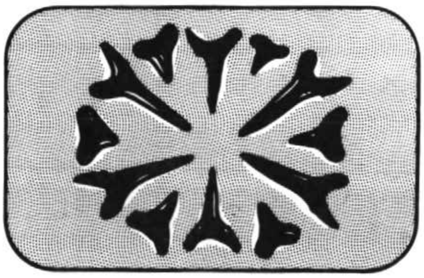
# Articles



## PALEOSCENE Introduction. Paleontology: Ancient and Modern†

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### Introduction

My purpose is to introduce a series of articles on paleontology that will appear in *Geoscience Canada* over the next several issues. The series is designed to provide brief modern syntheses of a variety of paleontological topics. Articles are intended to be sufficiently general to be read by non-paleontologists who wish or need to be well informed about paleontology. The papers will not necessarily be review papers; some will elaborate one particular view of a controversial subject, although opposing viewpoints will always be cited. In this way, the reader will be provided with an up-to-date assessment of each subject. Collectively, the papers will be a review of current concepts, ideas and research methods in paleontology. As such, the series will present ideas that are more current than those usually provided in textbooks and more comprehensive than those provided in popular media. Papers in the series will deal with aspects of biostratigraphy, paleoecology, paleoclimatology, paleobiology, evolutionary patterns and rates, as well as other practical applications of fossils as geochemical and geothermal indices. The series therefore will include articles on diverse subjects, all of which have fossil specimens as their central source material.

† Geological Survey of Canada Contribution 15186

The first part of this introduction will provide a brief view of the early history of paleontology and its role in the birth and development of geology. The second part will attempt to outline the interrelationships of the various facets of paleontology and their application to, and impact on, research in other disciplines.

### PALEONTOLOGY: ANCIENT

#### Folklore and Magic

Fossils must have been familiar objects to early man although whether or not he understood their origin must remain an open question. We do, however, know that fossils were recognized as unusual objects in the past because of the many qualities and origins attributed to them in folklore of several cultures. In North America, for example, the Pahvant Ute Indians of western Utah believed in the magical properties of specimens of the trilobite *Elrathia kingi* (Meek). This species is one of the most common inhabitants of teaching collections in geology departments because of its abundance in certain parts of Utah. The Ute Indians made necklaces and amulets of these trilobite specimens which they believed would ward off evil spirits.

Similar beliefs are known in European culture and perhaps the most famous folkloric fossils are the snakestones from the Whitby area of Yorkshire, England. The occurrence of coiled ammonite shells in rocks of the area was well known and they were believed to be the remains of once living snakes. Legend has it that St. Hilda, a seventh-century Saxon abbess, transformed them to stone so that she might clear the site for a new convent. The absence of heads on the snakes, believed to be the result of a curse from another saint, was rectified by local collectors who carved heads on the ammonite specimens (Figure 1). The carved ammonites were widely sought after, and found their way into collections in many parts of the world. Indeed, the town of Whitby became so renowned for these specimens that snakestones were included in the city coat of arms (Figure 2).

Similarly, the pointed, internal shells of fossil belemnites that occur commonly in Jurassic and Cretaceous rocks were variously considered to be thunderbolts from the gods, devil's fingers, St. Peter's fingers or gnome's candles according to taste and region. There was a local belief in Scotland, for example, that horses could be cured of worms by soaking some belemnites in their drinking water.

**Figure 1** *Snakestone from Upper Lias (Jurassic) rocks near Whitby, Yorkshire; the specimen is* Dactylioceras commune; *(illustration from Bassett (1982), courtesy of the National Museum of Wales).*


**Figure 2** *The coat of arms of Whitby, Yorkshire, incorporating snakestone symbols; (illustration from Bassett (1982), courtesy of the National Museum of Wales).*

Fossils have also been used in attempts to reconstruct mythical animals. This was done because of belief in the former existence of such animals and also because of the need to legitimize their existence on purely economic grounds. For example, the nasal horn of the fabled unicorn was long prized for its strong medicinal properties and attempts were made to find specimens. The many references to the efficacious qualities of unicorn horn, indicate that the horns of many other animals must have been ground and passed off as unicorn in Medieval times. Indeed, at various times the horn of the narwhal and the tusks of fossil woolly mammoths were considered to be the genuine article. The conviction that fossil mammoth bones represented skeletons of unicorns led to an attempt in 1663 to reconstruct the unicorn (Figure 3). This attempt may seem amusing to a modern audience but it underscores the early folkloric attitudes to fossils. Georges Cuvier, a famous nineteenth-century naturalist was later able to show that the unicorn was a zoological impossibility.

### The Plastic Force

Apart from folkloric interpretations, Medieval views considered fossils the result of a creative force orginating from within the earth. This view is an extension of Aristotle's idea of the spontaneous generation of organisms. The so-called plastic force (*vis plastica*) was regarded as a mysterious energy that was continually trying to produce organic bodies. Fossils were thought to be the force's unsuccessful attempts to create organisms because, although they were without life, they were in the form of living animals. Views of this type prevailed from earliest writings to the early eighteenth century.

It is difficult to believe that everyone held this magical view, but it was certainly prevalent among influential European philosophers of Medieval times. It is compelling to think that the common folk, particularly those engaged in pursuits that brought them close to nature, understood something of the origin of fossils. Unfortunately, we shall never know because most people had neither the skills nor the means to communicate their ideas to the public. Medieval views thus regarded fossils as mere concretions, magical products of mythical forces, constructions of divine forces, or as products of some other ethereal process. These beliefs persisted well into the eighteenth century buoyed by the lack of scientific investigation. Scholars of the fifteenth and sixteenth centuries who made great contributions to many other aspects of science tended not to distinguish between minerals and fossils and thus implied inorganic origins for fossils. For example, George Bauer (1494–1555), whose pen name was Agricola, actually coined the term "fossil" to mean something dug up. In his book entitled *De Natura Fossilium* published in 1546, he described ammonites as minerals.

Leonardo da Vinci (1452–1519), however, a man with major accomplishments in other fields of science, correctly interpreted the nature of fossils. He recognized that shells found in rocks in the mountains of northern Italy were parts of animals that dwelt in the sea that once covered the area. Despite these conclusions, the idea that fossils were inorganic persisted for many years. During da Vinci's time, the Christian view of the Great Flood was also current. Although this hypothesis later delayed progress on several paleontological fronts, its formulation demanded the recognition that fossils were the remains of once-living organisms. This was in many ways a step forward, particularly from the general belief in a plastic force. It was not until work in the seventeenth century that the basis for the understanding of fossils was laid.

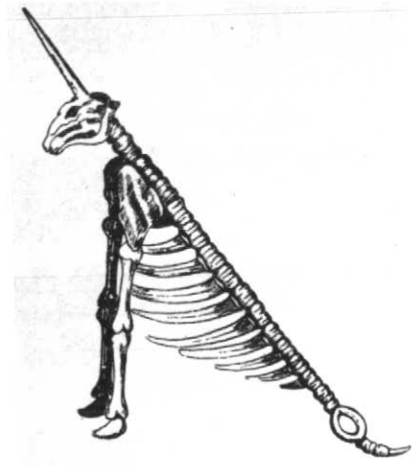

**Figure 3** *Reconstruction of a unicorn made by Otto von Guericke in 1663; (illustration from Bassett (1982), courtesy of the National Museum of Wales).*

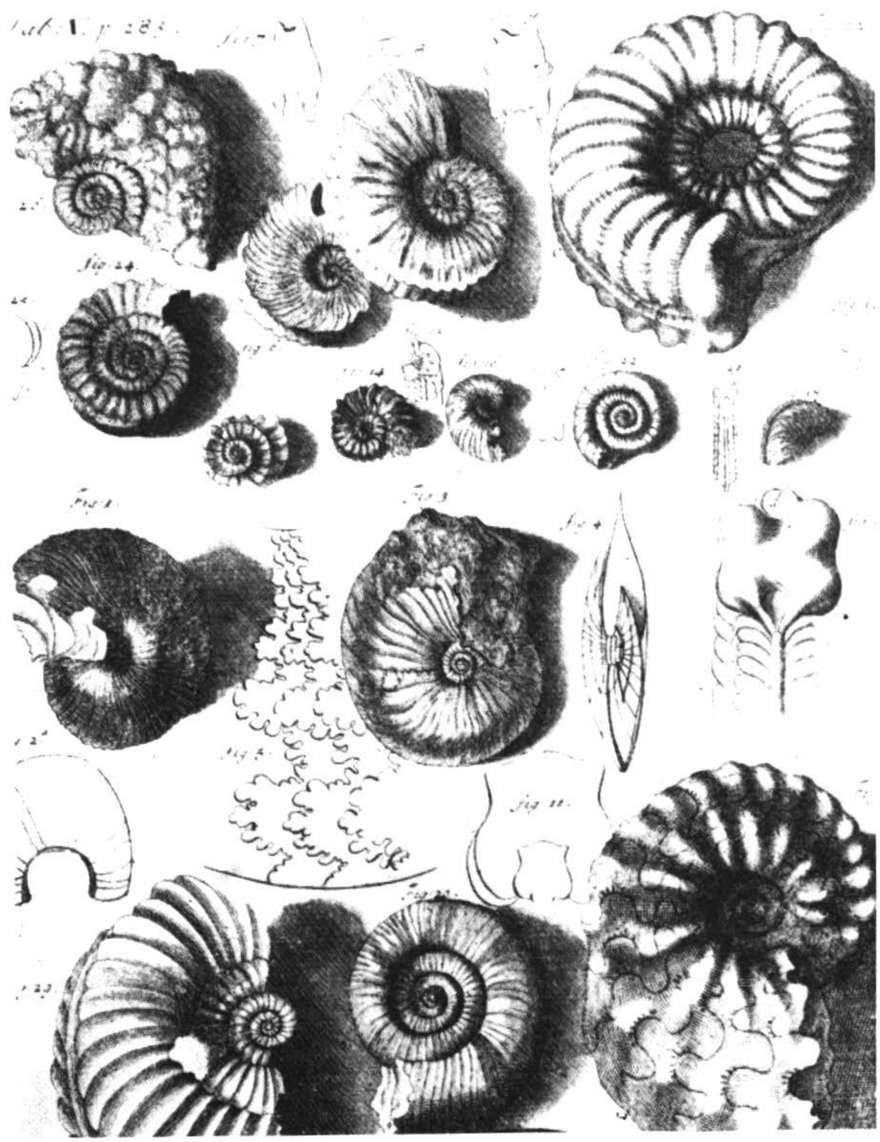

**Figure 4** *Ammonites from Plate 1a in Hooke's* Discourse of Earthquakes; *note the drawings of suture lines made by Hooke himself.*

**Seventeenth Century: Origins of Paleontology**

The organic origin of fossils was not generally accepted until the middle of the eighteenth century. The earliest scholarly discourses on fossils as organic remains are the writings of the Englishman Robert Hooke (1635–1703) and the Dane Niels Stensen (latinized as Steno, 1638–1686) published in the seventeenth century. It is worth noting that the heyday of the Diluvialists (proponents of the Great Flood) was coincident with the scientific work of these two men.

Hooke was a renowned physicist and mathematician who examined many natural phenomena, including fossils. He was the first to study fossils with a compound microscope and as a result, he made early contributions to the understanding of detailed microstructure. For example, he recognized the significance of petrified wood by virtue of its structure, and he also figured a foraminifer (a microfossil), ammonites (including sketches of their suture lines) and other fossils (Figure 4). He was an opponent of the idea that a mystical plastic force was responsible for the production of fossils and he documented his opposition by describing the various types of fossil preservation, so familiar to participants of first-year paleontology laboratories (i.e. internal and external moulds, casts, petrification). Hooke's main geological works were published late in the seventeenth century and they contained the seeds of many "modern" ideas relating to fossils. As a result of careful observations, he recognized that strata containing marine fossils found on land must have been uplifted from the sea and he suggested earthquakes as a mechanism. His extensive writings even hinted at the possibility of using fossils as indicators of time and climatic changes. This masterful work was completed more than one hundred years before William Smith came to grips with the same problems from an entirely practical point of view.

Steno was an anatomist who also published work concerning the nature and preservation of fossils. He was a fine observer and subscribed to a philosophy that required physical rather than magical causes for phenomena. He regarded detailed internal similarity of objects as a sign of common origin. By such reasoning he showed that fossil shark teeth were indeed from sharks. Contemporary seventeenth-century wisdom viewed the teeth, which were common in strata around the Mediterranean (particularly on the Island of Malta), as tonguestones or *glossipetrae* because of their resemblance to the shape of a human tongue (see logo at head of this article). They were believed to have grown in place in the rocks as a result of the plastic force or to have been placed there by some other feat of magic. It was a combination of Steno's acute powers of observation and the demands of a pragmatic philosophy that led him to the inescapable conclusion that *glossipetrae* were sharks' teeth. His next intellectual step was to explain how the teeth got into the rocks. Steno recognized that one could tell which of two solid objects "hardened" first by noting which object left an impression on the other. Thus, he reasoned that fossil shells or teeth were buried in wet, unconsolidated sediment because they had left their impression on the sediment. By extension of this type of reasoning and observation to other geological phenomena, Steno explained the sequential nature of events in materials now solid: fossils in strata, crystals in rocks and even groups of strata in basins of deposition. He was the first to produce a diagram illustrating the deposition of strata (Figure 5). He showed that sedimentary rocks were the deposits of oceans, lakes and rivers, that fossil shells once belonged to animals and that crystals precipitated from fluids. Thus Steno and Hooke took some of the first fundamental steps in geology.

Many well-illustrated treatises on fossils appeared during the seventeenth and early eighteenth centuries but the authors all continued in the belief that fossils were inorganic precipitates. One of these treatises, by Johannes Beringer of the University of Würzburg, has become a classic curiosity of paleontological literature. Professor Beringer made extensive collections of fossils from strata of Triassic age, however, in his publication *Lithographiae Wirceburgensis* (1726), a number of bizarre specimens with shapes of monsters, stars, moons, letters and other symbols are mixed with the real fossils. Shortly after the volume was published, Beringer discovered that these unusual specimens had been manufactured by a colleague and some students who scattered them across the countryside from which Beringer made his collections. Whether this was a student prank or a deliberate attempt to discredit Beringer is not certain, but it had a devastating effect on him and he died a short time later. This episode helped to ridicule the idea that fossils were mere precipitates or creations of mystical forces.

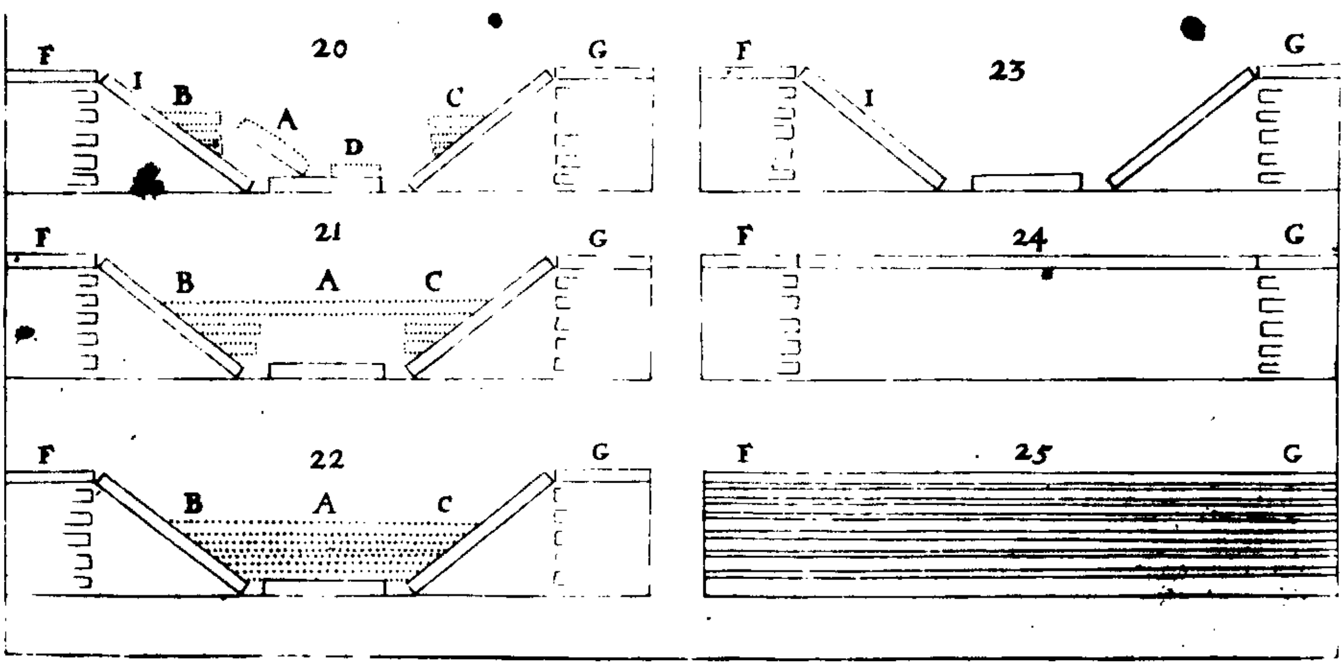


**Figure 5** *Steno's diagrammatic cross-sections of the geology of Tuscany, published in 1669; deposition of "primitive" strata* **(25)** *was followed by collapse* **(23)** *with subsequent deposition of fossiliferous strata (stippled area in* **22)** *followed by further crustal collapse* **(20)**.

### Eighteenth Century: Practical Paleontology

It was not until the middle of the eighteenth century, long after the publication of the works of Hooke and Steno, that the organic origin of fossils became generally accepted. In the early nineteenth century the basis for scientific paleontology was established. William Smith (1769–1839), who was later called the "father of stratigraphy", grew up in the late eighteenth century, a time of major industrial growth, and he became a surveyor and civil engineer, both professions that were much in demand for the construction of canals. His great experience with excavations for canal construction led him to recognize similar sequences of strata in different places, such that he was able to place isolated surface outcrops in a stratigraphic context. Where sequences were so similar in lithology that units could not be recognized, Smith used distinctive fossils to determine stratigraphic position, and in such a manner, he correlated sequences over long distances. Thus the principle of vertical sequences of faunas was discovered. It is interesting to note that Smith came to this conclusion more than fifty years before Charles Darwin published his major work on evolution, *The Origin of Species* in 1859. Smith made this discovery early in his career but was presumably too busy with his civil engineering to make it public. During this period Smith's career was sprinkled with many feats of engineering skill including landslide prevention, swamp drainage, irrigation and, of course, canal construction. In the course of all these projects Smith travelled widely and continued to make notes concerning bedrock with the clear intent of publishing a geological map. He was 46 years old when his maps were issued in 1815. There were fifteen sheets that, when placed together, made a single large (1.2 m × 2.4 m) map of England, Wales and part of Scotland. He identified 23 stratigraphic units and the areas of their outcrop were coloured appropriately. This was the first geological map of a large area and it set the style for geological maps that is still used at present. His work which is more important from a strictly paleontological point of view appeared over the next few years. In this work entitled *Strata Identified By Organized Fossils*, he published nineteen plates of fossils and demonstrated that they could be used to define a sequential order of strata.

Smith expended much of his personal wealth on the production of the geological maps and other publications and the resultant financial difficulties curtailed his scientific career. Ironically, he was forced to sell his large collection of fossils (2600 specimens) to the British Museum, for which he received 700 pounds Sterling. The sale of this and other assets did not satisfy his creditors and he ended up spending two months in jail in 1819. Despite his impressive scientific work, Smith was not part of the scientific establishment. This lack of recognition of his accomplishments by the learned men of the day can probably be attributed to his limited education and the fact that he earned his living from the practical application of his knowledge. He was not a member of the Geological Society that was formed in 1807. Indeed, no official recognition of his work was made until 1831, eight years before his death, when he was awarded the Wollaston Medal by the Geological Society.

The hallmark of Smith's work is its reliance on careful observation and its basis in practicality. He used paleontology as an aid to his exploits in civil engineering and he was fully aware of its significance in the prospecting for natural resources. In addition, Smith regarded geology as a both entertaining and healthy pursuit — by way of proof he lived to the then ripe old age of 70. His contribution to paleontology was enormous, practical and empirical. The modern basis of paleontology remains practical although the diversity of applications and avenues of approach has markedly increased.

While Smith worked on stratigraphy and fossils in England, Baron Georges Cuvier (1769–1832) and Chevalier de Lamarck (1744–1829) worked on fossils in France, laying the foundation for both invertebrate and vertebrate paleontology. Cuvier applied his skill in comparative anatomy, not only to debunking the unicorn, but also to many other studies of vertebrate fossils. Lamarck, most famous for his adherence to the theory of descent with modification and development of the theory of inheritance of acquired characteristics, made many detailed studies of invertebrate fossils.

These few introductory paragraphs serve only to outline the broad trends in the early observation and study of fossils. They are neither exhaustive nor original but cover an interval of history that will not be treated in articles of this series. For those interested in pursuing the early history of paleontology in more detail, some sources are provided below. The more substantive aspects of the development of paleontologic thought in the late nineteenth and twentieth centuries will be treated in other papers of this series.

## PALEONTOLOGY: MODERN

### Popular Paleontology

The general public relies on reports in the popular media for most of its information on developments in science. Several paleontologic "news stories" have made headlines in the twentieth century. Notable among these are stories of hominid remains, particularly the Piltdown Man hoax which is one of the most famous and spectacular scientific frauds of all time. The frequency of stories concerning fossil man is rivalled only by the numerous accounts of dinosaurs. Their large size and unusual appearance seem to hold a fascination over the public and consequently, articles on new finds of dinosaur skeletons are common fare in newspapers and magazines. Works of fiction, both in cinema and literature, commonly involve themes based on finds of living dinosaurs in remote parts of the earth. The actual discoveries of such "living fossils" are also featured news stories, for example the recovery of specimens of coelacanth fish, previously thought to be extinct, from the waters off southern Africa in 1939. The other main contributor to public paleontological notoriety is the subject of evolution. Much of this exposure is in the context of the "struggle" between evolutionists and creationists. Such stories are fraught with emotion and usually involved more with religion and law than with science. Besides, evolution is a fact (Smith observed it before Darwin wrote about it) and it therefore has no bearing on belief in God. The public view of paleontology is therefore strongly slanted toward the theoretical aspects of vertebrate fossils and evolution.

### Classroom Paleontology

The public perception of paleontology can be contrasted with geology students' first contact with the subject, which is by no means as romantic or provocative and usually consists of the sight of stacked drawers containing innumerable invertebrate fossils. The students discover that they are expected to be able to classify these specimens by the end of the course and some professors even expect them to be able to identify each specimen down to genus and species. Early memories of paleontology for many geologists consist of wrestling with hierarchical taxonomy and trying to remember not only the correct Linnean name for each specimen, but also how each fitted into the phylum to which it was assigned.

### Contemporary Paleontology

Teaching methods may have changed somewhat in recent years such that giant feats of memory are no longer required, but the fundamental importance of taxonomy in paleontology has not changed. Taxonomy, however, is often regarded (incorrectly) as the dullest of subjects fit only for the mindless who enjoy spending their time arranging objects into appropriate pigeonholes. It has even been regarded as something unworthy of scientific investigation and considered in the same category as baseball card or stamp collecting. This disdain is completely unjustified because systems of classification are not neutral frameworks into which objects are arbitrarily inserted, but rather they are evolving concepts that reflect and direct the philosophy behind studies of the objects being classified.

Thus modern paleontology has at its heart a taxonomy that is the philosophical driving force (Figure 6). The value of a fossil specimen in any application is directly proportional to the quality of the identification made. Poorly identified material results in inaccurate or erroneous conclusions, no matter what applications of the fossils are being considered.

Studies of well-identified fossil specimens from samples that are accurately located, both geographically and stratigraphically, can provide valuable information on one or all of three main fronts: (1) paleobiology and evolution of the group of organisms represented; (2) paleoenvironment of the organisms and thus the enclosing strata; and (3) relative biostratigraphic position of specimens and thus relative age of enclosing strata. The value of the results obtained on each of these fronts will depend on the groups of organisms represented in the samples. The more groups of fossils represented in the samples, the better will be the information and the more comprehensive will be the conclusions.

These three main objectives are interrelated. Biostratigraphy, for example, must take account of paleoenvironmental information in order to decipher whether the appearance of a new fauna in a sequence is the result of an environmental shift or evolutionary forces. Similarly, the relative stratigraphic position of fossils is important for determining evolutionary relationships — which species appeared first and why? The answers to such questions are seldom absolute and usually involve assessment of a wide variety of factors that impinge on each of the three main subject areas.

Studies of biostratigraphy, paleobiology and paleoecology are supported by more detailed studies and in turn provide information for several other major fields (Figure 6). For example, detailed studies of microstructure and chemistry of fossils may shed light on the affinities of both extinct and extant organisms. Interpretations of functional morphology (the study of the form and structure of an organism in relation to its environmental adaptation) will contribute to an understanding of the environment of deposition of the rock unit from which the fossils were collected and may also help to elucidate taxonomic relationships that are obscured by the superficial similarity of species that adopt similar life habits.

Studies of fossils of similar age from widespread geographic areas and diverse paleoenvironments, permit assessment of paleobiogeography which is the study of the past geographic distribution of organisms with respect to climatic, ecologic and evolutionary factors. Obviously, such studies can lead to conclusions concerning paleoclimatology, paleoecology, and paleoceanography.

Paleontology also plays a highly practical role in economic geology. Biostratigraphy provides relative age assignments based on sequences of zones established for various kinds of fossils. Examples of fossils that are widely used as zonal indices are graptolites in the Silurian, conodonts in the Devonian, foraminifers in the Carboniferous and ammonites in the Triassic. The absolute duration of a fossil zone varies considerably, but in the examples cited above zones are typically each of about one million years duration. This level of precision far exceeds the precision of the various radiometric methods. The age assignments provided by fossils are very important in correlation of strata within sedimentary basins that are sources for hydrocarbon and economic mineral deposits.

In addition to their importance in sedimentary basin analysis, fossils also provide information critical to the interpretation of orogenic belts. Biostratigraphic determinations on isolated faunas from deformed rocks provide the necessary correlations for unravelling tectonostratigraphic relationships. It is not uncommon to find that a few biostratigraphic determinations are the critical pieces of evidence in a tectonic interpretation. Fossils in orogenic belts can provide not only biostratigraphic information, but also evidence for the original depositional site of strata in suspect terranes. For example, when fossils of tropical aspect are found in close proximity to fossils of temperate or polar aspect of the same age, there is reason to suspect that the rocks hosting one or the other assemblage are allochthonous. Paleontology thus has a strong role to play in paleogeographic reconstructions, particularly with respect to interpretation of plate tectonics and analysis of suspect terranes.

In recent years assessment of a number of other important aspects of fossils has begun. Most important of these is the geochemistry of fossils and their enclosing sediments. Isotopic studies (particularly isotopes of carbon, strontium, oxygen, neodymium and sulphur) of original fossil material can provide information on paleoceanography, particularly with respect to levels of salinity and oxygenation. Analysis of absolute abundances of trace elements may also provide evidence of fluctuations in the chemistry of seawater. It has already been shown that phosphatic material (carbonate apatite) of conodonts, inarticulate brachiopods and fish retains an enriched, but unfractionated, chemical signature of the seawater in which it was deposited. Such studies are opening up exciting new avenues of research with implications for many aspects of earth history.

Another purely practical application of fossils derives from the fact that organic material changes colour with increasing temperature. This simple fact has permitted thermal alteration indices to be developed for fossil groups that have preserved organic matter. Palynomorphs and conodonts have been used

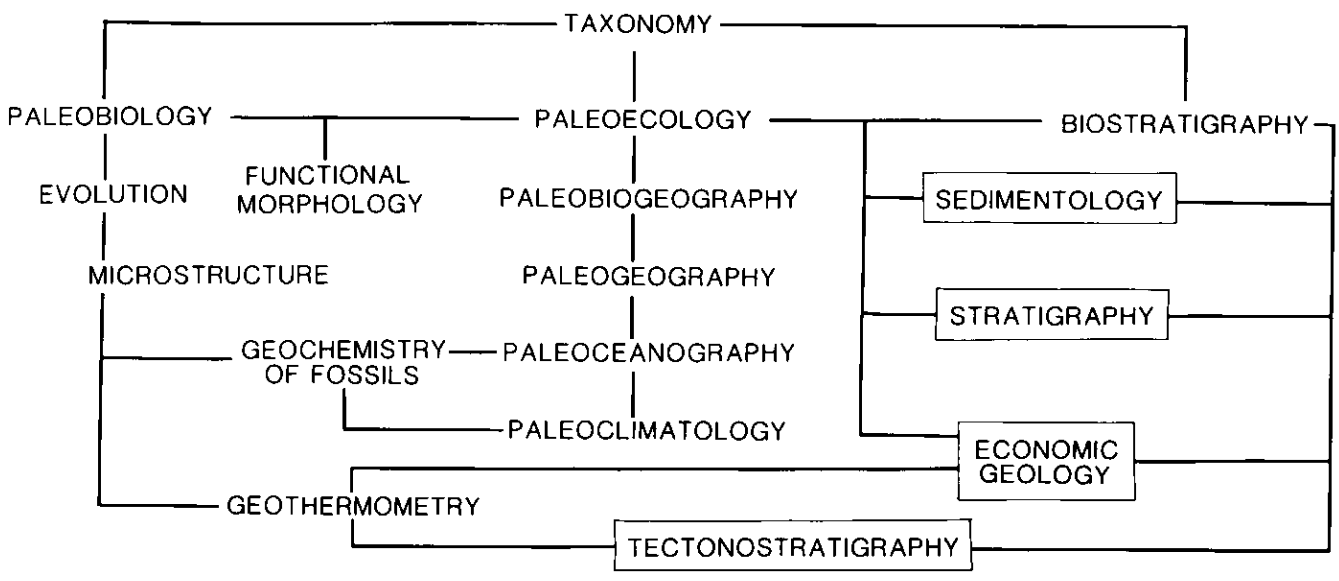


**Figure 6** *Diagram illustrating some interrelationships of the facets of paleontology and their contributions to other disciplines of geology; stratigraphy and sedimentology provide much information of value in paleontology; those disciplines for which fossils are not the main basis are outlined in rectangles.*

extensively in studies of thermal maturation of sediments; other groups, such as graptolites, are now under study for this purpose. Thermal maturation levels are important in the development and preservation of oil and gas deposits and therefore their determination is a key tool in hydrocarbon exploration.

Modern paleontology is therefore a diverse and dynamic subject with contributions to make in many fields of geology. Some debate is presently focussed on whether paleontology properly belongs within geology or biology departments of universities. This reflects the fact that paleontology is truly an interdisciplinary subject with important implications for, and interrelationships with, several fields of geology, biology and chemistry. This series of articles will attempt to highlight the various aspects of paleontology in concise, understandable terms. I hope that this article has provided a brief historical introduction illustrating the importance of paleontology in the early development of geology and a brief synopsis of the important aspects of modern paleontology and their applications. Other articles in the series will elaborate many of the topics touched on in this introduction.

**Acknowledgements**
I thank my colleagues in the Paleontology Division of the Geological Association of Canada for the opportunity to assemble this series of articles. M.J. Copeland, D.J. McLaren and A.D. McCracken of the Geological Survey of Canada are acknowledged for useful comments on this manuscript.

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Accepted 25 March 1986.