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Three early plant taphonomy experiments (1833–1836)

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ABSTRACT. Between 1833 and 1836 in England, then in Prussia and finally in France, young botanists experimented with making plant fossils to understand better how such fossils could be formed and how to interpret fossil assemblages. These experiments are described and discussed. Despite these promising beginnings, plant taphonomy was not really developed as a science until much later.

KEYWORDS: palaeobotany, Göppert, Lindley, Lortet, geology history, 19th century

INTRODUCTION

After definitively admitting that fossils are true remains of organisms, not caprices of Nature – *lusi naturae* – in the late eighteenth century, scientists began to seriously study the origin and significance of fossils as witnesses of past life forms in the first half of the nineteenth century. Fundamental prerequisites were then to know how these fossils had formed and what transformations they had undergone – that is the question of taphonomy. These prerequisites were later somewhat overshadowed by the discoveries of systematic palaeontology and its contributions to the theory of evolution. Taphonomy applied to palaeobotany did not develop until much later, in the second half of the twentieth century (Behrensmeyer and Kidwell, 1985; Ferguson, 1985, 2005; Cadée, 1991), even if many interesting writings on this subject predate it.

Here we report on three taphonomical experiments applied to plants, conducted between 1833 and 1837, in France, Germany and England. These little-known early plant-taphonomy experiments correspond to questions that are now somewhat outdated, but their interest is not only historical. Once transposed into a more contemporary form, some of their results still seem largely relevant for current plant taphonomy and deserve to be revisited.

Their scientific backgrounds are first summarised, and the context of their experiments is presented. The results they obtained are described and discussed. We translate all passages between quotation marks and italicised from the original text (German or French).

THREE EARLY PLANT TAPHONOMISTS

JOHN LINDLEY (1799–1865)

The son of a nurseryman and a self-taught botanist, John Lindley (Fig. 1) became a preeminent British botanist with the help of Hooker and Banks (Stearn, 1965, 1999). Chaloner and Pearson (2005) described how he got involved in palaeobotany. Shortly after his appointment to the chair of botany at the University of London, in 1828, he studied a fossil flora from Provence (Lindley, 1829), and soon after started in collaboration with geologist W. Hutton to publish *The fossil flora of Great Britain* (Lindley and Hutton, 1831–1837).

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Fig. 1. John Lindley (1799–1865) (National Galleries Scotland, Creative Commons licence)

Questioned by a hypothesis of Brongniart (1828), assuming that the proportion of Monilophytes and Spermatophytes in a fossil flora reflects the palaeoclimate, Lindley set up an experiment in 1833 to test whether this proportion might not result primarily from different fossilising abilities. He published his results in the first quarterly set of the third volume of *The Fossil Flora* (Lindley, 1835; about publication date see Loudon, 1835). The results of his experiment were soon well known (Loudon, 1835; Leonhard, 1837a, b) and are still relatively wellremembered (Chaloner and Pearson, 2005; Ferguson, 2005).

HEINRICH ROBERT GÖPPERT (1800–1884)

Following in his father's footsteps, a Prussian pharmacist, Heinrich Robert Göppert (Fig. 2) first studied pharmacy but then switched to medicine. He obtained doctor's degree in 1825 with a thesis about plant physiology. In 1826 he settled as a doctor in Breslau (then a town ruled by Prussians, now Wrocław, Poland) but soon became a professor at the University of Breslau. It was around 1833 that, inspired by the anatomist A.W. Otto, he began to conduct research projects into palaeobotany (Conwentz, 1885). He made rapid progress, aided by the palaeobotanical wealth and stratigraphic diversity of the region, Silesia, and the rapid spreading of coal mining (Pounds, 1958). In 1836 he published his first work on palaeobotany (Göppert, 1836a), an impressive work on the distribution of fern genera in the

Fig. 2. The monument of Heinrich R. Göppert (1800–1884) in the Botanical Garden, Wroclaw in 2018 (Courtesy of Ronny Rößler)

various geological levels from the Carboniferous to the Tertiary.

In this work, he first described his experiments in taphonomy (1836a: 43–44). As Göppert said that he had started palaeobotany in January 1834, the experiments probably took place in either 1834 or 1835.

PIERRE LORTET (1792–1868)

Pierre Lortet (Fig. 3), son of the famous botanist Clémence Lortet (1772–1835) from Lyon and father of the naturalist Louis Lortet (1836–1909), was best known as a doctor, a collaborator of Ampère, and as a politician (Magnin, 1913). Although Magnin (1913) stated that P. Lortet was "*specialised in geology and mineralogy*", he only briefly and incompletely mentioned Lortet's geological work, and neither Fournet (1867) nor Rabolt (2013) nor Bange (2017) listed Lortet's publications in this field. Sensitised to geology and botany at an early

Fig. 3. Self-portrait of Pierre Lortet (1792–1868), dated 1826. Private collection

age by his mother (Lortet et al., 2018), Pierre Lortet often wrote about geology and palaeontology in his diary. As evidenced by three geology notebooks kept at the Centre d'étude et de conservation des collections (Lyon, France), he followed the geology teaching of Joseph Fournet sometime between 1834 and 1837 and reported about it (Lortet, 1837b). The son and his mother collected numerous plant fossils from the Lyon area (from the Stephanian, the Kimmeridgian, etc.), which they sent to Brongniart after 1828 (Brongniart mentioned only Fénéon as a provider of plant fossils from the Lyon area in 1828) but before 1836 (Anonymous, 1836a; Brongniart 1849). Between 1835 and 1837 Pierre Lortet published eight more or less lengthy notes on geology (Lortet, 1835, 1836a–e, 1837a–b) in the *Neues Jahrbuch für Mineralogie* which had just been launched by K.C. von Leonhard, in Heidelberg. Pierre studied German literature and philosophy for three years (1825–1828) in Heidelberg, where he met and married Johanette "Nettchen" Müller in 1827. Her death in 1837 seems to put an end to Pierre Lortet's geological research (except for a brief account about a bonebed; Lortet, 1851).

The taphonomic experiments of Pierre Lortet are known to us only from a report og Leonhard (1838). In a footnote, Leonhard (1838) said that he had been informed of P. Lortet's experiments via a letter received from him in 1836 and that he had had before him the samples of artificial plant imprints that had accompanied the letter. It is curious that Leonhard in 1837 only mentioned Göppert's experiments, while the *Neues Jahrbuch für Mineralogie* was published annually. It was not until 1838 that Leonhard linked Göppert's and Lortet's experiments. It is little likely that Lortet's experiments were inspired by those of Göppert (1836a), and the fact that Leonhard reported on them (Leonhard, 1838) suggests that they were not just a mere replica of Göppert's experiments.

THREE EARLY PLANT TAPHONOMY EXPERIMENTS

IMMERSED IN A WATER-FILLED IRON TANK FOR TWO YEARS

In 1833 Lindley, holding the chair of botany at the University of London, a former secretary of the Royal Horticultural Society, which ran a garden at Chiswick, and well introduced in London nurseries and botanical gardens network had at hand an abundance and diversity of plant material. He selected mostly tropical evergreen trees and shrubs with leathery leaves (Supplementary File[1]), probably influenced by his first work on Provence Eocene fossil flora (Lindley, 1829). The tropical plants he used were grown in greenhouses, under conditions that usually make their leaves larger, thinner, with thinner cuticles and perhaps also richer in nitrogen. In 1833 the mean annual temperature in London, outside downtown, was 9.17°C (Howard, 1833; to be compared to 10.8°C today). It is not known where the water used to fill the reservoir came from, and the pH of the water in the Paleogene aquifer in London varies widely from 5 to 11 (Bearcock and Smedley, 2010).

The leaves or leafy branches were immersed in a large iron tank filled with water on the 21st of March 1833. "The vessel was placed in the open air, left uncovered, and left untouched, with the exception of filling up the water as it evaporated" (Lindley, 1835). The experiment was run for two years and a month, till the 22nd of April 1835. Lindley gave the results in a table, but with little standardisation. We have therefore grouped his mentions into seven classes (Table 1).

One should therefore be cautious in interpreting the results. As expected, the nine plant species with conservation grades 6 or 5 are all

[1] Supplementary File

Table 1. Standardisation of Lindley's indications about plant preservations

Lindley's locutions	Classes
Left no trace	0
A black mass	1
Scarcely to be recognized; much decayed; skeleton; bad condition	2
Recognizable (but decayed); good condition but …	3
Good condition; quite perfect but …; tolerably perfect; good preservation	4
Excellent condition; quite perfect; nearly perfect; perfect	5
Very perfect	6

evergreen with thick, leathery leaves. These nine species are all tropical to sub-tropical, except for the fir tree (*Picea abies*), which featured the best of all preservation. There are sixteen species with grade 4. They are also evergreen with leathery leaves, with two notable exceptions, a deciduous oak (*Quercus cerris*) and a large-leaved herbaceous monocot, the taro (*Colocasia esculenta*). Less expectedly, there are several evergreen species in those that left no trace. All herbaceous plants, regardless of mosses, mono- or dicotyledonous ones, also left no trace except for ferns (horsetails excluded) and bromeliads. Within the same genus, species have different abilities to be preserved, e.g. within *Araucaria* and *Quercus*.

PRESSED BETWEEN CLAY PLATES AND COOKED

Most fossil plant remains have a dark colour, reminiscent of charred plant parts. This observation probably influenced Göppert and Lortet, both familiar with fossils from the coal and brown-coal layers. They both tested the effects of heat charring on leaves and leafy twigs. The beginning of glowing red heat is at about 540°C. The zoll and line were pre-metric Prussian units of uncertain value; here we use 1 zoll = 2.6 cm = 12 line.

Göppert (1836a: 42–44) reports: "(…), *I have myself tried to make impressions artificially by placing ferns of the present world between soft clay plates and, after drying them out, exposing them for a short time to a temperature approaching glowing heat. In several cases, when the heating was carried out gradually, it was possible, when the clay plates were broken up, to find the plant shiny and black, firmly attached to the clay plate, exchanging its fossil imprints. If a clay blackened by asphalt or powdered coal was used, the imprint was always distinguished by a different, usually darker colour from the surroundings, from which it can be safely concluded that the carbon of the clay has no influence on the transformation of the plant. It is, therefore, by no means the coal mass that occupies the space formerly filled by the plant, but the substance of the plant itself, transformed into coal, which we see before us in the imprints. Therefore, we can also understand why we see different species with different colouring and lustre on one and the same slate plate, which is therefore not to be derived from the coal transfer, as Schlotheim thinks, but from the plant itself. I reserve the right to pursue this subject, which is probably also important from a geological point of view, in another place after completing several experiments which will require a longer period of time. When I heated the clay plates intensely for a longer time, the whole plant that had first been transformed into charcoal was of course burnt, but a complete imprint of it was present in the clay, both from the upper and the lower side, a state which is comparable to that in which we find the ferns in the charcoal sandstone or in the greywacke. Generally, there is no trace of coal here, or it is at least only present as a powder-like, extremely thin, loose and easily removable coating*."

It should be noted that Göppert concluded that these experiments required to be continued. It seems he did so (Göppert, 1836b; Leonhard, 1837b) but focusing on the question of mineralisation. He communicated his results widely in Germany and at the Académie des Sciences in France (Anonymous, 1836b). It is highly probable that P. Lortet was aware of this work by the end of 1836 at least.

Pierre Lortet's experiment is reported by Leonhard (1838) based on a letter and on specimens sent by the former: "*Lortet prepared layers of clay mixed with a large quantity of fine sand, in order to avoid shrinkage as much as possible, half a zoll (1.3 cm) thick and 4 to 6 zolls (10.4 to 15.6 cm) long and wide. In the middle of such a layer, dried fern fronds, fine thuya twigs and boxwood leaves were placed; around them* [i.e. these plants], *the clay was sprinkled in a thick layer of extremely fine sand, so that between this clay plate and a similar one to be placed over it and pressed on, a space was created where the two bonded less firmly together. After the mass had been exposed to the air in a shady place for about*

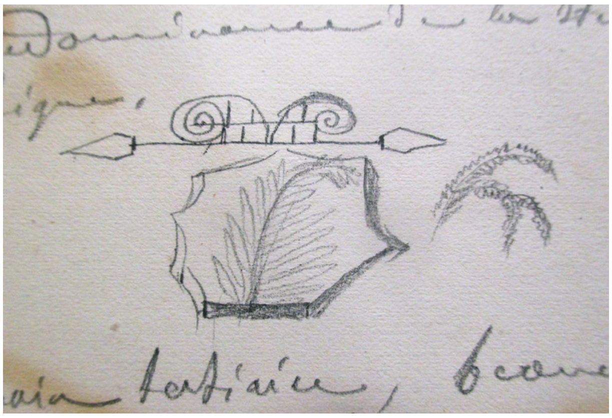

Fig. 4. Sketches by Pierre Lortet in a geology notebook (~1836). Rather than illustrating his experiments, these probably show *Zamites feneonis* (to the left) and a *Brachyphyllum* (to the right), similar to the fossils from the Kimmeridgian of Southern Jura communicated by Lortet to Brongniart. Centre de conservation et d'étude des collections de Lyon, France

fourteen days, it was placed in a brick oven. If only fine cracks appeared in the clay when it was allowed to heat to red heat, it was found that the plant parts were carbonised, and the small amount of carbon was sufficient to colour the clay masses over several lines (>4 mm) of depth. If, on the other hand, deeper cracks appeared during the kiln passage, only a small amount of ash remained, the impressions inside appeared white or reddish, the clay took on a waxy colouring, and in places, bleached. The above-mentioned impressions are quite similar to those found in schistose clays calcined by the burning of contiguous coal beds, (…)"

The fern species Lortet used are not specified but are probably species growing around Lyon (France), while the boxwood is *Buxus sempervirens* L., an evergreen shrub with coriaceous leaves. The "thuya" is not necessarily a *Thuya* species, as several species of, e.g., *Biota, Chamaecyparis* or *Tetraclinis* were known as "thuyas" in France at that time. Despite searches in his geology notebooks, we found no traces of Pierre Lortet's experiments (Fig. 4).

The similarity of Göppert's and Lortet's experiments is striking, but it should also be noted that Pierre Lortet, in addition to ferns, used two of the few temperate genera also selected by Lindley (*Buxus* and '*Thuya*').

DISCUSSION

Several aspects of plant taphonomy are addressed by the experiments mentioned above, including preservation after the plant parts had been put into water, diagenetic processes and lithification.

Lindley's experiment was designed to find out whether decomposition (i.e. microbial attack) could affect different systematic groups differently. For Lindley, the answer was yes, and disproved that an original composition, and hence a palaeoclimate, can be deduced from the systematic composition of a palaeoflora – "(…) *the numerical proportion of different families of plants found in a fossil state throws no light whatever upon the ancient climate*" (Lindley, 1835: 12). However, neither Lindley nor his exegetes considered that weathering could also be modulated by leaf C/N ratio, cuticle thickness, leaf succulence and secondary metabolites. Few have questioned Lindley's choice of plants, ignoring most native plants and with a significant bias towards tropical species with leathery leaves. Lindley's results could also be discussed from the perspective of the leaf economic spectrum (Wright et al., 2004) and further questions raised, including the influence of mycorrhizal traits (Shi et al., 2020).

Göppert and Lortet were interested in a later stage when the plant remains were caught in sediment, in this case, clay, and the fossil is formed as a more or less exact imprint in the rock. It seems that neither of them realised the role of oxygen affecting the process they described. They demonstrated that the carbonaceous material on the compressions did indeed originate from the plant, and also that it is not an exudation of the sediment. This point may seem trivial today, but we are still close to the time when fossils were seen as formed in the bosom of the Earth, shaped by its generative power and the malicious circulation of carbonaceous fluids, with no link to a past organism. The demonstration that original organic matter can withstand an intense carbonisation process under certain conditions helps to demonstrate the real origin of plant fossils from remains similar to present-day plants, even if the resulting forms are without equivalent in present-day nature. In experiments carried out in 1803, Hall had previously demonstrated that organic materials subjected to high temperatures and pressures could be transformed into "real coal" (Hall, 1812: 150). These experiments were those of a chemist, and although Leonhard referred to them (1838), it is not clear that the nascent palaeontology grasped the implications of these experiments.

Göppert (1836b) knew about Lindley's experiments, and surprisingly reflected that microbial alteration of plant remains had no effect because the fossils he observed were very well preserved. Clearly, the understanding of the mechanisms of fossilisation through the taphonomic process was still in its infancy. The term 'taphonomy' was proposed by the Soviet palaeontologist, Ivan Efremov, only much later, in 1940, and referring to animal remains exclusively. Even today, the biases induced by taphonomy are probably still underestimated (Pardoe et al., 2021).

Several coincidences are striking. The three experiments mentioned above were carried out over barely four years (1833–1836) by people of almost the same age, less than seven years apart. Two of these people were medical doctors who did not live by their art. All three had a solid background in botany. At the transition between the eras of generalist amateurs and professionalisation and specialisation of science, when it was still possible to have an encyclopaedic approach, all three arrived at the same moment at the same questions. For at least two of them, Brongniart was a proven inspirer. Born in 1801, and therefore of similar age, the physician and botanist Adolphe Brongniart was called "the father of palaeobotany".

The precursor works of palaeobotany in the 18th century, such as those of Johann Jacob Scheuchzer, are still those of "cabinets of curiosities". Faujas de Saint-Fond, discovering the extraordinary well-preserved fossil flora of Saint-Bauzile (Miocene, France), tried to study it as a scientist, in collaboration with botanists (Faujas de Saint-Fond, 1803, 1815). He gave up, listing "*the main obstacles that disgust botanists from engaging in this kind of research*": the need to study "*the system of their deposit in place* (...) *and the accompanying mineral substances*"; the variability of leaves in present-day species; the difficulty to identify some fossils with modern species; the state of preservation (in this order; Faujas de Saint-Fond, 1815: 449–450). Note that two out of these four points are taphonomical ones. Faujas summarised what the public opinion about palaeobotany was at that time.

Brongniart (1822) argued for the inclusion of fossils in the Linnaean system and binomials to name them just as Schlotheim and Sternberg before him. He saw this approach as a prerequisite for studying the biostratigraphic potential of fossil plants (*op. cit.* p. 4). At the same time, he laid the foundations for palaeoecological interpretation (*op. cit.* p. 80). In doing so, he understood the need for taphonomic studies. Brongniart outlined a programme of necessary research before reflection on palaeoflora interpretation (*op. cit.* p. 83–87). After a questionable delay, Lindley and then Göppert and Lortet took up Brongniart's questions and tried to answer them. However, the discovery of many plant fossils and the need to classify and name them soon overshadowed these pioneering taphonomic and palaeoecological questions to the benefit of systematic research.

As Abel (1986) emphasised, Brongniart was born too early, and even if after a decade, three young semi-amateurs in palaeobotany were able to seize some of his questions, the time was not ripe for the full exploitation of the foundations he had laid. Taphonomy had to wait another century before being born as a science.

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REFERENCES

Abel, O., 1986. La paléobotanique de Gaston de Saporta: Etude bachelardienne. Revue de Métaphysique et de Morale 91(4), 445–461.

Anonymous, 1836a. Liste des principaux dons faits à la société linnéenne de Lyon. Annales de la société linnéenne de Lyon pour 1836, 43–53.

Anonymous, 1836b. Lecture d'une lettre de M. Göppert sur la minéralisation des substances organisées. L'institut. 1° section, Sciences mathématiques, physiques et naturelles 4(186), 397.

Bange, C., 2017. Lortet Pierre (1792–1868). In: Saint-Pierre, D. (ed.), Dictionnaire historique des académiciens de Lyon 1700–2016. Éditions de l'Académie, Lyons, pp. 813–815.

Bearcock, J.M., Smedley, P.L., 2010. Baseline groundwater chemistry: the Palaeogene of the Thames Basin. London, British Geological Survey Open Report, OR/10/057.

Behrensmeyer, A.K., Kidwell, S.M., 1985. Taphonomy's contributions to paleobiology. Paleobiology 11(1), 105–119.

Brongniart, A., 1822. Sur la classification et la distribution des végétaux fossiles. Mémoires du Muséum d'Histoire naturelle 8, 91 p., 6 pl.

Brongniart, A., 1828. Prodrome d'une histoire des végétaux fossiles. Paris, Levrault.

Brongniart, A., 1849. Exposition chronologique des périodes de végétation et des flores diverses qui se sont succédées à la surface de la Terre. Annales des sciences naturelles 11, 285–338.

Cadée, G.C., 1991. The history of taphonomy. In: Donovan, S.K. (ed.), The Processes of Fossilization. Belhaven Press, London, pp. 3–21.

Chaloner, W.G., Pearson, H.L., 2005. John Lindley: the reluctant palaeobotanist. Geological Society London Special Publications 241(1), 29–39. https://doi.org/10.1144/GSL.SP.2003.207.01.04

Conwentz, H., 1885. Heinrich Robert Goeppert, sein Leben und Wirken. Gedächtnissrede (Mit einem Portrait). Schriften der Naturforschenden Gesellschaft in Danzig 6(2), 253–285.

Efremov, I.A., 1940. Taphonomy: a new branch of paleontology. Pan-American Geology 74, 81–93.

Faujas de Saint-Fond, B., 1803. Notice sur des plantes fossiles de diverses espèces qu'on trouve dans les couches fissiles d'un schiste marneux, recouvert par des laves, dans les environs de Rochesauve, département de l'Ardèche. Annales du Muséum d'histoire naturelle pour 1803, 339–344, pl. LVI and LVII.

Faujas de Saint-Fond, B., 1815. Nouvelle notice sur des plantes fossiles, renfermées dans un schiste marneux des environs de Chaumerac et de Roche-Sauve, Département de l'Ardèche. Mémoires du Muséum d'histoire naturelle 2, 444–459.

Ferguson, D.K., 1985. The origin of lea assemblages – new light on an old problem. Review of Palaeobotany and Palynology 46, 117–188.

Ferguson, D.K., 2005. Plant Taphonomy: Ruminations on the Past, the Present, and the Future. Palaios 20(5), 418–428.

Fournet J., 1867. Notice sur la vie et les travaux du docteur Lortet, ancien président de la Commission hydrométrique. Lyon, Vingtrinier.

Göppert, J.H.R. 1836a. Die fossilen Farnkräuter. – Nova acta physico-medica Academiae Caesareae Leopoldino-Carolinae Naturae Curiosum 17 (supplement), xxxii + 486 p., 44 pls.

Göppert, J.H.R., 1836b. Über den Zustand, in welchem sich die fossilen Pflanzen befinden, und über den Versteinerungsprocess insbesondere. Annalen der Physik 114(8), 561–573, and 115(9), 222–223. https://doi.org/10.1002/andp.18361140802 and https://doi.org/10.1002/andp.18361150928

Hall, J., 1812. Account of a series of experiments showing the effects of compression in modifying the action of heat. Transactions of the Royal Society in Edinburgh 6, 71–185.

Howard, L., 1833. The climate of London: deduced from meteorological observations made in the metropolis and at various places around it. Volume 3. London, Harvey and Darton.

Leonhard, K.C. von, 1837a. Göppert trug 1836 bei der Naturforscher-Versammlung in Jena. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1837, 117.

Leonhard, K.C. von, 1837b. Bericht über eine Veröffentlichung von H.R. Göppert. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1837, 241–243.

Leonhard, K.C. von, 1838. Dreißigste Vorlesung – Umwandelung von Pflanzen zu Kohle. Geologie oder Naturgeschichte der Erde 2, 398–406.

Lindley, J., 1829. Description of the plants alluded to in the preceding memoir. Edinburgh New Philosophical Journal 7, 298.

Lindley, J., 1835. Note upon the value of numerical proportions in the ancient flora of the world, with reference to a determination of climate. In: Lindley, J., Hutton, W. (eds), The fossil flora of Great Britain. Vol.3. James Ridway, London, pp. 1–12.

Lindley, J., Hutton, W., 1831–37. The fossil flora of Great Britain, or figures and descriptions of the vegetable remains found in the fossil state in this country. Vol. 1, 218 pp., pls. 1–79, (1831–1833), vol. 2, 208 pp., pls. 80–156, (1833–1835), vol. 3, 205 pp., pls. 157–230, (1835–1837). London, James Ridgway.

Lortet, P., 1835. Lias-Stück in einem Erzgang des Granits von Romanèche; Verhalten vom Granit, Porphyr, Schiefer und Kalk bei Chessy und zwischen Granit- und Kohlen-Sandstein bei La Palisse. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1835, 520–521.

Lortet, P., 1836a. Grundeis; Geschiebe in Nagelfluh mit Eindrücken. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1836, 195–197.

Lortet, P., 1836b. Ein Ichthyosaurus in Lias; Pflanzen in Oolith bei Lyon. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1836, 201.

Lortet, P., 1836c. Nagelfluh war einst weich; Erzgänge bei Vienne. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1836, 339.

Lortet, P., 1836d. Geognostische Bemerkungen um Lyon. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1836, 578–579.

Lortet, P., 1836e. Geognosticher Ausflug von Lyon nach Villebois. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1836, 692–693.

Lortet, P., 1837a. Ausflug ins *Isère* – Departement in Monat August 1836. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1837, 127–136.

Lortet, P., 1837b. Über des geologischen Vorlesungen des Herrn Fournet in Lyon. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1837, 522–535.

Lortet, P., 1851. Knochentrümmer-Gestein von Cette. Neues Jahrbuch für Mineralogie, Geognosie, Geologie und Petrefaktenkunde 1851, 674.

Lortet, P., Audibert, C., Bärtschi, B., Benharrech, S., Chambaud, F., Philippe, M., Thiébaut, M., 2018.

Les *Promenades botaniques* de Clémence Lortet, née Richard (1772–1835). Bulletin Mensuel de la Société Linnéenne de Lyon 87(7 & 8), 199–254.

Loudon, J.C. 1835. Literary notices. Lindley and Hutton's Fossil Flora. The Magazine of Natural History 8, 525–527.

Magnin, A., 1913. Les Lortet, botanistes lyonnais particulièrement Clémence, Pierre et Louis Lortet et le botaniste Roffavier. Annales de la Société Botanique de Lyon 37, 66–72.

Pardoe, H.S., Cleal, C.J., Berry, C.B., Cascales-Miñana, B., Davis, B.A.S., Diez, J.B., Filipova-Marinova, M.V., Giesecke, T., Hilton, J., Ivanoc, D., Kustatscher, E., Leroy, S.A.G., McElwain, J.C., Opluštil, S., Popa, M.E., Seyfullah, L.J., Stolle, E., Thomas, B.A., Uhl, D.T., 2021. Palaeobotanical experiences of plant diversity in deep time. 2: How to measure and analyse past plant biodiversity. Palaeogeography, Palaeoclimatology, Palaeoecology 580, 110618. https://doi.org/10.1016/j.palaeo.2021.110618

Pounds, N.J.G., 1958. The spread of mining in the Coal basin of Upper Silesia and Northern Moravia. Annals of the Association of American Geographers 48(2), 149–163.

Rabolt, M.-C., 2013. Louis Lortet (1836–1909), un médecin naturaliste en Orient. Unpublished PhD thesis report, Université Claude Bernard – Lyon I, France.

Shi, Z., Li, K., Zhua, X., Wang, F., 2020. The worldwide leaf economic spectrum traits are closely linked with mycorrhizal traits. Fungal Ecology 43, 100877. https://doi.org/10.1016/j.funeco.2019.100877

Stearn, W.T., 1965. The Self-Taught Botanists Who Saved the Kew Botanic Garden. Taxon 14(9), 293–298.

Stearn, W.T., 1999. The life, times and achievements of John Lindley 1799–1865. In: Stearn, W.T. (ed.) John Lindley 1799–1865. Antique Collectors Club in association with the Royal Horticultural Society, Woodbridge, Suffolk, pp. 15–72.

Wright, I.J., Reich, P.B., Mark, W., Ackerly, D.D., Zdravko, B., Frans, B., Jeannine, C.B., Terry, C., Cornelissen, J.H.C., Matthias, D., 2004. The worldwide leaf economics spectrum. Nature 428, 821e827.