The plant fossils in the paleontological collection of Georg Gasser (1857–1931)

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ABSTRACT

Plant fossils from South Tyrol have been known since the 19th century, but they appear only rarely in the literature on the area; generally, paleontological descriptions have been focused on invertebrate fossils, which were much more famous at the end of the 19th century. The paleontological collection of Georg Gasser (1857–1931) is dominated also by fossils of invertebrates. However, he was fascinated also by plant fossils, both as a window into the past and as being important for understanding the fossil fuels such as coal with which they are often associated. This resulted in a relatively abundant plant fossil collection (281 specimens) that is focused mainly on Carboniferous and Cenozoic fossils extracted during mining activities. Nonetheless, the collection includes also some plant fossils from the Permian and Triassic of the former Tyrol region, such as Zirl or Seiser Alm/Alpe di Siusi, which today is partly divided into Austria and Italian territories. This is evidence that Georg Gasser was interested also in local plant fossils, though they are not a primary type of fossils found in the area.

KEY WORDS

Karbon, Permian, Triassic, Austrian Kingdom, Central Europe

1. INTRODUCTION

Georg Gasser (1857–1931), a self-taught naturalist from Bozen/Bolzano Province, northern Italy, compiled one of the most extensive collections of natural history objects (originally about 40,000 minerals, fossils and zoological specimens) in historical Tyrol. His mineralogical collection is particularly well-known, whereas his palaeontological collection has received little attention. After decades in which numerous specimens were sold or destroyed due to inappropriate storage only part of the Gasser Collection still exists. The palaeontological collection amounts today to 3502 specimens stored in the Museum of Nature South Tyrol (NMS) in Bolzano/Bozen.
This collection is composed of isolated fossils, unprepared fossils still attached to smaller host rock material or smaller fossils mounted on glass supports. Fossils are often marked with collection numbers on small paper labels attached to the fossil. In some cases, more than one number is present, indicating previous owners. Other labels, if present, contain information about the historical classification (at species, genus or plant group level), the geographic origin, the lithostratigraphy, the chronostratigraphy, and short notes. Unfortunately, several relocations during and after Gasser's life have affected the preservation of the fossils as well as the presence and quality of the labels. The labels were handwritten in ink which has faded in varying degrees over time. Here, at least for some cases, a cross check between the historical numbering on the fossils and a (partially compiled) handwritten register provide additional information on the specimens. The register is organized following the systematic classification at the turn of the 20th century. The majority of specimens (92 %) are animal remains of all major animal groups excluding microfossils. Only approximately 8 % of the remaining palaeontological collection are plant fossils.
Here we present the paleobotanical section of the paleontological collection of Georg Gasser to identify the distinctive characters of the collection. The stratigraphic and geographical distribution of the fossils will be considered in detail to see if they reflect the historical and geopolitical context in which they were collected. The collection has the potential to give insights which locations were of scientific interest during the end of 19th and beginning 20th centuries. Some of the areas sampled during those times are not accessible anymore due to natural or anthropogenic changes of the landscape.

2. MATERIALS AND METHODS

In the last two years, a project funded by the Museum of Nature South Tyrol (see Kustatscher et al., this volume), focused on the establishment on a quantitative and qualitative census of the geoheritage of the "Georg Gasser" paleontological collection. The goal was to conserve and supplement the collection with information to present it again to the public, as Gasser originally intended. Part of the investigation included the study of historical documents of Georg Gasser to achieve a general understanding of his way of thinking, his collecting processes, and his buying or exchanging strategies (Wagensommer et al., this volume a, b, Wagensommer this volume a, b). Another important part of the project (Tomelleri et al., this volume a, b, c, Wagensommer et al., this volume c) was to inventory,

FIG. 1: Examples of labels associated to Gasser's paleobotanical specimens. Scale bars = 2 cm. **A.** "*Araucarites rhodeanus**", Zacisze, Nowa Ruda, PAL 3160; **B.** Incrustation ("Versintertes Holz"), Contrin Valley, PAL 3455; **C.** Angiosperm leaf indicated as "*Calamiten*" PAL 3109; **D.** Peat ("Torf"), Montiggl/Monticolo, PAL 3402; **E.** *Ruppia* sp.?*, Monte Baldo, PAL 3203.

catalogue, digitize and photograph the paleontological collection and if possible, to revise the specimens taxonomically. Unfortunately, missing labels and information on the provenance of the specimens and Covid-19 induced restrictions hampered a detailed systematic revision. Therefore, some specimens still carry their historical names given by Georg Gasser, which are indicated with an asterisk.

All 3502 paleozoological and paleobotanical objects were carefully and professionally cleaned and restored where necessary. For the palaeobotanical section, all available information denoted on a specimen was then entered in the database of the museum (acronym) with PAL as a prefix for plant fossils followed by a continuous numbering. Not only the specimen itself was photographed but also all available labels (for more details on the cleaning and conservation processes see Kustatscher et al., this volume).

3. THE PALEOBOTANICAL SECTION OF THE GASSER COLLECTION – AN OVERVIEW

The paleobotanical collection of Georg Gasser is composed of 281 specimens. The specimens include plant fossils preserved as impressions and compressions (adpressions), *steinkern* [internal molds], permineralizations and carbonifications. Unfortunately, about 13 % of the paleobotanical specimens are still without an attribution to at least a major plant group, 5 % have a generic identification, whereas 18 % are diagenetically altered plant organic matter. The poor preservation of some specimens prevents a determination completely, or cast the determination to species level on some labels into doubt. It is likely that this species identification in question was intended to increase the value of the specimen to the collector at the time of sale or purchase, despite its modest quality. Gasser needed specimens representing different plant groups to achieve his goal of getting people excited about nature. An example is the fossil identified as *Auracarites rhodeanus,* PAL 3160; Fig. 1A), a species found in Buchau, Neurode (now Zacisze, Nowa Ruda), which, however, does not show any particular diagnostic feature. The historical determinations include also some blunders by Gasser or by whoever gave him the reference, such as the sample from the Paleogene of Bad Häring indicated as *Calamites*, PAL 3109; Fig. 1B).

Finally, some labels reveal the demonstrative and didactic purpose of the specimen, as in the case of the incrustation from Contrin Valley, in which the inscription reads: 'Beispiel einer sog. "falschen" Versteinerung: Versintertes Holz mit gut erhaltener Faserstruktur vom Fassatal, Tirol – Contrinotal 1909' [Example of a so-called "false" petrification: Petrified wood with a well-preserved fiber structure from the Val di Fassa, Tyrol – Contrin Valley, 1909], (PAL 3455; Fig. 1C). Some specimens do not represent a plant fossil but rather accumulated organic material, such as coal. These specimens are closely linked to intensive exploitation of vast fossil fuel resources during the 19th and 20th centuries, due to industrial development and the great need for energy (see also Wagensommer et al., this volume a, b). Fossils excavated during mining operations were often systematically collected and sold. This includes especially Carboniferous and Cenozoic coal fields of Europe, but to a minor part also Carnian (Upper Triassic) and Lower Jurassic sequences rich in coal.

Therefore, several plant fossils in the Gasser Collection come from the important Permo-Carboniferous coal deposits of Germany, Poland and Czech Republic. This exemplifies the didactic function and value of the collection, giving an overview of the most famous Carboniferous plant fossil localities and their plant remains in Europe. Moreover, it shows which mines were active during the lifetime of Georg Gasser and, thus, produced abundant plant remains sold by the mining company or by the miners themselves (often via international resellers like Krantz in Bonn).

In comparison, plant remains of Mesozoic age are rare in the collection. They come from Zirl (Austria; Carnian, Late Triassic) and Steierdorf/Anina (Romania; Early Jurassic). Cenozoic plants are much more frequent, partly because they are more common in Europe and sometimes again linked to mining activities (see below). These include localities of Monte Promina (Croatia) and Bad Häring (Austria) for Paleogene and several localities in Austria and Germany as well as the outcrop of Schellenken/Zelenky in the Czech Republic for Neogene plant remains.

Plant fossils from around Bolzano are extremely rare: among them, a fragment of sandstone with plant remains from Mölten/Meltina, three samples from Seiser Alm/Alpe di Siusi, and a peat fragment from Monticolo/Montiggl (Fig. 1D). Two samples of anthracite and lignite, respectively of Vallonga and Leffe and a specimen from Monte Baldo (Trento/Verona) are among the plant fossils that were collected in historical Italy during the time Georg Gasser assembled his collection. These specimens seem rather the result of occasional discoveries, than derived from a methodical excavation campaign.

4. THE COMPOSITION OF THE COLLECTION

The plant fossils can be attributed to six main groups of vascular plants: lycophytes (15 %), sphenophytes (15 %), ferns (10 %), seed ferns (4 %), conifers (9 %), cycads (2 %), and angiosperms (8 %); 18 % are not assigned to any major plant group due to their poor preservation. Another part of the collection (18 %) includes coal, peat, lignite, anthracite, graphite, asphalt in which the original structure of organic source matter has been gradually lost due to progressive diagenetic processes (Figs. 2, 3). About 1 % are stromatolite samples. Although these microbial sedimentary structures are not strictly paleobotanical remains, they have been included in the paleobotanical section of the collection to include all photosynthesic organisms.

The specimens come from important fossiliferous sites that are well-documented and cited in the literature and from various geological periods. Only rarely, literature on similar specimens described from the area is difficult to find, such as Gasser's re-

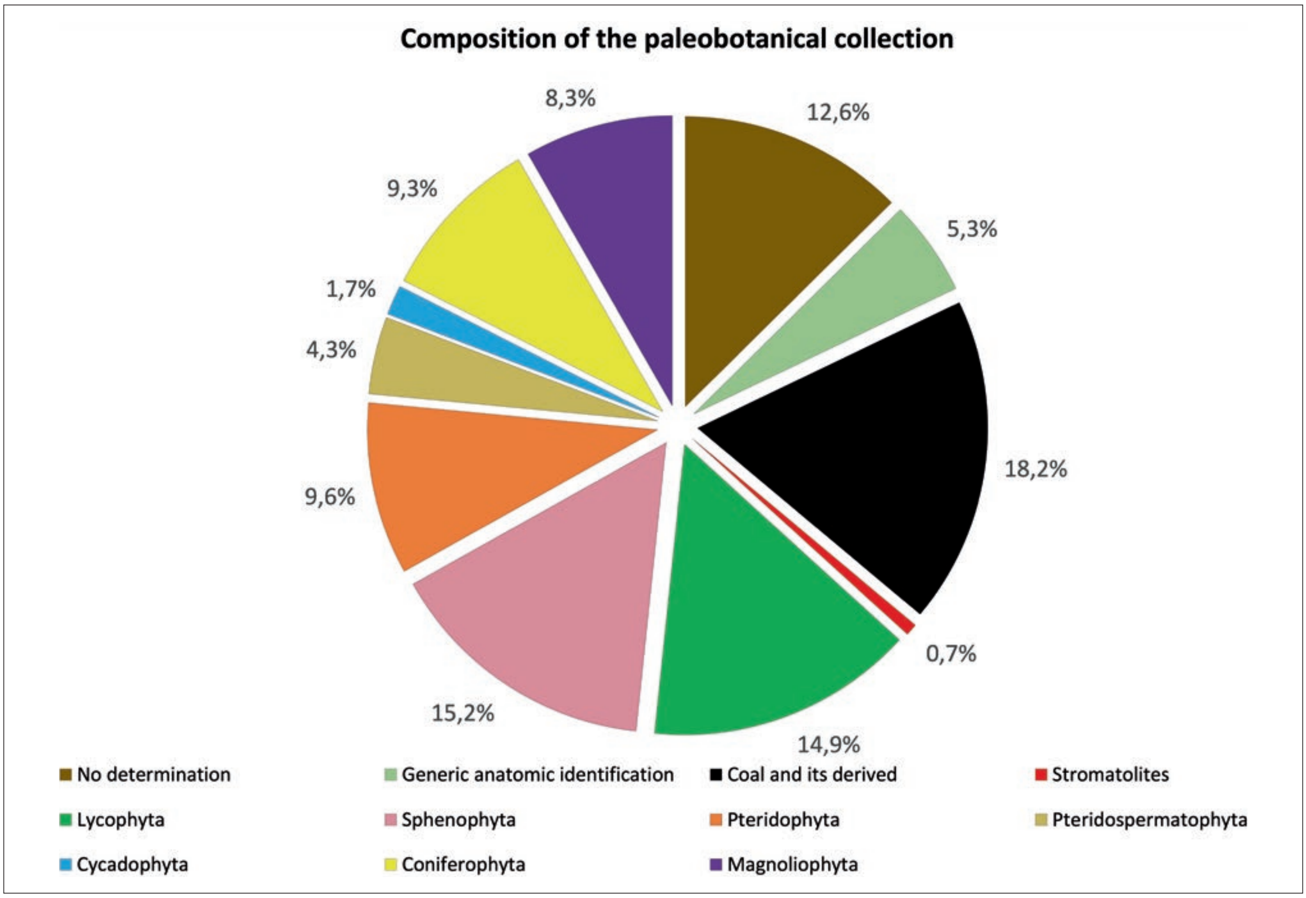

FIG. 2: Main plant groups and their relative abundance in Gasser's paleobotanical collection.

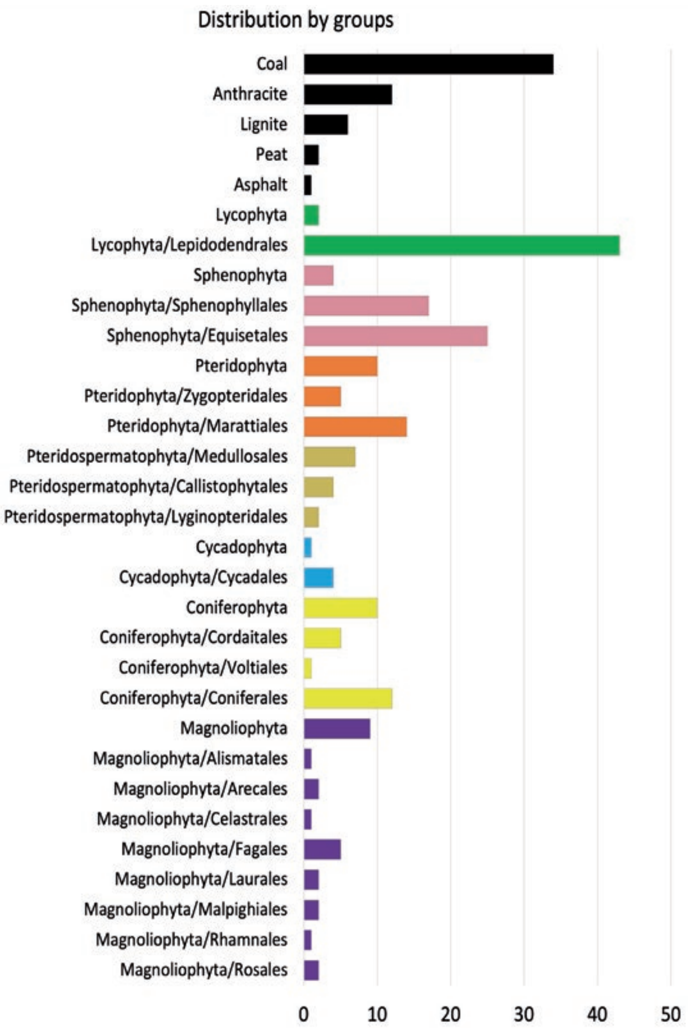

FIG. 3. Distribution of the various paleobotanical typologies, including groups without a taxonomic assignment.

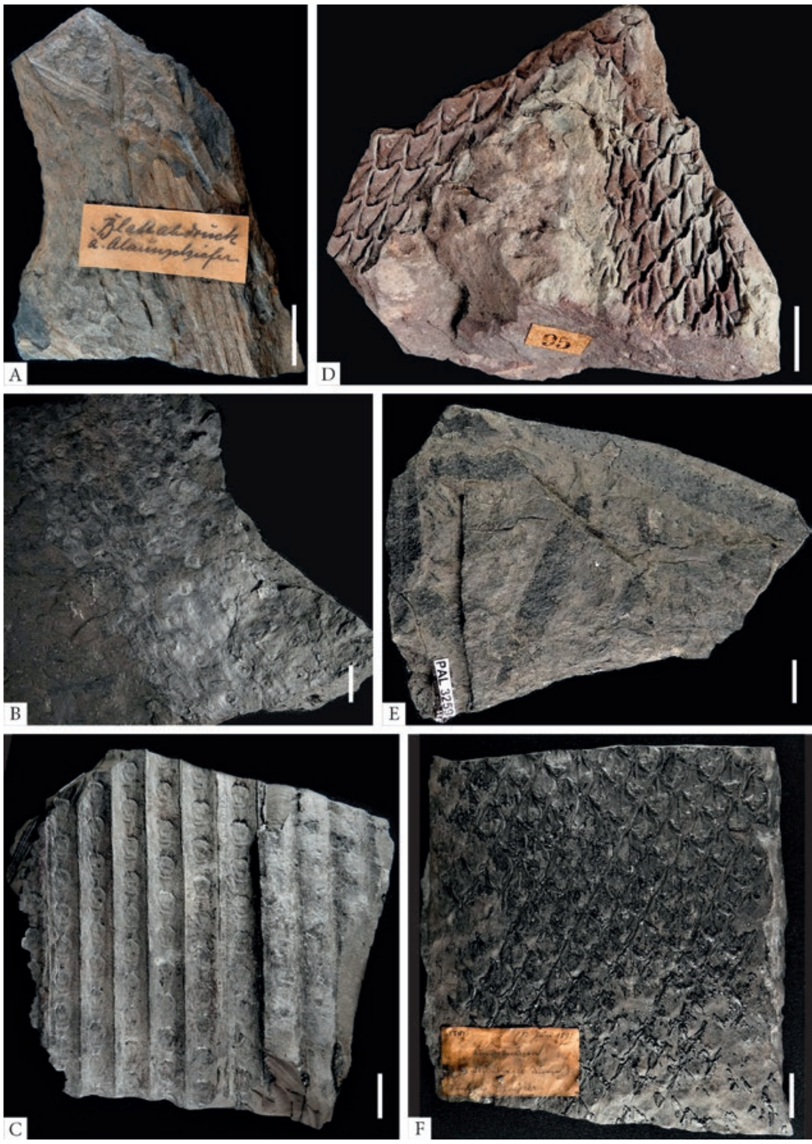

FIG. 4: Examples of lycophytes in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Cyperites bicarinatus*, Steinacher Jöchl, PAL 3193; **B.** *Stigmaria ficoides*, unknown locality, PAL 3149; **C**. *Sigillaria cordigera*, unknown locality, PAL 3148; **D.** *Lepidodendron aculeatum*, unknown locality, PAL 3154; **E.** *Lepidostrobophyllum lanceolatum*, unknown locality, PAL 3259; **F.** *Lepidodendron feistmantellii*, Zwickau, PAL 3219.

port as *Ruppia* (?), PAL 3203) from Monte Baldo (Fig. 1E) seems to be unique. In this case, the name *Ruppia* was given based on the morphological analogy of the specimen with the current botanical form.

The major plant groups identified in the collections are as follows:

4.1 LYCOPHYTA

The lycophytes evolved in the late Silurian and reached their heyday during the late Mississippian and most of the Pennsylvanian (Cleal, 2021a). Together with the sphenophytes they dominated the Euramerican paleoequatorial swamp ecosystems and were the main producers of their coal deposits (Taylor et al., 2009; Cleal & Thomas, 2019; Cleal, 2021a, b). The Gasser Collection includes numerous representatives of the order Lepidodendrales, including the genera *Lepidodendron*, *Sigillaria*, *Stigmaria*, *Cyperites*, and *Lepidostrobophyllum*. *Lepidodendron* is registered in the collection as stem casts (Fig. 4D, F) or adpressions, with their main characteristic being the diamond-shape microphyll leaf cushion morphology (Thomas & Cleal, 2020). There are also some rare cases of *Knorria*-type preservation, a mold-cast type of preservation of a *Lepidodendron* stem, in which almost all tissues external to the xylem were lost. *Sigillaria* can be distinguished from other Lepidodendrales based on the typical hexagonal outline (elliptical in some cases) of the leaf scars on the stem surface (Fig. 4C). The specimens of *Stigmaria*, a fossil-genus for lepidodendralean root-like structures (known as rhizophores), are characterized by their smooth to crenulated or rope-like surface, ornamented with circular or oval depressions (diameter < 1 cm) (Fig. 4B), arranged helically (Thomas & Seyfullah, 2015). Finally, *Cyperites* is represented by isolated linear leaves, usually less than 1 cm wide, whereas *Lepidostrobophyllum* is the compressed state of a sporophyll of a lepidostroboid cone (Fig. 4E).

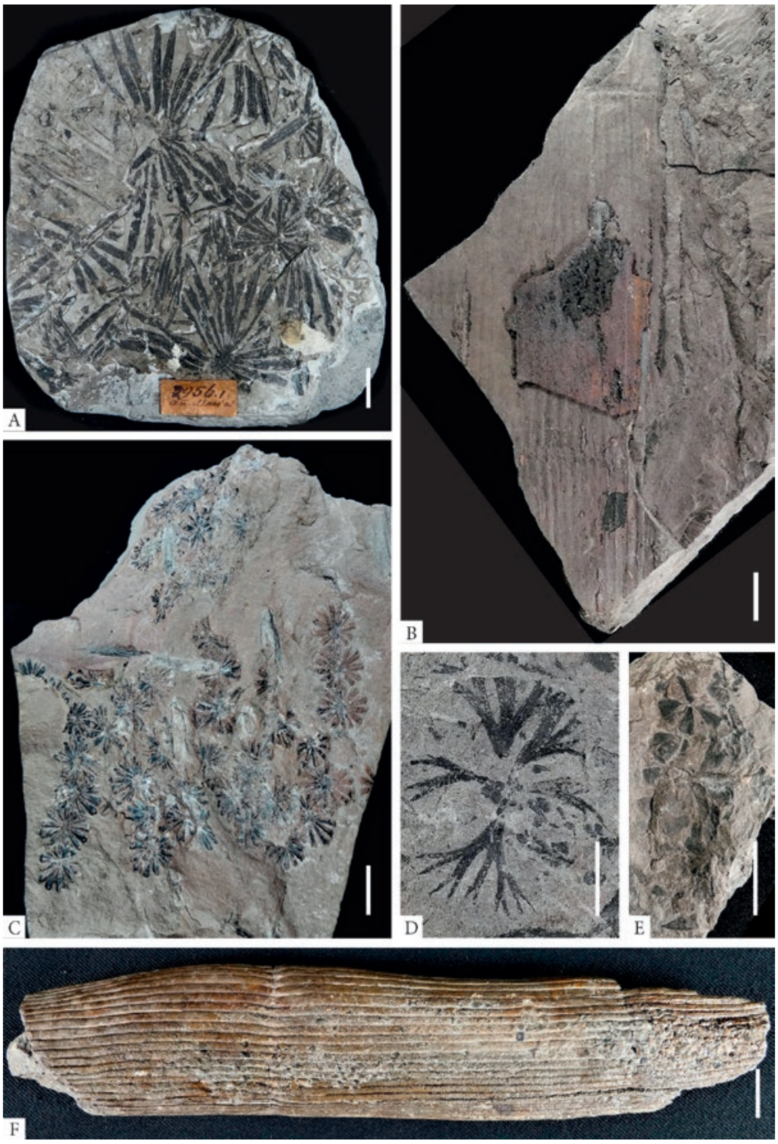

FIG. 5: Examples of sphenophytes in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Annularia inflata*, Zwickau, PAL 3180; **B.** *Calamites suckowii*, unknown locality, PAL 3215; C. *Annularia sphenophylloides*, Zwickau, PAL 3086; **D.** *Sphenophyllum laciniatum*, unknown locality, PAL 3098; **E.** *Sphenophyllum emarginatum*, Zwickau, PAL 3272; **F.** *Archaeocalamites radiatus*, unknown locality, PAL 3191.

FIG. 6: Examples of ferns in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Goniopteris dalmatica*, Monte Promina, PAL 3200; **B.** *Pecopteris plumosa?*, Rakovník, PAL 3096; **C**. *Corynepteris angustissima*, Zwickau, PAL 3192; **D.** *Artisophyton* sp., Untersachsenberg, PAL 3195; **E.** *Crenulopteris acadica*, Zwickau, PAL 3094; **F.** *Cyathocarpus candolleanus*, Zwickau, PAL 3178.

4.2 SPHENOPHYTA

Sphenophytes evolved during the Devonian but reached their maximum diversity during the Carboniferous (Cleal, 2021a). Two of its three orders, the Sphenophyllales (Devonian–Triassic) and the Equisetales (Devonian–recent), are present in the Gasser collection. The Sphenophyllales are represented by 16 identified typologies of the genus *Sphenophyllum*, belonging to the three species *S. emarginatum* (Fig. 5E), *S. laciniatum* (Fig. 5D), and *S. majus*. The Equisetales are represented in the collection by the genera *Calamites, Archaeocalamites, Annularia,* and *Asterophyllites*. The genera *Calamites* and *Archaeocalamites* include molds reflecting the internal structure of the stems, and compressions showing the external surface of the stems (Figs. 5B, F). The genera *Annularia* and *Asterophyllites* are represented by compressions of lateral shoots with whorls of lanceolate to elongate leaves preserved (Figs. 5A, 5C).

4.3 PTERIDOPHYTA

Pteridophytes are seedless vascular land plants that reproduce by means of spores produced in leaf-borne sporangia. The group includes ferns and fern-like plants. They former appeared in the Devonian and occupy today a wide variety of habitats. In the collection, two orders of the pteridophytes are identified Zygopteridales (fern-like plants) and Marattiales (true ferns). The Zygopteridales are represented by compressions of the leaf genera *Corynepteris, Pecopteris* (Figs. 6B–C) and *Zeilleria* (e.g., Galtier & Scott, 1979). The Marattiales are represented as impressions of *Artisophyton* stem fragments (Fig. 6D) typically identified by two vertical rows of leaf scars, and frond compressions belonging to the genera *Crenulopteris* and *Cyathocarpus* (Figs. 6E, 6F; e.g., Cleal, 2015).

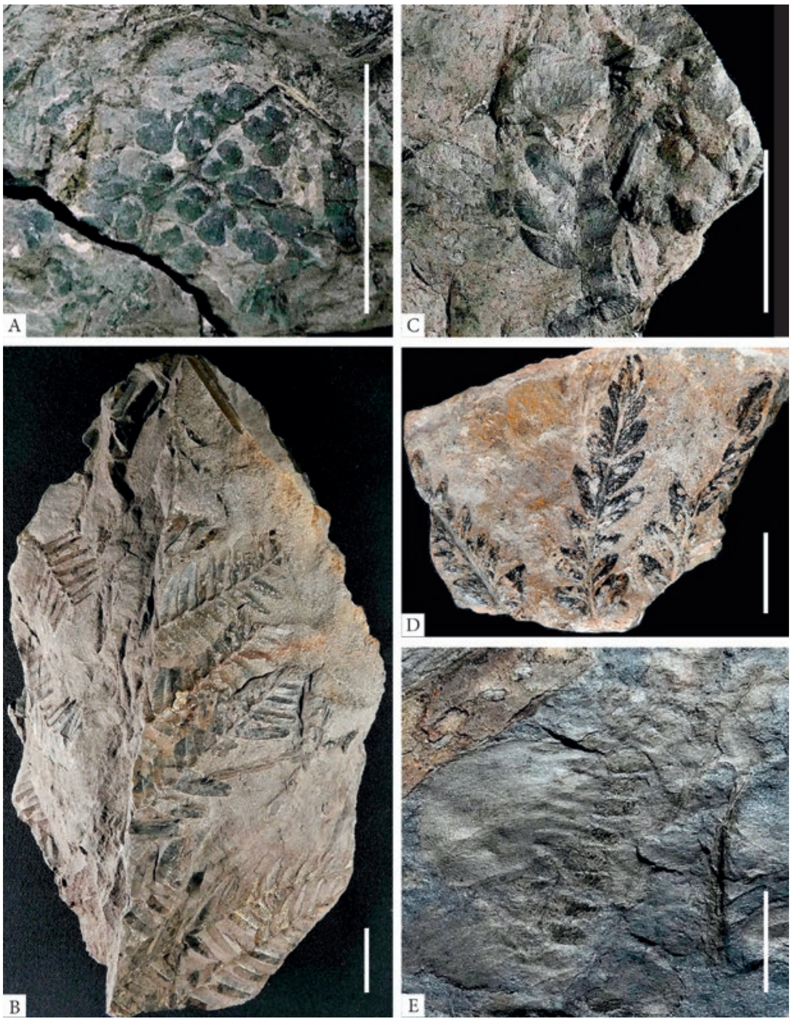

FIG. 7: Examples of seed ferns in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Sphenopteris* sp., unknown locality, PAL 3442; **B.** *Laveineopteris tenuifolia,* unknown locality, PAL 3220; **C.** *Laveineopteris* sp., unknown locality, PAL 3255 **D.** *Mariopteris* cf. *nervosa***,** unknown locality, PAL 3092; **E.** *Alethopteris* sp., Steinacher Jöchl, PAL 3171.

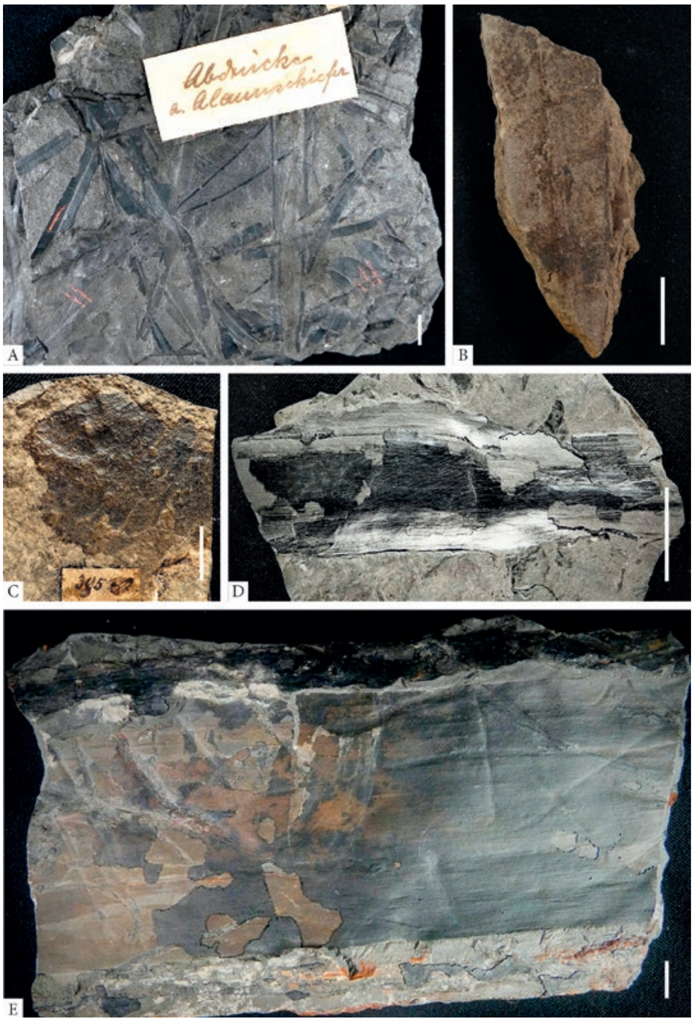

FIG. 8: Examples of Cycadales and Cordaitales in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Nilssonia* cf. *undulata*, Anina, PAL 3182; **B.** *Taeniopteris* sp., Zirl, PAL 3116; **C.** *Apoldia wengensis*, Seiser Alm, PAL 3156 **D.** *Cordaites* sp., unknown locality, PAL 3216; **E.** *Cordaites* sp., unknown locality, PAL 3141.

4.4 PTERIDOSPERMATOPHYTA

The first evidence of seed ferns in the fossil record is in the Upper Devonian (Anderson et al., 2007). They reach their maximum diversification during the Carboniferous, with several groups becoming extinct with the disappearance of the swamp environments at the end of the Carboniferous and with the aridification during the Permian (Cleal, 2021a, b). Some orders, like the Corystospermales and the Peltaspermales extended into the Mesozoic. The seed ferns are relatively rare in the collection with only 13 identified typologies belonging to the orders Lyginopteridales, Medullosales and possibly Callistophytales. The Lyginopteridales, the most primitive of the seed ferns, mostly had relatively narrow stems and a climbing type of habit. In the collection, this group is testified by compressions of *Mariopteris* (Fig. 7D), the fronds of a Lyginopteridales that was widespread in the swamps of the Carboniferous (Boersma, 1972) and a fragment putatively assigned to *Sphenopteris* (Fig. 7A). The Medullosales, dominant during the Pennsylvanian and early Permian, are represented by compressions and impressions of the frond genera *Laveineopteris* (Figs. 7B–C), *Alethopteris* (Fig. 7E), and *Neuropteris* (Wagner, 1968; Cleal & Shute, 1995).

4.5 CYCADALES

The Cycadales can be traced back to the Pennsylvanian and include both fossil and living members. In the Gasser Collection only five samples are present and three genera have been identified. These are the compressed fossil foliage genera *Nilssonia* cf. *undulata* (Fig. 8A), *Apoldia wengensis* (Fig. 8B), and *Taeniopteris* sp. (Fig. 8C).

4.6 CORDAITALES

The Cordaitales, an extinct group of gymnosperms, were widespread from the Pennsylvanian to the Permian. They grew in lowland peat mires, forming monotypic association or growing together with calamites, tree ferns, and lycophytes (Taylor et al., 2009; Cleal & Thomas, 2019; Cleal, 2021a, b) and also in better drained habitats surrounding the swamps. Only five specimens in the Gasser Collection belong to this group, two of them are identified as *Cordaites* sp. and include compressions (Fig. 8D) and impressions (Fig. 8E).

FIG. 9: Examples of coniferales in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Voltzia ladinica*, Seiser Alm, PAL 3198; **B.** *Doliostrobus taxiformis*, Bad Häring, PAL 3229; **C**. *Pelourdea vogesiaca*, Seiser Alm, PAL 3153; **D.** *Doliostrobus taxiformis*, Bad Häring, PAL 3172; **E**. *Pinus* sp., Gleichenberg, PAL 3167; **F.** *Pinus* cf. *haidingeri*, Kalksburg, PAL 3105.

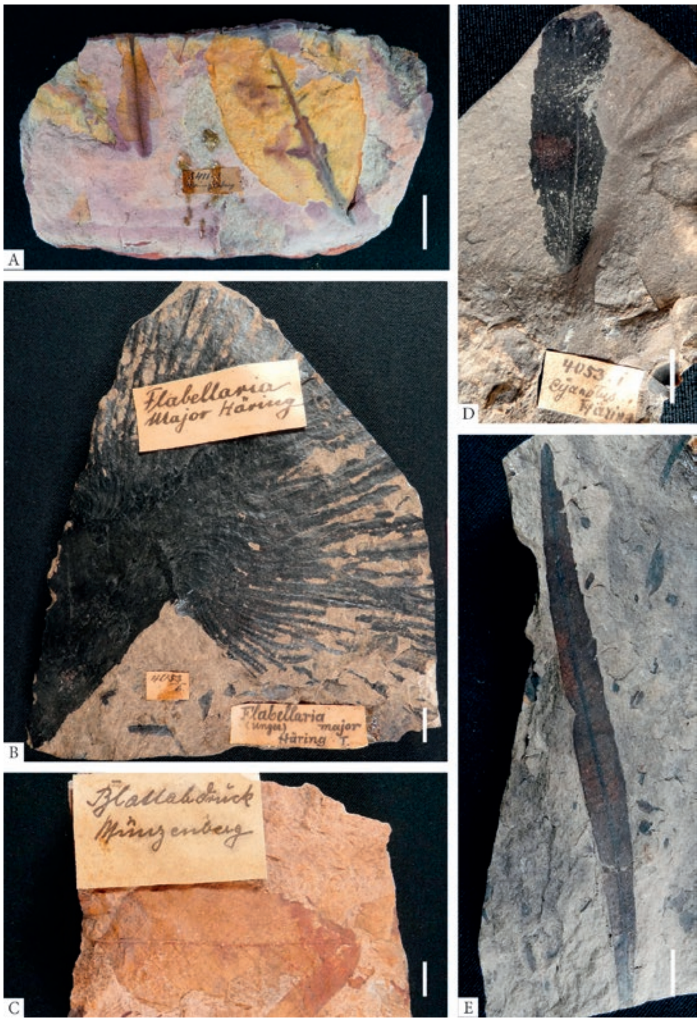

FIG. 10: Examples of angiosperms in the Georg Gasser Collection. Scale bars = 2 cm. **A**. *Cyclocaria cyclocarpa*, Münzenberg, PAL 3110; **B.** *Sabal raphipholia*, Bad Häring, PAL 3179; **C**. *Betula* cf. *subpubescens*, Münzenberg, PAL 3104; **D.** *Ziziphus ziziphoides*, Bad Häring, PAL 3157; **E.** *Myrica lignitum*, Bad Häring, PAL 3186.

4.7 CONIFERALES

The Coniferales are composed of a conspicuous number of genera both extinct and living. In the collection, a small number of specimens have been attributed to this group, that can be divided into Voltziaceae, Araucariaceae and Pinaceae. The Voltziaceae are a typical Permian–Triassic family; in the collection it is represented by the genus *Voltzia*. The family Araucariaceae extends back putatively to the late Paleozoic and had a wide distribution from the Late Triassic onwards (e.g., Roghi et al., 2022; Dal Corso et al., 2020; Nowak et al., 2020), with its widest distribution and highest diversity in the Jurassic. In the collection the family is represented by shoot fragments with leaves.
The Pinaceae, is today the largest modern conifer family that includes shrub and trees, with its oldest known fossils coming from the Upper Triassic (e.g., Roghi et al., 2022; Dal Corso et al., 2020). In the Gasser Collection, this family is represented by four permineralized pine cones, associated to *Pinus* sp. (Fig. 9E) and one mold signed as *Pinus* cf. *haidingeri* (Fig. 9F). Taxa of unknown botanical affinity within this group are leaves of the genus *Pelourdea* (Fig. 9C), well known from the Middle and Upper Triassic of the Southern Alps.

4.8 ANGIOSPERMS

The angiosperms represent today the dominant plants in most regions of the world, with a huge diversity. In the fossil record, there is proof for their radiation in the Cretaceous, while their complete establishment as the dominant group of plants starts from the Paleocene. In the collection, there is a limited number of specimens belonging to this group. Gasser determined them as representatives of the Alismatales (*Ruppia*?), Arecales, Celastrales (*Elaeodendron dubium*), Laurales (*Daphnogene cinnamomifolia*), Malpighiales (*Flabellaria*), and Rosales (*Ceanothus*). They are generally preserved as adpressions (impression-compressions), with some rare form of leaf incrustations.

5. CHRONOSTRATIGRAPHIC DISTRIBUTION OF THE SPECIMENS

The palaeobotanical collection of Georg Gasser does not document the entire chronostratigraphic scale. The findings are from specific geological intervals, demonstrating that the collection was not constructed in a rigorous way to represent either plant evolution through time and/or represent all iconic taxa from a certain time periods (Fig. 11, 13).

Out of 281 paleobotanical remains, 144 specimens come from the Paleozoic (Fig. 11). Out of these only few specimens (5) are Permian in age, all others are from the Carboniferous. The Mesozoic is less well represented in the collection with 17 specimens (Fig. 11). Two plant fossils come from the Jurassic and none from the Cretaceous; all the others are Triassic in age. Most of the Triassic specimens, were collected in the Carnian deposits of Zirl (Austria). A total of 63 specimens are from the Cenozoic (Fig. 11), mostly from the Oligocene in Bad Häring (Austria; 21 specimens). The Eocene is represented by 4 specimens from Monte Promina. The Miocene is represented by 15 specimens, mostly coming from the German locality Münzenberg (12 specimens). It is of note that the specimens from what, during Gassers lifetime, would have been considered Italy, such as for example Monte Baldo and Leffe (Pleistocene) are all Cenozoic in age.

Almost 60 (57) specimens could not be assigned to any interval of Earth History, due to missing labels and poor preservation or missing morphological features (Fig. 11). This includes mostly permineralized wood, and various fragments of coal, lignite, anthracite and charcoal.

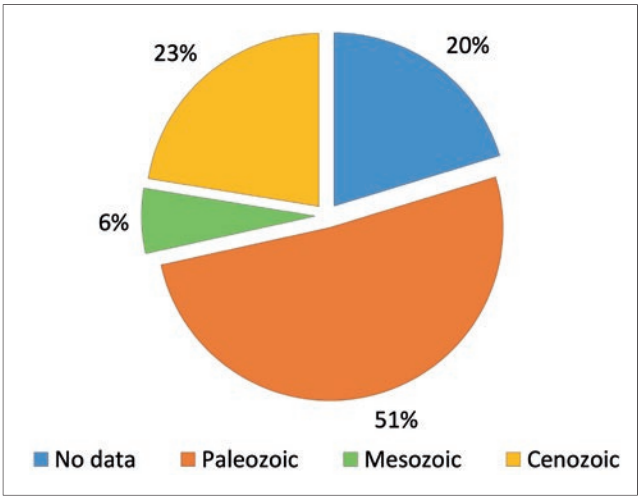

FIG. 11: Distribution of the specimens by age.

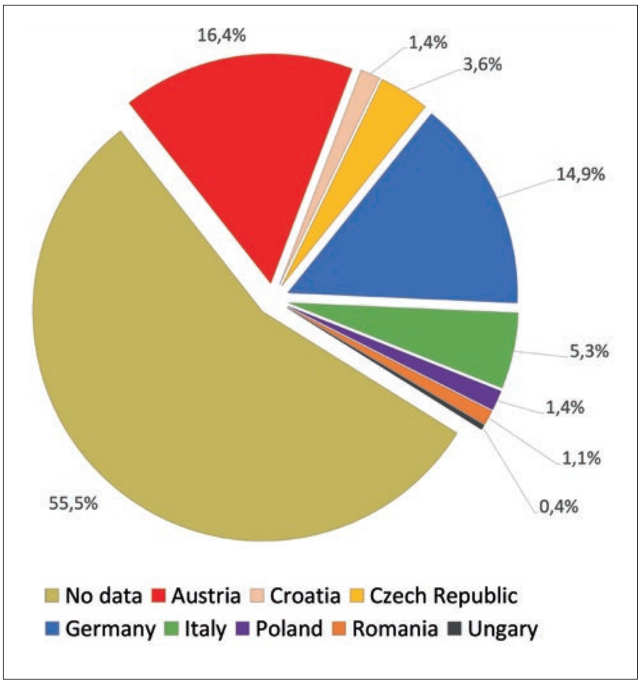

FIG. 12: Distribution of the specimens by country.

6. GEOGRAPHIC DISTRIBUTION OF THE SPECIMENS

It is noteworthy that the rocks outcropping in South Tyrol are mainly Permian and Triassic in age, and in particular the rocks surrounding the city of Bozen/Bolzano, where Georg Gasser lived and had his museum, are mainly of Permian age. The Gasser Collection, on the other hand, contains only two specimen from the Permian, out of 281. The Triassic, although well represented in this area, is underrepresented in the collection with 5 specimens out of 281.

The collection is a showcase into the most important and/or exposed outcrops of paleobotanical material during the lifetime of Georg Gasser (1857–1931). It reflects the increased availability of plant fossils due to increased mining activity in areas under the control of the Austro-Hungarian Empire or attached to the German Confederation, and connected via privileged lines of communication.

For this reason, localities in Austria, Germany, Poland, the Czech Republic and Romania are well represented with Carboniferous plant remains. Paleogene, Neogene and Quaternary specimens mostly come from the Austrian, German and Croatian territories (Figs. 12, 13, 14, 15). With very few exceptions (e.g., Zirl, Anina, Seiser Alm/Alpe di Siusi), the Mesozoic is almost completely absent, perhaps due to the fact that only few discoveries from that period were reported during the lifetime of Georg Gasser (1857-1931). The first ones who mentioned Triassic plant fossils from the Dolomites, were Wissmann & Münster (1841), Mojsisovics von Mojsvàr (1879), and Ogilvie Gordon (1927). Permian plant remains from the Dolomites were not described until after Georg Gasser's death in 1931 but are now well-known from the Vicentinan Alps and also from the Carnic and Julian Alps (Kustatscher & Roghi, 2014; Kustatscher et al., 2014, 2019).

An overview of the localities of the specimens' provenance is presented in Figs. 14 and 15, based on the information provided by the associated labels and confirmed, where possible, by literature. The presentation is sorted by state and then by current locality name, followed in brackets with a reference to the historical name as written on the card. Unfortunately, due to the loss of labels, the provenance of 55 % of the specimens is unknown (Fig. 12). In other cases, (less than 4 %) the geographic indication is rather vague (e.g., Bohemia/Böhmen, Tyrol, Transylvania/Siebenbürgen, Hungary, Westphalia).

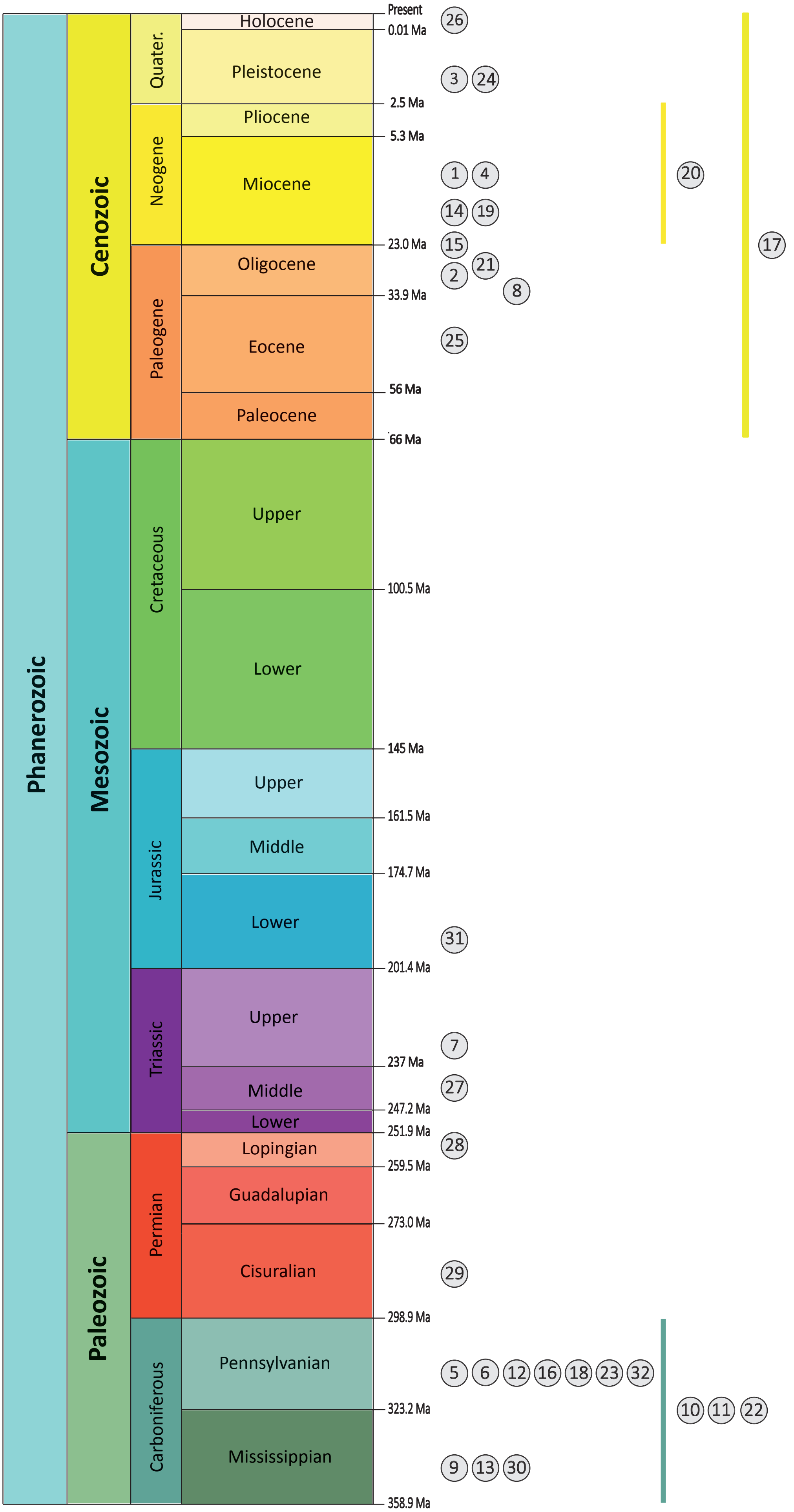

FIG. 13: Chronostratigraphic distribution of Gasser's paleobotanical specimens. **1.** Bad Gleichenberg ; **2.** Bad Häring; **3.** Hopfgarten im Brixental; **4.** Kalksburg; **5.** Nösslachjoch; **6.** Tarntaler Köpfe; **7.** Zirl; **8.** Monte Promina; **9.** Čermná ve Slezsku; **10.** Černá v Pošumaví; **11.** Dalovice; **12.** Rakovník; **13.** Staré Oldřůvky; **14.** Želénky; **15.** Appelsdorf; **16.** Halle (Saale); **17.** Iberg am Harz; **18.** Ilmenau; **19.** Münzenberg; **20.** Schrobenhausen; **21.** Sieblos in der Röhn; **22.** Untersachsenberg; **23.** Zwickau; **24.** Leffe; **25.** Monte Baldo; **26.** Montiggl/Monticolo; **27.** Seiser Alm/Alpe di Siusi; **28.** Mölten/Meltina; **29** Tisens/Tesimo; **30.** Kamienna Góra; **31.** Anina; **32.** Secu.

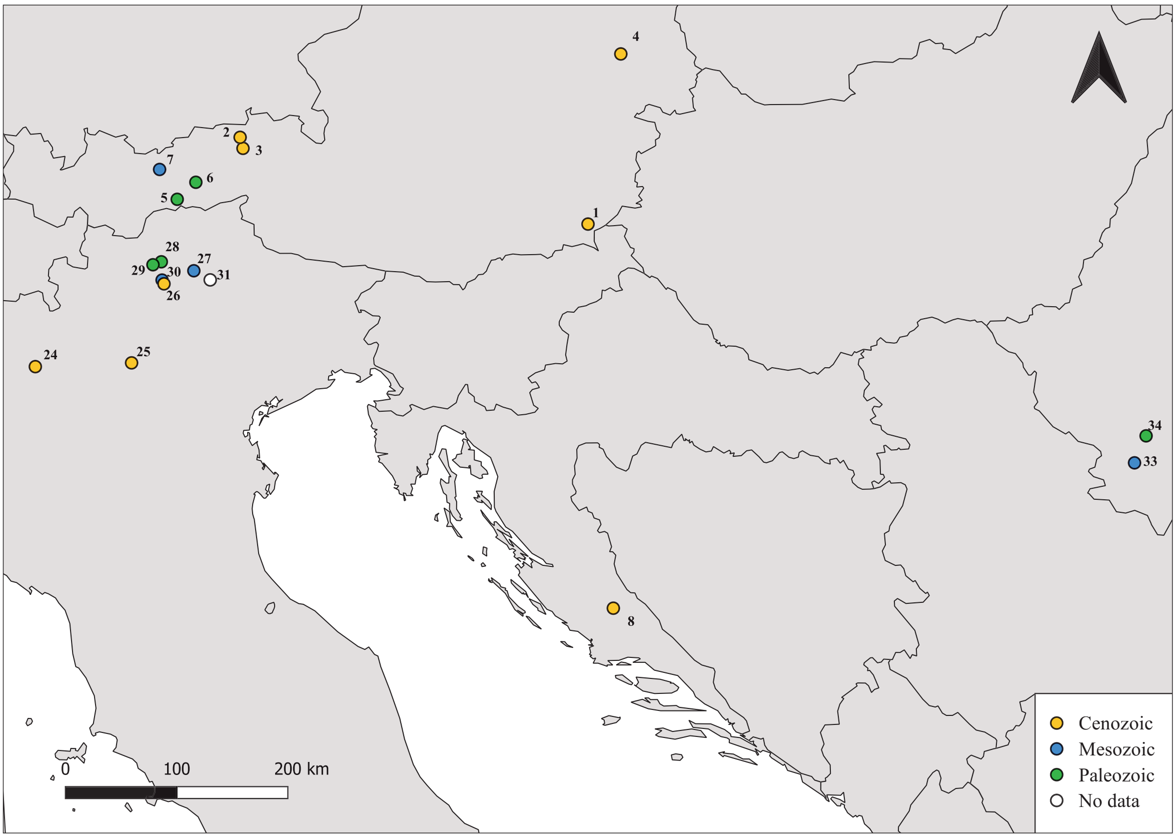

FIG. 14: Map of the southern part of Europe with the localities from the Georg Gasser paleobotanical collection. **1.** Bad Gleichenberg **;** **2.** Bad Häring; **3.** Hopfgarten im Brixental; **4.** Kalksburg; **5.** Nösslachjoch; **6.** Tarntaler Köpfe; **7.** Zirl; **8.** Monte Promina; **24.** Leffe; **25.** Monte Baldo; **26.** Montiggl/Monticolo; **27.** Seiser Alm/Alpe di Siusi; **28.** Mölten/Meltina; **29.** Tisens/Tesimo; **30.** Eppan/Appiano; **31.** Val Contrin; **33.** Anina; **34.** Secu.

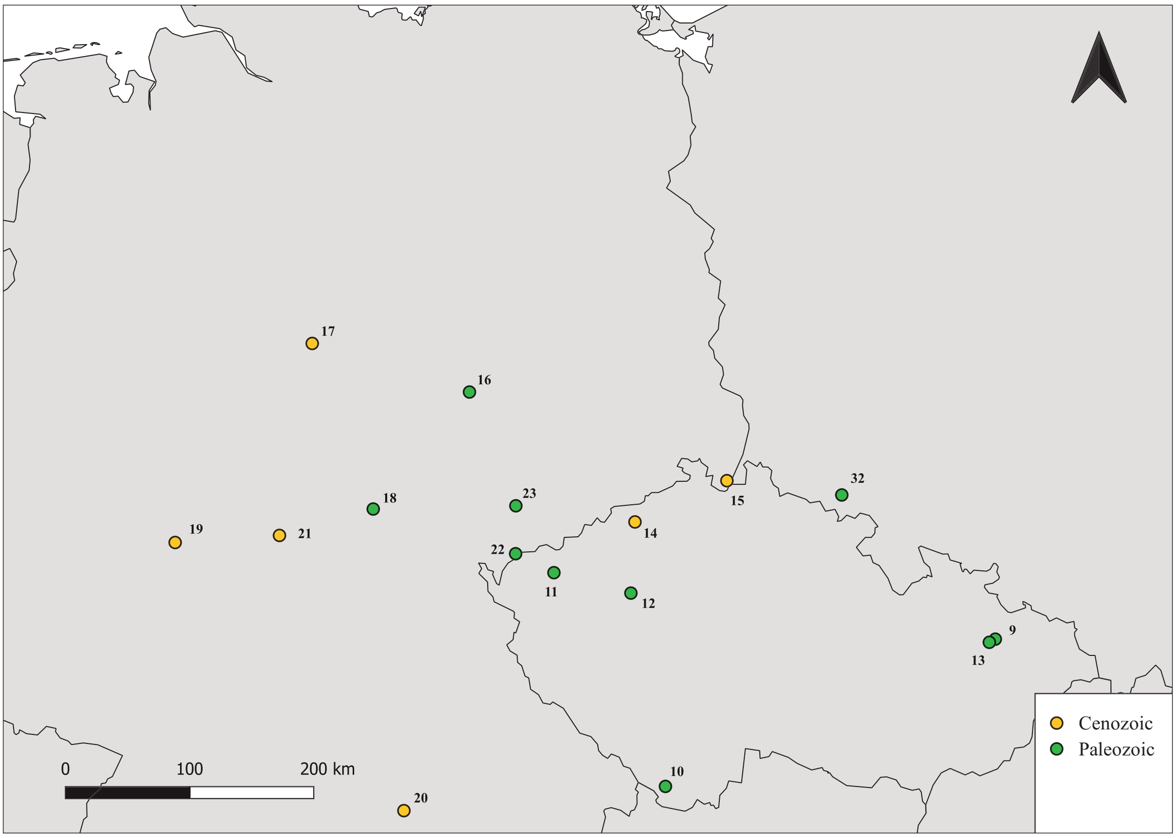

FIG. 15: Map of the central-northern part of Europe with the localities from the Georg Gasser paleobotanical collection. **9.** Čermná ve Slezsku; **10.** Černá v Pošumaví; **11.** Dalovice; **12.** Rakovník; **13.** Staré Oldřůvky; **14.** Želénky; **15.** Appelsdorf; **16.** Halle (Saale); **17.** Iberg am Harz; **18.** Ilmenau; **19.** Münzenberg; **20.** Schrobenhausen; **21.** Sieblos in der Röhn; **22.** Untersachsenberg; **23.** Zwickau; **32.** Kamienna Góra**.**

6.1 AUSTRIA

Bad Gleichenberg (Gleichenberg)
Age: Miocene
One of the main localities for fossil plants in Styria is Gleichenberg. Franz Unger collected fossil plants there and described them first in his *Chloris Protogaea* and then in a more detailed monograph (Unger, 1854; *Die fossile Flora von Gleichenberg*), integrated by Andra (1856) and Ward (1889).
Collection Georg Gasser: 4 specimens, *Pinus* sp. (PAL 3164–3167; Fig. 9E)

Bad Häring (Häring)
Age: early Oligocene
This place in Tyrol is one of the most famous fossiliferous localities for the Paleogene in Europe. The laminated bituminous marls found here have yielded a rich fossil flora described by Ettingshausen in 1853 (Erdei et al., 2012) and later redescribed by Butzmann & Gregor (2002) and Heyng et al. (2003), among others. The locality attracted attention due to the presence of coal deposits, mined for 200 years until after second world war. The seam contains homogeneous vitrain coal, mineral-rich coal, and carbonaceous clay. lignite layers are present (Schulz & Fuchs, 1991). The Paleogene plant fossil assemblage extracted during the mining provides evidence of a mesophytic forest with lowland elements (Butzmann & Gregor, 2002), characterized by the overall presence of angiosperms and gymnosperms. The latter was represented by conifers such as *Araucarites sternbergii* (Schulz & Fuchs, 1991). Rare elements are fungi, algae, briophytes, horsetails and ferns (Butzmann & Gregor, 2002).
Collection Georg Gasser: 21 specimens, *Doliostrobus taxiformis* (PAL 3172; Fig. 9D; PAL 3197, 3229; Fig. 9B), *Leguminocarpus* sp. (PAL 3268), *Myrica lignitum* (PAL 3186; Fig. 10E), *Elaeodendron dubium** (PAL 3199), *Zizyphus ziziphoides* (PAL 3157, 3199; Fig. 10D), *Sabal raphifolia* (PAL 3179; Fig. 10B), *Dicotylophyllum* sp. (PAL 3181), undeterminate angiosperm leaves (PAL 3109, Fig. 1B), "Schiefer-Pechkohle" (10 specimen, PAL 3425–33), lignite (PAL 3434)

Hopfgarten im Brixental
Age: Pleistocene
Geological reports (Richthofen, 1861; Blaas 1893; Fritz, 1947) document the presence of deposits of lignite found in this region of Tyrol and dated them as being deposited close to the Würm glacial interval (Schulz & Fuchs, 1991).
Collection Georg Gasser: lignite (PAL 3294)

Kalksburg (Wien)
Age: Miocene
Kalksburg, formerly an independent village was suburbanized to Vienna in 1938. Fuchs (1869) mentions a quarry east of Kalksburg yielding plant fossils (Domning & Pervesler, 2012). The palaeobotanical remains of Kalksburg were later determined by Wiesbauer (1874) describing, among others, fruits and nuts (Ward, 1889).
Collection Georg Gasser: *Pinus* cf. *haidingeri* (PAL 3105, Fig. 9F)

Nösslachjoch (Steinacher Jöchl, Tyrol)
Age: Pennsylvanian (late Carboniferous)
Plant remains have been reported from this locality since the 19th century, excavated during anthracite coal mining (Blaas, 1907; Schulz & Fuchs, 1991). Coal was mined there not as energy resource, but as a natural pigment called "Nösslach Erde", which was used especially for coloring tobacco. Plant groups described from the outcrop belong mainly to the lycophytes, ferns and cordaitaleans. The majority of the anthracite was formed from plants growing in an extensive forest bog (Schulz & Fuchs, 1991).
Collection Georg Gasser: 4 specimens, *Cyperites bicarinatus* (PAL 3170, 3193; Fig. 4A), *Alethopteris* sp. (PAL 3171; Fig. 7E), indeterminate fern fragment* (PAL 3159)
Remarks: Although they are missing labels, some of the anthracite samples in the collection could also come from this locality.

Tarntaler Köpfe (Tyrol)
Age: Pennsylvanian (late Carboniferous)?
In literature, there is no substantial record about plant-remains from the Tarntaler Köpfe. It lays geographically close to Nösslachjoch and the labels state "Nösslach Erde", as is indicated also for the specimens from Nösslachjoch. Thus, it cannot be excluded that the same locality was indicated by two different toponyms. The second option is that also at Tarntaler Köpfe the same bed crops out.
Collection Georg Gasser: 2 specimens, Coal (PAL 3447, 3448), indicated on the label as "Nösslach Erde".

Zirl (Tyrol)
Age: Carnian (Late Triassic)
The Late Triassic sequence of the Calcareous Alps crops out near Zirl in Tyrol. There, in an old quarry Wettersteinkalk, Wettersteindolomite, and the "Raibl Schichten" are exposed (Brandner & Polenschinski, 1986). Moreover, along the Zirler Höhenweg near the Kalvarienberg, the "Raibl Schichten" crop out even better, and are called, Zirler Formation or Cardita Schichten, respectively (Tollmann, 1976; Wöhrmann, 1889). The labels in the collection mention "Ob. Cardita Schichten".
Collection Georg Gasser: 10 specimens, *Equisetites arenaceous* (PAL 3253, 3254), *Taeniopteris* sp. (PAL 3116, Fig. 8C), *Radicites* sp. (PAL 3214), male conifer cone (PAL 3089), conifer stem fragment (PAL 3114, 3169), charcoal (PAL 3091), indeterminable fragments (PAL 3115, 3185)
Remarks: Only two of the specimens preserve the original labels mentioning this locality. However, the lithological comparison and plant fossils preserved, permitted to assign to the same locality also additional specimens.

6.2 CROATIA

Monte Promina
Age: late Eocene–early Oligocene
Known for more than a century, the flora of the Monte Promina was the subject of a monograph by Ettingshausen (1855) called *Die Eocene Flora des Monte Promina*. The Wetzler Collection coming from this area is housed in the Heimatmuseum Günzburg and has recently been published by Butzmann (2000).
Collection Georg Gasser: 4 specimens, *Daphnogene rotundifolium* (PAL 3112), *Goniopteris dalmatica* (PAL 3200, 3251; Fig. 6A), *Pronephrium stiriacum* (PAL 3251), *Sabal raphifolia* (PAL 3188)

6.3 CZECH REPUBLIC

Čermná ve Slezsku (Tschirm)
Age: Mississippian (early Carboniferous)
Plant fossil remains of Carboniferous age were described from Čermná ve Slezsku (formerly Tschirm) by Stur (1875).
Collection Georg Gasser: compression/impression of sphenophyte stem (PAL 3249)

Černá v Pošumaví (Schwarzbach)
Age: Carboniferous
This area was subjected to significant mining activities from the beginning of 19th century till the first half of 20th century. Graphite deposits are confined to an intercalation of carbonate rocks in biotite paragneiss of the Moldanubian Variegated Group (Drabek & Stein, 2015).
Collection Georg Gasser: graphite (PAL 3422)

Dalovice (Dallwitz)
Age: Carboniferous
Dalovice is a municipality in Karlovy Vary District, whose territory was marked by coal mining activities.
Collection Georg Gasser: coal (PAL 3410)

Rakovník (Rakonitz)
Age: Pennsylvanian (late Carboniferous)
The Kladno-Rakovník Basin is well known for plant fossils extracted during coal mining activities (e.g., Šimůnek & Cleal, 2020). The first paper discussing these plant remains was published in the second half of the 19th century (Stur, 1860).
Collection Georg Gasser: *Pecopteris plumosa*? (PAL 3096, Fig. 6B)

Staré Oldřůvky (Altendorf)
Age: Mississippian (early Carboniferous)
Belonging to the historical region of Moravia, part of Austro-Hungarian Empire, this territory has yielded some plants remains studied by Ettingshausen in 1865 (*Die fossile Flora des mährisch- schlesischen Dachschiefers*) and Stur (1875).
Collection Georg Gasser: compressed specimen of a putative fern rachis (attributed on Gasser's tag to extant leptosporangiate fern *Trichomanes dissectum**) (PAL 3183)

Želénky (Schellenken)
Age: early Miocene
The popular and well known porcelanite sites in north Bohemian represents a famous Lagerstätte of Neogene plants. Leaf impressions of ferns, broad-leaved trees and reeds occurring in the "pseudo-volcanic rocks" at Zelenky were described by Sommer (1833). Amongst the North Bohemian sites studied by Ettingshausen (1869) was also Zelenky. After World War II the locality attracted the attention of many paleobotanists because of its richness in fossil plants and easy accessibility. Over the last decades, the sedimentary deposits in this area have been mostly exploited for industrial purposes. A revision of the fossil plant association preserved here has been published lately by Kvacek & Hurnik (2000).
Collection Georg Gasser: shoot fragment of indetermined conifer (PAL 3158)

6.4 GERMANY

Appelsdorf, near Zittau
Age: Oligocene–Miocene
The area, located in the Zittau Basin in the northwest part of the Ohře rift system, contains Oligocene to middle Miocene sediments with mineable lignite (Kasiński, 1991). Plant fossils from Zittau were described by Engelhardt (1870) in his *Flora der Braunkohlenformation im Konigreich Sachsen*.
Collection Georg Gasser: lignite (PAL 3293)

Halle (Saale)
Age: Pennsylvanian (late Carboniferous)
In the Permian-Carboniferous Saale Basin, located to the SE of the Harz Mountains, outcrops of coal bearing sediments dated as "Stephanian" have yielded a rich plant fossil assemblage dominated by hygrophilous elements of a peat-forming forested swamp (Schneider et al., 2014). In the area of Halle late Carboniferous successions crop out, that occasionally yield plant fossils (Hofmann, 1985).
Collection Georg Gasser: 3 specimens, *Annularia* sp. (PAL 3138), *Asterophyllites* sp. (PAL 3138), *Sphenophyllum emarginatum* (PAL 3196)

Iberg am Harz
Age: Cenozoic
Reports of the presence of natural asphalt in this area are noted from, at least, the 19th century (Glocher, 1839).
Collection Georg Gasser: Asphalt (PAL 3445)

Ilmenau
Age: Pennsylvanian (late Carboniferous)
The area of Ilmenau is famous for its particularly well-preserved Lopingian plant remains, that are in part anatomically-preserved. The deposits of this mining district were mainly exploited for copper but are now almost completely inaccessible. The difficulty in carrying out any new scientific excavation campaigns makes specimens in museum collections a particularly important resource for future studies (Uhl, 2013). In the area, also late Pennsylvanian and early Cisuralian successions also crop out.
Collection Georg Gasser: 2 specimens, *Cyathocarpus arborea* (PAL 3187), undetermined fern frond fragment (PAL 3108)

Münzenberg
Age: early Miocene
There are two fossiliferous sites associated with the name of Münzenberg, both dated to the Miocene: one in the Leoben Basin, in Austria, the other, in Germany, near Wetterau, in the Hesse Region. Gasser's register specifies the provenance of the specimen from the location in Hesse, known in paleobotanical research since the 19th century (Ward, 1889).
Collection Georg Gasser: 12 specimens, *Alnus julianaeformis* (PAL 3100), *Betula* cf. *subpubescens* (PAL 3104, Fig. 10C), *Cyclocarya cyclocarpa* (PAL 3110, Fig. 10A), *Dicotylophyllum* sp. (PAL 3162, 3201), *Pterocarya* sp. (PAL 3163), *Quercus* sp. (PAL 3151), *Acer* sp. (PAL 3101), *Ziziphus ziziphoides* (PAL 3090), not better defined Arecales leaves (PAL 3106, 3176), a not better-defined seed (PAL 3117)

Schrobenhausen
Age: Neogene
SELMAIER (1970) described angiosperm wood from the locality.
Collection Georg Gasser: not better-defined angiosperm stem (PAL 3454),

Sieblos in der Röhn
Age: Oligocene
The fine-grained sediments of grey to brownish colour (called Dysodil or Blätterkohle) of Sieblos in der Röhn are rich in plant remains. The outcrops are not accessible anymore because the sand and sandstone quarries are inactive today.
Collection Georg Gasser: *Cinnamomum polymorphum* (PAL 3111)

Untersachsenberg
Age: Carboniferous
Findings of fossil plants from the "coal period" (Steinkohlenperiode), from this site, were noted more than one hundred years ago (LEIMBACH, 1890).
Collection Georg Gasser: *Artisophyton* sp. (PAL 3195; Fig. 6D).

Zwickau
Age: Pennsylvanian (late Carboniferous)
Zwickau is a historical coal mining site, which was first mentioned in the middle 1300s. The first studies on plant fossils from this locality were published in the first half of the nineteenth century by AUGUST VON GUTBIER (1834, 1835) (SCHNEIDER et al., 2005). The macroflora from the Zwickau Basin is characterized by the presence of lycophytes, sphenophytes, ferns, seed ferns and cordaitaleans (SCHNEIDER et al., 2005; HOTH et al., 2009).
Collection Georg Gasser: 19 specimens, *Lepidodendron feistmantellii* (PAL 3095, 3219; Fig. 4F), *Sigillaria* sp. (PAL 3233), *Sphenophyllum* sp. (PAL 3271), *Sphenophyllum emarginatum* (PAL 3272, 3273, 3274; Fig. 5E), *Annularia inflata* (PAL 3180; Fig. 5A), *Annularia sphenophylloides* (PAL 3086, 3174, 3250; Fig. 5C), *Pecopteris plumosa* (PAL 3241), *Crenulopteris acadica* (PAL 3093–3094; Fig. 6E), *Cyathocarpus arborea* (PAL 3232), *Cyathocarpus candolleanus* (PAL 3178; Fig. 6F), *Corynepteris angustissima (PAL* 3192; Fig. 6C), *Neuropteris auriculata?** (PAL 3132) and an undetermined rachis (PAL 3107).

6.5 ITALY

Leffe (Bergamo Province)
Age: early Pleistocene
The Leffe Formation was formed in a fan-delta, and consists of lacustrine and palustrine deposit of early Pleistocene age. The succession is rich in brown coal layers, deposits with mainly conifer shoot fragments dominated by *Tsuga* and fluviatile deposits with a rich carpoflora (e.g., RAVAZZI, 1995). The brown coal mine of Leffe has been well known since the 19th century and its exploitation, terminated after 1950's, facilitated the discovery of paleobotanical and paleozoological specimens (CREMASCHI & RAVAZZI, 1995).
Collection Georg Gasser: lignite (PAL 3299)

Monte Baldo (Verona Province)
Age: Eocene
There is no reference in the literature to plant fossils from Monte Baldo, although unrecorded plant remains have already been found from its Piabonian to Bartonian sediments (comm. pers. GUIDO ROGHI, 09.10.2022). The area is mostly famous for fossil crabs in the northern area of Monte Baldo, from the Jurassic to the Cenozoic, including Eocene crabs in life position. It has to be added that a similar lithology is also present in other sites of the Lepontian Alps and also at Bolca.
Collection Georg Gasser: *Ruppia* sp.* (PAL 3203; Fig. 1E)

Montiggl/Monticolo (Bolzano Province)
Age: Holocene
Between Monticolo and Cornaiano there are a series of depressions that house lake and marsh deposits, with peat layers (AVANZINI et al., 2007).
Collection Georg Gasser: peat (PAL 3402; Fig. 1D)

Seiser Alm/Alpe di Siusi (Bolzano Province)
Age: Ladinian (Middle Triassic)
MARIA M. OGILVIE GORDON (1927) was the first to describe and figure plant fossils from the Seiser Alm/Alpe di Siusi. The plant fossils came from the "Buchenstein Schichten" and from the "Wengener Schichten" of the area. The type of preservation of the fossils and also the relative abundance of the various plant groups suggest that our three remains come from the Wengen Formation, although no detailed outcrop nor formation name is mentioned on the labels.
Collection Georg Gasser: 4 specimens, *Apoldia wengensis* (PAL 3156; Fig. 8B), *Pelourdea vogesiaca* (PAL 3153; Fig. 9C), *Voltzia ladinica* (PAL 3198; Fig. 9A), sphenophyte stem fragment (PAL 3246)

Talferbett, Mölten/Meltina (Bolzano Province)
Age: Lopingian (late Permian)
In the area of Mölten/Meltina, the Gröden/Val Gardena Formation crops out, which is fossiliferous and yields rich impressions and compressions of plant remains (ASPMAIR, 1998; FRITZ & KRAINER, 1999; KRAINER, 2000).
Collection Georg Gasser: sphenophyte stem fragment (PAL 3206), conifer stem fragment (PAL 3202), plant debris (PAL 3205)
Remarks: Two further samples probably come from this locality, indicated only as "Südtirol" on the labels. Although the age is indicated as Triassic, the lithology and type of preservation does not resemble that of any other Triassic plant fossil localities known so far.

Tisens/Tiseno (Bolzano Province)
Age: early Permian (Cisuralian)
In the area around Tisens/Tiseno, northwest of the capital of South Tyrol, the Athesian Volcanic Complex with various sedimentary intercalations crops out (e.g., BARGOSSI et al., 2010). The indication of the area on fossil labels suggests that the plant remains, although badly preserved come from the Cisuralian successions.
Collection Georg Gasser: plant debris (PAL 3423–24)

6.6 POLAND

Kamienna Góra (Landeshut)
Age: Mississippian (early Carboniferous)
This outcrop is situated in the historical region of Silesia (southwest Poland), near the border of the Austro-Hungarian Empire during the lifetime of Georg Gasser. It has been known for centuries for its rich Carboniferous coal deposits plant fossils. The first illustrations and description of macroflora of Kamienna Góra were made by Volkmann (1720) in his *Silesia Subterranea* (Pacyna, 2012; Krzywiec & Arndt, 2021).
Collection Georg Gasser: 3 specimens, unidentified lycopsid stems with branch scars and two fragments of *Lepidodendron wedekindii* (PAL 3210, 3211, 3263)

6.7 ROMANIA

Anina (Steierdorf)
Age: Hettangian (early Jurassic)
The Anina coal mining district is located in the southwestern part of Romania, Caraş-Severin County, in the historical province of Banat. The coal bearing sediments represented by the lower part of the Valea Tereziei Member of the Steierdorf Formation, are famous for the richness and high diversity in Hettangian fossil plant species. Especially the sediments between coal seams nr. 2 and 3 are rich in plant remains, including more than 120 taxa. The plant remains were collected and studied in detail since 1850 (Korodi et al., 2017). In fact, the Jurassic plant beds were known to Baron von Ettingshausen (1852) who described in his monograph five species from this place, fully treated, then, in 1855 by Andra. The mining activity was closed in 2006 and a last revision was carried out by Popa (2000).
Collection Georg Gasser: *Nilssonia* cf. *undulata* (Fig. 8A), *Cladophlebis* sp., *Phlebopteris formosa* (PAL 3182)

Secu (Szekul)
Age: Pennsylvanian (late Carboniferous)
Located in the historical region of Banat, this area was in the focus of coal exploitation of the 19th century that allowed the recovery and study of fossil plants (e.g., Ward, 1889; Jongmans, 1922; Balogh, 1993).
Collection Georg Gasser: *Annularia inflata* (PAL 3226)

7. CONCLUSIONS

Living at the turn to the 20th century, Gasser witnessed the deep geopolitical transformations that took place in Europe. As a citizen of Tyrol and late South Tyrol, he was directly affected by the significant changes that took place in the territories under the influence of the Habsburg Empire and the German Confederation, established after the Congress of Vienna in 1815. Like all of Trentino-Alto Adige, Bolzano was until 1918 under the control of the Empire which is reflected in the composition of Gasser's paleobotanical collection that gives an overview of well- known deposits of Germany, Austria, Croatia, Czech Republic, Poland, Hungary, Romania.

Moreover, the origins of the plant fossils together with the representation of samples of coal in its various stages, is linked to the great impulse that was given to mining research by the industrialization in the 19th and early 20th centuries. For these reasons the geological period predominantly represented in the paleobotanical collection is the Carboniferous, being the time when large forests of lycophytes, horsetails, ferns, seed ferns, and cordaitaleans grew and gave later rise to the vast coal deposits of Central Europe, exploited millions of years later for fossil fuels. The specimens from this time period highlight the didactic function of the collection, because the collection focused on samples from certain locations and specific geological periods. All of them were already known in Gasser's time.
The area of South Tyrol is underrepresented in the Gasser Collection. The few samples that have survived till today, seem more the result of occasional picking rather than methodical collecting. On the other hand, it should also be considered that,during the lifetime of Georg Gasser, only few plant fossils from the region had been discussed and published in literature (e.g., Ogilvie Gordon, 1927). Therefore, it is remarkable that at least some plant remains from the area are in his collection, with representatives from the Mölten/Meltina, Seiser Alm/Alpe di Siusi and Tisens/Tiseno, although these are not the most famous localities for plant fossils in the Dolomites.

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