in various iron oxides, such as the minerals hematite, and magnetite. About 5% of the meteorites similarly consist of iron-nickel alloy. Although rare, these are the major form of natural metallic iron on the earth's surface. Industrially, iron is extracted from its ores, principally hematite (nominally Fe_2O_3) and magnetite (Fe_3O_4) by reduction with carbon.

While *BOG IRON ORE* (impure iron deposits that develop in bogs or swamps by the chemical or biochemical oxidation of iron carried in the solutions, such ore is used widely throughout Ivinia) is found nearly everywhere and can be mined easily, viable deposits of high-quality ore are more scarse. Important known iron ore deposits lie in Azerya, Chomsun, and Hepekeria.

3.6.1 PYRITE

Pyrite, also called iron pyrite, or fool's gold, is a naturally occurring iron disulfide mineral. Pyrite emits sparks when struck by steel. Pyrite is called fool's gold because its colour may deceive the novice into thinking he has discovered a gold nugget. Nodules of pyrite have been found in prehistoric burial mounds, which suggests their use as a means of producing fire. Pure pyrite (FeS_2) contains 46.67% iron and 53.33% sulphur.

Pyrite is widely distributed and forms under extremely varied conditions. For example, it can be produced by magmatic segregation, by hydrothermal solutions, and as stalactitic growth. It occurs as an accessory mineral in igneous rocks, in vein deposits with quartz and sulfide minerals, and in sedimentary rocks, such as shale, coal, and limestone. Pyrite occurs in large deposits in contact metamorphic rocks. Deposits of copper-bearing pyrite are widely distributed and often of great size. They usually occur in or near the contact of eruptive rocks with schists or slates. Pyrite weathers rapidly to hydrated iron oxide, goethite, or limonite; pseudomorphs of goethite after pyrite are common. This weathering produces a characteristic yellow-brown stain or coating, such as on rusty quartz.

Because of the availability of much better sources of iron, pyrite is not generally used as an iron ore.

3.6.2 LODESTONE

Lodestone (magnetite) is a magnetic mineral form of Fe_3O_4. Intensely magnetic magnetite is used as a primitive form of magnetic compass (also called *LODESTONE*).

3.6.3 BLOODSTONE

Bloodstone (haematite) is the mineral form of Fe_2O_3. The ore sometimes contains slight amounts of titanium. When shaped into ornaments, it is often called black diamond. Haematite is a very common mineral, coloured black to steel or silver-gray, brown to reddish brown, or red. Varieties include Bloodstone, Iron Rose, Kidney Ore, Martite, Paint Ore, and Specularite. While the forms of haematite vary, they all have a rust-red streak.

Deposits of grey haematite are typically found in places where there has been standing water or mineral hot springs. The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. But haematite can also occur without water, as the result of volcanic activity.

Haematite is mined as the main ore of iron.

3.6.4 BROWN IRON ORE

Brown iron ore (limonite) is a ferric hydrate of varying composition, the generic formula is frequently written as $FeO(OH)\cdot nH_2O$, although this is not entirely accurate as Limonite is not a true mineral, but a mixture of similar hydrated iron oxide minerals. It is never crystallized, but commonly occurs in concretionary forms or in compact and earthy masses. The colour presents various shades of brown and yellow, and the streak is always brownish, a character which distinguishes it from hematite with a red, or from magnetite with a black streak. It is sometimes called *BROWN HEMATITE*. Limonite has been known to pseudomorph other minerals such as pyrite. Hardness is 4–5.5, specific gravity is 2.9 to 4.3.

It forms mostly in or near oxidized iron and other metal ore deposits and as sedimentary beds in meadows and marshes. Together with hematite, limonite it is mined as ore for the production of iron. Deposits of brown iron ore of great economic value occur in many sedimentary rocks, such as Oolites. They appear in some cases to be altered limestones and in others altered glauconitic sandstones. An oolitic structure is sometimes present, and the ores are generally phosphatic, and may contain perhaps 30% of iron. Granular and concretidnary limonite accumulates by organic action on the floor of certain lakes in Ivinia, forming the curious "*LAKE ORE*." Larger concretions formed under other conditions are known as "*BEAN ORE*". Limonite often forms a cementing medium in ferruginous sands and gravels, forming "pan"; and in like manner it is the agglutinating agent in many conglomerates. In iron-shot sands the limonite may form hollow concretions, known in some cases as "boxes" containing some substance, like sand, which rattled when the hollow nodule was shaken.

BOG IRON ORE is an impure limonite, usually formed by the influence of micro-organisms, and containing silica, phosphoric acid and organic matter, sometimes with manganese. The various kinds of brown and yellow *OCHRE* are mixtures of limonite with clay and other impurities; whilst in *UMBER* much manganese oxide is present.

3.7 LEAD

Lead is a very soft, heavy, and highly ductile and malleable toxic metal. It is bluish white when freshly cut but tarnishes to dull gray when exposed to air. Lead has a bright luster. The metal is highly resistant to corrosion. Because of this property, it is used to contain corrosive liquids (e.g. oil of vitriol).

Lead is used in building construction (clamps for masonry, roof tilings), plumbing (pipes), and is part of solder, pewter, and fusible alloys. Metallurgic processes make use of lead to concentrate precious metals, especially silver, and to extract them from several types of ore. Lead can be toughened by adding a small amount of antimony or other metals to it. Pencils are often made of lead and *MINIUM* or *RED LEAD* (lead oxide) is used to produce lead glass.

Native lead rarely occurs in nature, but is usually found in ore with zinc, silver and (most abundantly) copper, and is extracted together with these metals. The main lead mineral is galena, which contains 86.6% lead. Other common varieties are cerussite, and anglesite.

Major lead deposits locate at Chomsun, Diramoa, Kaneum, Menema, and Vitho.

3.7.1 GALENA

Galena (lead glance, PbS) is a primary sulfidic ore of lead. Galena is one of the most abundant and widely distributed sulfide minerals, and is the main ore of lead. It is often associated with the minerals sphalerite and fluorite.

Galena occurs in many different types of deposits, often in metalliferous veins. Some deposits are of contact-metamorphic origin. Galena is found in cavities and brecciated (fractured) zones in limestone and chert. The mineral has occasionally been observed as a replacement of organic matter, and sometimes occurs in coal beds.

The mineral is easily weathered to secondary lead minerals, the upper part of galena deposits often containing cerussite, anglesite, and pyromorphite. Nodules of anglesite and cerussite with a banded structure and a galena core are common.

In many cases, galena contains silver and so is often mined as a source of silver as well as lead. In fact, galenas have long been the most important ore of silver in mining. Other commercially important minerals that frequently occur in close association with galena include antimony, copper, and zinc.

3.7.2 WHITE LEAD ORE

White lead ore (cerussite, or lead carbonate, $PbCO_3$), is an important ore and common secondary mineral of lead. It is formed by the chemical action of carbonated water on the mineral galena.

3.7.3 ANGLESITE

Anglesite is a naturally occurring lead sulfate ($PbSO_4$). A common secondary mineral that is a minor ore of lead, it is usually formed by the oxidation of galena and often forms a concentrically banded mass surrounding a core of unaltered galena. The formation of cerussite (lead carbonate) often accompanies or follows the formation of anglesite.

3.8 TIN

Tin is a malleable, ductile, highly crystalline, silvery-white metal whose crystal structure causes a *"TIN CRY"* when a bar of tin is bent (caused by crystals breaking). This metal resists corrosion from distilled sea and soft tap water, but can be attacked by strong acids, alkalis, and by acid salts. Tin can be highly polished and is used as a protective coat for other metals in order to prevent corrosion or other chemical action. Tin is malleable at ordinary temperatures but is brittle when it is heated. Solid tin has two allotropes at normal pressure. At low temperatures it exists as *GRAY TIN*. When warmed above that 13.2 °C it changes into *WHITE TIN*, which is metallic. It slowly changes back to the gray form when cooled, which is called the *TIN PEST* or tin disease. However, this transformation is affected by impurities such as aluminium and zinc and can be prevented from occurring through the addition of antimony or bismuth. Tin bonds readily to iron, and can be used for coating lead and steel to prevent corrosion.

The principal tin mineral is *TINSTONE* (cassiterite, SnO_2), a naturally occurring oxide of tin containing about 78.8% tin. Of less importance are two complex sulfide minerals, stannite (bell meatl ore, Cu_2FeSnS_4), and cylindrite ($PbSn_4FeSb_2S_{14}$). These two minerals occur in some hydrothermal lode deposits, often in association with other metals such as silver.

About 80% of the produced tin comes from alluvial or secondary deposits. Even in the richest tin fields, the concentration of tin is very low. This means that up to seven or eight tons of ore may have to be mined in order to recover one kilogram of cassiterite.

The manufacture of *BRONZE* has developed at 5,500 BT in Molkuria, and reached the Mafani Culture around 4,500 BT. The Ch´misan culture reached Bronze Age around 4,000 BT. In 3,500 BT, most lythian tribes have reached Bronze Age.

Tin deposits have been found on the borderland between Emelrene and Shorkyne, in Molkuria, Molnasia, and Pechran.

3.9 ANTIMONY

A metalloid, antimony has four allotropic forms. The stable form of antimony is a blue-white metal. Yellow and black antimony are unstable non-metals. Antimony in its elemental form is a silvery white, brittle, fusible, crystalline solid that vaporizes at low temperatures. Antimony resembles metal in its appearance and physical properties, but does not chemically react as a metal. It is attacked by oxidizing acids. Antimony and some of its alloys expand on cooling.

As an alloy, this semi-metal greatly increases lead's hardness and mechanical strength. The natural sulfide of antimony, *STIBNITE*, is used as a medicine and as a cosmetic. Antimony has been used for the treatment of *SNAIL FEVER* (schistosomiasis – a tropical flatworm disease).

Antimony glance (stibnite, antimony sulfide, Sb_2S_3), is the principal ore of antimony. This mineral has a brilliant metallic lustre, is lead- to steel-gray in colour, and fuses readily (at about 525° C). Stibnite occurs in massive forms in gneiss and granite. It is also found in limestone, presumably deposited by hot springs. Stibnite is used in the manufacture of fireworks, and as a cosmetic to increase the apparent size of the eye.

3.10 ZINC

Zinc is a moderately reactive metal that will combine with oxygen and other non-metals, and will react with dilute acids to release hydrogen. Zinc alloys and compounds have been used for centuries. Because of the low boiling point and chemical reactivity of this metal (isolated zinc would tend to go up the chimney rather than be captured), the true nature of this metal has still not been understood by lythian scholars.

Lotions made of *CALAMINE*, the common name of an ore of zinc, are used to treat skin rash.

The manufacture of *BRASS*, uses a technique where calamine and copper are heated together in a crucible, has developed at 5,500 BT in Molkuria: The zinc oxides in calamine are reduced, and the free zinc metal is trapped by the copper, forming an alloy. The resulting brass is either cast or hammered into shape. The Ch´misan culture reached Bronze Age around 4,000 BT. In 3,500 BT, most lythian tribes have reached Bronze Age.

Smelting and extraction of impure forms of zinc have being accomplished as early as BT 800 in Diramoa.

Areas well-known for their brass-production (and hence zinc deposits) are in Azerya, Diramoa, Karelia, and Shorkyne.

3.10.1 ZINC BLENDE

Zinc blende (sphalerite, ZnS), is a mineral that is the chief ore of zinc. It consists largely of zinc sulfide in crystalline form but almost always contains variable iron as (Zn,Fe)S. It is usually found in association with galena, pyrite, and other sulfides along with calcite, dolomite, and fluorite. Miners have also been known to refer to sphalerite as zinc blende, mock lead, false galena and black-jack.

Its color is usually yellow, brown, or gray to gray-black, and it may be shiny or dull. Its luster is resinous. It has a yellow or light brown streak, a hardness of 2.5–4, and a specific gravity of 3.9–4.1.

Crystals of suitable size and transparency have been fashioned into gemstones, usually featuring the brilliant cut to best display sphalerite's high dispersion – over three times that of diamond. Freshly cut gems are lively with an adamantine luster and could conceivably be mistaken for a fancy-colored diamond in passing. Collectors may pay a premium for stones over one carat, as clean crystals are usually quite small. Gem-quality material is usually a yellowish to honey brown, red to orange, or green.

3.10.2 CALAMINE

Calamine is the common name for an ore of zinc. It originates from the withered top (the so-called *IRON CAP* or *GOSSAN*) of sphalerite deposits. The ore contains two distinct minerals: dry bone (zinc carbonate, zinc spar, $ZnCO_3$) and zinc silicate (hemimorphite, $Zn_4Si_2O_7(OH)_2.H_2O$). The two minerals are usually very similar in appearance and can only be distinguished through chemical analysis.

HEMIMORPHITE is a sorosilicate mineral, most frequently occuring as the product of the oxidation of the upper parts of sphalerite bearing ore bodies. Hemimorphite is an important ore of zinc and contains up to 54.2% of the metal.

Like hemimorphite, *ZINC SPAR* is a withering product of zinc blende.

3.11 PALLADIUM

Palladium is a soft steel-white metal that resembles platinum, doesn't tarnish in air, and is the least dense and has the lowest melting point of the platinum group metals. It is soft and ductile when annealed and greatly increases its strength and hardness when it is cold-worked. Palladium is chemically attacked by oil of vitriol and aqua fortis (sulphuric and nitric acid).

Palladium is alloyed and used in jewelry. *WHITE GOLD* is an alloy of gold that is decolorized by the addition of palladium. Similar to gold, palladium can be beaten into a thin leaf form.

Palladium is found as a free metal and alloyed with platinum and gold with platinum group metals in placer deposits. Palladium could be extracted from some copper and nickel ores, but this process is not applied throughout Lythia.

3.12 NICKEL

Nickel is silvery white metal that takes on a high polish. It is hard, malleable, and ductile. It is magnetic, and is very frequently accompanied by cobalt, both being found in meteoric iron. On Kethira, the metal nature of nickel is unknown. It is chiefly valuable for the alloys it forms, especially with iron.

Nickel occurs combined with sulphur in millerite, with arsenic in the mineral niccolite, and with arsenic and sulphur in nickel glance. With iron, it occurs in terrestrial and meteoric deposits. The name "nickle" derives from the ore called *NICCOLITE* (nickel arsenide, NiAs) or "copper-nickel" after "Old Nick" and his mischievous gnomes because, though it resembled copper ore, it yielded a brittle, unfamiliar metal.

3.13 COBALT

Cobalt is a hard ferromagnetic silver-white element. It is frequently associated with nickel, and both are characteristic ingredients of meteoric iron. Elementary cobalt is unknown on Kethira.

COBALT GLANCE (Cobaltite, (Co,Fe)AsS) is a rare mineral composed of cobalt, iron, arsenic sulfide. Secondary weathering incrustations of *ERYTHRITE*, hydrated cobalt arsenate, are common. *SKUTTERUDITE* (cobalt arsenide) is a hydrothermal ore mineral found in moderate to high temperature veins with other Ni-Co minerals. Associated minerals are arsenopyrite, native silver, erythrite, and annabergite. Skutterudite has a bright metallic luster, and is tin white or light steel gray in color with a black streak. The specific gravity is 6.5. Hardness is 5.5– 6. The arsenic content gives a garlic odor when heated or crushed.

3.14 MANGANESE

Manganese is a gray-white metal, resembling iron. It is a hard metal and is very brittle, fusible with difficulty, but easily oxidized. Manganese is used to decolorize glass (removing the greenish tinge that presence of iron produces) and, in higher concentration, make violet-colored glass. Manganese oxide is a brown pigment that can be used to make paint and is a component of natural umber.

Manganese was in use in prehistoric times. Paints that were pigmented with manganese dioxide can be traced back 17,000 years. The Sindarin first used manganese compounds in glass-making, to either remove color from glass or add color to it. Manganese can be found in the iron ores used by several nations famed for their advanced weaponcraft. The fame is largely based on the inadvertent production of an iron-manganese alloy by smelting local iron-manganese ores, thus producing a steel with an exceptional hardness.

Manganese occurs principally as pyrolusite (MnO_2), and to a lesser extent as *RHODOCHROSITE* ($MnCO_3$), a rose-red mineral. *PYROLUSITE* is a soft, black, amorphous mineral, often with a granular, fibrous or columnar structure, sometimes forming reniform crusts. It has a metallic luster, a black or bluish-black streak, and readily soils the fingers. The specific gravity is about 4.8. It is used for decolorizing glass. As a coloring material, it is used in dyeing; for imparting violet, amber and black colors to glass, pottery and bricks; and in the manufacture of green and violet paints.

3.15 SALTPETRE

A major source of saltpetre (nitre, potassium nitrate KNO_3) are the deposits crystallising from cave walls or the drainings of decomposing organic material. Dung-heaps are a particularly common source: ammonia from the decomposition of urea and other nitrogenous materials undergo bacterial oxidation to produce nitrate.

NITRE-BEDS are prepared by mixing manure with either mortar or wood ashes, common earth and organic material such as straw to give porosity to a compost pile typically 1.5 metres high by 2 metres wide by 5 metres long. The heap is usually under a cover from the rain, kept moist with urine, turned often to accelerate the decomposition and leached with water after approximately one year. The liquid containing various nitrates is then converted with wood ashes to potassium nitrates, crystallized and refined for use.

One of the most useful applications of potassium nitrate is in the production of *AQUA FORTIS* (nitric acid), by adding oil of vitriol (concentrated sulphuric acid) to an aqueous solution of saltpetre, yielding aqua fortis and potassium sulfate which are separated through fractional distillation.

Saltpetre is also used as a fertilizer, for gunpowder, and in several fireworks such as smoke bombs, in which a mixture with sugar produces a smoke cloud of 600 times their own volume.

3.16 Vitriol

Vitriol is used as a name for any of certain hydrated sulfates or sulphuric acid. *Blue vitriol* is copper(II) sulfate pentahydrate; *green vitriol* – also called *copperas*, a name formerly applied to all the vitriols – is iron(II) sulfate. *White vitriol* is zinc sulfate; *red vitriol* is cobalt sulfate. *Oil of vitriol* is concentrated sulphuric acid.

Vitriols are precipated by seeping water in mines (especially if fire setting has been applied as a mining method) and slag heaps, and form colourful coatings, that may harm the careless miners and smelters.

3.17 Sal Ammoniac

Sal ammoniac (zalmiak) is a rare mineral composed of ammonium chloride (NH_4Cl). In its pure form, sal ammoniac is a clear white water-soluble crystalline salt with a biting taste. The crystals sublimate directly from the gaseous state, and tend to be short-lived, as they dissolve easily in water.

Sal ammoniac is used by alchemists, itcan also be included in solder as flux. Other applications are the use as cough medicine, causing the production of excess respiratory tract fluid which presumably is easier to cough up. In several countries (e.g. throughout Ivinia) sal ammoniac is used to spice up liquorice-type candies and alcoholic beverages.

Sal ammoniac is found around volcanic fumaroles and guano deposits.

3.18 Borax/Tincal

Borax or tincal ($Na_2B_4O_7 \cdot 10\ H_2O$) is a soft and light, colourless crystalline substance. It is used in many ways — as a component of glass and pottery (enamel glazes, strengthening pottery and ceramics), as a solvent for metal-oxide slags in metallurgy, as a flux in welding and soldering: A mixture of borax and ammonium chloride is used as a flux when welding iron and steel. It lowers the melting point of the unwanted iron oxide (scale), allowing it to run off. Borax is also used as a soap supplement, a disinfectant, a mouthwash, and a water softener. Borax has been known since early times, when it was obtained from saline lakes in Kyamu and taken to Diramoa to be refined.

Borax occurs naturally in evaporite deposits produced by the repeated evaporation of seasonal lakes.

3.19 Soda Ash

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline compound with a cooling alkaline taste, and found in the ashes of many plants. It is soluble in water, but can occur naturally in arid regions, especially in the mineral deposits (evaporites) formed when seasonal lakes evaporate. Deposits of the mineral *natron*, a combination of sodium carbonate and sodium bicarbonate, have been mined from dry lake bottoms in Hepekeria and north-western Diramoa since ancient times. Natron is used for millenia in the preparation of mummies.

Soda ash is used in the manufacture of glass, paper, and soap.

3.20 Arsenic

Arsenic is a notorious poisonous metalloid that has three allotropic forms; yellow, black and grey/metallic. When heated it rapidly oxidizes to arsenous oxide, which has a garlic odor. Arsenic and some arsenic compounds can also sublime upon heating, converting directly to a gaseous form. Arsenic has been known and used in Mafan and elsewhere since ancient times.

As the symptoms of arsenic poisoning are somewhat ill-defined, it is frequently used for murder. Arsenic and many of its compounds are especially potent poisons. Arsenic kills by massively disrupting the digestive system, leading to death from shock. See arsenic poisoning. Arsenic and its compounds are used in various alloys, e.g. in the bronze, which makes the alloy harder.

Mispickel (arsenopyrite, $FeSAs$) is the most common mineral from which, on heating, the arsenic sublimes leaving ferrous sulfide. Other arsenic minerals include realgar, mimetite, cobaltite and erythrite.

3.21 Brimstone

Brimstone (sulphur) is an abundant, tasteless, odorless non-metal. Sulphur, in its native form, is a yellow crystaline solid. It burns with a blue flame that emits sulphur dioxide, notable for its peculiar suffocating odor. Sulphur is insoluble in water.

Sulphur finds use in the production of *OIL OF VITRIOL* (sulphuric acid, H_2SO_4), gunpowder, and fireworks. The discovery of sulphuric acid is credited to a 4th century TR azery physician and alchemist, who obtained the subtance by dry distillation of minerals including green vitriol ($FeSO_4 \bullet 7H_2O$), and blue vitriol ($CuSO_4 \bullet 5H_2O$). When heated, these compounds produce a dilute solution of sulphuric acid. For this reason, sulphuric acid is known to western lythian alchemists as oil of vitriol and spirit of vitriol, among other names.

In nature, sulphur can be found as the pure element or as sulfide (e.g. pyrite, cinnabar, galena, sphalerite and stibnite) and sulfate (e.g. gypsum) minerals. It is found in its free form near hot springs and volcanic regions hence the name brimstone, from being found at the brim of craters.

4 CONCENTRATION

Before minerals are refined in expensive processes that require fuel and additives, they are concentrated to raise the efficiency of that later processes. Whenever possible, the concentration work is done in proximity to the mineral deposit to minimize transportation of useless gangue minerals.


Figure 2: Crushing of the ore.

4.1 Crushing

To enable miners to separate valuable *ORE* from worthless rock or *GANGUE MINERALS*, the native rock must be crushed into relative small parts. This effect can be reached when winning the minerals, at daylight on a special, plastered *CRUSHING FLOOR* (Figure 2), or just before further metallurgic processing within specialized facilities, called *STAMPING MILLS*.[1]

Stamping mills are usually set up near the haulage shaft or gallery, where water is available. Water power can be used to drive the stamping mill. The mill consists of several wooden *PISTONS* whose bottoms are weighted with heavy stone *STAMPING SHOES*. The pistons are attached to a wooden frame above a stone flute which holds the ore to be crushed. A waterwheel drives a *CAMSHAFT* that lifts the pistons, which, while falling back, crack the ore within the flute into smaller pieces.

An other method to crush ore is the use of *ORE GRINDS* (see Figure 4). They work similar to grain mills: Ore is ground into small parts or even to fine dust between a fixed and a rotating milling grind.

4.2 Classifying/Screening

After the minerals have been crushed, they are sorted by their size. Classification is usually done by screening the ore. Several sieves, called *SCREENS*, of decreasing mesh size are used to classify the ore depending on its *GRAIN SIZE*. By this means, material small enough for the following steps of processing are selected, the remainder is returned to the step of crushing.


Figure 3: Stamping mill.


Figure 4: Grinding of ore with a water powered mill.


Figure 5: Screening of crushed ore.


Figure 6: Three methods of screening ore.

4.3 Sorting

SORTING is the term for the separation of different minerals. Sorting can be done by hand or mechanized, using differing physical properties of the minerals to sort.

4.3.1 Handpicking/hand sorting

Most minerals can be identified by their outer appearance (e.g. geometry and color of the crystals). By visual inspection and further crushing of the minerals with a handpick or hammer, the ore is separated from the gangue minerals. This kind of sorting is done in a separate building called *SORTING BENCH* (Figure 7). Though this is a hard and unhealthy work due to noise, dust and dampness, this is a common task for invalid miners, for women and even for children (Figure 8).

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[1] The first Hârnic crushing mill was built in 342 TR. Today about 96 crushing mills are in use, most of them are animal or slave powered.

Figure 7: Handpicking at the sorting bench.

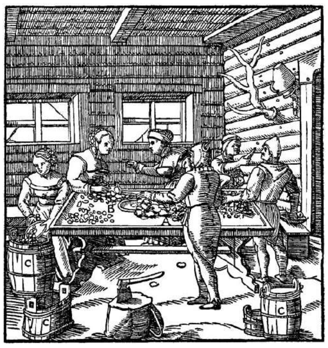

Figure 8: Handpicking by women and children.

4.3.2 WASHING

Figure 9: Washing with fleece covered tables.

A more efficient way of sorting is to make use of the higher specific gravity of ores compared to gangue minerals. The raw ore is crushed or ground into relative small pieces (fine-grained material can be processed directly). Then, water is used to separate the dense ore from the light rock: while the heavy mineralized ore sinks down quickly, the light debris sinks down slower and can be washed out by lateral movement of the water. The water can be set into motion within a container (e.g. the *WASHING PAN* commonly used to wash river gold) or by a steady current on a slightly declining *TABLE* or *SLUICE BOX*. The table usually has horizontal rugs or riffles to enhance the sedimentation (Figure 10; such a kind of table is the "long tom"). Other tables are covered with *HIDES*, whose pores can concentrate even small portions of ore (Figure 11). A ram's hide, or *FLEECE*, is used to separate smallest gold foils from placer sediments or ground rock: The slightly lipophilic gold particles adhere to the fatty hairs of the unshaved hide (Figure 9).

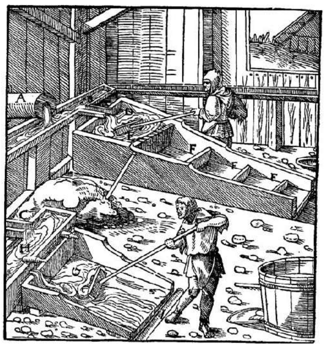

Figure 10: Washing on the rugged table.

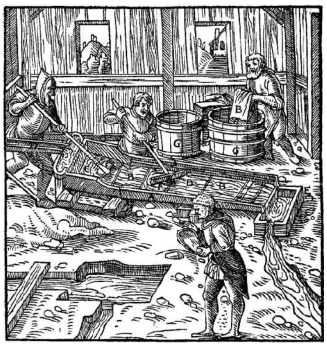

Figure 11: Washing on a table spanned with hides.

5 SMELTING

Figure 12: Heap-roasting.

After the steps of crushing, screening, and sorting the ore has reached the state of a concentrate, i.e. the content of the metal-bearing mineral has been increased to a level allowing for a profitable metal extraction.

The next step in the metallurgic process is *SMELTING*. This is usually the most complicated and challenging step, beause its success depends on several mutable factors, as the quality of ore, *ADDITIVES* and *FUEL*. Impurities within these basic materials – sometimes even traces of harmful substances – can raise problems to the smelting process. As all ingredients vary in their chemical composition, a smelter must carefully observe the process and intervene according to his experience to face problems. Suitable measures include controlling temperature and oxygene level, choosing the appropriate mix of base materials, and readapting the right amount of additives (e.g. fluxes like quartz, limestone, or iron).

5.1 FUEL

Wood is the most used fuel on Lythia, but also dried dung and turf are in wide use. In some regions of the far-east, natural gas is used for cooking and in salt-pans. To our knowlegde coal (and coke) is only used by the Khuzdul.

While these types of fuel are good for many applications, as warming, and cooking. For most metallurgic processes, their energetic capacity and density are inadequate. Also, impurities within most organic fuels may harm the metallurgic processes. Instead, charcoal is used. In combination with a sufficient airflow (blast) it allows to reach the high temperatures needed to smelt ores and to reduce the contained metals.

5.2 FLUXES

FLUXES or *ADDITIVES* are sustances, that are added to the ore/fuel mix during the smelting process. Their function depends on the process actually applied. Usually, they help in reducing the metal's melting temperature and thereby make smelting feasible. They also prevent the hot metal from oxidation, improve its separability (preventing it to adhere or being absorbed by the slag). Typical additives are limestone, lead ores (litharge, galena), furnache slags (amorphous silica), soda ($Na(OH)_2$), salpetre (KNO_3), burt alum, vitriol, sand or borax. Coal, charcoal or organic substances as flour or even blood are used to absorb oxygene set free during the reduction.

Usually, several additives need to be combined to get a potent flux. The recipe is tried out in series of trial-and-error experiments for each ore. Since the flux is crucial to the economic operation of a smelter, its composition is often kept as a well-concealed secret of a mine's master smelter.

5.3 FURNACES AND HEARTHS

The temperature needed to smelt metal from its ore is created by burning some kind of combustion material. Usually, *WOOD* is used to fire the furnaces, but if high temperatures are needed, smelters rely on *CHARCOAL*. In *BLAST FURNACES*, the temperature can be increased by blowing air into the furnace through *NOZZLES*. Early metallurgists relied on the natural drought created by the wind. Therefore, they built their furnaces near the crestline of hills and restricted smelting to the seasons with sufficient airflow to fan their kilns. This method is simple and effective, but restricts smelting to certain times and locations. To overcome this limitations and achieve more reliable and controllable smelting conditions, artificial blow can be used. It is created either by mouth-blown *BLOWPIPES*, or by *BELLOWS*, which are operated by men, by animals or – if financial and natural resources allow for it – by waterwheels (so called *BLOWING MILLS*).[2]

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[2] Although the first *FORGE MILL* that combines water-powered bellows with water-powered forge hammers was notably constructed in 702 TR by master millwright Pano of Lehia at Gosus/Melderyn, sheer blowing mills have been in use for half a century before. The design of forge mills was brought in from Shorkyne and spread quickly

The construction of a smeltery must be undertaken with care. The location should ease the transport of needed fuel and prepared ore. As the step of concentration and blow-mills need a steady supply of large amounts of water, the presence of a stream or an other water supply is essential. Though, the location of a smeltery should be save from flooding. These facts make slopes above the valley bottoms below the mines an ideal location for smelteries. They usually process ore from several mines within the area.

When a suitable location for the smeltery is found, the furnace must be carefully constructed: As moisture will interfere with the reagents, and might even damage the walls of the furnace during the smelting process, the furnace bottom must be prepared and isolated from the surrounding ground. Usually, a pit or *WATER TANK* is excavated and probably dressed with masonry. A vent allows vapour to evade from the pit out of the furnace. The pit is filled with a packed mixture or pulverized earth and pulverized charcoal.

Above the pit, the furnace walls are erected either by masonry lined with a clay-charcoal dressing or refractory bricks, or by a simple cylindric or conic clay-wall. While furnaces of the first type can be used several times, the latter one must be torn down after a single smelting. To stabilize the lining, the furnace will be pre-heated prior to use. The function of the lining is to reflect the heat, and to prevent the reagents to react with the furnace-wall itself. Depending on the purpose of the furnace and the process to achieve, the furnace will get additional outfittings.

For a shaft furnace, the base of the front wall will usually be made of clay with a *TAP-HOLE* to allow the tapping of the furnace – this is to open the furnace by penetrating the clay sealing of the tap-hole with an iron stake (*TAPPING-BAR*; **FIGURE 17, H**) to tap the slag or liquefied metal from the bowl of the furnace. In front of the Furnace, below the tap-hole, a round depression is prepared to contained tapped slag or metal. This cavity is called *FOREHEARTH*. Depending on the intended mode of operation, furnaces can be built with an *OPEN* or a *CLOSED PASS* (tap-hole) in its front. Furnaces with permanently open tap-holes may have two consecutive forehearths – an upper and a lower one (**FIGURE 16, C-D**). By this design, tapped liquids can be separated according to their density – the heavy metal sink to the bottom, while the light slag float on top of it.

5.4 TYPICAL PROCESSES


Figure 13: Smeltery with shaft furnaces in operation.

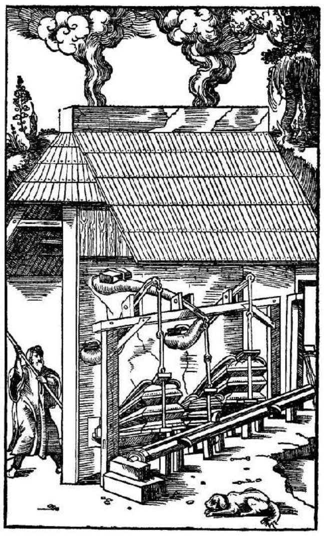
Figure 14: Backside of the smeltery with shaft furnaces, showing the bellows.

5.4.1 CALCINATION & REDUCTION

At least for low-grade ores, the first step in the metallurgic process is the *CALCINATION* or *ROASTING*. The goal is to crack up large blocks of ore, a second to remove the harmful sulphur and arsenic from sulphidic/-arsenic ores by reduction, thus gaining oxidic ore.

The simplest form of calcination is called *HEAP-ROASTING*, which is perforemd by throwing medium-sized pieces of ore into a bonfire (**FIGURE 12**). A more advanced method is to apply lyered pulverized ore and charcoal to a *SHAFT FURNACE* (**FIGURES ,14,15**, and **18**) or a *WIND-BLOWN FURNACE* erected on the slope of a hill, so that the wind blows into the furnace, and fans the fire.


Figure 15: Shaft furnace with hand-powered bellows.

For high graded ores, this step can be omitted.

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through eastern Hârn. Today, there are 19 forge mills, only four of them west of the Kald, none yet in Orbaal (See **MILLERS 19**).

5.4.1.1 SMELTING OF LEAD

Examples are the calcination of galena at 800-900°C: $2\ PbS + 3\ O_2 \rightarrow 2\ SO_2 + 2\ PbO$, and the subsequent reduction at 1,000-1,200°C:

1. $2\ C + O_2 \rightarrow 2\ CO$,
   $CO + PbO \rightarrow CO_2 + Pb$
   (*"DIRECT REDUCTION"*),
2. $C + 2\ PbO \rightarrow CO_2 + 2\ Pb$
   (*"INDIRECT REDUCTION"*).

Lead ores thus produce *WORK LEAD*, containing samll quantities of gold, silver, copper, antimony and zinc. Argentiferous lead ores may produce work lead with a silver content of 0.2-0.3%.

5.4.1.2 SMELTING OF COPPER

Another example for reductive smelting is the smelting of copper (Figure 20)

Figure 18: Construction of the shaft furnaces from Figures 13, and 14.

Figure 19: Tools for closing the front of a shaft furnace.

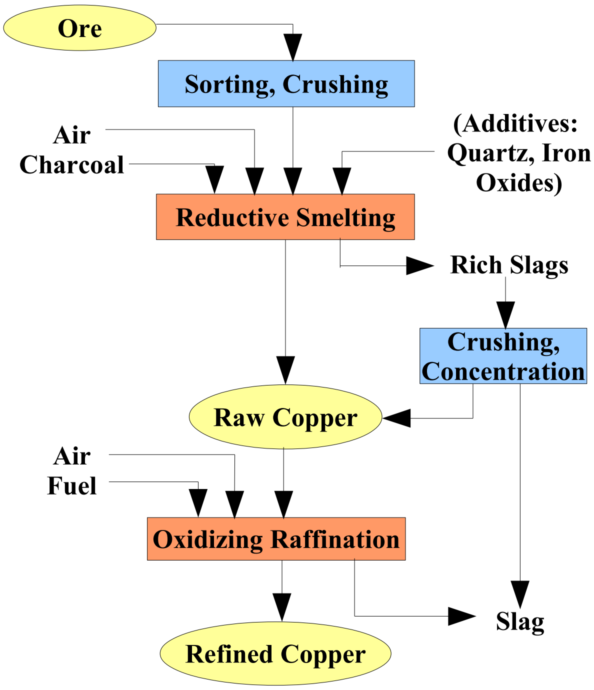

Figure 20: Smelting of oxidic copper ores (e.g. malachite, 57.5% Cu).

5.4.2 PIG IRON PROCESS

A *BLAST FURNACE* is the most advanced method used to produce *PIG IRON* from calcinated oxidic or sulphidic iron ore and charcoal. The furnace is built in the form of a tall chimney-like cauldron lined with refractory brick. Charcoal, limestone and iron ore are poured in the top, which would normally burn only on the surface. Air is blown into the middle by means of bellows, thus the "blast", allowing combustion in the middle of the mixture. The results of this localized burning is a liquid that sinks to the bottom of the furnace, with the lighter materials on top. The furnace is opened to allow the *SLAG* to pour out, and once emptied, another hole is hewn into the bottom to remove the pig iron. The exact nature of the reaction is: $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$. Air blown into the furnace reacts with the carbon in the coal to produce carbon monoxide, which then mixes with the iron oxide, reacting chemically to produce pure iron and carbon dioxide, which leaks out of the furnace at the top. The temperature in the furnace typically runs at about 1500°C, which is enough to also decompose limestone (calcium carbonate) into calcium oxide and additional carbon dioxide: $CaCO_3 \rightarrow CaO + CO_2$. The calcium oxide reacts with various acidic impurities in the iron (notably silica) and floats with the slag, thereby further purifying the iron. The pig iron produced by the blast furnace is not very useful directly due to its high carbon content, around 4-5%, making it very brittle. Further processing was needed to reduce the carbon content for use as a construction material. For some time the product of the blast furnace was used almost directly as wrought iron after additional processing, as the conversion to steel using the crucible technique was too expensive to operate on a large scale.

5.4.3 CAST IRON PROCESS

The cast iron process is dominant in eastern Lythia (esp. Diramoa), but almost unknown in western Lythia.

If iron ores are heated with carbon to 1420–1470 K, a molten liquid is formed, an alloy of about 96.5% iron and 3.5% carbon. This product is strong, can be cast into intricate shapes, but is too brittle to be worked, unless the product is decarburized to remove most of the carbon.

5.4.4 CUPELLATION

The extraction of silver from argentiferous lead (work lead) is called *cupellation*. Cuppelation can also be applied to separate gold from lead. It is an advanced metallurgic process in which the work lead is heated to a high temperature (about 800° C) under strongly oxidizing conditions within a cupellation furnace (**Figures** 21**,** 22). The work lead is placed on a *cupel* (a flat, porous dish made of a refractory, or high-temperature-resistant, material) and then a blast of hot air is directed on it in a special furnace. An iron *cupellation hat* covers the cupel and helps to increase the temperature. Other, more traditional designs use masoned domes instead of the hat to cover the cupellation furnace. The impurities, including lead, copper, tin, and other unwanted metals (lead in the first line), are oxidized and partly vaporized and partly absorbed into the pores of the cupel. Branches of fir wood are used to skim off the slags. The noble silver and gold remain in the elemental form. Granulated iron is added to bind any sulphur still impuring the silver. The slags still have a significant silver-content and are recirculated to the process. The complete process takes 4 days, including the preparation of the furnace, and the smelting process.

Figure 21: Construction of a cupellation furnace.

Figure 22: Cupellation furnace in operation.

5.4.5 LIQUATION (SEIGER PROCESS)

Argentiferous copper is processed by *liquation* in the so-called *Seiger process*. This process allows for the thermal separation of different metals (lead, copper, silver) found together in polymetallic, sulphidic ores. Raw copper is smelted with lead in a blown shaft furnace or a special *liquation furnace* (**Figure 25**). Within its reducing atmosphere, the temperature exceeds the smelting point of lead, but not that of copper. A lead has a large affinity to silver, it solutes the silver, liquates out, and is cast into round plates. The plates are smelted on an open charcoal fire within an open kiln, and the smelted argentiferous lead is admitted to the cupellation process.

The by-products of the process contain considerable amounts of lead and silver and are re-processed for several times.

The complete liquation process has six stages (**Figure 23**):

1. *Leading*: Melting argentiferous copper with lead in a blast furnace to form “liquation cakes”. If the copper contains too little silver to allow liquation directly, the coppewr is enriched in the *Splicing* step: by melting and drawing off from a settling pot the less argentiferous *tops* from the the metal. The liquation cakes are made from the silver rich *bottoms*.
2. *Liquation* of the argentiferous lead from the copper in a special furnace under non-oxiding conditions (**Figure 25**).
3. *Drying* the residual copper, which retains some lead with a free admisson of air. Expelling lead is oxidized.
4. *Cupellation* of the argentiferious lead in a cuppelation furnace (**Figures** 21**,** 22).
5. *Refining* of the residual copper from the drying furnace by oxidation of impurities and poling in a refining furnace
6. *Re-alloying and Re-liquation* of the by-products.

Ususal losses during the liquation process are:

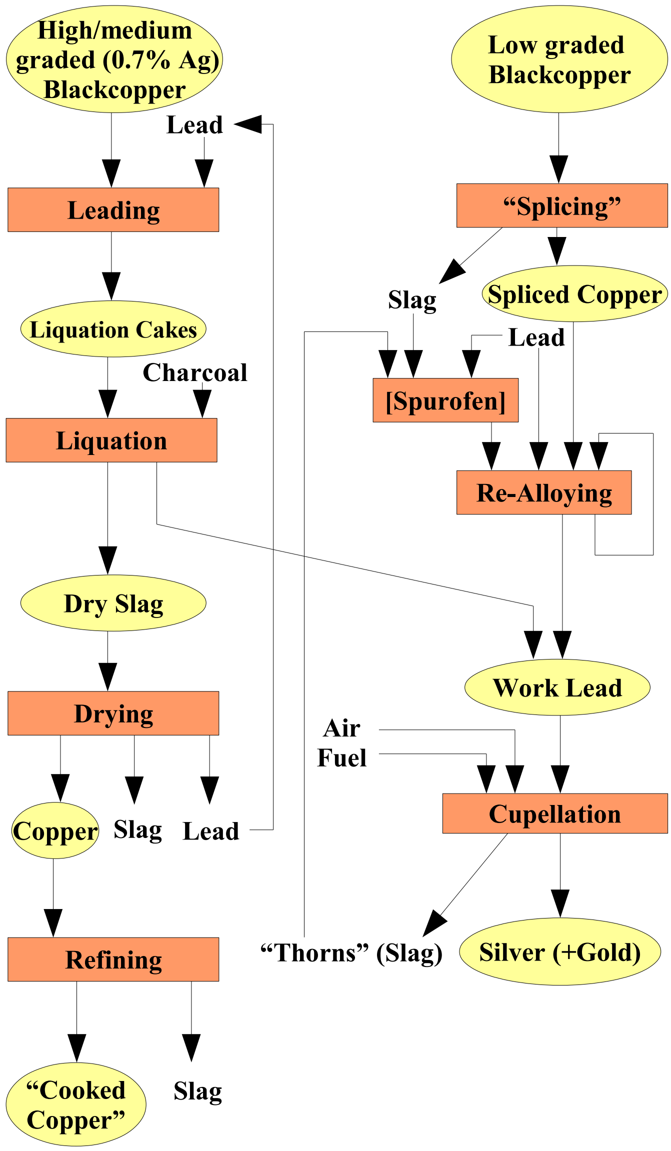

Figure 23: Processing scheme for copper and silver from argentiferous copper ores.

- 20% of the contained silver,
- 9.1% of the copper,
- 16% of the lead.

5.4.6 Amalgamation

Silver and gold may be concentrated by use of mercury (quicksilver). Mercury, a rare liquid metal, is able to alloy with native silver and native gold. It solutes even smallest quantities of the metals from the matrix rock.

For Amalgamation, the ore is ground and put into a barrel. Mercury is added and the content of the barrel is stirred continuously.

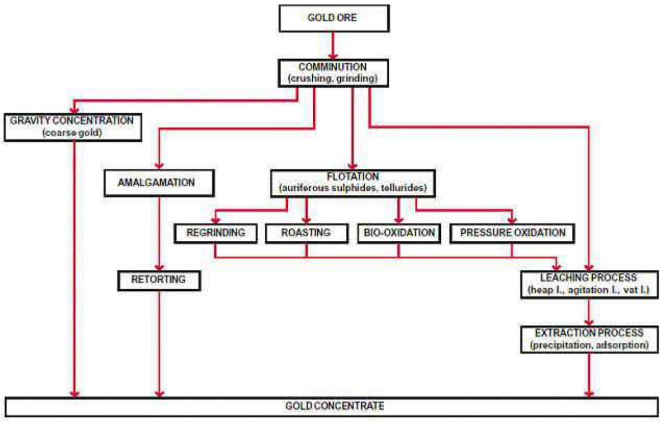

Figure 24: Concentration and Extraction for Gold Ores

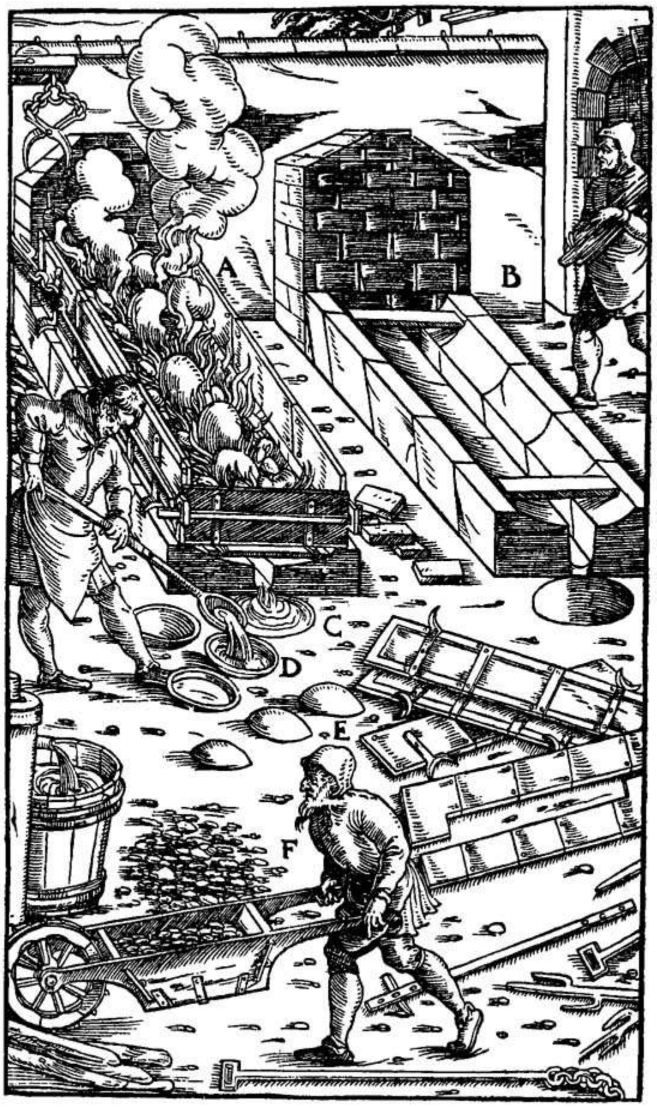

Figure 25: Liquation Furnace.

5.4.7 Leaching

llll

5.4.8 Steelmaking (via soft iron)/Rennfeuer-Verfahren

llll

5.4.9 STEELMAKING (VIA CAST IRON)

Llll

6 ALLOYING & REFINEMENT

7 SMELTERIES

[...]Silver smelting: *“Ores originally smelted using only simple wind-blown bole hearths but that method was found wanting - only capable of reducing the larger 'bing' ore and leaving appreciable amounts of lead and silver in the residues. There ensued a period of experimentation with smelting methods - including the 'hutt', a form of liquation - culminating in the bole / furnace complex which served the lead-silver industry until the advent of the ore hearth process in the 16th century. ”*

“The preparation, smelting and refining required to process the silver-bearing ores were an integrated part of Crown operations at Bere Ferrers. During the first few years of operations in the late 13th century production was based on the wood fired, wind blown 'bole' smelting technique brought from the lead mining areas of northern England. However the bole was not capable of efficiently smelting all the ore mined and was soon augmented by charcoal fired, bellows blown furnaces developed through a period of experimentation. Transport by horse and by river played an important part in the processing operations. Ore was moved from the mines to washing sites where waste was removed by simple gravitational separation. From there it was taken to one of a number of smelting sites. Bole smelting sites were located as far afield as Milton to the east of the Tavy. Residues from smelting were removed for crushing and washing to separate the waste. Those parts still rich in lead and silver were then re-smelted in the furnace.“

*“A **Bole hill** (also spelt **Bail hill**) was a place where lead was formerly smelted in the open air. The bole was usually situated at or near the top of a hill where the wind was strong. Totley Bole Hill on the western fringes of Sheffield consisted of a long low wall with two shorter walls at right angles to it at each end. At the base of a bole 20 foot long were laid great trees called blocks. On these were laid blackwork, partly smelted ore about half a yard thick. Then came ten or twelve trees called shankards. On top of these three or four courses of fire trees were laid with fresh ore. This was ignited and burnt for about 48 hours. This smelted lead, which ran down channels provided for the purpose and was cast into sows of about 11 hundredweight. A single firing produced 16 fothers of lead (about 18 tons) from 160 loads of ore (about 40 tons) and 30 tons of wood. Much of the ore was left incompletely smelted having become blackwork. Some of this was smelted in a foot-pump blown furnace, but some was left to be used when the bole was next fired. Bole smelting was replaced by smelting in smeltmills in the late 16th century. That was in turn replaced by smelting in cupolas, a variety of reverberatory furnace in the 18th century. ” (Wikipedia)*

*“A **bloomery** is a type of furnace once widely used for smelting iron from its oxides. The bloomery was the earliest form of smelter capable of smelting iron. A bloomery's product is a porous mass of iron and slag called a **bloom**. This mix of slag and iron in the bloom is called sponge iron, which is usually consolidated (shingled) and further forged into wrought iron. The bloomery has now largely been superseded by the blast furnace, which produces pig iron.*

A bloomery consists of a pit or chimney with heat-resistant walls made of earth, clay, or stone. Near the bottom, one or more clay pipes enter through the side walls. These pipes, called tuyères, allow air to enter the furnace, either by natural draft, or forced with a bellows. An opening at the bottom of the bloomery may be used to remove the bloom, or the bloomery can be tipped over and the bloom removed from the top.

The first step taken before the bloomery can be used is the preparation of the charcoal and the iron ore. The charcoal is produced by heating wood to produce the nearly pure carbon fuel needed for the refining process. The ore is broken into small pieces and roasted in a fire to remove any moisture in the ore. Any large impurities in the ore can be crushed and removed. Since slag from previous blooms may have a high iron content, slag from previous blooms can be broken up and recycled into the bloomery with the new ore.

In operation, the bloomery is preheated by burning charcoal, and once hot, iron ore and additional charcoal are introduced through the top, in a roughly one to one ratio. Inside the furnace, carbon monoxide from the incomplete combustion of the charcoal reduces the iron oxides in the ore to metallic iron, without melting the ore; this allows the bloomery to operate at lower temperatures than the melting temperature of the ore. As the desired product of a bloomery is iron which is easily forgeable, nearly pure, and with a low carbon content, the temperature and ratio of charcoal to iron ore must be carefully controlled to keep the iron from absorbing too much carbon and thus become unforgeable. Limestone can also be added to the charge (about 10% of the ore weight) as a flux, to remove impurities.

The small particles of iron produced in this way fall to the bottom of the furnace and become welded together to form a spongy mass of the bloom. The bottom of the furnace also fills with molten slag, often consisting of fayalite, a compound of silicon, oxygen and iron mixed with other impurities from the ore. Because the bloom is highly porous, and its open spaces are full of slag, the bloom must later be reheated and beaten with a hammer to drive the molten slag out of it. Iron treated this way is said to be wrought, and the resulting nearly pure iron wrought iron.”

“During the Han Dynasty (202 BC–AD 220), Chinese ironworking achieved a scale and sophistication not reached in the West until the eighteenth century. In the first century, the Han government established ironworking as a state monopoly and built a series of large blast furnaces in Henan province, each capable of producing several tons of iron per day. By this time, Chinese metallurgists had discovered how to puddle molten pig iron, stirring it in the open air until it lost its carbon and became wrought iron. (In Chinese, the

process was called chao, literally, stir frying.) By the 1st century BC, Chinese metallurgists had found that wrought iron and cast iron could be melted together to yield an alloy of intermediate carbon content, that is, steel.[27][28][29] According to legend, the sword of Liu Bang, the first Han emperor, was made in this fashion. Some texts of the era mention "harmonizing the hard and the soft" in the context of ironworking; the phrase may refer to this process. Also, the ancient city of Wan (Nanyang) from the Han period forward was a major center of the iron and steel industry.[30] Along with their original methods of forging steel, the Chinese had also adopted the production methods of creating Wootz steel, an idea imported from India to China by the 5th century AD.[31] "

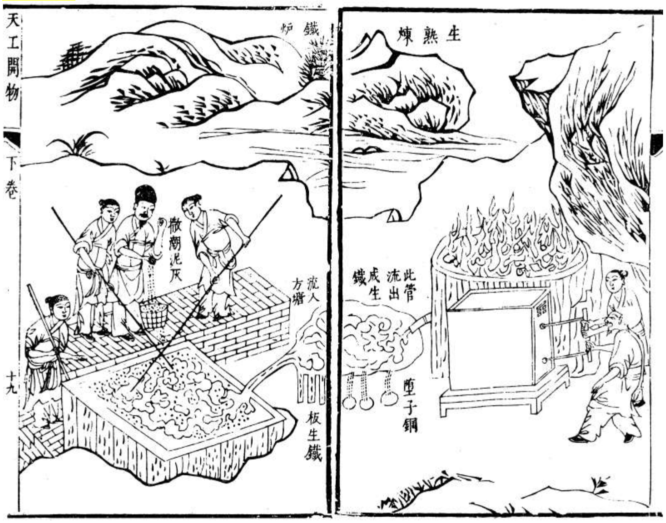

Figure 26: The puddling process of smelting iron ore to make pig iron from wrought iron, with the right illustration displaying men working a blast furnace, from the Tiangong Kaiwu encyclopedia, 1637.

8 OCCUPATIONAL DISEASES

Inhaling and coming in touch with aggressive and poisonous smokes and dusts often results in typical diseases. Some of these illnesses are so characteristic, that Lythian physicians have discovered their relation to the work in mines and smelteries.

8.1 Silicosis

Pneumoconioses by effect of lung-traveling, flint-acid dust; inhaled silicon dioxide-containing dust (SiO_2) like quartz, cristobalit or tridymit in grain sizes < 5 µm produces connective tissue based nods and fibrotic modifications within the lungs; predisposition for tuberculosis. **Symptoms**: Dry cough with ejection, progressive difficulty in breathing with chest pain and right heart load; usually restrictive, frequently also combined impairment of ventilation, on a long-term basis development of a pulmonal hypertonia and cor pulmonale.

8.2 Poisonings

8.2.1 Lead poisoning

Poisoning, above all by inhalation of Pb-containing dust, smoke or steam. **Symptoms**: Insidious beginning with tiredness, inappetence, stomach-ache, headache and pains of the joints, obstipation, gastrointestinal colic attacks and paleness, later (caused by vasoconstriction) possibly development of shrinking kidneys, angina pectoris attacks, gangrene of the distal extremities, chronic encephalopathia saturnina, at the growing skeleton condensation of the spongiosa at the shaft ends of the long tube bones, with the adult lead inflicted osteosclerosis; more frequently also painful peripheral nerve paralysis, above all paralysis of the radialis, rarely paralysis of the fibularis. **Diagnosis**: black-blue to slate-gray lead seam of the gums (lead sulfide). **Therapy**: EDTA (ethylene diaminte tetra-acetic acid) i.v. as an antidote.

8.2.2 Arsenic poisoning

Intoxication, above all by high-poisonous white arsenic. Chronic arsenic poisoning: Arsenicmelanosis (dark gray pigmentation), arsenic-ceratosis (wart-like hyperceratosis of the palms and soles or planar hyperceratosis with rhagades), Mees-strips, acne-like skin lesions of the face, possibly carcinoma of the skin, hepatopathy, polyneuropathy, encephalopathy. The effect of white arsenic is based on a damage of the blood capillaries.

8.3 Consumption (lung tuberculosis/ silicotuberculosis)

Sog. Lungenschwindsucht; Tuberkulose der Lunge (häufigste Form der Tbc)

[...]

8.4 Lung fibrosis by metallic dust

Change of the lung framework to scarred connective tissue, usually as the final state of a chronic inflamed lung disease; leads to the development of a restrictively impaired ventilation with decreased oxygen partial pressure and formation a chronic cor pulmonale; **Diagnosis**: dyspnea under load, later even quiescent dyspnea, cough, fever thrusts, decrease of weight, clubbed fingers, cyanosis.

8.5 Noise trauma deafness

Damage of the ear by long-term effect of noise (exposure of many years, starting from 85dB(A).

9 SIDE EFFECTS OF MINING AND METALLURGY

This section wants to discuss the side effects of mining and processing ores. Smelteries consume vast quantities of natural resources, as fuel (primary wood) and water (both as power source and process water), first using the local, later related ones. Piling up heaps of possibly poisonous overburden, ashes and slags, changes the landscape itself. The needs of large installations as smelteries will cause changes in the local infrastructure and economic system: trails will be build to transport raw materials and products, specialised workshops to supply the specific demands of tools and their maintenance, markets to deal with food and products.

[...]

9.1 EFFECT ON THE ENVIRONMENT

[...]

9.1.1 HEALTH RISKS

Stressing the organism with poisonous gases and heavy metals via breathing air and the food chain.

[...]

9.1.2 SOIL CONTAMINATION

Concentration of heavy metals in sediments and soils by washing out or displacement of heaps (overburden and slags).

[...]

9.1.3 WATER POLLUTION

[...]

9.1.4 AIR POLLUTION

[...]

9.1.5 FORREST DESTRUCTION

[...]

9.1.6 CHANGING THE LANDSCAPE

[...]

9.2 ECONOMIC EFFECTS

[...]

9.2.1 INFLUENCES ON THE LOCAL INFRASTRUCTURE AND ECONOMY

[...]

9.2.2 INFLUENCES ON FINANCIAL POLICY AND GLOBAL ECONOMY

[...]

10 REFERENCES

[Agricola1557] Agricola, Georgius: De Re Metallica Libri XII, Basel 1556 (lat.), Basel 1557 (german by P. Bech).

[AlterBergbau] Steuer, Heiko; Zimmermann, Ulrich [editors]: Alter Bergbau in Deutschland, (special issue of: Archäologie in Deutschland), Hamburg 2000.

[Araka] King, Edwin; Kowan, Dave: Araka-Kalai. Harnmaster Adventure Module, Blaine/ Vancouver 1987.

[Azadmere] Crossby, N. Robin; Dalgliesh, Tom; King, Edwin: Azadmere. Dwarven Kingdom, 1st edition 3rd printing, Blaine/ Vancouver 1989.

[Bushels] Hamlin, Garry; Strommen, Randolph L.: 100 Bushels of Rye. Adventure Module, 1st edition, Blaine/ Vancouver 1988.

[CastlesH] King, Edwin; Porter, Richard: Castles of Hârn, 1st edition, Blaine/ Vancouver 1987.

[CastlesO] King, Edwin; Dalgliesh, Tom: Castles of Orbaal, 1st edition, Blaine/ Vancouver 1992.

[Chybisa] Crossy, N. Robin; King, Edwin: Chybisa. Kingdom Module, 2nd edition, Blaine/ Vancouver 1987.

[Cities] Crossby, N. Robin; Steinhilber, Garry; Dalgliesh, Tom: Cities of Hârn, Blaine/ Vancouver 1983.

[Czaya1990] Czaya, Eberhard: Der Silberbergbau, Leipzig 1990.

[Dead] Kapp, Oliver; Bohnsack, Frank: Dead of Winter, 1st edition, Blaine 1998.

[Evael] Frazer, John; King, Edwin; Porter, Richard: Evael. Kingdom of the Elves, 1st edition, Blaine/ Vancouver 1986.

[Freise1908] Freise, Friedrich: Geschichte der Bergbau- und Hüttentechnik. Erster Band: Das Altertum, Berlin 1908.

[Greeves1978] Greeves, T.A.P: An outline archaeological and historical survey of tin mining in Devon, England, 1500-1920; in: ICOHTEC Internationales Symposium zur Geschichte des Bergbaus und Hüttenwesens Freiberg 1978 - Vorträge Band 1; Freiberg 1978.

[Hârndex] Crossby, N. Robin; Dalgliesh, Tom; King, Edwin: HârnWorld. A Real Fantasy World, (HârnDex), 2nd edition,Blaine/ Vancouver 1990.

[HârnMap] Crossby, N. Robin; Dalgliesh, Tom; King, Edwin: HârnWorld. A Real Fantasy World, (HârnMap), 2nd edition,Blaine/ Vancouver 1990.

[HârnPlayer] Crossby, N. Robin: HârnPlayer. A Player's Guide To HârnWorld, 1st edition, Blaine 1994.

[HârnWorld] Crossby, N. Robin; Dalgliesh, Tom; King, Edwin: HârnWorld. A Real Fantasy World, (HârnWorld), 2nd edition,Blaine/ Vancouver 1990.

[Healy1978] Healy, John F.: Mining and metallurgy in the greek and roman world, London 1978.

[Heroth] Castle of Heroth, 1987.

[HM1] HârnMaster 1st edition

[HMB] Crossby, N. Robin; Dalgliesh, Tom; King, Edwin; Sgammato, John; Stengel, Cal: HarnMaster Barbarians, Blaine 2000.

[HMC] Crossby, N. Robin; Bratager, Kevin; Dalgliesh, Tom: HârnMaster. Core Rules, 2nd edition, Blaine 1996.

[HMG] Crossby, N. Robin: HârnMaster Gold – Player Edition. Second Edition Roleplaying Rules by N. Robin Crossby Author's Cut, 1998.

[HMM] Crossy, N. Robin; Bratager, Kevin; Dalgliesh, Grant; Dalgliesh, Tom: HârnMaster Magic. Tome of the Shek-Pvar, 1st edition, Blaine 1997.

[HMMn] Crossby, N. Robin; Dalgliesh, Tom; Davidson, Jonathan; Sgammato, John: HârnManor, 1st edition, Blaine 1999.

[HMR] Crossby, N. Robin; Dalgliesh, Tom; Fraser, John; King, Edwin: HârnMaster Religion. Libram of the Pantheon, 1st edition, Blaine 1998.

[IviniaIndex] Crossby, N. Robin: Ivinia, (Ivinia Introduction), Blaine/ Vancouver 1985.

[IviniaIntr] Crossby, N. Robin: Ivinia, (Ivinia Index), Blaine/ Vancouver 1985.

[IviniaMap] Crossby, N. Robin: Ivinia, (Ivinia Map), Blaine/ Vancouver 1985.

[Kaldor] Crossby, N. Robin; Dalgliesh, Tom; Gutteridge, Lance; Fraser, John; King, Edwin: Kaldor. Kingdom Module, Blaine/ Vancouver 1986.

[Kanday] Dalgliesh, Tom; Huber, Mikkel; King, Edwin; Porter, Richard; Sanderson, Jim: Kanday. Kingdom Module, 1st edition, Blaine/ Vancouver 1996.

[LdBk1] Heise, Fritz; Herbst, Friedrich: Lehrbuch der Bergbaukunde. Mit besonderer Berücksichtigung des Steinkohlenbergbaus, (Vol. 1), 6th ed., Berlin 1930.

[LdBk2] Heise, Fritz; Herbst, Friedrich: Lehrbuch der Bergbaukunde. Mit besonderer Berücksichtigung des Steinkohlenbergbaus, (Vol. 2), 7th ed., Berlin/ Göttingen/ Heidelberg 1950.

[Liessmann1997] Liessmann, Wilfried: Historischer Bergbau im Harz, 2nd corrected and extended edition, Berlin/ Heidelberg/ New-York 1997.

[Melderyn] Crossby, N. Robin; Dalgliesh, Tom; Huber, Mikkel; King, Edwin; Porter, Richard; Simpson, Terry: Melderyn. Kingdom Module, 1st edition, Blaine/ Vancouver 1987.

[Menglana] Crossby, N. Robin; Dalgliesh, Tom; Huber, Mikkel: Menglana. Kingdom Module, 1st edition, Blaine/ Vancouver 1987.

[Nasty] King, Edwin: Nasty, Brutish and Short. The Orcs of Hârn, 1st edition Blaine 1997.

[Orbaal] Clemens, Brian; Fraser, John; King, Edwin; Kowan, Dave; Dalgliesh, Tom: Orbaal. Kingdom Module, 1st edition, Blaine/ Vancouver 1987.

[Panaga1] Crossby, N. Robin: The Staff of Fanon. Adventure Module, 1st edition, Blaine/ Vancouver 1988.

[Panaga2] Crossby, N. Robin: Kiraz. The Lost City, 1st edition, Blaine/ Vancouver 1989.

[Panaga3] Crossby, N. Robin: Curse of Hlen. Panaga Awaits..., 1st edition, Blaine/ Vancouver 1993.

[Pilots] Crossby, N. Robin; Dalgliesh, Tom: Pilots' Almanac. Maritime & Piloting Rules, 1st edition, Blaine/ Vancouver 1988.

[Pschy1994] Pschyrembel Klinisches Wörterbuch, 257th ed., Berlin/ New York 1994.

[Rethem] Rethem. Kingdom Module, 1st edition, Blaine/ Vancouver1985.

[Rosumek1982] Rosumek, Peter: Technischer Fortschritt und Rationalisierung im antiken Bergbau. (Habelts Dissertationsdrucke: Reihe Alte Geschichte; H. 15), Bonn 1982.

[ShekPvar] Crossby, N. Robin: The Ancient & Esoteric Orders of the Shek-Pvar, 1st edition, Baine/ Vancouver 1990.

[Shorkyne] Crossby, N. Robin: Shoryne. Regional Expansion Module, 1st edition, Blaine/ Vancouver 1991.

[SonOC] King, Edwin; Clemens, Brian: Son of Cities. An Expansion Module for Cdities of Hârn, Blaine/ Vancouver 1987.

[Tharda] Floy, Margaret; King, Edwin: Tharda. Republic Module, 1st edition, Blaine/ Vancouver 1987.

[VGE1999] Brabeck; Lyons; Scharlibbe: VGE-Bergbau-Fachwörterbuch, Essen 1999.

[VH1] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 1), Wiesbaden 1993.

[VH2] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 2), Wiesbaden 1994.

[VH3] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 3), Wiesbaden 1994.

[VH4] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 4), Wiesbaden 1994.

[VH5] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 5), Wiesbaden 1994.

[VH6] Bohnsack, Frank [editor]: Var-Hyvrak, (Issue 6), Wiesbaden 1995.

[Wagenbreth1985] Wagenbreth, Otfried; Wächtler, Eberhard [editors]: Der Freiberger Bergbau. Technische Denkmale und Geschichte, 1st ed., Leipzig 1985.

[Wilsdorf1987] Wilsdorf, Helmut: Kulturgeschichte des Bergbaus. Ein illustrierter Streifzug durch Zeiten und Kontinente, Essen 1987.

[Winkelmann1956] Winkelmann, H.: Schwazer Bergbuch, [Hrsg.: Gewerkschaft Eisenhütte Westfalia], Bochum 1956.