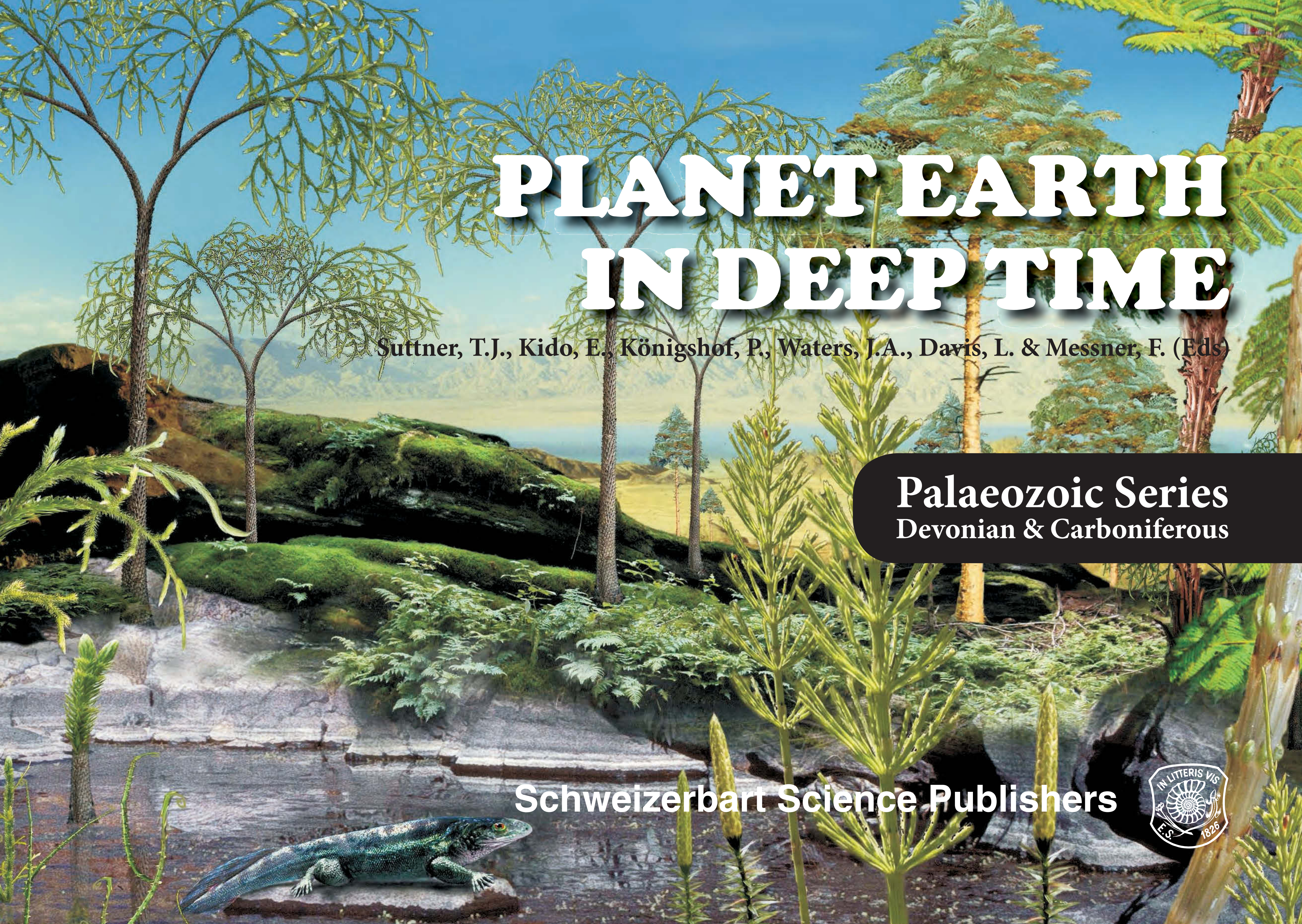
PLANET EARTH IN DEEP TIME

Suttner, T.J., Kido, E., Königshof, P., Waters, J.A., Davis, L. & Messner, F. (Eds)

Palaeozoic Series
Devonian & Carboniferous

Schweizerbart Science Publishers



Planet Earth – In Deep Time
Palaeozoic Series

Devonian & Carboniferous

Suttner, T.J., Kido, E., Königshof, P., Waters, J.A., Davis, L. & Messner, F. (Eds)

Planet Earth – In Deep Time
Palaeozoic Series

Devonian & Carboniferous

Suttner, T.J., Kido, E., Königshof, P., Waters, J.A., Davis, L. & Messner, F. (Eds)

With 201 coloured figures

Schweizerbart Science Publishers · Stuttgart · 2016

Planet Earth – In Deep Time. Palaeozoic Series. Devonian & Carboniferous
Suttner, T.J., Kido, E., Königshof, P., Waters, J.A., Davis, L. & Messner, F. (Eds)

We would be pleased to receive your comments on the content of this book: editors@schweizerbart.de

Editors addresses:

Suttner, Thomas J. – University of Graz, NAWI Graz, Institute for Earth Sciences (Geology and Palaeontology), Heinrichstrasse 26, 8010 Graz, Austria
Email: thomas.suttner@uni-graz.at

Kido, Erika – University of Graz, NAWI Graz, Institute for Earth Sciences (Geology and Palaeontology), Heinrichstrasse 26, 8010 Graz, Austria
Email: erika.kido@uni-graz.at

Königshof, Peter – Senckenberg, Forschungsinstitut und Naturmuseum Frankfurt, Senckenberganlage 25, 60325 Frankfurt, Germany
Email: Peter.Koenigshof@senckenberg.de

Waters, Johnny A. – Department of Geology, Appalachian State University, Boone, NC 28608, USA
Email: watersja@appstate.edu

Davis, Laura – 86 Tuscarora Ave, Beaufort, SC 29907, USA
Email: lauradavis013@gmail.com

Messner, Fritz – Auenbruggergasse 8, 8073 Feldkirchen, Austria
Email: fritz.messner@gmx.com

Dust Cover: Artistic reconstruction of terrestrial ecosystem development from Silurian to Carboniferous in a transition-free time-series from left (back cover) to right (front cover). Computer generated collage by Messner F. (2007).

Note for fossil collectors: Some fossil localities provided here are found in protected areas such as Geoparks, natural heritage or active military training ground, where access is restricted. Formal application and approval of access must absolutely be obtained before entry.

ISBN ebook (pdf) 978-3-510-65492-5
ISBN 978-3-510-65335-5
Information on this title: **www.schweizerbart.com/9783510653355**

Publisher: E. Schweizerbart‘sche Verlagsbuchhandlung (Nägele u. Obermiller)
Johannesstraße 3A, 70176 Stuttgart, Germany
mail@schweizerbart.de
www.schweizerbart.de
Printed on FSC-certified paper
Layout: Thomas J. Suttner and Erika Kido
Printed in Germany by Tutte Druckerei GmbH, Salzweg

Preface

The International Geoscience Programme (IGCP) is a cooperative enterprise of IUGS (International Union of Geosciences) and UNESCO (United Nations Educational, Scientific and Cultural Organisation). IGCP is an international and multi-disciplinary programme. It covers different fields in the Earth sciences and complements other UNESCO and IUGS scientific programmes. IGCP began officially in 1972 when it was accepted at the International Geological Congress at Montreal. Attempts to create a global research effort began long before and there had been intensive work particularly by geologists in Europe (Austria, Germany and UK) and Australia, to promote what was to become the most successful of IUGS/UNESCO-supported programmes. The primary aims of IGCP are to facilitate international collaboration among scientists in research on geological problems, particularly between those individuals from more industrialised and those from developing countries. The first Scientific Board under the chairmanship of Sir Kingley Dunham (UK) with Simon van der Heide acting for IUGS initiated some 28 projects. In the "early days" the scientific focus was primarily on basic science. The priority was the importance of accuracy and definition of nomenclature to correlate whether geological data was stratigraphic or otherwise. Identification and understanding of geological processes, discovery and assessment of economic minerals, and the evolution of life are themes that are still reflected today, although the removal of the word "correlation" shows a shift in emphasis away from the traditional basic geologic projects. More recently, the emphasis changed towards societal-oriented themes. IGCP's scientific objectives include:

- Improving our understanding of the geoscientific factors affecting the global environment in order to improve human living conditions;
- Developing more effective methods to find and sustainably exploit natural resources of minerals, energy and groundwater;
- Increasing the understanding of geological processes and concepts of global importance, including an emphasis on socially relevant issues; and
- Improving standards, methods and techniques of carrying out geological research, including the transfer of geological geotechnological knowledge between industrialised and developing countries.

The objectives of IGCP are met through individual projects. Over the past decades, thousands of scientists have actively taken part in IGCP projects and for many of them the projects have been a gateway to a successful career. More than 500 projects have resulted in thousands of scientific papers dealing with different geological disciplines. There is no doubt that IGCP is one of UNESCO's most successful scientific programmes.

Current and future climate change is one of society's greatest challenges, in particular in terms of economy. It is well known that climate change affects ecosystems, water supply and the frequency and magnitude of hazardous phenomena among others. Furthermore, climate change is a global issue that can be addressed only through international cooperation. Climate modelling is a useful tool for a better understanding of climatological processes but cannot be done without the knowledge of organisms and changing palaeo-biodiversity. It is widely recognised that a temperature rise of about 1°C has occurred within the last 100 years and another rise is likely even if the amount is still in discussion. This shows how insecure is our knowledge of the complexity and functions of the Earth's climate system. The geologic and palaeontologic record of climate change is the best resource of information on the Earth's climate system. It provides a record of trends in mean climate and changing palaeo-biodiversity. If we can understand climate conditions that have existed during the history of recorded climate we gain a more fundamental understanding of the climate system than is attainable through studies based solely on modern conditions. Furthermore, understanding climate change over the full variety of temporal and spatial scales recorded in the geologic sequences contributes to the knowledge of the fundamentals of climate dynamics. This knowledge is essential if we are to model future climate with confidence.

In this context the IGCP 596 on "Climate Change and Biodiversity Patterns in the Mid-Palaeozoic" is an important contribution to a better understanding of climate change in Earth history. The project is in line with UNESCO's philosophy as is shown by the large number of contributions from different countries and languages. It is a nice example in terms of public outreach and provides important information on both geological sections/areas and geosciences in general. The book will enhance visibility within the scientific community and beyond the Earth Science community.

Prof. Dr. Roland Oberhänsli

IUGS President

Contents

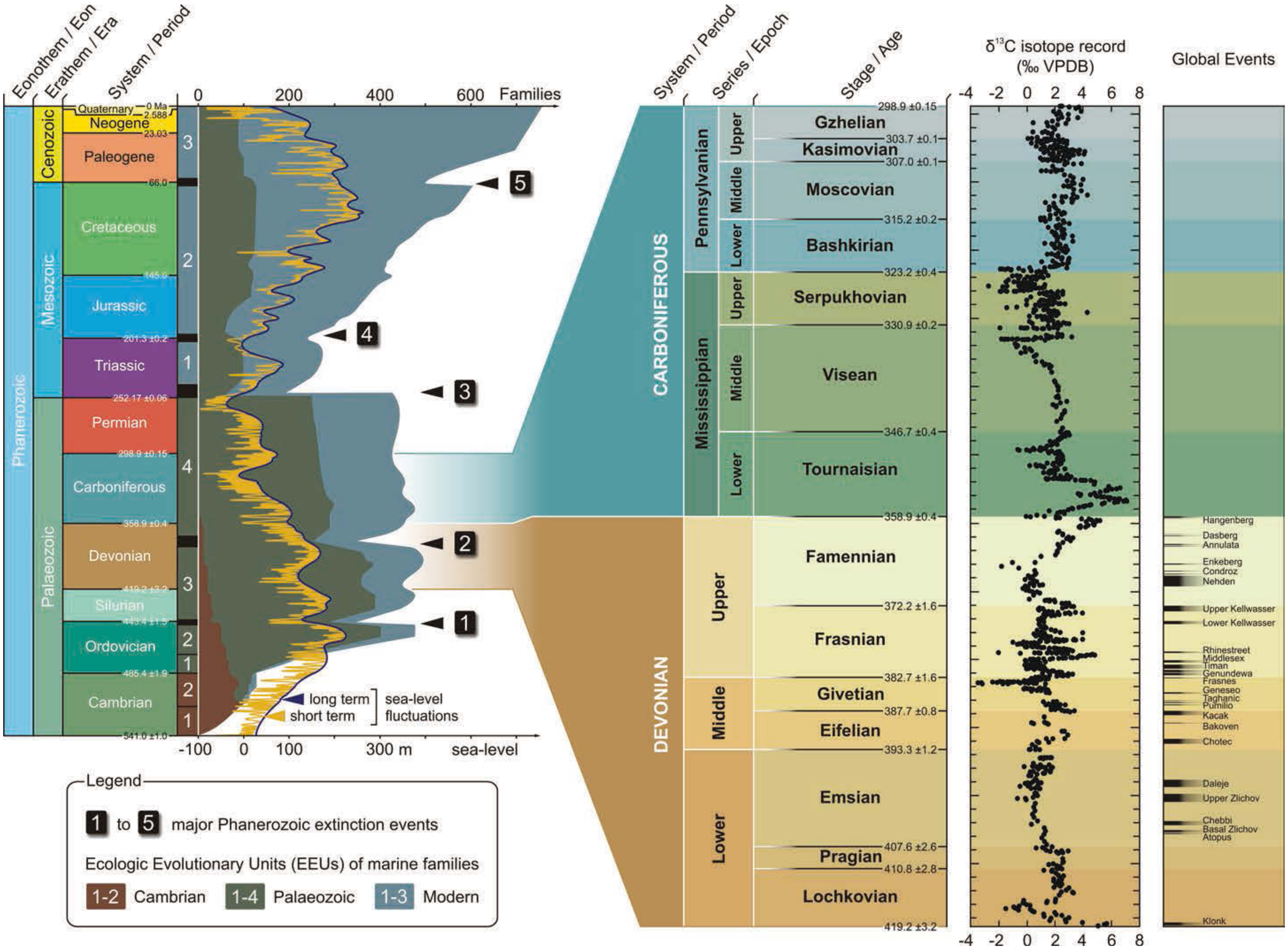
Introduction

Sedimentary layers follow the basic law that the oldest layer is on bottom and youngest on top when the sequence of sediments is not overturned. Stratigraphy observes the inherent nature of sediments, such as lithology, composition of fossils, geochemistry (e.g., isotopic compositon), geophysics (e.g., magnetic remanence) and age. During much of Earth history, sedimentation has been controlled by eustatic change of the sea level. The sea-level rise and fall during the depositional process results in certain cyclicity and is reflected in the sediments. The causes of sea-level fluctuations are the change of seawater volume, which is associated with the development of glaciers for example, and the long term aspect—the change of alignment of continents and oceanic basins.

The sea-level fluctuations, the division of Ecologic Evolutionary Units, the marine family diversity, and the time of well-known mass extinction events (Big Five) are shown in the left figure of the next page. In terms of diversity, the marine fossil record is divided into three Successive Evolutionary Faunas (Cambrian, Palaeozoic and Modern), which have distinctive compositions and progressively increasing diversity. During the intervals of Evolutionary Faunas, new organism-groups brought new morphologic adaptations into the existing communities. During their radiation, communities increased in diversity and complexity through geological time. Nine intervals shown (two in Cambrian, four in the remaining part of the Palaeozoic, and three in Modern) conform to Ecologic Evolutionary Units (EEUs), which are assigned as the ecologic subdivision of Evolutionary Faunas.

Five large mass extinctions in the Phanerozoic, which caused catastrophic loss of taxonomic groups on Earth, occurred during the end-Ordovician, Late Devonian, end-Permian, end-Triassic and end-Cretaceous. The crises during the end-Ordovician and end-Frasnian (Late Devonian) probably resulted from intense glaciation. Forty-nine percent and 35% of marine genera decreased respectively. The largest mass extinction since the Cambrian is documented at the end-Permian leading to the loss of 58% percent of marine genera. The effects of volcanism are considered as one of the causes of this event. The Central Atlantic Magmatic Province (CAMP), one of the major volcanic provinces developed during the Triassic, erupted voluminous flood basalts and is considered a major cause responsible for the end-Triassic crisis. During this crisis, 40% of all marine genera went extinct. The end-Cretaceous mass extinction was linked with impacts and major volcanic eruptions. Thirty-nine percent of marine genera disappeared. Extinction events destroyed common community organizations. Reorganization of communities was the consequence. Many clades moved into new environments, which resulted in new association of species or replacement by invading species.

The Devonian was a relatively warm period with an acme in diversity, size and latitudinal distribution of reefs during the Middle Devonian. Nonetheless, apart from the end-Frasnian mass extinction, several climate perturbations that resulted in additional more-or-less-severe biotic events have been documented (Figure next page, right side). During the Carboniferous (except for late Visean and late Gzhelian) extensive pulses of glaciation coincided with high-frequency sea-level fluctuations observed in deposits globally.



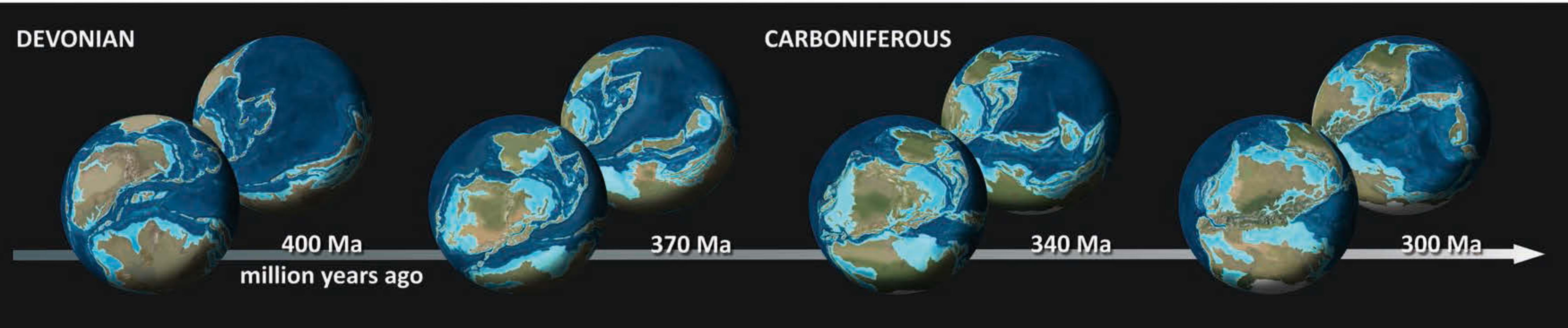
Eonothem / Eon
Erathem / Era
System / Period
Families
0
200
400
600
Phanerozoic
Cenozoic
Mesozoic
Palaeozoic
Quaternary
Neogene
Paleogene
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
long term
short term
sea-level fluctuations
-100
0
100
300 m
sea-level
Legend
1 to 5 major Phanerozoic extinction events
Ecologic Evolutionary Units (EEUs) of marine families
1-2 Cambrian
1-4 Palaeozoic
1-3 Modern
System / Period
Series / Epoch
Stage / Age
CARBONIFEROUS
DEVONIAN
Pennsylvanian
Mississippian
Upper
Middle
Lower
Gzhelian
Kasimovian
Moscovian
Bashkirian
Serpukhovian
Visean
Tournaisian
Famennian
Frasnian
Givetian
Eifelian
Emsian
Pragian
Lochkovian
298.9 ±0.15
303.7 ±0.1
307.0 ±0.1
315.2 ±0.2
323.2 ±0.4
330.9 ±0.2
346.7 ±0.4
358.9 ±0.4
372.2 ±1.6
382.7 ±1.6
387.7 ±0.8
393.3 ±1.2
407.6 ±2.6
410.8 ±2.8
419.2 ±3.2
δ13C isotope record (‰ VPDB)
Global Events
Hangenberg
Dasberg
Annulata
Enkeberg
Condroz
Nehden
Upper Kellwasser
Lower Kellwasser
Rhinestreet
Middlesex
Timan
Genundewa
Frasnes
Geneseo
Taghanic
Pumilio
Kacak
Bakoven
Chotec
Daleje
Upper Zlichov
Chebbi
Basal Zlichov
Atopus
Klonk

Continents and Plate Tectonics

The Earth's crust moves in mm- to cm-scale per year. This movement results in diastrophism (i.e., deformation of earth's surface) which is folding and faulting within the crust. The cause of diastrophism was earlier explained by Alfred Wegener in 1912, when he proposed the theory of continental drift (The Origin of Continents and Oceans; Wegener, 1915). It was advanced by the theory of mantle convection in 1928 and by the theory of seafloor spreading in the early sixties. These theories were summarised and developed as plate tectonics by John Tuzu Wilson after the late 1960s. Plate tectonics is a theory that explains the diastrophism based on the motions of tectonic plates on the earth's surface, which consist of continental and oceanic lithosphere.

Following the plate tectonics theory, configuration of ocean basins and continents through geological time are reconstructed based on palaeomagnetic data and palaeogeographic interpretation of fossil occurrences. The palaeogeographic maps have been improved and published by several scientists (e.g., Scotese and McKerrow, 1990; Golonka, 2002; Kiessling and others, 2003; Paleomap Project by Scotese: http://www.scotese.com; Reconstructing the Ancient Earth by Blakey: http://cpgeo-systems.com/paleomaps.html). During the Devonian, the super-continent Gondwana covered vast areas of the southern hemisphere and the continent Siberia was located in the northern hemisphere. Other major continents such as Laurussia lay between them. Gondwana was divided from eastern Laurussia by the Proto-Tethys Ocean and from the microcontinents (e.g., Avalonia), which existed in the south of Laurussia by the Rheic Ocean. The Carboniferous was the time when formation of the supercontinent Pangaea began. Two major oceans were spread in this period: the Palaeo-Tethys Ocean (a successor of the Proto-Tethys Ocean) and the Panthalassa Ocean that surrounded Pangaea. The collision of continents or microcontinents, and the accretion of terranes that went with the formation of Pangaea caused mountain-building activity that produced the Appalachian Mountains, Ural Mountains and the Rhenish Massif among other mountain chains.

In this book, palaeogeographic reconstructions by Ronald Blakey (NAU Geology) are used. The location of the countries that appear in the book is plotted on the modern map (right page) with the colour code to each country provided below. The location of fossil sites in those countries is plotted on Devonian and Carboniferous palaeogeographic maps in each contribution.


DEVONIAN
CARBONIFEROUS
400 Ma
million years ago
370 Ma
340 Ma
300 Ma

What are scientific collections and why they are important?

IGCP 596 is specifically interested in the interaction between climate change and biodiversity in the Devonian and Carboniferous Periods (419 – 299 million years ago) when the terrestrial ecosystems experienced a biodiversity boom and oceanic ecosystems suffered catastrophic extinctions.

Fossils are used to investigate these changes in biodiversity of different periods in Earth history. Palaeontology has become a key component particularly in palaeoclimatic research. Together with sedimentary rocks, fossils are the repository of nearly all palaeoclimatic data, especially quantitative data. For instance, stable isotope geochemical interpretations of palaeoclimate are most commonly measured from fossils. Understanding the evolution, palaeobiology, and palaeoecology of organisms is crucial to palaeoclimate interpretations of stable isotope records. For example, vertical or horizontal migrations during ontogeny, as well as seasonality in reproduction may have consequences for estimates of ocean temperatures from marine microfossils. The palaeobiology and palaeoecology of organisms is also very important to interpretations of shifts in palaeobiogeographic patterns in terms of palaeoclimatic change.

Therefore, natural history collections are vital scientific research tools. Palaeontological collections are fundamental for all palaeontological information and they are essential for research in all areas of palaeontology, from taphonomy to palaeoecology to evolutionary palaeobiology. They are also essential for systematic studies and for all areas that depend on systematics, such as biostratigraphy, palaeobiogeography and reconstruction of the history of life.

Furthermore, palaeontological collections provide important resources for palaeontological education at all levels (e.g., graduate school, education in and out of museums). Many institutions host huge numbers of organisms, particularly museums such as the Smithonian (USA); Natural History Museum, London (U.K.); American Museum of Natural History, New York (USA); and the Senckenberg Museum, Frankfurt (Germany). The unique importance is also based on the fact that smaller institutions and universities have decided to rid themselves of their collections. Access to scientific collections is a prerequisite to investigate the extinct fauna and flora. Palaeontological collections will benefit enormously from greatly increased accessibility to information provided by computer technology. Therefore, related to this project, a network of taxonomic workers will help to update the systematics of Mid-Palaeozoic terrestrial and marine organisms. These datasets will be made available to the public by using existing e-infrastructures such as the *Paleobiology Database*.

Based on the scientific collections – a key component in palaeontological research and research infrastructure – the project might help give understanding to our present-day situation and climate change in the future by documentation of Mid-Palaeozoic climate change and its effect on biodiversity.


GA

Planet Earth – In Deep Time

Devonian & Carboniferous

International Geoscience Programme (IGCP)
IGCP Project 596 (2011-2015)
Climate change and biodiversity patterns in the Mid-Palaeozoic

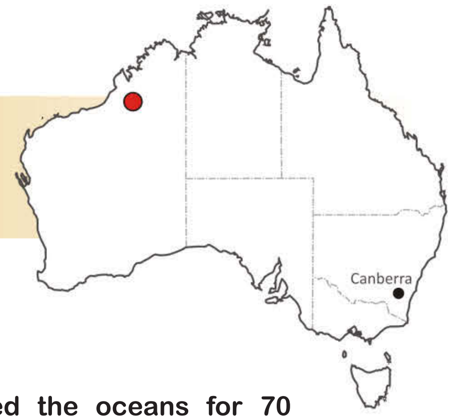
The face of Planet Earth has changed significantly through geologic time. The configuration of continents and oceans and the organisms that inhabited them are very different from those we see today. Dynamic processes still active today, such as plate tectonics and climate change, have shaped the earth's surface and impacted biodiversity patterns from the beginning. IGCP 596 is specifically interested in the interaction between climate change and biodiversity in the Devonian and Carboniferous Periods (419 – 299 million years ago) when the terrestrial ecosystems experienced a biodiversity boom and oceanic ecosystems suffered catastrophic extinctions.

Greenhouse climates dominated the Early and Middle Devonian (419 – 383 Ma) world, but changed to icehouse conditions in the Late Devonian (383 – 359 Ma). The early Carboniferous world was relatively warm until cooling in the early late Carboniferous (323 – 299 Ma) resulted in a huge polar ice shield in the southern hemisphere that covered most of Gondwana. The Mid-Palaeozoic was also a time of very high plate tectonic activity that caused major palaeogeographic changes. During the Devonian two supercontinents, Euramerica and Gondwana, together with Siberia formed the biggest landmasses of our planet. They successively amalgamated into the supercontinent Pangaea during the late Carboniferous. As the continental landmass grew, vascular plants, arthropods, hexapods and first tetrapods spread on land. Their radiation formed the base of new terrestrial ecosystems unknown before the Devonian Period. The success of terrestrial invaders, as documented by the fossil record, culminated with the development of vast forests consisting of tree-like forms like *Calamites* (Order Equisetales), lycophyte trees (e.g. *Lepidodendron*, *Sigillaria*) and other rooted plants that covered huge areas during the Carboniferous. That unique rise among land plants and the formation of top-soil led to distinctive changes in environmental conditions. Based on proxy-data, we can show that the rapid rise of land plants was coupled with strongly decreasing atmospheric CO_2 values from 4000 ppm to nearly present day values of about 350 ppm during the latest Devonian. Increased weathering activity and soil formation by rooted plants lead to intensified run-off and changed water chemistry, which seriously affected marine communities globally.

The tectonic and climate history of the Devonian and Carboniferous as well as the novelty of soil-formation due to the explosion of life on land, and other processes, some of which are not yet fully understood, are linked with a series of ecological turnovers and extinction events primarily in the oceans. Results of this project should help to clarify whether climate change (e.g. interaction of CO_2 and temperature) from greenhouse conditions during the Early-Middle Devonian to icehouse conditions during the Late Devonian – early Carboniferous represents a major trigger for variations in biodiversity or if a combination of multiple factors is responsible for such changes.

Waters J.A.

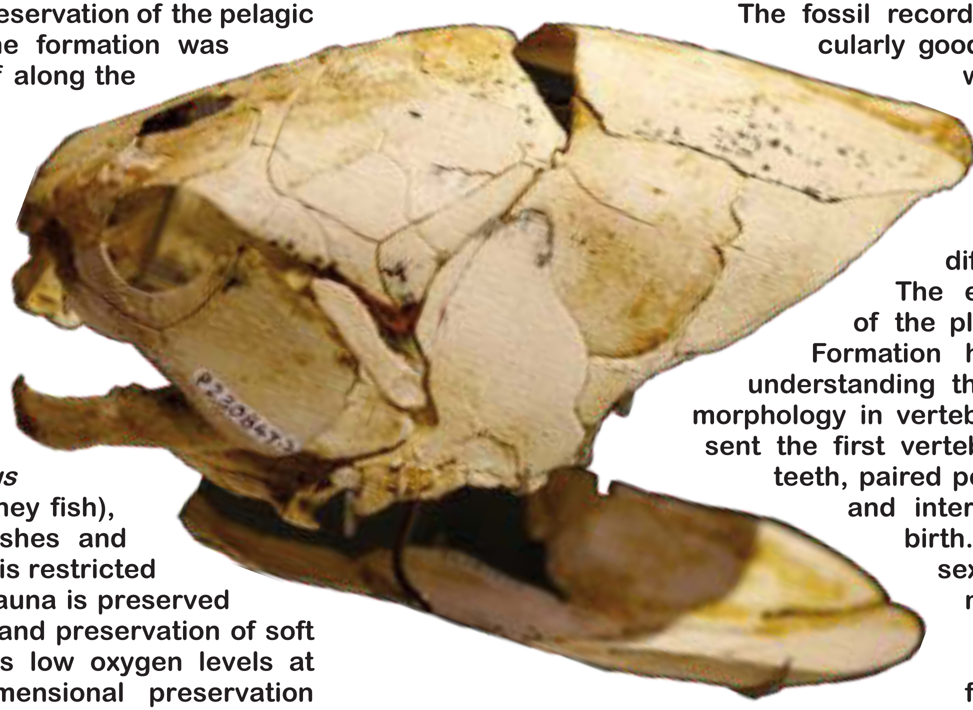
AUSTRALIA
DEVONIAN (Canning Basin)



The Devonian Reef sediments of the Canning Basin in the northwest of Western Australia are divided into a number of different facies types representing different palaeoenvironments. The early Frasnian Gogo Formation is world renown for the exceptional preservation of the pelagic marine vertebrate and invertebrate fauna. The formation was deposited in the deeper waters of a barrier reef along the northern margin of Gondwana.

The Gogo Formation comprises fine black shales interbedded with thinly laminated carbonate nodules. The fossils form the nucleus of the nodules and are composed of mostly pelagic organisms. They include invertebrates such as phyllocarid and concavicarid crustaceans, radiolarians, sponges, conodonts and a single eurypterid. However, the area is best known for the fish fauna, which is dominated by placoderms (extinct armoured plated fish; Figure: *Eastmanosteus calliaspis*), but also includes osteichthyans (boney fish), rare sharks and acanthodians, marine lungfishes and tetrapodamorphs. In contrast, the bottom fauna is restricted with only rare molluscs and brachiopods. The fauna is preserved three dimensionally and includes original bone and preservation of soft tissues. The restricted benthic fauna suggests low oxygen levels at sediment/water interface and the three dimensional preservation indicates a high sedimentation rate resulting in rapid burial. Over 50 fish species were recorded from this site with the placoderms as the most abundant and diverse group. The preservation of a complete ecosystem provides important information about the past species diversity and allows a more accurate reconstruction of the extinct reef community.

Trinajstic K.



Placoderms (Phylum Chordata) ruled the oceans for 70 million years from the Silurian until the end of the Devonian.

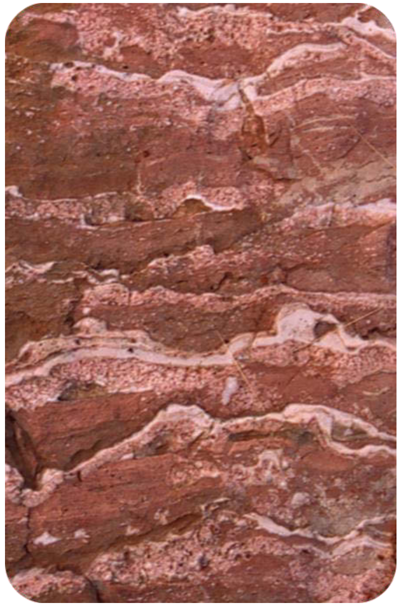
The fossil record of placoderms is particularly good as the head and thorax were covered with plates made of dermal bone. Their diverse body forms and different arrangements of the skull plates distinguish different placoderm taxa. The exceptionnal preservation of the placoderms from the Gogo Formation have been important to understanding the evolution of the novel morphology in vertebrates. Placoderms represent the first vertebrates to have jaws with teeth, paired pectoral and pelvic girdles, and internal fertilization with live birth. The first evidence of sexual dimorphism, where males looked different to females, was observed by Watson in ptyctodonts from Scotland, however it was not until 2008 when a single embryo attached by an umbilical cord was discovered from the Gogo Formation that internal fertilization with live birth was confirmed in the ptyctodont *Materpiscsi attenbourough,* name after Sir David Attenbourough.

Trinajstic K.

LAIDLAW RANGE

AUSTRALIA
DEVONIAN (Canning Basin)

One of the best known localities in the reefs of the Canning Basin is Windjana Gorge, which was eroded by the Lennard River. The limestone forming the gorge walls record ~10 million years of reef growth (middle Frasnian to early Famennian), with movement of the reef margin recording the response of the reef builders to relative changes in sea level.



The Canning Basin reefs grew continuously through an important time of global change with a cooling greenhouse Earth and a major set of global extinctions in the late Devonian. The major Frasnian reef builders were stromatoporoids and calcimicrobes and they belonged to a diverse ecosystem with sponges, corals and skeletal organisms such as crinoids, ammonoids, nautiloids, trilobites, brachiopods, molluscs and armoured fishes (Figure: Frasnian reef fabric with platy stromatoporoids, calcimicrobes beneath and finely layered red sediment with fossil fragments). Towards the end of Frasnian, the Canning Basin reefs were affected by global environmental changes. Significantly, this region was characterised by tectonic activity causing fault movements and rapid relative sea-level changes. Anoxic ocean water does not appear to have been a factor in the faunal changes in the Canning Basin at this time. Local environmental changes and cooling global climate severely impacted the stromatoporoids and they were largely extinct before the end of Frasnian. The microbes were not so obviously affected if at all, and unlike many other regions around the world, they continued to build major reefs in the Famennian. Overall, global cooling and tectonic quiescence in the Canning Basin eventually led to the demise of reefs before the end of Famennian.

George A.

Tabulata and Rugosa (Phylum Cnidaria, Class Anthozoa, Subclass Zoantharia) were sessile marine organisms that produced calcified skeletons. These coral groups appeared independently in the Ordovician and became extinct at the end of the Permian. Palaeozoic corals are found in different facies including limestone, calcarerous siltstone and shales. In the shallow marine environment, tabulates, rugosans and other calcified metazoans produced extensive carbonate platforms. In the Canning Basin, corals were important components of the platform lagoons and, to a lesser extent, the reef margins.

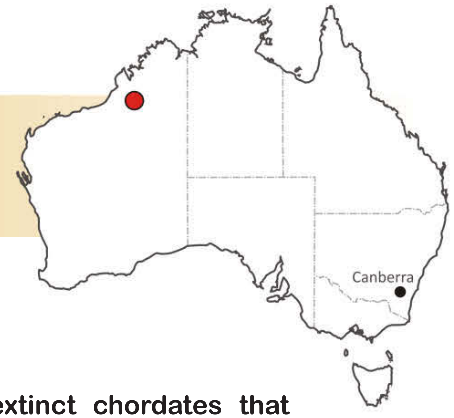
The Tabulata developed exclusively compound forms. Massive coralla with common skeletal tissue, massive cerioid coralla with mural pore (small holes developed in the wall, which link neighbouring corallites) and branching coralla were dominant. The Rugosa developed mainly solitary corallites, but produced also colonial forms of fasciculate, massive cerioid and amural growth-type. Tabulate corals were characterised by a simple skeleton with well-developed tabulae and inconspicuous septa. In contrast, rugose corals had septa typically consisting of a major and minor one, with diversely developed tabulae, dissepiments and axial structures.

Although several coral species were encrusting after their planulae (larvae) had settled on hard grounds, the vast majority of corals lived on soft substrates when mature. Coral diversity was highest in warm, shallow environment. Compared with recent zooxanthellate scleractinian corals, Tabulata and Rugosa are thought not to have had symbiotic algae.

Kido E.

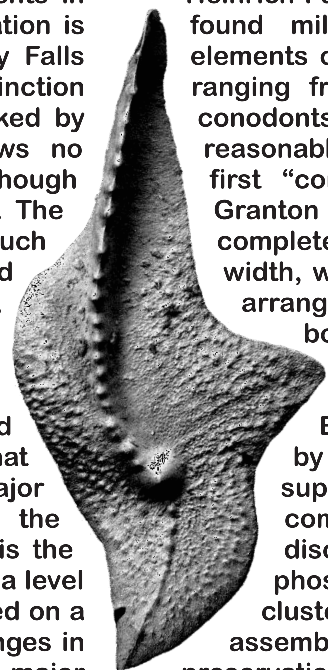
WINDJANA GORGE

AUSTRALIA
DEVONIAN (Canning Basin)



The Virgin Hills Formation (early Frasnian – middle Famennian) in the Canning Basin reef complexes is a characteristically reddish silty limestone well known for its diverse and beautifully preserved marine fossils. It was deposited in marginal slope and basin environments in front of a steep reefal margin in warm tropical seas. The formation is exposed along the SE Lennard Shelf. A section through Casey Falls records two significant events; the Frasnian/Famennian (F/F) extinction and the end of reef building in the Canning Basin – both marked by significant faunal overturns. The Virgin Hills Formation shows no significant facies change across the F/F extinction boundary, although the water depth is interpreted to be in the hundreds of metres. The fossils include stromatolites, microbes and algae; invertebrates such as conodonts (Figure) crinoids, tentaculites, and brachiopods; and rare vertebrates such as scales from jawless fish (thelodonts), shark teeth and scales and placoderm plates.
There are local occurrences of stromolitic boundstone encrustation within the Virgin Hills Formation. The control of their timing and distribution is speculative, but imply relatively starved conditions in a distal setting, which the silty nodular carbonates that dominate the Virgin Hills Formation also reflect. There is a major palaeoenvironmental change with reef building ceasing in the *trachytera* conodont Zone. Overlying the Virgin Hills Formation is the late Famennian Bugal Gap Limestone. After an apparently brief sea level fall the late Famennian – Tournaisian Fairfield Group was deposited on a marine carbonate ramp that draped the relic reefal profiles. Changes in lithology and depositional environment were accompanied by a major change in the fauna at this time. In the Fairfield Group conodonts are rare, but brachiopods, ostracods and corals are abundant. There is also an increase in the type and variety of shark teeth and scales, and in the teeth and scales of boney fish (palaeoniscoids), however the placoderms become extinct at the Devonian – Carbonifeous (359 Ma) boundary.

Trinajstic K., Hocking R. and Playton T.E.



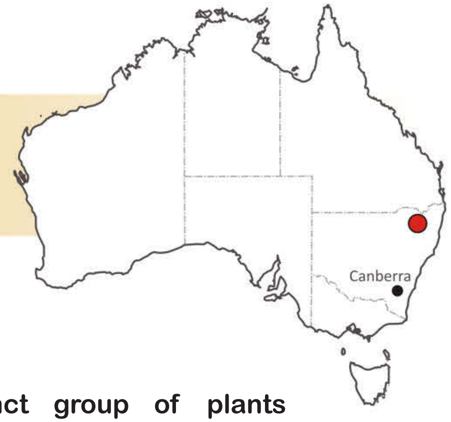
Conodonts belong to a group of extinct chordates that occurred from the Cambrian through the late Triassic. They were first described in a monograph on Silurian fish by Christian Heinrich Pander (Riga, Lithuania) in 1856. Since then, the commonly found millimetre-sized, coniform to complex-shaped tooth-like elements of this fossil group has been assigned to several groups, ranging from plants up to marine vertebrates. To which group conodonts finally belong is not clarified yet. Currently it seems most reasonable to assign them to marine basal chordates. In 1983 the first "conodont-animal" was described from the Mississippian Granton Sandstone, Scotland. That specimen is unique, as it is a complete body-fossil of 40.5 mm in length and less than 1.8 mm in width, with soft tissue preserved all over. Conodont elements are arranged *in situ* in the head region of the specimen. Another body fossil from late Ordovician deposits of South Africa reached a length of at least 400 mm.

Based on soft tissue analysis, conodonts are characterised by having two large eyes, a posterior and caudal fin supported by rays, v-shaped muscle segments and a complexly arranged feeding apparatus including 15 to 19 discrete elements. These elements consist of apatite (calcium phosphate) and are usually found disarticulated, as fused clusters in coprolites of marine predators, or as natural assemblages with apatite elements *in situ* with soft tissue preservation. It is proposed that they were active swimmers near the sea-bottom. Whether they were predators or parasites, or had a saprophage or grasping life style is uncertain. Although this group still has some systematic and palaeobiological uncertainties, its apatite elements are one of the most important tools used for microfossil biostratigraphy during the entire Palaeozoic and early Mesozoic.

Suttner T.J.

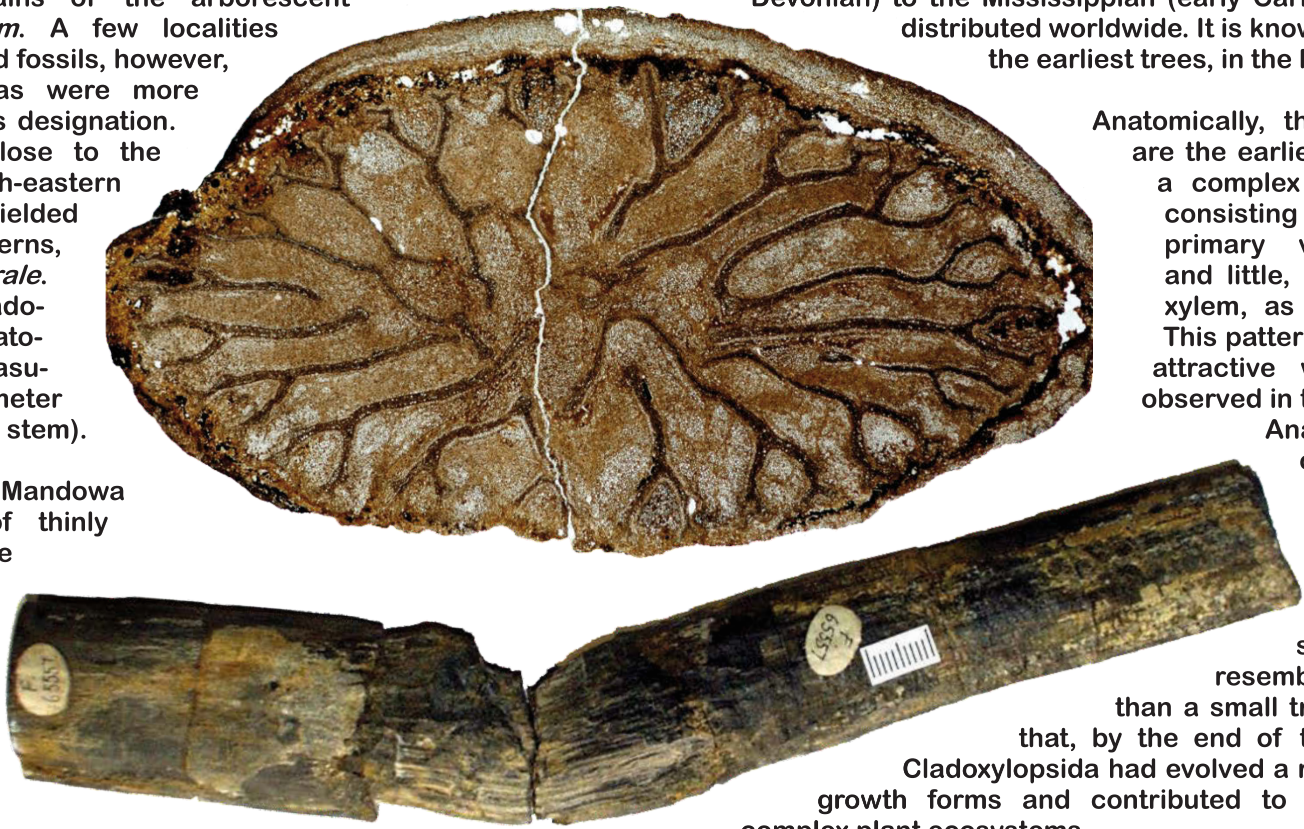
CASEY FALLS

AUSTRALIA
DEVONIAN (North-Eastern New South Wales)



The late Devonian floras of Australia are commonly called "*Leptophloeum* floras" due to the overwhelming occurrence of compression/impression remains of the arborescent lycopsid genus *Leptophloeum*. A few localities yielding anatomically preserved fossils, however, indicate that Australian floras were more diverse than suggested by this designation. The plant beds occurring close to the locality of Barraba, in north-eastern New South Wales, have yielded several plants affiliated to the ferns, among which is *Polyxylon australe*. This endemic species of Cladoxylopsida is represented by anatomically preserved stems measuring up to 25 mm in diameter (Figure: transverse section and stem).

The plant beds belong to the Mandowa Mudstone, which consists of thinly bedded and massive mudstone alternating with thin beds of siltstone and fine grained sandstone. The depositional environment was a distal marine shelf to continental slope. The plant beds in the Mandowa Mudstone at Barraba are Famennian (late Devonian) in age.



Meyer-Berthaud B.

Cladoxylopsida represent an extinct group of plants affiliated to the ferns. It ranges from the Eifelian (Middle Devonian) to the Mississippian (early Carboniferous) and is distributed worldwide. It is known to have evolved the earliest trees, in the Middle Devonian.

Anatomically, the Cladoxylopsida are the earliest plants to show a complex vascular system consisting of a network of primary vascular strands and little, if any, secondary xylem, as in modern ferns. This pattern is generally very attractive when stems are observed in transverse section. Analysis of the branching pattern in *Polyxylon australe* shows that this plant had widely spaced branches borne on slender stems and resembled a liana rather than a small tree. This suggests that, by the end of the Devonian, the Cladoxylopsida had evolved a range of elaborate growth forms and contributed to the formation of complex plant ecosystems.

Meyer-Berthaud B.