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Abstracts

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Silurian calymenid trilobites from eastern and Arctic North America

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Calymenid trilobites have been poorly known in the Silurian of northern Laurentia (i.e., that portion of the palaeocontinent lying to the north of the Transcontinental Arch). Only very recently has material adequate for formal naming been described. Fieldwork in the Cape Phillips Basin of the central Canadian Arctic Archipelago has yielded several well-preserved silicified species, some of which are very similar to material recently described from the Selwyn Basin to the south in the central Mackenzie Mountains.

Most northern Laurentian Silurian calymenid diversity belongs to an endemic new genus, *Arcticalymene*, but some representatives of *Diacalymene* Kegel, 1927, have been recovered. *Arcticalymene* is a highly autapomorphic clade, yet it also displays significant ingroup disparity. It has several features interpreted as homeomorphic with the Baltic *Papillicalymene* Shirley, 1936. The genus was common in the Cape Phillips Basin during the Sheinwoodian and early Homerian, but became extinct during the late Homerian. With its extinction, calymenids disappeared forever from the northern Laurentian record; no later forms are known.

The calymenid faunas of southern Laurentia have little in common with those of the north, but are dominated instead by species of *Calymene* s.s., *Calymene* s.l., and *Diacalymene*, along with other, less diverse groups. An exception is a new species of *Diacalymene* from the Sheinwoodian Rochester Shale of New York, which is exceedingly similar to coeval forms from northern and Arctic Canada. As more data on many different groups become available, it is increasingly obvious that there was little faunal exchange between the northern and southern Laurentian realms for much of the Silurian.

Microbes and mineralization - the fossilization of soft tissues

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The degradation of organisms deposited on or in sediments is extremely efficient and as a consequence very little organic material is incorporated into the geological record (usually less than 0.1% of primary production). In apparent contradiction to this rapid decay are examples of fossilized soft-tissues that preserve detailed information down to the cellular level as a result of replication by early diagenetic minerals. To investigate the preservation of such fossils we have embarked on an experimental study of the timing and controls on decay processes and mineralisation (particularly in calcium phosphate). The decisive conditions appear to be established in the earliest stages of decay when steep chemical gradients are created by microbial activity. Decay experiments with shrimps stabilized in agar gel allow the geochemical gradients generated by cultures of sediment bacteria to be monitored with microelectrodes on a very fine scale over extended periods. The profiles obtained are mirrored by those revealed by the analysis of sediment surrounding some soft-bodied fossils. Such experimental and analytical approaches are the route to understanding the controls on soft-tissue preservation.

Early Paleozoic paleogeography and paleoceanography: Sr and Nd isotope geochemical data from conodonts

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A rich database from worldwide conodont collections from Lower Paleozoic strata has generated new models of ocean systems, in particular using data on conodont paleoecology and paleobiogeography. Conodont apatite appears to retain the original trace and rare earth element signatures that were imprinted during inital burial. Strontium and neodymium isotope analyses have been undertaken using conodonts with predominantly low CAI values. A pattern of seawater history emerges from over 70 Sr analyses: the Early Ordovician is characterized by relatively constant values ($^{87}Sr/^{86}Sr$) of 0.7089; a sharp early Middle Ordovician excursion attains values of 0.7078; a drift back to values of 0.7087 occurs through the Ashgill to early Late Silurian interval. Neodymium isotope values ($^{143}Nd/^{144}Nd$), using over 50 different conodont samples from most of the paleoplates and representing four time slices, reveal broad patterns of discrete ocean masses that can be used to test current paleogeographic reconstructions. The combination of conodont paleobiogeography and conodont Sr and Nd isotope geochemistry provides an improved understanding of Early Paleozoic ocean systems and events.

Micro- and ultrastructure of calcareous annelid-tubes: observed structures and fabrics, and their potential for both taxonomy and palaeoecology

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Examination of numerous calcareous (aragonitic and calcitic) annelid-tubes from the Jurassic to Recent, by means of Scanning Electron Microscopy, has been undertaken to elucidate micro- and ultrastructural elements present.

This study confirms previous assumptions concerning the microstructure of calcareous annelid-tubes, indicating that the majority of such tubes have a chevron-shaped blue-print on which they are constructed, but also recognises the occurrence of other forms (e.g. laminar, and pseudo-laminar). Additionally, further information concerning the finer structural details (ultrastructure), recognises a number of fabric types (e.g. granular, ordered, unordered, semi-unordered, concentric, prismatic, spherulitic and 'acicular').

Both microstructure and ultrastructure are consistent within species, and may possess some use as taxonomic keys for the identification of both modern and fossil calcareous annelid-tubes. However, given taphonomic processes such as changes wrought by recrystallization and weathering, such a use presently appears to be restricted to post-Eocene material.

Detailed information concerning micro/ultrastructure, and particularly the distribution of ultrastructural elements can also be used to indicate likely parameters for tube construction, such as speed of fabrication, degree of applied force, and mobility, which have obvious connotations for palaeoecological study, as well as concerning the nature of the tube constructor, and therefore taxonomy.

Arthropod phylogeny in the light of Cambrian problematica: new evidence from the Sirius Passet fauna

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A great mass of new data has been brought to bear on the problem of arthropod phylogeny in recent years, especially from palaeontological and molecular sources. Whilst it would be wildly over-optimistic to suggest that this has resulted in an arthropod "grand unified theory", at least certain problems are coming into focus.

One such problem is the relationship between the various extant "lobopodian" groups, such as the onychophorans and tardigrades, and the arthropods proper. In recent years, several new lobopod-like taxa have been described from the Cambrian *lagerstätten,* and more await description. Perhaps the most controversial has been the Sirius Passet taxon *Kerygmachela*, which was initially described as a lobopod, and compared with the more arthropod-like *Anomalocaris* and *Opabinia*; although this conclusion has been disputed. Several issues remain to be resolved concerning these taxa, for example, i) are they really related? ii) do they constitute a paraphyletic or monophyletic grouping?, and iii) do they tell us anything about a possible lobopod-arthropod transition?

These issues will be discussed in the light of new anomalocaridid material from the Sirius Passet fauna, and some (perhaps surprising) answers suggested, with interesting, though no doubt controversial, implications for the earliest evolution of the arthropods.

Exceptionally preserved phyllocarids and problematic fossils from Gogo, Western Australia

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The fishes of the Upper Devonian Gogo Formation are well known not least for the remarkable three-dimensional preservation of their skulls. Less well known are the bivalved arthropods from Gogo which comprise about 22% of the fossil assemblage. New species of the phyllocarids (Crustacea: Malacostraca) *Montecaris* and *Schugurocaris* preserve both cuticle ultrastructure and phosphatised muscle tissue. These Gogo taxa prompt a reconsideration of the classification of phyllocarids. The Gogo concretions also yield large specimens consisting only of soft tissue, which were dubbed 'Mushia' by the first expedition to collect fossils at Gogo in 1963. Investigation has revealed cuticle, muscles and other non-mineralized soft tissues. This new evidence shows that the 'Mushia' material includes a number of taxa whose affinities can now be interpreted. The preservation of soft tissues at Gogo rivals that elsewhere in the fossil record.

Biostratigraphic correlation of graptolites, conodonts and corals in the Upper Telychian of Scotland.

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The marine Silurian sediments of the North Esk inlier in the Pentland Hills near Edinburgh are well known for the diversity, preservation and abundance of fossils present. This is only one of a few Silurian sections that contain biostratigraphically significant graptolites, conodonts and shelly fossils.

A moderately diverse coral fauna is present, including important elements of the distinctive later Llandovery - earliest Wenlock suite, such as *Palaeocyclus porpita*, *Angopora hisingeri* and *Favosites multipora*. The graptolites include *Monograptus parapriodon*, *Monoclimacis geinitzi* and *Oktavites excentricus*, some of which have not previously been recorded from Scotland. This assemblage is characteristic of the middle of the *spiralis* interval.

The section from which graptolites and corals are most abundant has been measured and sampled in detail, and conodonts extracted. In the lower part of this section, a low diversity fauna, including the zonal index species *Pterospathodus celloni* and elements indicative of the upper part of the *P. celloni* Biozone is present. Higher up, fragments of *P. amorphognathoides*, typical of low in the *amorphognathoides* Biozone are found. Therefore the boundary between the *P. celloni* and *P. amorphognathoides* conodont Biozones can be identified with some accuracy in this section, and correlated with a subdivision of a graptolite Biozone.

The first dinosaurs from Scotland: A cetiosaurid? (Sauropoda) from the Bathonian, and ceratosaurs (Theropoda) from the Hettangian and Bathonian of the Isle of Skye

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For many years palaeontologists have been searching for the Scottish dinosaur, but it was not until 1982 when the first evidence that dinosaurs inhabited what is now Scotland came to light. A dinosaur footprint was discovered from near the top of the Lealt Shale Formation (Bathonian, Middle Jurassic), Isle of Skye. In the last two years, however, bones of three different dinosaurs have been discovered in Scotland.

In 1994, the femur of a sauropod was discovered in northern Skye by a BP Exploration geologist. The bone was found in rocks of the Valtos Sandstone Formation (Bathonian, Middle Jurassic) near where the dinosaur footprint had been found previously. The specimen had been damaged by a collector who later mailed the missing piece to the Hunterian Museum anonymously. Jan Wolfe of the Oystercatcher Restaurant, Staffin, discovered another fragment yards from the original BP find, now known to be the distal end of the same bone. The caudal vertebra of a small ceratosaur was also found near this site in 1995.

Another limb bone, described as a theropod tibia, was discovered in rocks of Hettangian age (Lower Jurassic) in southern Skye.

These bones represent the first skeletal dinosaur material found in Scotland.

On the occurrence of jaw apparatus in some Sinemurian ammonites from Dorset

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The beautiful preservation of ammonites from nodules occurring in the Obtusum Zone of the Sinemurian (Lower Jurassic) of Dorset has long been recognised. The brown and yellow calcitic moulds complete with body-chambers and intact peristomes are in contrast with the pyritised phragmocones which are preserved in the adjacent mudstones and shales. One of us (JCWC) has recently developed a hypothesis explaining the nodules as representing the sites of burial of live ammonites, whilst the pyritised specimens represent death assemblages. This hypothesis is supported by the occurrence of *in situ* preservation of the jaw apparatus in several genera of ammonites, including examples where both upper and lower jaws are preserved in a virtually undistorted manner.

Conodont Pearls?

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Conodont pearls have been known for some time. First described in 1881, their occurrence in conodont residues has been intermittently recorded since.

The pearls have been attributed to various groups including acritarchs, conulariids and bryozoans, but have subsequently been interpreted by Glenister *et al.* (*Science,* **193**, 1976) as belonging to the conodont animal, based on composition, co-occurrence and similar behaviour in response to thermal alteration. Although the structures are only found in association with conodonts, they are not found in all conodont residues. This led Glenister *et al*. to conclude that they were not vital to the animal and so could be pearls which developed by secretion around an irritation as in the pearls of bivalves.

The morphology, composition and structure of conodont pearls supports an alternative explanation which has implications for the living environment, life history and brain structure of conodonts.

Microfossils join the Megafauna: arthropods from Riversleigh, an Australian Tertiary *Lagerstätte*

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One of the most important Australian fossil assemblages is that recovered from the Tertiary deposits of Riversleigh (Queensland). Famed for its megafauna (including marsupial lions and thingodonts), the fossils of Riversleigh have trebled the mammal record previously recorded for the entire continent. Recent discovery of an insect/myriapod fauna has increased the importance of Riversleigh. These arthropods are significant because the Tertiary record of Australian insects is particularly spartan. So far recovered are beetles (including a larva), a ?dipteran and a myriapod.

The fossils are preserved in 3D as a result of phosphatization of the soft tissues. Original structures are replaced at a resolution of microns. Most remarkable is the preservation of the cuticle and eyes. The cuticle preserves individual layers, pore canals, and even wrinkles in the arthrodial membrane. Eyes, which are rarely preserved in fossil arthropods, except in trilobites, and arthropods in amber, are preserved virtually intact at Riversleigh. The cornea is preserved, the emplacement of the rhabdom is distinct, and one specimen displays bacteria lining the interior. Also, the coleopteran larva preserves a rare 'schizochroal-type' apposition eye.

The depositional environment of Riversleigh is interpreted as a shallow intermittently anoxic, lime-rich pool in a rainforest. A comparison with other fossil examples suggests that Riversleigh represents an important category of insect preservation.

Controls on acritarch distribution

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Acritarchs and algae are believed to be photosynthetic phytoplankton representing the primary producers in the palaeo-oceans. The palaeoecology of these groups has received little attention, although it is accepted that they were at least weakly facies controlled. Several authors have attempted to explain the occurrence of microplankton by proposing models of distribution. Gray & Boucot (1972) proposed a depth stratification model in which different morphological groups occupied different positions in the water column. Jacobson (1979), Dorning (1981) and Dorning & Bell (1987) considered that the distribution of separate morphological groups was affected by water depth and nutrient supply.

The factors affecting the distribution of phytoplankton may result from mode of life (life cycle and phytoplankton size) or from the environment. Physical controls are: temperature, nutrient supply, light, turbidity, water depth and salinity. The distribution of fossil phytoplankton can be compared with modern oceanic studies and the significance of this may be important in the interpretation of paleoenvironments.

The evolution of teredinid bivalves (shipworms)

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The Teredinidae are a group of highly specialized obligate wood boring bivalves, colloquially known as shipworms. In modern oceans, they dominate the exploitation of woody substrates and cause substantial damage to man-made wooden structures. "*Teredo*" is common in the fossil record, for example from the London Clay, where bored wood is preserved exceptionally well within carbonate concretions (Huggett & Gale, 1995). However, the evolutionary history of the Teredinidae is poorly understood. The trace fossil *Teredolites longissimus*, attributed to the Teredinidae, first occurs in the Upper Jurassic, but the oldest teredinid body fossils (calcitic pallets) hitherto described are from the Palaeocene of Iraq. In this presentation, teredinid pallets belonging to the genus *Bankia* are described from the Lower Cretaceous (Albian) Blackdown Greensand of Devon, and the evolution of the teredinids through the Cretaceous is discussed drawing on evidence from this and other teredinid fossils from Western Australia and South Africa.

Changes in acritarch assemblages across the Ordovician-Silurian boundary

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Diverse and well-preserved acritarch assemblages have been recovered from the Upper Ordovician-Lower Silurian carbonate rocks of Anticosti Island, Canada and from subsurface material in Estonia.

The late Ordovician glaciation was a period of falling sea-level and cooling global temperatures. The glacial maximum, during the latest Ashgill, appears to coincide with a turnover and extinction amongst acritarch microflora. Data obtained from Anticosti Island and Estonia indicate that there was selective extinction of certain acritarch groups and temporary disruption of other geographically widespread and long ranging genera. Assemblages in the earliest Silurian were temporarily dominated by opportunistic genera which decreased in significance as new genera appeared to replace those in the groups most severely affected by the extinction.

In comparison, the type Llandovery area in South Wales, yields less well-preserved acritarchs but a similar pattern is observed. Recovery was more rapid, with the introduction of new species occurring at a lower level within the Llandovery. The overall composition of assemblages differs from those of Anticosti Island and Estonia.

Realistic palaeontological reconstructions using computer graphics

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The work presented here is built upon an ongoing project to use computer graphics to reconstruct palaeontological specimens that have been serially sectioned. Its aim is to produce more realistic computer images for visualisation and analysis as well as enabling further modelling work, such as animation, morphometric analysis and evolutionary simulation. One of the main criteria of the project has been to use low-performance (and therefore easily accessible) computer software and hardware. Most reconstructions, made using either specialist bespoke programs or "off-the-shelf" computer-aided design (CAD) packages, are only wireframe skeletons. Although these can be useful for initial analysis of well-sampled objects, further inspection requires non-ambiguous images that have further received processing. The use of hidden line and surface removal, shading textures and lighting can create more realistic images, that are easier for the researcher to comprehend. The images can combined with other media, such as text or photos, be easily distributed in an electronic form and animated to further increase the researchers understanding of shape and form.

The role of palaeontological data in a phylogenetic reconstruction of the Stomatopoda (Crustacea: Malacostraca)

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The Stomatopoda (mantis shrimps) form a distinctive order within the Malacostraca. It is an ancient group of benthic, obligate, carnivorous, crustaceans, of which the recent representatives inhabit the shallow waters of tropical and sub-tropical seas and oceans. The a-taxonomy of this group is nowadays well established. The order contains about 400 species, subdivided in 5 superfamilies. In spite of several studies on speciation processes, ethology, functional morphology, and the advanced neurophysiology of their visual systems, the phylogeny of the stomatopods still remains unresolved.

Palaeontological information may contribute significantly to the resolution of this group's phylogeny. Up till now, however, the fossil record of stomatopods was characterised as scarce and fragmented.

A search for fossil stomatopods amongst the collections of several museums resulted in a considerable number of new species. Also the re-examination of fossil stomatopods, most of them described at the end of the nineteenth century, revealed important information.

A cladistic analyses of the characters from both Recent and fossil stomatopods demonstrates in which way palaeontological data may, or may not, contribute to the resolution of this group's phylogeny.

The cephalopod Order Actinocerida in the Silurian

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The cephalopod Order Actinocerida flourished during the Ordovician Period. They continued until the Carboniferous, but with more modest success. In the British Silurian they are uncommon and often ill preserved. Their taxonomy and distribution, both stratigraphical and geographical, are reviewed and a few comments made upon comparisons with other parts of the world.

Developmental flexibility in the Silurian trilobite *Aulacopleura konincki*: possible implications for the Cambrian radiation

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Recent work has suggested that some Cambrian trilobites are morphologically plastic when compared with later forms. This generalization was tested by examining growth and variation of the Silurian proetide *Aulacopleura konincki* and comparing the results with Cambrian trilobites, and Silurian trilobites from the same beds. This taxon was selected for its homeomorphy with primitive "ptychoparioid" trilobites common in the Cambrian.

Morphometric analysis of growth in *A. konincki* reveals several important features: 1. the morphological variability is approximately constant at each stage; 2. shape tends to be more tightly canalized than the numbers of post-cephalic segments, which can be quite variable; and 3. there is a major ontogenetic transition that occurs at glabellar lengths of about 1.7 mm. This transition divides the ontogeny into two distinct growth phases, is smooth rather than abrupt, and is expressed as changes in overall growth patterns, especially in the pygidium. The transition is not strictly correlated with the number of thoracic or pygidial segments. These results suggest a re-evaluation of the concepts of meraspid and holaspid growth stages in trilobites, using growth trajectories rather than thoracic segment number to define the stages.

A. konincki was developmentally flexible as some Cambrian trilobites, but it does exhibit striking

variability, especially in segment numbers, and the patterns contrast with those of the other Silurian taxa collected from the same beds. Phylogenetic analysis shows that the homeomorphy with the Cambrian forms is covergent, which may imply that developmental flexibility is a general characteristic of taxa assuming the morphotype. If morphology is indeed a proxy for ecology, then developmental plasticity in Cambrian "ptychoparioids" may be an environmental response. This is being tested through analyses of the relationships between plasticity and phylogeny in the taxa co-occurrent with *A. konincki*.

Tall tales from the west

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Crinoids formed the upper tiers of many late Palaeozoic epifaunal, suspension feeding, benthonic communities. In the Carboniferous the highest tier usually consisted of crinoids with stems around 1m long. The most abundant disarticulated columnals from the Bundoran Shale (L. Carboniferous; Arundian) at Bundoran, County Donegal are derived from columns that attained a length of nearly 2m or more. Several stems, none of them with crown attached, occur aligned on a bedding surface, apparently as a result of transport by storm generated currents. Two show the distal end of the column and holdfast which consisted of several stout radicular cirri. The columns are straight, or in one case very slightly flexed, and probably were vertical throughout their length in life. They almost certainly belonged to a cladid crinoid. Columns of such length pose questions regarding the maximum current velocities that the crinoid could have experienced without being dragged free of its anchorage.

Rhabdosporites langii, *Geminospora lemurata* and *Contagisporites optivus*: an origin for heterospory within the Progymnosperms

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A major Mid Devonian floral event is the incoming and proliferation of the archaeopteridalean progymnosperms. They are generally accepted to have originated from the aneurophytalean progymnosperms. The spores from both groups (the microspore *Geminospora lemurata* and its megaspore *Contagisporites optivus* - Archaeopteridales; *Rhabdosporites langii* -Aneurophytales) are well represented in the Orcadian Basin, Scotland. Study of a long section in southern Orkney shows that *G. lemurata* first occurs not by progressive size reduction of *R. langii* but as a small thick walled spore ('early form') which is presumed to originate by heterochrony directly from an immature *Rhabdosporites*. It then progressively increases in size. This early stage of evolution can be timed using the lacustrine cyclicity. Subsequently a rapid increase in abundance occurs with *G. lemurata* replacing *R. langii* as the dominant element of the palynofloras. Originating after the first appearance of *G. lemurata* are spores transitional in morphology between *R. langii* and *C. optivus* indicating the progressive development of the megaspore. These changes together with the presence of a three walled species of *Rhabdosporites* give a hint of the complex changes occurring within the sporangia of the archaeopteridalean group at this time. These changes show how detailed investigation of related spore taxa can reveal the pattern of the development of heterospory in the progymnosperms.

This permits for the first time a test of the theoretical models for the development of heterospory. The recognition that an 'early form' of *G. lemurata* exists indicates that some caution should be exercised in using the first occurrence of this species as a stratigraphic marker.

Biotic response to Plio-Pleistocene climate change in a New Zealand invertebrate fauna

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The Wanganui Basin, North Island, New Zealand (3.6 Ma - Recent) is particularly suited to study of biotic response to large scale physical environmental changes because it contains abundant invertebrate macrofaunas exhibiting wide environmental tolerances as a group but including taxa with more limited tolerances, excellent preservation potential, high species diversity and well-understood ecological characteristics. Good independent stratigraphical control is provided by several means and there is independent evidence for environmental change from sedimentology and isotope geochemistry.

Preliminary analysis of a database of approximately 1000 molluscan taxa occurring at 264 localities from 65 horizons, including 35 highly fossiliferous marine shellbeds, reveals an episode of marked faunal turnover at about 1.0 Ma, approximately contemporaneous with excursions in $^{87}Sr/^{86}Sr$ ratios and $d^{18}O$ values measured in shells which may be of global significance. Two alternative preliminary hypotheses are suggested: Wanganui faunal turnover may be linked to a global event involving major fluctuation in input of terrestrial weathering products into the ocean and a simultaneous temperature drop, or alternatively may be the result of more localised causes, such as the arrival of the cold Antarctic current on New Zealand's W coast or perturbations due to eruptions of the Taupo Volcanic Complex.

Phanerozoic atmospheric CO2 concentration as indicated by stomatal parameters in fossil plants

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It is now widely accepted that atmospheric carbon dioxide has fluctuated extensively through the Phanerozoic. Physical lines of evidence including carbon cycle modelling and carbon isotopic analysis have demonstrated peaks of elevated CO2 as high as 17 times the pre-industrial atmospheric CO2 concentration of 280umol/mol. We make the assumption that the negative correlation between stomatal density (the number of stomatal pores on the leaf surface per mm^2) and atmospheric CO2, which has been firmly established in living plants and fossil leaves from the Quaternary and Tertiary, also holds for the whole of the Phanerozoic. Extremely low stomatal densities and indices have been observed in the Devonian, Jurassic and to a lesser extent Eocene species studied compared with those of their selected nearest living equivalent species from the present day. These data are consistent with elevated CO2 concentrations at those times inferred from the physical evidence. In contrast we have recorded very high stomatal density and index data from fossil plant species which developed during the suggested low CO2 atmosphere of the Carbo- Permian glaciation. In this sense we have provided biological data which is consistent with the existing physical data. We have therefore shown that stomatal data from fossil plants of Devonian, Carboniferous, Permian, Jurassic and Eocene times may be used to indicate the palaeo-atmospheric CO2 concentration under which they grew and developed.

A New Discovery of Ediacaran Body and Trace Fossils

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Body and trace fossils in the Clemente Formation of northwestern Sonora extend downward the geologic range of convincing specimens of the Ediacaran biota. Taxa present in this formation include a cyclomedusid, a sekwiid, an erniettid, a possible eoporpitid, and several different species of bedding plane trace fossils. These fossils record the earliest known diverse community of megascopic eukaryotes. The ichnofossil evidence indicates that infaunal animals were part of this shallow marine community.

Body fossils from the Clemente Formation occur up to 75 meters below a distinctive oolite in the Clemente Formation. This oolite permits long-distance correlations between strata of Mexico and the United States. Correlations utilizing both this oolite and a distinctive trace fossil known to occur in both eastern and western North America confirm the antiquity (approximately 590 million years) of the body fossils.

Extinction and survivorship of bivalves across the Triassic-Jurassic boundary in Alpine Europe

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The end-Triassic witnessed one of the five major Phanerozoic extinctions affecting marine and non-marine organisms. Bivalve molluscs from Alpine Europe provide a signal of selective extinction allowing a test of two hypotheses invoked to explain the crisis: (i) changes in sea-level with associated anoxia; and (ii) a productivity decline.

Rhaetian bivalve communities are dominated by either (i) diverse infaunal and epifaunal bivalves representing normal marine shallow subtidal conditions, or (ii) epifaunal zooxanthellate(?) megalodontid dominated communities representing restricted peritidal conditions. In most Triassic/Jurassic boundary sections, bivalves occur in pre-Planorbis beds recording the recovery fauna following the end-Triassic mass extinction. The pre-Planorbis bivalve communities are dominated by epifaunal filter feeders such as *Chlamys*, *Plagiostoma*, ostreids and, at few localities, infaunal *Cardinia*. Abundant and diverse bivalve communities frequently appear less than 2 meters above the base of the pre-Planorbis beds or in the first shallow subtidal beds above intertidal facies suggesting the recovery was fairly rapid. The Hettangian bivalve faunas contain less than 30% holdover taxa from the Rhaetian; all of which are epifaunal filter-feeders. Alpine survivors are all epifaunal suspension feeders.

Short-lived changes in relative sea-level cannot account for the magnitude and mode of extinction. The selective survival of epifaunal taxa is attributed to their more efficient feeding capacity during a productivity crisis rather than selective resistance to anoxia or competition for ecospace.

Invertebrate palaeoecology in the northern Red Chalk

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The Red Chalk (Hunstanton Formation) represents a distinctive succession of marls and chalks that was deposited in NE England from mid Albian to early Cenomanian time. Studies have been undertaken of three contrasting environments: a shallow water - littoral environment (Rifle Butts); a shallow water shelf dominated environment (South Ferriby); and a deep-water basinal environment (Speeton). These different environments are illustrated by studies on the stemmed crinoids. The crinoids *Hemicrinus* and *Apiocrinites* are common in the shallow water section at Rifle Butts where they probably lived attached to exposed Jurassic hardgrounds or Cretaceous stromatolites. The isocrinid diversity in the storm-dominated shelf deposits at South Ferriby is relatively high (2 to 5 species in each sample). The deep-water isocrinids from Speeton have low diversity (dominated by a single species). Many isocrinids appear to show adaptions to their environment. Other groups also show environmentally controlled distribution, and some of these will be considered.

Palaeontology of the Lower Cambrian Emu Bay Shale fossil *Lagerstätte*, Kangaroo Island, South Australia

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The Emu Bay Shale fossil *Lagerstätte*, at the Big Gully site on the north coast of Kangaroo Island, correlates with the Tsanglanpuian of China (Botomian of Siberia) using contemporary faunas, and is thus slightly younger than the more famous Chengjiang *Lagerstätte* from Yunnan, China. Common elements of the fauna are the trilobites *Redlichia takooensis* and *Hsuaspis bilobata*, the most common forms; the phyllocarids *Isoxys communis*, rare specimens of which have eyes preserved, and *Tuzoia australis* and the enigmatic form *Myoscolex ateles*. The rest of the fauna is comprised of the much rarer *Naraoia*, *Anomalocaris briggsi*, *Anomalocaris* sp., *Xandarella* sp. and the presumed worm *Palaeoscolex antiquus*. No sessile forms have been found.

The fauna is characterised, in some cases by large size, but overall by an unusual preservational style, namely red-stained fibrous calcium carbonate. The exception is *Myoscolex* which is composed of phosphatized muscle blocks, which is the earliest example of phosphatized muscle tissue in the fossil record yet identified. The appendages of *Myscolex*, only very rarely preserved, suggest an affinity with the Middle Cambrian form *Opabinia* rather than with the annelida as previously suggested. The Emu Bay Shale assemblage confirms the cosmopolitan nature and diversity of Lower-Middle Cambrian forms.

Exceptionally preserved conchostracan branchiopods (Arthropoda: Crustacea) from the Moyadd Coal Formation (Namurian-Westphalian) in the Castlecomer Coalfield, Ireland

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Conchostracan branchiopods are small crustaceans; the carapace is bivalved, hinged in the midline, and encloses the head, trunk and appendages. Typically, the carapace is all that is preserved in the fossil record, often as isolated valves. These specimens are one of few known examples in which the appendages have been preserved.

Among the set of specimens available, the most frequently preserved parts are the antennae, mandibles, claspers and telson with anal spines and caudal furcae. Trunk appendages are occasionally preserved. This may reflect their originally having been composed of a less labile tissue (chitin), which acted as a template for mineral precipitation.

The exceptional preservation of these specimens (e.g. preservation of spines on the segments of the antennae) implies minimum post-mortem transport; the exact depositional setting remains to be elucidated. Extant conchostracan branchiopods are typical of continental settings, but can withstand a range of water pH's and salinities; in the fossil record, examples of their carapaces can occur with marine faunas.

The trilobites and brachiopods of the Wrae Limestone - making more and more from less and less in the Ordovician of the Southern Uplands

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The Wrae Limestone is a conglomerate within probable Ashgill (late Ordovician) siltstones near the southern edge of the Northern Belt of the Scottish Southern Uplands. Its interpretation exemplifies problems common to many orogens - separation of lithoclast age from timing of final emplacement, separation of biofacies from temporal faunal correlation and the use of biofacies in determining provenance. Most of the macrofossils were recovered over a century ago when the limestones were worked and as understanding the tectonic significance of the Wrae Limestone has become more important, the amount of macrofaunal evidence has diminished. The trilobites are closest to those of the early Caradoc of Girvan, north of the supposed Southern Uplands - Midland Valley terrane boundary. The edge of the Midland Valley platform may thus have been the source of the carbonate clasts. Some of the trilobites range through the spectrum of biofacies present in the Lower Caradoc of Girvan. However, species of *Phorocephala* and *Dubhglasina* suggest deeper waters than those supporting the illaenid/cheirurid association, possibly at the margin of the *Nileus* association. The brachiopods are more enigmatic. As a whole, the assemblage is not directly comparable with any faunas in the Girvan-Appalachian belt. It is dominated by coarse ribbed orthoids, smooth triplesiids and several plectambonitoids, having more in common with later Ordovician brachiopod biofacies associated with carbonate mudmounds. Such faunas are much less well known than their siliciclastic counterparts.

What maintains stasis in the fossil record?

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Last year I argued that stasis dominates the fossil record. Nothing since has caused me to change my

mind, but the question remains "what maintains stasis?" Only the effects of selection are amenable to test in the fossil record. Effects of selection are predictable for any measurable, continuously variable character, such as size. Directed selection should shift the mean, increase skew and probably increase kurtosis, whereas stabilizing selection should maintain the mean, increase kurtosis, but not affect skew. Random mortality should not change mean, kurtosis or skew. If stasis in the fossil record results from time averaging of variations in the direction of selection, then directed selection should dominate modern populations but fossil samples should show the effects of random mortality. Thus to test whether or not selection maintains stasis in the fossil record requires data on the relative frequency of stabilizing versus directed selection in both modern and fossil populations. A few examples of what we expect to find are not enough.

Planktonic foraminifer biostratigraphy of pelagic caps on Marshall Islands Group guyots

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Pelagic accumulations on small flat-topped sea mounts (guyots) provide the only opportunity for coring carbonate oozes across large areas of the Pacific Ocean. During ODP Leg 144, three guyots (Limalok, Lo-En and Wodejebato) were drilled in the Marshall Islands area .The general morphology of their pelagic caps had suggested that winnowing and reworking might be prohibitively severe for palaeoceanographic study. The initial aim was therefore to determine to what extent internal stratigraphies are preserved.

The oozes are exceptionally homogeneous, pure and unconsolidated. It was disheartening to see the sediment slopping up and down inside the core-liners when laid out on deck. All sedimentary structures were obliterated. Massive down-hole caving between strokes of the piston-corer was unavoidable. Biostratigraphy was therefore the only fruitful method for further investigations.

Planktonic foraminifer studies have permitted detailed stratigraphies to be developed. Despite local differences, there is a general similarity in the development of the pelagic caps through three distinct phases. Backtracking of subsidence curves reveals the approximate depth at which sediment accumulation began. Although high-resolution stratigraphy is impossible, spectacular carbonate preservation means that the pelagic caps are invaluable for longer-term taxonomic, palaeoceanographic and geochemical studies.

Conodont Vision, Locomotion and Foraging Strategies

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Until very recently, interpretations of how conodonts lived were pure speculation, but the last few years have seen an enormous increase in our knowledge of conodont anatomy and functional morphology. We now know that conodonts were elongate, eel-shaped, jawless vertebrates with a ray supported caudal fin, V-shaped myomeres, eyes, and a mouth containing an anterior bilaterally operating raptorial apparatus and posterior occlusal teeth.

From this evidence we can reconstruct conodonts as active, swimming animals, propelling themselves along the sea floor or through the water column by anguilliform undulations of their body. The absolute and relative size of their eyes, coupled with the recently documented evidence of extrinsic eye musculature, indicates that conodonts had good vision, probably comparable to that of lampreys. Conodonts had a simple body plan, and given this morphological constraint it is unlikely that they were able to adopt foraging strategies linked to locomotor specializations. Similarly, suction feeding, the means by which most extant aquatic predators acquire their food, was probably not possible. The complexity and diversity of conodont apparatuses may reflect the need to compensate for these anatomical limitations through the evolution of specialized mechanisms for food capture and trituration.

High resolution stable isotopes and Eocene Nummulites

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Nummulites is a large foraminiferan that lived in shallow water tropical/ subtropical conditions through the Palaeogene. Diversity, size and morphological complexity peaked in the middle Eocene, followed by decline through the late Eocene and extinction in the middle Oligocene. Recent relatives harbour diatomaceous symbionts, so fossil *Nummulites* provide a chance to study the evolution and palaeobiology of a photosymbiotic association. Stable isotopes from test calcite are being used to explore the palaeobiology, symbiosis and changing environments through their evolution.

Hitherto, whole specimens of measured size have been analysed ('bucket chemistry'). Such studies reveal great spatial variation in $d^{13}C$ and $d^{18}O$, related to water mass chemistry (cf. modern Florida Bay). *Nummulites prestwichianus* from the Barton Clay Formation (upper middle Eocene) of the Hampshire Basin, show signals like those of modern symbiont-bearers, with $d^{13}C$ progressively heavier with growth, and $d^{18}O$ varying seasonally. Current studies are of single whorls or chambers (e.g. *N. laevigatus*, Bracklesham Beds; *N. obtusus*, W. India), plus comparable studies of living *Amphistegina*. The aim is to ascertain the lifespan and seasonal environmental variation, from evolutionary climax to extinction.

Camel-spiders and cladograms

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Some new specimens of Palaeozoic spiders and the first Mesozoic solpugid (Camel-spider) show interesting phylogenetic and biogeographic relationships to known fossil and Recent spiders and solpugids. The fossil solpugid, from the Cretaceous of Brazil, belongs to the extant southern African family Ceromidae, which may have had a pan-Pangaean distribution at that time. Many previously described Palaeozoic spiders (Araneae) do not show autapomorphies for the group, so they may not be true spiders. The new specimens help to clarify relationships amongst Palaeozoic Araneae and their relatives. Whilst stratigraphic data cannot be used to construct cladograms of (extant or extinct) taxa, well supported cladograms can predict the relative time of origin of clades. Fossils provide the only direct means of estimating the longevity of clades and constructing evolutionary trees.

Phylogenetic relationships among Ordovician crinoids

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The diversification of crinoids from their first appearance in the Tremadoc was rapid with most of the major Palaeozoic clades present by the late Ordovician. However, the character of the fauna, particularly during the early to mid-Ordovician interval, differed markedly from that throughout the remainder of the Palaeozoic. In addition to the major clades there were a number of minor groups of apparently 'aberrant' morphology, among them the hemistreptocrinids, hybocrinids, *Ramseyocrinus* and *Colpodecrinus*. Cladistic analysis of these crinoid 'oddities' has enabled them to be placed within the current crinoid phylogeny and indicates that their unusual morphology is a consequence largely of the retention of plesiomorphic characters, lost in other early taxa, and the misinterpretation of cup plate homologies. There is no evidence for greater morphological disparity among crinoids during the Ordovician or for a period of experimentation in crinoid design.

Discovery of poppy fruits (Papaveraceae) in the Late Cretaceous

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Fossil fruits now assigned to the form genus *Palaeoaster* have been described in the paleobotanical literature five times since the previous century. Two wildly disparate systematic placements have been proposed and rejected: Eriocaulaceae, a monocot family, and Sterculiaceae, a dicot family in the subclass Dilleniidae. Based on a comparative analysis of over 200 fossil fruits referable to *Palaeoaster*, including several specimens of extraordinary preservational quality, this genus can be unequivocally placed within the extant Papaveraceae (Ranunculidae). A preliminary cladistic analysis of fruit morphological and anatomical characters places this fossil genus within the subfamily Papaveroideae. Both the morphology and the taxonomic placement of this fossil support a controversial hypothesis (recently taken up by P. K. Endress) of the

evolution of syncarpy, a character of most angiosperm fruits and one that is generally considered to be of major evolutionary significance.

The Hunsrück Slate Fossil-*Lagerstätte*: Depositional Setting and Taphonomy

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Previous models for the deposition of the Lower Devonian Hunsrück Slate, a *Konservat-Lagerstätte* famed for the pyritisation of soft parts, have ranged from mud flats to bathyal depressions. New evidence reveals that deposition occurred just below the storm wave base (SWB) on the lower part of a prograding sedimentary fan. The dominant deposit is fine grained turbidites. Above the SWB the water column was fully oxygenated, and the slates are characterised by the presence of shelly lenses. Below the SWB the water column was oxygen depleted. Anoxia occurred just below the sediment water interface, as evidenced by the occurrence of phosphatic nodules and diagnostic trace fossils.

The majority of the Hunsrück Slate trace fossils are post-depositional, the organisms thriving in temporarily elevated oxygen levels following the deposition of turbidites. The two most abundant traces are *Chondrites* and pyritised *Planolites*. The lowest oxygen levels are represented by *Chondrites*-dominated lithologies, while *Planolites* (the closed burrow of an infaunal deposit feeder) reflects enhanced sedimentary oxygen levels on a minor depositional lobe. Most of the epifaunal trace fossils are the work of arthropods. These show various adaptations to sifting the unconsolidated sediment at the top of turbidites.

Clearly the Hunsrück Slate sea contained sufficient oxygen to support a scavenging and deposit feeding benthos. This factor must be taken into account in interpreting the pyritisation of both organisms and their traces.

Genetic algorithms in palaeontological modelling

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Genetic algorithms are iterative procedures for finding optimal solutions to non-linear numerical problems. The essence of the method is to represent possible states of a system as strings of binary characters and allow solutions to evolve in a manner analogous to real genetic systems, incorporating selective reproduction, crossover and mutation.

It is claimed that the method is more efficient than rival techniques for solving complex problems and there are many potential uses in standard numerical analysis in palaeontology. More interestingly, genetic algorithms can be used to optimise computer simulations of morphologies that occur in the fossil record. This can lead to functional interpretations: the criteria by which a computer model is optimised may be analogous to the circumstances driving evolution.

Initial experiments have found the optimal morphologies for dichotomously branching organisms under various conditions and constraints. Investigations of more complex forms are feasible provided that: 1) the morphology is amenable to numerical description; 2) numerical criteria can be defined to discriminate successful from unsuccessful morphologies. Candidate groups for study include ectocochliate cephalopods.

What makes a fossil bone? Diagenesis of the inorganic phase of bone mineral

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Recently much attention has been given to the chemistry of fossil bone mineral. This is due in part to the possibility of using trace element and isotope chemistry of fossil bone to elucidate aspects of vertebrate biology, and in part due to the possibility of retaining original organic molecules in fossil bone. Very little is known however, about the processes of change involved in the fossilisation of bone, particularly the effect of environment on trace and major element substitution in bone apatite. Work in progress at Bristol is beginning to unravel some of the processes which convert recent to fossil bone mineral, and also suggests some potential taphonomic tools, such as chemical indicators of reworking within vertebrate assemblages.

Ecosystem recovery after the end-Permian mass extinction

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The end-Permian mass extinction was the largest such event in the entire Phanerozoic. In the marine realm, over 90% of species were wiped out. Recovery of the fauna was apparently very slow, with "complex" ecosystems such as reefs not appearing until the Middle Triassic. New data from northern Italy (Lombardy, Dolomites and Carnic Alps) and Slovenia show that recovery began much earlier in western Tethys.

The Griesbachian is dominated by a low diversity, high abundance fauna (e.g. *Lingula*, *Claraia*) which is characteristic of opportunistic blooms in an otherwise stressed environment. The presence of "disaster" taxa such as stromatolites and *Earlandia* is also noticeable. Trace fossils are very small and rare, and coupled with sedimentological data suggest widespread anoxia. This conclusion is supported by independent data from gamma-ray spectrometry of the units.

The end-Griesbachian and lower Dienerian show a return to normal oxygenation. The disaster taxa are no longer seen, and although *Lingula* and *Claraia* are still present, other benthos (especially gastropods and echinoderms) have appeared. Recovery can be documented in the trace fossil assemblages, and a modest level of tiering re-appears.

Recovery drops off in the Smithian, due to a return to stressed conditions. The fauna at this time is dominated by small bodied ophiuroids and small, infaunal bivalves. The sediments show that there was high input into the basin, producing turbid and possibly brackish conditions.

By Spathian times the ecosystem is back to normal conditions. There is a large burst of radiation throughout the fauna. There is evidence of tiering above and below the sediment and ammonoids make a return to western Tethys. This recovery continues up into the Middle Triassic.

Vertebrate palaeoecology of the northern Red Chalk

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Bulk sampling of the marls and marly chalks of the Red Chalk has yielded a varied vertebrate fauna, in particular an assemblage of at least 20 taxa of small to medium sized sharks. The bulk of these forms are of very modern affinities, in many cases allowing direct comparisons of the ecological requirements of extant and fossil species. Comparisons between the faunas of the shelf setting at South Ferriby and the basinal environment at Speeton show a higher diversity and abundance of small benthic generalists (squalids, scyliorhinids and orectolobids) at Speeton, with more active hunters (lamnids and mitsukurinids) at Ferriby. This northern fauna as a whole also differs from that of the Gault of southern England, notably by the extreme abundance of *Hexanchus* in the Red Chalk, suggesting biogeographical as well as ecological factors were affecting shark distribution in the mid Cretaceous.

A general summary of the palaeoecology of the Red Chalk will be provided.

Skeletal Ultrastructures and their Preservation in Stenolaemate Bryozoans

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The ultrastructure of the calcareous skeleton of bryozoans provides a rich, but hitherto much neglected, source of phylogenetic characters. High resolution SEM studies of growth surfaces (rather than fractured or cut/polished sections) of calcitic stenolaemate bryozoans have revealed a broad range of ultrastructural fabrics including granular, fibrous, foliated, planar spherulitic and semi-nacreous. A comprehensive analysis of stenolaemates has shown that all have multi-layered skeletal walls comprising combinations of up to four distinct fabrics. The order of succession of fabrics within the walls follows consistent patterns which can be defined as fabric suites. All ultrastructures have distinctive fine-scale features, including terminal interfacial crystallites angles, growth parallel lineations and surficial spikes. Crystallographic orientations vary greatly between the different fabrics. Quality of ultrastructural preservation varies widely in fossil stenolaemates. In the best preserved examples, wall surfaces may show well-defined crystallites directly comparable with modern fabrics. Interfacial angles may be preserved as may features such as minute surface spikes. Well preserved skeletal ultrastructures can be valuable in determining the phylogenetic affinities of extinct taxa (e.g. Mesozoic melicerititids) and may contribute to the debate concerning the monophyletic or polyphyletic status of post-Palaeozoic stenolaemates.

La Voulte-sur-Rhone (Callovian): fossilized soft tissues from a "toxic sludge"

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The Jurassic (Callovian) shales and siltstones of La Voulte (Ardeche, France) have yielded a diverse and exceptionally well-preserved marine fauna including the oldest recorded octopus. The sediments were deposited in a small, fault bounded basin with bottom waters periodically oisoned with sulphides and heavy metals. The prolific fauna is dominated by three dimensionally preserved worms, ophiuroids, naked cephalopods, Bositra and Crustacea (including thylacocephalans). Soft tissues are preserved in abundance by a complex combination of apatite, calcite, pyrite and galena. Quartz, sphalerite and other metal sulphides are also commonly associated with the fossils. Their relationship to one another records the progressive changes in chemistry of the decaying carcasses with time and suggests that fossilization was controlled by volcanic (?hydrothermal) activity. EDAX elemental maps of sections through several fossils indicates that pyrite (except when associated with structural soft tissues such as the endoskeleton of crustaceans) is secondary after apatite and calcite. This has important implications for interpreting the timing and process of mineralization of soft tissues in other fossil biotas.

Following in Hitchcock's Footsteps - Trackways from the Connecticut Valley, U.S.A.

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Fossil trackways have been known from the early Jurassic Newark Supergroup lake shore sediments of the Connecticut Valley, eastern USA, for more than 150 years. They record the activity of dinosaurs, small vertebrates and invertebrates. Animal body fossils are rare and generally badly preserved. The remains of plants may also be found, usually in the form of impressions. The faunal assemblage is unusual in that vertebrate and invertebrate trace fossils occur in association, revealing a more complete picture of the palaeoecology of the area than is usually available. While the dinosaur trackways have received much attention, the invertebrate traces have largely been neglected since their original description by Edward Hitchcock, over a hundred years ago. Hitchcock recognized 23 ichnogenera and 35 ichnospecies of invertebrate trackways made by insects, myriapods and "worms".

Actualistic experiments have allowed a reassessment of the traces and tracemakers. Using present day arthropods and varying environmental conditions it has been possible to gauge the relative importance of substrate condition, mechanisms of preservation and taphonomic effects, on the final trackway. Combined with cluster analysis, these experiments help to clarify the interrelationships of the trace fossils.

The Balladoole 'coral': an arboreal Carboniferous bryozoan in disguise

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Michelinia balladoolensis, originally described by John Smith (1911) from the Lower Carboniferous of the Isle of Man, is an unusual fossil with a distinctive morphology. Smith regarded it as a tabulate coral, but subsequent workers have tentatively assigned it to the conulariids or to the Bryozoa. Restudy of the type specimens, together with material from the Hotwells Limestone of the Mendips, the Asbian of Armagh, and newly collected specimens from the Bee Low Limestones of Derbyshire, demonstrates that *M. balladoolensis* is a cystoporate bryozoan provisionally referable to *Meekoporella*. Colonies of *Meekoporella balladoolensis* comprise small inverted pyramids, open-ended and typically five-sided; compound colonies are constructed of clusters of contiguous pyramids. The walls of the pyramids consist of bifoliate sheets joined along their edges. Feeding zooids open both on the inside and outside of the pyramids in 3 mm wide strips separated by narrow furrows (maculae) devoid of feeding zooids. These maculae were formerly interpreted as the septa of the coral. Colonies were apparently arboreal, living attached to crinoid stems or other cylindrical substrata which supported them some distance above the sediment surface in reefal settings.

Reserve Talks

Lower Ordovician conodont biostratigraphy and paleoecology of northern Laurentia

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The northern half of Laurentia straddled the paleoequator during the Early Ordovician and was subjected to a series of transgressive-regressive cycles. Superbly exposed stratigraphic sequences have been intensively sampled for conodonts especially in the Newfoundland Appalachians, the Arctic Islands, and the Western Cordillera. Broad reconstructions of the carbonate platform/shelfbreak/slope facies and conodont biofacies are possible. The latest Cambrian and Early Ordovician was a period of rapid evolution and diversification for conodonts within a framework of strong faunal provincialism. A refined biozonation has been developed for the Midcontinent Realm faunas and improved ties are now possible to the North Atlantic Realm biozonation. Paleoecologic studies of the abundant faunas are beginning to reveal the pattern of biofacies along the environmental gradients and the complex adjustments forced by eustatic, tectonic and evolutionary events.

Is the fossil record good enough?

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Palaeontologists assume that the fossil record gives a reasonable outline of the history of life, whereas many biologists (and creationists) assume the exact opposite. Palaeontologists must prove that it is legitimate to draw conclusions of a narrative nature from the fossil record, such as patterns of palaeobiogeographic distribution, stratophenetic lineages on a fine scale, and ancestor-descendant successions on a larger scale. The fossil record cannot be tested directly as an indicator of the true pattern of the history of life, but indirect tests are possible if it is acepted that stratigraphic, cladistic, and molecular data on the order of occurrence of taxa are independent. Comparative studies of this kind have shown that (1) cladistic and stratigraphic data on the order of appearance of clades correspond, (2) knowledge of the fossil record of tetrapods has improved by 5% in the past 26 years of research, and (3) the fossil record of continental vertebrates is as good as that of (marine) echinoderms. These comparisons are extended now by studies of fishes and arthropods, and overall the news is gratifying to palaeontologists.

There is now a body of quantitative evidence about the quality of large parts of the fossil record, and a series of tests that may be applied to other groups. The fossil record is adequate as a source of narrative data on the history of life, and different parts of the fossil record, preserved in different settings, seem to be equally good. Further, the labours of palaeontologists in discovering new fossils, and in revising phylogenies and stratigraphic data, apparently improve the quality of that data source.

Patterns of Evolution and Environmental Change in the Lower Chalk

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Orbitally induced chalk/marl cycles in the Cenomanian of the Anglo-Paris Basin provide an outstanding stratigraphic control for assessing patterns of morphological change on varying time scales.

Multiple morphological characters of "infaunal" (*Tritaxia pyramidata*) and "epifaunal" (*Lenticulina rotulata*) benthic foraminifera have been measured from samples taken at twenty thousand and one hundred thousand year intervals in three laterally equivalent sites.

One of the aims of the study is directed to testing Sheldon's model of environmental stability and evolutionary pattern. The model suggests that evolutionary patterns tending more toward stasis and occasional punctuation are to be found within unstable and widely fluctuating environments where generalist and "all purpose" morphologies are selected for, whereas patterns more similar to phyletic gradualism occur when the environment is stable enough for specific selective pressures to be tracked consistently.

The sections chosen for study provide a range of environmental stability which has been assessed by micropalaeontological means to supplement the numerous physical and palaeontological studies available in the literature.

The Cybelinae: From trilobites to tectonics.

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The taxonomy, and inter-relationships through time, of members of the sub-family Cybelinae are assessed using a combination of cladistics, phenetics and stratigraphy. The original taxonomy of this sub-family is retained. Early genera of this essentially marginal cratonic/ocean island group were geographically widespread at low palaeolatitudes, independently giving rise to several daughter genera. This primarily occurred during an intense mid Ordovician radiation event.

The evolutionary and dispersal patterns discerned are related to continental movements and their timing, also assisting in the placement of individual terranes. These patterns provide a source of primary data and act as an independent check on palaeocontinental reconstructions made using other techniques such as palaeomagnetics and structural geology. These results arefound to favour some reconstructions over others.

Posters

Irish Carboniferous Ichthyoliths

Mags Duncan
Department of Geology, Trinity College, Dublin 2, Ireland

Problems with *Gnathodus*

Davida Geraghty
Department of Geology, Trinity College, Dublin 2, Ireland

The Case of the missing Carbon (or, what really happened at the end of the Ordovician)

Jim Marshall, Simon Mitchell and Charlie J. Underwood

Department of Earth Sciences, University of Liverpool, Brownlow Street, Liverpool, L693BY, UK.

The influence of environmental change on microevolutionary patterns in the Oxford Clay

Jane Wares
Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, England.

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