# THE FOSSIL COLLECTOR

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Hindlimbs, pelvis and vertebrae of a recently discovered hypsilophodontid dinosaur from Dinosaur Cove, Victoria.

Photo, courtesy T.H. Rich.

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## THE FOSSIL COLLECTORS' ASSOCIATION OF AUSTRALASIA

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## EDITORIAL

Many of you, particularly those who live in Victoria, will be aware that on New Year's Day, a three year old boy died when he was crushed by falling rock at the well known Beaumaris fossil locality on the shore of Port Philip Bay, south of Melbourne.
While the accident was not directly related to fossil collecting, the child's father having taken him to the area while he looked for worms, comments in the press and on T.V., have inferred that the continual collecting of fossils was slowly destroying the cliffs and that this might have been one of the reasons for the rock fall. However, other factors such as wave action, water runoff and continual vibration of the partly unconsolidated sandstone by heavy traffic on Beach Road, very close to the top of the cliff, are in this case, far more likely to be the major contributing factors.

This rock fall is not an isolated occurrence. In fact, a recent visit to the site by the Editor was made as a result of a report of a rock fall at (as far as can be ascertained from press photographs) precisely the same point. During this visit another recent and much more extensive rock fall was noted some 300 metres N.E. in an area not normally visited by fossil collectors.

The reason for mentioning this incident, is to emphasise the risk we all take, whether collecting or not, when we walk along beaches or clamber over fallen rock below cliffs.

So many of the fossils we collect are from boulders that, at some time in the past, plummeted down from the face of a cliff or quarry; yet we never believe that the next fall might occur when we are there. Admittedly some areas are considerably more stable than others, but how often do we look up to assess the danger, and even when we do, ignore it because we've just seen a rare specimen? At least, as adults, we should be aware of the risks we take. Children on the other hand cannot be expected to understand these risks or notice tell-tale signs of an impending fall. To be quite honest, few fossil collecting sites are suitable for young children.

Material urgently required for the next bulletin - closing date for articles and snippets, APRIL 30TH, 1990.

Frank Holmes

## 1990/91 SUBSCRIPTIONS

Subscriptions for the coming financial year (March 1st 1990 to February 28th,1991) will remain at the present level as listed below. Holding the current subscription rate for another year in the face of continuing increases in postal charges and printing and stationery costs is only possible because of the necessity to defer publication of the September,1990 issue, due to the expected absence of the editor on vacation. To keep faith with our policy of three bulletins a year, it is proposed to produce a 'double' issue no later than January,1991.

| | | |
|---|---|---|
| Surface Mail | Australia and New Zealand | $7.50 |
| | All other countries | $8.50 |
| Air Mail | New Zealand | $9.50 |
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(All figures are quoted in Australian currency)

Subscriptions should be forwarded to the Secretary, together with the enclosed Subscription Renewal Form duly completed and signed.

## FINANCES

Statement of finances as at 9th January, 1990 :

| | |
|---|---|
| Carried forward from previous year | $ 1,655.44 |
| Add income 1.3.1989 to 9.1.1990 | 1,289.22 |
| | $ 2,944.66 |
| Less expenditure 1.3.1989 to 9.1.1990 | 1,337.22 |
| | $ 1,607.44 |
| Deduct advance subscriptions | 93.96 |
| Balance in hand (excluding cost of this Bulletin) | $ 1,513.48 |

## GEMBOREE 1990 - BUNDERBERG, QUEENSLAND

It is hoped that an informal meeting of F.C.A.A. members will be held at the Bunderberg Gemboree on Friday, April 13th. 1990, at 7·30 p.m. However, at this stage it is not possible to confirm if any of our State Representatives will be available to chair a meeting. Those attending the Gemboree should check on arrival to ascertain if the meeting is to be held, and if so, the location.

## IN THE NEWS

### HERRERASAURUS - THE WORLDS OLDEST DINOSAUR?

Scientists in Argentina have discovered the remains of what is believed to be the world's oldest dinosaur in the foothills of the Andes Mountains.

The 230 million year old Early Triassic fossil is the nearly complete skeleton of a bipedal carnivore called *Herrerasaurus* which stood two metres tall and weighed more than 100 kg.

The discovery of this ancient fossilised skeleton has given scientists the most complete picture of the early stages of dinosaur evolution.

Details of the discovery made last year by a joint US-Argentine expedition, were released at a meeting of the Society of Vertebrate Paleontology in Austin,Texas. (Cont.)

HERRERASAURUS - THE WORLDS OLDEST DINOSAUR?

Alfredo Monetta, from the University of San Juan, led the expedition which found two other nearly complete fossils of the same species in sandstone deposits next to a river.

Recovering this complete skeleton was largely due to luck, because its skull and neck were just beginning to weather out from the rock in which it was embedded. This meant the skeleton was largely undamaged.

Before this latest discovery, Argentine scientists had found only a smattering of *Herrerasaurus* bones and some fragmentary fossils of similar animals.

Although this particular animal was comparatively small (other incomplete fossils of the *Herrerasaurus* were four metres long), its skeleton was so well-preserved that tiny ear bones and plates in the iris of the eyes showed in the rock.

*Herrerasaurus* was a lightly-built animal with a long bird-like skull and teeth similar to a shark's.

It was a predator which ran on its two hind legs to chase prey. Its front limbs were short and it had very long claws and semi-opposable thumbs for grasping food.

Paul Sereno from Chicago University believes *Herrerasaurus* was not a direct ancestor of later dinosaurs but was closely related to more primitive forms.

But it also had some surprising advanced features, such as a dual-hinged jaw which did not appear in other dinosaurs for 50 million years. The extra hinge behind the teeth allowed *Herrerasaurus* to hold its prey more tightly than with a single-hinged jaw and indicates it was on an evolutionary side-branch.

*Herrerasaurus* was named after Victorino Herrera, a goat farmer and amateur fossil hunter who discovered the first fragmentary bones and led scientists to the area in north-west Argentina many years ago.

While dinosaurs evolved during the Triassic Period, between approx.250 million and 210 million years ago, the *Herrerasaurus* flourished in the early part of that period when most of the earth's land masses were gathered into the single super-continent, Pangaea.

Extract from an article by Owen Craig in the Sun-Herald, November, 26th 1989.

## DISCOVERY ADDS TO KNOWLEDGE OF MARSUPIAL EVOLUTION

Further excavation of an early Tertiary fossil bed in the lower slopes of Boat Mountain (so named because its flat-topped profile resembles an upturned hull), near Murgon in southern Queensland have brought to light almost 30 mammal teeth none of which has any close affinity with known Australian animals either living or extinct.

The site has been known since 1933 when a few bones were found projecting from eroded mudstone in a gully and sent to the Queensland Museum. They were identified as parts of extinct turtles and crocodiles but not considered of major importance as similar material had been found elsewhere. However, in the mid 1970's Dr.Alan Bartholomai, the museum's director, and visiting US palaeontologist Dr.Eugene Gaffney, visited the site to examine the turtle material more closely. A paper describing these fossil trionychids was published in 1979 (Journal of Paleontology 53: 1354 - 1360).

While on a heritage survey of fossil sites in 1982, Hank Godthelp found more turtle and crocodile remains at Boat Mountain. This resulted in a further investigation of the site in 1985 by Godthelp, accompanied by Dr. Michael Archer and a group of students. During this visit they found small fish scales in a thin band of white clay sediment. Because similar associations of finely grained white clay and small fish previously found in central Australian sites also contained small mammalian fossils, it was reasoned that Boat Mountain might also contain such fossils. It was not until 1987 that a sample batch of clay collected from the 1985 trip was eventually washed, dried and sieved. The microscopic examination which followed revealed the first of the tiny fossil teeth that have made this site so important in the search for information about Australian marsupial evolution.

A further, more serious collecting trip during 1988 revealed additional layers of fossil-bearing sediments.

All the teeth found are from very small animals which probably looked quite uninspiring. They were definitely not like kangaroos - possibly more like possums and bandicoots. If anything they look most like the South American marsupials from between 30 and 60 million years ago, thus giving further support to the theory that marsupials did not first emerge in Australia.

Very old mammalian fossils, especially extinct marsupials which are quite different from the modern animals, have proved extremely elusive in Australia. The Boat Mountain specimens have not been positively dated, but based on geological and circumstantial evidence are believed to be between 30 and 65 million years old, certainly much older than those from the more widely known Miocene beds at Riversleigh in north-west Queensland.

Exactly how they fit into the jigsaw puzzle of overall marsupial evolution will require many more years of research, however, it seems probable that these teeth date from the time of the final isolation of Australia from Antarctica - before our marsupials had gained their uniquely Australian character.

Other fossils found at Boat Mountain include snakes, lizards, primitive frogs, two types of birds and many fish.

Extract from an article by Bob Beale in The Age "Good Weekend" 19th August, 1989.

## DINOSAUR FREEWAY

According to Martin Lockley, an associate professor of geology at the University of Colorado, Denver, over 100 million years ago, dinosaurs of the Cretaceous period may have had their own version of a coastal highway along the edge of an ancient sea that stretched from the present-day Gulf of Mexico to the Rocky Mountains and beyond into western Canada.

Along what was once the coast of this ancient sea Lockley and others have discovered what he calls "mega-tracksites" where the earth was heavily trampled by several types of dinosaurs and at least one species of bird.

Since many large dinosaurs are believed to have lived in herds and behaved in much the same manner as the moose or caribou of today, these discoveries, linked with other evidence, have fuelled speculation that dinosaurs may have travelled up and down this coastal highway. In addition, dinosaur bones of the same type have been found as far south as New Mexico and as far north as western Canada.

As this coastal plain would have been an ideal migration route, coupled with the discovery of the footprints along the shoreline for thousands of miles, it is probably the best evidence yet for dinosaur migration.

Adapted from a report by Rick Boling in Equinox No.45 (The magazine of Canadian Discovery), May/June, 1989.

IN THE NEWS CONTINUED PAGE 40

# MACROFOSSIL EVIDENCE FOR *NOTHOFAGUS* (ANTARCTIC BEECH) HISTORY IN SOUTHEASTERN AUSTRALIA

by Dr. Robert S. Hill, Dept.of Plant Science, University of Tasmania.

The genus *Nothofagus* (Fagaceae) occupies a unique position in Southern Hemisphere biogeography. Currently there are about 35 species split into four subgenera (Hill & Read 1990). Subgenus *Brassospora* is restricted to New Caledonia and the highlands of New Guinea, subgenus *Fuscospora* occurs in New Zealand and Tasmania (*N. gunnii* ), subgenus *Menziesospora* occurs in New Zealand, South America and Australia (*N. cunninghamii* and *N. moorei*), and subgenus *Nothofagus* is restricted to South America. This is a classic Gondwanic distribution, and it has led to *Nothofagus* being the subject of dozens of attempts at reconstructuring Southern Hemisphere plant migration routes. Over the last twenty years, papers have been published which suggest almost every conceivable place of origin and migration route with apparently little consensus (Fig.1). This is even more bewildering when you consider that each author was essentially using the same information in their reconstructions. *Nothofagus* has been considered as the ideal genus for biogeographic reconstruction, since it exhibits the following features:

1. It has an entirely Southern Hemisphere distribution, although the rest of the family is restricted to the Northern Hemisphere.

2. It has poorly dispersed seed which cannot survive immersion in sea water. Therefore, it can be assumed that the genus has migrated via continuous land connections.

3. It has an extraordinary fossil record, which extends well back into the Cretaceous in South America, Antarctica, Australia and New Zealand. However, fossils are unknown in Africa and India.

All this information begs the question - why is there so much confusion in the literature of *Nothofagus* biogeography if all the information is available? The simple answer is that most biogeographers have ignored or mis-used the fossil record.

The fossil pollen record has recently been revised by Dettmann et al (1989), who have managed to convert an enormous mass of disjointed observation into a single cohesive study. In the process they have extracted a great deal of new information and have attempted to reconstruct the past history of the genus. Essentially, they suggest that southern South America and the

Antarctic Peninsula may have been a Cretaceous centre of diversity for *Nothofagus*. Later occurrences of some pollen types in New Zealand and Australia represents a migrational lag which involved West Antarctica.

The macrofossil record is not as well understood as the pollen record, but in southeastern Australia it is of particular significance because of the diversity of types present and the excellent state of preservation. The following account briefly describes these types and then comments on their significance to biogeography and palaeoecology.

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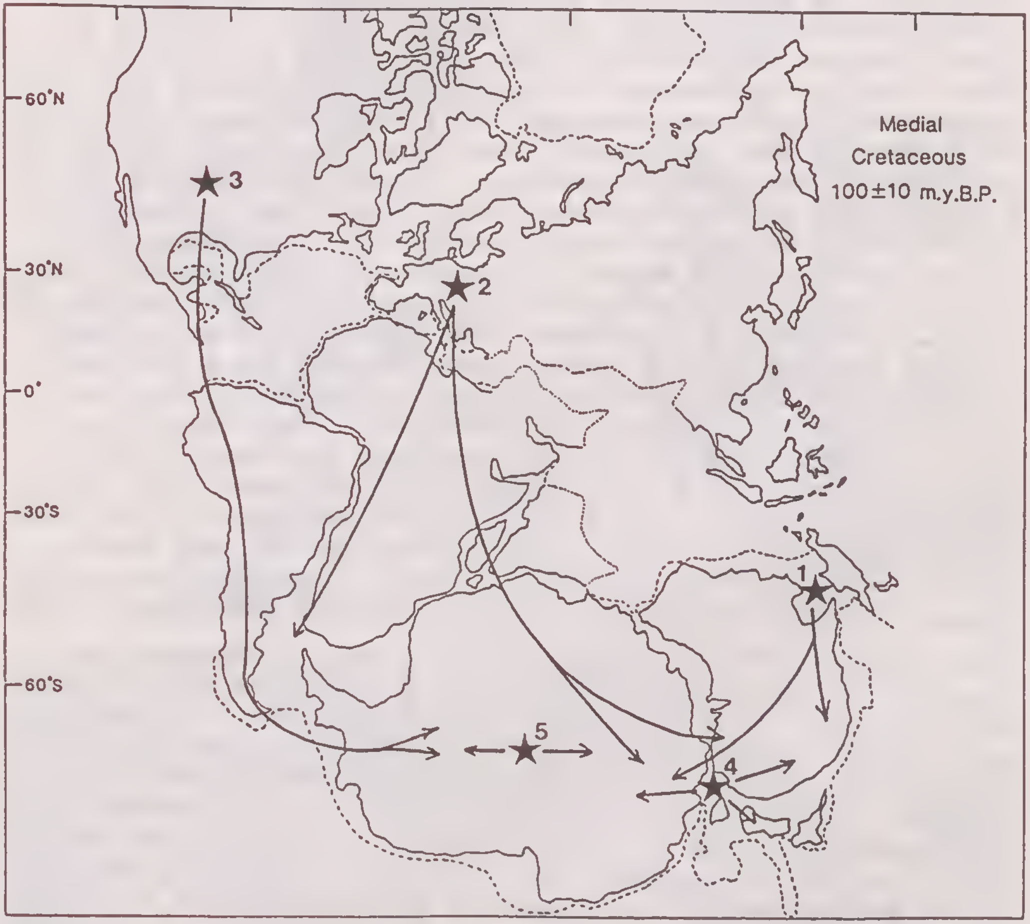



FIGURE 1.
Map showing the approximate positions of the Southern Hemisphere land masses 100 million years ago. The stars indicate some suggested places of origin for *Nothofagus* and the arrows the migration routes for the genus following its origin. The sources of information are: 1. van Steenis (1971); 2. Raven & Axelrod (1972); 3. Schuster (1976); 4. Hanks & Fairbrothers (1976); and Cranwell (1963).

## MACROFOSSIL EVIDENCE FOR *NOTHOFAGUS* (ANTARCTIC BEECH) HISTORY IN SOUTHEASTERN AUSTRALIA (Cont.)

### *Nothofagus* macrofossils

Macrofossils which have been identified in southeastern Australia are usually leaves, sometimes reproductive structures, and occasionally wood (e.g. Bishop & Bamber 1985). The leaves are most commonly of a type which can be related to one of the living Australian species.. *Nothofagus gunnii*, which is the only deciduous *Nothofagus* species outside South America, is relatively common in Oligocene macrofloras in Tasmania, and in all cases the fossil leaves are indistinguishable from the living species (Hill 1984, Hill & Gibson 1986). A variety of fossil species (Hill 1983a,b) have been allied to the group which today is represented by *N.cunninghamii* (Victoria and Tasmania) and *N.moorei* (northern N.S.W. and southern Queensland). These fossils have been placed into a series which is thought to represent an evolutionary reduction in leaf size starting from a *N.moorei*-like ancestor and concluding with living *N.cunninghamii* (Hill 1983b, manuscript submitted - Fig.2). However, other leaves have also been found in Tasmanian Oligocene deposits which no longer have living relatives in Australia. These include two species which belong to subgenus *Brassospora*, which are closely related to high altitude species in New Guinea, and a species in subgenus *Nothofagus*, which is closely related to *N.nitida* in South America (Hill manuscript submitted). All these leaves are accompanied by cupules, which surround the reproductive structures, and are of major taxonomic significance (Hill 1987). These cupules (Fig.3) are of considerable importance, since they confirm the affinities of the leaves, and are the only macro-fossil evidence of reproductive structures recovered along with similar cupules from Bacchus Marsh in Victoria (Christophel 1985).

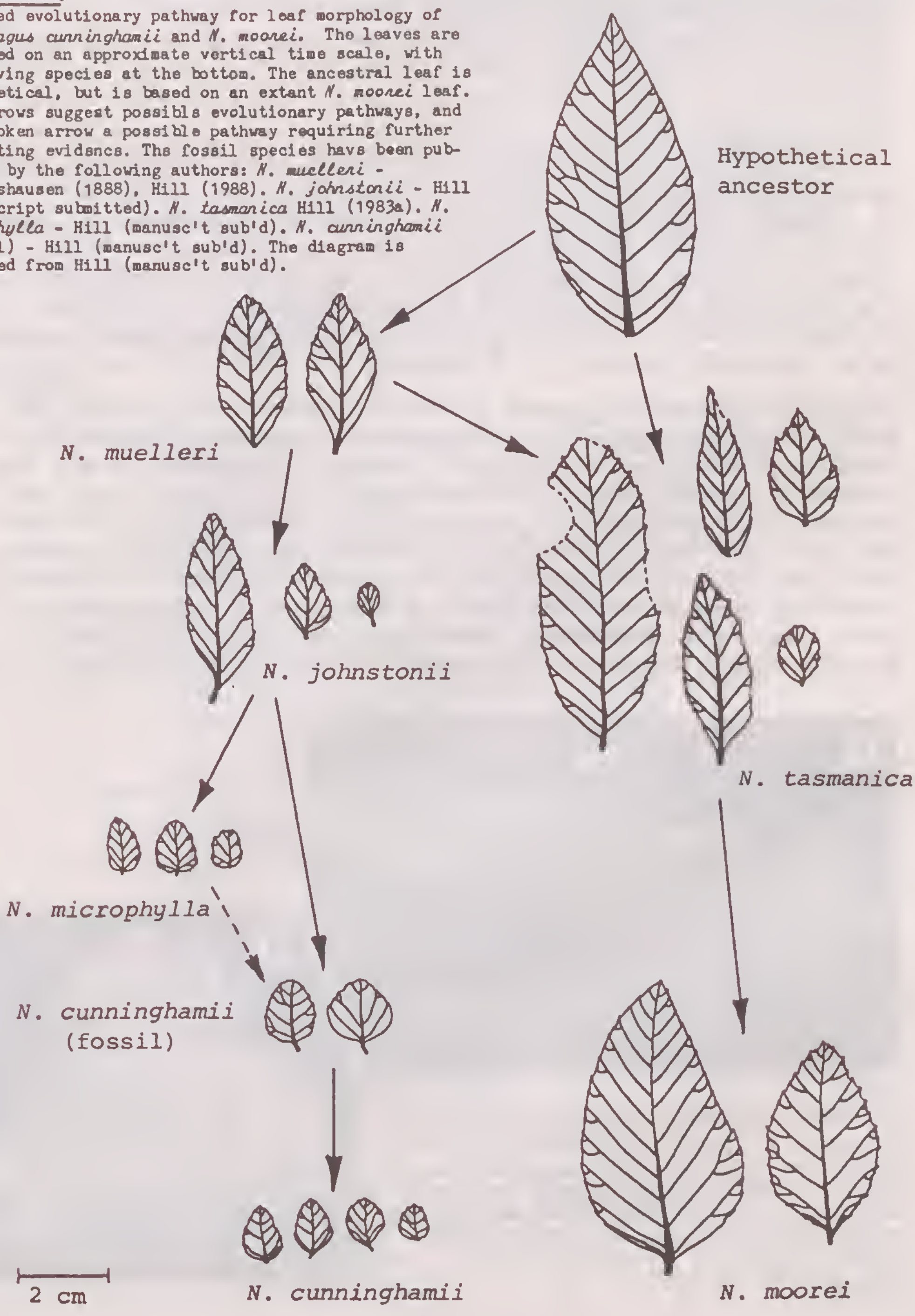
These fossils tell us two quite distinct things. Firstly, we now know that subgenus *Nothofagus* once extended as far as Australia (it is now restricted to South America). This is very important from a biogeographic point of view, since based on living distributions it would be (and has proven to be) impossible to predict. Proof of the total extinction of a group from an outlying geographic area is the sole province of the palaeontologist. Many other extinctions may have taken place, suggesting that the living distribution of *Nothofagus* is not necessarily a safe guide to past distributions.

Secondly, the ecological implications of these finds are profound. In one Oligocene deposit in Tasmania we have *Nothofagus* species which have their affinities today in southeastern Australia, the

Cont...

FIGURE 2.

Proposed evolutionary pathway for leaf morphology of *Nothofagus cunninghamii* and *N. moorei*. The leaves are arranged on an approximate vertical time scale, with the living species at the bottom. The ancestral leaf is hypothetical, but is based on an extant *N. moorei* leaf. The arrows suggest possible evolutionary pathways, and the broken arrow a possible pathway requiring further supporting evidence. The fossil species have been published by the following authors: *N. muelleri* - Ettingshausen (1888), Hill (1988). *N. johnstonii* - Hill (manuscript submitted). *N. tasmanica* Hill (1983a). *N. microphylla* - Hill (manusc't sub'd). *N. cunninghamii* (fossil) - Hill (manusc't sub'd). The diagram is modified from Hill (manusc't sub'd).



MACROFOSSIL EVIDENCE FOR *NOTHOFAGUS* (ANTARCTIC BEECH) HISTORY IN SOUTHEASTERN AUSTRALIA (Cont.)

highlands of New Guinea, and southern South America. It would be difficult to conceive of more disjunct affinities than that. An explanation of their past co-occurrence almost certainly lies in the prevailing climate. A combination of mild temperatures with extremely wet and humid conditions brought about by the warm equatorial waters circulating to cooler high latitudes gave rise to climatic conditions which have no modern analogue. As this climate deteriorated some species became extinct (and their relatives survive in South America), some migrated northwards (to New Guinea), some evolved in the region into new forms (*N. cunninghamii*), and some remained unchanged (*N. gunnii*). This is a remarkable variety of strategies to find within a single genus.

It has often been suggested in the literature that during the Early Tertiary southern Australia was covered in tropical rain-forests of one type or another. However, it is now clear that temperate species must have been present on a large scale and were an important part of the vegetation in some areas at least. The best estimate at this stage is that this area was predominantly the high altitude region along the east coast of Australia, extending down to the mountains of Tasmania. *Nothofagus*, and other temperate indicators, have now been recovered as macro-fossils from a number of Palaeocene-Oligocene localities in this

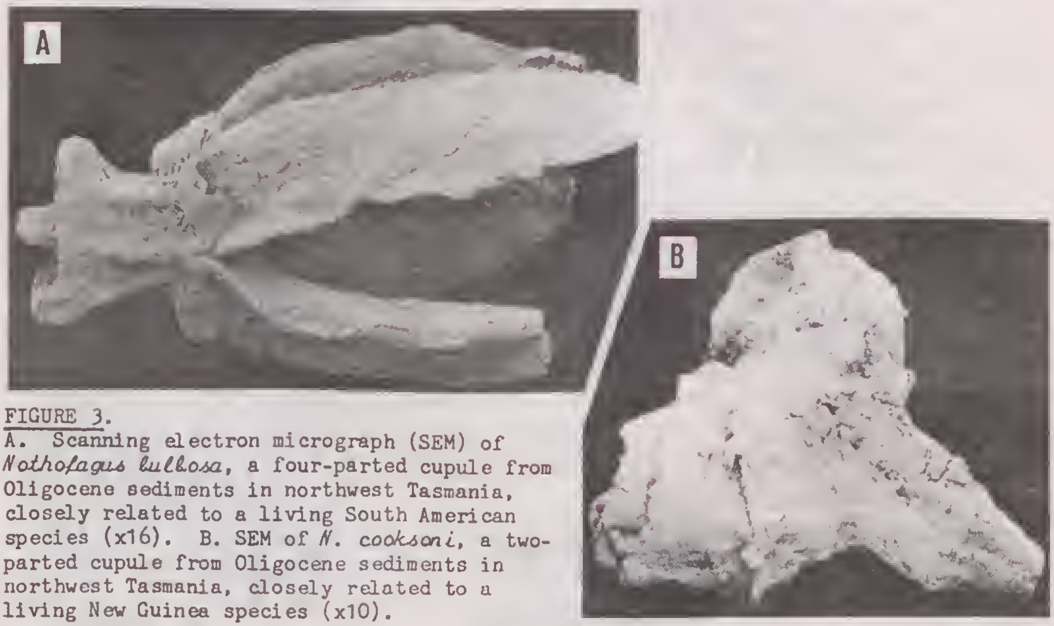



FIGURE 3.
A. Scanning electron micrograph (SEM) of *Nothofagus bullosa*, a four-parted cupule from Oligocene sediments in northwest Tasmania, closely related to a living South American species (x16). B. SEM of *N. cooksoni*, a two-parted cupule from Oligocene sediments in northwest Tasmania, closely related to a living New Guinea species (x10).

region, and evidence is mounting in support of this hypothesis. At one late Oligocene-Early Miocene Tasmanian site there is even evidence for subalpine vegetation, still with *Nothofagus* as an important component (Hill & Gibson 1986, Macphail et al - manuscript submitted).

Thus,it can be seen that the fossil history of *Nothofagus* is complex, and befitting a genus which has been extant for at least 80 million years. There is still much to learn about the past history of *Nothofagus*, and other aspects have already been seen in deposits where preservation is not as good and conclusions are not as firm. As more fossil material comes to light the history of *Nothofagus* will continue to reveal itself, and undoubtedly continue to surprise us.

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MACROFOSSIL EVIDENCE FOR *NOTHOFAGUS* (ANTARCTIC BEECH) HISTORY IN AUSTRALIA (Cont.)

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## AN INTRODUCTION TO THE PLEISTOCENE VERTEBRATE FAUNA OF THE SOUTH EAST OF SOUTH AUSTRALIA - Part 2

by John Barrie.

The extant Koala (*Phascolarctus cinereus*) is a highly specialised arboreal animal most closely related to the Wombat. Its diet is almost exclusively Eucalyptus leaves and has rarely been observed drinking. The koala is a slow moving creature, resting in the fork of a tree for much of the time. They are able to survive incredible falls with little adverse effect.

Its lack of tail is unusual for a tree dweller and may be the result of its ancestors being, for a time, terrestrial.

The female pouch opens backwards, is very broad and has two nipples, though it is usual to produce only one off-spring at a time.

The skull (Fig.1) is surprisingly narrow compared to the broad aspect of the face. The lower jaws are deep set, but individually narrow in cross-section, its masticating action is primarily crushing and the symphysis fuses in adults. An unusual cavity is present within the maxilla above molars M4 and M5, which appears to be a "window" opening into the nasal chamber. Of the skulls observed by me only *Thylacoleo* shares a similar cavity above P3 and M1 & 2.

The molars (Fig.2A & 2B) are selenodont (with cusps like a pair of inverted W's), not continuously growing as in Wombats whose gritty diet quickly wears away the tooth crown.

Dental formula -

$$\frac{I^1\ I^2\ I^3}{I_1} \qquad \frac{C \quad PM^3\ M^2\ M^3\ M^4\ M^5}{PM_3\ M_2\ M_3\ M_4\ M_5}$$

The incisors are well developed as a nipping device and a small pair of canines are retained in the upper jaw. There appears to

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FIGURE 1.
Skull of fossil *Phascolarctos cinereus* from Naracoorte (skull length = 162mm.).

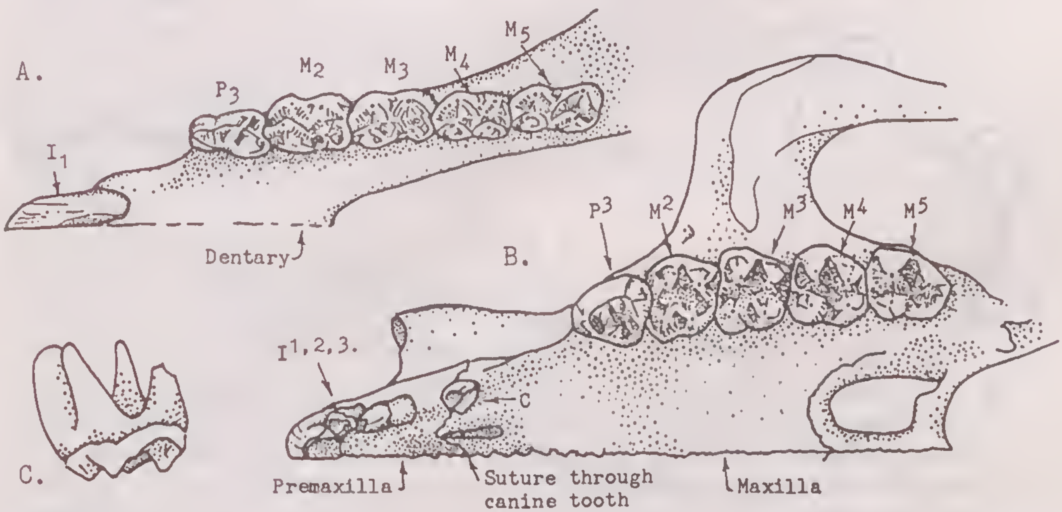


FIGURE 2.
Fossil *Phascolarctos cinereus*: A, occlusal view of lower teeth (length $I_1$ - $M_5$ = 62mm.); B, occlusal view of upper teeth (length $I^1$ - $M^5$ = 75mm.); C, fused roots to lingual side of upper $M^5$ (width of crown 9mm.).

AN INTRODUCTION TO THE PLEISTOCENE VERTEBRATE FAUNA OF THE SOUTH EAST OF SOUTH AUSTRALIA - Part 2 (Cont.)

be no tooth replacement, the young developing their permanent teeth (Fig.3A & 3B). The molars (Fig.2C), in the upper jaw are broad with four roots, the lower molars are narrow with two roots. The lingual (tongue side) pair of roots in the upper molars are fused and curve away towards the eye orbit as do the upper teeth in Wombats.

The sharply curved claws are well developed for climbing trees. Digit I on the pes (foot) ends in a blunt knob and opposes digits II and III (the syndactylous grooming toes) and digits IV and V the manus (hand) has digits I and II opposing digits III,IV and V. The undersurface of the paws are granular, but the pads are poorly defined.

Although there is much size variation in the extant species, fossil koalas are frequently larger than these. No giant koalas have been found by the author, however, they are reported from Naracoorte, Mt. Gambier and Yorke Peninsula.

Recorded representation of the koala family are :

| | | |
|---|---|---|
| 1. | *Kookor notabilis* | Early Miocene |
| 2. | *Kookor jimbarratti* | " " |
| 3. | *Litokoala kutjamarpensis* | Mid Miocene |
| 4. | *Perikoala palankarinnica* | " " |
| 5. | *Phascolarctos stirtoni* | Pleistocene |

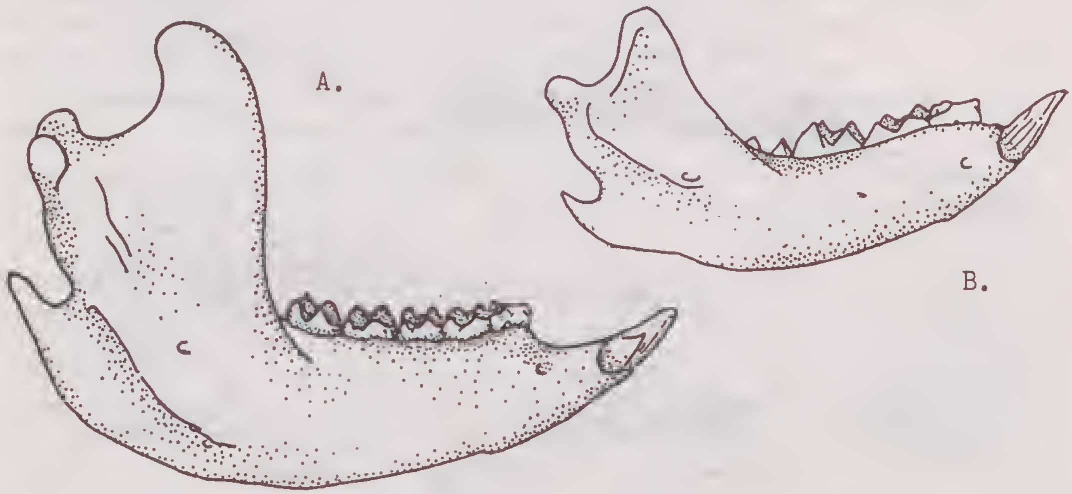


FIGURE 3.
Fossil *Phascolarctos cinereus*: A, lateral view of adult dentary (length 102mm.); B, lateral view of reconstructed juvenile dentary (length 63mm.).

6. *Phascolarctos cinereus* Pleistocene to recent.

Recent reports from Riversleigh note a strange Miocene possum/koala. A common ancestor is a probability. It has been suggested that if we were to find a pre-Miocene marsupial in Australia it would be likely to have teeth like a koala.

Unfortunately for palaeontologists, similarity of tooth form is not always a good indication of animal relationships (phylogeny). Many animals, both placentals and marsupials have convergent features. Study of a broad range of features, particularly relative to the circulatory and nervous systems is more reliable. Fossils preserving no soft tissue and frequently in fragmented condition present special difficulties with phylogenetics.

## GEOLOGIC TIME - AN INTRODUCTION TO RELATIVE AND ACTUAL DATING OF ROCKS AND FOSSILS AND THE AGE OF THE EARTH

Compiled by Frank Holmes.

In the second issue of The Fossil Collector (June 1980), we published an article on the methods used to determine the age of fossils. In the intervening nine years membership has not only increased but also changed, to the extent that over two thirds of current members would not have seen Bulletin No.2. Because we consider the topic is not only interesting, but important to the understanding of the geological background to palaeontology, the article is repeated here in a completely revised and updated form.

### INTRODUCTION

Past efforts to determine the age of the earth and to set down a sequence of geological and evolutionary events resulted in the formulation of what we know today as a Geologic Time Scale.

While such a scale is reproduced in numerous different formats, the data on which it is based stem from two fundamental elements of time.

Relative time which sets one event or period in the earth's history as occurring before or after another; and more recently (within the last 80 or so years), a series of actual dates based on various radiometric dating techniques.

Before we discuss the early attempts to estimate the age of the earth and the subsequent development of modern dating methods, we need to take a brief look at relative geologic time and the history of stratigraphy and biostratigraphy, since the modern Geologic Time Scale is based primarily on the knowledge gained by geologists and palaeontologists during the 19th century about the appearance and disappearance of particular fossils in sedimentary rock sequences. It is still being refined today.

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GEOLOGIC TIME (Cont.)

HISTORY OF STRATIGRAPHY

In 1669 Nicholaus Steno made the first clear statement that layered (stratified) rocks show sequential changes. This discovery, known as the Principle of Superposition, is the basis of all sedimentary geology. Steno also realised that strata are always deposited horizontally, or nearly so, although they may often be found dipping quite steeply - Principle of Original Horizontality.

Lehmann (1756), Arduino (1760), and Peter Pallas (1777), all worked on categorising rocks into three divisions. Primary, Secondary and Tertiary, thus providing a basic framework for stratigraphic thinking and relative time relationships between strata.

Unfortunately up until the early part of the 19th Century, it was generally considered that all rocks within a 'division' must be of a similar age with junctions between'divisions' being caused by major catastrophies such as the biblical flood.

As a compromise between Creation and accumulating scientific observation, Abraham Werner (1775) put forward a theory that all rocks were precipitated from a primeval ocean in a specific sequence (Fig.1), and that the present configuration and features of the landscape are what was left when the water receded. The theory, known as Neptunism, could not be substantiated in the field; failed to satisfactorally explain where the receding waters went; and even more importantly failed to provide an adequate explanation for the formation of basalts extruded from volcanoes. In spite of the failure of many of Werner's ideas to stand up to close scrutiny during the late eighteenth and early nineteenth centuries, his general scheme was still taught as late as the 1820's.

The gradual realisation that sequences of strata differ significantly among widespread localities (unlike Werner's theory of one set sequence everywhere in the world) marked the beginning of modern geology and the understanding of stratigraphy.

Probably the most important factor in this shift in thinking was James Hutton's concept of gradual change (uniformitarianism) based on observation of rocks in Scotland and expounded in his "Theory of the Earth", a paper read before the Royal Society of Edinburgh in 1788 and published in an expanded form seven years later in 1795. At first Hutton's book created little attention since it was obscure and poorly organised. Although John

Playfair (1802) clarified Hutton's views in his "Illustrations of the Huttonian Theory of the Earth", it was left to Charles Lyell in his "Principles of Geology" (1830-1833) to formally establish the Principle of Uniformitarianism - the present is the key to the past.

However, it was William Smith (1769-1839) who discovered that each successive sedimentary unit contained its own specific assemblage of fossils and that this could be used to relate units in widely separated areas. This discovery, known as The Law of Faunal Succession, above all else, led to the designation of the Geologic Systems (Periods) that we use today.

At the same time Georges Cuvier (1769-1832), a French zoologist worked out stratigraphic sequences for both terrestrial vertebrates and marine invertebrates in the Tertiary of the Paris Basin. By discovering fossil vertebrates that have no known living counterparts, he showed at last that extinction was a reality. Unfortunately, the incomplete record represented by the Paris Basin and the lack of gradational forms led to the hypothesis that worldwide catastrophies destroyed all prevailing life at a particular time, which was then followed by NEW faunal creation. Once again it is not surprising that the biblical flood was taken to be the last catastrophe of all.

## FORMATION OF A RELATIVE GEOLOGIC TIME SCALE

The geologic systems (major stratigraphic units such as the Cambrian etc.) which we use today, were not the work of one man, but of numerous geologists working independently, mainly during the first half of the nineteenth century.

Cont...

| | | |
|---|---|---|
| Gravel<br>Clay<br>Sand | Fourth Series | Partial Formations |
| Basalt<br>Coal<br>Gypsum<br>Salt<br>Limestone<br>Sandstone | Third Series | |
| Some limestones (dolomitic)<br>Greywacke<br>Schist (fine)<br>Slate | Second Series | Universal Formations (Direct from sea) |
| Other X'talline rocks<br>Schist (coarse)<br>Gneiss<br>Granite | First Series of precipitation | |

Figure 1. Werner's sequence of rocks precipitated from a primeval ocean.

GEOLOGIC TIME (Cont.)

As can be seen by the following dates, the documentation and naming of the various systems (periods) was quite random.

The Cambrian together with the Silurian were named respectively by Sedgwick and Murchison (1835) after ancient Welsh tribes. However, it was not until 1879 when Lapworth named the Ordovician that the disputed interval between the systems studied by Sedgwick and Murchison was settled. The boundaries of Lapworth's Ordovician were established purely on palaeontological investigation.

The Devonian was the name given by Sedgwick and Murchison in 1840 for the sequence discovered in Devon between the Silurian and Carboniferous. The Carboniferous, meaning coal bearing, was named by Conybeare and Phillips in 1822. The American equivalent of the Carboniferous, the Mississippian (Lower) and Pennsylvanian (Upper) were named respectively by Alexander Winchell (1870) and Henry Shaler Williams (1891). Neither name has found use outside North America.

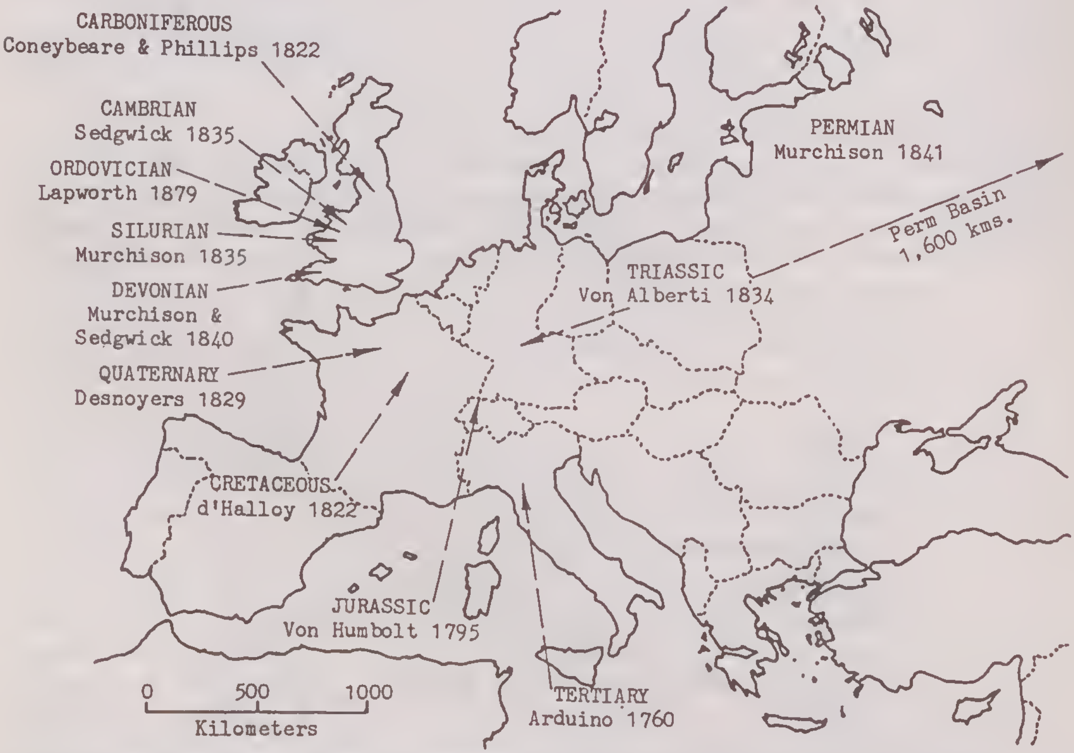


Figure 2. Summary of the naming of geologic systems in Europe. Adapted from Eicher 1976.

In 1841 Murchison named the Permian after the Province of Perm in Russia, where he found that the fossils differed markedly from those found in older strata already described.

The name Triassic was given by Alberti in 1834 to sequences of rocks with a striking three fold division, as found in Southern Germany.

Another German, Humbolt, gave the name Jurassic to the strata of the Jura Mountains in northern Switzerland (1795) but at the time considered it only as a "formation" in Werner's Neptunist scheme. Buch redefined the 'formation' as a true system in 1839.

The Cretaceous, the latin word for chalk, was used to describe the strata encircling the Paris Basin by d'Halloy in 1882, while the Tertiary is the term used by Arduino in 1760 to describe one of the three original divisions of rocks.

This latter system was later divided into Series (epochs); Lyell naming the Eocene, Miocene, and Pliocene in 1833; von Beyrich the Oligocene in 1854; and Schimper the Palaeocene in 1874.

The Quaternary (Desnoyers 1829) was later sub-divided by Lyell into Pleistocene (Glacial age) in 1839 and Recent (post glacial) in 1833.

To complete the picture, Phillips in 1841 named the Palaeozoic (Ancient), Mesozoic (Middle), and Cainozoic (Recent), subdividing the periods into three Eras based on the major changes in life which occurred at the end of the Permian and Cretaceous.

Once the various systems had been described and related one to another, scientists had a series of Time-Stratigraphic Units and their corresponding Geologic Time Units (periods), each one younger than the one below and older than the one above. These units are independent of rock type or relative thickness and encompass quite varied lengths of time. For example the Cretaceous extended for approximately 80 million years yet the Silurian only covers about 30 million years. However, the actual time span of these systems was pure speculation before the advent of radiometric dating.

Until recently, rocks older than the Palaeozoic have been widely known simply as Pre-Cambrian due to the lack of knowledge of any fossils contained therein or of any reliable means of dating or correlation.

One of the most recent Geologic Time Scales now includes names of broadly based eras or systems extending back from the Cambrian until the formation of the earth, although only the immediate Pre-

Cont...

GEOLOGIC TIME (Cont.)

| 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|
| ERA | PERIOD | EPOCH | STAGE | AGE (my) | ST'E ab'n | INT. (my) |
| CENOZOIC Gz | QUATER-NARY | HOLOCENE | | 0.01 | Hol | |
| | | PLEISTOCENE | | 1.64 | Ple | |
| | TERTIARY TT; Neogene Ng | PLIOCENE 2 | Piacenzian | 3.40 | Pia | 22 |
| | | Pli 1 | Zanclian | 5.2 | Zan | |
| | | MIOCENE 3 | Messinian | 6.7 | Mes | |
| | | | Tortonian | 10.4 | Tor | |
| | | 2 | Serravallian | 14.2 | Srv | |
| | | | Langhian | 16.3 | Lan | |
| | | Mio 1 | Burdigalian | 21.5 | Bur | |
| | | | Aquitanian | 23.3 | Aqt | |
| | Paleogene Pg | OLIGOCENE 1 | Chattian | 29.3 | Cht | 42 |
| | | Oli 2 | Rupelian | 35.4 | Rup | |
| | | EOCENE 3 | Priabonian | 38.6 | Prb | |
| | | 2 | Bartonian | 42.1 | Brt | |
| | | | Lutetian | 50.0 | Lut | |
| | | Eoc 1 | Ypresian | 56.5 | Ypr | |
| | | PALEOCENE 2 | Thanetian | 60.5 | Tha | |
| | | Pal 1 | Danian | 65.0 | Dan | |
| MESOZOIC Mz | CRETACEOUS K | $K_2$ SENONIAN Sen | Maastrichtian | 74.0 | Maa | 81 |
| | | | Campanian | 83.0 | Cmp | |
| | | | Santonian | 86.6 | San | |
| | | | Coniacian | 88.5 | Con | |
| | | GALLIC Gal | Turonian | 90.4 | Tur | |
| | | | Cenomanian | 97.0 | Cen | |
| | | $K_1$ | Albian | 112.0 | Alb | |
| | | | Aptian | 124.5 | Apt | |
| | | | Barremian | 131.8 | Brm | |
| | | NEOCOMIAN Neo | Hauterivian | 135.0 | Hau | |
| | | | Valanginian | 140.7 | Vig | |
| | | | Berriasian | 145.6 | Ber | |
| | JURASSIC J | MALM Mal | Tithonian | 152.1 | Tth | 62 |
| | | | Kimmeridgian | 154.7 | Kim | |
| | | | Oxfordian | 157.1 | Oxf | |
| | | DOGGER Dog | Callovian | 161.3 | Clv | |
| | | | Bathonian | 166.1 | Bth | |
| | | | Bajocian | 173.5 | Baj | |
| | | | Aalenian | 178.0 | Aal | |
| | | LIAS Lia | Toarcian | 187.0 | Toa | |
| | | | Pliensbachian | 194.5 | Plb | |
| | | | Sinemurian | 203.5 | Sin | |
| | | | Hettangian | 208.0 | Het | |
| | TRIASSIC Tr | $Tr_3$ | Rhaetian | 209.5 | Rht | 37 |
| | | | Norian | 223.4 | Nor | |
| | | | Carnian | 235.0 | Crn | |
| | | $Tr_2$ | Ladinian | 239.5 | Lad | |
| | | | Anisian | 241.1 | Ans | |
| | | SCYTHIAN $Tr_1$ Scy | Spathian | 241.9 | Spa | |
| | | | Nammalian | 243.5 | Nml | |
| | | | Griesbachian | 245.0 | Gri | |

| 1. | 2. | 3. |
|---|---|---|
| ERA | PERIOD | EPOCH |
| PALEOZOIC Pz | PERMIAN P | ZECHSTEIN Zec |
| | | ROTLIEGENDES Rot |
| | CARBONIFEROUS C; PENNSYLVANIAN C2 | CZELIAN Gze |
| | | KASIMOVIAN Kas |
| | | MOSCOVIAN Mos |
| | | BASHKIRIAN Bsh |
| | MISSISSIPPIAN C1 | SERPUKHOVIAN Spk |
| | | VISEAN Vis |
| | | TOURNASIAN Tou |
| | DEVONIAN D | $D_3$ |
| | | $D_2$ |
| | | $D_1$ |
| | SILURIAN S | PRIDOLI Prd |
| | | LUDLOW Lud |
| | | WENLOCK Wen |
| | | LLANDOVERY Lly |

FIGURE 3. A GEOLOGIC TIME SCALE.

The above scale is adapted from "A Geologic Time Scale 1989" published in card form by The British Petroleum Company plc. by arrangement with Cambridge University Press, July 1989, and is based on information compiled by W.B. Harland, R.L. Armstrong, A.V. Cox, L.E. Craig, A.G. Smith and D.G. Smith. The F.C.A.A. is grateful to Cambridge University Press for permission to use the above material.

Notes: Abbreviations for the names of Eras (col.1.), Periods (Col.2.), and Epochs (col.

| 4. | 5. | 6. | 7. |
|---|---|---|---|
| STAGE | AGE (my) | ST'E ab'n | INT. (my) |
| Changxingian | 247.5 | Chx | |
| Longtanian | 250.0 | Lgt | |
| Capitanian | 252.5 | Cap | |
| Wordian | 255.0 | Wor | |
| Ufimian | 256.1 | Ufi | 45 |
| Kungurian | 259.7 | Kun | |
| Artinskian | 268.8 | Art | |
| Sakmarian | 281.5 | Sak | |
| Asselian | 290.0 | Ass | |
| Noginskian | 293.6 | Nog | |
| Klazminskian | 295.1 | Kla | |
| Dorogomilovskian | 298.3 | Dor | |
| Chamovnicheskian | 299.9 | Chv | |
| Krevyakinskian | 303.0 | Kre | |
| Myachkovskian | 305.0 | Mya | |
| Podolskian | 307.1 | Pod | 33 |
| Kashirskian | 309.2 | Ksk | |
| Vereiskian | 311.3 | Vrk | |
| Melekesskian | 313.4 | Mel | |
| Cheremshanskian | 318.3 | Che | |
| Yeadonian | 320.6 | Yea | |
| Marsdenian | 321.5 | Mrd | |
| Kinderscoutian | 322.8 | Kin | |
| Alportian | 325.6 | Alp | |
| Chokierian | 328.3 | Cho | |
| Arnsbergian | 331.1 | Arn | |
| Pendleian | 332.9 | Pnd | |
| Brigantian | 336.0 | Bri | 40 |
| Asbian | 339.4 | Asb | |
| Holkerian | 342.8 | Hlk | |
| Arundian | 345.0 | Aru | |
| Chadian | 349.5 | Chd | |
| Ivorian | 353.8 | Ivo | |
| Hastarian | 362.5 | Has | |
| Famennian | 367.0 | Fam | |
| Frasnian | 377.4 | Frs | |
| Givetian | 380.8 | Giv | 46 |
| Eifelian | 386.0 | Eif | |
| Emsian | 390.4 | Ems | |
| Pragian | 396.3 | Pra | |
| Lochkovian | 408.5 | Lok | |
| | 410.7 | Prd | |
| Ludfordian | 415.1 | Ldf | |
| Gorstian | 424.0 | Gor | |
| Gleedonian | 425.4 | Gle | |
| Whitwellian | 426.1 | Whi | 31 |
| Sheinwoodian | 430.4 | She | |
| Telychian | 432.6 | Tel | |
| Aeronian | 436.9 | Aer | |
| Rhuddanian | 439.0 | Rhu | |

| 1. | 2. | | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|
| ERA | PERIOD | | EPOCH | STAGE | AGE (my) | ST'E ab'n | INT. (my) |
| PALEOZOIC Pz | ORDOVICIAN O | BALA Bal | ASHGILL Ash | Hirnantian | 439.5 | Hir | 71 |
| | | | | Rawtheyan | 440.1 | Raw | |
| | | | | Cautleyan | 440.6 | Cau | |
| | | | | Pusgillian | 443.1 | Pus | |
| | | | CARADOC Crd | Onnian | 444.0 | Onn | |
| | | | | Actonian | 444.5 | Act | |
| | | | | Marshbrookian | 447.1 | Mrb | |
| | | | | Longvillian | 449.7 | Lon | |
| | | | | Soudleyan | 457.5 | Sou | |
| | | | | Harnagian | 462.3 | Har | |
| | | | | Costonian | 463.9 | Cos | |
| | | DYFED Dfd | LLANDEILO Llo | Late | 465.4 | Llo3 | |
| | | | | Middle | 467.0 | Llo2 | |
| | | | | Early | 468.6 | Llo1 | |
| | | | LLANVIRN Lln | Late | 472.7 | Lin2 | |
| | | | | Early | 476.1 | Lin1 | |
| | | CANAD-IAN | ARENIC | | 493.0 | Arg | |
| | | | TREMADOC | | 510.0 | Tre | |
| | CAMBRIAN € | | MERIONETH Mer | Dolgellian | 514.1 | Dol | 60 |
| | | | | Maentwrogian | 517.2 | Mnt | |
| | | | ST.DAVID'S StD | Menevian | 530.2 | Men | |
| | | | | Solvan | 536.0 | Sol | |
| | | | CAERFAI Grf | Lenian | 554 | Len | |
| | | | | Atdabanian | 560 | Atb | |
| | | | | Tommotian | 570 | Tom | |
| SINIAN Z | VENDIAN V | | EDIACARA Edi | Poundian | 580 | Pou | 40 |
| | | | | Wonokan | 590 | Won | |
| | | | VARANGER Var | Mortensnes | 600 | Mor | |
| | | | | Smalfjord | 610 | Sma | |
| | STURTIAN | | | | 800 | Stu | 190 |
| RIPHEAN Rip | KARATAU | | | | 1050 | Kar | 250 |
| | YURMATIN | | | | 1350 | Yur | 300 |
| | BURZYAN | | | | 1650 | Buz | 300 |
| ANIMIKEAN | | | | | 2200 | Ani | 550 |
| HURONIAN | | | | | 2450 | Hur | 250 |
| RANDIAN | | | | | 2800 | Ran | 350 |
| SWAZIAN | | | | | 3500 | Swz | 700 |
| ISUAN | | | | | 3800 | Isu | 300 |
| HADEAN Hde | EARLY IMBRIAN | | | | 3850 | Imb | 50 |
| | NECTARIAN | | | | 3950 | Nec | 100 |
| | BASIN GROUPS 1-9 | | | | 4150 | BG1-9 | 200 |
| | CRYPTIC | | | | 4560 | Gry | 410 |

3.) are included at the bottom of each section. Columns 5 & 7 list Age and Intervals (INT.) respectively, in millions of years (my). The Ages quoted for boundaries between Stages (col.5.) are continually being refined as more accurate information becomes available. Column 6, lists suggested Stage name abbreviations (ST'E ab'n).
Some Stage names, in particular those used for the Late Permian, should be considered as provisional. The search for the most complete stratigraphic sequence within a Stage is a continuing saga; the final selection and adoption of acceptable names being the responsibility of the International Subcommission of Stratigraphic Classification (ISSC).

GEOLOGIC TIME (Cont.)

Cambrian Era has been further sub-divided into Series and Stages.

Geologic Systems are themselves divided into Series (Lower, Middle, Upper), the Series into Stages, such as the Lancefieldian, Bendigonian etc., Stages of the Ordovician in Australia, and the Stages into Time-Stratigraphic zones named after the predominant fossil found in the unit e.g., the *Tetragraptus approximatus* Zone (La3) of the Lancefieldian Stage of the Lower Ordovician.

One of the biggest problems faced in describing and dating the various systems has always been to define exact boundaries. Many of the original boundaries were chosen at unconformities in a specific region. However, later discoveries in other areas often showed complete sequences, thus creating the problem of where to place the 'missing' strata - with underlying or overlying sequences.

To overcome this problem general guidelines are set down concerning the placement of critical boundaries. These involve selection of sections with as continuous as possible sedimentation, no marked lithological changes, unbroken evolutionary lineages in several different fossil groups and finally, to define only the lower boundary.

BIOSTRATIGRAPHY

Biostratigraphy, the dating and correlating of rocks by means of fossils, provides the most accurate means of determining relative geological ages, during the Phanerozoic - the name given by Chadwick (1930) to cover geologic time since the beginning of the Cambrian. It requires not only a knowledge and acceptance of organic evolutionary change but a realisation that environmental influences also play an important part in the overall evolutionary pattern.

The following quote from Eicher (1976) defines in simple terms the basis for biostratigraphic zonation :

> " No plant or animal has existed for all geologic time. Each species evolved from some ancestor and so had a beginning. If it is extinct today, it also had an ending. Each extinct species therefore must divide geologic time into three parts; the time before it evolved, the time during which it existed, and the time since it became extinct. Any rocks that contain the species must have been deposited within the time during which the species existed. If the total time during which the species existed is short, then its presence in the rocks provides precise placement in the geologic time scale. But if the total time during which the species existed is great, then sedimentary rocks in different regions might well contain the species and yet differ widely in age. "

To keep this article to an acceptable length it is not possible to discuss biostratigraphy in further detail - this important subject will have to be dealt with in a future bulletin.

## THE AGE OF THE EARTH

The history of mans' efforts to find the age of the earth, and now the age of the universe, is in itself a fascinating study which is still continuing, although modern radiometric dating techniques and the conquest of the moon have established what is now considered to be an accurate age for this planet of 4,560 million years.

Probably the earliest estimates based on myth and tradition were those of the ancient Persians and Egyptians who considered man, and presumably the world had existed for about 12,000 years. On the other hand the Chaldees of Mesopotamia are quoted as believing man had been on the earth for 473,000 years.

In the western world early attempts to give an age to the earth were based on the literal acceptance of biblical writing. In the mid 17th century Archbishop Ussher worked out his long and famous chronology of biblical events, which set the creation of the universe as 4,004 BC., thus giving the age of the earth as approximately 6,000 years.

From the late 18th century up to the time of the discovery of radioactivity by Becquerel in 1896 and the subsequent experimentation in the dating of minerals by Boltwood and Rutherford, various attempts were made to establish geological time based on such things as deposition, salinity and heat loss from the earth (Kelvin).

They are important in understanding the problems faced by evolutionists, such as Darwin, as various estimates of the age of the earth (usually less than 100 million years) seemed to allow insufficient time for gradual evolution of the kind of life that inhabits our planet. Darwin in fact guessed that about 400 million years were needed to account for the observed succession of animal fossils.

Kelvin, cofounder of thermodynamics, deduced the time that the earth could have been habitable based on estimates of the age of the sun and the rate of heat loss from the earth. Although his first results (1862) gave possible ages ranging up to 400 MY, by 1897 he had shortened the range to between 20 and 40 MY. Established on precise physical measurement, these figures seemed irrefutable until the discovery of radioactivity and the realisation that the sun has maintained a nearly constant energy output since its formation and not a diminishing output due to a constant and irreversible loss of heat energy by radiation.

Cont...

GEOLOGIC TIME (Cont.)

RADIOMETRIC DATING

In 1902 Rutherford and Soddy postulated the change of radioactive elements into other elements during the emission of radioactive rays. This led to the first experimental dating of rocks by Rutherford in 1906 and Boltwood in 1907. Using rough early estimates of decay rates for Uranium-Lead, Boltwood arrived at ages not far removed from current accepted figures e.g.,Devonian 370 and Silurian or Ordovician 430 million years. By 1917 Barrell had already established that the age of the earth was at least 1,400 million years old and that the time that had elapsed since the beginning of the Cambrian System was between 550 MY and 700 MY.

Radiometric dating (radiochronology) can be divided into three main techniques which include about a dozen individual methods now in common use.

1. The Carbon 14 (radiocarbon) method based on the actual count of particle emissions (radioactivity) and used primarily on plant and animal remains (bones) of less than 40,000 years old.

2. Methods based on end products where ages are obtained from the ratio of daughter isotopes to radioactive parent isotopes as with the decay of uranium (U 235) to lead (Pb 207). This method is applicable to a wide range of rocks and minerals.

3. The use of isotope ratios, in particular the ratios of "common" nonradiogenic lead (Pb 204) to the radiogenic leads (Pb 206 and Pb 207).

The Carbon 14 Method (1)

Carbon 14, or C 14 is a radioactive isotope of carbon produced in the upper atmosphere by cosmic ray bombardment of Nitrogen 14. Being unstable it returns to N 14 at a constant rate equivalent to a half life of 5,730 years.

Some of this C 14 is oxidised to $CO_2$ and finds its way into plants and animals by way of photosynthesis, grazing and predation, where a dynamic balance is maintained between incoming C 14 and decay as long as the host creature lives. Upon death the ratio of C 14 to C 12 (the latter being the stable non radioactive isotope of carbon that makes up almost 99 percent of the carbon on earth) immediately begins to decrease as the radiocarbon C 14 converts back to N 14. As the end product of C 14 decay is identical to ordinary Nitrogen

14, the amount of radioactivity remaining in the specimen being dated is measured by actual counts of particle emission (its radioactivity) as opposed to the measurement of the end product (daughter isotope) used in most other radiometric dating techniques.

Because of the short half life of C 14, radiocarbon dating is generally restricted to organic remains no older than 40,000 years, although with the use of particle acceleration in conjunction with mass spectrometry for counting, in certain circumstances the range can be doubled.

The accuracy of radiocarbon dating depends on the constant production of C 14 in the upper atmosphere and its rapid absorbtion into living tissue relative to the rate of decay. It is now known that the production of C 14 varies with solar activity and fluctuations in the Earth's magnetic field. Errors due to these factors and discrepancies in the amounts of C 12 and C 14 in the atmosphere, due to industrial and military activity, are now reduced by a system of cross referencing to tree ring data (refer page 30 ) and greater caution in selecting samples.

Another method that falls within this category is the use of Chlorine 36 to date polar ice and groundwater at great depths. Cl 36 like C 14 is produced by cosmic radiation striking the atmosphere and settling in rain. It decays to Argon 36 and has a half life of 310,000 Years.

<u>Uranium - Lead and similar methods based on daughter-parent isotope ratios (2).</u>

Radiometric dating based on the presence of elements such as uranium,potassium and rubidium in a mineral or rock at the time of formation, is dependent on the rate of change (radio-active decay) of one kind of atom, known as the parent, into another kind of atom, known as the daughter by the emission of alpha and beta particles.

Each kind of atom is distinguished from another by the number of protons and neutrons in its nucleus. The number of protons determines the element (atomic number) and the number of protons and neutrons, the mass (atomic weight). The element and mass numbers together thus specifying a single particular kind of atom often referred to as a nuclide.

For example the two nuclides (isotopes) of uranium, U 235 and U 238, both have the same number of protons (92) but because they have different numbers of neutrons, have different masses.

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GEOLOGIC TIME (Cont.)

Each radioactive nuclide has its own mode and rate of decay which is a constant unchanging property. Once the nuclide is incorporated in a mineral or rock when it crystallises, the rate of decay is controlled only by time. Radioactive decay is at a geometric rate (Fig.4), unlike the linear rate of sand passing through an hour glass, the rate being described by its half life - the time for half the parent atoms to decay. This time can vary between one nuclide and another from microseconds to trillions of years.

While radiometric dating depends on physical laws, four main assumptions have to be made in accepting the methods based on daughter to parent (D/P) isotope ratios :

a. That the formation time of the rock or mineral was short enough to be considered geologically instantaneous.

b. That the system remains closed, i.e., no daughter or parent atoms are lost or gained other than by radioactive decay.

c. No atoms of the daughter nuclide were present in the mineral or rock when it formed, or if so, their presence can be detected, and

d. That the decay constant is accurate.

Although each method has its own inherent advantages and disadvantages there are two primary causes of error; partial loss of radiogenic daughter atoms (particularly the gas Argon) and errors in laboratory analysis.

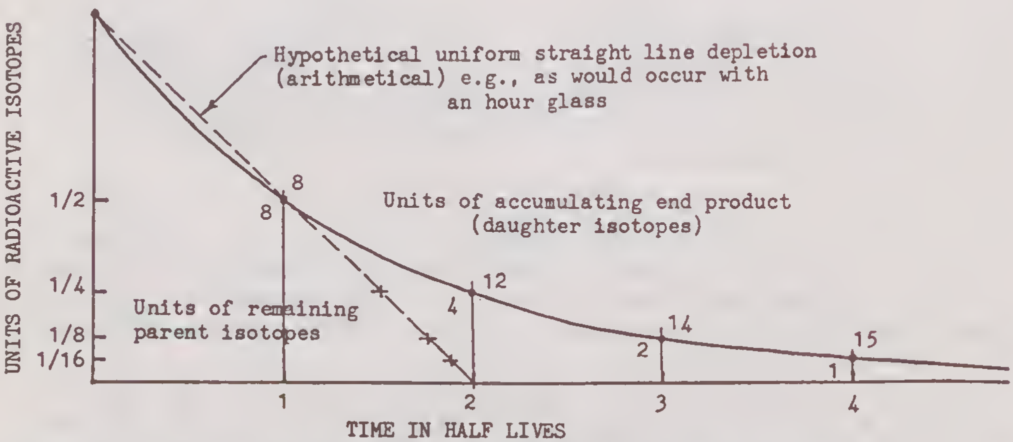


Figure 4. Curve showing exponential characterists of radiation decay.

Luckily many procedures have now been developed for reading these geologic clocks and for correcting potential errors. In addition, similar ages found by the use of different dating methods on the one rock, comprise a self-checking process. There is no way these different methods could give similar ages purely by chance.

It is essential that several specimens are analysed before a date for a particular rock sequence is given. The resulting date is written for example as 350 $\pm$ 10 million years, the plus or minus figure representing the scatter of dates from the tests due to minor measurement errors and variations between specimens. This latter figure means that in all probability, a further test of a sample from the same rock would yield a date within a 20 million year time range.

The more advanced our measurement techniques become, the greater the accuracy of the result, provided of course the basic assumptions are correct. Remember the problems caused by Kelvin's theory for determining the age of the earth. Not only was he unaware of the heat produced by radioactivity but he also chose the wrong constant for the cooling of a solid body by conduction.

In addition to the more common radiometric dating techniques listed in Fig.5., other methods have been developed which are increasing our knowledge of very early events in earth and cosmic history. These include Samarium - Neodyminium (Sm - Nd), used to determine the age of molten rock (magmas) before crystallisation; Lutetium - Hafnium (Lu - Hf) used for dating very old rocks and meteorites; and Rhenium - Osmium (Re - Os) for early earth events and cosmic evolution (Cloud 1988).

<u>Isotope Ratios (3)</u>

With Lead - Lead dating, the age of a rock or mineral specimen is calculated from the lead isotope ratios alone. This is possible because of the following factors :

a. The Uranium 238/Uranium 235 ratio (138:1) in terrestrial samples, meteorites and on the moon, is constant.
b. As previously noted, radiometric decay of the two uranium nuclides is constant, resulting in an increase through time of quantities of the radiogenic Lead 206 and Lead 207, the ratio between these isotopes also changing with time.
c. We know the ratios between Lead 204 (non radiogenic lead), Lead 206, Lead 207 and Lead 208 existing today.

As well as forming the basis of a separate dating method, the

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GEOLOGIC TIME (Cont.)

above information is used to correct errors in the Uranium and Thorium decay systems, resulting from lead loss (concordia - discordia methods).

A new technique involving the ratio of Argon 40 to Argon 39 (made by irradiation of common potassium, K 39) has been developed and is reported to overcome some of the problems associated with argon loss etc., in the K - Ar method (Cloud 1988).

FISSION TRACK DATING

The presence of nuclear particle fission tracks was first discovered in the 1950's when small tunnels, like bullet holes, were observed by scientists examining mica under an electron microscope. These holes (tracks) are produced when high energy particles if the nucleus of uranium (primarily U 238) are fired off in the course of spontaneous fission-fragmentation of an atom into two or more lighter atoms and nuclear particles.

This process is different from the radiometric decay process (alpha decay) previously discussed, the particles being bigger and carrying a great deal more energy. In Uranium 238 approximately every 2 million standard emissions of alpha particles is accompanied by a single catastrophic fission event which results in damage to the crystal structure of non metallic minerals such as Apatite, Sphene and Zircon. This damage (number of tracks formed) can be counted (for a given area) under a high powered microscope after the specimen has been chemically etched. The corresponding half of the specimen is then annealed in a furnace to erase the tracks due to spontaneous fission of U 238, and sent to a nuclear reactor where it is bombarded with nutrons to induce U 235 fission, as U238 does not undergo fission in this situation.

Another method is to bombard the original ground and etched specimen when covered by a sheet of mica which will then reveal the reactor induced tracks.

With the knowledge of the normal decay constants of Uranium nuclides; the fission decay constant, the ratio of U 238 to U 235 and the counting of spontaneous and induced fission tracks it is possible to determine the age of the specimen.

It is most useful in dating rocks between 40,000 and one million years old, the range not suitable for the Carbon 14 and Potassium-Argon methods. However, it is also used for dating minerals up to several hundred million years old.

While pressure, deformation and ionizing radiation do not

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| ISOTOPES | | SYMBOL | PARENT HALF-LIFE | EFFECTIVE DATING RANGE | SUITABLE MATERIAL FOR DATING | PROBLEM AREAS-COMMENTS |
|---|---|---|---|---|---|---|
| METHODS BASED ON END PRODUCTS | | | | | | |
| Parent | Daughter | | | | | |
| URANIUM-238 | → LEAD-207 | (U-Pb) | 4,510 my | 10 my-4,600 my | Uranium and Thorium rich crystalline minerals, principally Zircon, Spene & Monazite, also Uranite. Whole rock can be dated by the isochron principle. | Determining quantity of any original lead in sample. Lead loss through time due to its relative solubility. |
| URANIUM-235 | → LEAD-206 | (U-Pb) | 713 my | 10 my-4,600 my | as above | as above |
| POTASSIUM-40 | → ARGON-40 | (K-Ar) | 1,300 my | 100,000 y-2,000 my | Muscovite, Biotite, Plagioclase, Hornblend & Augite. Whole igneous extrusives. Glauconite & Sanidine in sedimentary rocks. | Argon (gas) loss through time by heating (200°C). Old rocks affected by later events, young rocks often contaminated. |
| | → CALCIUM-40 | (K-Ca) | | | Occesional use on very old rocks with very high initial K/Ca ratio. | Calcium-40 is the naturally occurring common isotope. |
| RUBIDIUM-87 | → STRONTIUM-87 | (Rb-Sr) | 47,000 my | 10 my-4,600 my | Muscovite, Biotite, potassium feldspars, Lepidolite & Olivine. Whole metamorphic rocks. Glauconite in sedimentary rocks. | Probably the most reliable method. Affected by high grade metamorphism only. Errors occur in dating younger rocks. Initial Rb/Sr ratios can be corrected by isochron method. |
| METHOD BASED ON ISOTOPE RATIOS | | | | | | |
| LEAD-206 / LEAD-207 | | (Pb/Pb) | | | Ratio of these daughter isotopes of Uranium is used to determine lead loss in U-Pb dating by concordia-discordia method. Used to date the earth. | Not affected by lead loss. Ratio remains constant for any specified age. |
| METHODS BASED ON ISOTOPES PRODUCED BY COSMIC RADIATION | | | | | | |
| CARBON-14 | → NITROGEN-14 | (C-14) | 5,730±40y | 100 y-44,000 y | Wood, charcoal, peat, grain & similar plant material. Bone and shell etc. | Affected by fluctuation in solar activity and the earth's magnetic field, also external contamination. |
| CHLORINE-36 | → ARGON-36 | (Cl-36) | 0.31 my | | Polar & glacial ice, groundwater at great depths. | Depends on the use of particle acceleration for measuring very small levels of radiation. |

Figure 5. Table showing the more common methods of Radiometric Dating.

GEOLOGIC TIME (Cont.)

effect the system; temperature change and in the case of apatite, weathering and hydrothermal fluids, can effect the accuracy of fission track dating.

DATING BASED ON ANNUAL OCCURRENCES

a. Tree ring dating, known as dendrochronology, has been known since at least 1757 when Buffon and Duhamel recognised the same frost-damaged annual ring in several different trees.
   Using cores from California's bristle cone pine, the oldest living specimen of which is more than 4,600 years old, in conjunction with the remains of dead but well preserved trees of the same species, researchers have built up a climate and tree-ring record dating back just under 8,700 years. In western Europe, using a different species of tree, another sequence has been established which records approximately 7,250 years of growth.
   Not only do the distinctive tree ring sequences show past climatic variation, they have become essential for checking the accuracy of more recent radio carbon (C 14) dating by comparing the latter results with an actual date (number of rings since the present). The only major problem is the possibility that in an area or at a time when seasons were not well defined (winter, summer wet-dry), drought, for example, may have stopped the formation of a distinct pair of rings for a given year. This of course would mean that ring counting would give a younger rather than older age.

b. Varves, paired layers of dark and light clay and silt that settle where lakes freeze over in winter but are open during the rest of the year, can also be counted to provide an actual age.
   As with tree rings, these vary in thickness from year to year depending on seasonal conditions, thus allowing a degree of correlation within a given area and the provision of longer measurable sequences. Sediments formed by varves are of particular use in determining climatic variation since the last major advance of Pleistocene ice.

PALAEOMAGNETIC DATING (Magnetostratigraphy)

The basis of palaeomagnetic dating is the retention by rocks of a magnetic imprint acquired in the geomagnetic field that existed at the time the rocks were formed.

With igneous rocks, this occurs when minerals, in particular magnetite, titanomagnetite and hematite, which have become fero-magnetic during early cooling, reach a temperature between 50 and 100°C at which point the magnetism becomes locked in the rocks. With sedimentary rocks an alignment of feromagnetism occurs soon after settling.

For reasons not yet fully understood the earth's magnetic field reverses polarity 180° at irregular intervals. These reversals, when dated by radiometric methods such as Potassium-Argon decay, are used in the formation of a palaeomagnetic time scale which permits the crude positioning of rocks in geologic time. It is valuable in the correlation of both land and deep sea drill cores.

The time required for these reversals to take place is believed to be about 5,000 years, consequently only those magnetic fields which remain locked into a reversed direction for somewhat greater than 10,000 years are accepted.

As with virtually all the dating methods discussed, considera-tion has to be given to certain features which may effect the accuracy of results. With palaeomagnetic dating these include the loss of magnetic record due to weathering; self reversing minerals such as pyrrhotite and ilmenohematite; and over-printing of earlier magnetic events. However, the latter can easily be accounted for.

Harland et al (1982), includes a detailed palaeomagnetic time scale for the last 165 million years (middle Jurassic to present). The irregularity of these reversals can be illustrated by the fact that there were 178 reversals of different durations during the 63 million years of the Tertiary Period, yet only 55 during the 79 million years of the Cretaceous. In fact there is no reversal recorded at all for a 30 million year time span in the middle Cretaceous.

## FURTHER METHODS OF DATING "RECENT" HISTORY

In addition to Carbon 14, the following are some of the dating techniques that have been developed to date various materials of a more recent geological age.

### Amino acid racemization

A system used to date bones and some shells of Quaternary age, based on the ratio of Amino acid dextrorotatory (right handed) and laevorotatory (left handed) molecules (D/L) found in the fossil. In a living organism the structure of all amino acids, the building blocks out of which proteins are construc-ted, are composed of left handed molecules. After death how-

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GEOLOGIC TIME (Cont.)

ever, the molecules begin to convert to their right handed form, until an equilibrium (50/50 left and right handed) is reached, at which point the D/L ratio remains constant.

Because the rate of change is dependant on temperature, use of the system is restricted to areas where past environmental conditions, and consequently temperature, is considered to have remained reasonably consistent with that existing today. In addition, as D/L ratios have been found to vary between specimens from a single geological deposit and between different parts of an individual shell, accurate dates can only be obtained when based on results from numerous specimens. In spite of this amino acid D/L ratios have frequently been used in stratigraphic correlations and relative age determination.

Thermoluminescence

Most minerals when buried in the earth, absorb the decay products of radioactive isotopes (alpha, beta and gamma rays). When heated to a specific temperature, energy stored as electron displacement in the crystal lattice of the mineral is given off as visible light. The quantity of light released is a measurement of how much radioactive bombardment the specimen has undergone since crystallisation. By relating this to the trace amount of radioactive isotopes in the sample an age can be determined.

Thermoluminescence is helpful in dating samples as old as one million years. As well as being used to date fossil bone and teeth, it is useful in determining when ancient (buried) pottery was fired and when more recent lavas cooled.

Another method of prime use to the archaeologist, rather than the palaeontologist, is Obsidian hydration layer counting used to determine the age of obsidian artefacts by measuring the amount of hydrogen left behind in the hydration process started by the exposure of a fresh surface to humid air.

SUMMARY

Over the last two hundred years or so, scientists by careful observation and study of geologic and evolutionary processes, have gradually built up a detailed stratigraphic history of the earth, based initially on relative time determined by the appearance and disappearance of various fossils within specific rock sequences.

Since the discovery of radioactivity and the subsequent development of radiometric dating, it has become possible to accurately date the stratigraphic boundaries that divide the Systems, Series and Stages (Periods,Epochs and Ages).

This global stratigraphic scale is a combination of two scales, one of time intervals (chronometric) and the other, the span between defined boundaries (chronostratic). It is more simply referred to as a "Geologic Time Scale".

With the exception of Carbon 14 dating, radiometric dating techniques cannot directly give an age to a particular fossil. Generally they can only provide an age for the igneous and metamorphic rocks and their constituent minerals that lie above or below the sedimentary beds in which the fossils are found.

No doubt, in years to come other methods and techniques will be developed which will provide even greater accuracy in dating rocks and their associated fossils.

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## MAJOR T.L. MITCHELL AND AUSTRALIAN VERTEBRATE PALAEONTOLOGY by N.W. Archbold.

The following article is based on extracts from a chapter by P.V. Rich and N.W. Archbold in the book 'Vertebrate Palaeontology in Australasia' edited by P.V. Rich, R.F. Baird and E.M. Thompson (see Books and Book Reviews, page 40 ).

Major (later Sir) Thomas Livingston Mitchell was the Surveyor-General of New South Wales from 1828 until his death in 1855 (see Foster's 1985 book for a full treatment of the life of this remarkable explorer). Although not the first to collect

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MAJOR T.L. MITCHELL AND AUSTRALIAN VERTEBRATE PALAEONTOLOGY (Cont.)

vertebrate fossils in Australia, Mitchell's collections were to attract considerable interest in Europe and form the foundation for future studies.

Mitchell mapped in detail the Wellington Valley Caves of New South Wales. He first visited them on 26th June,1830 with a local colonist, George Ranken, who had previously discovered some bone fragments (Ranken,1916). Ranken had taken his specimens to Sydney in order to send them to Professor Robert Jameson of the University of Edinburgh (Anderson,1933).

Ranken's discovery of fossil bones was announced in the Sydney Gazette of 25th May,1830 in an anonymous letter (signed L.) by the Rev. Dr. John Dunmore Lang. Lang left Sydney on the 14th August,1830 with Ranken's specimens, his own Sydney Gazette letter and a short manuscript by Mitchell on the Wellington Caves. By early 1831 all were in the hands of Jameson, the two notes being published in the Edinburgh New Philosophical Journal. Both notes were credited to Lang, but in the subsequent volume Mitchell's note was correctly attributed to him (see Lang 1831, Mitchell,1831a).

Mitchell revisited the caves on the 3rd July,1830 and collected further specimens. These were apparently sent to the Geological Society of London with a letter dated the 14th October,1830 (read at the Geological Society of London meeting of 13th April, 1831 - see Mitchell, 1831b).

Various specimens collected by Ranken and possibly Mitchell were examined by William Clift, Conservator of the Hunterian Museum (College of Surgeons), who identified dasyurids, wombats and kangaroos (Clift,1831). Joseph Barclay Pentland (see footnote by T.G. Vallance in Dugan 1980) living in Paris, commented extensively on material sent to Paris from England and also independent information on the Wellington caves from Peter Cunningham, author of the 1827 book Two Years in New South Wales (see Pentland 1831,1832 and Jameson 1831b). Jameson also offered editorial comment on William Clift's conclusions (Jameson 1831a - see Dugan 1980 on the importance of this for challenging Baron Georges Cuvier's contemporary catastrophist theories). William Buckland (1831) considered that some bones might represent either rhinoceros or hippopotamus, and Baron Cuvier (see Pentland 1833b, 1833c) also examined specimens.

Such was the interest in Europe on the Wellington caves discoveries, that many of the notes and letters discussed above were translated and published in contemporary German journals (Mitchell 1832a, 1832b; Pentland 18331, 1833c; Jameson 1832a, 1832b).

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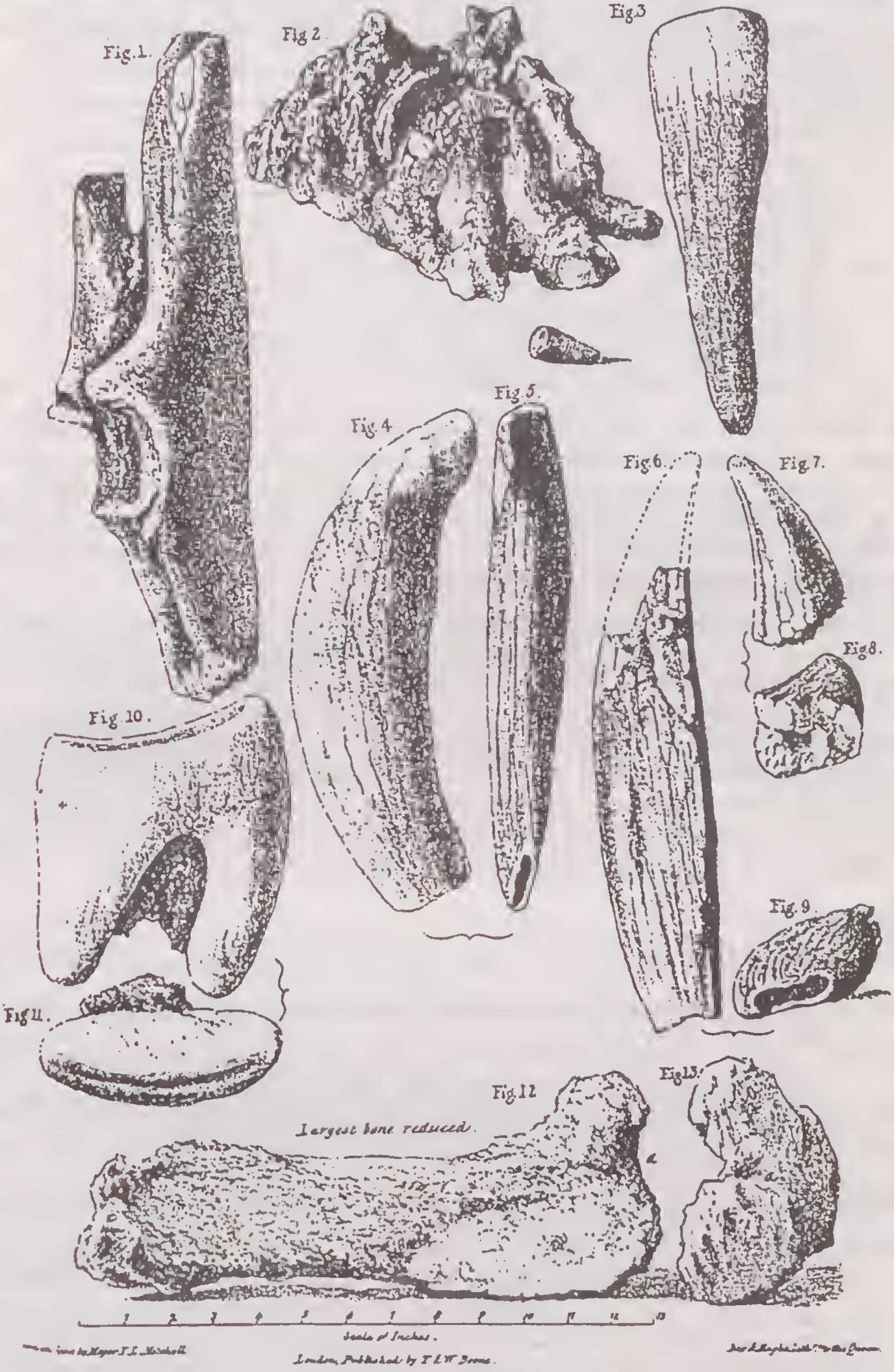

Plate from T.L. Mitchell (1838) illustrating the first Australian vertebrate fossils reported in a scientific publication.

MAJOR T.L. MITCHELL AND AUSTRALIAN VERTEBRATE PALAEONTOLOGY (Cont.)

Mitchell's records on the discovery of vertebrate fossils at Wellington caves are not without humour, for as he noted in his diary :

> "The pit (Breccia Cave) had been first entered only a short time before I examined it, by Mr. Ranken, to whose assistance in the researches, I am much indebted. He went down, by means of a rope, to one landing place, and then fixing the rope to what seemed a projecting portion of rock, he let himself down another stage, where he discovered, on the fragment ( a giant bird femur, probably from a member of the family Dromornithidae) giving way, that the rope had been fastened to a very large bone, and thus these fossils were discovered" (Mitchell 1838: 362).

The bone which Mr. Ranken misjudged was the "lower end, mutilated, and encrusted with the red stalagmite of the cave..." of a femur that was identified by Sir Richard Owen as belonging to a large bird, previously unknown. It was figured in Mitchell's (1838) publication but was subsequently lost, perhaps during the bombing of London during World War II.

Mitchell's discoveries of fossil bones had aroused the interest of overseas scientists in extinct Australian vertebrates, and there followed many years of European and Australian alike collecting fossil remains. Most all of this material was sent from the shores of Terra Australis for description and study by foreign experts, as the needed expertise and comparative collections did not exist in Australia. It was not until the latter part of the 19th century, however, when indigenous workers began to study the local fossils in any serious way.

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## 2ND INTERNATIONAL COLLOQUIUM ON THE MIDDLE PALAEOZOIC FISHES, ESTONIA, LATVIA, SEPTEMBER 12TH - 20TH, 1989.

This colloquium with its theme of "Fossil fishes as living animals" will undoubtedly be regarded as a seminal one. Its very location and field programme broke new boundaries. The promised publication of symposium papers will draw together many new ideas about the lifestyles of our earliest vertebrate relatives.

The rare opportunities for scientists in any discipline to meet and talk, to discuss new specimens and ideas, and to visit classic field localities are of paramount importance; so much is achieved in a short space of time that this should be enough to persuade the powers that be that individuals must attend such meetings. This colloquium is regarded as one in a series, albeit too erratic, which began with the Nobel Symposium on Current Problems in Early Vertebrate Phylogeny held in Stockholm in 1967.

The 1st Middle Palaeozoic fish colloquium was also held in Tallinn in 1976 - a 'first' for the Institute of Geology of the Estonian Academy of Sciences as well as for most of the people who attended. In that year 11 overseas workers joined about 30 from the Soviet Union, most meeting for the first time. But this time there was more than Spring in the air. There was even more than the joy of reunion with colleagues rarely seen or of meeting new people who you may have known through their scientific writings or from correspondence. For this is the era of Glasnost; the noble capital of Estonia has once more taken on the look of a gem on the shores of the Baltic as as renovations to the old city continue - expressions of the creativity, determination and energy of the people are evident all around.

Our hosts were the Institute of Geology, Academy of Science of the Estonian SSR, and the Nature Museum of the Latvian SSR at Riga, supported by sponsorship from the International Palaeontological Association and by colleagues from the University of

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2ND INTERNATIONAL COLLOQUIUM ON THE MIDDLE PALAEOZOIC FISHES
ESTONIA, LATVIA, SEPTEMBER 12TH - 20TH, 1989. (Cont.)

Riga. They exhibited the great flair shown first in 1976 by organising a first-class scientific meeting. As well they provided an enjoyable social and cultural background so that we (especially the visitors) might understand something of the fascinating and often desperate history of the Baltic States.

During the excellent field excursions new ground was broken when the first foreign party for 50 years, guided by Drs. Tiiu Märss and Rein Einasto (Tallinn), toured the classic Silurian rocks of Saaremaa (formerly Oesel Island), thanks to the work of our Estonian colleagues. This region now provides a standard biostratigraphical zonation based on microvertebrates ( Märss 1989, Blieck et al 1988). In Latvia, Dr. Elga Kurik (Tallinn and Drs. Lyarskaya and Kürss (Riga) led visits to Devonian localities around the Gauja River region where fossil fishes have been collected for 150 years. A useful summary excursion guidebook was produced by Mark-Kurik, Märss and Kürss (1989).

Twelve countries were represented in 1989, with 26 participants coming from Australia, Canada, China, West Germany, France, Holland, Norway, Poland, Sweden, the UK and USA; of the 30 participants from the USSR, most were from Moscow, with some from Kiev, Leningrad, Lvov, Novosibirsk and Saratov, and 'local' representatives from Tallinn, Tartu and Riga. French speakers (including Canadians) were dominant among the 'foreigners', and most important for our discipline was the predominance of new young faces especially among the Soviet contingent. Thus is seems that palaeontological work, particularly in its biostratigraphical application, is alive and well in the USSR - a feature also noted in China at the Beijing/Yunnan Symposium on Early Vertebrates held two years ago. Tragically, Western Governments appear to be pursuing policies which are destroying the academic base for geological and palaeontological research and which discourage young people from taking up postgraduate research in these disciplines. Even the dedicated few who used to enter vertebrate paleontology to work on the important problems presented by Palaeozoic fishes seem to have disappeared in the late 1980's; the presence of an amateur from one European country at this meeting may be indicating the way the wind is blowing again for palaeontology back to the 18th and 19th centuries when only a few men, usually well-off, often without formal training, pioneered many scientific studies. But this path is fraught with difficulties as the people involved arc individuals, not well supported and often lacking even basic equipment, and generally not in communication with the mainstream or professional members of the science.

The meeting was held in the ancient town-hall of Tallinn with simultaneous Russian - English translation available. The talks ranged widely, concentrating on functional and environmental aspects of the lives of early vertebrates.

Of particular interest was the debate about marine versus non-marine environments in mid - Palaeozoic times, and whether any fishes were adapted to truly freshwater habitats. The consensus questioned most of the co-called freshwater occurrences because they are backed up with only negative evidence, such as the absence of marine invertebrates. Many new faunas from the Ordovician to Permian from the USA, USSR, Poland, Australia and China, were exhibited and several were those known only from microfossils.

The structure, ontogeny, and especially the early evolution of hard tissues, of vertebrates and even the pre-vertebrate animals were also topics which stood out. The questions raised about which hard tissue is the most primitive have much relevance to the current debate about the phylogeny of the early vertebrates.

New schemes presented included Gagnier's (Paris) for Ordovician heterostracan-like animals, and Blieck's (Lille) for mid Palaeozoic chordates in general. Perhaps the most delightful presentation was that from Upeneice (Riga). She is working on baby asterolepidids, only a few centimetres long, from the now famous Late Devonian (early Frasnian) Lode Quarry of Latvia from which Lyarskaya (1981) and her team have excavated many hundreds of complete placoderms and other fishes.

Another important outcome of the Tallinn colloquium was the presence of so many people interested in the study and use of 'microvertebrates' (vertebrate micro-fossils), which are proving their worth in biostratigraphy - they are found often in areas where no other useful fossils exist. This branch of palaeontological research is beginning to be recognised both by research-funding bodies and by oil companies around the world. Much of this work, however, is still in its infancy. Tallinn witnessed the assembly of 35 scientists who are part of a newly formed international working group which has set up research programmes to investigate the use of Palaeozoic microvertebrates in biostratigraphy with the aim of establishing a set of useful standards and zonal fossils. Informal working groups include one on each major system. They will also consider changes in faunas across system boundaries, particularly the Devonian- Carboniferous, and investigate any response to such global events as the Late Ordovician and Carboniferous-Permian climatic changes and the Frasnian-Famennian extinction. Since late 1988 this group has produced a newsletter called Ichthyolith Issues.

Anyone interested in purchasing copies should contact the editor, Dr. Sue Turner, Queensland Museum, P.O.Box 300, S.Brisbane, Queensland 4065, Australia.

Susan Turner, Queensland Museum.

## BOOKS AND BOOK REVIEWS

THE FOSSIL BOOK: A record of Prehistoric Life
by Carroll Lane Fenton and Mildred Adams Fenton; revised and expanded by Patricia Vickers Rich, Thomas Hewitt Rich and Mildred Adams Fenton. Published by Doubleday, New York. Recommended retail price $65.00 (available in Australia from January, 15th, 1990).

The Fossil Book was first published just over 30 years ago. It has now been completely revised and expanded to 740 pages (258 more than the 1958 edition) to include more than 1,500 photographs and drawings of fossils, not only those of North America, but from other parts of the world including Australia and Antarctica.

As well as updating the classification and greatly expanding the chapters on vertebrate fossils, a new chapter has been added on plate tectonics and changing climates.

It is an extremely readable and authoritative guide to the fossil world ideally suitable for non specialist enthusiasts and collectors.

Unlike so many other books on fossils it is a complete overview, covering invertebrates, vertebrates and plants.

The wide coverage of this book is well illustrated by the following list of contents:

Tales Told by the Dead
Rocks, Fossils and Ages
Continents Have Moved and Climates Have Changed
Groups, Names and Relationships
Earth's Oldest Remains
A Variety of Protists
Sponges True and Problematical
Simple Coelenterates: the Cnidarians
"Moss Animals" or Bryozoans
The Sturdy Brachiopods
Worms, Burrows, Trails and Other Problematica.
Animals in Three Parts: the Trilobites
Crustaceans
Arthropods from Shoals to Air
Snails and their Kin
The Greening of the Land
Amphibians, Ancient and Modern
A Myriad of Reptiles on Land
Farewells to Land
Scale Bearers and Lizard Hipped Dinosaurs
Bird-hipped Dinosaurs
Flying and Gliding Reptiles
Birds, Inventors of the Feather
Hairy Reptiles with Complex Ears: the Early Mammals
The World Blossoms
The Great Placental Radiation
Moving Continents, Changing Climates and Their Effects on Mammals
Beasts and Birds of the Ice Age: the Interplay of Climate and Man

(Cont.)

The Fossil Book (Cont.)



VERTEBRATE PALAEONTOLOGY OF AUSTRALASIA - Edited by P.V.Rich,R.F.Baird,J.M. Monaghan and T.H. Rich.

Although based on the 1982 book "The Fossil Vertebrate Record of Australasia", "Vertebrate Palaeontology of Australasia" is virtually a complete new volume with contributions from 29 co-authors.

It is due to be published later this year by Chapman & Hall,London and Thomas Nelson, Melbourne. Further information will be included in our next bulletin.

DE VIS SYMPOSIUM - Problems in vertebrate biology and phylogeny, an Australian Perspective.

Copies of the Abstracts of the above symposium held in Brisbane, May,1987, are still available from Dr.Sue Turner, Queensland Museum, P.O.Box 300, South Brisbane, Queensland, 4101, for $10.00 plus postage. It is hoped that the full symposium volume (Memoirs of the Queensland Museum 28) will be published early this year.

# IN THE NEWS (Cont.)

## DINOSAUR FIND IN QUEENSLAND

Queensland Museum scientists are ecstatic at a grazier's historic discovery near Richmond in Central Queensland of one of the world's few dinosaurs with skin detail still intact.

The three metre long Middle Cretaceous ankylosaur, affectionately named Arald by museum staff, lived about 100 million years ago feeding on plants and insects. It had bony armour and tough crocodile like skin to protect it from carnivorous predators.

According to Dr. Ralph Molnar, the museum's curator of vertebrate fossils, the dinosaur most likely died on land close to a river and probably became mummified within a month before a flood washed it down the river into the sea where it became waterlogged and sank to the bottom. The specimen is about 70 per cent preserved, including about 90 per cent of the skull. The main significance of the find lies in the fact that the skin impressions of its dorsal armour are preserved. It is considered to be the most complete dinosaur yet discovered in Australia and the first in the Southern Hemisphere with "skin".

Only three other examples of the species with intact back armour have previously been discovered - in Canada, Mongolia and the United States.

Although discovered late last year, it was not until preliminary cleaning took place in the Queensland museum, that the full significance of the find was established. The discovery followed shortly after that of a Pliosaur from the same property.

Adapted from a report in The Melbourne Sun, Jan. 19th., 1990.