The Alchemy of Glass: Counterfeit, Imitation, and Transmutation in Ancient Glassmaking by Marco Beretta

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Reviewed by
Paul T. Keyser
IBM T. J. Watson Research Center
pkeyser@us.ibm.com

In this book, Beretta sets out to demonstrate the role of glass in ancient alchemy, especially the role of glassmaking and glassworking in ancient alchemical theory [xi]. The extended argument of the book is that glass was seen as metallic, that glassblowing was achieved only after and because furnace-makers achieved sufficient temperatures, and that the rise of alchemy and of glassblowing were nearly contemporaneous and causally linked: I return below to these theses. Beretta emphasizes the complex and multicultural origins of alchemy [xi] and builds upon an earlier essay [2004, xiii], in which he raised several of the points developed in this book. As there, so here, Beretta deploys a wide range of sources. The slim volume is beautifully produced on high-quality paper in a sturdy binding, and is enriched with over five dozen well-reproduced high-resolution images, most in color, many of which depict objects rarely or never seen in print. There are five chapters:

(1) 'Artificial and Natural Glass in Mesopotamia and Egypt',
(2) 'The Greek Philosophers: Between Crystal and Glass',
(3) 'A Technical Revolution: The Introduction and Cultural Impact of Glassblowing',
(4) 'Glass and Alchemy', and
(5) 'From Byzantine Glass to Early Modern Alchemy'

plus an epilogue. The relevance of glassmaking to alchemy is clear, though noting it is hardly novel [see, e.g., Keyser 1990]; and a modern work of synthesis on ancient alchemy is welcome. The emphasis throughout [e.g., 3–4, 37, 47, 84, 95n21] on the slippery border between artificial and natural stuffs is valuable, as is the collection of images of glass vessels of possible or certain alchemical function.

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The work should be on the shelf of every scholar working in ancient science or technology.

Alas, the book is a flawed gem and demands caution. Errors small and large pervade the text, and many of the arguments deployed are muddled or mistaken. Despite its beauty and value, readers must read with care. Six categories of defect could be fixed in a second edition and are the sort that might be found in any book in our imperfect world—I am sure there are some in this review—though rarely in such numbers. But the logical muddles and invalid conclusions seriously undermine the main thesis of the work.

Let me first describe the remediable defects:

(1) translation troubles,
(2) typographical or spelling errors,
(3) citation muddles,
(4) missing or garbled references,
(5) chronological confusions, and
(6) the use of outdated authorities.

Beretta has been ill-served by his editor(s), since all of these defects should have been caught before the work was printed. It is not their presence that is noteworthy and disappointing—every book has some—it is their total number.

Translation troubles might confuse the reader, as when 'vile' is used for base (metal) [x, 22, 109] and the 'asteroid' of Theophrastus must surely be a meteorite [49]; others are minor. Similar are the typographical errors, such as 'sardonic' for sardonyx [92–93] or 'breath' for breadth [132]. Some names are garbled, both ancient[2] and modern.[3] And some words from Latin or Greek are garbled.[4]

[2] 'Dami[n]geron' [53], 'Eut[h]oc[h]ius' [128, 195], 'Ira[e]naeus' [95n20], 'R<h>etorius' [54, 197], 'T<h>rasyllus' [102–103, 198], or even 'Trimalchus' for 'Trimalchio' [110].

[3] 'Dercahin' for Derchain [17] and Scar[a]borough [129, 188, 197].

[4] Thus, 'lap<is> lazuli' [17], 'hyalocides' for 'hyaloeides' [47], 'megnes' for 'magnes' [59], 'hyalöides hyton' for 'hyaloeides khiton' [70], 'artifici[fici]osum' [87n6], 'cheriokmeta' for 'cheirokmeta' [103n49], 'ungu[n]entarii' [112, Figures 7–8], and 'rython' for 'rhyton' [114–115].

Moreover, Beretta does not always make it easy to check his ancient sources, sometimes giving only page numbers in a translation (which might not be available to every reader); in addition, some references are incomplete or wrong.[5] For example, Anaximenes, Empedocles, Heraclitus, and Philolaus are cited [24–28] from the very reliable translation and commentary of Kirk, Raven, and Schofield 1983—but for readers lacking that book the fragment numbers in Diels and Kranz 1951 should be given at each occurrence rather than only once [24n4]. Moreover, the citations that *are* given are somewhat muddled.[6] Similarly, Beretta cites Theophrastus, *De lapidibus* by page numbers in the edition and commentary of Caley and Richards 1956 without always providing section numbers,[7] although Beretta's citations of Plato, Aristotle, Lucretius, Vitruvius, Strabo, and Pliny are all in order.

Modern citations too are sometimes garbled, especially at 87n7, where Beretta cites the *Gospel of Philip* in the translation by 'Wesley

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[5] See also:
- 111n77, where the missing citation of Pliny is 36.195, and add a reference to Stern 1999, 441–442 on the whole episode;
- 29 where the reference back is to page 26, citing *De igne* 73.

[6] Thus,
- 24n3: Heraclitus fr. 219 in Kirk, Raven, and Schofield 1983 = Diels and Kranz 1951, 22B90.
- 24n4: on Empedocles' theory, I would cite Inwood 2001 rather than Kingsley 1995; and the fragment cited, A37, does not correspond to the fragment quoted, which is Diels and Kranz 1951, 31B6.
- 25 and n6: correct 'love-lived' to 'long-lived' and 'offering' should be plural; and Empedocles fr. 356 in Kirk, Raven, and Schofield 1983 = Diels and Kranz 1951, 31B23.
- 27n13: the Empedocles fragment is from Aetius [Diels 1879, 2.11.2, not 2.11.1] = Diels and Kranz 1951, 31A51a.
- 27n15: Anaximenes fr. 154 in Kirk, Raven, and Schofield 1983 = Diels and Kranz 1951, 13A14, (from Aetius [Diels 1879, 2.14.3–4]).
- 28n17: the Philolaus fragment is Diels and Kranz 1951, 44A19 (from Aetius [Diels 1879, 2.20.12, not 2.25.11]); and a citation of Huffman 1993 266–270 would be good here.

[7] Some prefer the more recent edition and commentary of Eichholz 1965. See:
- 47n64: *De lap.* §30;
- 48n67: *De lap.* §§48–49; and
- 49n69: *De lap.* §24, where Beretta's page reference is in fact to the commentary section of Caley and Richards 1956.

Wisenberg'. Although Beretta does not give a source citation, this is from the website http://www.theologywebsite.com and the translator is Wesley W. Isenberg. But why not use the widely available and reliable translation in Robinson 1988?

Beretta's quotation [42] of the *Periplus maris erythraei* §6 from the magisterial edition of Casson [1989] omits the section number; and Beretta claims that the passage refers to India when in fact the items listed, including 'glass stones', are for export to Adulis, a port on the southern Red Sea near 15° N, 40° E [Casson 1989, 109–112]; the glass exported to India was unworked (ἀργή) [*Periplus* §§49, 56].

More serious, though still reparable, are the confusions over dates. Hecataeus of Abdera is placed in late Antiquity (the fourth century AD) rather than in the fourth century BC [14, possibly by a typo: <B>CE]. Diodorus of Sicily is once placed in the first century AD [30], perhaps another typo, since his correct date (first century BC) is given later [89]. Following the unreliable *Souda*, Beretta tentatively assigns Philostratus to the 'first century CE' [52]; but one of the works of Philostratus referred to, the *Life of Apollonios of Tyana*, concerns a man who died *ca* AD 97, and was written in the third century AD [see Anderson 1986]. Moreover, it was Philostratus the father of the author of the *Life of Apollonios of Tyana*, who wrote the other work referred to, the lost *Lithognomikon* [see Keyser and Irby-Massie 2008, 660].

The *Revelation* attributed to John is a mysterious book, but its date is pretty securely late first century AD [Mounce 1998, 15–21: cf. 11–15]. Thus, Beretta's dating of the work to the 'end of the second century CE' [89: cf. 27n14] is unexplained and strictly impossible, since Irenaeus of Lyon (*ca* AD 180) records it as a long-known book [*Adversus haereses* 5.30.3]. Beretta also twice quotes the book in Latin although the Greek is extant and widely available.

Often a date is given vaguely and wrongly. Strabo is dated to 'about a century' after Cicero's *Pro Rabirio* [42]—'75 years' actually—and said to be first century AD [80n4], but later Strabo is said to be 'some decades' after the Flavian writer Josephus [58]: Strabo's *Geography* was composed around AD 20 [see Keyser and Irby-Massie 2008, 763–764]. Varro is dated correctly, albeit vaguely, to the first century BC [25n5], but then [94] is said to have written 'some decades before Pliny' (who was over a century later), which is at least misleading.

Beretta argues from Athenaeus, *Deip.* 11 [784c][8] that, despite the lack of archaeological evidence, glass was worked in Alexandria in the third century AD [43]. He tries to strengthen that argument from the *Historia Augusta*, which he dates to the late third century AD [85–86]—but all parts of that work are very likely by one author writing at the end of the fourth century AD.

The last category of remediable errors concerns Beretta's use of outdated modern authorities. For example, when discussing faience (the vitreous coating baked onto sand cores by Egyptians and others, and often colored blue), Beretta cites the expert Harden 1956 in 1–2n3, and the magisterial Forbes 1966 in 9–10n19. Those were fine works in their day and are still worth consulting, but why not cite the more recent and reliable work in his bibliography, Shortland *et alii* 2001? Other recent works on faience that ought to have been cited by Beretta are Moorey 1994, 166–186 and Nicholson and Peltenburg 2000 [cf. Lucas 1962, 156–167]. On Egyptian natron, Beretta [6n11] cites a work from 1877 (not in his bibliography), and his own work on the medieval German writer Georgius Agricola: better would have been Shortland *et alii* 2006b. On the rise of Phoenician trade, Beretta [7n13] cites Partington 1935—a fine old book, but hardly relevant; better would have been Negbi 1992 or Aubet 2001 [esp. 97–143, 159–193]. Important for Beretta's argument is that the Egyptians were focused on colors and color-transformations: he is surely correct, but in 22n63 and 98n28 he cites Hopkins 1927 when more relevant would be Baines 1985.

Far more serious than such readily remediable defects are the flaws in Beretta's arguments. The thesis of his book is that glass was crucial to the development of ancient alchemy. More precisely, Beretta wishes to argue that glass and metals were long treated alike, and that when at last furnace-makers achieved a temperature high enough to allow glassblowing, the new properties and wide use of glass encouraged the growth of alchemy—and that the expansion of glassblowing was nearly contemporaneous with that of alchemy. A few minor auxiliary arguments are raised to support that case, to which I first turn.

[8] This passage occurs in the lacuna filled out by the epitome, but reads like an inserted scholium; it is found in the alphabetical section on the names of vessels, *s.v.* Βαυκαλίς.

Beretta wishes to show that that scholars typically regard the scope of alchemy as being merely 'gold-making' [ix–xi, 88, 96, 106], which underwrites his contention that the role of glass in alchemy is under-appreciated. There may be some surveys or studies of alchemy that adopt such a perspective—Beretta cites one modern work [x n6]—but given the overall outlook of scholars, this is a straw man. Recent works cited by Beretta, such as Lindsay 1970, Hershbell 1987, and Letrouit 1995, certainly do not adopt that view; nor did my own survey [1990].

Beretta briefly treats the Greek *kyanos* [20, 37], rightly connecting it with 'Egyptian blue'—as in Theophrastus *De lap.* §58 and Vitruvius, *De arch.* 7.11.[9] However, as Trowbridge [1930, 11–19] has shown, the substance was known to Homer. Moreover, the Mycenaean tablets record *ku-wa-no* (which may derive from Hittite *kuwanna*) and the *ku-wa-no-wo-ko*, arguably the *kyanourgos*; and there is archaeological reason to believe that *kyanos* was produced in Mycenaean Greece [see Goetze 1947, Nightingale 1998]. Thus, *kyanos* was not 'exclusively Egyptian' [22] and glassmaking was not wholly foreign to Greek culture.

Beretta twice falls into the error of referring to 'glass paste' [49, 64] which is an effectively meaningless designation [see Lucas 1962, 193–194; Forbes 1966, 112–114]. Moreover, he confuses the issue in Theophrastus, *De lap.* §49, and follows J. M. Stillman [1924, 21] in interpreting the passage as a reference to 'the coloring property of copper once it is combined and melted together with glass paste' [49]. But Theophrastus is recording an unusual 'earth' which, when mixed with copper during its smelting, produces a 'beautiful color'. So Theophrastus, like Aristotle [*De gen. et corr.* 1.10 328b13–14], is speaking of the production of brass or bronze by adding something to copper ore, where Aristotle specifies that it is κασσίτερος, almost certainly tin or its ore. Theophrastus, then, is not referring to glass or *kyanos* here [see Caley and Richards 1956, 162–167].

Let me now turn to the fundamental errors in Beretta's attempt to connect the rise of alchemy with the expansion of glassblowing.

First, Beretta often draws a close connection between valuable metal and glass in order to connect glassmaking with the alchemical

[9] Beretta [12] cites 'VII, 2'.

goal of producing valuable metallic materials [see 3–4, 16, 31–32, 36–37, 51–52, 89, 131]. There were indeed deep connections between glass and metal in that the processes of their creation or extraction were similar and were perceived as similar, especially in so far as they were both produced by fire from substances of very different properties and were susceptible of melting; and in that, for much of the ancient period, some glass and some metal were both regarded as valuable.

But the sense in which, for ancient alchemists or glassworkers or metalworkers, glass was 'like' metal was never, so far as our evidence goes, such that we can say that they saw glass as being the same as metal or a kind of metal. It is not even clear that there was an ancient concept of 'metal' in our sense of a material that is fusible, malleable, opaque, and specular, miscible or susceptible of alloying with others of its kind. (Crucial and always implicit in our concept is that a metal be electrically and thermally conductive, concepts utterly out of view in antiquity.) There was no agreed term that maps exactly to our 'metal': Halleux [1974, 19–60] shows that μεταλλ- usually refers to things 'mined' and that our 'metal' is perhaps only in view in Isidore, *Etym.* 16.17.2, as *metalla*, where he lists precisely seven species: *aurum*, *argentum*, *aes*, *electrum*, *stagnum*, *plumbum*, and *ferrum*. Aristotle appears to indicate metals in *Meteor.* 3.6 378a19–28 where he distinguishes ὀρυκτά (e.g., realgar, ochre, ruddle, sulfur, and cinnabar) from μεταλλευτά (e.g., iron, gold, and copper) and in *De sensu* 5 443a15–21 which, while discussing their smells, lists those three plus silver and tin as μεταλλεύοντα. However, *Meteor.* 4.10 388a10–13 lists λίθος among the μεταλλευόμενα.[10] For example, we commonly think of mercury as a metal; but there is no evidence that it was seen in antiquity as a member of the same category as gold, silver, copper, tin, lead, and their alloys [Halleux 1974, 108, 179–188]. On the other hand, although iron was usually listed with gold, silver, copper, and so on (thus, implicitly a 'metal'; explicitly a metal in Pliny, *Nat. hist.* 34.142–143), almost no Greco-Roman text

[10] On Theophrastus' lost *On Metals*, see Halleux 1974, 171–174 and Sharples 1998, 169; there are very few fragments, and we do not really know how Theophrastus conceived the category. Theophrastus, *De lap.* §1 indicates that the μεταλλευόμενα were created from water, in contrast to other substances created from earth.

states clearly that it was fusible.[11] So we ought not to phrase the question as 'Was glass considered as a metal, or not?' but rather as 'In what way was glass considered and to what other substances, if any, was it considered similar, and how?'

The primary connection is simply that which Plato already drew in the *Timaeus*, that what we call metals, plus some stones as well as glass, all shared the mysterious property that they could be melted like ice and then cooled and solidified again. That is what likely lies behind *Timaeus* 59b–c and the passages quoted by Beretta: Aristotle's *Meteor.* 4.10 389a7–9, which includes glass and stones with some metals (gold, silver, copper, tin, lead) as fusible [36–37]; and Galen's *Simpl. med.* 9.1.4 on earths from which are produced silver or gold or iron or glass [51–52].[12] Moreover, for much of its history, glass of certain colors was not simply a 'fake' gem but a gem artificially produced, so that such glass was received as a valuable product; that seems to be the sense of *Timaeus* 61b [31–32] and is likely what the Egyptians meant [16].

A few texts refer to glass having the 'look' of gold [3, 89, 131]. I suggest that here we have to do with the scintillating sheen of well melted and cast glass, which although not as specular as polished metal is nevertheless remarkable and evidently was desirable [cf. pseudo-Aristotle, *De coloribus* 3 793a13–19]. In any case, the comparison cannot refer simply to the color, nor to the value.

Second, Beretta claims that the making of transparent glass and glassblowing both require high-temperature furnaces that were not developed until the fourth or first centuries BC, respectively. With respect to transparent glass, Beretta claims that

> the possibility of producing perfectly transparent glass crucially relied upon the availability of furnaces capable of producing temperatures of 1000°C;

[11] Aristotle, *Meteor.* 3.6 378a27–28 gives iron as one example of substances that are either fusible or malleable (ἢ χυτὰ ἢ ἐλατά: the two other examples, gold and copper, are both); and *Meteor.* 4.6 383a30–b5 seems to describe (some stage of the smelting of) iron as melting, but he means 'grow soft' like horn (as he says there and at 4.9 385b6–12 and 4.10 388b30–33): cf. the parallel (or paraphrase?) in Pliny, *Nat. hist.* 34.146. See the discussion in Halleux 1974, 189–198.

[12] Quoted without the citation from Halleux 1974, 136.

and concludes that these were attained by the fourth century BC in Greece [37], and that 'new kinds of furnaces that could reach higher temperatures' enabled the production of transparent glass [98]. With respect to glassblowing, Beretta writes [11–12n26],

> The highest temperature reached in glassmaking during antiquity reached 1000–1100°<C> only around the first century BC,

and cites Neuburger 1919. Beretta also claims that the

> construction of furnaces which reached high temperatures (above 1000°<C>) and which made raw glass liquid

was one of the crucial factors that enabled glassblowing [64].

Indeed glassblowing can only be done above a certain minimum temperature, which depends upon the composition of the glass; and for typical Greco-Roman glass that temperature was perhaps around 1050°C.[13] But that temperature was regularly attained in kilns and furnaces many millennia before glassblowing was invented. The casting of copper requires temperatures of 1000 to 1100°C, and is attested from *ca* 5000 [*sic*] BC [Radivojević *et alii* 2010]. Moorey [1994, 150–151] records kiln temperatures of 1050–1150°C by 4500 [*sic*] BC in Mesopotamia. Nicholson and Jackson [2000] report easily achieving 1000°C with reproductions of Egyptian furnaces (of *ca* 1350 BC); and with some work temperatures of 1100–1150°C were attained. Shortland [2000, 22–23] computed the temperatures at which various vitrified materials found at Amarna would have vitrified and determined that they had been subjected to temperatures of 1050–1200°C. He also performed experimental refirings at 1100–1250°C which confirmed those calculations [2000, 35–42]. Rehder [2000, 40] reports examinations of furnaces at Hagia Triada, Crete, from the 14th century BC, showing that they had attained temperatures of 1250°C. Stern [1999, 446; 2008, 522–526] has argued that a new form of glass furnace was developed about a century after glassblowing was invented, which allowed greater control of the temperature; moreover, the actual temperatures attained in such Roman imperial

[13] See Stern 1999, 451; but note Fischer 2008, 78 which reports 950°C, apparently confirmed by Stern's discussion [1999, 452–454] of blowing that starts with a chunk, at *ca* 900–950°C.

furnaces have been shown to be only slightly higher than prior furnaces [see Taylor and Hill 1999]. In sum, there is no evidence of any new development in furnace technology that allowed or encouraged the discovery of glassblowing.

Likewise, transparent glass can only be produced if the materials are heated sufficiently to allow gas bubbles to escape (and if no opacifier, such as tin or antimony or others, is added); transparent glass was made in many colors, including colorless. But here also, the ability to produce transparent glass long predates Greek philosophy or alchemy. Transparent glass bowls are known from Gordion *ca* 700 BC [von Salden 1959: cf. Stern 2008, 528–529]; and as early as *ca* 1450 BC, some Egyptian glass is transparent [Shortland and Eremin 2006, 584–588, 591]. The marvels of transparent glass or rock crystal (clear quartz) referred to by Philolaus [Diels and Kranz 1951, 44A19], Herodotus [*Hist.* 3.24], and Aristophanes [*Nubes* 768], depend upon no novelty in the manufacture of glass [cf. 27–31]. On the other hand, the references in Anaximenes [Diels and Kranz 1951, 13A14] and Empedocles [Diels and Kranz 1951, 31A51a] to the *krustalloeides* are references to 'ice-like' solids, contrary to what Beretta maintains on pages 26–27.

Third, Beretta bases his case for the connection between glassblowing and alchemy in part upon alleged coincidences of date. Such arguments are unsound even when the dates are secure, which they are not either for the invention of glassblowing itself (for which we still have only an archaeological *terminus ante quem*) or for the alchemical texts (almost none of which are dated precisely). However, Beretta misuses even that set of evidence and most of his mistakes about dates tend towards forcing them into synchronization with the expansion of glassblowing—recall the dates of Diodorus of Sicily, Strabo, Philostratus, and Varro, discussed above.

The date of Heron of Alexandria was long disputed, but Beretta [80n41, 117] seems to accept a date in the first century AD.[14] However, Beretta also claims that Heron wrote 'about the same time that glassblowing was introduced' [80]. No, he wrote at least one century later, so that he provides no evidence of a connection between alchemy

[14] Strictly, the modern consensus is for the mid-first century AD: cf. Keyser and Irby-Massie 2008, 384–387.

and the invention of glassworking. Beretta is quite right to emphasize that the use of transparent glass for scientific apparatus, such as the experiments of Heron or indeed of the alchemist Maria, for example, does allow tests and procedures that would otherwise be difficult or impossible. Beretta [110] claims that 'as early as the first century CE, the appreciation of glass' chemical neutrality was extremely common', citing Dioscorides on storing mercury. Beretta also provides six valuable images of glass apparatus [see Fig. 15 on p. 81 and Figs. 5, 10, 12, 14, 15 on pp. 109–123]. However, many pharmacists before Dioscorides stored compounds in glass, presumably due to its inert character—the earliest attested is Mnesitheus of Cyzicus (*ca* 180 BC);[15] in at least one case, a glass container is used for its transparency by the pharmacist Krates (*ca* 10 BC) [Keyser and Irby-Massie 2008, 489–490]. None of the other evidence cited by Beretta supports his *terminus* of the first century AD, and of the five alchemical authors whom Beretta cites for the use of glass apparatus [113–120], likely the earliest is Maria, whose dates are famously uncertain. (The others are Iulius Africanus, Olympiodorus, Synesius, and Zosimus.)

Already in 2004, 258–269, Beretta himself argued that at (or by) the time of Celsus (*ca* AD 15–35) and Rufus of Ephesos (*ca* AD 70–100), the nomenclature of the parts of the eye began to refer to 'glassy' humors and tunics, due to the recent development of glassblowing. He now reprises that argument [69–74]. First, the nomenclature has to do with transparency not glassblowing, and transparent glass had long existed, as I have already shown. Moreover, a 'linguistic reform' [71] in the nomenclature of the eye that is first attested in Celsus is very likely due to the work of the influential Herophilean oculist Demosthenes 'Philalethes' (*ca* 50 BC to AD 25) [Keyser and Irby-Massie 2008, 239–240]. Further, the introduction into medicine of the concept of a 'glassy' (*hyaloeides*) material dates back to the doctor Praxagoras of Kos (*ca* 300 BC) and his student Phylotimos, who have the 'glassy humor' as one of their chief constructs [Keyser

[15] Apuleius Celsus of Centuripae (*ca* AD 30), Cornelius (*ca* 100 BC), Mnesitheus of Cyzicus (*ca* 180 BC), Spendousa (*ca* 10 BC), and Truphon of Gortun (*ca* AD 5): for these dates, see Keyser and Irby-Massie 2008, 119, 216, 561, 756, 817 respectively.

and Irby-Massie 2008, 694–695]; presumably they were indeed referring to the transparency of glass, well-known at that time.

Beretta [86–88] quotes Pliny's encomium on fire [*Nat. hist.* 36.68], to which he compares the 'relatively new Stoic notion of *pur technikon*', citing von Arnim 1905–1924, 1.44. More apropos to Pliny on fire might have been Theophrastus, *De igne* 1–3. But in any case, Beretta should explain that the citation of Zeno fr. 171 in von Arnim 1905–1924 derives from Cicero, *De nat. deor.* 2.57, and Diogenes Laertius, *Vitae* 7.156. There is nothing 'new' about the doctrine, not at the time of Pliny nor even of Cicero. Moreover, Beretta wrongly relates the passage to recent developments in alchemy. The powerful transmuting effects of fire surely did play a role in the development of theories of material change, as can already be seen in Plato's *Timaeus*; and surely the making of glass was one (of many) such effects considered. But that inspiration long antedates glassblowing [cf. Keyser 1990].

Beretta [89–97] argues, from several passages each in Diodorus of Sicily and Pliny (plus one fragment of Varro and a passage in Irenaeus of Lyon), that treatises on the imitation of gemstones began to be produced at around the same time as, and because, glassblowing was invented; and that those treatises influenced the expansion of alchemy. The imitation of gems is a well known part of the alchemical literature, and two of the earliest such works are usually placed before 100 BC [see Keyser and Irby-Massie 2008, *s.vv.* Bolos, Petosiris]. Beretta [98–107] adds to his argument regarding imitation of gemstones the evidence provided by the fragments of pseudo-Democritus, which include material on gemstones. Now this mass of material is certainly an important part of the alchemical corpus; but it is likely due to multiple authors, composing a wide variety of works (on stones, on alchemy, on pharmacy, on medicine, and even on agriculture), variously dated between 250 BC and AD 200 [see Keyser and Irby-Massie 2008, 236–239]. This material thus provides no basis for an argument that any particular pseudo-Democritus wrote in response to the development of glassblowing. Glassblowing would not affect the means of production of imitation gems, and there is no basis for dating all such works after the invention of glassblowing.

Beretta claims, as another part of his case that glass production came to Greece from Egypt, that in contrast to Egyptians the

Greeks rarely dealt with gemstones, at least up through the time of Theophrastus, *De lapidibus*; and that only with the poetry of the Alexandrian writer Poseidippos did gemstones become widely known to Greeks [45–46: cf. 96 on imitating gems]. The facts, however, are that Greeks made extensive use of some gemstones, especially as signets, from the archaic period onwards. Aside from the slipperiness of the category 'gemstone', the difficulty is that the referents of most words (in Greek or whatever language) for gemstones shifted over the course of centuries, and most of them never at any time referred to what we would call a single mineral species. For example, Theodoros of Samos (*ca* 550 BC) carved a σμάραγδος as a signet [Herdotus, *Hist.* 3.41], which must have been some hard (green) gemstone, if not our emerald (green beryllium-aluminum silicate). Pythagoras' father, Mnesarchus of Samos, was also a gemcutter [Diogenes Laertius, *Vitae* 8.1], and others are known. Plantzos [1999, 13] notes the ring set with ὄνυξ preserved in the Parthenon treasury in the late fifth century BC [*Inscriptiones graecae* I^3, 1.351.23–24], though no-one can say whether that stone was the same kind of stuff as the ὀνύχιον of Theophrastus, *De lap.* §31, itself likely our crypto-crystalline banded quartz. Boardman and Wilkins [1970, 374–379] note that preserved archaic signets were typically carved from various kinds of crypto-crystalline quartz (agate, chalcedony, cornelian, jasper, onyx, and sard) plus the softer rarer lapis lazuli, which last is the σάπφειρος of Theophrastus, *De lap.* §23. Boardman [1968] includes two signets carved from amethyst [Nos. 32 and 70 on pp. 27 and 45], and probably the ἀμέθυσον of Theophrastus, *De lap.* §30 is the same kind of stone. Plato [*Phaedo* 110d] lists as example gems the ἴασπις, the σάρδιον, and the σμάραγδος; but what they were besides valuable, he does not say.[16] Aristotle, *Meteor.* 4.9 387b17–18 knows a valuable red stone ἄνθραξ, known also to Theophrastus *De lap.* §18, that is immune to fire. Of course, amber (ἤλεκτρον) was known and used from very early times.

Some gemstones did arrive in the Greek world in the Hellenistic period or later, but that says nothing about earlier Greek confection of glass stones. The diamond arrives with the rise of Indian trade [cf, *Periplus* §56], whereas the ἀδάμας of Plato, *Timaeus* 59b and *Politicus* 303e, of Theophrastus, *De lap.* §19, and Heron, *Pneum.* 1

[16] In Theophrastus, *De lap.* §27 ἴασπις is green, and in §30 σάρδιον is red.

[Schmidt 1899, 6.11–28] likely refers to the dark, dense, and hard osmiridium grains found with placer gold [cf. Meeks and Tite 1980]. Earlier, ἀδάμας may have referred to steel or iron [cf. Halleux 1974, 90–91, esp. n20]. Stones such as the green βήρυλλος, the green τόπαζον/ς or τοπάζιον, and the golden(?) χρυσόλιθος are attested first in the *Septuagint* and are not attested in Poseidippus. The blue ὑάκινθος and the yellow-green(?) χρυσόπρασος are not apparently attested before the *Revelation to John* 21.20, late first century AD.

In summary, Beretta's book is composed of very fine materials—a wide range of sources, beautiful images, a rich topic, and a good imagination. But the elements have not fused well, so that the compound is a missed opportunity. Glass in antiquity was certainly one of the chief artificial pyrotechnical products, along with the smelting of ores, the creation of dyes and pigments, and even the brewing of beer and wine, that ultimately led to the development of alchemical theory. Beretta's account of this, however, is muddled and flawed, and offers little novelty. Glassblowing was a surprising discovery that led to novel and beautiful forms, and a much wider use of glass, and the availability of glass vessels and instruments, exploited by a variety of ancient scientists (workers in alchemy, in optics, in pneumatics, and in pharmacy). Here Beretta's account offers greater novelty but less conviction. Scholars and students should surely read the book but we should read with caution.

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