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PSELLOS' PETRIFIED ROOT: TRANSMUTATIONS AND NATURAL WONDERS FROM CLASSICAL ANTIQUITY TO BYZANTINE TIMES

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Abstract

This paper analyses a specific case of petrifaction described by the Byzantine scholar Michael Psellos. It starts with a passage from Psellos' *How to Make Gold*, which describes a petrified oak root, and gives an account of various instances of petrifaction reported by ancient authors. A distinction between hot and cold petrifactions is proposed along with a possible explanation for the petrified root, although it is uncertain whether ancient sources were dealing with an actual piece of petrified wood or one of the first recorded observations of fulgurites.

Questo articolo analizza un particolare caso di pietrificazione, descritto dallo studioso bizantino Michele Psello. Si parte da un passaggio de *La Crisopea* di Psello, che descrive una radice di quercia pietrificata, e poi si dà conto di diversi esempi di pietrificazione, come narrati dalle fonti antiche. Si propone inoltre una distinzione tra pietrificazioni per caldo e per freddo, insieme a una possibile spiegazione per la radice pietrificata, sebbene non sia certo se le fonti antiche abbiano avuto a che fare con un vero e proprio pezzo di legno pietrificato o invece si tratti di una delle prime osservazioni attestate di folgoriti.

1 Psellos' *How to Make Gold*

1.1 *Psellos and his alchemical work*

Constantine Michael Psellos (1018–c.1078 CE) was a famous and prolific Byzantine polymath and politician.[1] To name but a few related figures, Psellos studied under John Mauropus, and, together with John Xiphilinos, he belonged to the powerful political and intellectual circle of Constantine Leichoudes. Both Leichoudes, as Constantine III (1059–1063 CE), and Xiphilinos, as John VIII (1063–1075 CE), became patriarchs of Constantinople.[2]

In a short treatise titled *How to Make Gold*,[3] Psellos tackles the philosophical and practical issues around transmutation of matter, in order to achieve the alchemical goal of 'aurifaction'.[4] This research was probably started upon the request of Michael I Keroularios (1043–1059 CE), the well-known ecumenical patriarch of the East-West Schism.[5] Psellos pictures alchemy in a broad sense: in his view, this art (τέχνη) incorporates various techniques, including the artificial production of stones.[6] This approach is original when compared with the definition provided by the 10th-century Byzantine encyclopaedia *Suda*: here alchemy is simply defined as "the preparation of silver and gold",[7] and this seems to be precisely what Keroularios wanted to learn from Psellos' treatise.[8]

The date of composition of *How to Make Gold* is around mid-11th century,[9] probably during the reign of Constantine IX Monomachos (1042–1055 CE), a period characterised by cultural vitality[10] and important monetary reforms.[11] The intellectual fascination of making alchemical gold aside, chrysopoeia could have been especially useful in a time when gold currency (νόμισμα) was debased, probably for budgetary reasons.[12] In fact, under Constantine IX the value of gold coins was lowered not by clipping, i.e. shaving metal from the coin's edges, but by reducing their gold content by about a quarter and without decreasing their weight.[13] This fostered the circulation of gold coins which had different

[1] On his chronology, cf. Jenkins 2017, pp. 447–448; Karpozilos 2004; Kaldellis 2012. See also Polemis 1965, p. 73: "the last period of the great scholar's life, being entirely undocumented, remains obscure in the extreme".

[2] Treadgold 1997, p. 691.

[3] "Τοῦ αὐτοῦ [Ψελλοῦ]. Πρὸς τὸν πατριάρχην κῦρ Μιχαὴλ περὶ τοῦ ὅπως ποιητέον χρυσόν", Bidez et al. 1928 (henceforth cited as CMAG VI), p. 24.

[4] Needham and Gwei-djen 1974, pp. 10–11.

[5] In a certain group of manuscripts, the dedicatee is Xiphilinos, cf. Ruelle 1889, pp. 261–262 and CMAG VI, p. 10. After analysing both internal evidence and manuscripts, Ruelle concluded: "nous croyons avoir établi que la lettre sur la *Chrysopée* a été rédigée à la demande de Michelle Cérullaire et dans le premièrs années de son patriarchat", Ruelle 1889, p. 266. On the wavering relationship between Psellos and Keroularios, cf. Criscuolo 1990, pp. 9–14.

[6] CMAG VI, pp. 30, l. 19–32, l. 5.

[7] Suda, *s.v.* *Χημεία* (χ 280 Adler).

[8] CMAG VI, p. 32, ll. 5–9.

[9] CMAG VI, p. 5 and Albini 1988, pp. 19–20. The most famous witness on Greek alchemy, MS *Marcianus gr. Z.* 299, was copied between the end of the 10th and the beginning of the 11th century, cf. Saffrey 1995, p. 1.

[10] Under Constantine IX, Psellos was a leading figure, ὕπατος τῶν φιλοσόφων, in the newly established University of Constantinople, cf. Markopoulos 2008, pp. 790–791.

[11] Cf. Harvey 2008, pp. 636–637; Morrisson 1976; Hendy 1985.

[12] Georganteli 2008, p. 166.

[13] Minting new lighter gold coins, without altering their metallic purity, was another debasement method used by some earlier emperors, such as probably Nikephoros II Phokas (963–969 CE). Cf. Treadgold 1997, pp. 503, 578.

value but equal weight, a fact that caused inflation throughout the Byzantine Empire.[14]

If this might somewhat explain the interest in alchemy during Monomachos' reign, it may be worth mentioning that a conflictual relationship between political power and alchemy is already attested for the reign of Diocletian (284–305 CE), also marked by an important reform of coinage: "After seeking out the books written by the ancient [Egyptians] concerning the alchemy of gold and silver, he burned them so that the Egyptians would no longer have wealth from such a technique, nor would their surfeit of money in the future embolden them against the Romans".[15]

1.2 *Psellos on petrifactions*

In order to justify his naturalistic vision about alterations of matter,[16] Psellos wrote that there are naturally occurring transmutations no less marvellous than the alchemical production of gold. We must remember that "Psellos pursued a deeper understanding of natural causation, and he chided his students for invoking the divine far too quickly in their attempts to explain mundane events".[17] This rationalistic view is evident in a few passages of *How to Make Gold*, where Psellos says that alchemy is not a secret lore connected with mystic rites, but a rational art dealing with natural alterations of matter.[18]

Having described the orderly and mutual cycle of elemental changes,[19] Psellos presents two kinds of petrifaction, as an example of these marvellous natural transmutations:

> And not quite long ago (at that time I was an adolescent or a bit older, being initiated to the beginnings of philosophy) I myself gazed at a root, as I think, of an oak, perfectly changed into stone, and it was a marvellous sight; for it was a borderland between both natures; it was marked by fibrous side-shoots in accordance with the essence of trees, and was covered up by a tight sheath, that was wrinkled, and, at the same time, showing navel-like ducts; but the whole object was hard and nothing but stone. At that time I simply wondered [at this fact] and gave up; later on, after studying philosophy at a higher level, I held that the oak had been struck by a lightning, not the one that burns and blackens, but by a very light and fast one: it suddenly collided with the pores of the oak, destroyed all its moisture and,

[14] Treadgold 1997, p. 595.

[15] Suda, *s.v.* *Διοκλητιανός* (δ 1156 Adler); this fact is also mentioned in *JoAntR*, 248 and *AASS*, II, 557, 4. For a contextualisation of this episode in the general history of Greek alchemy, cf. Principe 2013, pp. 22–23; Martelli 2019, pp. 49–50; Merianos 2020, p. 238. On Diocletian's monetary policy, cf. Hendy 1985, pp. 448–462.

[16] "Psello sostiene un capovolgimento di valori, che sancisce quanto era ormai storicamente avvenuto, il sorgere di una corrente di pensiero e di cultura 'laica' a Bisanzio, che si giustappone a quella tradizionale controllata dalla Chiesa", Criscuolo 1990, pp. 16–17. On this so-called Byzantine humanism, cf. Lemerle 1971.

[17] Jenkins 2017, p. 449. See also Katsiampoura 2008, p. 667: "precisely this insistence on defending the relation between cause and effect in the physical world is what really impresses. At no point in text are there to be found references to the divine will".

[18] CMAG VI, pp. 26, ll. 4–9, 30, ll. 16–19.

[19] Psellos describes the mutual transformation of the four elements in a similar way to Aristotle, cf. CMAG VI, p. 28, ll. 13–27 and Arist., *GC*, 331a7–b36. Also cf. infra § 2.5.

> after exhausting the airy essence in the pores, it bound the fibres that were separated close together, and remodelled the porousness of the substance to stony hardness. However Strabo the geographer gave an account on the nature of a very cold water source that produces a similar hardness in looser substances, a fact that is much more marvellous than the transformations brought about by fire.[20]

For a tentative explanation of this passage, I will proceed as follows: after illustrating a few basic notions about plants and lightning bolts, I move to discuss both kinds of petrifaction, which are caused either by hot or cold agents. Then I investigate more closely which kind of object Psellos saw: fulgurites represent a possible explanation, in addition to petrified wood.[21] To the best of my knowledge, this explanation has never been presented in secondary literature. Since Psellos identified his root as probably originating from an oak, I also briefly analyse the natural and religious connections between oaks and lightning bolts. I conclude with a few words on Theophrastus' interest in petrified things, and similarities with Psellos' account. The general Aristotelian theory of matter, upon which Psellos builds his own explanations, will not be analysed in this paper.

2 Petrifactions

2.1 *Some basic notions*

Psellos' text briefly describes the interplay between the four elements (earth, water, air, fire) and the interaction between specific natural objects (lightning bolts, plants, stones) in terms of Aristotelian natural philosophy. I will discuss the four elements in § 2.5, in order to better clarify a specific transmutation from fire to earth.

First, let's begin with a brief remark on terminology. Psellos employs a periphrasis ('to change into stone', εἰς λίθον μεταβάλλειν)[22] to describe the root-to-stone transformation, and does not employ the two most common verbs that usually refer to petrifaction, namely ἀπολιθόω or λιθόω, both also conveying a metaphorical meaning with reference to obstinacy.[23]

[20] "Ἐγὼ γοῦν αὐτὸς ἐθεασάμην οὐ πάνυ πρὸ πολλοῦ χρόνου (ἔφηβος γὰρ τότε ἦν ἤ καὶ πρόσω, καὶ τὰ προτέλεια τῆς φιλοσοφίας μυούμενος) ῥίζαν, ὡς οἶμαι, δρυὸς ἀκριβῶς εἰς λίθον μεταβληθεῖσαν, καὶ ἦν θαυμάσιον τὸ ὁρώμενον· μεταίχμιον γὰρ ἀμφοτέρων τῶν φύσεων ἦν· διείληπτο μὲν γὰρ ἰνώδεσιν ἀποφύσεσι κατὰ τὴν τῶν δένδρων οὐσίαν, στεγανῷ τε κελύφει κατακεκάλυπτο, τὰ μὲν ῥυσσούμενον, τὰ δὲ καὶ εἰς ὀμφαλίτιδας πόρους δεικνύμενον· τὸ δ' ὅλον ἀντιτυπὲς ἦν καὶ λίθος καθαρῶς. Τότε μὲν οὖν ἁπλῶς θαυμάσας ἀφῆκα· ὕστερον δὲ γενναιότερον τῇ φιλοσοφίᾳ προσβάς, κεραυνῷ βεβλῆσθαι ἡγησάμην τὴν δρῦν, οὐ τῷ καυσώδει τούτῳ δὴ καὶ μελαίνοντι, ἀλλὰ τῷ λεπτοτέρῳ καὶ ταχυτέρῳ, ὃς δὴ ἀθρόον τοῖς τῆς δρυὸς προσελάσας πόροις καὶ τὴν ἰκμάδα πᾶσαν ἐξαναλώσας, τήν τε ἐν τοῖς πόροις ἀερώδη οὐσίαν ἐκδαπανήσας, τό τε διεστηκὸς συνέσφιγξε τῶν ἰνῶν καὶ εἰς λίθου στερρότητα τὴν τῆς ὕλης μανότητα μετεποίησεν. Ὁ μέντοι γεωγράφος Στράβων ἱστορεῖ καὶ φύσιν τινὰ ψυχροτάτης πηγῆς τὴν τοιαύτην ἀντιτυπίαν ταῖς μανοτέραις ἐντιθέναι τῶν φύσεων, ὅ πολὺ θαυμασιώτερον τῶν ἐκ τοῦ πυρὸς μεταβολῶν πέφυκεν", CMAG VI, pp. 28, l. 28–30, l. 15. Translation is mine.

[21] In fossil formation "for petrifaction to occur, groundwater containing minerals must gradually dissolve organic structures of bone, tooth, replacing them with crystalline calcite, gypsum, or silica and thereby slowly transforming them into stone", Mayor 2011, p. 67.

[22] Apollod., III, 47, 5 and Suda, *s.v.* *Εὐτρόπιος* (ε 3776 Adler), both examples deal with petrifactions in a mythological context.

[23] Arr., *Epict.* I, 5, 3 and Clem.Al., *Protr.* I, 4, 2.

Stones (λίθοι) are described by Aristotle as homoiomerous bodies,[24] and they are said to have no moisture in them.[25] In a rare hint about petrifactions, Aristotle also claims that, when the soul departs from the body, only its shape (σχῆμα) remains, similarly to what happens in petrified beings.[26]

Each body derives its shape, or rather its physical delimitation from the interaction between dry and moist;[27] the quality of dryness predominates in earth, while the quality of moistness does in water.[28] Sublunary bodies, such as stones or plants are subjected to the cycle of coming to be and perishing,[29] and are mainly composed of earth and water.[30] They are solidified both by heat and by cold, which, through different processes, remove moisture from these bodies.[31]

2.2 *Plants*

Many references to the elemental and structural composition of plants are scattered in Aristotle's writings. We find that wood is predominately composed of air and earth,[32] and wood, leaves, and bark are cited as examples of bodies composed more of earth than water.[33] Psellos describes how moisture and 'airy essence' are both destroyed by a lightning bolt passing through a tree: interestingly, air is not only a constituent part of wood, but also of sap, which is said to contain more air than water.[34] We may add that Galen mentions bone, cartilage, nail, hoof, horn, hair, stone, wood, sand, and clay as objects with a higher portion of dryness than moistness.[35]

From the point of view of its material structure, wood has pores that stretch continuously lengthwise.[36] With respect to its density, Aristotle believes that boiling something means that its inner moisture tends to be drawn out by the heat of the liquid around;[37] stone cannot be boiled since it contains no moisture, while wood is not subject to boiling since it is dense enough to not let inner moisture to be mastered by external moist heat.[38]

Finally, as far as inflammability is concerned, the Aristotelian system posited

[24] Arist., *Mete.* 388a14. For a general overview, from the four elements to the homoiomerous and anhomoiomerous bodies, cf. Arist., *PA*, 646a13–24.

[25] Arist., *Mete.* 380b25.

[26] Arist., *PA*, 641a19–21.

[27] Arist., *Mete.* 381b24–32.

[28] Arist., *Mete.* 382a3–4, Alex.Aphr., *in Mete.* 199, 9–14, and Olymp., *in Mete.* 301, 3–9. In another place, Aristotle himself assigns coldness to water and moistness to air, cf. Arist., *GC*, 331a3–6.

[29] Alex.Aphr., *in Mete.* 199, 14–16.

[30] Arist., *Mete.* 382a3–6. Homoiomerous parts in animals and plants are made of these, cf. Arist., *Mete.* 384b30–31 and Olymp., *in Mete.* 319, 10–14; metals and minerals needs vaporous or dry exhalations, cf. Arist., *Mete.* 378a15–b24.

[31] Arist., *Mete.* 383a16–19, Thphr., *Lap.* I, 3, and Thphr., *Ign.* 8.

[32] Arist., *Mete.* 384b15–16 and Olymp., *in Mete.* 318, 17–27.

[33] Arist., *Mete.* 389a12–13.

[34] Arist., *Mete.* 385b3–5, 386b13–14. The word 'ἰξός' may also refer to European mistletoe (*Viscum album*), or to birdlime, a sticky substance prepared from mistletoe berries or oak-gum; cf. Arist., *GA*, 715b28–30, Ath., X, 451d, Gal., *SMT*, VI, 9, 2 (XI, 888, 11–889, 2 Kühn), XI, 31 (XII, 349, 16–17 Kühn), and Suda, *s.v.* *ἰξός* (ι 396 Adler).

[35] Gal., *Mixt.* I, 6 (I, 539, 16–540, 1 Kühn = p. 19, 31–20, 2 Helmreich).

[36] Arist., *Mete.* 386a9–17.

[37] Arist., *Mete.* 380b19–21.

[38] Arist., *Mete.* 380b25–27.

that the pores of wood can be penetrated by fire,[39] and that there is also a kind of moisture weaker than fire in them;[40] this moisture is airy, not watery as in ice or green wood, both resistant to combustion for this very reason.[41] The main point here is that wood is flammable but does not melt, i.e. its shape tends to persist, and this fact derives from a particular spatial disposition of airy moisture.[42]

2.3 *Lighting bolts*

Aristotelian meteorology is a vast subject. One could summarise Aristotle's thought by saying that "winds, earthquakes, and violent phenomena are all made from the same dry exhalation".[43] When rising, dry exhalations are surrounded and ejected downwards, unnaturally and violently,[44] by the condensed vaporous exhalations in the atmosphere.[45] They can thus become a lightning bolt (κεραυνός), if they are fine enough to ignite.

Furthermore, Aristotle presents a distinction between two types of lightning bolt: a quicker and very fine or gleaming (ἀργής) type and a slower and less fine or smoky (ψολόεις) lightning bolt, which burns and blackens things.[46] This distinction is attested in other ancient sources,[47] and used by Psellos as well.[48] Echoes of the slower and burning kind could still be found in Victorian scientific accounts on lightning bolts.[49]

2.4 *Cold petrifactions*

A type of cold petrifaction is exemplified in limestone formations, like cave stalactites and stalagmites, both petrified from earthy liquids.[50] This kind of stony formation is usually called πώρινος λίθος, πῶρος, or *porus* in many ancient sources.[51] Psellos reports Strabo's account on petrifying waters,[52] but even Pliny or Ps.-Aristotle describe similar phenomena, such as rivers or springs that petrify nearby vegetation, and even report tales of trapped workers petrified in

[39] In this burning process, πνεῦμα may have a role to play, cf. Arist., *Mete.* 371b2–17 and Thphr., *Ign.* 28.

[40] Arist., *Mete.* 387a19–21 and Thphr., *Ign.* 63.

[41] Arist., *Mete.* 387a22 and Olymp., *in Mete.* 331, 16–25. Flames produced by green wood are also redder, cf. Thphr., *Ign.* 31.

[42] Arist., *Mete.* 387b26–28.

[43] Wilson 2013, p. 227; cf. Arist., *Mete.* 370a25–32.

[44] Arist., *Mete.* 342a13–16, Thphr., *Ign.* 1, 7–9, and Battegazzore 1984.

[45] Arist., *Mete.* 369a12–29.

[46] Arist., *Mete.* 371a15–b14 and Wilson 2013, p. 232. For lightning, these adjectives are also well attested in poetry, cf. Hom., *Il.* VIII, 133, Hom., *Od.* XXIII, 330, XXIV, 539, and Hes., *Th.* 515.

[47] Plin., *Nat.* II, 137 and Plu., *Moralia*, 665e–f, 893d–f, 1005b.

[48] *PselDoct*, 149 and Olymp., *in Mete.* 202, 2–7, 8–12, 208, 10–14.

[49] "In all the foregoing cases it will be observed that the metal chains, rod, wires & c. were not of sufficient size to convey away the charge of lightning; but, being delayed in its progress, the astonishing heating power of the electric fluid and sufficient time allowed to fuse or to burn away combustible materials", Tomlinson 1848, p. 123. On this sufficient time to burn something, cf. Thphr., *Ign.* 35.

[50] Arist., *Mete.* 384a18–19

[51] Hdt., V, 62, Arist., *Mete.* 388b25–29, 389a14, Thphr., *Lap.* I, 7, Plin., *Nat.* XXXVI, 132, and Alex.Aphr., *in Mete.* 210, 31–33.

[52] Str., XIII, 4, 14.

a mine.[53]

Pliny also describes two kinds of petrifying stones, both used for sarcophagi: the former destroys corpses in forty days, except for teeth, and petrifies grave goods; the latter, referred to as *porus*, preserves corpses.[54] Both types of cold petrifactions seem to be related to some sort of stony coating action: over time, lime-rich waters cover nearby objects in calcified deposits. This not only provides us with a link between stones solidified by cold and petrifaction of objects, but it also seems to point to ancient observations of phenomena such as the Knaresborough Dropping Well:

> The Dropping Well spring emerges from the Edlington Formation and its associated gypsum strata lying to the west of Knaresborough close to the contact with the underlying Cadeby Formation. The water is high in both sulphate and carbonate, the latter being actively deposited as a tufa ramp and screen below, in which artefacts are petrified as a tourist attraction.[55]

Another kind of cold petrifaction is attested in Pliny's *Natural History*, where it is noted how the bone marrows of animals fallen into mine shafts can be congealed and petrified by (Aristotelian) exhalations, thus changing into a substance very similar to *lapis specularis*.[56] This may also be an explanation for the petrifaction of trapped miners mentioned above. In this respect, Adrienne Mayor describes how some fossil bones can be filled with calcite and selenite crystals, and end up closely resembling the actual phenomenon described by Pliny.[57]

Finally, ancient sources mention a phenomenon that links plants and petrifactions more closely: flowing out of the bark of trees, some kinds of natural gum turn into a cold stony substance. Weather, terrain heat, and contact with air all seem to be causal factors.[58] This kind of petrifaction by air seems related to the ones mentioned in bamboo (tabasheer) and coral physiology; Pliny talks in great detail about corals, and he also reports instances of solidification by air exposure.[59]

2.5 *Hot petrifactions*

In Aristotle, a type of hot petrifaction is the underground formation of 'fossils' (ὀρυκτά), which are solidified by the heat of dry exhalations.[60] In this respect, Psellos' petrified root is unusual: while it is described as "nothing but stone", its formation is quite different from usual stones and minerals since it does not

[53] Ps.-Arist., *Mir.* 834a26–30, 838a11–14, Ps.-Arist., *Pr.* 937a11–19, and Plin., *Nat.* II, 226, XXXI, 29–30, XXXVI, 161.

[54] Plin., *Nat.* XXXVI, 131–132, Thphr., *Ign.* 46, Cels., IV, 31, 7–8, V, 7, and Dsc., V, 124, 1. For another brief mention of petrifying stones, cf. Thphr., *Lap.* 4.

[55] Cooper et al. 2013, p. 147.

[56] Plin., *Nat.* XXXVI, 161 and Eichholtz 1962, pp. 10–12. *Lapis specularis* is a secondary gypsum, quite transparent and easily manufactured into a 'stone glass' for windows. For a historical, mineralogical and archaeological perspective on this, cf. Guarnieri 2015.

[57] Mayor also reports that natives of Siwalik Hills in Nepal call these, supposedly magical, fossils *bijli ke har* (lightning bones), cf. Mayor 2011, pp. 131–135.

[58] Ps.-Arist., *Plant.* 829a16–23.

[59] Thphr., *Lap.* VI, 38, Thphr., *HP*, IV, 11, 13, and Plin., *Nat.* XXXII, 21–24.

[60] Arist., *Mete.* 378a20–26, cf. Eichholz 1949; Wilson 2013, pp. 276–277.

happen underground, and dry exhalations are involved only in a very specific form, the lightning bolt.

Nemesius, bishop of Emesa (fl. c. 390 CE) may have been a direct or indirect source for Psellos' explanation. Chapter five of his *On the Nature of Man* is devoted to elemental theory of matter.[61] It is not easy to determine a precise source for this chapter, but Posidonius or (a source in common with) Galen's *On the Elements According to Hippocrates* may have influenced Nemesius' arguments.[62]

Nemesius introduces the elements in ascending order (earth, water, air, fire), resembling Psellos' hierarchy based on relative density and rarefaction.[63] While we do not have many tales of marvellous petrifactions by heat as by cold, there is a striking passage in Nemesius on the relation between earth and fire, respectively, the heaviest and the lightest element, which are the constituents of the two external and non-contiguous spheres in our sublunary world:

> For in order that the elements should not be related only upward and downward, but should have also a circular relationship, he [God] somehow bent back and returned the extremes to each other, I mean fire and earth. For fire, by merely losing its heat, becomes earth. This is illustrated by thunderbolts (ἐκ τῶν κεραυνῶν): for when fire is carried down and cooled down from its extreme heat it turns into stone. Therefore every thunderbolt contains stone and sulphur. Sulphur is like cooled-off fire which is no longer hot in actuality but only potentially, but is actually dry.[64]

Elements are said to be hierarchically ordered, upwards and downwards according to their density or rarefaction. Aristotle claims that each of the four elements (earth, water, air, fire) is characterised by a single quality (respectively, dry, cold, moist, hot).[65] Each of the four elements may thus be thought of as a set of two qualities, a characterising quality and a secondary one: e.g., earth is DRY and cold. This opens up a circular order, since each element has its characterising quality in common with the secondary quality of the previous element, while the opposite of its characterising quality becomes the secondary quality of the subsequent element: i.e. earth (DRY, cold), water (COLD, moist), air (MOIST, hot), fire (HOT, dry), earth (DRY, cold), and so on.[66] In order to illustrate the transformation of fire into earth – a less obvious change that is not instanced in easily observable natural phenomena (e.g. the boiling or freezing of water) – Nemesius uses the example of lightning bolts/thunderbolts (κεραυνόι): when its heat cools down, the fire (HOT, dry) of a lightning bolt transmutes into earth (DRY, cold).

[61] In manuscript tradition, Nemesius' *De natura hominis* is sometimes attributed to Gregory of Nissa, and this famous work was also translated into several languages (Armenian, Syriac, Arabic, Latin), influencing many medieval writers, cf. Sharples and van der Eijk 2008, p. 4.

[62] For a general discussion on Nemesius' sources, cf. Sharples and van der Eijk 2008, pp. 18–23. On the sources for the chapter on elements, cf. Jäger 1914, pp. 68–96; Lammert 1941, Lammert 1953; Siclari 1974, pp. 137–149; Kallis 1978, pp. 10–47.

[63] Nem., V, 5–6. Also cf. Gal., *Hipp.Elem.* IV, 2 (I, 442–443 Kühn = p. 86–88 De Lacy); Galen here is criticising various pre-Socratic monist philosophies. For a discussion on different groupings of the four elements, cf. De Lacy 1996, pp. 45–48.

[64] Nem., V, 48, 25–49, 6. Cf. Nemesius, *On the Nature of Man*, p. 94.

[65] Arist., *GC*, 331a3–6.

[66] Arist., *GC*, 331a36–b4.

The name λίθος κεραύνιος or *ceraunia* is attested in ancient sources to describe a family of gemstones.[67] Among this group, there were stones said to be only found in lightning-struck places, and thought to possess supernatural powers against lightning bolts.[68] According to archaeological evidence and literary sources, it is likely that these stones were Neolithic flint axe-heads: understood as natural stones in Graeco-Roman times, they were reused as amulets and inscribed with magical formulae for this reason.[69]

Furthermore, it is worth noting that, at least since Homer, ancient sources often referred to the strict correlation between lightning bolts and sulphur; this is explicit even in a late source like Psellos, when he calls sulphureous (θειώδης) the fire of lightning bolts.[70] A probable explanation, in my opinion, is the distinct smell of (what we now understand to be) ozone, which is often noticeable right after a lightning strike. This correlation is also reported in 19th-century scientific literature, not far from the time of Schönbein's discovery of ozone (from ὄζειν, to smell).[71]

3 *Back to Psellos' root: fulgurites and oaks*

3.1 *Fulgurites*

In the light of the information discussed so far, let's try to interpret the marvellous petrifaction described by Psellos. His explanation seems to rest on hot petrifactions, which imply a close connection between fire and earth. This connection might have been substantiated by fortuitous ancient observations of fulgurites. These "are glasses formed by the rapid heating of rock, sand, or soil by a cloud-to-ground lightning strike",[72] with a tubular shape that could resemble the root of a tree.[73] We find 'fulgurite' as a term for these objects at least since 1831,[74] while only a few years earlier fulgurites were referred to as "les tubes que les Allemands appellent Blitzröhre (tubes fulminaires)".[75]

Fulgurites not only can resemble roots but the very tree roots can actually be involved in their formation process:

> As the lightning passes through the soil, this energy melts, vaporises, and chemically reduces the target material, resulting in a rapid physical, chemical, and morphological change. When lightning reaches the conductive layer or when it possesses too little energy to change the target material, fulgurite formation stops. About 104–105 amps

[67] For *ceraunia*, cf. Plin., *Nat.* XXXVII, 134, Tert., *Cult.fem.* I, 1, 3 and Isid., *Or.* XVI, 13, 5, 15, 24. For λίθος κεραύνιος, cf. P. Holm., 205 and Bolus, *Symp.* 9.

[68] Plin., *Nat.* XXXVII, 135, Isid., *Or.* XVI, 13, 5, and Halleux and Schamp 2003, p. 249.

[69] Tim.Gaz., 30, 26–28 (Haupt), Isid., *Or.* XVI, 15, 24, and Faraone 2014. On prehistoric flints ('thunder-stones') and lightning bolts, cf. Frazer 1911, p. 374 and Frazer 1936, pp. 188–191.

[70] *PselDoct*, 150, 7, 170, 7. For the literary association between lightning and sulphur, cf. Hom., *Il.* VIII, 133–135, XIV, 414–417, Hom., *Od.* XIV, 305–308, Plu., *Moralia*, 665d, Sen., *nat.* II, 21, 2, 53, 2, Lvcan., 7, 160, Pers., 2, 24–25, Lvcr., 6, 221.

[71] Tomlinson 1848, pp. 117–121 and Rubin 2001, pp. 40–42.

[72] Pasek et al. 2012, p. 477.

[73] Viemeister 1972, pp. 138–139. For an interesting description of a newly-formed fulgurite, cf. Gilbert 1823, p. 441

[74] Anonymous 1831, p. 188.

[75] Anonymous 1821, p. 290.

> of electrical current, corresponding to about 30–300 coulombs of electrons and about 106–108 V, flow through the target material, following areas of high conductivity or moisture content such as plant roots and other subsurface features.[76]

This rapid physical and chemical change is partly described in Psellos' account, where we find a root that is in-between plant life and mineral world: a lightning bolt that quickly passes through a tree destroys all of its moisture without burning it, and preserves the shape of the stricken root while hardening the target material.

Aristotle already argued that trees can be penetrated by fire because of their pores and the moisture contained in wood. In terms of modern physics, it is observed that

> the moisture content of a tree is a measure of its electrical conductivity and hence its attractiveness to a wandering lightning bolt trying to get easily to ground. Since moisture conducts electricity, lightning would rather pass down a tree than go through virgin air. Trees contain water in two forms: as water held in the cell walls of the wood itself and as free water contained in cell cavities.[77]

Since wood usually floats on water, and air is less heavy than water, Aristotle claimed that air (MOIST, hot) was a major elemental part of wood, together with earth. Moisture is also a fundamental component of living trees, and Aristotle defined this moisture as mainly composed of air. He also identified wood structure as composed of pores stretching continuously lengthwise.[78] This lengthwise structure arranges the airy moisture of wood continuously altogether, like a fuse. It was thought that only a very quick fire, for instance a lightning strike, could burn all this well-stretched and permeating moisture, and preserve the shape of the tree at the same time.

In this regard, it is to be noted that "when struck by lightning, trees are not always set afire. Sometimes they are shattered or split, but frequently they merely lose some bark".[79] This might partly explain ancient accounts of finer lightning bolts that penetrate things without burning them. It is not unreasonable to assume that this fact was widely known in antiquity: it seems far easier to observe that a lightning-struck tree does not always burst into flames than to notice how the bronze sheet of a lightning-struck shield could melt, while its wooden structure could not.[80] Observations about substances such as wood, burned, blackened, or unscathed by lightning bolts, logically led natural philosophers to distinguish different subtypes of a single natural phenomenon[81] or to assume more complex explanations.[82]

[76] Pasek et al. 2012, p. 478. According to Pliny, lightning bolts do not pass through soil for more than five feet, Plin., *Nat.* II, 146.
[77] Viemeister 1972, p. 179.
[78] Cf. supra § 2.2.
[79] Viemeister 1972, p. 180.
[80] Arist., *Mete.* 371a24–26.
[81] Plin., *Nat.* II, 137–138.
[82] Arist., *Mete.* 371b2–17

3.2 *Oaks*

Psellos says that the petrified root seen in his youth was probably from an oak (δρῦς). This may not be as coincidental as it seems: not only are oaks particularly prone to be struck by lightning bolts,[83] they also have a religious connection to the god Zeus: his weapons during the Titanomachy – as is well-known – were the Cyclops-forged lightning bolts.[84]

A famous oak, probably a *Quercus macrolepsis*,[85] was the sacred tree of Dodona, a prominent oracular feature of the local sanctuary of Zeus.[86] Another term for oak, φηγός, is also attested with reference to the tree of Dodona,[87] albeit this double denomination seems to be quite fluid.[88] In Italy too there was a strong connection between oaks and the cult of Jupiter.[89] Oak is therefore a tree sacred to Zeus, as often stressed in secondary literature.[90]

Lightning bolts, on the other hand, are Zeus' weapons of choice and, in this regard, it is worth noting that a natural property of oaks seems to validate this connection between the tree, the god, and his weapons:

> an oak is decidedly a good conductor of electricity, so far as trees go; that it grows in loam and sandy soils where trees are most frequently struck by lightning; and, furthermore, is an excellent example of a tap-rooted tree with its root system extending deep into the soil, all of which qualities place the oak in great danger of lightning damage as compared to other trees.[91]

Thus, a natural phenomenon strengthens the religious and cultural significance that oaks had in the eyes of ancient authors and scholars.[92]

4 Theophrastus' *On Petrified Things*

4.1 *Theophrastus' writings*

Although it cannot be discounted that Psellos did in fact observe fulgurites, his mention of a petrified root might partially rely on the writings of Theophrastus of Eresos (372/1 or 371/0 – 288/7 or 287/6 BCE),[93] who was interested both in plants and petrifactions. In the catalogue of his writings composed by Diogenes

[83] Viemeister 1972, pp. 180–183

[84] Apollod., I, 2, 1, 7, I, 6, 2, 38.

[85] Parke 1967, pp. 30–31.

[86] Hom., *Od.* XIV, 328, XIX, 297 and Suda, *s.v.* *Δωδώνη* (δ 1447 Adler).

[87] Hom., *Il.* VII, 60 and Hdt., II, 55.

[88] As an example, Sophocles uses both terms, in the same play, for the sacred tree of Dodona; cf. S., *Tr.* 171, 1170.

[89] Parke 1967, pp. 20–21; Cook 1903a, Cook 1903b, and Cook 1904.

[90] Frazer suggested an archetypal Indo-European god of oak and thunder, cf. Frazer 1911, pp. 343–375.

[91] Covert 1924, p. 492. Theophrastus was aware that oaks are deep-rooting, cf. Thphr., *HP*, I, 6, 4; he also reported that some types of moisture-rich oaks were said to be often struck by lightning bolts, cf. Thphr., *HP*, III, 8, 5 and Plin., *Nat.* XVI, 24.

[92] Frazer's final opinion on this matter was that "on the present theory, which I now prefer, the god of the sky and the thunder was the great original deity of our Aryan ancestors, and his association with the oak was merely an inference based on the frequency with which the oak was seen to be struck by lightning", Frazer 1913, p. 300.

[93] Dorandi 1999, pp. 49–50.

Laërtius, it is mentioned a work probably titled *On Petrified Things* (περὶ τῶν ἀπολιθουμένων).[94]

While this work is entirely lost today, we have few interesting references to petrifactions in Theophrastus' extant books. We are told of petrified plants in the outer sea near the Pillars of Heracles,[95] and mushrooms near the Red Sea coast a slightly above the latitude of Coptos, that grow after relatively abundant rain, and are petrified by the sun.[96] Similar information is also reported by Pliny, who speaks of mushrooms that are turned "in pumicem" by the sun.[97] These recall Strabo's account of petrified lentils near the Pyramids of Egypt, probably lenticular fossils (nummulites) understood as petrified meals of ancient workers.[98] The Red Sea is also noteworthy for the presence of stones that, when cut in half, reveal small marine animals in the inner layers;[99] it is not unreasonable to see an ancient observation of fossils here.[100]

In his *Enquiry into Plants*, having talked about plant diseases, Theophrastus also enumerates afflictions due to season or specific location. We might expect petrifaction to be mentioned among the afflictions, like freezing, scorching, or nefarious effects of certain winds, but unfortunately there is no mention of petrifying lighting bolts.[101]

4.2 *Theophrastus' petrified forest*

As we have seen, not much survives of Theophrastus' writings on petrifactions. However, an important piece of evidence still remains, although not reported in textual sources. The ancient village of Eresos, Theophrastus' hometown, is located inside the area (c.150 km^2) of one of the world's biggest preserved fossilised forest ecosystems, formed approximately 18.5 million years ago, being covered by pyroclastic material and petrified *in situ*. The Petrified Forest of Lesvos (Απολιθωμένο Δάσος Λέσβου), a Protected Natural Monument since 1985 (PD 443 /1985), contains many trunks, some even standing and with a root system, branches, fruits, and leaves. It is interesting that *Quercus macrolepsis*, the sacred oak of Dodona and maybe the kind of tree root seen by Psellos, is listed among the trees of this petrified forest, as seen in the Tentative List submitted by the Permanent Delegation of Greece to UNESCO.[102]

This is not proof, but certainly strong evidence for assuming an early and pervasive interest of Theophrastus in the natural phenomenon of petrifaction. Moreover, we cannot refrain from suggesting a fascinating parallel: the young Theophrastus, wondering about the petrified (oak) trees of his hometown before leaving Lesbos to study under Aristotle, mirrors the young Psellos, wondering about a petrified (oak) root before ascending to a better philosophical understanding of nature.

[94] D.L., V, 42. For philological problems regarding this title, cf. Sharples and Gutas 1998, pp. 23–25.
[95] Thphr., *HP*, IV, 7, 1.
[96] Thphr., *HP*, IV, 7, 2.
[97] Plin., *Nat.* XIII, 139.
[98] Str., XVII, 1, 34 and Mayor 2011, p. 71.
[99] Thphr., *Fr.* 4, 70.
[100] For fossil ivory, cf. Thphr., *Lap.* VI, 37 and Plin., *Nat.* XXXVI, 1, 34.
[101] Thphr., *HP*, IV, 14, 11.
[102] See Permanent Delegation of Greece 2014.

Conclusions

Psellos is not usually considered an original thinker by modern scholars: "Psellus a beaucoup écrit, mais souvent, il n'a fait que copier".[103] We cannot discuss here how valued originality was in Byzantine cultural production through the ages, but we can better appreciate Psellos' works after reading his own words: "I drew my small measure of wisdom from no living fount: the sources I discovered were choked up, and I had to open and cleanse them myself. Their waters, too, were hidden in the depths and only brought to the surface after I had expended much energy".[104]

As much as we have to consider these words as highly rhetorical, we have to keep in mind that Psellos could have had access to Classical, Hellenistic, or Late Antique philosophical sources lost to us. His description of a petrified oak may either provide important information on natural observations in 11th-century Byzantium or it might represent Psellos' scholarly appropriation of some ancient observations, perhaps derived from Theophrastus' lost work *On Petrified Things* itself.

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[103] CMAG VI, p. 21. Another example: "In composing his philosophical (and other) works Psellos frequently did little more than produce a more or less coherent concatenation of short excerpts taken from a (usually unacknowledged) Greek source", O'Meara 1981, p. 33; cf. Jenkins 2017, pp. 449–450. On the cultural value of *excerpta* for the 9th- and 10th-century Byzantium, cf. Odorico 1990.

[104] *PselChron*, 6, 42. Translation in Psellos 1966.

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