Luminescent wood in coal and ore mines

- A historical review

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Abstract

Light emission by fungi was already known in the ancient world. Although this phenomenon was mentioned only very briefly by Aristotle and Pliny the Elder, naturalists mostly neglected the subject until the early observations were confirmed in underground locations by miners in the 18th century. In 1796 the German naturalist Alexander von Humboldt was one of the first to describe the luminescence of rhizomorphs (thick "root-like" mycelium strands) in the mines of Freiberg (Germany). A bright luminescence of wooden panels and beams in a coal mine was reported, so bright that pit lamps were not necessary. High levels of air humidity seemed an important requirement for light emission and increased temperatures stimulated luminescence as well. Light was emitted by the "plants" (termed *Rhizomorpha subterranea*, *R. aïdela*, *R. stellata*, *R. noctiluca*) mainly from the tips of the mycelium strands. Today, it is rather difficult to see this spectacle in nature, e.g. in forests, mainly because of increasing "light pollution" of the environment. This report records the perception of this phenomenon in mining locations and discusses the original (mostly German) literature of the 18th and 19th centuries.

Keywords: *Armillaria*, bioluminescence, glowing wood, light emission, lumincescent fungi, rhizomorphs

Early History

Light emission from rotting wood is a widespread phenomenon and is a part of many myths and fairy tales (Schertel, 1902). However, today it is rather difficult to see this spectacle in nature, mainly because of increasing "light pollution" of the environment. Therefore, it is not surprising that luminescent wood has mainly been observed in very dark locations such as the shafts and galleries of mines. Historical written records of "glowing wood" in coal or ore mines date back to the 18th century (Brandl, 2007). The goal of this report is to show the perception of this phenomenon in mining locations and to access the original (mostly German) literature of the 18th and 19th centuries. However, literal translation is not always possible because of the particular wording and phrasing of the original literature. The term "plant" is used very often, although dependant on the context, "fungi" and "rhizomorphs," respectively, are meant.

Light emission by fungi was already known in the ancient world. However, this phenomenon was mentioned only very briefly by the Greek philosopher Aristotle (384 to 322 BC) and the Roman writer and natural philosopher Pliny the Elder (Gaius Plinius Secundus, 23 to 79 AD). Pliny wrote (lib. XVI, cap. XIII):

"Galliarum glandiferae maxime arbores agaricum ferunt. est autem fungus candidus, odoratus, antidotis efficax, in summis arboribus nascens, nocte relucens. signum hoc eius, quo in tenebris decerpitur." [Translation (Bostock and Riley, 1855): "It is in the Gallic provinces more particularly that the glandiferous trees produce agaric; such being the name given to a white fungus which has a strong odour, and is very useful as an antidote. It grows upon the top of the tree, and gives out a brilliant light at night: this, indeed, is the sign by which its presence is known, and by the aid of this light it may be gathered during the night."]

In the German translation of Külb (1856), "agaricus" is related to *Agaricus quercinus* (syn. *Agaricus labyrinthiformis*, *Agaricus dubius*, *Daedalea inzengae*, *Hexagona minor*, *Lenzites quercina*, *Merulius quercinus*, *Trametes hexagonoides*, *Trametes quercina*, *Xylostoma giganteum*). Later, Hennings (1904; cited by Harvey, 1957) assigned the term "agaricus" tentatively to *Pleurotus olearius* (syn. *Omphalotus olearius*, *Omphalotus illudens*, *Clitocybe olearea*, *Clitocybe illudens, Pleurotus phosphorus*).

The first comprehensive review on light emitting plants (including fungi and also animals) was written by the Swiss naturalist and physician Conrad Gessner in 1555. However, luminous fungi were treated only marginally in his work; Gessner mainly referred to the statements of Aristotle and Pliny and mentioned a mushroom as being visible in darkness due to the emission of light (*"fungus in tenebris cernitur"*), translated as "the mushroom is recognized in the dark."

Today, at least 64 species of light-emitting fungi have been identified which fall into three distinct evolutionary lineages: *Armillaria*, *Omphalotus*, and *Mycena* (Desjardin et al., 2008).

"Self Combustion" of Wood

Almost one hundred years ago, the Austrian botanist and plant physiologist Hans Molisch wrote about the fascinating emission of light from wood (Molisch, 1912):

"Es dürfte wenige physiologische Erscheinungen geben, die schon frühzeitig die Aufmerksamkeit der Menschen in so hohem Grade erregt haben wie das Leuchten des Holzes. Namentlich in der Zeit des Aberglaubens übte der Anblick leuchtenden Holzes auf die Gemüter einen mächtigen Einfluss, und viele glaubten in dem in der Finsternis magisch leuchtenden Holze allerlei Spuk und Zauberei vermuten zu dürfen." [Translation: "The luminescence of wood is probably one of the few physiological phenomena which drew already the attention a long time ago. Especially in

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times of superstition, luminescent wood had a great influence on the mind, and many suspected spook and magic when confronted with it in the dark."]

Figure 1 shows a piece of wood which emits light. The light is easily visible in a very dark room after adaptation of the eyes to the darkness for about five

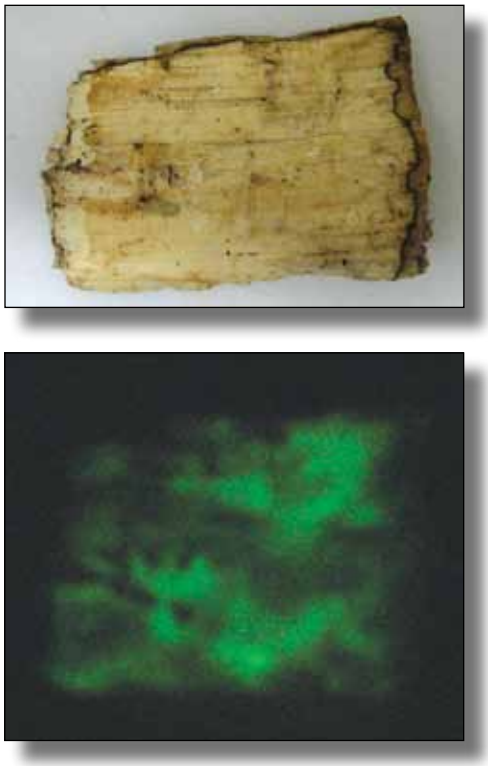

Figure 1. Luminescent wood, photographed in daylight (top) and in the dark (bottom) with an exposure time of 15 sec.

minutes.

Originally, the reason for the light emission was attributed to the rotting of wood based on oxidation processes (Heinrich, 1815). A kind of "self-combustion" was assumed or a decomposition of water concomitant to a slow combustion of hydrogen released (*"ein Vegetiren im Feuchten, ein Zersetzen des Wassers, ein damit gleichzeitiges, sanftes Verbrennen des frey werdenden Wasserstoffgases in der unterirdischen Atmosphäre zu erkennen"* from Nees von Esenbeck, 1823). [Translation: "A rotting under damp conditions, a decomposition of water, a gentle combustion of hydrogen gas released in the subterrestrial atmosphere."]

The cause, however, was in the infection of the wood by fungi, mainly *Armillaria mellea* (honey mushroom) (Molisch, 1912). Rhizomorphs of *A. mellea* (thick tubular "root-like" morphological structures) emit greenish-white light whereas the fruit body is non-luminescent: *"Das Licht wird überall gleich beschrieben als ruhig und gleichförmig anhaltend, bläulichgrün bis schön grün"* (Heller, 1853) or "The light is everywhere described as quiet and uniform, bluish-green to green."

Both Conrad Gessner and Francis Bacon (philosopher and statesman) recognized that the light emission from wood was not related to heat radiation. Bacon wrote (Bacon, 1620):

"Omne ignitum ita ut vertatur in ruborem igneum etiam sine flamma perpetuo calidum est;[…] *sed quod in proximo est videtur esse lignum putre, quod splendet noctu neque tamen deprehenditur calidum,* […]*."* [Translation: "All things which are lit will end up in fiery redness and are always hot even without flames, (…) but what comes nearest seems to be rotten wood, which shines by night and yet is not found to be hot, (…)."]

Today it is known that the light originates from a metabolic reaction of the fungus where electrons are transferred to an acceptor (luciferin) which is cleaved by an enzyme (luciferase) in the presence of oxygen. This results in the formation of an electronically excited state of the luciferin and the subsequent emission of light with a maximum wavelength of approximately 525 nm during return to the ground state (Airth and McElroy, 1959; Hastings, 1996). An example of a mushroom (*Mycena illuminans*) exhibiting light emission from stems and fruit bodies is shown in Figure 2.

In a funny story, Friedrich Ludwig reported how luminous wood was picked up from the ground to lighten the route when returning home close to midnight from a trip trough the dark forest (Ludwig, 1901):

"An der Strasse, die von Greiz nach dem idyllisch gelegenen Ida-Waldhaus führt, waren an einem Waldschlag, der von hallimaschkranken Fichten bestanden war, Wurzelstöcke ausgerodet und in Klaftern aufgeschichtet worden. Da das von dem Hallimaschpilz befallene Holz regelmässig leuchtet, bieten derartige Schlage in finsterer Nacht einen prächtigen Anblick und die Passanten ziehen öfter mit den leuchtenden Holzstücken vom Waldhaus nach Greiz heimwärts, was dem Beschauer wie ein gespenstischer Laternenzug erscheint." [Translation: "On the road leading from Greiz (town in Thuringia, Germany) to idyllic Ida-Waldhaus, wood and roots from *Armillaria*-infected pine trees have been stacked. Because the wood emits light continuously, these stacks present a gorgeous sight in the dark and pedestrians often walk home with the luminescent wood, giving the impression of a spooky parade."]

The Austrian physician and chemist Johann Florian Heller addressed the early descriptions by Aristotle and Pliny and related them to the occurrence of fungi in mining locations (Heller, 1853):

"Eines der interessantesten altliterarischen Daten, welches ich bisher auffinden konnte und unter den alten Autoren von wirklichem Werthe erscheint, ist die Mittheilung von Aristoteles (de anima Lit. II. Cap. VII.), dass nämlich manche Schwämme im Finstern einen leuchtenden Schein verbreiten sollen. Spätere Naturforscher läugneten es, bis man wieder bei Grubenbauten durch die Bergleute die schon von Aristoteles gemachte Beobachtung bestättigt fand." [Translation: One of the most interesting facts in the ancient literature is the remark of Aristotle (de anima Lit. II. Cap. VII.) that many sponges emit light in the dark. Later however, naturalists denied

Figure 2. Tropical mushroom *Poromycena manipularis* growing on wood (Danum Valley Field Center, Borneo, Malaysia). Photo taken with flash (top) and without illumination (bottom; exposure time of 30 sec).

this phenomenon until the observation made by Aristotle was confirmed in underground mines by miners."]

"Glowing wood" in Coal and Ore Mines

According to Alexander von Humboldt it was Johann Carl Freiesleben (at this time assessor of the board of mines) who in 1796 was the first to observe luminescence of rhizomorphs in the mines of Freiberg (Germany). Von Humboldt (1799) stated:

"Erst seit kurzem halte ich mich durch glaubwürdige Zeugen versichert, dass in den Gruben selbst phosphorescierendes Holz gesehen worden ist. Alte Bergleute in der Marienberger-Bergamtsrevier haben diese seltne Erscheinung beobachtet, und ein allgemein geschätzter, vortreflicher Beobachter, Herr Freiesleben hat mir im Sommer 1796 Fragmente einer unterirdischen Pflanzen geschickt, welche er selbst leuchtend gefunden und frisch für mich gesammelt hatte. Diese Pflanze war ein Lichen filamentosus und meinem L. pinnatus nahe verwandt. An der Wirklichkeit dieses Phänomens ist demnach keineswegs zu zweifeln." [Translation: "Reliable witnesses confirmed the presence of phosphorescing wood in the mines. Old miners of the Marienberg mine observed this rare event and I was given fragments of an underground plant freshly sampled by Mr. Freiesleben. There is no doubt about the occurrence of this phenomenon."]

Von Humboldt noticed that the temperature optimum of the luminescence was between 8 and 15°C whereas at temperatures of >32°C light emission was not observable any more. However, he was not able to isolate light-emitting compounds from wood (Harvey, 1957). It was the director of the board of mines (von Derschau) who noticed that light was exclusively emitted from black lines and streaks on the wood which could be scrapped off by hand. In a letter, he reported the bright luminescence of wooden supports and wooden beams in a coal mine; so bright that pit lamps were not necessary (Harvey, 1957). Von Derschau's letter was published by the German botanist Theodor Friedrich Ludwig Nees von Esenbeck (Nees von Esenbeck, 1823):

"Der Steiger bemerkte mir, dass man in dieser Strecke an einzelnen Stellen keiner Lampe bedürfe, indem das Holzwerk hinreichend leuchte. [...] *Bei näherer Betrachtung fand ich das Holzwerk mit blaulich leuchtenden Linien und Puncten überzogen, welche die einzelnen Thürstöcke und Kappen bezeichneten, und an einigen Stellen so hell schimmerten, dass man bei diesem Schein die Fläche meiner Hand wahrnehmen konnte. Meine Begleiter wollten dies dem faulenden Holz zuschreiben, so oft ich aber nach jenen leuchtenden Puncten griff gerieten immer Teile der Pflanze* […] *in meine Hand. Eine noch nähere Untersuchung bewiess mir, dass nur diese Pflanze* […]

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das Leuchten hervorbringe, und zwar besonders die End- und Triebspitzen derselben, welche letztere gewöhnlich weiss sind und zuweilen herunterhängen. Beim Zerreiben einer solchen Spitze in der Grube leuchteten die Finger einige Secunden lang." [Approximate translation: "I was told by the foreman that in certain locations no pit lamps are necessary because the wood was emitting enough light. A close observation showed the presence of bluish lines and spots on the wood, so bright at some locations that my hand was visible. My companions attributed the phenomenon to rotten wood, but whenever I tried to touch the spots I always caught parts of these plants [termed *Rhizomorpha subterranea* by von Derschau]. A closer investigation showed that light was emitted especially from the tips of the shoots. After grinding the tips, my fingers glowed for a few seconds."]

The German geologist Johann Jacob Nöggerath added to Nees von Esenbeck's publication the following remarks:

"Die Gewohnheit, Bergwerke nur mit Geleuchte zu befahren, ist vielleicht allein Ursache, dass diese auffallende Erscheinung nicht früher beobachtet wurde." [Translation: "The practice to work in the mines only with pit lamps is perhaps the reason that this remarkable occurrence was not observed earlier."]

Several years later in a letter to Nöggerath, Freiesleben reported observations made by assessor Erdmann in the coal mines of Grossburgk [village close to Dresden, Germany]. Erdmann reported the light emission from wooden supports, so intense that people located in front of the supports were clearly recognizable (Freiesleben, 1825):

"Die leuchtende Pflanze habe ich hier (in Burgk) in wundersamer Schönheit gefunden; ich werde den Anblick ihrer Herrlichkeit nie vergessen. Wie in ein Zauberschloss tritt man in das Ort, wo sie sich in solcher Menge befindet, dass sie Seitenstösse, Firste und Thürstöcke ganz übersponnen hat, und in ihrem strahlenden Phosphorglanze fast das Auge blendet. Der Schein, den sie verbreitet, ist wie blasses Mondenlicht, so dass zwei Personen, nahe zusammenstehend, die Umrisse ihrer Körper erkennen können." [Translation: "I have found the luminescent plant in wondrous beauty. I will never forget its magnificence. The location looks like a magic castle. Plants are present in such amounts that wooden frames and supports are completely covered. The eyes are almost blinded by the bright phosphorescence. The shine is like faint moonlight and the persons standing close to each other can recognize their silhouettes."]

Years later, Heller addressed again von Derschau's letter and expanded the report with own observations.

Figure 3. Drawing of wood overgrown with a fungal mycelium (from Heller, 1853). Figure 3. Drawing of wood overgrown with a fungal mycelium (from Heller, 1853).

Original figure legend: (1) Leuchtender Pilz auf Holz (*Pinus silvestris*). [...] (2) Ebenfalls leuchtender Pilz aus dem Innern eines leuchtenden Stück verwesten Holzes (Salix) mit unbewaffnetem Auge zu sehen. (3) Leuchtender Pilz (*Rhizomorpha noctiluca*) auf verwestem Holz von Pinus silvestris bei 300maliger Diametralvergrösserung. […] [translation: "(1) Luminescent fungus on wood (*Pinus silvestris*). […] (2) Again a luminescent fungus from the interior of a piece of rotting wood (Salix), visible to the naked eye. (3) Luminescent fungus (*Rhizomorpha noctiluca*) on rotting wood of Pinus silvestris at 300x magification]. Heller, 1853):

"Zwei Arten der Pflanzengattung sind es vorzüglich, welche man in den Gruben und am Gehölze überhaupt findet, welche stark leuchten, nämlich Rhizomorpha aïdela (v. Humboldt) und Rh. stellata (v. Nees). Die Pflanzen kommen, wenn sie sich völlig ausbilden, bis zu einigen 20 Fuss langen Ranken, die sich längs der feuchten Zimmerung ziehen, vor […]. *Es ist ein ziemlich hoher Grad von Feuchtigkeit immer eine wesentliche Bedingung, dass das Leuchten eintrete. So ist auch etwas mehr Wärme eine besondere Beförderung doch keineswegs Bedingung des Leuchtens. So leuchten die Rhizomorphen nach meinen und Anderer Beobachtungen viel schöner in Gruben, wo die Temperatur höher ist und selbst über 20° R. reicht.* […] *Vorzüglich kommen diese Rhizomorphen in Kohlengruben vor, ja man findet sie selbst auf Thonschiefer aufsitzen."*

[Translation: "Two plant species, which glow strongly, are found in the mines and on the wooden panels, namely *Rhizomorpha aïdela* (v. Humboldt) und *Rh. stellata* (v. Nees). Fully grown, plants can be 20 feet long, growing along the wooden frames […] A high degree of humidity is an important requirement for light emission. Increased temperatures stimulate luminescence as well. I observed that rhizomorphs luminesce more intensely at higher temperatures even at 20°R. […] Rhizomorphs occur especially in coal mines, but can even be found on clay shale."]

In Heller's publication, a drawing of the fungal mycelium responsible for the light emission is presented for the very first time (Fig. 3).

Luminescent Wood In Our Forests

Bioluminescence (light emission by animals, plants, fungi, or bacteria) is widespread in nature and luminescent leaves and wood are easy to find on a walk through the forest, even during the day (Bothe, 1931). Molisch and Dobat give a simple description (Molisch and Dobat, 1979):

"Wenn man eine Umfrage halten würde, wie viele Menschen von Hundert leuchtendes Holz in der Natur gesehen haben, so würde sich nur eine verhältnismässig geringe Zahl dazu

bekennen. Die meisten Menschen gehen nicht gern im finsteren Wald spazieren, und so bleibt es gewöhnlich dem Zufall überlassen, bis endlich jemand auf leuchtendes Holz stösst. Man hat es infolgedessen für eine grosse Seltenheit gehalten, aber zu Unrecht, denn es gelingt ziemlich leicht, sich solches Holz zu verschaffen: Löst man von alten, verwesenden Baumstümpfen z.B. der Kiefer (Pinus), der Fichte (Picea) oder der Eiche (Quercus) die Rinde ab und findet auf dem nackt zutage

Figure 4. Rhizomorphs on the stump of a pine tree (has exposed luminescent wood) after removal of the bark.

liegenden Holz schwarze 'Adern' oder verzweigte schwarze Stränge [see Fig. 4], *so ist es sehr wahrscheinlich, dass man leuchtendes Holz vor sich hat. Zuerst sammle man die schwarzen Stränge für sich, lege sie zwischen feuchtes Papier oder in eine Büchse und beobachte in der Nacht mit wohlausgeruhtem Auge. Dann wird man in vielen Fällen besonders die jungen, noch weiblichen Spitzen der schwarzen Stränge im Finstern leuchten sehen. Die Stränge sind das Dauermyzel (sog. Rhizomorpha) des schon genannten Hallimasch, aus dem die nicht leuchtenden Fruchtkörper hervorkommen."* [Translation: "Only a small percentage of people has ever seen luminescent wood in nature, because nobody likes to walk through the forest in the dark. Therefore, luminescent wood is found only by accident. As consequence, its occurrence was wrongly taken as rarity, but this kind of wood is easy to obtain: Bark has to be removed from old decaying stumps of e.g. pine, spruce, or oak. Between the bark and the wood, black "veins" or branched strands can be found and it is very likely that one has exposed luminescent wood. The black strands can be collected, kept between wet paper or in a box, and observed in the night. In many cases, especially the young tips of the black strands glow in the dark. These strands represent the durable mycelium (so called rhizomorphs) of the honey mushroom producing the non-luminescent fruit bodies."]

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References

Airth, R.L., and W.D. McElroy. 1959. Light emission from extracts of luminous fungi. *Journal of Bacteriology* 77: 249-250.

Bacon, F. 1620. *Novum organum. Liber secundus aphorisorum de interpretationae naturae sive de regno hominis*. London, 404 pp.

Bostock, J., and H.T. Riley. 1855. *Pliny the Elder: The Natural History*. London: Henry G. Bohn, 555 pp.

Bothe, F. 1931. Über das Leuchten verwesender Blätter und seine Erreger. *Planta* 14: 752-765.

Brandl, H. 2007. Die "Lichtfäule" in Gruben und Bergwerken – ein historischer Rückblick. *Minaria Helvetica* 27b: 41-48.

Desjardin, D.E., A.G. Oliveira, and C.V. Stevani. 2008. Fungi bioluminescence revisited. *Photochemistry and Photobiological Sciences* 7: 170-182.

Freiesleben, J.C. 1825. Lichterscheinungen. I. Leuchten der Rhizomorphen. *Journal der Chemie & Physik* 44: 65-73.

Gessner, C. 1555. *Conradi Gesneri medici de raris et admirandis herbis, quae sive quod noctu luceant, sive alias ob causas, lunariae nominantur, commentariolus & obiter de aliis etiam rebus quae in tenebris lucent*. Zurich: Apud Andream Gesnerum F. & Iacobum Gesnerum, 87 pp.

Harvey, E.N. 1957. *A History of Luminescence from the Earliest Times Until 1900*. Philadelphia: The American Philosophical Society, 692 pp.

Hastings, J.W. 1996. Chemistries and colors of bioluminescent reactions: a review. *Gene* 173: 5-11.

Heinrich, P. 1815. *Die Phosphorescenz der Körper oder die im Dunkeln bemerkbaren Lichtphänomene der anorganischen Natur.* Nürnberg: Verlag Johann Leonhard Schrag.

Heller, J.F. 1853. Ueber das Leuchten im Pflanzen- und Thierreiche. *Archiv für physiologische und pathologische Chemie und Mikroskopie* 6: 44-54, 81-90, 121-137, 161-166, 201-216, and 241-251.

Hennings, P. 1904. Über leuchtende Hutpilze. *Naturwissenschaftliche Wochenschrift* 3: 170-171.

Külb, P.H. 1856. Cajus Plinius Secundus, Naturgeschichte. Stuttgart, Metzlersche Buchhandlung. 5 Vol.

Ludwig, F. 1901. Phosphorescierende Tausendfüssler und die Lichtfäule des Holzes. *Centralblatt für Bacteriologie, Parasitenkunde und Infektionskrankheiten (2.Abt.)* 7: 270-274.

Molisch, H. 1912. *Leuchtende Pflanzen. Eine physiologische Studie.* Jena: Gustav Fischer Verlag, 198 pp.

Molisch, H., and K. Dobat. 1979. *Botanische Versuche und Beobachtungen mit einfachen Mitteln*. Stuttgart, Gustav Fischer Verlag, 281 pp.

Nees von Esenbeck, T.F.L. 1823. Correspondenz. *Flora* 6: 115-123.

Schertel, S. 1902. Über Leuchtpilze, unsere gegenwertigen Kenntnisse; ihr Vorkommen in Litteratur und Mythe. *Deutsche Botanische Monatsschrift* 20(3): 39-42, 56-60, 76-77, 139-152.

von Humboldt, F.A. 1799. *Ueber die unterirdischen Gasarten und die Mittel ihren Nachtheil zu vermindern.* Braunschweig: Verlag Friedrich Vieweg, 384 pp.