Journal of Palaeosciences 72(2023): 171–174
2583–4266/2023

Large–leaved *Annularia* species (Equisetopsida) in Pennsylvanian Variscan Euramerica–a Preliminary Review

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SUPPLEMENTARY DATA

THE following published records of the six or seven species now recognised within *A. stellata auct.* are limited to those that are verified by identifiable illustrations or have been verified by direct observation of the specimens. Records from outside of Euramerica have been excluded as none have been reported in association with *C. tuberculata*–like strobili and were therefore probably from a different group or groups of equisetopsid plants.

Annularia stradonicensis Cleal, sp. nov.

Czech Republic (Central and Western Bohemia): the types.

Annularia inflata Lesq.

USA (Illinois): The species has been extensively documented from Mazon Creek (Noé, 1925; Jennings, 1990; Darrah, 1969; Wittry, 2006, p. 92).

USA (Indiana): White (1880, pl. 2, fig. 1), Lesquereux (1884, pl. 7, fig. 1); although only line drawings, the leaf and whorl shape clearly corresponds to that of *A. inflata.* There is also a recent, unillustrated record by Bashforth *et al*. (2016). However, the specimen from Indiana figured as *A. stellata* by Wood (1968, pl. 4, fig. 1) was transferred to *Annularia fertilis* Sternb. by Álvarez–Vázquez & Wagner (2017).

USA (Missouri): Elias (1931, pls 12–15), Cridland (1968, pl. 1), Clinton (?Bolsovian)–types of *Carpannularia americana* Elias.

USA (Ohio): Abbott (1958, pl. 41, fig. 58; pl. 43, figs 62, 64), Kimberley, Athens County (upper Asturian / lower Cantabrian); this includes evidence of epidermal structure.

USA (Appalachians): Gillespie & Latimer (1960, pl. 6, fig. 4). Blake *et al*. (2002) recorded but did not figure rare specimens as *A. stellata* from the upper Kanawah and Allegheny Formations (lower Bolsovian to lower Cantabrian); see also records in White (1900, 1913). Given their stratigraphical age it is likely that they represent *A. inflata*.

Venezuela: Ricardi–Branco *et al*. (2005, fig. 3). Just two poorly–preserved specimens were recorded, but the figured specimen appears to be correct for *A. inflata*. The associated macroflora suggests a late Asturian age.

Canada (New Brunswick): Álvarez–Vázquez & Wagner (2017, figs 4, 5), (?)Asturian "Fern Ledges Flora"; see also Matthew (1906a, b).

Canada (Sydney Coalfield): Bell (1938, pl. 89, pl. 90, figs 1, 2), Zodrow & McCandlish (1980, pl. 94, 95); ranges through the Sydney Mines and Waddens Cove Formations (upper Bolsovian to lower Cantabrian).

United Kingdom: Mainly from areas of the Variscan foredeep (Cleal, 1997, 2018), notably the Radstock Coalfield (Walton, 1936, figs 24–26; Seward, 1898, fig. 88; Crookall, 1969, pl. 149, fig. 3; Thomas & Cleal, 1994; Cleal, 2018); a detailed collation of occurrences is given in Moore (1938). Also in the upper Middle Coal Measures, Pennant and Grovesend formations of South Wales (upper Bolsovian to Cantabrian), but unillustrated (e.g., Cleal, 1978, 2007). There is no evidence from the coalfields of the cratonic northern area of Britain.

France (Nord–Pas–de–Calais): Zeiller (1886, pl. 61, figs 4–6); ranges from the base of the lower Bolsovian Six–Sillon Member (or possibly the upper Pouilleuse Member) to the top of the succession (Mollina–Solís, pers. comm, 2022).

France (St. Étienne): Doubinger *et al*. (1995, fig. 70), identified as *Annularia mucronata* Schenk but with the characteristic oblanceolate leaves of *A. inflata*; Rive de Gier Formation (Barruelian).

Germany–France (Saar–Lorraine): Laveine (1989, pl.

46, figs 1–4), Rößler & Thiele–Bourcier (1999, pls 1–4); mainly from the upper Steinbesch Formation (uppermost Asturian) to the Wahlschied Formation (Saberian), only rarely in lower parts of the succession. Specimens from the upper Heiligenwald Formation (Roehl (1869, pl. 4, fig. 6) were made the types of *A. westphalica* by Stur (1887), here regarded as a heterotypic synonym of *A. inflata*. Examples of *A. inflata* with *C. tuberculata* strobili attached have been reported from the Wahlschied Formation (Rößler & Thiele–Bourcier 1999); examples with similar strobili in association are also known from the upper Asturian in the Lille Collection.

Germany (Ruhr): Josten (1991), ranging upwards from the base of the Dorsten Formation (base of Bolsovian).

Germany (Piesberg): Jongmans & Kukuk (1913, pl. 21, figs 1, 2; pl. 22, fig. 4); restricted to the lower Asturian (Josten & van Amerom, 1999). Associated strobili described by Krings & Sommer (2000).

Germany (Zwickau): Stur (1887); types of *A. geinitzii*.

Czech Republic (Central and Western Bohemia): Bashforth *et al*. (2011, pl. 1 fig. 4); from Nýřany Member (upper Asturian), identified as *A. carinata* but clearly showing the obtuse leaf apices of *A. inflata*. Also possibly from the middle Stephanian Slaný Formation, Žihle Basin (Šimůnek *et al*., 2010, fig. 3C).

Czech Republic (Intrasudetic Basin): Opluštil *et al*. (2017, pl. 4, fig, 6) from the Jívka Member (Saberian) shows anisophyllous whorls of leaves with an obtuse apex and occasional small mucron. They also record it from the Petrovice (upper Bolsovian) and Svatoňovice Members (upper Asturian) without illustrations.

Bulgaria (Dobrudzha): Tenchov (1987, pl. 15, figs 4–6); reported to range from the lower Bolsovian upper Makedonka Formation to the Asturian Gurkovo Formation (Tenchov & Thomas 2015).

Turkey (Zonguldak): Several unillustrated records from the upper Bolsovian Karadon Formation (e.g., Jongmans, 1955; Cleal & van Waveren, 2012). Specimens from here in the Jongmans Collection (Naturalis, Leiden) have been seen and confirm their identification as *A. inflata*.

Ukraine (Donets): The figure in Zalessky 1907, fig. 3) is very diagrammatic but appears to show whorls of narrowly lanceolate leaves with a blunt apex, and are reportedly associated with *Calamostachys tuberculata*–like cones; better specimens with the characteristic leaf–form from the upper Moscovian were figured by Novik (1952, pl. 17, figs 5–7); Boyarina (2016) reported the species rarely from the uppermost Gozovskii Horizon (lower Asturian) to the lower Isaevskaya Suite (lower Cantabrian). The stratigraphically younger (Kasimovian–Gzhelian) records in Boyarina (2022) are unillustrated and so cannot be assessed in the context of the taxonomy presented here.

Spain (Cantabrian Mountains): Diéguez (1985, pl. 1, fig. 6), Palencia (Asturian age), identified as *Annularia stellata* fa. *longifolia* Diéguez.

Annularia sardiniana Cleal *et al.*

Italy: San Giorgio Formation (Asturian), Sardinia (types).

Annularia carinata Gutbier

Germany (Chemnitz Basin, Saxony): Types, Planitz Formation (Autunian), Reinsdorf.

France (St. Étienne): Doubinger *et al.* (1995, figs 66, 67–identified as *Annularia radiata* Brongn.); Faisceau de Grüner (Saberian)

France (Decazeville): Zeiller (1878, pl. 160, fig. 3), Vetter (1968, pl. 6, fig. 5); ranges through the Banell, Campagnac and Bourran Formations (Stephanian B and lower Stephanian C).

France (Lower Loire): Saint–Pierre–la–Cour Mine, Mayenne, middle Stephanian (Zeiller, 1878, pl. 160, fig. 2).

Italy–Austria (Carnic Alps): Kerner (1897, pl. 8, fig. 1), Fritz *et al*. (1990, fig. 5), Opluštil *et al*. (2021, pl. 3, figs 5–8; pl. 4, figs 1–3); mainly from the Pramollo / Aurenig Group (Saberian).

Italy (Tuscany): De Stefani (1901, pl. 9, fig. 10; pl. 11, figs 5, 6), San Lorenzo Schists, Iano, Florence (?)Stephanian C.

Spain (Cantabrian Mountains): Wagner & Álvarez–Vázquez (2010, pl. 21, fig. 1), La Magdalena (Saberian).

Ukraine (Donets): Specimens figured by Novik (1952, pl. 17, figs 8, 9) from the Gzhelian have anisophyllous whorls of leaves with acute apices, typical of *A. carinata*.

Annularia spinulosa Sternb.

Germany (Döhlener Basin, Saxony): Types; also Geinitz (1855; refigured Schimper, 1869, pl. 26, fig. 2); (Barthel, 2000; figs 1–3); Döhlen Formation (Autunian).

Germany (Saale Basin, Saxony): (Schlotheim, 1804, p. 32, pl. 1, fig. 4–types of *A. stellata*); Germar (1845, pl. 9, figs 1–3); Beyschlag (1899); from Halle Formation (Autunian), Wettin.

Germany (Thuringian Forest Basin, Thuringia): Germar (1845, pl. 9, figs 1–3); Stur (1887, pl. 13b, fig. 3); Potonié (1893; refigured Potonié, 1896, fig. 32; Potonié, 1897, fig. 195; Frech, 1899, pl. 50b, fig. 1; Potonié & Gothan, 1921, fig. 152); from Manebach Formation (Autunian), Illmenau.

Germany (Nahe Basin): (Kerp & Fichter, 1985, pl. 7, figs 1–3); from lower Nahe Formation (upper Rotliegend, possibly Artinskian–Schneider *et al*., 2020), Sobernheim. Also recorded but not figured from the lower Rotliegend (Asselian) Lauterecken Formation

France (St. Étienne): Doubinger *et al*. (1995, fig. 65), Crus de Littes (Stephanian C).

France (Blanzy–Creusot): Zeiller (1906, pl. 38, fig. 1), Langiaux (1984, fig. 49), Charbonier *et al*. (2008, fig. 3A–C), Charbonnier (2014, fig. 3A), Perrier & Charbonnier (2014, fig. 3A), Daviero & Lecoustre (2000, pl. 1, fig. 5); specimens clearly show the large isophyllous whorls of linear leaves with a pronounced basal collar; Stephanian C.

Czech Republic (Boskovice Basin): Opluštil *et al*. (2013, fig. 21A), Padochov Formation (Autunian); other unillustrated examples are recorded from the Stephanian C–Autunian of the Blanice and Krkonoše–Piedmont basins.

Romania (Reşiţa Basin): Stur (1870) recorded *A. stellata auct.* from several localities and some excellent examples confirming them as *A. spinulosa* have been found by M. Popa.

Spain (Cantabrian Mountains): Diéguez (1985, pl. 1 figs 1, 2, 4, 5; pl. 2, figs 1, 2), Stephanian C, identified as *A. stellata* fa. *typica* Diéguez, fa. *flabellata* Diéguez, fa. *crassa* Diéguez and fa. *pseudorientalis* Diéguez.

Annularia noronhai Correia, Šimůnek, Cleal & Sá in Correia *et al*., 2021, p. 261

Portugal: Stephanian C (Gzhelian) shales (horizon H6), São Pedro da Cova, Douro Basin–Types.

USA (New Mexico): DiMichele *et al.* (2013, fig. 4.2), Kinney Quarry. This specimen was identified as *Annularia spinulosa* but has whorls of more linear leaves and wider basal collar than that species, and compare well with the types of *A. noronhai*.

Annularia* aff. *carinata Gutbier

USA (New Mexico): lower Abo Formation, Kinney Quarry and Cañon de Cobre floras (DiMichele *et al*., 2010, 2013, 2021; Wachtler, 2016, p. 130, figs 1, 2).

USA (Texas): DiMichele *et al*. (2005, fig. 7E), Markley Formation.

REFERENCES

This list comprises the references mentioned in the above collation, but which are not listed at the end of the main paper.

Bashforth AR, Drábková J, Opluštil S, Gibling MR & Falcon–Lang HJ 2011. Landscape gradients and patchiness in riparian vegetation on a Middle Pennsylvanian braided–river plain prone to flood disturbance (Nýřany Member, Central and Western Bohemian Basin, Czech Republic). Review of Palaeobotany and Palynology 163(3): 153–89. doi.org/10.1016/j.revpalbo.2010.10.001.

Bashforth AR, DiMichele WA, Eble CF & Nelson WJ 2016. A Middle Pennsylvanian macrofloral assemblage from wetland deposits in Indiana (Illinois Basin): a taxonomic contribution with biostratigraphic, paleobiogeographic, and paleoecologic implications. Journal of Paleontology 90(4): 589–631. doi.org/10.1017/jpa.2015.69.

Bell WA 1938. Fossil Flora of Sydney Coalfield, Nova Scotia. Geological Survey of Canada, Ottawa (Memoir, 215), 334 p.

Beyschlag FK 1899. Das jüngere Steinkohlengebirge und das Rothliegende in der Provinz Sachsen und den angrenzenden Gebieten. Abhandlungen der Königlich Preussischen Geologischen Landesanstalt, Neue Folge 10: 1–263.

Blake BM, Cross AT, Eble CF, Gliiespie WH & Pfefferkorn HW 2002. Selected plant megafossils from the Carboniferous of the Appalachian region, eastern United States: geographic and stratigraphic distribution. Memoir–Canadian Society of Petroleum Geologists 19: 259–335.

Boyarina N 2016. Makrofloristicheskie zoni srednego i berkhnego Karbona (Pensil'vanskoi podsistemi) Donetskogo besserina. Geologichnii Zhurnal 2016(1): 21–35.

Boyarina N 2022. Late Pennsylvanian vegetation changes in the Donets Basin: syndynamic aspect. Visnyk of V.N. Karazin Kharkiv National University, Series Geology. Geography. Ecology 56: 8–23. doi.org/10.26565/2410–7360–2022–56–01.

Charbonnier S 2014. Synthèse sur la flore des nodules du Lagerstätte de Montceau–les–Mines (Carbonifère supérieur, France). Annales de Paléontologie 100(2): 103–17. doi.org/10.1016/j.annpal.2013.12.005.

Charbonnier S, Vannier J, Galtier, J, Perrier V, Chabard D & Sotty D 2008. Diversity and paleoenvironment of the flora from the nodules of the Montceau–les–Mines biota (Late Carboniferous, France). Palaios 23(4): 210–222. doi.org/10.2110/palo.2006.p06–078r.

Cleal CJ 1978. Floral biostratigraphy of the upper Silesian Pennant Measures of South Wales. Geological Journal 13(2): 165–194. doi.org/10.1002/gj.3350130204.

Cleal CJ 1997. The palaeobotany of the upper Westphalian and Stephanian of southern Britain and its geological significance. Review of Palaeobotany and Palynology 95(1): 227–253. doi.org/10.1016/S0034–6667(96)00036–X.

Cleal CJ 2018. The Carboniferous coal swamp floras of England: a window on an ancient tropical ecosystem. Proceedings of the Geologists' Association 129(3): 329–351. doi.org/10.1016/j.pgeola.2017.05.005.

Cleal CJ & van Waveren IM 2012. A reappraisal of the Carboniferous macrofloras of the Zonguldak–Amasra Coal Basin, north–western Turkey. Geologia Croatica 65(3): 283–298. doi.org/104154/gc.2012.19.

Darrah WC 1969. A Critical Review of the Upper Pennsylvanian Floras of Eastern United States with Notes on the Mazon Creek Flora of Illinois. Darrah, Gettysburg PA, 220 p.

De Stefani C 1901. Flore carbonifere e permiane della Toscana. R. Istituto di Studi Superiori Pratici e di Perfezionamento, Firenze, 212 p.

Doubinger J, Vetter P, Langiaux J, Galtier J & Broutin J 1995. La flore fossile du bassin houiller de Saint–Etienne. Muséum National d'Histoire Naturelle, Paris (Mémoires du Paléobotanique, 164), 357 p.

Frech F 1899. Die Steinkohlenformation, p. 257–433. *In*: Lethaea geognostica, I Theil, 2 Band, 2 Lieferung. Schweizerbart, Stuttgart.

Fritz A, Boersma M & Krainer K 1990. Steinkohlenzeitliche Pflanzenfossilien aus Kärnten. Naturwissenschaftlichen Vereins für Kärnten, Klagenfurt (Carinthia ii Vol. 49), 187 p.

Geinitz HB 1855. Die Versteinerungen der Steinkohlenformation in Sachsen. W. Engelmann, Leipzig, 61 p.
Germar EF 1845. Die Versteinerungen des Steinkohlengebirges von Wettin und Löbejün im Saalkreise. Schwetschke, Halle, 16 p.
Gillespie WH & Latimer IS 1960. A Guide to the Common Fossil Plants of West Virginia. West Virginia Geological and Economic Survey, Morgantown, 59 p.
Jennings JR 1990. Guide to Pennsylvanian Fossil Plants of Illinois. Illinois State Geological Survey, Champaign IL. (Educational Series Volume 13), 75 p.
Jongmans WJ 1955. Notes paléobotaniques sur les Bassins houillers de l'Anatolie. Mededelingen van de Geologische Stichting 9: 59–89.
Josten K–H 1991. Die Steinkohlen–Floren Nordwestdeutschlands. Fortschritte in der Geologie von Rheinland und Westfalen 36: 1–434.
Kerner F 1897. Die Carbonflora des Steinacherjoches. Jahrbuch der Kaiserlich Königlichen Geologische Reischsanstalt 47: 364–386.
Kerp H & Fichter J 1985. Die Makrofloren des saarpfälzischen Rotliegenden (? Ober–Karbon–Unter–Perm; SW–Deutschland). Mainzer Geowissenschaftliche Mitteilungen 14: 159–286.
Langiaux J 1984. Flores et Faunes des Formations Supérieures du Stéphanien de Blanzy–Montceau (Massif Central Français): Stratigraphie et Paléoécologie. Société d'Études des Sciences Naturelles et Historiques, Montceau–de–Mines (Revue Périodique de "La Physiophile" 100), 270 p.
Lesquereux L 1884. Principles of Paleozoic Botany, pp. 6–106. *In*: Thirteenth Annual Report–Indiana Department of Geology and Natural Resources, Vol. 2. Wm. B. Burford, Indianapolis.
Matthew GF 1906a. A review of the flora of the Little River Group. Transactions of the Royal Society of Canada 12(4): 99–149.
Matthew GF 1906b. New species and a new genus of Devonian plants. Bulletin of the Natural History of New Brunswick 24: 393–398.
Moore LR 1938. The sequence and structure of the Radstock Basin. Proceedings of the Bristol Naturalists' Society 8: 267–305.
Noé AC 1925. Pennsylvanian flora of northern Illinois. Bulletin of the Illinois State Geological Survey 52: 1–113.
Opluštil S, Šimůnek Z, Zajíc J & Mencl V 2013. Climatic and biotic changes around the Carboniferous/Permian boundary recorded in the continental basins of the Czech Republic. International Journal of Coal Geology 119: 114–151. doi.org/10.1016/j.coal.2013.07.014.
Opluštil S, Šimůnek Z, Pšenička J, Bek J & Libertín M 2017. A 25 million year macrofloral record (Carboniferous–Permian) in the Czech part of the Intra–Sudetic Basin; biostratigraphy, plant diversity and vegetation patterns. Review of Palaeobotany and Palynology 244: 241–273. doi.org/10.1016/j.revpalbo.2016.11.011.
Perrier V & Charbonnier S 2014. The Montceau–les–Mines Lagerstätte (Late Carboniferous, France). Comptes Rendus Palevol 13(5): 353–367. doi.org/10.1016/j.crpv.2014.03.002.
Potonié H 1893. Die Flora des Rothliegenden von Thüringen. Abhandlungen der Kaiserlich–Königlichen Geologischen Reichsanstalt, Neue Folge 9(2): 1–298.
Potonié H 1896. Die floristische Gliederung des deutschen Carbon und Perm. Abhandlungen der Kaiserlich–Königlichen Geologischen Reichsanstalt, Neue Folge 21: 1–58.
Potonié H 1897. Lehrbuch der Pflanzenpalaeontologie mit besonderer Rücksicht auf die Bedürfnisse des Geologen (1–2). F. Dümmler, Berlin, 208 p.
Potonié H & Gothan W 1921. Lehrbuch der Paläobotanik. Borntraeger, Berlin, 537 p.
Ricardi–Branco F, Rösler O & Odreman O 2005. La Flora Euroamericana de Carache (Carbonifero Tardio–Permico Temprano), Municipio de Carache, Noroeste de Venezuela. Plantul, 3(3): 153–167.
Schimper WP 1869. Traité de paléontologie végétale: ou, La flore du monde primitif dans ses rapports avec les formations géologiques et la flore du monde actuel, Vol. 1. J. B. Baillière et fils, Paris, 738 p.
Schneider JW, Lucas SG, Scholze F, Voigt S, Marchetti L, Klein H, Opluštil S, Werneburg R, Golubev VK,. Barrick JE, Nemyrovska T, Ronchi A, Day MO, Silantiev VV, Rößler R, Saber H, Linnemann U, Zharinova V & Shen SZ 2020. Late Paleozoic–early Mesozoic continental biostratigraphy — Links to the Standard Global Chronostratigraphic Scale. Palaeoworld 29(2): 186–238. doi.org/10.1016/j.palwor.2019.09.001.
Seward AC 1898. Fossil Plants for Students of Botany and Geology, Vol. 1. University of Cambridge, Cambridge, 452 p.
Šimůnek Z, Lojka R, Zajíc J & Drábková J 2010. Paleontologicke vyzkumy v karbonu okoli Jesenice (zihelska panev). Zprávy o Geologických Výzkumech 43: 163–166.
Stur D 1870. Beiträge zur Kenntniss der Dyas–und Steinkohlen–Formation im Banate. Jahrbuch der kaiserlich–königlichen geologischen Reichsanstalt 20: 185–200.
Tenchov Y 1987. Megaflora. 1. Chlenestostableni i Lepidofiti, Vol. 1. Bulgarian Academy of Sciences, Sofia, 165 p.
Thomas BA & Cleal CJ 1994. Plant fossils from the Writhlington Geological Nature Reserve. Proceedings of the Geologists' Association 105(1): 15–32. doi.org/10.1016/S0016–7878(08)80135–6.
Vetter P 1968. Géologie et paléontologie des bassins houillers de Decazeville, de Figeac et du Détroit de Rodez. Published Doctorate Thesis, University of Toulouse, Toulouse, 194 p.
Wachtler M 2016. The evolution of horsetails from Permian Angara–Land till Euramerica, pp. 105–135. *In*: Wachtler M & Perner T (Editors)–Early Permian Origin and Evolution of Flowering Plants–The Flowering of Angara–Land. DoloMythos, Inichen (Italy).
White CA 1880. Paleontology. Fossils of the Indiana rocks. *In:* Annual Report of the Department of Statistics and Geology of the State of Indiana., Vol. 1880, pp. 471–522. Indianapolis: Carlon & Hollenbeck.
White D 1900. Relative ages of the Kanawha and Allegheny series as indicated by the fossil plants. Bulletin of the Geological Society of America 11(1): 145–178. doi.org/10.1130/GSAB–11–145.
White D 1913. The fossil flora of West Virginia. Report of the West Virginia Geological Survey 5A: 390–491.
Wittry J 2006. The Mazon Creek Fossil Flora. Esconi, Downers Grove IL, 154 p.
Wood JM 1968. The Stanley Cemetery Flora (Early Pennsylvanian) of Greene County, Indiana Geological Survey, Indianapolis, 73 p.
Zalessky MD 1907. Materiali po kamennougol'noi flora Donetskago besseina. I. Izvestiya Geologicheskogo Komiteta 26(8–10): 351–494.
Zeiller R 1878. Végétaux Fossils de Terrain Houiller (Atlas). Imprimerie Nationale, Paris, 26 p.
Zeiller R 1886. Bassin houiller de Valenciennes: description de la flore fossile (Atlas). Maison Quantin, Paris, 752 p.
Zodrow EL & McCandlish K 1980. Upper Carboniferous Fossil Flora of Nova Scotia: In the Collections of the Nova Scotia Museum, with Special Reference to the Sydney Coalfield. Nova Scotia Museum, Halifax, N.S., 275 p.