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Coverphoto: Reconstruction of the Bajocian (170 Ma: Middle Jurassic) flora of Eriksdal, southern Sweden by Michael Rothman (© Naturhistoriska Riksmuseet)

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MADE IN SWEDEN

The history of palaeobotanical research at the Swedish Museum of Natural History, Stockholm

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Abstract

The Palaeobotany Department of the Swedish Museum of Natural History was established in the late 1800s and has supported research on a diverse range of plants of all ages. The Department hosts, manages, and regularly contributes additional material to, one of the largest fossil plant collections in Europe. The fossil collections have provided the basis for several thousand scientific publications by staff and visiting scientists over the course of its history. In addition to the work of its staff, the department has hosted many hundreds of visiting scientists over the past 140 years. It will continue to provide an invaluable resource for research on the evolution of plant and fungal life on Earth for long into the future. Now under the management of just its sixth administrative Head since 1884, the department is forging new pathways in palaeobotanical research utilizing cutting-edge technologies to provide advances in plant systematics, phylogeny, biogeography, biostratigraphy, palaeoenvironmental analysis, plant-animal interactions, and fossil fungal/microbial studies. The department is aware of multiple risks facing the survival of palaeontological collections in the 21st century and has put in place strategies to maintain access to and relevancy of the collections for future generations.

Introduction

Palaeobotanical research has been carried out at the Swedish Museum of Natural History (Naturhistoriska riksmuseet: NRM) for over 150 years. Although the name of the department in which this research has been carried out has changed on several occasions owing to museum restructuring during this interval, for the sake of clarity, this department is called the ‘Palaeobotany Department’ up to 2016 in the following text.

The quantity and coverage of the collections has increased steadily over the years. In 1950, the collections of the Palaeobotany Department were estimated to contain around 56,000 specimens (Halle 1950). Currently, the department hosts about 400 000 plant fossil specimens—from Proterozoic microfossils to enormous Triassic silicified logs. The departmental collections have particular strengths in Devonian plants from Spitsbergen and Bear Island, Carboniferous plants from western Europe, Permian plants from China, France and Antarctica, Triassic plants from Sweden, Germany, Austria and Australia, Jurassic plants from Sweden, Yorkshire and China, Cretaceous plants from Quedlinburg and Franz Josef Land, Cenozoic plants from Iceland, Greenland, Spitsbergen, Greece, Japan, Chile and Antarctica, and post-glacial (Quaternary) floras of Sweden. The department also hosts important thin section and cuticle mounts from a diverse array of fossils, globally important Cretaceous charcoalified mesofossils, and the H.-J. Schweitzer collection of fossil plants of diverse ages. Because the collections have been studied since the early stages of palaeobotanical research in Europe, the department hosts a very large number of type and illustrated specimens. The department also houses a large library of historical palaeobotanical literature—much of it in the form of original reprints obtained via academic exchange.

The following account can not be considered comprehensive. It builds largely on internal unpublished summaries of the departmental history compiled by T.G. Halle (1950) and O. Johansson (2016). Owing to page constraints, it is intended to provide only a summary of the historical development of the Palaeobotany Department at NRM. It is beyond the scope of this article to give an account of the numerous visiting scientists who have published studies of the NRM palaeobotanical collections. Links to lists of publications emanating from researchers in the department are appended to the text.

Origins

The origins of the Swedish Museum of Natural History date back to the foundation of the Royal Swedish Academy of Sciences on June 2, 1739, by six scientists and politicians: Jonas Alströmer, Anders Johan von Höpken, Sten Carl Bielke, Carl Linnaeus (later von Linné), Mårten Triewald and Carl Wilhelm Cederhielm. Meetings of the academy were originally held in the House of Knights (Riddarhuset) in Stockholm's old town (Gamla Stan), but later moved to Stora Nygatan (also in Gamla Stan) and, in 1828, to Westman Palace in the northern part of central Stockholm. In the early years of its existence, several members of the Academy built up collections of natural history objects for their own interests and for scientific discussion. As interest in these collections grew, they were made available for viewing by the public as early as 1786. This collection formed the basis for the establishment of the Swedish Museum of Natural History by the Royal Academy in 1819. A dedicated gallery (the so-called 'Natural History Collection') was opened to public viewing in Westman Palace in 1831. The collections continued to grow markedly during the late 1800s and early years of the 1900s as material was returned to Stockholm from various Swedish expeditions to the Arctic, South America, Asia, and Antarctica among other regions. In 1884, the Academy used the building at Wallingatan 1 in the Greenland Södra district to house the new department for Archeogonates and Fossil Plants. The continually growing collections eventually necessitated a move of premises to vacant land in the northern suburbs of Stockholm. Since 1915, the Royal Academy has been located in Frescati, northern Stockholm. The Swedish Museum of Natural History was constructed as a separate building complex on adjacent land. It opened in 1916 and remains at this site today.

Although the oldest collections of fossil plants in the museum date back to the 1700s, palaeobotanical materials increased markedly after the expeditions of Adolf Erik

Nordenskiöld in the mid- to late 1800s. Nordenskiöld had been a member of Otto Torrel's 1858 expedition to the Arctic where he recovered Paleogene plants from Spitsbergen that were later described by Oswald Heer (Heer 1868–1882). Nordenskiöld was appointed director of the Mineralogy Department at the museum in 1858 and became the leading figure in Swedish Arctic exploration. On his last voyage (to west Greenland) in 1883, he took Alfred Nathorst who collected significant plant fossil assemblages for the museum. Ten years earlier, Nordenskiöld had collected a substantial number of plant fossils from Pålsjö in Skåne (southern Sweden) that Nathorst had described and published.

Early development

In 1864, a curator was employed to manage the palaeozoological collections, which then also included the palaeobotanical material. The expansion of the collections during the 1870s and 1880s by the addition of considerable quantities of fossil plants from expeditions to the Arctic and contributions from the coal mining areas of southern Sweden led Nordenskiöld to petition the academy and government for a dedicated professorship in palaeobotany.

Thus, in 1884, Alfred Gabriel Nathorst (1850–1921) was appointed professor by royal decree and curator of the newly established Department of Palaeobotany at the Swedish Museum of Natural History (although the position was not made permanent until 1910). The early development of palaeobotanical research at the museum was almost entirely through the efforts of Nathorst. Through his stewardship, the department grew to a size and significance beyond that to be expected for a small country with relatively few fossil plants. Nathorst had studied both botany and geology and by the age of 19 had already published observations on the Cambrian geology of southern Sweden. Within five years he had amassed several publications on Quaternary to Mesozoic ichnofossils and plant fossils of southern Sweden and was awarded a PhD in 1874 by Lund University. By 1876, he was employed as a geologist at the Swedish Geological Survey (SGU). However, it was his work on fossil floras of the Arctic that raised Nathorst's profile to wider attention.

Nathorst (Fig. 1A) made his first voyage to Svalbard with engineer Hjalmar Wilander in 1870, and in 1882 he visited Svalbard in the company of Gerhard De Geer. The following year he participated in Adolf Erik Nordenskiöld's Swedish Greenland Expedition. His subsequent expedition in 1898 visited Bear Island, Svalbard and King Karls Land. He also participated in an expedition to Greenland in 1899 in search of S.A. Andrée's lost polar ballooning expedition (from 1897). Nathorst's polar research provided him with extensive and important fossil plants from the Arctic enabling him to build on Oswald Heer's palaeobotanical work from the 1860s to 1880s. Nathorst also described extensive fossil floras from the coal-bearing Triassic–Jurassic successions of Skåne. Although fossil plants had been documented from this region by earlier palaeobotanists, such as Adolphe Brongniart and Sven Nilsson, Nathorst was the first to systematically document these rich fossil floras within a stratigraphic framework. This provided an initial basis for biostratigraphic subdivision and correlation of the Scanian sedimentary successions. Nathorst was also at the forefront of technical methodologies for his time. During his early career, his papers were mostly descriptive and focused on macromorphological characters. However, in the first decade of the 20th century, he successfully used collodion transfers and acid maceration for the study of epidermal features of fossil leaves. In 1904, Nathorst was awarded the Lyell Medal for his contributions to Artic and palaeobotanical research.

For much of his career, Nathorst worked in primitive cramped premises in a ramshackle apartment house opposite the main Academy of Sciences' building at Wallingatan. Nathorst's 'laboratory' was essentially just a slightly altered apartment kitchen. However, thanks to his good connections with palaeobotanists around the world, Nathorst was able to establish a rich collection of comparative material for study and exhibition. One of his final achievements was to plan and implement the palaeobotanical department and exhibition space in the newly constructed museum at Frescati in 1916. Nathorst retired the following year, broken in health from overwork and with a scanty pension, but the material that he collected and assembled remains the core of the museum's palaeobotanical collections to this day. Perhaps the greatest importance of Nathorst's scientific work is that it laid the foundations for future geological and palaeontological advances.

Fig. 1. Early palaeobotanists at the Swedish Museum of Natural History: **A**, Alfred Gabriel Nathorst; **B**, Thore Gustaf Halle; **C**, Ernst Valdemar Antevs.

In those early years of palaeobotanical research, Nathorst led a small department that included, at various times, a research assistant (Thore Gustaf Halle: 1884–1964), two scientific illustrators (Carl Axel Hedelin: 1861–1894, Lovisa Thérèse Ekblom: 1867–1941), a research student (Ernst Antevs: 1888–1974), an assistant (Viola Thérèse Eriksson [née Ekblom]: 1897–?) and a caretaker (B. Eriksson). From 1891 to 1898, the botanist Dr Gunnar Andersson was loosely attached to the department and worked mainly on late glacial and post-glacial Quaternary floras, especially the distribution of the '*Dryas* flora' and *Trapa natans*, along with plant impressions in the widespread calcareous tufa deposits around Sweden. Per Dusén (1855–1926), agricultural engineer and later honorary DSc was employed primarily as a technical assistant but took part in expeditions to Cameroon (1890–1892) and Patagonia (1895–1897), after which he described some of the collected Cenozoic plant remains. He also described Paleogene floras (Dusén 1908) from Seymour Island collected on the 1901–1903 Swedish Antarctic Expedition by Otto Nordenskiöld. In the early 1900s, he collected Permian material from Brazil, later described by G. Lundqvist (1919). The bryologist Hjalmar Möller was linked to the department and worked briefly (1901–1902) on Jurassic floras from Bornholm, publishing two papers (Möller 1902, 1903).

Nathorst's student, Ernst Valdemar Antevs (1888–1974), went on to have a distinguished career in his own right. Antevs (Fig. 1C) initially worked on Jurassic macrofloras from the Höör Sandstone in Skåne and obtained his PhD from Stockholm University in 1917. He also collected (in 1916) and published on Devonian plants from Bear Island (Antevs & Nathorst

1917). He was employed by Stockholm University from 1917 to 1935, then moved to the United States where he took up citizenship and worked extensively on North American Quaternary geology and the archaeological sites at Gila Pueblo and Clovis. He joined the University of Arizona Department of Geochronology in 1957. Antevs is particularly noted for coining the term ‘palynology’ (Traverse 1988).

Consolidation

As a student, Thore Gustaf Halle (1884–1964) was paid for his early work at the palaeobotanical department and, in 1914, he was hired on a permanent basis as a scientific aid and later an assistant. Following Nathorst’s retirement, Halle (Fig. 1B) received the title of professor (in 1918) and was elevated to head of the Palaeobotany Department. Throughout his life, Halle shouldered great responsibilities. After taking over as head of department from Nathorst, he later (1921 to 1947) was, simultaneously, director of the museum. He also became deputy secretary of the Academy of Sciences in 1939.

Halle began his studies at Uppsala University and in 1905 (under his original name: Gustavson 1905) he wrote his first scientific article *Contributions to the moss flora of the Hökensås area*. During his university studies, Halle participated in Associate Professor Rutger Sernader’s lectures and became interested in the development of Sweden’s Quaternary flora and the postglacial climate. The following year, Halle (1906) wrote an article about small Quaternary plant-bearing tufa deposits in Fröjels parish on Gotland. Through these studies he came into contact with A.G. Nathorst at the Department of Palaeobotany, NRM. This led to Halle’s engagement in palaeobotanical investigations at the department as early as 1907. In the following years he wrote articles on herbaceous lycopsids from the Paleozoic (1907) and sphenopsids from the Mesozoic of Skåne (1908).

Halle’s (1911) doctoral dissertation *On the geological structure and history of the Falkland Islands* under the supervision of Professor Arvid-Gustaf Högbom of Uppsala University dealt primarily with Permian plants and stemmed from fieldwork that he had undertaken at age 23 on botanist and explorer Dr. Carl Skottsberg’s expedition to the Falkland Islands, Patagonia and Tierra del Fuego. He soon also published significant studies on the Mesozoic flora of Graham Land, Antarctica (Halle 1913) and on Lower Devonian plants from Röragen, Norway (Halle 1916). Halle’s detailed descriptions, contributions to fossil plant morphology, development of palaeobotanical research methods, and versatility in the field of palaeobotany soon gained the attention of fellow researchers.

From April 1914, Johan Gunnar “China-Gunnar” Andersson (1874–1960), of the Swedish Geological Survey, was in China as an ‘advisor on mining issues’ to the Chinese government. He was instrumental in establishing the Chinese Geological Survey and sent fossils collected during his fieldwork to A.G. Nathorst that same year, urging him to send someone to collect and study the rich fossil floras discovered there. Andersson and Nathorst succeeded in inspiring T.G. Halle to undertake a research trip from 1916 to 1917 (a time of great conflict in Europe) to the provinces of Hebei, Jiangxi and Henan. Halle compiled extensive collections of plant fossils from various regions of China with the assistance of J.G. Andersson and local geologists, although the work was cut short by a severe illness contracted by Halle. An agreement was made with the Chinese authorities to divide the collections into equal parts and to send half of the collections to Sweden for study and curation. However, the transport of this material ended in disaster when the Swedish steamer

Peking sank in a typhoon in the China Sea in 1919 carrying the entire collection. J.G. Andersson, in collaboration with the Chinese Geological Survey, A. Lagrelius (of the Swedish ‘China Committee’, and Professor Erik Nyström of Taiyuanfu, managed to at least partially compensate for the loss by excavating new specimens from the same localities over the following three years and shipping them to Halle in Stockholm. Material was also received from Erik Norin (Uppsala University) who made collections in 1921–1922 (Norin 1922) on the initiative of Professor Erik T. Nyström at Shanxi University. The Chinese collections were immense (over 19600 Palaeozoic specimens alone), so Halle’s research focused on the well-preserved Permian material from Shanxi province. After ten years of research, Halle published his most significant work, the monumental (316 p.) monograph *Palaeozoic plants from Central Shansi* (Halle 1927), which provides the fundamental basis of our knowledge of China's Permo-Carboniferous flora (Lundblad 1969a, Andrews 1980). Following taxonomical identification of the specimens, half of the material was returned to China according to the agreement and is today housed at the Nanjing Institute of Geology and Palaeontology.

Halle's knowledge extended over most facets of palaeobotany. His publications reveal evidence of his particular skills as a morphologist and developer of new methodologies. Some of his later works dealt with morphological and anatomical studies of *Whittleseya* and related taxa (Halle 1931) and the structure of reproductive organs affiliated with seed-ferns (Halle 1933). However, administrative duties likely prevented Halle from fulfilling his great potential as a scientist during the latter part of his career. Nevertheless, he was instrumental in mentoring students working on Palaeozoic and Mesozoic collections in the department, including G. Lundqvist (1919) and Britta Lundblad (1950). In 1918, Tsanheng C. Chow, of the China Geological Survey, began his studies at the museum on Liassic floras of Skåne (Chow 1924)—an arrangement stemming from Halle’s visit to China two years earlier. Around this time, Halle and Nathorst also mentored Nils Johansson, who published several studies on the Triassic floras of Skåne and Jurassic flora of Norway (Johansson 1920, 1922a, 1922b). Johansson soon left palaeobotany to do research in forestry and undertake popular-science writing. Halle’s last major work was *The extinct plants* (1938–1940) in Carl Skottsberg’s *Växternas liv* (*The Life of Plants*), which had the character of a Swedish palaeobotanical textbook and was unique in its kind. Lundblad (1969a, 1969b) and Andrews (1980) regretted that this work was never translated into any of the major languages.

Walton (1966) addressed the importance of Halle's techniques in his later work, that by recovering the more durable cuticle and sporopollenin components of coalified fossils he made it possible to identify and resolve the position of pollen grains in complex reproductive organs and, thus, enabled their better reconstruction (Andrews, 1980).

Halle published primarily palaeobotanical works but he maintained a life-long interest in extant bryophytes. His only publication on this topic was *Bidrag till Hökensåsbygdens mossflora* (Contribution to Hökensåsbygden's moss flora), published under his birth name (Gustafson 1905). Nevertheless, he remained an avid collector, particularly of aquatic mosses (Krusenstjerna 1964). These materials are now held in the collections of the Botany Department of the Swedish Museum of Natural History.

Halle was awarded an honorary doctorate by the University of Cambridge in 1930. He retired in 1950. Halle was greatly regarded, not only for his accuracy and self-criticism, but also for his benevolent leadership, and tolerant and friendly relationship with the people around him. Rudolf Florin (1948) wrote in tribute to Halle on his 60th birthday that “The high quality of Halle's work is known among palaeobotanists. With great technical ingenuity and skill ... combined with a critical attitude to himself and his work, he must be seen as one of the most important for the development of palaeobotany in the twentieth century. Through his outstanding human qualities, Thore Halle has received in abundance the sympathy, affection and esteem from his colleagues".

Carl Rudolf Florin (1894–1965) filled the position of assistant (keeper) in palaeobotany at the museum in 1918 when Halle was elevated to the professorial head of department. Florin (Fig. 2A) was a botanist by training, whereas his colleagues (Halle and Nathorst) were trained primarily as geologists. Florin's earliest works focused on applied aspects of botany, especially pollination of commercial fruit trees. He passed the Swedish 'filosofie kandidat'-examination in 1919, and graduated as 'filosofie licentiat' from Stockholm University in 1920. Nathorst, in the final years of his life, while still working at the department, encouraged Florin to continue his work on Cenozoic floras of the Arctic region and East Asia. However, after a small preliminary study around 1920, Florin gravitated towards the topic that would dominate his subsequent career: the epidermal morphology and reproductive architecture of conifers and their relatives.

Florin discovered that epidermal and stomatal morphology provided the best means of separating similar *Taxodium* and *Sequoia* sterile foliage. The 25-year-old botany student was inspired to make a broader study of fossil conifer epidermal morphology but realized that the first step in this process would need to be a thorough comparative analysis of the epidermal morphology of extant conifers, which at that time had been neglected by systematists. This became the focus of his doctoral thesis, which he defended at Stockholm University in 1931 and became assistant professor later that year. Florin's thesis spans nearly 600 pages and covers the development of stomata in 36 species and 25 genera of conifers. In parallel with his work on extant conifers, he also investigated various fossil conifers and other gymnosperms. He demonstrated the difference between the developmental pathways of haplocheilic stomata of Cycadales and the syndetocheilic stomata of Bennettitales—two groups that have very similar leaf gross morphologies. Florin's (1936) study of the anatomy of Ginkgoales (including six new genera) from the Cretaceous of Franz Josef Land is remarkably well illustrated and employed both traditional serial sectioning and bulk maceration of the chert in hydrofluoric acid to extract the entombed plant remains that were embedded in paraffin and cut by microtome. Florin continued to work on a range of fossil conifers and other gymnosperms of Carboniferous to Cenozoic age through the course of his time at the museum. Perhaps his most significant work was '*Die Koniferen des Oberkarbons und des unteren Perms*' (1945), comprising 729 pages and 186 plates, and based on material from over 75 collections across Europe and North America. Publication and subsequent reprinting of this popular monograph is said to have saved the publisher, Schweizerbart'sche Verlagsbuchhandlung of Stuttgart, from bankruptcy at the end of World War II (Lundblad 1966). The work is all the more significant in that some of the collections on which it was based were destroyed during the war. The recognition that both cordaitalean and conifer seed-bearing cones represent compound structures with spirally arranged, radially symmetrical, reduced, ovule-bearing axes subtended by a bract, became known in later years as the 'Florin model' of gymnosperm reproductive architecture and has become a useful model for understanding the evolution of reproductive structures in other seed plants (McLoughlin & Prevec 2019, 2021). Florin was elevated to professor in 1942 (at the relatively late age of 48 compared with his contemporaries Nathorst and Halle, who had both taken up leadership roles at around 34 years of age). In 1944, he resigned from the museum to take up the position of Professor Bergianus—head of the Stockholm Botanic Gardens and the Bergius Foundation, which supported the gardens' upkeep. However, he continued to work on the department's fossil collections (especially late Palaeozoic and Mesozoic gymnosperms) for many further years and, despite the added administrative and editorial burdens of his new position, his productivity did not significantly decrease. His last great paper, published in 1963 was '*The Distribution of Conifer and Taxad Genera in Time and Space*', which contains 68 maps outlining the geographic and stratigraphic distribution of conifer taxa and argues that conifers were already differentiated into distinct southern and northern hemisphere families (separated by the Tethys Sea) in the late Palaeozoic. Florin published around 125 papers that marked him as one of the most significant palaeobotanists of the 20th century. He was presented with numerous awards during his career and took on a diverse range of administrative positions for professional societies (Lundblad 1966).

Transformation and trouble

Olof Hugo Selling (1917–2012) studied both geology and botany and developed particular interests in Pacific Quaternary floras. Sharp-witted and intelligent, Selling (Fig. 2B) moved into the relatively new research field of palynology. He carried out palynofloral studies in Hawaii in 1938 and across the Pacific and Australia in 1948 (his field research likely being greatly affected by events in the Pacific during World War II). From 1945, he was an assistant in the Palaeobotany Department. He was awarded a PhD by Stockholm University in 1949 and, in 1951, succeeded Thore Halle as head of the Palaeobotany Department at the relatively young age of 34. Halle's advice to Selling on his elevation to the leadership position was "Håll dig väl med Florin, annars får du ett helvete!" ["Stay well with Florin, otherwise you'll get one hell!"]. Selling would have been well advised to listen to his former boss.

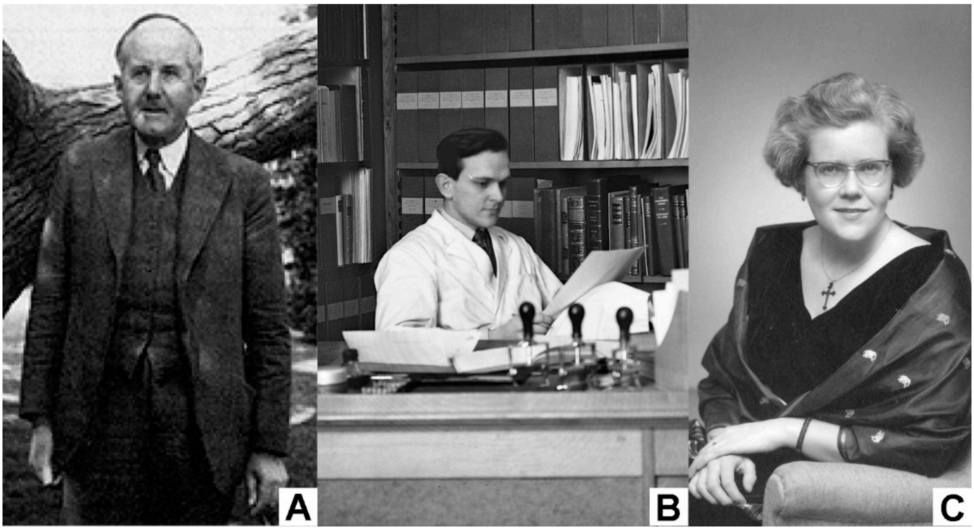

Fig. 2. Mid-20th Century palaeobotanists at NRM: **A**, Rudolf Florin; **B**, Olof Selling; **C**, Britta Lundblad

The first part of 1950 was a busy time in the department as a consequence of the change in leadership, reorientation of much research towards younger (Neogene–Quaternary) floras, preparations for the Seventh Botanical Congress in Stockholm, and a large influx of international visitors before and after the meeting. Signatures in the Palaeobotany Department's visitors book from that year represent a 'who's who' of palaeobotanical researchers in the mid-20th century (Fig. 3). 1950 was also marked by celebration of the 100th anniversary of A.G. Nathorst's birth. That year, Olof Selling also compiled a list of palaeobotanical literature from 1939–1947 that contained a section outlining what happened to the palaeobotanical collections in Europe during World War II.

Selling was productive in publishing research works through the 1940s and early 1950s. His work focused primarily on the relatively new science of palynology, and especially pollen and spores of Quaternary deposits and extant plants (particularly ferns) of Hawaii, Melanesia and New Caledonia. His studies of palynomorphs from sedimentary samples collected by Thor Heyerdahl in 1955 on Easter Island revealed that the Island had once been covered in forests of an extinct palm. This work remains unpublished and is only referenced by Heyerdal & Ferdon 1961), who mentioned personal communication with Selling indicating the common occurrence of fossil pollen from compositae and an extinct palm. However, he did publish further works on the fossil record of *Trapa*, on Mesozoic gymnosperms from the Arctic, and serial sectioning of calamitalean cone compressions. Selling also hosted visiting scholars, such as Mahendra Nath Bose from India, who published several papers on material in the NRM collections.

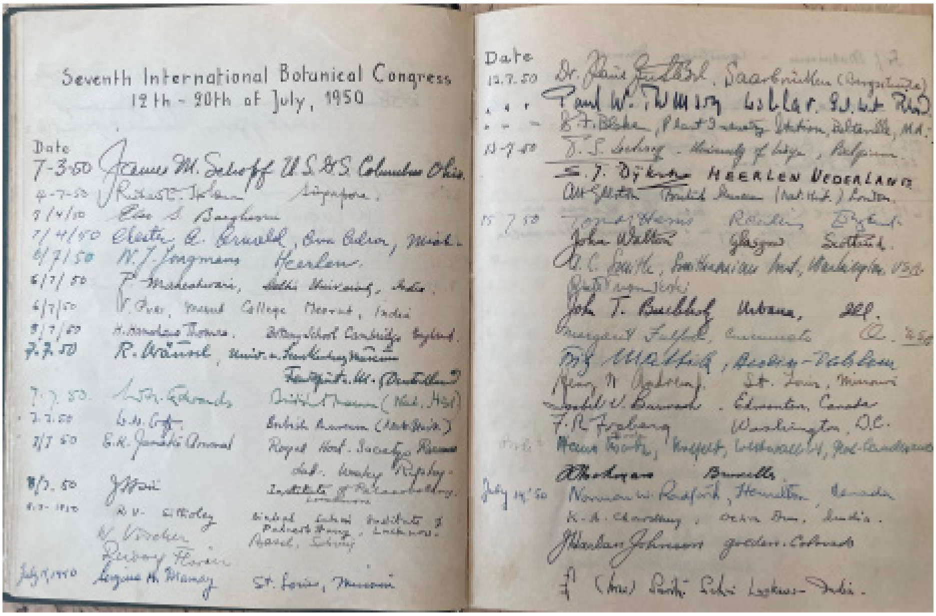

Fig. 3. NRM Palaeobotany Department guestbook entries for early 1950.

Selling's career was cut short by controversy (the so-called "Selling affair") and he produced very few publications in the last 10 years of his leadership of the Palaeobotany Department. The Selling Affair is said to have originated as a personal dispute between Olof Selling and

Rudolf Florin, who was at that time Professor Bergianus (Head of Stockholm's Hortus Bergianus Botanical Garden). At that time, both the Garden and the Museum were under the auspices of the Royal Academy of Sciences. Florin used facilities at the museum for storage and processing of fossil materials. The two palaeobotanists differed in their research interests, were a generation apart in age, but it is difficult to say, 70 years later, whether their personalities differed strikingly or, instead, were all too similar. Regardless, their personalities certainly clashed. Animosity between the two scientists reached a breaking point when it is claimed that Selling reclaimed Florin's key to the doors at the Palaeobotany Department, preventing Florin from accessing the laboratory. The dispute escalated as Florin and his colleagues from the Academy, with the help of psychiatrist Olof Dagberg, sought to have Selling removed from his position on the grounds of mental instability (or more specifically 'quarrelsome paranoia'), without having any reasonable basis for this. In those times, illness was one of the few justifications by which a professor could be removed from their post. Initially, it appeared as though the Academy would succeed in their goal as Selling was diagnosed as suffering from *paranoia querilantis* and suspended from his post in 1955. However, after a new examination, the previous diagnosis was quashed and Selling was reinstated in 1956. Selling was then prosecuted again by the Chancellor of Justice, who attempted to have Selling subjected to yet another examination.

The perceived victimization of Selling by his opponents via the legal system led journalist Vilhelm Moberg and Herbert Tingsten (then chief editor of Sweden's largest newspaper, *Dagens Nyheter*) to publish several newspaper articles and an account of the Selling Affair as a short booklet (*Komplotterna*: Moberg 1956). This was one of several legal scandals in Sweden during the 1950s and ended with the Minister of Justice, Herman Zetterberg, being forced to resign in 1957. A further consequence was the separation of the Swedish Museum of Natural History from governance by the Royal Academy and its transfer, as an independent government agency, to the Ministry of Culture.

The legal case ended in the Svea Court of Appeals in 1958 with Selling being convicted on a trivial misconduct charge and for defamation of Rudolf Florin and Britta Lundblad (a palaeobotanical colleague at the Museum), but cleared of other charges and accusations of insanity. Selling retained his position as head of the Palaeobotany Department but, in 1966, he left the museum to work in a private business. Although the Selling Affair is commonly pitched as a personal conflict between the main parties involved, the roots of this dispute may lie deeper in the attitude to science between the respective academicians as a clash between more traditional (19th century) natural romantic 'knowledge' acquired by painstaking studies of material already held in institutions, and more progressive late-20th century methodologies, field-based research, and hypothesis- and process-driven approaches to science (Wikander 2017). Regardless, of the causes, the dispute led to a significant change in the administration of the museum and greatly impacted the personal lives and scientific careers of those involved.

Re-consolidation

Anna Birgitta (Britta) Lundblad (1920–2008) obtained a licenciate in 1947 and a PhD in 1959. Lundblad (Fig. 2C) worked as a geologist at the Geological Survey of Sweden (then located within the Swedish Museum of Natural History) from 1947 to 1948 and became a curator in the Palaeobotany Department at the museum in 1951 following Thore Halle's retirement. She rose to senior curator in 1965 but was also granted an associate professorship at Stockholm University in 1960 and held an extra research position at the Swedish Research Council from 1960 to 1966. She ultimately succeeded Olof Selling as acting head of the Palaeobotany Department in 1966, and was conferred professorship, then promoted to full head of department, from 1969 until her retirement in 1986.

Following the recommendation of Thore Halle, Britta Lundblad began re-studying the Mesozoic floras of Skåne in the late 1940s. These floras had been little studied for the previous 30 years (since the classical works of Nathorst and Antevs). She published a series of papers on individual selaginellalean, isoetalean, peltasperm, ginkgoalean and liverwort taxa between 1948 and 1959. At the same time, she was working on revisions of the entire Triassic–Jurassic flora of Skåne, the results of which appeared in two monographs and a stratigraphic summary (Lundblad 1950, 1959a, 1959b) dealing with cryptogams and gymnosperms (excluding conifers). During these studies, Lundblad carried out regular correspondence with Tom Harris in the UK, who had worked on coeval floras from Greenland in the 1930s. Lundblad's work helped to clarify the patterns of floristic turnover through the end-Triassic extinction event and to more precisely place this important horizon within the Scanian stratigraphic succession. She also highlighted the importance of cuticular studies for differentiating certain gymnosperm species that otherwise appear very similar on macro-morphological criteria. Although she continued to write the occasional paper on Mesozoic cycads and ginkgoaleans, Permian liverworts and Silurian fossils through the 1960s and 70s, her publication rate reduced markedly after 1959. This might have been a consequence of both the stress involved in dealing with her immediate superior (Olof Selling) and the legal issues with which they had become enmeshed, and also because of the added administrative load that she took on as head of department after 1966. She, nevertheless, made time to supervise Duan Shuying (later of the Institute of Botany, Chinese Academy of Sciences) as a doctoral student in 1986.

Annie Skarby and Hans Joachim Schweitzer both worked for short periods in the department in 1967. Although never employed in permanent positions in the department, the fossil assemblages compiled by these individuals would, in later decades, make invaluable contributions to the museum's palaeobotanical collections.

Hans Tralau (Fig. 4A) was born in Lübeck in 1932 and died of cancer in Stockholm on 14th March 1977 at the age of 44. He began work in the Palaeobotany Department in 1957 and was promoted to intendent in 1964. Tralau published on both extant and fossil plants—his earliest work in 1958 being on Scandinavian montane gentians. His palaeobotanical work through the 1960s focused on Cenozoic plants and especially included a biogeographic component. His most cited publications are on the Cenozoic fossil record and biogeography of *Azolla*, Asiatic dicots in Europe, montane and boreal plants of Scandinavia, *Nypa*, and *Ginkgo* (Tralau 1959, 1963a, b, 1964, 1967, 1968). However, he also extended his work to palynological and palaeobotanical analyses of the coal-bearing Middle Jurassic strata of Eriksdal, Skåne (Tralau 1967, 1968).

In 1969, Tralau initiated the projects Index Holmensis and Bibliography and Index to Palaeobotany and Palynology (with collaborators Margareta Söderman and Rita Baechler). The Index Holmensis aimed to map the distributions of all extant plant taxa. The Index to Palaeobotany and Palynology aimed to provide an alphabetical and chronological compilation of publications related to fossil plants that would enable palaeobotanists to remain up to date with the widely dispersed literature in their fields. These were early attempts to generate computerized global databases of extant and fossil plant records that might be considered precursors to modern platforms, such as the Paleobiology Database and GBIF. Such a monumental task required considerable funding, many employees and constant oversight of data quality—tasks that consumed most of Tralau's time through the 1970s. Employees of the project included Wilhelm von Eckermann, Bengt Bogestad, Ragnhild Eng, Anders Wallmon, Rolf Almkvist, Irma Rodriguez, Saul Weintraub, Per Granath, and Tord Reimers. Because of the great efforts involved in compiling the maps and literature for these projects in an era before email communications and global electronic databases, workrooms were built in the exhibition hall for the handling and preparation of information. The projects were funded largely by the Swedish Research Council. Tralau's plan to develop a database for Quaternary plant remains from Scandinavia (Lundblad 1977) never came to fruition. However, current efforts to complete the databasing and photography of the NRM palaeobotanical collections will go some way towards achieving that goal.

Just before the departure of Olof Selling, palynologist Dorothy Guy-Ohlson (1943–) (Fig. 4B) obtained her first position at the department, as an assistant professor for one month in 1965. In 1968, she became an exchange research student at Lund University under the supervision of Hans Tralau. Later she worked as a part-time extra curator (in the years 1972–1977) then as a curator (1977–1978) and from the end of 1978 as a senior curator. Guy-Ohlson undertook work in very broad fields of palynology. During the 1970s and 80s, she was particularly involved with palynological studies in collaboration with the Swedish Geological Survey in efforts to provide greater biostratigraphic resolution for the numerous Mesozoic rock units encountered in bore cores in Skåne. During the 1990s, while continuing some palynostratigraphic work, she also became well known for her work on the taxonomy and palaeoenvironmental significance of fossil algae including *Botryococcus* and *Tasmanites* (Guy-Ohlson 1992, Guy-Ohlson & Boalch 1992, Boalch & Guy-Ohlson 1992, Guy-Ohlson 1996). In the mid-1990s, Guy-Ohlson undertook secondment to work as a researcher in the Research Directorate-General of the European Commission where she investigated aspects of the mobility of researchers within the European Research Area.

New approaches

Following the retirement of Britta Lundblad, Else Marie Friis (1947–) was selected as the new head of the Palaeobotany Department in 1987. Else Marie (Fig. 4C) was born and raised in Denmark and obtained a Licenciate degree in science (PhD) in 1980 from Aarhus University. Her early work focused on the floras and palaeoclimatic setting of the Miocene lignites of central Jutland. After a stint in the UK as a British Council Research Scholar (1980–1981), she returned to Aarhus University. Her research switched primarily to fossil flowers after collaboration with Annie Skarby (Stockholm University) who, along with Nils-Erik Ross, had discovered remarkable, three-dimensionally preserved charcoalified flowers and other plant remains in Santonian–Campanian deposits at Åsen, Skåne. Her work in the following years saw the publication of a series of new charcoalified flower types from Åsen that contributed greatly to our understanding of early angiosperm floral evolution. In 1987, she co-edited a book on *The Origins of Angiosperms and Their Biological Consequences* with William Chaloner (Royal Hooloway, University of London) and Peter Crane (then at the Field Museum, Chicago) and later that year took up the position of head of Palaeobotany at NRM. Although the Åsen fossils were remarkably well preserved, their Late Cretaceous age did not capture the features of the initial radiation of angiosperms in the Early

Cretaceous. Hence, her later work, commonly in collaboration with Kai Raunsgaard Pedersen (Arhus University) and Peter Crane (Field Museum, Royal Botanic Gardens Kew, the University of Chicago, Yale University, and the Oak Spring Garden Foundation), began to target older Hauterivian–Albian charcoalified floras from North America, Portugal and elsewhere. The new data on fossil flowers, integrated with research on extant flower morphology was synthesized in the book *Early Evolution of Flowers* edited by Peter Endress (University of Zurich) & Else Marie Friis (1994).

Fig. 4. Palaeobotanists at NRM during the late 20th Century and early-2000s: **A**, Hans Tralau; **B**, Dorothy Guy-Ohlson; **C**, Else Marie Friis; **D**, Paul Kenrick; **E**, David Cantrill.

From her early research, Friis employed cutting-edge techniques for the anatomical and morphological categorization of charcoalified and mummified plant fossils. She was an early leader in the application of SEM and TEM techniques to fossil reproductive structures. In the early 21st century, she also pioneered non-destructive Synchrotron Radiation X-ray Tomographic Microscopy for the study of charcoalified flowers and seeds. Much of this and other research was synthesized in her 2011 book *The Early Flowers and Angiosperm Evolution* co-authored with K.R. Pederson and P.R. Crane. Her work has greatly advanced understanding of the reproductive architecture and phylogeny of early angiosperms and related groups of seed plants.

During her time in the department, Friis initiated a reorganization of the collections in 1987–88 to achieve a more logical (chronological and geographical) arrangement of the fossil assemblages. She also supervised a series of local and international postgraduate students and postdoctoral researchers including Vijayalakshmi Srinivasan, Suembikya Frumin, Patrick Herendeen, Helena Eklund, Jürg Schönenberger, Maria von Balthazar, Xiao-Ju Yang, Sandra May Lindfors, Jonas Hagström, Catarina Rydin, Leng Qin, Caroline Strömberg and Mario Mendes. Else Marie's work has also received widespread recognition via an honorary doctorate from Uppsala University (1999), membership of various international academies of science, and a series of awards from Swedish and Danish institutions. She was named geologist of the year in 2005 by the Swedish Geological Society. Else Marie Friis has stayed as an active researcher also following her retirement in 2015 greatly contributing to the topic on early angiosperm evolution.

In 1992, Paul Kenrick (Fig. 4D) was employed as a senior curator in the department. During seven years of research in the department, he studied early land plant evolution, lycopsid phylogeny, and Palaeozoic marine algae. In 1993, he also collected additional Devonian plant fossils from Röragen, Norway. A major outcome of his term of employment at the museum, was the publication with P.R. Crane of the book *The Origin and Early Diversification of Land Plants: a cladistic study* (Kenrick & Crane, 1997), which provided a fundamental re-evaluation of early land plant phylogeny. Paul was also instrumental in the early development (in 1993–1995) of the department's electronic collections database, replacing a card index system that had been initiated in 1953. He resigned at the end of 1998 to take up a curatorial position at the Natural History Museum in London.

In mid-1998, Thomas Denk (1969–) was hired as a senior curator working on relationships within Fagaceae and related groups. He also initiated studies of the Cenozoic vegetation and climate evolution in the Mediterranean to Caucasus regions, along with the development of the Arctic floras through the Cenozoic. Denk (Fig. 5C) supervised four PhD students working on departmental collections: Friðgeir Grímsson (on Icelandic Neogene floras); Georg Tschan (on Fagaceae and Platanaceae fossils), and Tuncay H. Güner and Johannes Bouchal (on mid-Cenozoic macro- and palynofloras from Turkey).

Following the departure of Dorothy Guy Ohlson, David Cantrill (1962–) took up a position of senior curator in the department in 2001 before departing in 2006 to become professor and chief botanist at the Royal Botanical Gardens Victoria in Melbourne. During his time in Stockholm, Cantrill (Fig. 4E) worked mostly on Cretaceous and Cenozoic fossils from Antarctica (e.g., Cantrill & Poole 2002, Cantrill & Hunter 2005, Cantrill & Nagalingum 2005). He mentored two postdoctoral researchers, Hervé Sauquet and Livia Wanntorp, for single years working on Proteaceae.

Following David Cantrill's departure, Stephen McLoughlin (1964–) (Fig. 5B) was employed in 2007 as senior curator, working primarily on Southern Hemisphere Permian to

Cretaceous floras and installed as professor in 2015. His immediate tasks involved leading the curatorial work on the H.-J. Schweitzer collections that had been accessioned to the museum as a permanent loan from Jena University, and the Permian macrofloras from China collected mainly by Halle. He also contributed a large quantity of material to the collections through his expeditions to Antarctica (permineralized Permian peat) and from Australia (Permian and Mesozoic macrofloras). McLoughlin's research has focused primarily on the taxonomy and evolution of various gymnosperm and fern groups with particular emphasis on glossopterids and associated plants (McLoughlin 2011, 2012, McLoughlin & Prevec 2019, 2021, Slater *et al*. 2011, 2012, 2013, 2015), but also various Mesozoic 'seed-ferns' (e.g., Bomfleur *et al*. 2014a, 2014b, 2015, 2017, 2018, Unverfärth *et al*. in press) and Bennettitales (e.g., Pott & McLoughlin 2009, 2011, McLoughlin *et al*. 2011), partly in collaboration with postdoctoral researchers Christian Pott and Benny Bomfleur and PhD student Ben Slater. His recent work, partly with postdoctoral researcher Chris Mays, has particularly targeted the environmental and biotic changes through Permian–Triassic extinction crisis (e.g., Fielding *et al*. 2019, Vajda *et al*. 2020, Mays *et al*. 2021a, 2021b, McLoughlin *et al*. 2020, 2021c) and plant-insect interactions (McLoughlin *et al*. 2021a, 2021b, McLoughlin & Mays 2022).

The new Department of Palaeobiology

Following a decision by the museum administration to streamline the Research Division from twelve to six departments, Palaeobotany was merged with Palaeozoology in 2014 to form the Department of Palaeobiology. On April 1st, 2015, Professor Vivi Vajda (1963–) was appointed head of the amalgamated Department of Palaeobiology, replacing the two former heads, Else Marie Friis (palaeobotany) and Stefan Bengtson (palaeozoology). After a major renovation of collection facilities, offices and laboratories, the palaeobotanical collections were moved from the Botany building to the adjacent Palaeobiology building.

Vajda (Fig. 5A) undertook her studies at Lund University, earning her PhD in 1998. After postdoctoral studies at GNS Science in New Zealand (2000–2001), she was promoted to assistant Professor at Lund University in 2003, obtained a Royal Swedish Academy of Sciences Research Fellowship (2008–2012) and was promoted to Professor in 2010. She supervised numerous Masters and three PhD students during subsequent years and remained at that institution until 2015. In 2018, she was elected member of the Royal Swedish Academy of Sciences and, a year later, inducted into the Hungarian Academy of Sciences. Vajda's immediate focus was to lead the curatorial work on the Swedish Mesozoic palaeobotanical and palaeozoological collections, i.e., the work of digitizing, photographing and identifying the huge quantities of material collected during the previous 150 years. She also increased the size of these collections through accessions of new material from the Triassic-Jurassic transitional beds through departmental expeditions to Skåne. During the year of restrictions imposed by the Covid-19 pandemic, she directed efforts towards the digitization of the vast collection of Mesozoic foraminifera and other microfossils identified and curated by F. Brotzen in the 1950s from the Höllviken drillcores, and other cores from southern Sweden. These small fossils were suitable for staff to transport and digitize while working from home. She was also instrumental in efforts to upgrade the department's collection databases to more stable platforms.

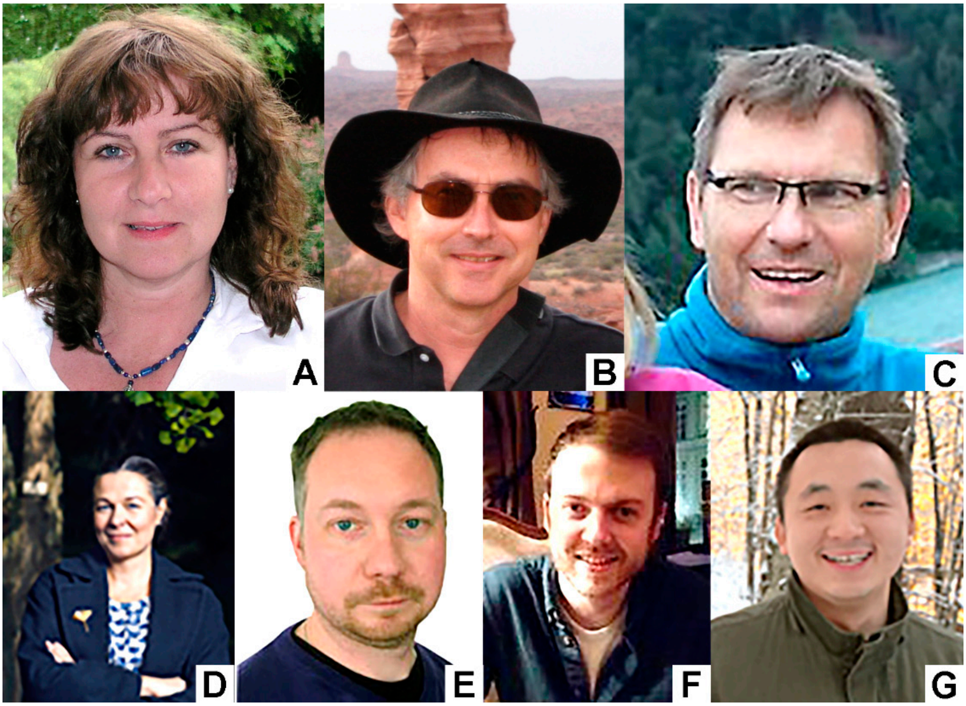

Fig. 5. Current (2022) palaeobotanists at NRM: **A**, Vivi Vajda; **B**, Stephen McLoughlin; **C**, Thomas Denk; **D**, Margret Steinthorsdottir; **E**, Magnus Ivarsson; **F**, Sam Slater; **G**, Jungang Peng.

Vajda formed an international research group, partly through her involvement in the IGCP, with PhD students Jungang Peng (Fig. 5G) and Quin Yuan, and postdoctoral researchers Sam Slater (Fig. 5F) and Liqin Li, focusing on the palynological aspects of multi-disciplinary studies of Earth's major extinction and oceanic anoxia events (e.g., Li *et al.* 2020, Schaefer *et al.* 2020, Slater *et al.* 2022). This, and additional collaborative work on plant stomatal distributions with departmental researcher Margret Steinthorsdottir (Fig. 5D), has collectively raised the profile of palynology and palaeoclimate studies in the department. Vajda's other interest, geobiology, uses novel techniques, including Raman spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, X-ray spectroscopy at the Max IV laboratory in Lund, and X-ray imaging of fossils plants to resolve questions of plant relationships and biological-regolith-atmosphere-impact processes and linkages in Earth's past (e.g., Vajda *et al.* 2017, Yuan *et al.* 2021, Krüger *et al.* 2021). Research in this field, in collaboration with her postdocs Yuangao Qu, Ashley Kruger and Susan Nehzati, and departmental researcher Magnus Ivarsson (Fig. 5E), highlight the importance of museum collections and the new knowledge that they can provide with cutting-edge techniques.

The future

Some fossil plants have now been held in the NRM collections for over 200 years and there is every prospect that, if cared for appropriately, they will remain useful research materials for several hundred and perhaps thousands of years into the future. How long can such collections last? Certainly not forever. There will always be threats to the preservation of fossil materials in institutional collections. Threats to the collections vary from abrupt and catastrophic to slow and piecemeal. Some of the key threats are outlined below and, in each case, staff at the Palaeobiology Department have been engaged in plans to mitigate against these potential dangers.

1. *Political strife*. The physical ravages of the Second World War and the associated looting of cultural collections across Europe show the vulnerability of museum materials to political strife. Political strife can manifest itself very quickly as shown by the recent Russian invasion of Ukraine. NRM has plans in place to remove and physically safeguard the most important components of the collections (mainly types and illustrated materials), should they be threatened by conflict.

2. *Social attitudes*. Staff at the museum are aware that societal attitudes can change over time and that certain social doctrines can impose existential threats to cultural objects. The destruction of historical monuments in Afghanistan and Syria in recent years and the widespread support of creationist ideologies in some domains make palaeontological collections and exhibitions on evolution particular targets by certain social groups. NRM places the bulk of its fossil collections in secure storage, accessible only to *bone fide* researchers in order to protect the most scientifically valuable materials.

3. *Economic pressures*. Financial pressures are constantly imposed on large museum collections. Apart from the costs involved in organizing and caring for the collections, there is a price for occupying floor space in the building of a major government authority. Several large fossil collections around the world have been moved to outer suburban storage facilities to reduce costs, but this lessens their accessibility to researchers and exhibition staff alike. The Department of Palaeobiology has made concerted efforts to retain the collections in close proximity to the curators and researchers so as to optimize their care and maximize their use in research.

4. *Relevance*. As advances are made in other fields (e.g., genetics, geochemistry and geochronology) there may be some who question the relevance of fossils to understanding plant and animal phylogenies, palaeoclimates and the dating and correlation of strata. Research at the Palaeobiology Department has consistently applied cutting-edge technological innovations to employ fossils for an ever-widening array of studies. Current research employing high-resolution X-ray tomographic methods is providing new insights into the architecture of extinct plants for which genetic data is unavailable, and geochemical analyses are opening new frontiers in the identification of microfossils and plants, and their palaeoclimatic and phylogenetic signatures. Moreover, the large datasets provided by the *ca* 400 000 plant specimens held in the museum's collection have the capacity to contribute accurate 'big data' to platforms such as the Paleobiology Database and GBIF, which can then be used for more refined global biogeographic and biostratigraphic analyses.

5. *Accidents*. Museum collections are under constant threat of accidental damage by fire, water leaks or natural disasters. The Palaeobiology Department maintains a constant monitoring system for fire, temperature and humidity, and undertakes regular maintenance

of its new compactus storage system. Radon levels in the collection are also regularly monitored for the safety of people working in the facilities.

6. *The hands of time*. No matter how carefully fossils are treated, they eventually deteriorate via abrasion, handling, and oxidation. Staff of the department are actively working to reduce handling and abrasion damage to fossils by employing better storage containers that reduce movement of the specimen when opening drawers. However, many of the fossils are delicate, organically preserved compressions that will be subject to eventual deterioration through oxidation. Digital imaging of such fossils represents the best option for retaining at least the macroscopic features of such fossils into the distant future.

7. *Access to new material*. Replacing old collections with new material from the original sites is another way of maintaining the value and quality of the collections. However, access to many of the traditional collecting sites (quarries and coal mines) is likely to decline as nations move progressively towards alternative fuels and undertake land remediation of excavation sites. Moreover, national, provincial and local laws that prohibit fossil collection or disturbance of public land are becoming increasingly common around the world. Further, land ownership or traditional custodianship laws in various countries are making it increasingly difficult to collect fossils from certain regions. In Skåne, the coal mines that once provided a rich source of Mesozoic fossils had all closed by the late 1960s, and few outcrop sections remain from which plant fossils can be collected. Palaeobotanists will need to become ever more opportunistic to take advantage of fossiliferous strata that are briefly exposed during highway and building construction to replenish collections. The department is also mindful that making fossil locations available on online databases leaves them open to increased risk of commercial or excessive amateur exploitation. NRM plans to restrict geographic information of certain important fossil sites to *bone fide* researchers.

8. *Reducing vulnerability through exchange*. Certain countries (e.g., New Zealand and Argentina) have, in recent years, taken the approach of safeguarding their palaeontological heritage by enacting laws that prevent the permanent export of fossils. All fossils from those countries must be studied on site or, if sent for study abroad, must be exported under strict conditions that the material be returned to institutions in the home nation. In part, this is a reaction to the 'colonial attitudes' of many European nations and researchers of the 19th and 20th centuries, which resulted in the removal of tremendous quantities of fossils, especially from developing and Southern Hemisphere countries, to institutions mainly in Europe, North America, and Japan. However, there is a downside to the retention of cultural materials within the borders of their nation of origin. Firstly, this strategy can lead to an insular focus of institutional researchers. If institutions house materials only from their own countries or provinces, researchers working at those institutions have less access to fossil materials from other regions that may be critical to the broader geographic implications of their studies—and fossil distributions obey no political boundaries. Their research tends to become increasingly provincial in focus and relevance. Secondly, the strategy of holding 'all your eggs in one basket' makes national palaeontological collections greatly more vulnerable to loss through political strife, accidents, or natural disasters. The destruction of the main building of the National Museum of Brazil, Rio de Janeiro, by fire in 2018 highlights the vulnerability of large cultural collections. Approximately 92.5% of that museum's archive of 20 million items were lost in the 2018 fire, although around 1.5 million items stored in a separate building were undamaged (Solly, 2018). Exchange of key assemblages of palaeontological materials between international institutional collections lessens the risk of

entire suites of fossils being vulnerable to total loss and, if distributed between continents, potentially provides greater access for researchers with limited travel funds.

9. *The digital future*. The Palaeobiology Department at NRM is actively pursuing the task of electronically registering all of its fossil collections within a user-friendly database. At the time of writing >90% of the plant fossil collections are databased. Currently, that database is not accessible online, but future plans entail an upgrade to a more stable Filemaker platform and the release of digital information to global biodiversity platforms, such as GBIF. Further, the department is in the early stages of photographing its collections. It is planned that these digital images will be linked to the database and eventually made available online. Beyond this, there is scope for 'value-adding' to the collections by online presentation of statistical data on the distribution of fossil plant taxa, both palaeogeographically and stratigraphically.

Summary

After nearly 140 years since the appointment of the first professor of palaeobotany, research on fossil plants at the Swedish Museum of Natural History is going from strength to strength. At the time of writing, the department hosts three senior palaeobotanists / palynologists in permanent positions, one on a contract position, two research fellows on fixed-term positions, three long-term guest researchers, and three technical staff involved primarily with caring for the palaeobotany collections. Additionally, the department has one emeritus palaeobotanical researcher and a scientific artist (Pollyanna von Knorring) whose work has focused principally on the reconstruction of fossil plants and terrestrial ecosystems.

The department is continually exploring new approaches to the analysis of plant fossils, with refined X-ray and neutron tomographic methods, and novel geochemical and spectroscopic approaches offering great potential for the advancement of palaeobotany into the future. Moreover, research in the department is now exploring a greater range of avenues than in earlier decades, with current studies focusing on palynostratigraphy, mass-extinction and recovery events, *in situ* spores and pollen, fossil fungi, deep biosphere communities, astrobiology, plant-arthropod interactions, plant systematics and anatomy, biogeography and palaeoclimate research. The palaeobotanical staff at NRM maintain a high productivity, collectively generating 50 publications in 2021. The department welcomes applications for short- or long-term visits by researchers wishing to study the palaeobotanical collections and we look forward to future collaborative research.

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Lists of papers published by palaeobotanical staff while employed at the Swedish Museum of Natural History

A list of A.G. Nathorst's publications can be found at:
https://scholar.google.com/citations?hl=en&user=_vElzUgAAAAJ

A list of T.G. Halle's publications can be found at:
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A list of E.V. Antevs' publications can be found at: https://www.geo.arizona.edu/Antevs/antvsref.html

A selected list of R. Florin's publications can be found at:

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