ARCHIMEDES

in the Middle Ages

VOLUME FOUR

A SUPPLEMENT ON THE MEDIEVAL
LATIN TRADITIONS OF CONIC SECTIONS
(1150–1566)

PART I: Texts and Analysis

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The text on the following three pages was translated from a Latin manuscript written no later than 1372, i.e. at least 50 years prior to the time of van Eyck.

Conditions of a Good Steel

But, because it is strongly required that the instrument for hollowing out [mirrors] be of steel that is good, choice and hard, therefore note the three conditions of a good steel. The first of these is smoothness of the exterior surface with fine continuity of the parts, that is, without fissures. The second is frangibility and the third is clearness of color at the place of fraction. Whence the first and the third designate [its] purity and the second testifies to its hardness. Let the purging or refining of steel be done by the following method. Take an oblong piece of iron like an iron rod that is a little wide, say, one thumb wide. Let pieces of steel be broken up together and arranged without any space between them. Then let this whole mass be sprinkled with smith's water mixed with a certain kind of earth of saffron which all the smiths use for consolidating iron and steel, for without such wetting the pieces of steel could not be consolidated in any way with the iron or with each other. Now therefore, the iron rod, to the degree that it has been forged and hammered, is needed for the consolidation together of the pieces of steel and also for the preservation of the steel lest some of its pure parts be consumed by the fire (just as silver is preserved in its refining by lead mixed with it). Then let this mass, sprinkled in this way, be placed in the fire (and these things are taught and openly prepared in the smith's shop). The procedure is this. Let a certain aperture be made in the bottom [of a crucible], in which aperture iron rods are set crisscross, intersecting each other orthogonally like the bars of iron windows, and by means of this aperture the impurities of the metal can run out below and the pure material can be preserved. And after this mass has been well fired so that it is almost white, let it be removed [from the fire] and let it be hammered quite strongly so that the pieces of steel might be consolidated. And let it again be placed in the fire and while it is in the fire let it be frequently sprinkled with sand and gravel to bring about better consolidation. Then again let it be hammered quite strongly until the consolidation becomes firm and sufficient. However, in [the course of] any removal [of it] from the fire it ought to be considered whether some impurity can be found [in it]. This impurity would be recognized by some blackness appearing in the body of the metal below its fired surface. If it is found, let it be cut out by the cutting instrument which smiths use. Thereupon let the mass so consolidated be cut, while it is well fired, into several pieces by means of the same instrument, with the parts not completely separated or cut away but adhering somewhat to each other. Then let this mass be hardened by this method. Let it be placed again into the fire until it is red like a ripe cherry, and afterwards let it be submerged in water until the fire is extinguished and the heat consumed. Then let it be hammered into pieces at the aforesaid incision spots. And by this same method a second mass and a third and a fourth (indeed as many as you need for your work) may be completed. Then let these masses be consolidated two by two in this way. Let one of the

pieces to be consolidated be fired, and when fired let it be roughed by the cutting iron so that it may be better incorporated with another piece. Then let one piece be placed on the other and both put into the fire, and let them be fired and well consolidated. Then let them be removed [from the fire] and hammered together and firmly consolidated. And in the manner just described for these two pieces, the same thing can be done for two or three other pieces. When done, again let these masses be broken up and again hammered and consolidated, and this procedure can be repeated as many times as need be until the steel is sufficiently purified. Then let all the pieces be reduced to a single mass, which ought to be softened by fire and carefully hammered and reduced to the intended shape in such a way that there is no blister, fissure, or impurity that arises from careless hammering. Then it ought to be hardened. Concerning this, note that there are three methods of hardening steel. The first of these produces the hardest and most brittle steel, and this is done by placing it in cold water after extensive firing to the point that the heat of firing produces a whiteness of the color of the sun between rising and its high point in the heaven. The second method produces a hard and brittle steel but not so excessively as before, and this is done by placing it in cold water after it reddens in the fire like a ripe cherry; [this is] after it has been allowed to be somewhat heated until there is in it the purple color of iron; and this method is suitable for instruments that cut iron or soft steel or masonry or another kind of hard metal, and this method is suitable for making a mirror of steel. However, when it is taken away from the fire, let the exterior circumferential piece be wetted with the aforesaid water to an amount of two fingers thus: ⊙, so that it will not introduce any [un]due concavity to that which has been diminished earlier by hammering. And after its removal from the water let only its middle part be heated. But this method of heating produces a diversity of colors in the surface of the mirror after its polishing. The third method of hardening differs from the second in that the final heating has as its object a purple color like the color of violet in the steel. And this method of heating is suitable for knives and instruments designed to cut woods. Still another method of hardening is put forth by Albertus Magnus in *On Minerals*, Bk. II, Tract. 3, Chap. 2 on the cause of images appearing in stones. He speaks as follows. "But those things which we have tried, we describe here. For let steel be hardened and purified often until it almost has the color of silver, and then there are fashioned out of it instruments for cutting with suitable and subtle angles. And then some juice of radish is squeezed and mixed in equal amount with a water extracted from earthworms that have been crushed and squeezed through a cloth, and afterwards the glowing instrument is extinguished in that water twice or thrice or as many times as necessary for it to be made hard enough to scratch gems and to cut another iron as [if it were] lead." So much Albert.

As for polishing to be done to our mirror, emery is valuable. This is a stone having an iron-like color like that of a good adamant or having a

dark citrine color, and it is similar to flints found in running streams. And it ought to be pulverized in a bronze mortar and the powder strained through a linen cloth or sifted through a sieve tightly woven of hairs. This powder ought to be mixed with water and the whole mixture ought to be placed on a lead [strip] and thus the polishing [is done] by means of the lead so sprinkled. Whence it can be polished first with a gross emery powder and then with a finer powder to remove the streaks caused by the gross powder. For the same [operation] is valuable the emery used and ground on a stone [slab], which emery the goldsmiths use and call *pochea* and which is commonly valued at three *solidi* per pound. There is also a certain other *pochea* called *colcur* which the jewelers and crystal workers use and which is commonly valued at twenty *solidi* per pound, although it polishes best with a wood [base] or on a sheet made of lead and tin. Also furbishers of swords use, for furbishing, two kinds of stones, of which one is finer than the other. And first they line the surface to be furbished with blood and they furbish it with the grosser stone, and they frequently put [more] blood on it. Then, with the finer stone and with blood, they furbish it as before until images appear somewhat. Then they wipe clean the whole surface and remove the blood. Then they put on the surface powder of lime and they take the iron instrument prepared for this and furbish as before until images appear and until no vestige of the preceding stones remains at all. It will be clear, therefore, out of what has been presented how an instrument ought to be fabricated and how hardened so that with it a burning mirror will be shaped, and, in addition, how the said mirror will be polished. So we have, therefore, come to the end of our principal proposal. But though we have brought our desired proposal to its desired end, because a certain conclusion that seems on the face of it marvelous follows from the [construction of a] hyperbola, therefore we have thought it worthy to add the said conclusion here, and it is this.

Eleventh Conclusion

[11] TO BE ABLE TO PROTRACT TWO LINES—ONE STRAIGHT AND THE OTHER CURVED OR EACH CURVED WITH SIMILAR CURVATURE—SUCH THAT THE FARTHER THEY ARE PROTRACTED THE CLOSER THEY APPROACH [EACH OTHER], WITHOUT, HOWEVER, [EVER] MEETING, EVEN IF THEY ARE SO PROTRACTED INDEFINITELY.

For example, let a right cone be taken, which cone triangle *abc* [see Fig. 4.13] bisects by passing through the apex of the cone and the center of its base *d*, as the first [conclusion] of this [work] proves, it having been posited that the said cone lies on the surface of the horizon so that its apex is toward the north and its base toward the south, and let it lie so that side *ab* of triangle *abc* (which latter bisects the cone) lies upon the horizon. Therefore, the said triangle will be completely in a meridian